Housebuilding Supply Chains: Remove Waste - Improve Value

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There is little published work regarding value and waste in UK housebuilding supply chains. In this paper, we review the current status of research in supply chains generally and housebuilding supply chains specifically. The "wastes" and "values" within housebuilding supply chains are identified and categorized and some key potential improvement methodologies are proposed. Starting from the concepts of "value" and "waste", relevant supply chain models are evaluated and a case study is used to suggest improvements towards a more efficient housebuilding supply chain. Finally, we present a template for waste detection in housebuilding supply chains.

The construction industry has seen a plethora of initiatives and improvement ideas for general construction including supply chains [1] which has led to several practitioners, academic institutions and bodies promoting best practice. However, only a minority deal with the specific interest of housebuilding, even though this industry sector represents a major area of national spend, uses large national resources (both labor and materials), and is under performing against required build quotas [2]. It differs from general construction in that the market volume and specialization make it more comparable with general batch production, and so therefore lends itself to the application of "lean thinking" for delivering more efficient and effective supply chains.

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We begin by reviewing the concepts of value and waste and more specifically how they relate to housebuilding supply chains. Then, we review research on supply chain management. Next, we review general trends and areas of relevant research in construction supply chains and housebuilding supply chains. A case study based on previous research, is used to show the meaning and relevance of value and waste in housebuilding supply chains. Finally, we present improvement opportunities that are viable within the context of an engineering change model.

Value and Waste

Understanding and creating value is central to many disciplines especially marketing and supply chain management. There are many definitions of "value" most relating to the customer, their perceptions and costs or the payment made. According to Porter [3] "Superior value stems from offering lower prices than competitors for equivalent benefits, or providing unique benefits that more than offset a higher price". Many customers do not primarily aim to buy goods or services for their own sake but rather for the benefits or the end results that these goods or services bring. Different authors define value in different ways, Lindfors [4] defines value as "a quantity, which grows when customer satisfaction increases or expenses associated with a product decrease". Christopher [5] states that value "has long been the axiom of marketing and that customers don't buy products, they buy benefits". Put another way, the product is purchased not for itself but for the promise of what it will deliver. Value may be: quality, exclusivity, convenience or possibly service response (an intrinsic value); the common denominator is cost to the customer [6].

Holbrook [7] describes eight types of consumer value, concerned with different aspects of consumption. Here consumer value definitions are based on those of Hilliard [8] , and are said to be interactive, relativistic, comparative, personal, situational and based on experience. Kotler [9] says marketing is concerned with exchanges and transactions between two parties where something of value is given up for something of greater value.

A source which is more supply chain oriented [10], proposes that although focusing on delivering superior value to customers may well be an obvious activity, it is surprising how little this executive task of focusing on value is actually carried out. It goes on to say, "Customer value is a combination of functionality of product or service in terms of the benefits that are offered to the customer and the price that is charged". The price or the cost of exchange figures frequently in many definitions or understanding of value. "Since price forms a part of the total cost of ownership it follows that there has to be a relationship between the price charged and the customer's perception of value" [11].

Nine core streams emerge around the concept of value - eight of which focus strongly on the customer or the end user [12]. The general consensus is that Value Adding (VA) activities and processes, add value to a product or service as perceived by the customer. Non-value adding activities or processes have a cost but no perceived value – this may be termed as "waste". A Value Chain or Value Stream mentioned by many authors refers to the specific parts of the business or organization that actually add value. In other words, in a theoretically perfect value chain there are only value-adding activities. The inference here is that, to identify, evaluate and eliminate these non-value adding activities will result in major improvements and move toward another well-versed paradigm, "lean". "The logic of lean production, leaving aside for the moment its implication for working practices and social impact, describes the value-adding processes unencumbered by waste (non-value adding activities)" [13]. Similarly "lean supply" or a "lean supply chain" is where inefficiencies and waste have been removed to the benefit of the whole supply chain.

The removal of waste, either within an organization, or at the interfaces between organizations, is a way to increase value and competitive advantage. However, in themselves, greater efficiencies may not be a primary competitive weapon, as we have just reviewed, value is mainly in the eye of the beholder and consideration must be given to the delivery of total value to the customer. This means the delivery of not only greater cost reductions, but also the delivery of quality products at minimum lead-times and maximum service [14].

