A LEAN APPROACH TO SUSTAINABLE CONSTRUCTION

Richard Fellows¹ and Anita M M Liu²

¹Dept. of Civil and Building Engineering, Loughborough University, UK ²Professor, Dept. of Civil and Building Engineering, Loughborough University, UK r.fellows@lboro.ac.uk

ABSTRACT

For many years, the construction industry has been driven by the 'holy grail' of efficiency gains. To that end, processes of lean production have been embraced and adapted to facilitate lean construction. More recently, much attention has been devoted to sustainability and, in particular, sustainable development and sustainable construction. This paper presents a critical review of lean construction and sustainable construction with a view to examining the potential for fostering moves towards sustainability through adoption of lean principles and practices. The paper concludes that fuzziness in definitions of terms and practices creates problems for practice and that recognition of interdependence between participants and resultant adoption of common, long term objectives will enhance efficiency and effectiveness towards sustainability.

Keywords: corporate objectives, lean construction, performance, productivity, sustainability

1. INTRODUCTION

Productivity is critical for business survival and success; construction is no exception. Historically, the theme was articulated by Parry-Lewis (1965), building on the economics of Smith (1977), Malthus (2004) and Ricardo (1990) and taken up, in detail, by Bishop (1975); Central Council for Works and Buildings (1944), Banwell (1964), Latham (1994), Egan (1998), Construction Industry Review Committee (2001) etc., reflect the theme. However, studies are not always free from distortions – the adoption of 'demonstrator projects' in UK to show the benefits of 'partnering' merely confirm the enhanced performance of 'favoured nation status' (Bishop, 1975) projects, together with the preparedness of powerful, self-interested groups to employ propaganda to further their own ends.

Perhaps because of the widespread and quite severe criticisms of its performance, the construction industry has been eager to adopt any principles and practices which appear to offer a modicum of potential for improvement. Such critical perspectives, as articulated in a wide array of government-sponsored reports (e.g., Latham, 1994; Egan, 1998; Construction Industry Review Committee, 2001) have prompted construction to scrutinise practices in other industries world-wide – notably automotive, especially in Japan, and aerospace – to determine practices to adopt for efficiency improvement. Much research has been devoted to such ends, although examinations of necessary cross-industry and cross-national (cultural) adaptations (e.g. Womack, Jones and Roos, 1990) have been, largely, ignored.

Generally, the dominant perspective is that of monopoly capitalism, leading to widespread opportunistic behaviour (Williamson, 1985), under which the financially-powerful set the agenda and, politically, are legitimised (if not authorised and encouraged) to do so. That approach is reinforced through the dominant propaganda machines of mass media with which the financially-powerful are politically aligned, as under the totalitarianist perspective articulated by, e.g., Green (1998).

While much may be helpful within the lean perspective (Womack *et al.*, 1990; Ballard, 1999), it is its (almost) complete usurping by a particular sector of the community with its consequent subjugation to pander to their desires which, given emerging evidence (e.g., Cusumano, 1994; Green, 1999; Green and

May, 2005) may be detrimental to the performance of the industry, other sectors and stakeholders. Such detriments are exacerbated by the seeming failure of lean practices to adapt to or embrace technological and other changes.

Recognition of the perspective adopted for any analysis or exposition is important as the conclusions and recommendations, almost invariably, are grounded in value judgements through which the values of the researcher are embodied in the perspective adopted and so, impact on the research questions, methods of investigation and the outputs. While the scientific method purports to adopt the 'view from nowhere' (Nagel, 1986), in reality, it is almost inevitable that a Kuhnian conception is more apposite, 'what a man sees depends both upon what he looks at and also upon what his previous visual-conceptual experience has taught him to see' (Kuhn, 1996).

Similar, but, perhaps, more extensive, criticisms can be levelled at many publications relating to sustainability – whether regarding sustainable development or sustainable construction. A significant problem in that arena concerns conceptualisation and definition of the basic terms, an absence of precision over which is likely to lead to potentially false and damaging conclusions – in essence, the loose definition of sustainability and its use when 'green' is more appropriate, lulls people into a false sense of security (sustainability). A potent example is the notions of 'sustainable economic growth' (as well as 'sustainable development' and 'sustainable construction' in the context of current practices).

