A LEAN APPROACH TO CONSTRUCTION: AN HISTORICAL CASE STUDY

Michael Horman
The University of Melbourne, Melbourne, Australia
Russell Kenley
The University of Melbourne, Melbourne, Australia
Victor Jennings
The University of Melbourne, Melbourne, Australia

Abstract
The paper outlines a case study revealing the early employment of flow principles in construction. Insights are gathered with a view to assist present-day efforts to adopt alternative management approaches in construction, such as lean production and just-in-time.

The case is that of Jennings, previously one of the largest house-building organisations in Australia. Concurrent with Toyota's development of lean production, including the just-in-time production method, Jennings employed some of the principles to which lean ideas are attributed. Their practices included the use of flow production, supply-chains, standardised design approach, unitary production, and quality measurement.

Jennings' practices are reviewed and the way in which the organisation initially adapted them to the characteristic conditions of construction examined. Further the circumstances surrounding the dilution of these principles, an act which has partly led to the novelty of lean approaches in construction today, are reviewed.

Keywords: construction flow, supply-chains, standardisation, housing, Jennings

Michael Horman is a lecturer at the University of Melbourne. He is currently completing a Ph.D. exploring the use of lean production principles in the management of construction projects.

Russell Kenley is a construction industry consultant and senior lecturer at the University of Melbourne. He specialises in Business Process Re-engineeering and project management and heads a major research project into the financial structure of the construction industry.

Victor Jennings is a researcher at the University of Melbourne. He specialises in the statistical analysis of international trends and changes in housing and urban areas.

INTRODUCTION

Recently increased attention in construction has been paid to alternative management approaches, such as lean production and just-in-time. While it appears that inspiration for construction to consider adopting these approaches arose from the recent recognition of improvements in manufacturing, there is evidence that the principles upon which they are based existed in construction well before the current influx of interest.

This paper outlines a case study revealing the early employment of flow principles in construction. The case is that of *Jennings*, a prominent Australian construction company mostly involved in housing and general contract construction since the early 1930s. Concurrent with Toyota developing its production system that emphasised ameliorated production flow, during the 1950s and 60s Jennings independently developed and employed cognate initiatives to enhance operational performance.

Jennings' practices are reviewed in this paper. Whilst lean production at its present level of maturity was not employed at Jennings, nevertheless elements of lean thinking can be identified in their practices. The characteristics of the lean production and just-in-time approaches are identified in these practices, including the use of flow production, supply-chains, standardised design approach, unitary production, and quality measurement.

Important lessons may be learnt from the early Jennings' experience to assist present efforts to adopt lean production and just-in-time in construction. This case provides insight in support of the effective utilisation of these approaches. Sourced from experience, it offers an additional perspective for present efforts when tackling surrounding issues such as sustaining the continued use of such approaches and how the company contended with the characteristic conditions of construction.

JENNINGS' PROFILE

Jennings commenced as a small house-building company but rapidly developed into one of the largest construction companies in Australia (Garden 1992). It was formed by Albert Victor (AV) Jennings, in suburban Melbourne, Australia, commencing in 1932 in the midst of the depression. Whilst initial projects were individual houses, the value of constructing homes in groups or estates to achieve efficiency was soon recognised and such projects formed the staple for the business. The post-Second World War shortage of housing presented Jennings with a significant market and it was contracted to build large housing developments for government authorities.

In the late 1940s Jennings diversified their operations. They acquired contracts to design and build groups of War Service homes[1] and sought work from road building to factories. By 1950, Jennings had become the largest building company in the country and in the same year was floated as a public company.

In 1952, Jennings expanded operations into larger general building and civil engineering projects and this mainly proved unsuccessful. Gradually they moved towards a large number of smaller general building projects, particularly schools and other public buildings, and by the late 1950s began developing private housing estates again.

By 1965, the company was well established in private housing across Australia, with an established research and development division. However it was evident that the regional structure of the company was inadequate to neither take advantage of the

[1] This was perhaps the first design-and-construct housing project awarded by an Australian government (Garden 1992, p90).