Value, from a house-buyer's point of view, has been studied using quantitative analysis termed "home-buyer satisfaction" [15] which measures design, house quality and service quality, via 51 questions. The survey results showed that service was the most important of the three dimensions, but questions on overall cost (price), delivery time, and meeting promised delivery date, were not asked. Atkin [16] in a study of the use of IT (information technology) for speculative housebuilding not only showed a 50% reduction in design time (through use of CAD – computer aided design) but also a great reduction during the build process in "delays caused by errors and inconsistencies" when information was shared with manufacturers and major suppliers. Such use of IT can improve the efficiency of the building operation by reducing time and costs and hence increasing value.

Defining and understanding "waste" in supply chains can be complex and confusing. The term "waste" is often associated with environmental issues especially material or physical waste rather than the inefficiency of activities or operations. However, waste (muda) is defined by Ohno [17] as follows: "we regard only work that is needed as real work and define the rest as waste". Another definition of waste, originating from Toyota, is "anything other than the minimum amount of equipment, materials, parts and working time absolutely essential to production" [18].

Many published articles link value or value-adding activities with waste. Koskela [19] for example, describes non-value adding activities as taking up time, resource or space without adding value, but describes value adding activities as those converting materials and/or information as a benefit for the

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customer. The conclusion here is that it is useful to identify those operations that are wasteful and should be removed.

Alarcon [20] defined a lean understanding of waste related to the construction site as "anything that is different from the minimum quantity of equipment, material, parts and labor time that is absolutely essential for production". From a supply chain perspective "waste" can be defined as any excess of materials, resources, time and energy that are not really necessary in performing any activity or process throughout the supply chain.

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In the following part of the paper, we review existing work on supply chains and conclude with a summary of classifications of waste.

Supply Chain Management Research

There is a substantial amount of published material on supply chains and supply chain management much emanating from manufacturing and retail industries. This appears to form the basis of most analysis, understanding and improvements that lead to best practice. The origins appear to be from logistics with Houlihan [21] the first to use the terminology. The supply chain management concept focuses attention on holding inventory in the location and at the quantity that is optimal for the entire supply chain [22], "Clearly exchanging information is central to the supply chain concept" [23].

A clear and early definition of supply chain management by Stevens [24] is "a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via the feed forward flow of materials and the feedback of information", or another via Cooper [25] is "an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user". Other authors stress the importance of appropriate partnering, working as a team, integration of the supply chain, being "market-facing", having clear and accurate information flow throughout the chain all with the aim of eliminating the major areas of inefficiency, many at the interfaces [26].

As expressed by Harland [27] supply chains can mean different things to different people. The complexity and length (or span of influence) can vary from an intra-organizational supply chain, to a dyadic one (buyer and supplier), to one that stretches from the initial raw material to the final customer. Also there is the network supply chain concept, which is a more realistic but more complex concept where many and various suppliers and customers are inter-linked through a web of buyer-seller relationships. In this paper, we use a case study to portray a housebuilding supply chain stretching from raw materials and semi-finished goods through to the end customer.

Towill [28] puts forward the idea of a seamless supply chain where all participants work as one, saying "there are enormous benefits to be obtained by improving information flow and material flow, both being much enhanced via time compression of value added activities and the elimination of non-value added activities". However, having all supply chain participants working in collaboration goes against traditionalist buyer/seller relationships, especially in construction, which is renowned for its contractual and litigational culture.

In many instances, especially for goods or services that are core and valuable, businesses have realized the strategic importance of selecting the correct, but fewer suppliers, and forming "co-makerships or partnerships" as a way of reducing "waste". On these occasions strategic decisions are made for sharing information, having quality improvement goals, sharing the risks (pains and gains), having some agreed level of mutual commitment, so improving the flow of materials or services. All this can help increase customer satisfaction by minimizing cost and waste and creating value, the essence of good supply chain management.