This paper critically examines the definitions and concepts regarding lean construction and sustainable construction and progresses to investigate how lean concepts and practices impact on greening and sustainability in the construction industry. The objective is to advance the debate on a sound basis and to help provide a platform to foster real advances.

2. LEAN CONSTRUCTION

Generally, writers on lean – production, organisations, construction, thinking, etc. – do not define the terms but, instead, proffer descriptions of objectives, principles and processes (practices) involved. Distillation of those descriptions yields a perspective on lean which determines it to be a demand-pull process with customer satisfaction as the overt, driving objective. That objective permeates lean principles and processes but not exclusively – as epitomised in the desire to eliminate waste and inventory, thereby acknowledging the self-oriented goal of reducing (main) producer-supplier costs; i.e., enhancing supply efficiency/productivity (and, hence, profitability). Demand-pull relates not only to the 'final' customer for the output but is reflected in the supply process via the 'last planner' system (Ballard, 2000) which employs a chain of customers for the successive (micro) stages of the supply. Howell (1999) notes that the concepts underpinning lean production include

- "Identify and deliver value to the customer...eliminate anything that does not add value.
- Organize production as a continuous flow.
- Perfect the product and create reliable flow through stopping the line, pulling inventory, and distributing information and decision making.
- Pursue perfection: Deliver on order a product meeting customer requirements with nothing in inventory."

Clearly, there is an underpinning dichotomy of objectives of lean – overtly, demand-pull and so, customer-orientation (effectiveness), whilst covertly accentuating (opportunistic) pursuit of the corporate objectives of the 'main supplier' (main contractor; final supplier; assembler of the final output) as the most powerful of the organisations constituting the supply chain. Hence, the view may be taken that much of the discourse advocating lean supply constitutes totalitarianist propaganda (see, e.g., Green, 1998, 2002).

Given lean's origins in the Japanese automotive industry, notably, Toyota, its derivation from the production concepts of Shewhart (1931), Deming (1986) and Juran and Gryna (1988) are evident. However, those philosophies stress continuous improvement as an essential for continuing success through the twin goals of customer delight and supply productivity, with the latter being strongly focused on the people in production, as opposed to a Taylorist, mechanistic perspective.

While customer orientation is relatively clear in production industry, it is rather fuzzy in construction. Construction customers include 'commissioning clients' (employers in construction contracts), various users of buildings and works, owners, financiers, community groups – indeed, the stakeholder perspective is invaluable in identifying customer functionaries over the anticipated life of a construction project. Lean production assumes customers want immediate delivery with maximum quality (attributes) and at minimum cost. Given the common diversity of construction customers, immediacy of delivery may not be desired (acquisition of an investment good must fit with requirements of strategic development), quality is determined by the values held by the assessor, but cost minimisation is likely to be common (whether monetary or real costs).

However, in construction, as in other business contexts, cost minimisation to the customer is antithetical to the supplier as both are profit seekers! In that context, lean offers no remedy to such basic and direct conflict of interests; the only saving grace relates to waste elimination but the question of who benefits from the resultant efficiency gains (notably, cost reduction) remains subject to prevailing market forces.

The time issue relates to the duration of the supply process from a transaction commencement point – usually, the placing of the order (by the customer to the immediate supplier – retailer) to receipt of the output by the customer. Dependent upon retail / wholesale inventories, and the degree of individuality in the goods as specified by the customer, that order may have negligible to highly significant effects back along the supply chain. However, in construction, most supplies are 'bespoke to order' which involves major individual inputs from the design and 'production' processes but, further and significantly, the determination of the specification of what the client demands – indeed, the gamut of difficulties and concerns of briefing (often couched as 'wicked problems') – both strategic and project (see, e.g., Kelly, Macpherson, and Male, 1992; Atkin and Flanagan, 1995; Green and Simister, 1999).

The quality aspects, *hopefully* emergent from briefing, (although, in practice, likely to fall short of being comprehensive and fixed and so, generating variations) are, most obviously, dependent upon the desires and value system of the commissioning client (and their interpretations of their own output market – especially for speculative developments) as interpreted and translated into 'feasible construction' by the designers.

