A SUPPLY CHAIN MANAGEMENT SELF ASSESSMENT FRAMEWORK FOR WASTE MINIMISATION FOR THE RESIDENTIAL SECTOR

LITERATURE REVIEW

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1.0 Introduction

This literature review is a milestone report for the research project entitled 'A Supply Chain Management Self Assessment Framework for Waste Minimisation for the Residential Sector'. The project is funded by the Environmental Protection Agency Waste Fund and is managed by Sustainability Victoria. RMIT University is the lead organisation for this project on behalf of the Australian Housing Supply Chain Alliance. Members of this Alliance who are partners for the project include Metricon, Australand, FMG Engineering, Boral, Master Builders Association Victoria and RMIT University. The project is being undertaken from December 2012 to February 2014. This review is an important task which will underpin the development of the project.

The overall aim of the project is to develop and test a new framework that can be used by volume residential construction organisations to develop benchmarking profiles in relation to:

(a) Practitioner/staff awareness/knowledge and capabilities of best practice in integrated SCM across design, procurement, tendering and construction functions to achieve organisational objectives for waste avoidance and reduction;

(b) Practitioner/staff capabilities to respond to changes in supply chain environments at a project level; and

(c) Organisational capacity at a portfolio level to support policy, systems and procedural changes to adapt to future waste avoidance and reduction strategies.

The outcome of which is to assist the building industry in Australia to reduce and avoid construction material waste. In Australia, as with many other developed countries, waste from materials and the building process is a significant environmental and economic issue (BRE, 2006; Ling and Lim, 2002; DSEWPC, 2011). Over the past two decades, supply chain management (SCM) has had increasing attention within the construction management literature. However, there is has been little real evidence of its adoption at a systemic level in the industry in any of the construction sectors including; residential, commercial and civil. The purpose of this document is to provide a targeted literature review of recent developments in international best practice for construction waste minimisation in supply chain management for the housing construction sector. The review is organized in the following sections:

1. Waste in construction

2. Supply chain management

3. Supply chain management and waste minimisation in the residential construction sector

2.0 Waste in Construction

Waste in construction has been identified as a significant problem in Australia. Construction waste or construction and demolition (C&D) waste includes a mixture of inert and non-inert materials arising from construction, renovation, demolition activities including excavation, civil and building construction, roadwork, site clearance, demolition and building renovation (Shen *et al*, 2004; Tam and Tam, 2008; Poon, 2007; Yuan *et al*, 2011).

2.1 Data and benchmarking

The strategic approach to management of the problem of construction and demolition materials waste is often underpinned by an analysis of data including such measures as; volume of waste generated; volume of waste transported to landfill; volume of waste recycled; carbon dioxide equivalent and embodied energy; cost of transportation to landfill and landfill levy cost. This type of data can then provide baseline data, targets and action plans. The information can be provided at an industry level on a regional basis which is often aggregated or can be developed at site and project level. Aggregated data is more useful to consider when reporting or evaluating industry policy and sectoral level interventions and the project level analysis is more useful for companies to use when they are attempting to implement organizational benchmarking and developing and evaluating the impact of their action plans. It has been noted by many that this type of data is not readily available (BRE, 2006). It has been suggested that construction and demolition waste can account for approximately 30% of all solid waste streams (Brooks et al, 1994; Mincks, 1994; Bossink and Brouers, 1996) and hence this has prompted national and/or regional policy development and implementation strategies in various countries in the past decade such as UK, Australia, Singapore, Hong Kong, United States of America and the Netherlands.

Waste being transported to landfill in Australia increased from 2004 till 2007. In Australia, construction waste has been estimated to account for 16-40% of total waste (Bell, 1998)with nearly one ton of solid waste sent to landfill per person annually (Reddrop and Ryan, 1997). In 2004-05 C&D waste generation in Australia totalled 15.1 million tonnes of which 7.5 million tonnes was residual waste to landfill (WCS Market Intelligence, 2008). In 2006-2007 the C&D waste stream accounted for 38% of total waste, amounting to approximately 16.6 million tonnes (DSEWPC, 2011). In 2008-2009 C&D waste generation in Australia increased to a total of 19.0 million tones of which 8.5 million tones was disposed to landfill while 10.5 million tones or 55% was recovered and recycled (Hyder, 2011). In Victoria in 2008-2009 a total of 3.15 million tones of C&D material was recovered for reprocessing, however, 47% of waste to landfill was generated from the C&D sector (Sustainability Victoria, 2010).

The problem of construction waste is an international problem. Construction waste is not limited to Australia (Mills et al, 1999; Yuan et al, 2011). In 2006, in the UK, the volume of construction, demolition and refurbishment waste accounted for approximately 100 million tonnes annually. In the UK almost a third of all total waste each year is attributed to the construction industry, approximately 50% of which is recycled (BRE, 2006) and the wastage rate in the UK construction industry was as high as 10-15% (McGrath and Anderson, 2000). Furthermore, it is suspected that this is an issue which is identified to worsen as the push to improve energy efficiency through refurbishment and demolition of properties intensifies over the coming decades. The reduction of construction waste has become a priority in the UK with a 20 year strategy to reduce construction waste developed in 2006 (BRE, 2006). In addition to the environmental impacts of waste materials, there are also significant economic impacts as well. The cost of waste disposal is predicted to increase in future years (BRE, 2006), further adding to the economic impacts. Consequently the effective management of construction waste is high on the agenda both in Australia and internationally. Table 1 provides some data on the amount of C&D waste generated in a number of countries including The Netherlands, Australia, United States of America, Germany and Finland.

Table 1. C&D Waste as percentage of all solid waste entering landfills in various countries (Bossink and Brouwers, 1996)

Country	C&D Waste (by weight) (%)
The Netherlands	26
Australia	20-30
United States	20, 23, 24, 29
Germany	19
Finland	13-15

In Singapore, the "*… Housing and Development Board confirmed that wastage is indeed a problem for the construction industry and estimated that material wastage accounts for approximately 2% of the contract sum*" (Ling and Lim, 1995). In Singapore construction materials waste is disposed of either through incineration (90%) or landfill (10%). It is a significant problem for a country where land is at a premium and so a national waste management strategy is critical for Singapore. The US Environmental Protection Agency (USEPA, 2002) estimated that approximately 136 million tons of building related C&D waste were generated in 1996 with demolition waste accounting for 48% and renovation 44% of the total waste. *"In Hong Kong, from 1993 to 2004, the annual generation of C&D waste has more than doubled, reaching an amount of about 20 million tons in 2004 a single year*" (Poon, 2007).