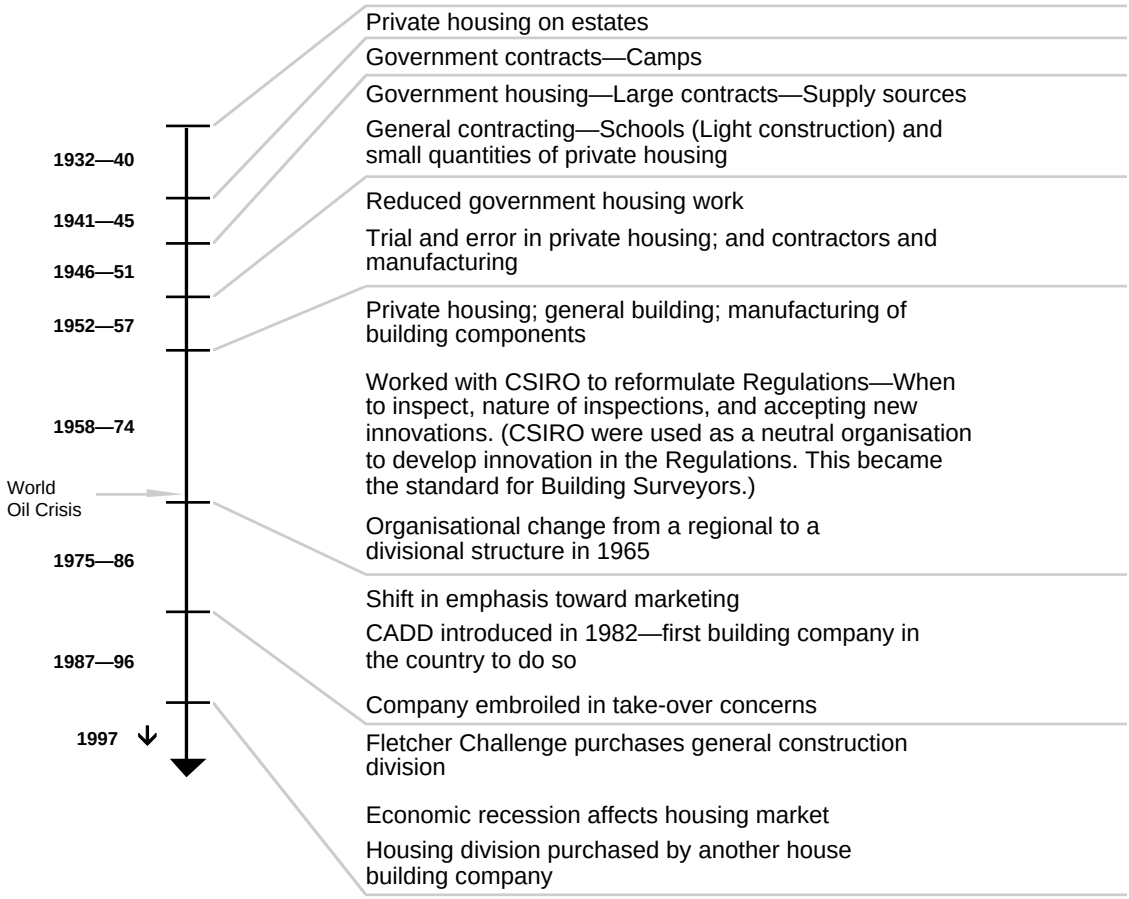

Figure 1 Timeline revealing the changes at Jennings as its business evolved.

economies of scale nor provide focus for the large private housing activity nor the contracting or manufacturing. Vic Jennings, the new Managing Director and son of AV, reorganised the company structure into national product groups of which private housing was one. The company grew significantly with turnover moving from $24 million in 1965 to $191.6 million in 1974. The company became involved in remote-area construction providing housing for new mining towns in remote parts of Australia. Their skills at efficiently providing quantity housing coupled with their expertise in material supply operations proved effective in these projects.

In the late 1970s the company suffered adversity in the economic downturn resulting from the world oil crisis. Jennings divested poorly performing divisions, namely mining and manufacturing, whilst expanding and then withdrawing from the US market in construction, development and property investment.