Given that reduction of waste, in all its forms (see, e.g., Skoyles and Skoyles, 1987), is highly desirable, both for resource utilisation and for profitability, the significance of eliminating variations remains considerable – in terms of all types of resource inpouts. Those relate to concerns of efficiency and, particularly for variations, effectiveness. However, concerns for global efficiency of project realisation are, in a market capitalist environment, almost inevitably subjugated to opportunistic pursuits of the more powerful participants (as in cultural hegemony; Gramsci, 1992). That is likely to lead to an efficiency trade-off throughout the realisation processes in which the more powerful enjoy gains at the expense of the less powerful and, given a long term survival perspective with the power changes involved, a possible reduction in overall efficiency of project supply – such as where just-in-time supplies in the supply chain may preclude sub-suppliers enjoying (and passing on some of) the gains of larger scale production in tandem with inefficiencies of small (part) load frequent deliveries.

In discussing the transfer of lean principles and practices from the Japanese to North American automotive industries, Womack, *et al.* (1990:161) acknowledge the presence of overt practices of lean production but recognise that the underpinning philosophy has not transferred – in North America, the primary approach remains as cost reduction through securing economies of scale from single (rather than multiple) sourced suppliers, inventory reduction through just-in-time deliveries, etc. Clearly, the nature of the sub-supplies govern whether economies of scale resulting from single sourcing outweigh diseconomies from component variety in those suppliers are highly dependent upon the success (output quantity, and price) of the main supplier (assembler) and, as such, become more susceptible to turbulence in final outputs.

Howell (1999) asserts that lean "is about building reliability" rather than trust *per se*. "The relationship…in Japan is not built primarily on trust, but on the mutual interdependence enshrined in the agreed-upon rules of the game" Womack *et al.*, 1990:155). He continues by stressing a slightly different

aspect of the well-known coordination problem, "...systems do not work very well when every person tries to optimize their performance without understanding how their actions affect the larger web."

3. SUSTAINABLE CONSTRUCTION

Generally, definitions of sustainability, and derived forms of sustainability, follow that of the World Commission on Environment and Development (1987) (the Brundtland Report), "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Countries participating in the 1992 United Nations Conference on Environment and Development (The Earth Summit) in Rio de Janeiro, agreed an action plan for the 21st century - AGENDA 21. That plan recognises that humans depend on the Earth to sustain life and that there are extensive and inexorable linkages between human activity and environmental issues. Chapter 7 of Agenda 21 specifies the overall objective of human settlement to be "...to improve the social, economic and environmental quality of human settlements ...". Such statements articulate the notions of different *forms* of sustainability – social, economic, environmental etc. The UK government suggests that the principles of sustainable development comprise (DETR, 1999):

- Maintaining high and stable levels of economic growth and employment
- Prudent use of natural resources
- Effective protection of the environment
- Social progress that meets the needs of everyone

These, unarguably desirable, principles have been developed into principles for sustainable construction (DETR, 2001):

- Constructing projects that are more cost-effective to produce and run as they have been constructed with less and yield more
- Constructing projects that contribute positively to the surrounding environment, using materials and systems that are easily replenished and perform better over their full life cycle
- Promoting high standards of living for people.

The OED defines sustainable as *Capable of being borne or endured; supportable, bearable.... Capable of being maintained at a certain rate or level.* Whilst to endure is *to last.* Hence, something is sustainable if it continues to exist...at the limit, for ever. Thus, the concept of limits, or boundary, is important; such limits may be temporal, geographical but should be drawn as widely as possible – pragmatism, convenience and intelligibility act to constrain the extent of limits and, therefore, merit scrutiny and, advisedly, resistance to their imposition.

Irrespective of context, for sustainability, the resources of the earth can be used only up to the rate at which they are replenished. It is, now, abundantly clear that such consumption of resources is being exceeded (see, e.g., González-Benito and González-Benito, 2005). What, essentially, humans are doing is using up many of the world's natural resources, transforming them into both desired and undesired (waste, pollution) forms and failing to replenish the resources in either the original or sufficiently close substitute forms.