Of particular interest to policymakers and industry practitioners alike is research in Ireland by Duran et al (2006) where they explored the economic viability of construction and demolition waste recycling. Through conducting surveys and interviews with 29 local authorities responsible for waste management, 15 aggregate producers and general recycling centers, suppliers of crushers, waste management companies and policy makers the study uncovered that economic viability is likely to occur when the cost of land filling exceeds the cost of recycling. The study also identified that recycling centres benefit from economies of scale whereby an increase in the scale of a centre implies a decrease in recycling costs. Furthermore the study also analysed the use of taxes and subsidies as tools to encourage recycling. One important conclusion of the study is a suggestion that market based instruments are likely to be the best option for policy makers. "In order to encourage recycling, the prices charged to users of landfills and primary aggregates should be high" (Duran et al, 2006, p. 319). The findings of Duran et al (2006) were confirmed by work carried out by the Department of Sustainability, Environment, Water, Population and Communities – Queensland Department of Environment and Resource Management which identified that *'high landfill disposal costs provide an incentive to process mixed C&D waste in order to recover certain high value and high volume components and avoid landfill disposal costs"* (Hyder, 2011, p. 11).

A pilot project "Developing a Strategic Approach to Construction Waste" was established by the UK's Building Research Establishment (BRE) to identify activities and drivers to dictate the future direction of the construction industry in relation to resource efficiency. The work carried out by the BRE has produced some important data and environmental benchmarks in relation to construction waste in the housing sector and some of these are reproduced below.

Some initial data on the amounts of waste produced from different types of construction have been identified and a number of environmental performance indicators are outlined in Table 2 below. The indicators are given as m3 waste per 100m2 floor area to enable like for like comparison; and m3/£100,000

Table 2 Environmental performance indicators (BRE, 2006)

D: Demolition
E: Excavation
G: Groundworks
M: Mainframe
S: Services
P: Partitions
F: Fit-out

	Civil Engineering	Leisure	Health Care/ Hospitals	Residential	Office	Education/ Schools
Benchmarks	**E, G, M**	**G, M, S, P, F**	**G, M, S, P, F**	**G, M, S, P, F**	**G, M, S, P, F**	**G, M, S, P, F**
Key performance indicator (KPI) = m3/£100,000 project value	52.3	6.1	7.9	17.3	8.4	13.2
Environmental performance indicator (EPI) = m3/100m2	61.7	3.7	11.7	19.2	14.1	22.2

Benchmarking data on the amount of waste per house has been developed through BRE's analysis of 23 housing projects. Table 3 presents this data in relation to the average amount of waste produced across the sites which is 19.2m3 waste per 100m2 floor area. Using this figure and applying it to a typical semi of 80m2, BRE (2006) estimated an average material waste generation of 15.36m3 of waste per house. Furthermore "*when adding in an average of 50% void space in the skips that would collect this waste – this equates to around 30m3 of skipped waste. A typical skip has a volume of 6.125m3, so around 5 skips will be needed to contain the waste from 1 house. Based upon the Envirronmental Agency conversion factors, the weight of waste from our generic house is 9.6 tonnes*" (BRE, 2006, p. 9).

Table 3 Benchmarking data in relation to amount of waste per house (BRE, 2006)

Project type	Housing EPI (m3 waste/100m2)		
	Average		
Waste Group	Residential x 23 no	Conversion factor	Tonnes
Timber	1.3	0.3	0.39
Concrete	2.5	1.11	2.775
Inert	1.1	1.3	1.43
Ceramic	2.8	0.78	2.18
Insulation	1.0	0.16	0.16
Plastic	0.6	0.22	0.132
Packaging	2.9	0.55	1.59
Metal	1.3	0.8	1.04
Plaster & cement	3.2	0.4	1.28
Miscellaneous	2.5	0.4	1.0
Total EPI	**19.2**		**11.997**

Past work in the UK has shown that a typical construction skips costs £1343 when the cost of the skip is added to the cost of labour and materials that fill it. The BRE (2006, p. 10) outline the breakdown of this as:

1. *"skip hire £85 (quite low compared to current prices) – 6.4% of cost*
2. *labour to fill it £163 - 12.1% of cost*
3. *cost of materials in skip £1095 – 81.5% of cost*

Therefore the financial cost of waste for our generic house is for 5 skips, around £6715, and rising".

In Australia it has been estimated that the cost of disposal of waste generated during the construction of a residential house is between $2000 to $3000 per house. There has also a been suggestion made on the volume of waste generated in the construction of a volume builder house on a flat block to be 18 to 23 m3 of waste per house in Victoria (Hyder, 2011, p. 47).

In Australia the management of environmental issues including the management of C&D waste is the responsibility of Australian states and territory governments. The Australian Government does not directly legislate management of C&D waste (DSEWPC, 2012). Research undertaken by the Department of Sustainability Environment, Water, Population and Communities (DSEWPC)(2012) identified the cost of landfill as a significant driver for re-use and recycling of C&D Waste. According to the DSEWPC, in 2009, *"landfill costs in Australia ranged from $42 per tonne to $102 per tonne. In addition to the cost of land-filling by operators, there can be an additional charge levied by the state and territory jurisdictions. In New South Wales for example, the government's Section 88 Landfill Levy applies to regulated areas and ranged between $20.40 per tonne and $70 per tonne. The lower limit is set to rise by $10 (plus adjustment for the consumer price index) per year until 2015-18. It is expected that this will drive additional re-use and recycling from the construction industry*" (2012, p. 10).

Victoria has had a long history of landfill levy application (Hyder, 2011). Table 4 provides information in relation to the waste levies charged for municipal solid waste (MSW) and industrial waste. The levy for industrial waste is applied to C&D waste disposed to landfill that does not contain prescribed industrial waste.

Table 4 Waste levies for Victoria (Sustainability Victoria, 2011)

Geographic area	Waste levy (per tonne)		Forecast waste levy increase
	2010-2011	2011-2012	
Metro/ provincial	MSW: $30 Industrial: $30	MSW: $40 Industrial: $40	Increasing to $53.20 for both MSW and Industrial by 2014-15
Rural	MSW: $15 Industrial: $25	MSW: $20 Industrial: $35	Increasing to $26.60 for both MSW and $46.60 for Industrial by 2014-15

Work undertaken by Hyder Consulting for Sustainability Victoria has uncovered the relationships between amount of waste sent to landfill and an increase in landfill price. Figure 1 presents an estimation of responses to the price of landfill for the three key waste streams of MSW, C&I and C&D. According to Figure 1, there is a suggestion that C&D waste generation is likely to most rapidly respond to a pricing signal thereby resulting in increased waste being diverted from landfill (Hyder, 2011).