Construction Supply Chains

A considerable amount of published work exists on construction supply chains, much emanating from a few organizations or institutions. Such organizations include independent bodies like the International Group for Lean Construction (IGLC), Science and Technology Policy Research (SPRU), University of Sussex, and Loughborough University. Also, UK Government led or assisted bodies like Construction Industry

Board (CIB), Department of the Environment Transport and Regions (DETR), Construction Research and Innovation Strategy Panel (CRISP), Construction Industry Research and Information Association (CIRIA), and Construction Productivity Network (CPN - which is part of CIRIA) have contributed to the literature. The UK Government has commissioned several reports to improve construction including those of Latham [29] and Fairclough [30]. Specific recommendations for construction iinclude partnering, lean construction, design and standardization – all aimed at improving efficiency in the industry and related closely to removing waste in the supply chain.

Although there is much literature that addresses handling, operations and transport, there is little on detailed analysis of overall supply chain improvements. It appears that the tendency is to concentrate on separate specific areas within the supply chain. An example of this is Horman and Kenley [31] who concluded from "meta-analysis" of some 24 case studies that there is an average of 55% wasteful activities in construction processes. The studies which were "on-site based", including concrete work, carpentry, bricklaying and pipefitting activities showed that there is a large variation but on average, a large amount of waste in these activities. Proverbs and Holt [32] assessed the situation by mainly analyzing concrete formwork and related activities, and propose that construction contractors, as the vanguard of the supply chain, are best placed to meet increasing client demands for economic construction. They suggested that contractors should gain early supplier involvement and that suppliers should change their culture from "product" to "service" providers, a more "value" related measurement. They concluded that although upstream alliances are common (contractor to client), there is a lack of down stream alliances such as mini-partnering arrangements with contractors and suppliers, which would increase the effectiveness of the whole supply chain.

A more holistic view is given by Agapiou et al. [33] who looked at construction supply chains from the builders' merchant perspective. They identified a trend towards consolidation in the sector; that JIT (Just-In-Time) principles in construction are not easily implemented; and that collaboration is ad hoc and there is a lack of overall perspective. They concluded that construction companies can only improve the supply chain through partnerships and long-term relationships with merchants.

Also, Vrijhoel and Koskela [34] and [35] through defining the roles of construction supply chains identified the causes of overall waste. They conclude most is due to a low level of partnership and non-co-ordination that they term "obsolete myopic control".

A definitive holistic approach to improving supply chains is that of modeling, where, for example, planning / modeling software called IDEF0 is used. Using this, Karka and Lahdenpera [36] presented the possibility of systems modeling of the different stages of the contractor focused supply chain. This encompasses all stages starting at the initialization of the project, the various design stages, build stages and possibly maintenance stages. Work done on simulation modeling [37] with reference to the logistics of a total construction supply chain in Poland considered different strategies of material and information flow and showed that this holistic approach should reduce overall logistics costs.

In general, much construction is make-to-order and very project biased. Much time and effort is concerned with project definition, briefing, contractual arrangements, different design iterations, etc., prior to build [38]. The impact and value of briefing on large construction projects is considerable [39]. Another modeling system, Process Protocol (see http://pp2.dct.salford.ac.uk/mainpage.htm, is based on, but reportedly less cumbersome than, IDEF0 [40]. Again the modeling is aimed at the whole construction project with emphasis on initiation, design and project control, rather than supply chain functions and the improvement potential therein.

A survey, of 40 large UK contractors showed the construction industry to be relatively slow in adopting SCM [41]. It revealed that contractors are more oriented towards clients than suppliers and have more arrangements with clients than with suppliers. They tend to "regard suppliers on a par with employees and sub-contractors, that is, as suppliers of a service they have the

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opportunity to dispense with largely as they please". This goes against the growing trend in electronic, automotive and other manufacturing sector businesses where there is greater supplier involvement and suppliers are encouraged to improve "value" and reduce total cost in the supply chain.

Work carried out in the Netherlands, [42] reported that about 40% of building production costs can be related to communication. There is also a shift of added value towards the preliminary stages of construction such as pre-assembly and prefabrication. This aligns with the fact that ancillary construction industry accounts for over 70% of all innovation (product and process) within the Dutch construction industry [43].