The 1980s were a period marred by takeover concerns. In 1986, Fletcher Challenge, a New Zealand construction company, was invited to take a controlling share in the company.

With the onset of the 1990s recession, Jennings was again facing financial difficulties. In 1991, the general construction division was sold to Fletcher Challenge.

Later in 1996, the remainder of the company consisting mainly of the housing division, was purchased by another significant house building company, and still operates under the Jennings name.

THE JENNINGS' APPROACH TO HOUSE PRODUCTION

Jennings' operations can be distinguished from those of other builders by their efforts to achieve continuous production flow to produce large quantities of houses. It was this emphasis that enabled the organisation to achieve production efficiency whilst meeting the required design flexibility of its market. Emphasising production flow to achieve efficient but flexible operations is the essence of 'lean production' as described today (Ohno 1988; Womack et al 1990; Womack and Jones 1996).

Being a comparatively large building organisation by the 1950s, it may seem unremarkable that Jennings' operations were oriented toward producing houses in quantity. Yet even in their initial period, with their emphasis on housing estates and groups, Jennings recognised the utility of building houses in quantity rather than individually. Their capabilities enabled them to operate with great accomplishment in this type of construction well before they became a large organisation.

With the shift away from government contracts toward private housing developments in the late 1950s, building large quantities of houses at the least cost was not sufficient to ensure success in the private housing market which demanded greater flexibility in the design and the details of their homes. Furthermore because Jennings were essentially contractors who built houses to their own designs, they had to engender confidence in prospective clients that they could perform. This required an understanding of the total process of the development of designs and their realisation.

The challenge for Jennings was to provide the essential flexibility for clients, yet still produce efficiently. To this end, they obtained an important insight: the production process should be designed so that production could be in continuous flow. In particular production was arranged and managed so as to maintain a continuous flow of work. Thus over the period spanning the late 1950s to early 1970s, Jennings employed this approach and refined their operations to efficiently produce large quantities of houses, whilst attending to the particular needs of individual clients. The growth in turnover and profits over this period attests to the success of this approach.

JENNINGS' OPERATIONS

Having discerned Jennings' approach to house construction, this section describes six aspects of their operations to further elucidate the approach and insights yielded from their experience. Each aspect is related to current literature.

Contracts - ordering, production, and scheduling of works

Jennings was able to ensure the efficient production of a varied range of house designs through arranging the production process to maintain a continuous flow of work. In practice this meant that certainty of project commencement dates had to be provided and projects had to be arranged into a tightly coupled sequence.

Rather than scheduling individual project activities, Jennings gathered them into groups of interrelated tasks to form production stages, such as work up to the floor level, framing, and closing out. Such a group could be further categorised according to the difficulty of the work and duration. The production stages for a number of projects would be shuffled in order to ensure continuity of work for the trades over the projects. As far as labour and equipment contractors were concerned, projects did not necessarily have to adjoin each other spatially, since they returned home each evening with their equipment and it was just as easy for them to move to one location or another within a region of several kilometres. This practice of shuffling ensured the full utilisation of resources which was a requirement of an efficient production system.

In order for Jennings to provide certainty of the commencement of production phases they devised the notion of time gaps, where time was scheduled between phases without corresponding activity. These buffers ensured that the overall system was robust to the external variations of climate and site. Time gaps could be adjusted to ensure continuity of work for trades.

The production process was buffered from the ordering process due to the variability in the latter. Jennings only producing houses in response to specific customer orders. Whilst this was as a consequence of a risk policy that avoided speculative housing, the approach replicates the practice of "pulled" production rather than "pushed" production as advocated in lean production and just-in-time (Ohno 1988; Womack and Jones 1996). However customer orders were obtained in variable quantities and at variable times which did not suit efficient production flow. The insertion of a buffer, as depicted in Figure 2, decoupled production from the variability of the order process. In a similar manner, the 'workable backlog' in Ballard and Howell's *Last Planner Technique*, shields production from the uncertainty and variation of poor planning (Ballard and Howell 1994; Howell and Ballard 1994). In addition to the variable quantity and order-rate, the throughput time of the order process was not constant as matters such as contract signing, finance arrangements, design adjustments, selection of finishes, and the like, varied between clients. The buffer served to control the feed-rate of orders to production that enabled the scheduling of firm commencement dates and continuous production flow.