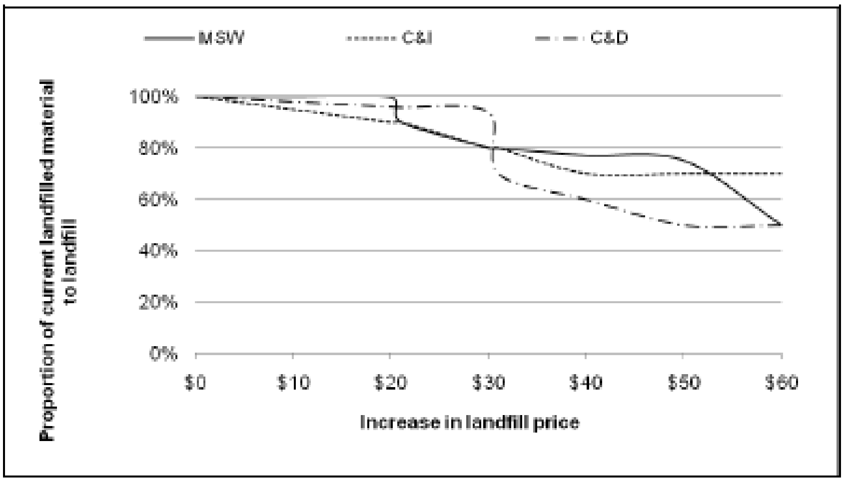

Figure 1 Assumed diversion responses of waste streams to increases in the price of landfill (Hyder, 2011)

Furthermore it was identified that not only was pricing important but the geographic location of reprocessors was also important in terms of facilitating C&D material recovery particularly in metropolitan Melbourne (Hyder, 2011). A Sustainability Victoria commissioned study found that "*resource recovery from C&I and C&D waste streams in the North Eastern and Mildura regions of Victoria was significantly hampered by the movement of wastes to landfills in NSW where landfill cost were typically lower (in part due to landfill levies in the non-regulated area of NSW). The study indicated this made landfill disposal a cheaper alternative for many materials, compared to separation and recovery. The study indicated that in some instances the cost differential between townships in Victoria could be double those in NSW*" (Hyder, 2011, p. 96).

Apart from the attempt to develop baseline data for benchmarking purposes, the other most significant contribution underpinning the UK BRE report was that an holistic approach to the life cycle of products and materials was needed. Waste is being produced through manufacture, distribution, design, construction, refurbishment and demolition.

"Long term targets for waste reduction, reuse and recycling are the best way to define what can be achieved and focus our combined efforts within the framework of a combined target. This is not easy to do for a wastestream that is fragmented in the following ways:

1. *Waste is being produced and sent to landfill by the actions of the whole supply chain – manufacture, distribution, design, construction, maintenance, refurbishment, demolition, (resource management).*

2. *Waste from manufacture, construction, refurbishment and demolition are lumped together for reporting purposes but are different in terms of amounts, composition, causes, levels of integration and separation.*

However, different targets for each part of the supply chain or activity would be less meaningful unless set against overarching, global targets i.e. each will have a role to play in reaching the target but the actions and relative contribution may differ in accordance with their ability to deliver. An example of this could be waste reduction and demolition waste, whereby the only realistic way to prevent demolition waste would be to have a longer lasting building – this is not something the demolition sector can achieve. It is more the design, durability of products/materials and maintenance of the building that can achieve waste reduction in this instance." (BRE, 2006; p8).

Significant reductions in waste will only be possible if they are accrued throughout the supply chain. The BRE (2006) suggests an allocation of the target of 50% waste reduction across the relevant supply chain, ie distributed in accordance with the ability to deliver those savings. An idea of what this might look like is given by BRE in Figure 2 below.

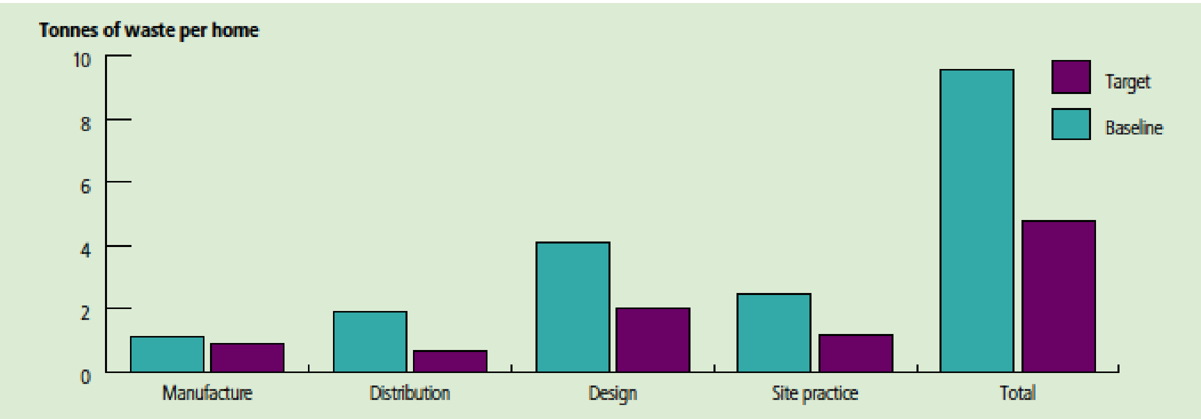

Figure 2 Allocation of target – baseline vs target waste per house (BRE, 2006)

The DSEWPC developed a "Construction and Demolition Waste Guide – recycling and re-use across the supply chain" which is underpinned by the idea that the myriad of supply chain stakeholders play out their roles in delivering a sustainable built environment. The guide documented a series of case studies to outline various C&D waste recycling and re-use initiatives across Australia and demonstrate a range of opportunities at various stages of the supply chain. Whilst the case studies clearly demonstrate the benefits and profits associated with the initiatives there is little discussion on the actual strategies used to integrate the supply chain as well as the specific actions of supply chain actors. The approach taken in our research project is underpinned by the strategy that it is the actions of the whole supply chain that will ultimately reduce waste to landfill in the Australian housing sector but is an attempt to go further than simply documenting case studies of outcomes. It is our contention that there has been little research in housing waste minimization that moves beyond the rhetoric of claiming that supply chain management is the answer to waste minimizationto towards developing and piloting strategies that could be embedded in organisations.

2.2 Sources and causes

To be able to reduce the amount of waste generated it is important to know what the source and causes are. The source and cause of construction and demolition waste has often been considered to be the responsibility of the contractor however this is a simplistic view of a complex problem. Clearly there are problems handed to the site operatives in relation to waste that are beyond their control. It has been identified that project design, product manufacture, estimating, procurement and materials handling as well as site construction practices all have a role to play in reducing on-site waste. The construction process involves many players and all have a contribution to play in waste minimization. This section explores the site operatives as well as upstream contributors to the challenge of waste minimization. Often the focus is on waste recycling and much effort is expended on fixing the problem at the end of the waste chain. Although these efforts are to be acknowledged it is also worthwhile to examine the source and then identify the cause and develop strategies to address the root cause of the problem to minimize waste and reduce effort in a 'band-aid' approach at the end of the construction process.

In a study to examine the waste minimisation strategies and behaviour of main contractors in Singapore as a way of curbing the waste problem caused by subcontractors, Lim (2005) identified the four main causes of waste generation on site to include;

1) wasteful practice of subcontractors,

2) lack of integration and coordination of team players,

3) inefficient usage of construction materials by subcontractors and

4) incidence of rework.