Two cases studies of the logistics system of the Dutch building supply chain found that concern with overall costs in the supply chain [44], this is considered to comprise of five elements – sourcing, production, inventory, transport, and service (the SPITS model) originating from TNO Into (1994). The first case study involved decentralized production of highly customized pre-fabrication of concrete products. This case study showed a reduction of on-site, inventory and transportation costs, but an increase in the factory production costs. The second case study analyzed the ceramic tile supply chain, where it was found that due to deregulation and demand for increased variety, centralization and cross docking was introduced resulting in customization earlier in the supply chain. This meant that with the use of IT, lower inventories could be held, service was improved but unfortunately transport cost increased. The impact this had on overall costs was not analyzed.

Published research into holistic improvement of housebuilding supply chains is limited...

As indicated earlier the IGLC has contributed greatly to the published literature base surrounding lean construction with much of it relevant to supply chains in some form or other. Ballard and Howell [45] introduced the concept of Lean Production Theory (LPT) derived and related to JIT and Ohno, and promoted the idea of shielding production [46] from uncertainty (Toyota concept of "level production" – heijunka) as a way of removing waste. This concept leads to the "last planner" principle, apparently successful because construction top level plans are continually being adjusted by external influences and it is really only the person at the end of the chain of command (site manager or equivalent) who can best decide activities and so shield production from disruption.

In this section, we assessed much published work on general construction supply chains and has shown that much of this work concentrates on improvements in separate specific areas in isolation, yet it is recognized that the majority of inefficiency or waste occurs at interfaces between links in the supply chain. However, general construction by its nature tends not to be repetitive and therefore not always conducive to strategic supply formations, unlike housebuilding, which being the next and final topic of review can be different in this respect.

Housebuilding Supply Chains

There is little published work concerning housebuilding logistics or supply chains, particularly regarding holistic efficiency improvements and the removal of waste. Again, as stated above, specific areas have been studied in isolation, these including; on-site material and resource waste [47], standardization and design [48], pre-assembly [49] effects of partnering for general improvements [50], customer-focus [51], and rework and its causes [52].

Research at a more specific and focused level between house builders and universities and major house builders by themselves is taking place, but due to its commercial nature little is published. Work by the major house builders includes rationalizing the supply base (including national agreements), working with specific builders merchants, forming stronger partnerships, and looking at better information technology. Published research into holistic improvement of housebuilding supply chains is limited, some examples being Naim [53] and Towill [54].

Primary data by Parker [55] on partnering in the supply chain was obtained by surveying 19 top UK housebuilding companies. Out of these, 15 had partnering agreements with suppliers. All 15 thought that partnering was working; all felt it was a key strategy, yet on average they could increase partnering with suppliers by 40%. Results

showed that on average 73% of partnership agreements involved contracts and 73% of partner supplier still had to tender for work (the later process often time and resource consuming).

It can be said the UK housing industry consists of two main sectors: private (speculative – direct sell to consumers) and social housing (build for private or public/local authority landlords). Within the two parts there is a larger variation of companies in terms of their size, market sector, and abilities. According to the NHBC (1998) 109 of the largest builders (less than 1% of all builders registered in the UK) collectively controlled three-quarters of the market. The following listing, gained from previous research into housebuilding supply chains [56] highlights the difference between housing and general construction in the UK, by describing the housing sector as follows.

- Firm, stable demand – relatively speaking demand for UK housing remains greater than supply regardless of research and government intervention.
- Designs are stable – public housing still uses many common elements for materials and operations. Most private housing is batch produced from a limited portfolio of designs. This means a great deal of repetition in the materials and process used especially by the major builders.
- Design is relatively firm, and most are tried and tested – private housing customer choice is limited and controlled.
- Volume is relatively high, with many sub-elements replicated.
- Relationships in the supply chain can be stable with great potential for long term strategic partnering as opposed to project partnering now common in large construction projects.
- Processes within the supply chain and on site are repetitive and can be likened to batch manufacturing with many improvement techniques applicable.
- Customers are often naive and uninformed – especially for private housing.
- Build for private housing is mainly "make-to-schedule" – "complete to order".
- Private housing involves large speculative investment (speculation) prior to order commitment by a customer.