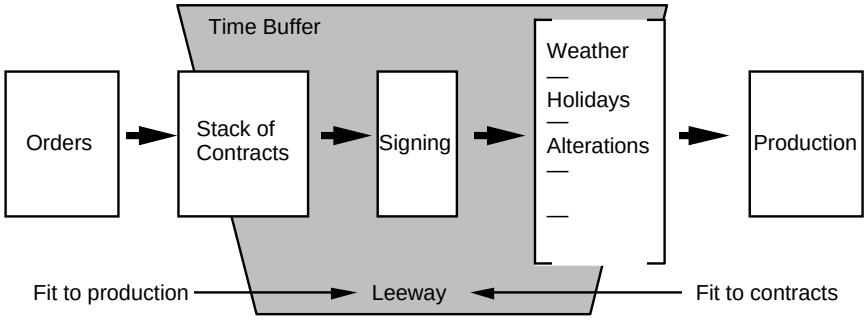

Figure 2 Flow diagram depicting Jennings' order to production process.

Jennings recognised that in order to efficiently produce variable products that met specific customer requirements one had to address process flow. It is this notion that is central to approaches such as lean production and just-in-time (Ohno 1988; Womack et al 1990; Koskela 1992). Furthermore Jennings' practices to achieve production flow replicate those advocated by Howell and Ballard for use in construction, namely the strategic use of buffers (Howell et al 1993; Ballard and Howell 1994a; 1994b; 1997; Howell and Ballard 1994). The Jennings' case confirms the importance of addressing the inherent variability of construction in order to ensure the system is robust and ameliorates continuous production flow.

Product development

Rather than operating in the custom-designed housing market or speculatively offering pre-built homes, Jennings developed and presented to their market a limited range of standard house design models from which customers could select.

Jennings developed design models to be presented once per year with occasionally special new designs provided during the year. This provided a framework and discipline

to the product development process. The development process was divided into two components, the development of new designs, and the improvement of existing designs, with the latter being much more frequent. With multiple orders occurring for each design model, Jennings could spread development costs across the number of orders received.

Whilst products were developed and marketed on the basis of standard models, clients were not precluded from making adjustments. The pricing of standard extras was on the same basis as the rest of the building. However in order to ensure that variations did not adversely affect the production system, which relied on the consistency of design approach, a policy on variations was incorporated into the production process to ensure changes made to individual houses were within the scope of the production process.

Product development maintained an awareness of market needs. Practices like value analysis and the construction of prototype houses to test both constructability aspects and market response were employed. Value analysis ensured that only design features were provided that clients wanted and were prepared to pay for. One important consequence of this work was the realisation that 'inside-out' planning was critical for client satisfaction. Since clients mainly live inside a house, window locations were determined from the client viewpoint looking out and with respect to room layout and furnishings, rather than from outside looking in. The plan layout and the zoning of distinct living areas were seen as very important.

Jennings' product development was not solely restricted to developing marketable houses and land but also addressed production issues. Arising from research and development efforts, their concept of design was gradually extended to embrace production. The buildability of designs was ensured through aspects such as the standardisation of detailing and the rationalisation of the modules used for placing windows and doors. The development of the "rationalised frame", a timber frame that allowed the relocation of openings at twelve inch modules improved design, placement and layout flexibility whilst maintaining optimum production efficiency. In addition to these practices and the building of prototypes, production feedback was used to modify design to improve production. Whilst constructability is presently being promoted for the wider construction industry (see for instance, Chen and McGeorge 1994; Francis et al 1996), the idea of incorporating the constraints of subsequent processes into the design for the purposes of improving the overall process was practiced by Jennings.

Jennings' approach to product development replicates many of the elements of concurrent engineering being advocated presently in manufacturing and construction (Huovila et al 1994; Baxendale et al 1996; Love et al 1996). In the design process, close liaison occurred with stakeholders such as material and product suppliers; production personnel; building research groups; regulatory authorities; and various groups concerned with markets and marketing. This was done so as to develop an integrated multi-functional approach to product development that provided the best possible products in the least possible overall development time.