However our contention in this study is that the source of waste can occur at any stage of a construction project and can result from a variety of causes. We have to acknowledge that this contention is not particularly new and valuable research work by Bossink and Brouwers (1996) began in the mid 1990s where they examined the various activities in the Dutch supply chain to attempt to identify possible options to reduce waste generation in construction activities (Table 1). They identified 5 sources of waste related to 1) design 2) procurement 3) materials handling 4) operations 5) residual and 6) other. Their analysis provided quantitative data on volume of waste, amount of waste material as a proportion of the total cost of that material procured and then cost of removal of that waste from site as a percentage of the total waste costs (including purchasing costs, transport to landfill sites and waste management costs). This quantitative data is interesting for comparisons and will be useful to our study and we shall use as a starting point for benchmarking in our two case studies. Further to the quantitative work on 5 housing sites was a the small piece of research they conducted which included brainstorming sessions with 8 representatives of contracting companies. This qualitative data provided an inventory of the causes of production of waste created by the use of various construction materials. This built upon a desk top review they had previously conducted and a compilation of a table of the empirical results as well as the previous work by Gavilan and Bernhold (1994) and Craven et al

(1994) was produced. We have reproduced that table now (table 5) as it is provides a comprehensive listing of various sources and causes of construction materials waste.

Table 5 Sources and Causes of Construction Waste (Source: Table 8 Extended List of Sources and Causes of Waste based on Tables 4 and 8 Table 4: Source and Causes of Construction Waste Gavilan and Bernold, 1994; Craven et al, 1994 as cited in Bossink and Brouwers, 1996)

Source	Cause
Design	Error in contract documents
Design	Contract documents incomplete at commencement of construction
Design	Changes to design
Design	Choices about specifications of products
Design	Choice of low quality products
Design	Lack of attention paid to sizes of used products
Design	Designer not familiar with possibilities of different products
Design	Lack of influence of contractors and lack of knowledge about construction
Procurement	Ordering error, over ordering, under ordering, and so on
Procurement	lack of possibilities to order smaller quantities
Procurement	Use of products that do not fit
Materials handling	Damaged during transportation to site/on site
Materials handling	Inappropriate storage leading to damage or deteriorisation
Materials handling	Throw away packaging
Operation	Error by tradesperson or laborer
Operation	Equipment malfunction
Operation	Inclement weather
Operation	Accidents
Operation	Damage caused by subsequent trades
Operation	Use of incorrect material requiring replacement
Operation	Required quantity of products unknown due to imperfect planning
Operation	Information about types and sizes of products that will be used arrives too late
Residual	Cutting uneconomical shapes
Residual	Offcuts from cutting materials to length
Residual	Over mixing of materials for wet trades due to a lack of knowledge of requirements
Residual	Waste from application process
Residual	Packaging
Other	Criminal waste due to damage or theft
Other	Lack of on site materials control and waste management plans

Knowing and understanding the causes of waste coupled with measuring the volume and cost of waste are important steps in construction waste minimization. The next section explores the research literature on construction waste minimization and in particular strategies and actions undertaken by organisations.

2.4 Construction waste minimisation

Waste minimization is any systematic technique, process or methodology used to achieve waste reduction primarily through avoidance or reduction at source (CIRIA, 1995; Crittenden, 1995). In the previous section on Construction waste, we identified government approaches through policy development, however, this section shall focus on the industry practices and organizational and project level strategies and actions that can assist in waste minimization.

Construction waste minimisation involves many waste reduction activities which can lead to economic, social and environmental benefits (Greenwood 2003). In terms of economic benefits, potential large savings can be made by construction organisations through reductions in material expense and waste disposal costs. In addition, an organisation's involvement and experiences in waste minimisation could be a valuable marketing tool for bidding on projects that participate in local and national green building certification programs (Greenwood 2003). In regards to social benefits, construction waste minimisation can help to create skilled employment, conduct knowledge-based business, and increase work safety through cost savings and staff training related to waste management (Greenwood 2003) Finally, environmental benefits of minimising construction waste can be achieved through the effective use of natural resources and reduce waste to landfill (Greenwood 2003).

Past work into construction waste minimisation have identified a number of key approaches or practices for construction organisations seeking to reduce and avoid waste including:

- Waste management integrated as part of the design process: Various measures which can be used to reduce waste during the early stages of the design process including dimensional coordination and standardisation, minimisation of the use of temporary works, provision of detailed designs and limitation of design modifications (Poon, 2007)

- Use of prefabricated materials and products: The use of prefabricated products reduces waste generation on site and can also contribute to better quality and cost savings. Conduct of a waste minimisation assessment which examines opportunities for waste avoidance reduction, reuse and recycling (EPA, 1998)

- Incorporation of waste minimisation targets and measures into organisations' environmental management plans (EPA, 1998)

Despite the potential benefits of adopting waste minimisation practices including cost savings, better quality products and safer sites; substantial evidence has demonstrated that there is a gap between theory and actual implementation of the suggested practices for waste minimisation by construction organisations. Some of the barriers to effective implementation of waste minimisation practices include:

- a lack of economic incentives to reduce and avoid waste (Yuan et al, 2011):
- the culture of the construction industry which is resistant to change (Maloney and Federle, 1993; Lingard et al, 2000)
- the unique nature of each project, hostility and unpredictability of the production environment, fragmented nature of the project organisations used to procure buildings (Teo and Loosemore, 2001)
- a lack of awareness, interest or commitment to environmental issues (Ofori, 2000) particularly at senior management level
- a perception that waste management is not cost-effective (Bossink and Brouwers, 1996; Graham, 1996) and is actually a costly and a time consuming activity

- lack of training and tools to implement waste minimization strategies
- poor coordination and integration between various participants as projects progress
- poor review and feedback loop mechanisms to provide information upstream to early decision makers

The literature indicates that many of the barriers to effective waste management revolve around underlying structural and behavioural characteristics of the construction industry. These barriers are at sector, organization, project and individual level. Individuals are highly resistant in their behaviour and attitude towards new work practices to minimize waste and are therefore not embracing the potential benefits of effective waste management. However, it is not only the individual level there are systemic and structural barriers that inhibit change such as the fragmented silo mentality of the industry and the cultures that underpin organisations. At times the inertia of the industry appears overwhelming to overcome to catalyse significant change in work practices.

Perceptions can play a key role in the diffusion of new practices. However, human behaviour and perceptions are changed by work practices. One of the greatest influences on firm work practices is the cluster of firms that they deal with on a daily basis; that is their clients, collaborators and suppliers. Firm practices are also constantly being shaped by their competitors whereby firms can sometimes be lead to change work practices when competitors are embracing change by adopting new practices. Firms and individuals leading firms are of the perception that it can be too risky not to change when working within such a competitive work environment that is the construction industry (London, 2008)

The attitudes of key players inevitably influence the level of waste generated on a project (Faniran and Caban 1998). It has been argued that clients have the greatest influence over waste minimization practices since clients set the environmental conditions and standards to which the project team must comply (Dainty and Brooke, 2004). However, any effort to influence waste management practices on projects would be of limited value if those further down the supply chain do not buy-in to effective waste management practices (Teo and Loosemore, 2001; Dainty and Brooke, 2004). Within this context, the frequently discussed fragmented nature of the construction industry is likely to pose as a significant barrier to embedding a culture of waste minimization throughout the supply chain.