Housebuilding, especially for the multi-regional, high volume house builders, is very akin to the manufacturing sector from which much best practice regarding supply chain management is derived.

In summary, there is little analysis of the UK's housebuilding supply chains from an holistic perspective. Employing techniques previous used by Cardiff University to investigate and recommend improvements to supply chains, the authors will attempt to analyze a "multi-facet raw material to end product" housebuilding supply chain using the following case study.

Case Study

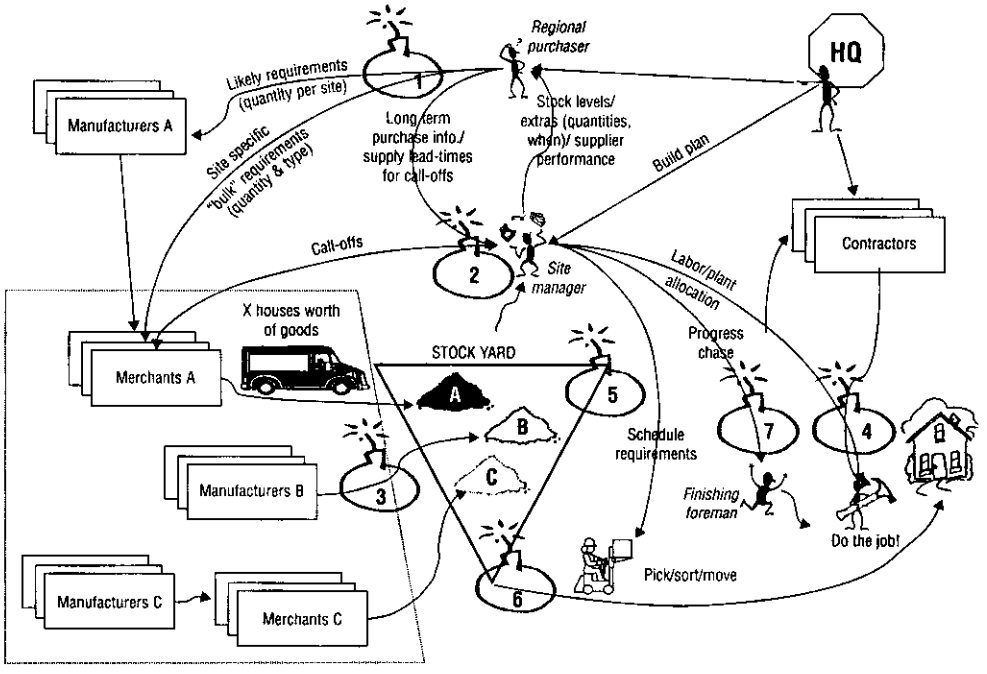
The work described here emanates from UK Government (EPSRC) funded research into housebuilding. Here the UK private housebuilding sector was studied where traditional methods and techniques were being employed. A list of key participants in this research is shown in Table 1. The research methodology employed consisted of visits and observations at participants' premises, mapping of business processes, questionnaires for quantitative data (both customer and supplier side) and semi-structured interviews of key personnel. This included detailed analysis of four housebuilding sites owned by two major volume house developers, plus some observational analysis at other sites to confirm the information gathered. There was a good deal of commonality in the materials, operations and service provisions across the sites. The supply base is somewhat adversarial with mixed single and multi-sourcing (including multi–merchant sourcing) and use of several labor resources. An understanding of the general processes employed and the principle methodologies that underpinned them were validated by presentations and discussions with the practitioners involved, this included the identification of waste/improvement areas for each participant or relevant area of the supply chain.