An integrated approach to both design and production yields the optimal final product. The Jennings' experience confirms the utility of practices such as concurrent engineering and constructability which encourage the efficient and timely provision of products that meet the diversity of customer needs.

Control - time, cost and quality

Jennings' use of direct labour and equipment contractors permitted them to manage production with a considerable degree of control. Jennings' employment of direct labour and equipment contractors, maximised their control of site production and operational flexibility. Labour and equipment costs were determined for particular work packages and only adjusted on an annual basis, therefore costs remained constant for projects built during that period.

With Jennings' directly supplying the majority of materials to projects, they also had considerable control over their materials supply management and cost.

Jennings prescribed standard production procedures as a means of ensuring effective control of time, cost and quality. Site operations conformed to Jennings' standard procedures document (Jennings' Housing and Land Group-ACT Division 1976). The standard procedures were used to manage production, in conjunction with Jennings' sophisticated scheduling which planned materials, labour and equipment contractors, areas of work and types of houses.

Jennings had an extensive quality control system as part of their operations. Much of their approach to quality was developed as a result of investigation of practices at General Motors Holden (Australia) (Jennings and Grant 1997). Whilst they emphasised an efficient production system for producing large quantities of houses, clients were only concerned with their particular house. Thus it was necessary to provide progress reports on every individual house, and upon completion have pre-handover and handover checklists to assure the quality of their products.

To adopt a quality system that embraced quality from the client perspective as well as provide operational standards for performance, Jennings developed a definition of quality to be "the finish as seen in the display homes". This provided a standard for clients, which the company committed to meeting, while contractors could ascertain what was required of them. Finishes were of prime importance to clients, as this is what they could see. By conducting their quality assurance checklists, Jennings ensured that houses were presented to clients in a state of full quality. However this approach also addressed standards for all other aspects of the house, as the required level of finishes could not be achieved if the remainder of the house was poorly constructed.

These checklists provided Jennings with a quality assurance system that became the basis of a feedback system to measure production and subcontractor performance, to pick up weaknesses in design and, in particular detailing. This feedback was a means to improve product and operational performance.

Jennings' approach to control bears similarity to that of lean production and just-in-time. Standardising work practices is a feature of the 'lean thinking' principle of flow (Womack and Jones 1996), and flow in just-in-time (Ohno 1988). Developing close relationships with labour and materials suppliers is central to supply-chains. Having a quality control system functioning throughout the organisation's operations, assuring quality as observed from the customer's perspective, replicate the practices of current approaches like total quality management and lean production (Koskela 1992; Armstrong 1994).

Labour and equipment contractors

Whilst the usual arrangements for house construction contractors was to complete projects with in-house trades and labour, Jennings preferred to maintain a smaller supervisory workforce and utilise expertise provided by labour and equipment contractors. Over time Jennings developed relationships with better contractors, as the arrangements on their projects attracted such organisations. Whilst there were no formal

long-term arrangements, both Jennings and their labour and equipment contractors operated in a fashion that extended beyond the short-term of the present project. Jennings used these contractors to train their apprentices and enable junior supervisors to obtain experience, imitating the management exchange practices of Toyota with their suppliers (Womack et al 1990).

The capacity of Jennings to operate with their labour and equipment contractors in such a fashion related to their efforts to arrange continuity of work for these organisations over a series of projects. It was evident that if continuity could be offered to tradesmen then incentive existed for them to master new house types and earn better money. The payment system adopted was to establish on an annual basis a price for particular work packages, such as a wall frame. If there were no delays in moving from one job to another and if work was organised for them, then contractors could earn considerably more than on conventionally arranged projects. By providing an organised pattern of work, continuity and quality standards, Jennings tended to attract the best tradesmen to their projects, which in turn facilitated better time control, and better overall organisation.