Science indicates, at present, that the world, as a sub-system within the universe and beyond, comprises matter and energy as fundamental, interchangeable constituents ($E = mc^2$). Clearly, given global warming, our world is not a closed system and, with our current knowledge of 'black holes', is not truly sustainable; for more practical purposes, it is helpful to consider the matter and energy of the planet in terms of forms and quantities of each form, coupled with a perspective of changes over time. Further, it is appropriate to endeavour to identify influences on those quantities and changes and to determine what may lie within the control of humans. (Generally, humans believe that they are more in control than is the reality.)

A major problem in the debate on sustainability, certainly in the context of development and construction, is fostered by the various forms of sustainability which are considered with the evident

result that the basic, scientific principle is, largely, ignored. Basic sustainability, by definition, is a (very) long term concept but the human condition of bounded rationality (perhaps, coupled with self-interest) means that we have quite limited capacity to consider the future – populations, resources and the likely effects of present day actions upon them. Such limitations are exacerbated by widespread complacency as in the popular view that 'science and engineering will solve the problems'.

4. **DISCUSSION**

Corporate objectives

A typology of corporate objectives comprises (generic) business, technical and relational categories. It is very clear, however, that, despite much rhetoric regarding relational and technical aspects, they are regarded as means for securing business benefits accruing to the individual organisation – notably, in terms of financial performance metrics.

Traditionally, corporate objectives within market capitalist systems have focussed on profit maximisation as the means of ensuring survival of the organisation through generating wealth for the owners. That simplistic perspective is severely limited and should be modified, at least, to profitability. Baumol, (1959), given the separation of ownership and management of (larger) organisations, suggests that their behaviour indicates their primary objective to be maximisation of revenue, subject to a minimum profit constraint.

Hutton (1996) documents the common requirement in Western stock markets for companies to produce, at least, non-decreasing streams of dividends, irrespective of prevailing economic conditions, as expressed through the investment criteria operated by 'fund managers' of the 'institutional investors' – the major, influential, active investors in the global stock market. A supplementary requirement is for the market value of the companies to be preserved in real terms, a requirement of corporate manager (and many owners) to combat potential aggressive take-overs for 'asset stripping', etc. Hence, there remains major pressure on companies to pursue profit.

Neo-classical economic theory indicates that a firm must earn normal profit as a long period minimum requirement for survival. Normal profit is the minimum return required by the (average) owner of the firm to keep the investment in that firm and is assessed as compensation for risk-bearing etc. As market conditions, including financial markets, become increasingly turbulent (due to interactions, globalisation and so on), levels of normal profit fluctuate also. Further, corporate financing employs ever greater diversity of sources and 'financial products' and, taking taxation legislation into account as well, firms are concerned with (growth in) market share and profit; and thence, dependent upon their capital structuring, their return on capital employed (profitability).

However, aside from the corporate survival desire (to do so as a separate, distinct entity – hence, to avoid being taken-over), the primary objective is growth of the organisation. Given a finite market, growth is achieved, very commonly, by amalgamations of organisations – effectively, take-overs – but subject to scrutiny and approval by authorities set-up to control 'monopolies'. (The ultimate would be a single, global, conglomerate organisation!)

Womack *et al.* (1990;193-194) document developments of conglomerates in Japanese industry. "*...zaibatsu...*family-owned holding companies controlled industrial empires that consisted of a large company in each of the major sectors...construction....Each *zaibatsu* included a bank, and the deposits in the bank were the major source of funds for investments by companies in the group. The Americans eliminated these tightly organized groupings during their post-World War II occupation...." After the American occupation ended, keiretsu evolved in place of the zaibatsu. Keiretsu have member companies in each major industrial sector but are held together be inter-ownership of equity and the reciprocal obligation culture of the society.

Given that sales are secured on a combination of price, quality and propaganda to engender value-formoney perceptions by (potential) customers then, cost reductions, quality (functionality) ensurance and customer convincing are vital. In industries like construction, where production cost advantages are relatively rare, and any are short-lived amongst competing organisations, attention to cost reductions through organisational structural changes become more important. 'Flatter' structures reduce indirect costs by removing layers of management but transfer responsibilities to other personnel (usually down the hierarchy). Additionally, transaction cost perspectives prompt examination of costs of alternative ways of structuring supply processes between mixes of hierarchies (firms) and markets.