Figure 1 depicts a "rich picture" representation of the building site based generic supply chain state, with the Site Manager playing a key role in the tactical running and day-to-day operations of all aspects of the build. The figure focuses on the major issues concerning the planning and control of the supply chain and its associated operational logistics. Although not meant to

Table 1
Summary of Industrial Partners' Profiles Involved in the Research

Company	Role	Number of employees	Turnover £M	Construction sector	Customer type
A	Manufalcturer	700	80	Social / Private	Contractors
B	Manufacturer	340	30	Social / Private	Contractors / Housing Association
C	Main Contractor	300	90	Social	Housing Association
D	Developer	1,012	312	Private	Individual Customers
E	Architects	130	5	Social	Housing Association / Contractor
F	Housing Association	370	45 (only for rental)	Social	Social Tenants
G	System Integrator	20	1.4	Social / Private	Individual Customers / Developers
H	Manufacturer	1,000	171	Social / Private	Merchant
I	Consultant	1	0.05	Social / Private	Developer / Contractor

Figure 1
Rich Picture of a Housebuilding Supply Chain



Source: Adapted from Mohamed M. Naim and James Barlow, "An Innovative Supply Chain Strategy for Customized Housing", *Construction Management and Economics*, Vol. 21 (2003)m pp. 593-602.

be comprehensive it highlights seven critical "waste spots" identified via research team brainstorming sessions where a pictorial summary of gathered data for participants and the relevant supply chain was amassed. These problems areas were validated by consensus with participants as already discussed. This supply chain representation is realistic and is a hybrid encompassing a combination of dyadic, raw material to the final customer and network types. It includes information flows between the site and

regional/national headquarters and the interface with suppliers, manufacturers, merchants and contractors.

The figure and its "waste spots" form a basis to illustrate the traditional problems of waste in housebuilding supply chains. These spots will now be defined. Table 2 provides a description of the seven types of waste spot.

- **Waste spot #1** *(little supplier management /involvement)* – At a regional and site level, loose purchasing agreements are made with manufacturers, suppliers and builders merchants but these are based primarily on price. There are no guaranteed time scales for actually buying and calling off the material. Involvement and collaboration is low hence the suppliers have little vision of long-term market requirements.
- **Waste spot #2** *(lack of supply chain integration)* – The site manager has the unenviable task of "juggling a number of balls" at the same time. He obtains a considerable amount of information but, without a clear strategy of how best to utilize the information, this becomes more of a detriment to the supply chain than a benefit. This concurs with theoretical studies about information transfer in the supply chain [57]. Information transfer to the supply base is merely in terms of call-offs. To ensure supply chain integration it requires trust to be developed in the supply chain and appropriate information to be shared [58].
- **Waste spot #3** *(no time compression strategy)* – Manufacture and supply lead-times are protracted. Supplier delivery performance is poor. A lack of partnership, supplier development and an environment of confrontation yield a vicious circle of blame. Some suppliers get volatile short-term call-off information from the site and no medium term demand requirements. Thus, they are unable to respond adequately to site needs. Both the regional purchaser and the site are uncertain about the suppliers' abilities and impose unrealistic requirements. Late changes in site requirements occur and the supplier is unable to quickly respond. This is a common phenomenon in the supply chain, and has a detrimental effect upon the business's competitive advantage [59].
- **Waste spot #4** *(inability to rapidly re-configure)* – Similar to Waste spot #3, sub-contractors are selected by headquarters (again based on price rather than value) but are called as and when required by the site without medium term planning horizons. Due to the associated uncertainty (material delays, weather, or change of plan) sub-contractors commit themselves to a number of different sites without actually having capacity available to do so (the waste of waiting for materials or sequence to start is high - 10% to 30% of times skilled trades can be waiting [60]. There can therefore be a poor response from the contractors when they are required on site.
- **Waste spots #5** *(stock – excess cost)* – A clear symptom of the uncertainty in the supply chain is "muda" (waste), in the more obvious forms of excess stock. It is necessary to build a stockyard of material due to the uncertainties or mura (inconsistency) mentioned in the previous Waste spots. This is merely a comfort stock and has little strategic value.

There are no guaranteed time scales for actually buying and calling off the material. Involvement and collaboration is low hence the suppliers have little vision of long-term market requirements.