Just as Toyota recognised the utility of managing the supply-chain (Womack et al. 1990; O'Brien 1995) so also did Jennings. Both understood the worth in developing stronger links between the supplier and client through encouraging longer-term arrangements rather than short-term market-relationships. Both recognised the worth in providing circumstances to assist mutual benefit: continuity of work for the subcontractor and more reliable and capable service for the client. Both understood that such arrangements facilitated production feedback to optimise the overall process.

Developing supply-chain relationships is of utility to both parties. The potential gains that accrue from this relationship has led Womack and Jones (1996) to extend the notion to emphasise the value stream.

Materials supply

Whilst Jennings addressed continuous production workflow in their operations, they also attended to the supply of materials as a means to facilitate efficient production. The latter aspect was recognised far earlier than the former. With the limited availability of resources in the post-Second World War period, Jennings purchased materials supplies businesses so as to ensure the maintenance of adequate materials and supplies.

Jennings' ownership of their material suppliers allowed them to control the manner in which materials were supplied to their sites. Jennings held stocks and orders at the supplier's premises because the costs of leaving materials under less favourable conditions on site were considerable. Staging production led to packaging of groups of items that could be delivered to site just in time for the commencement of the next production stage. Items were packed in such a way that when delivered to site, they were found in the order in which they were to be used, a similar practice adopted by Toyota (Ohno 1988). With standard practices, detailed production schedules, and close liaison with suppliers, precise material quantities were supplied to site within three days of a request, although suppliers were given a complete house order with nominal dates prior to production commencing.

Similar to the supply-chain arrangements at Toyota, Jennings' suppliers were encouraged to operate in the wider marketplace. This was regarded as an important measure to ensure that Jennings' activities were not undermined by uncompetitive supplier practices. A policy was developed that materials had to be supplied to the wider market of at least equivalent value to that supplied to Jennings' projects to ensure competitiveness.

The ownership of suppliers also allowed the organisation to test and implement new approaches, designs, and organisation of materials.

Whilst materials deliveries operated on an essentially just-in-time basis, this arrangement did not extend to their production. O'Brien (1995) has observed that many of the potential gains of just-in-time were not achieved by the supply-chain when only delivery and not production are aligned to just-in-time. This finding is consistent with the experience at Jennings.

Initiatives for improving performance

Jennings recognised that superior operational performance provides competitive advantage. To achieve this effectively and efficiently, they adopted initiatives to continually improve and learn as part of normal organisational practice. Feedback systems provided performance information to determine improvement potential. Extensive research and development focused on product development and improvement, enhanced production performance, and the integration across these processes. Examples such as factory-built and pre-glazed windows, pre-hung doors with fitted architraves, room service flooring, and pre-painting of timber, were developed to improve product quality and production efficiency—all of which subsequently became common in the industry. Jennings collaborated with research organisations like the CSIRO to refine regulatory inspection and approvals procedures. These were later to become the industry standard for building surveyors. Jennings were one of the first Australian construction organisations to employ Computer Aided Design and Drafting (CADD) which enabled design simulation prior to prototyping to improve product development. CADD improved production by providing precise information to individual contractors and helped to further improve the understanding of the total design-production process and the integrity of the system.

As part of the strategy of continuous improvement, Jennings addressed broader housing issues. It was active in its support of the Indicative Planning Council,[2] the Australian Institute of Urban Studies, and the CSIRO, who were seeking improved methods of financing houses.

Central to the impetus for the adoption of approaches like lean production and just-in-time is the need for the organisation to continuously improve to enhance performance and thus their competitive position (Ohno 1988; Womack et al 1990; Koskela 1992; Melles 1994; Schniederjans 1993). Jennings, understanding this same issue, devoted considerable effort to continually seek out potential and testing alternatives as a means to improve performance.

COPING WITH CHARACTERISTIC CONDITIONS OF CONSTRUCTION

The character of construction is frequently distinguished from other industries by its production of one-of-a-kind products, site production and temporary organisations (Groàk 1992; Koskela 1992). Yet these features increase the degree of variability and thus discourage efficient production.