Structural changes in the world's construction industry, in most, if not all, countries (and internationally) over recent years, indicate that total costs are reduced through re-structuring away from firms to use of markets. Thus, in context, indicating transaction costs are reduced by using market mechanisms.

A particular problem for construction organisations, due to the importance of the public sector as customer and the (price) competition orientation of many private sector customers, is the market competition requirements of most procurement arrangements. The great gamut of 'anti-monopoly' legislation, which is applied throughout supplies of construction projects, is antithetical to the espoused notions of 'partnering', 'relational contracting', long period supply arrangements in lean processes and similar mechanisms purported to foster performance improvements through team building, commitment, uncertainty reduction, investment encouragement, etc., etc.

Employment practices

Womack *et al.* (1990; 251) note that "…lean-production system…needs dedicated generalists willing to learn many skills and apply them in a team setting." Whilst such a requirement is appropriate for employment practices in Japan where people (traditionally) are hired into the lower levels of a firm and progress upward by spiralling around different departments; employment is 'for life' and remuneration etc. is based on age, seniority – ascription. That is fostered by the long term orientation of Japanese society. Further, Japan has a collectivist culture, both vertical (work) and horizontal (domestic) which is conducive to teamwork.

In contrast, Western societies are more individualist and short term oriented. People acquire education and skills to benefit their own employment prospects as remuneration and promotion are based on individual attributes and expertise (achievement); such persons are mobile between alternative employers and so, team formation and maintenance are more problematic.

Green (2002) and Green and May (2005) provide a comprehensive review of the human resource aspects of lean practices, noting distinct parallels with Taylorist organisation. Any empowerment of the workforce is to facilitate achievement of production targets in both quantity and quality terms. Drawing on research which documents effects upon the workforce in Japan, the outlook is bleak.

Heijunka

Heijunka, resource smoothing, is not only a principle of lean production but is a common practice in construction. However, its practice is likely to be short term and self oriented as a component pursuit of corporate objectives. Coupled with just-in-time supply requirements, construction suppliers and subcontractors are likely to find their delivery requirements more turbulent as resource smoothing is programmed for the benefit of customers and 'main contractors'.

Whilst employment is likely to be created in the logistics sector - occasioned by the increased delivery requirements of frequent 'small loads' and associated *kanban* (even if in electronic form) - that countermands drives for sustainability by consuming more resources to effect the deliveries and the associated control documentation.

5. CONCLUSIONS

Lack of (good) definitions of the primary terms and concepts maintains fuzziness (lack of clarity – as in confusion between 'sustainability' and 'greening') and so, renders analysis and, therefore, progress problematic. Further, the fuzziness exacerbates the use of propaganda and other, often opportunistic, manipulations in pursuit of individual, often, to the detriment of global ends. That is especially

concerning for pursuit of sustainability where conflicts between concepts / stakeholders detract from effectiveness and efficiency of initiatives.

Objective analysis of the concepts and processes of lean – to determine the pros and cons – will foster a better appreciation of its potential contribution to global advancement through attention to effectiveness and efficiency with the over-riding perspective of continuous improvement of both. There seems to be considerable potential for gain in scrutinising lean in the context of the well-developed notions of productivity (in general) and buildability/constructability (more particularly) but ensuring that a 'total project life' view is adopted.

The current situation in knowledge and practices of lean and sustainability in the construction industry indicates potential conflict between them due to fuzziness and, more especially, opportunistic behaviour. However, in a context of recognised interdependence and greater integration to enhance identification and pursuit of common objectives (i.e., a more collaborative, collectivist – and long term – perspective), endeavours to secure reductions in resources consumption, and, hence, reduced costs, coupled with maintaining or, preferably, enhancing, effectiveness, could make significant contributions towards a sustainable future.