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Table 2
Waste Spot Analysis

Waste Spot	Description
#1	Little supplier management /involvement
#2	Lack of supply chain integration
#3	No time compression strategy
#4	Inability to rapidly re-configure - Need more collaboration between various sites and activities for each key supplier or sub-contractor
#5	Stock – excess cost
#6	Stock – material wastage
#7	Poor quality - waste should be prevented by better supplier management, quality operating systems, quality circle approach. Need more collaborative team approach not blame culture

Sometimes material that is required will not be available from the stockyard, at other times it may be available. As the stockyard is often not properly engineered into the site layout or controlled, it becomes merely a dumping ground for material. Material from the stockyard may or may not arrive to the right house at the right time in the right quantity. More than likely it will not be synchronized with staff availability.

- **Waste spots #6** *(stock – material wastage)* – Due to having a store of unscheduled material, losses occur through damage, deterioration, mislaying or theft and hence waste is high. The picking, sorting and moving of material is ad-hoc and due to poor material identification leads to waste time.
- **Waste spot #7** *(poor quality)* – The ultimate symptom of the traditional supply chain is the need for a finishing foreman (snagging). His role is simply to ensure corrections are carried out and hence his very task is wasteful. He chases contractors and materials. He identifies faults and assigns re-work programs (some sites even have pre-snagging checks). He often interacts with the new homeowners and attempts to address the snag list; yet all the waste spots indicated previously, still exist. He is an indication that total customer value is poor and in particular, the in-process quality is at a very low level. The emphasis here could wrongly be on correct and cure and not pro-active continuous improvement and prevention.

Analysis

Each of these waste spots is now analyzed in generic terms for primary improvement opportunities using the engineering change model proposed by Towill [61], illustrated in Figure 2. This categorizes the focus of any change program according to technological, organizational structure and attitudinal issues. Table 3 illustrates these opportunities in relation to other potential improvements previously described.

Waste Spot #1

Here the introduction of closer relationships with key suppliers plus use of new information and communication

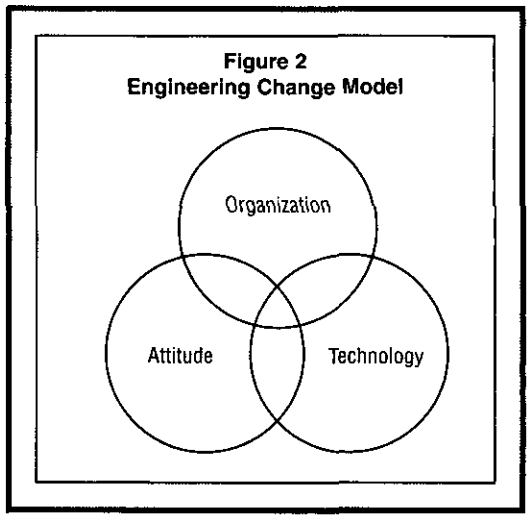

Figure 2
Engineering Change Model

technologies will enable improved information and material flow. Measurable of total costs and value instead of price will focus better on improvement. Here "overproduction" by the suppliers due to demand amplification (Forrester 1961 in Mason-Jones and Naim [66]) is highly likely. Also "waiting time" at site occurs due to irregular demand causing uncoordinated deliveries.

Waste Spot #2

To increase integration of the supply chain good information flow is essential. As highlighted by Taylor and Bjornsson [63] new Internet systems offer great opportunities for value creation. Collaborative Planning Forecasting and Replenishment (CPFR) is usually associated with a technological solution in which e-Business enables a more holistic perspective of the supply chain. Again adequate trusting relationships need to be put into place to ensure that the supply chain as a whole has agreed and shared understanding of the its strategic intent, its operational activities and that the processes are co-ordinated to provide optimum value. Without such improvement there will continue to be waste terms of: waiting, due to late materials arrival; transportation, due to excessive movement and double handling; and, stock on hand, due to early material arrival.

Waste Spot #3

The drive to business process orientation is well recognized not only in the Business Process Re-engineering literature but also lean thinking and agile production.