However, contrary to the traditional view that the construction industry is fragmented, unstructured and unpredictable, London (2008) has identified that the project-based industry has a deeper level of complexity in that there is an underlying structure to the activities of the supply chains, supplier firms and procurement relationships, which can be classified based upon specific patterns of attributes. Firms may not work on every project with the same customer and supplier connections; however, firms are typically located within a cluster of business networks, which develop and are maintained over numerous years (London, 2008). There is thus an indication that there are indeed longer-term relationships between the different players within the supply chain who have a degree of influence over each in other in their behaviour and attitudes towards the adoption of effective waste minimisation practices. As such, it is important to gain a deeper understanding of how this takes place within the supply chain that is specific to the residential C&D waste sector. It is proposed that those alliances whether formally or informally constituted will provide the greatest opportunity for innovation to take place in waste minimization.

Various factors have been identified in the literature as those which can influence the successful implementation of a waste management plan by construction organisations including (Ling and Lim, 2002):

- Involvement of senior site staff
- Commitment of top level management
- Cooperation of sub-contractors
- Support of workers
- Establishment of clear corporate policy, goals and objectives in waste management
- Increasing workers' environmental awareness
- Support of clients
- Presence of waste management experience
- Support of government
- Presence of clear and effective internal communication on waste management
- Presence of waste management expertise
- Availability of recycling facilities
- Availability of proven successful plan
- Support of design consultants

Through conducting 30 interviews and questionnaires with 30 construction professionals in Singapore, Ling and Lim (2002) identified that the three most important factors were involvement of senior site staff, commitment of top-level management and co-operation of subcontractors. The study concluded that the critical factors influencing the success of a plan are directly linked to the internal environment which the organisation has control over and therefore commitment and support throughout the whole organisation is essential for successful implementation (Ling and Lim, 2002). These findings support the earlier work of Teo and Loosemore (2001) which also identified top management supportiveness as one of the most critical factors for waste reduction behaviour.

Another study conducted in Singapore (Lim, 2005) to examine main contractors' waste minimisation strategies for managing subcontractors uncovered seven key main strategies for influencing the reduction of waste on site which are training of subcontractors, quality of documentation provided to subcontractors, cooperation among team players, main contractor's control over subcontractor's workmanship, main contractor's control over subcontractor's usage of materials, goal-setting with subcontractors and main contractor's control of suppliers' material quality.

It has been identified that written waste management plans can be both an incentive and guide towards encouraging best practice waste management on construction sites (Ling and Lim, 2002). However there is often little verification of such plans and limited monitoring of any improvements made (Tucker et al, 2005). It is thus important to not only implement waste minimisation practices but to also monitor and evaluate its outcomes and effectiveness. It is also important to differentiate between waste management onsite that is concerned with waste minimization and those activities that are dedicated to managing the waste on site towards being recycled or transported off site to landfill.

2.5 Summary

Each process or stage of a construction project can produce construction waste. In order to minimise construction waste, many governments around the world have sought to implement various waste minimisation policies and best practice guidelines. A number of key approaches or measures for reducing and avoiding waste have also been presented by various of scholars and experts. Significantly the focus of these policies and best practice guidelines has tended to be on the implementation phase of waste minimisation practices. The importance of monitoring and evaluating the outcomes and effectiveness of the waste minimisation practices is largely neglected.

Furthermore whilst past studies have revealed the significance of organizational behaviour and attitudes in the implementation of waste minimization plans, there is still limited research which investigates the critical role that different players including competitors, suppliers, collaborators/partners; within the supply chain play in influencing the perceptions and attitudes towards waste minimisation. Waste minimisation involves the promotion of favourable attitudes and encouragement of ownership of the process at all levels of the construction process (Tucker et al, 2005). Given that waste can arise at any stage of the process, from inception to design to construction to operation of the facility (Dainty and Brooke, 2004) cooperation between various supply chain players is critical in order to achieve an integrated approach to waste minimisation on projects.

3.0 Supply Chain Management – an overview

It is not the purpose of this review to detail the development of Supply Chain Management (SCM) and its integration into the construction sector. Several seminal reviews and original research works provide this information already. For example Hong Minh (2002), London and Kenley (2001) and O'Brien et al(2009). This review builds upon these and provides developments in this area since these publications. In doing so, a review of developments across the past 5 years (since 2008) is the primary aim of this review. While the focus will be on post-2008 developments, pre-2008 publications will be drawn upon where appropriate. Furthermore it is not the purpose of this review to detail the issue of material waste in the construction sector as this will be the focus of the final section which attempts to draw together key research themes in this area.

This review is structured into several sections. Firstly a brief overview of SCM is provided; development of SCM and the construction industry are then presented and then the discussion is narrowed to SCM and waste reduction and avoidance in the residential construction sector. A summary of recent developments of SCM, the construction sector and waste minimisation concludes this review.

3.1 Definitions

SCM has developed out of concepts such as logistics and operations management (Vidalakis, Tookey and Sommerville, 2011) and has developed as a response to increasing competition (CSIRO, 2001). Early criticisms of SCM were that it was not discernibly different to logistics management (McGeorge, Palmer and London, 2002). It was initially applied within the manufacturing sector, with the key example being that of Toyota Production System.

There are a range of definitions for SCM especially within construction industry applied within the literature which has been described as confusing and have been criticised for being too vague (Bankvall et al, 2010; Khalfan and Maqsood, 2012; Petrovic-Lazarevic, Matanda and Worthy, 2006; Pryke, 2009). The lack of consistent definitions has been seen to be hampering the development of SCM, both in theory and in practice (London, 2008).

Tennant and Fernie (2012) explore the definitions of supply chain management and summarize that there are two broad schools of thought; a functional school and a philosophical school. The example advocaters of a functional school are Cox *et al* (2006) and Spekman *et al* (1998). They believe supply chain management is a sourcing strategy. This "*involves the buyer undertaking proactive supplier development work, not only at the* *first-tier of the supply chain, but also at all stages in the supply chain from the first tier through to raw material supply*" (Cox, et al., 2006 p.34).

Alternatively, commentators of a philosophical school (Cooper & Ellram, 1993) interpret supply chain management as a 'way of working'. This largely abstract interpretation traverses many organisational and operational boundaries (Tennant and Fernie, 2012). Consequently, supply chain management is not just about explicit corporate functions such as purchasing, logistics and production, supply chain management also pervades tacit aspects of business such as teamwork, professionalism and networking (CSCMP, 2013).

London (2008) identifies various definitions from four different approaches including distirubtion, production, strategic procurement and industrial organisation economics and states that SCM is about delivering superior outcomes at less cost to the supply chain as a whole. SCM involves the systematic management and physical distribution of products from their raw material state, through the manufacturing processes to the point of sale for the product (London and Kenley, 2001). The supply chain is defined as the 'network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hand of the ultimate customer' (Christopher, 1992). These organisations are dynamic and interdependent and can quickly be reconfigured to respond to changing requirements from the customer (CSIRO, 2001). However London (2008) was more targeted in producing a definition that was more useful to the construction industry rather than a retelling and borrowing from lean manufacturing or transport logistics sectors.