REFERENCES

- Atkin, B., Flanagan, R. (1995) Improving Value for Money in Construction: Guidance for Chartered Surveyors and their Clients, London: Royal Institution of Chartered Surveyors.
- Ballard, G. (2000) The Last Planner System of Production Control, PhD Thesis (unpublished), University of Birmingham, UK.
- Banwell, Sir H. (1964) *The Placing and Management of Contracts for Building and Civil Engineering*, London: HMSO.
- Baumol, W. J. (1959) Business Behaviour, Value and Growth, New York: Macmillan.
- Bishop, D. (1975) Productivity in the Construction Industry, In Turin, D. (ed.) Aspects of the Economics of Construction, London: George Godwin, 58-96.
- Central Council for Works and Buildings (1944) *The Placing and Management of Building Contracts* (the Simon Report), London: HMSO.
- Cusumano, M.A. (1994) The Limits of "Lean", Sloan Management Review, Summer, 27-32.
- Construction Industry Review Committee (2001) *Construct for Excellence* ('The Tang Report'), Hong Kong: Government of the Hong Kong Special Administrative Region.
- Deming, W.D. (1986) *Out of the crisis: quality, productivity and competitive position*, Cambridge : Cambridge University Press
- DETR (1999) A better quality of life: a strategy for sustainable development in the UK, London: The Stationery Office.
- DETR (2001) *Building a better quality of life: a strategy for more sustainable construction*, London: The Stationery Office.
- Egan, J. (1998) *Rethinking Construction*, Report from the Construction Task Force, Department of the Environment, Transport and the Regions, London: HMSO.
- González-Benito, J., González-Benito, O. (2005) An Analysis of the Relationship between Environmental Motivations and ISO14001 Certification, *British Journal of Management*, **16**, 133-148.
- Gramsci, A. (1992) Prison Notebooks, New York: Columbia University Press.
- Green, S. D. (1998) The technocratic totalitarianism of construction process improvement: a critical perspective, *Engineering, Construction and Architectural Management*, **5**(4), pp 376-386.
- Green S.D. (1999) The missing arguments of lean construction, *Construction Management and Economics*, **17** (2), 133-137.
- Green, S.D. (2002) The Human resource Management Implications of Lean Construction: critical perspectives and conceptual Chasms, *Journal of Construction research*, **3** (1), 147-165.
- Green, S.D., May, S.C. (2005) Lean construction: arenas of enactment, models of diffusion and the meaning of 'leanness', *Building Research and Information*, **33** (6), 498-511.

- Green, S. D., Simister, S. J. (1999) Modelling construction business processes as an aid to strategic briefing, *Construction Management and Economics*, **17**, No. 1, 63-76.
- Howell, G.A. (1999) What is Lean Construction 1999, *Proceedings, International Group on Lean Construction-* 7, University of California, Berkeley, 26-18 July.
- Hutton, W (1996), The State We're In (2nd Edn.), London: Vintage.
- Juran, J.M., Gryna, F.M. (1988) Juran's Quality Control Handbook (4th Edn.), New York: McGraw-Hill.
- Kuhn, T.S. (1996) *The Structure of Scientific Revolutions (3rd Edn.)*, Chicago, The University of Chicago Press.
- Kelly, J., Macpherson, S., Male, S. (1992) *The Briefing Process: a Review and Critique*, London: Royal Institution of Chartered Surveyors.
- Latham, Sir M., (1994) Constructing the Team, London: HMSO.
- Parry-Lewis, J.. (1965) Building Cycles and Britain's Growth, London: Macmillan.
- Malthus, T.R. (2004) The Nature and Progress of Rent, Whitefish MT: Kessinger Publishing.
- Nagel, T., (1986) The View from Nowhere, Oxford, Oxford University Press.
- Ricardo, D. (1990) *The Principles of Political Economy and Taxation*, Cambridge: Cambridge University Press.
- Shewhart, W.A. (1931) Economic control of quality of manufactured product. New York: D. Van Nostrand Company.
- Skoyles, E.R., Skoyles, J.R. (1987) Waste Prevention on Site, London: Mitchell.
- Smith, A. (1776 [1977]), An Inquiry into the Nature and Causes of the Wealth of Nations, Chicago: University Of Chicago Press.
- Williamson, O. E. (1985) The Economic Institutions of Capitalism, New York: The Free Press.
- Womack, J. P., Jones, D.T., Roos, D. (1990) *The Machine .that Changed the World*, New York: Rawson Associates.
- World Commission on Environment and Development (1987) *Our Common Future* (the Brundtland Report), Oxford: Oxford University Press.