Table 3
Primary Change Opportunities

Waste Spot	Technological	Organizational	Attitudinal
#1	EDI, e-commerce	Information flow structured	Share information, trust, relationships
#2	CPFR - collaboration, planning, forecasting, & replenishment. Site based e-commerce	Co-ordination of strategies, planning and operations	Share information, trust, relationships
#3		Process orientation, Supply chain integration	Awareness and adoption of time compression strategies
#4		Buy/reserve capacity, reduce supply base, supply & fit	
#5 & #6	Pre-assembly, pre-fabrication, house kits quick assembly, standardization, JIT	Supplier relationships, supplier development	Continuous improvement
#7		Training, accountability,	TQM – ownership & commitment

Codification of business processes (that is, process mapping) enables the dismantling of functional barriers within and between businesses in the supply chain and ensures orientation towards delivering total value. This waste spot is again related to poor supply chain integration, poor supplier relationship management and non-realization of time compression benefits. The results here are mainly slow and erratic delivery, not actually an Ohno waste; however excessive or under delivery of materials give waiting-time wastes and stock-on-hand wastes that are only too prevalent in most industries.

Waste Spot #4

The ability to offer customer choice requires a supply chain infrastructure with sufficient capacity to respond quickly and flexibly. The current attitude in the housebuilding industry requires a focus on total value and just not cost. Buying dedicated capacity from preferred contractors ensures that resource is readily available when required and in fact will reduce total costs. The move to supply and fit within the industry reduces the supply base, improves commitment/ accountability and gives control on materials (moves from a product to a service provision). Analysis of the wastes here shows they are similar to #3 but related to sub-contractors and not suppliers. However, the inability to plan the work sufficiently leads sub-contractors to a "wait and rush" environment and thus to potential quality problems. Relating to Ohno there are "waiting" and "defective products" wastes and the potential for wastes from "transportation".

Waste Spot #5 and #6

Classic tools and techniques recently branded as the Lean Toolkit [64] including 5S, poka-yoke (or fool proofing) and small group working (kaisen) enable the process operators to own the solutions to eliminating waste and delivering greater efficiencies. For these two areas, reductions in stock and improvements in process are necessary. Technological enablers need to be innovated such as modular open systems, pre-assembly, timber frame systems that allow quick assembly of housing elements and reduce the volume of materials required. A major principle for Ohno and JIT is the reduction of unnecessary stocks that hide inefficiencies and promote the elimination of the root causes of problems.

The ability to offer customer choice requires a supply chain infrastructure with sufficient capacity to respond quickly and flexibly.

Waste #7

Total Quality Management (TQM) as advocated by Deming [65] and Oakland [66] is mainly a philosophical approach in which everybody in the organization, and the supply chain, takes ownership of quality.

They are responsible for ensuring their activities do not impact detrimentally on subsequent operations in the supply chain. Quality is everybody's responsibility and built into the process, with post-inspection, if any, kept to a minimum. This area is problematic in housebuilding primarily due to the multi-disciplinary, transient, and in some operations low skill nature of labor. Ohno preaches involvement and empowerment – "teamwork is everything". A zero-defect (ZD) philosophy has been a key to the world class standing held by the Japanese manufacturing industry.

Conclusions

In this paper, we reviewed literature relevant to housebuilding supply chains and shown there is little published information on a systematic approach to categorizing waste or recommending improvements in such supply chains. The philosophy of classifying waste has been applied to a case study representing a housebuilding supply chain. Seven areas of waste have been observed, analyzed and suggestions made for improvement.

All the waste spots require a degree of change in one or more of the change categories described. A change in attitudinal factors is the main driver for subsequent implementation of a number of re-engineering strategies in construction/ housebuilding supply chains. Attitudinal factors influence all waste spots and may be summarized within a supply chain context as the introduction of partnering arrangements, becoming a proactive learning organization, awareness and adoption of improvement techniques and technologies and having a mechanism of monitoring the improvement. It must be stressed that major house builders are "batch manufacturers" and can in principle apply most supply chain improvements. The introduction of new information and communication technologies that enable new information flow structures to be put in place is currently offering great opportunities for improved overall efficiency of the supply chain. However, to ensure supply chain integration, the realization must be made that all areas of waste affect and determine final customer value. This is not to say that such a reduction in waste will give a proportional increase in value as customer perceptions and priorities are pivotal and difficult to predict. But it is clear that there is room for substantial improvement and that partnering and/or better working relationships within the supply chain is one way forward.

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