"Supply chain procurement is the strategic identification, creation and management of critical project supply chains and the key resources, within the contextual fabric of the construction supply and demand system, to achieve value for clients." (London, 2008) This definition then provides a platform for an innovation and productivity improvements that large organisations (such as volume house builders) are seeking to achieve. It provides a useful starting point for our study on waste minimization because without strategic identification, creation and management of critical project supply chains and key resources seen within the context of the supply and demand economic system we can not hope to reduce waste and bring key supply chain actors along on the journey. It is the influence that large volume housebuilders have on the whole supply chain that will enable some transformations to take place – both culturally, operationally and economically.

3.2 Benefits and barriers

Many benefits can be achieved through SCM including (Cheng et al, 2010):

- Reduced costs,
- Improved responsiveness and ability to changes;
- Reduced uncertainty for project owners in cost savings
- Increased service level; and ,
- Facilitate decision making.

In an integrated supply chain, information is shared both up and down stream, improving efficiencies. A responsive supply chain is able to deal with a range of elements including quantities demanded, short lead times, large variety of products, achieve a high service level and account for uncertainty of consumers and suppliers (Bankvall *et al*, 2010).

When Benton and McHenry (2010) present the potential benefits of supplier partnerships (see Table 6), they also state that due to the following barriers, the development of an integrated supply chain remains an extremely difficult task. Barriers to SCM, include; failure to share project information; fear of loss of control; lack of self awareness; lack of partner awareness; enormity of the project complexity; inability to recognize project goals; lack of understanding project owner; lack of understanding of supply chain; myopic thinking; myopic strategies; and deficiency of mutuality. The lack of critical scrutiny of SCM and its integration into the original sectors has been raised as a significant issue with SCM development (Bankvall *et al*, 2010).

Table 6 Potential Benefits of Supplier Partnerships (Benton & McHenry, 2010)

Reduced Uncertainty for Project Owners in	**Cost Savings**
• Material costs • Quality • Timing • Reduced supplier, subcontractor base easier to manage	• Economies of scale in • Scheduling • Purchasing • Logistics • Decreased administrative costs • Fewer switching costs • Enhanced project integration • Technical or physical integration • Improved equipment utilization
Reduced Uncertainty for Subcontractors and Suppliers in	**Time Management**
• Market • Understanding of project owner's needs • Project specifications	• Faster project completion • Improved cycle time for subcontractor
Reduced Uncertainty for Owners and Partners in	**Shared Risks and Rewards**
• Convergent expectation and goals • Reduced effects from externalities • Reduced opportunism • Increased communication and feedback	• Joint capability and development • Market shifts • Increased profitability • Project development • Accident reduction
Joint Work Method Development	**Stability**
• Increased shared technology • Greater joint involvement of project design	• Lead times • Priorities and attention
Greater Flexibility	

3.3 Lean Manufacturing

SCM has closely been linked to the "lean" approach. The objective of lean management is to achieve 'zero waste'. A number of sources of waste have been identified including; :overproduction, waiting, transportation, Inappropriate processing, unnecessary inventory, unnecessary motion and defects. Womack and Jones (1996) defined the five main elements of "lean thinking," which are now widely accepted. These five main elements that enable a lean approach are:

1. Value—Identify value since it is lean manufacturing's role to deliver value to the customer.

2. Value stream—To create customer value, managers need to identify which activities add value and which do not.

3. Flow—Managers must focus on the flow through the value chain in the factory and eliminate non-value-adding activities. This usually involves a "single piece" flow concept.

4. Pull—The value chain is based on a pull approach; that is, customer demand drives manufacturing activity and material flow.

5. Perfection—Continuous improvement in pursuit of perfection.

Past research has suggested that the lean approach aids competitiveness (Nystuen, 2002; Parker, 2003; Liker 2004). Sheridan (2000) states that conversion to lean production could bring four fold productivity after studying in Japanese companies.

Lathin (2001) suggests that a reduction of 90% in lead time, 90% in inventories, 90% in the cost of quality and 50% increase in labour productivity could be achieved by adopting lean production for the traditional mass producers. Lawson (2013) states that lean production could bring the benefit of the elimination of all categories of waste. Through a comprehensive study of 72 manufacturing companies including the top 50 organizations in Australia based on the number of employees, venue and profitability and whose names were supplied by the "Business Council of Australia" and the "Australian Chamber of Commerce", Sohal and Eggleston (1994, p.6) suggest that: "Two-thirds of the companies said that a strategic advantage had been generated...with the greatest improvements stemming from market competitive positioning, customer relationships and quality constrains".

Although lean production has many benefits, there are also drawbacks. It can be a challenge to record and accurately track inventory and material usage, especially when material usage varies due to errors or the nature of the process, or there are very long lead times. Lawson (2013) summarized the concerns of lean production as follows:

1. Firstly, capacity utilization is often sacrificed in conventional JIT environments (Slack *et al*. 2001, p. 485) in favor of reducing inventory. One solution to this is to create an annual- hours contract with staff so that capacity is elastic.

2. Secondly, there will be a bottleneck when kanban cards start piling up at a work cell due to the longer task completion time than the taskt time. Furthermore, capacity planning is difficult in a pull-based JIT or orderless environment, especially if there is different product portfolio and the operation times vary.

3. Thirdly, there are not enough historical records for analysis of processes and continuous improvement because the limits of lean manufacturing techniques, which is a main disadvantage of lean manufacturing. Furthermore, techniques such as kanban are inadequate among suppliers, customers, subcontractors and other partners in a global supply chain. Some lean manufacturing techniques are limited within a factory.

4. Finally, lean production has to focus on total productive maintenance because there is no safety buffer in a lean environment. If anything breaks down in the production process, the entire material flow quickly stops.

In brief, lean manufacturing has often been seen as difficult to implement in construction because of demand variations, changes of product mix and global distribution of supply partners (London, 2008).

3.4 Supply Chain Management and the construction sector

SCM has been proposed as a solution to the construction industry inefficiencies (Bankvall et al, 2010). It is now an approach which is on the national agenda for many countries (London, 2008). While emanating more recently from the manufacturing industries, improved efficiencies in the construction sector have been flagged for almost as long as construction has been around. For example Henry Ford, the founder of the Ford motor company,

> '*dreamed about mass-producing homes using standard but modularised designs with the modules built in factories to slash design and production costs while still providing variety. A number of entrepreneurs actually created modular designs and briefly set up production lines in the Unites States to make the modules for prefabricated houses immediately after World War II*' (Womack and Jones, 2003, p. 51).

Authors such as Lonngren, Rosenkranz and Kolbe, (2010) and Cheng et al, (2010) argue that the construction sector is one of the least integrated industry and in order to achieve economic and labour efficiencies in the construction sector there needs to be a restructure of the building supply chain. However, others such as London (2008) question if the construction industry is as inefficient as everyone claims given the complexity of the nexus of contracts that culminate on a construction project and perhaps alternative measures of efficiency should be developed rather than adopting ill fitting productivity measures from other sectors.