Recognising this, Jennings arranged their operations to limit the adverse impact of variability. The construction of custom-designed homes were avoided. Rather a range of product models were designed after extensive market research with limited features customised by clients. This enabled the standardisation of work practices and the scheduling of production to ensure continuous workflow, as a means to limit the inefficiency of producing varied products. Although variability between sales, ordering and production is far from an exclusive problem to construction, it was alleviated by

[2] A peak body for the housing industry.

decoupling sales and ordering from production. Level production could be maintained by controlling the feed-rate of orders to production. Buffers to decouple production phases minimised the impact of environmental and site factors on site production. The difficulties resulting from temporary organisation were minimised by an integrated approach to product development and production and the development and maintenance of labour and material supply-chains.

The Jennings' case provides evidence that the characteristics of construction are not an insurmountable impediment to the employment of flow principles in construction.

THE SHIFT AWAY FROM LEAN CONSTRUCTION - MARKETING OVERTAKING OPERATIONS

Despite the success of their operations, Jennings' approach to house production gradually changed. This appears to be largely as a result of the shift in balance between marketing and production. There were a number of causes that contributed to this shift. During the late 1970s, the organisation was affected by the world oil crisis that significantly impacted and altered the economic environment. In addition senior management was restructured as a result of the early death of the Housing and Land Group General Manager.

Already the majority of senior personnel were marketing-oriented and an appreciation for production expertise at this level was further abated by the restructure. The marketing-orientation perhaps resulted in off-site management becoming dominant in the organisation where previously it was in balance with (site) production. The result was a less-disciplined overall organisation. By Johansson et al's (1993, pp2-4) typology for progression toward the market-driven process-orientation of total quality management and just-in-time, which may be used to interpret this change, Jennings appears to have regressed to out-moded practices.

The shift toward marketing was also reflected in the company's research and development efforts as its breadth narrowed. Research and development focused on increasing marketing awareness and improving product flair. There is no doubt that this was executed with great skill as Garden (1992, p149) notes: 'it was not until it was realised that house building was a marketing exercise, which needed to discover and fulfil client's wishes, that the [marketing] exercise became successful'. However the consequence of this emphasis was the diminishing of effort and lack of creativity to improve production. As a consequence there appears to have been a gradual loss of integration between, and development of, design and production thus curtailing the effectiveness of the overall operation.

The Jennings' experience highlights a number of factors to sustaining a lean approach to construction. The balance between marketing and production must be maintained so as to enable the efficient production of a variety of products. An imbalance disintegrates the overall process and results in sub-optimal performance. To avoid being undermined, the approach must have senior management authority and support.

DISCUSSION

The Jennings' case reveals that the principles behind approaches such as lean production and just-in-time are not new to construction. Their approach to house production from the 1950s to 70s utilised flow principles. Production flow was emphasised to maintain production efficiency whilst meeting wider customer choices. In particular production was arranged and managed so as to achieve a continuous flow of work.

Just as importantly, this case confirms the utility of flow principles to construction operations. The Jennings' case provides a more comprehensive example of the utilisation of flow principles in construction than others reported in the literature. Such cases tend to be limited to exploring particular aspects and thus have difficulty in demonstrating the full potential of flow principles to construction. It is clear that lean production and just-in-time exploit the flow principle to a greater extent than Jennings, nevertheless the Jennings' case is an extensive illustration of a number of lean practices including flow production, integrated product development and production, supply-chains, and quality assurance. The growth of the company over the period when such principles were employed indicates the worth in adopting flow principles. With greater aptitude than other cases, Jennings enables a fuller appreciation of the potential of lean approaches to construction.

The Jennings' experience offers insight to assist present-day efforts to adopt lean production and just-in-time in construction. It confirms that the conditions of construction are not insurmountable impediments to flow principles. It confirms the use of buffers to cope with some of the features of construction. It reveals that greater advantage is achieved when flow principles are extended to all operations, in particular beyond production to develop an integrated approach to product development, design and production. It also confirms that for the sustenance of the approach, the marketing and production functions of an organisation must be integrated and balanced. An imbalance in one or the other clearly results in sub-optimisation and impedes the overall performance of the organisation. The Jennings' case confirms that the flow principle has much potential to offer organisations operating in construction.

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