Since the early 1990s, the construction sector has begun to embrace SCM. However, Aloini et al (2012) question if this has happened and state that attempted integration of SCM into the construction sector has been met with significant challenges and is still too fragmented currently to claim any sort of success. This is also surmised by others (Bankvall et al, 2010; Khalfan and Maqsood, 2012; Shin et al, 2011). To date, the construction industry is lagging behind with regards to the integration of SCM approaches, in particular with achieving the required integration and managing the complex supply chains (Bankvall et al, 2010). Bankvall et al (2010) in summarising the SCM in construction literature, state that there are researchers who believe that the construction sector lacks the will to do what is required to successfully implement SCM. Furthermore thy find that there are questions over the assumptions embedded into SCM not fitting within fragmented industries such as construction.

The difficulty of applying SCM to the construction industry is well known (Doran and Giannakis, 2011; Eriksson, 2010). As London (2008, p. 11) states

> '*ultimately, effective SCM requires the ability to be able to identify and locate differing levels and types of differentiation across various SM options. It is suspected that very few firms have this holistic perspective of SC and typically manage on one tier; which is their immediate suppliers*'

Construction projects are highly dependent on the co-ordination of a large number of stakeholders. Aligning all stakeholders to improve supply chain efficiencies is challenging, especially as many of these actors do not have the power or ability to co-ordinate such a change (Formosa and Isatto, 2011). On the other hand, Bankvall *et al*,(2010) provide an overview of the challenges of SCM integration into the construction sector and what has occurred to date to attempt to overcome these challenges. Less attention has been paid to the nature of the construction supply chains and their industrial organisational economic environment because it is the nature of the power relationship between the customer and the supplier that ultimately will drive the procurement relationship (London, 2008).

SCM involves a high level of expertise, knowledge and skills at executive and site operational level to ensure that policies and processes support the desired practices. SCM involves four key sets of activities; Developing supplier group strategy maps; Implementing strategic sourcing processes and practices; Streamlining supplier coordination systems; and managing supplier performance for improved alignment (London, 2008).

3.5 SCM in Australia

Until the early 2000's, there had been limited application of SCM in the construction sector in Australia. An early study into SCM and the construction sector was completed by CSIRO (CSIRO, 2001). This study focused on improving client-supplier relations through the use of information technology. The project developed a web-based system for Bovis Lend Lease to assist the company with SCM. The aim of the tool was to improve the supply chain to become more efficient. While outcomes of the project identified the importance of information technology and focusing on developing client-supplier relationships to improve efficiencies, the research did not address the reduction or avoidance of waste materials. However, it concluded that SCM was a useful approach to apply to the construction sector in Australia.

Building upon this, Petrovic-Lazarevic et al (2006) interviewed eight Melbourne residential builders regarding SCM and the role and importance of relationships within the supply chain. They found that relationships and trust between building companies and suppliers is seen as important in achieving and sustaining competitive advantage. In this regard the focus was on improving economic efficiencies and ensuring timely completion of work for the companies involved and does not mention waste. Interestingly, they found that while trust with suppliers was a key element in building relationships and more efficient supply chains, many of the companies periodically searched the market for alternative suppliers to ensure they were getting the most competitive price and quality for products and services. They also found that smaller companies tended to have more personal relationships with suppliers.

The most comprehensive study in the area of construction supply chains was that produced by London (2008) which involved mapping more than 1500 procurement relationships in the construction industry on 5 major construction sites including the Federation Square, the state Hockey and Netball stadium, a high rised housing apartment block, Etihad stadium (formerly known as the Colonial Stadium) and a large greenfield housing development estate in Williamtown. The mapping involved identifying the way in which the decision was made to procure the supplier at each successive tier including the negotiating tactics during tendering and after tendering – the study focused on the simply act of procurement as a means of defining the structural and behavior characteristics of the construction supply chain. Through exploring tendering behaviours and procurement decisions the economic market within which each procurement relationship was embedded was described – thus describing the countervailing power of supplier and customer. Some 11 different product sectors were mapped including bricks, timber, composite facades, insitu concrete, pre-cast concrete, air conditioning, fire services, glazing, aluminium, structural steel and formwork.

London (2008) presents sectoral case studies of interest to this research project; one on concrete and one on brick – two of the three materials which are the focus of this research. Both case studies present the actors involved, their roles and the process of moving from a raw material to end product. It provides a greater understanding of how the supply chain works for each material. For example it was found that subcontractors typically purchased required concrete from the one manufacturer, therefore once the subcontractor is selected, the supplier of the concrete is known. In addition the case study found that for the three main concrete suppliers in the case study area, they all purchase products from each other's quarries, providing further complexities in attempting to develop an integrated supply chain. While useful in terms of presenting the supply chain and a number of issues within these, the focus is on understanding it from an economic efficiency point of view. There is no discussion on material waste reduction or avoidance.

In addition Bankvall et al (2010) present a case study on the third material of this research: plasterboard. Again there is no discussion in terms of waste material, although it is touched on in the debate about ordering customised or standard sized plasterboards. The argument for customised plasterboard is that it doesn't require any cutting onsite, saving both materials (onsite) and time, particularly as the manufacturer has the machinery to cut the boards, rather than relying on humans to do it onsite. However, it reduces flexibility in that the plasterboard might not be able to be used on any other projects if it can't be used on the one it was designed for. It also takes longer for customised plasterboard to be made by the manufacture. The plasterboard supply chain is thought to be a fairly simple sequence of activities compared to other construction products and materials.

London's extensive study of more than 1500 procurement relationships described the structure and behaviour of the Victorian construction industry [including housing residential and commercial sectors]. In this study (London, 2008), it was identified that although there is the perception that the industry is highly fragmented, project oriented and consisting of temporary project transactional relationships these relationships are actually often embedded within long term relationships between clusters of subcontractors and contractors which have often extended for decades. Different trades have different economic market structural and behavioural characteristics and supply chain management best practice can only be developed with an understanding of these characteristics. This is most useful to our study because it provides a starting point on how to focus on which supply chains the house builder will have the greatest influence over in relation to waste minimization.

In summarising issues with the traditional house building processes, Womack and Jones (2003) state that there is a significant portion of the construction time spent both waiting for other trades to arrive and finish their work before the next phase can begin and in redoing work that was not done correctly the first time. This has been allowed to go on as consumers feel powerless to do anything about it, meaning that the system continues to be inefficient because there is a lack of anyone holding the construction industry accountable. However, the authors argue that the processes required for construction of a house are suitable to follow a lean thinking or SCM approach.

The problem is the manufacturing sector is a relatively more neat and easy process when compared to the building industry, meaning that the application of SCM is proving more difficult (Aloini et al, 2012). London (2008) adds that a lack of continuity between projects is a significant issue within the building industry in relation to SCM. Furthermore the complex network of actors along the supply chain, including customers, planners, designers, contractors, subcontractors, suppliers and government agencies. These characteristics of the building industry in Australia (and internationally) have been argued to be a reason both why SCM application will (CSIRO, 2001; London and Siva, 2012) or will not work. Aloini et al (2012) state that these characteristics have hampered the adaptation of SCM from the relatively more straightforward application in the manufacturing sector.

While SCM is emerging as an alternative management approach in the construction industry in Australia, it is yet to be embraced by Australian Government policies. The Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, 2011) released a construction and demolition waste guide in 2011. In this there is a strong focus on recycling and re-use across the supply chain with only limited attention paid to reducing and avoiding waste to begin with. Similarly, SCM is only briefly discussed in this guide. This shows that the concept of SCM in the construction sector in Australia, is not yet entrenched in the governments thinking and policy development.

3.6 SCM Internationally

Internationally, countries such as the UK have begun to discuss and assess the benefit of applying SCM in the construction sector. The application of SCM in the UK emerged after the Latham report in 1994 (Kalfhan and McDermott, 2006). For example BRE (2006) (although pre-2008) suggests that it is critical to improve the efficiencies of supply chains across the building industry as it is the cumulative actions of the supply chain which determine total outcomes. They have set a 50% waste reduction target over current best practice. While not specifically discussing SCM, the report does list a number of actions needed across the supply chain which include:

- Quantifying the effects of different types of contracts and procurement on resource efficiency, also exploring the use of incentives and penalties to reach targets
- Greater use of consolidation centres to maximise resource use, minimise over-ordering and surplus materials
- Producer responsibility – voluntary agreements with manufacturers and other stakeholders that are based upon reducing the life cycle resource impacts of products
- Local collections or milk rounds for surplus products and materials, with resulting local supplies of small/part packages of products/low impact materials – possibly with community sector but health and safety risks would need to be mitigated.

Another seminal piece of research, also from the UK, is the PhD work of Hong-Minh (2002). Hong-Minh investigated the re-engineering of the UK private house building supply chain and found that a reduction of the supplier base and the centralisation of supply greatly improved the performance of the supply chain. This compressed the ordering cycle and construction time required resulting in reducing total supply chain inventory costs by 20% and the amount of labour required by 49%.

This was more than the efficiencies found by Khalfan and McDermott (2006) whose research of the application of SCM in the UK construction industry found economic efficiencies of 1-2% on professional fees and time efficiencies of 10-15%. Further benefits identified from this process include the ability to apply lessons learnt in future projects, improved performance management systems, fewer delays and added value. In addition, the application of SCM and narrowing of suppliers was found to improve relationships, improve work quality (through increased certainty about future work and ability to retain skilled and quality workers) and improve resource organisation due to knowing in advance.

3.7 Current viewpoints and discussion

SCM is difficult to implement correctly. Aloini et al (2012 p. 736) state that SCM 'must be properly formulated, strategically planned, organized and executed. Thus, the adopting organizations (mainly the general contractor and its subcontractors) have to deal with managerial, organizational, relational and technological issues which must be appropriately managed in order to effectively apply SCM principles, models and techniques and to overcome the barriers to construction SC application.'

Walker (2012) argues that to achieve efficiencies in the construction sector, there needs to be a focus on developing 'value'. This is because having required resources does not guarantee optimum value. To achieve this optimum value, there is a requirement for commitment and social capital exchanges, an approach which goes beyond current SCM approaches. The basic premise, in moving from SCM to value chain management, is to consider each and every supply chain participants as value generating actor for both, the final client as well as to other participants, thus assuming each participant is a client of another participants when jobs are done and services or materials are supplied in this value chain.

The introduction of SCM from other industries (e.g. manufacturing) has meant that there has been significant focus in the research and in practical applications of SCM in the construction sector of testing the management approach and evaluating outcomes. In doing so, there has been 'particular emphasis on the development of normative ideal types for effective SCM' (Vidalakis et al, 2011, p. 215) however London (2008) identified quite early on that this was perhaps not the most effective way to introduce supply chain management into a project based industry. A project and portfolio based blueprint of key construction supply chain activities was proposed and this is presented and briefly discussed in the following section.

The focus of research and application of SCM in the construction sector has typically been on understanding and developing relationships between suppliers and clients across the supply chain in the anticipation of overcoming the barriers to the integration of SCM (Bankvall et al, 2010; Bygballe, Jahre and Sward, 2010; CSIRO, 2001; London, 2008; Meng, 2010; Petrovic-Lazarevic et al, 2006). It has long been recognised that poor relationships in the building supply chain stem from the fragmented nature of the building industry and the lack of guarantee of future work (CSIRO, 2001). In particular it is about building these relationships early enough in the project (or before it even starts) to ensure that maximum efficiencies can be achieved throughout the project (Walker, 2012).

Meng (2010) has identified that there are limitations of previous research investigating relationships, SCM and the construction industry. These limitations include; lack of rigorous criteria and indicators for defining relationships; lack of description of relationships; and actual assessment has proved problematic. In the research, Meng (2010) found that there are 18 key relationship indicators. Of these there are some which are more important than others. Furthermore, London (2008) adds that there is limited understanding of the wider complexities of relationship development and decision making, with the focus to date being on understanding the cost element of this rather than the sociopolitical economics underpinning the way relationships are fomed, negotiated and enacted.

There has been a focus on the relationship between site productivity and improved material management (London and Kenley, 2001). A recent development on the importance of building relationships in SCM has been the research of Khalfan and Maqsood (2012) who explore the idea that through improved knowledge management and long-term relationships with suppliers, 'supply chain capital' is built. Through repeated use of the same suppliers and the ongoing improvement in relationships and knowledge management, the supply chain capital continues to build. This results in efficiencies, a reduction in waste and an increase in innovation and learning from previous jobs. There is a continued failure to advance the discussion beyond this focus and attempt to explore these elements in greater detail. Indeed, London and Siva (2012) argue, in their research study on developing a methodology for creating an innovation underpinned by a supply chain approach, that there is much rhetoric stating 'that SCM will solve problems, however, we know little beyond this'.

3.8 Summary

The building industry in general has been described as being resistant to change and failing to take a more holistic view of the industry and associated problems (London and Siva, 2012). Vidalakis et al (2011) discuss how a significant gap in the current SCM and construction literature and practice is the lack of logistical focus. Due to the temporary nature of projects and short-term nature of work, it is at times difficult within the construction industry to build up a reliable supply chain (Khalfan and Maqsood, 2012). Vidalakis *et al*, (2011, p. 215) argues that there has been too much focus on the strategic aspects of SCM and ignoring the '*fundamental implicit assumption of logistics management expertise inherent within SCM'*. Furthermore, the focus on contractor organisations has resulted in the role of intermediary organisations (such as material suppliers) being overlooked (Vidalakis et al, 2011). There is too much focus on understanding projects in isolation without taking the more holistic industry approach (Bankvall et al, 2010).

The concept of SCM has been implemented in the manufacturing sector since the 1940s. However, its transferability, adoption and diffusion in the construction industry especially in Australia has been slow (London, 2008). In summary there are three key reasons for this in relation to the house building sector:

- Low levels of managerial skills and knowledge
- Lack of implementation tools to support employees to develop SCM policies, processes and practices
- Lack of competitiveness in larger volume house build organisations and a subsequent lack of incentive for change and continuous improvement

Existing research has highlighted the problems in applying SCM within the construction industry. Issues such as short-term working arrangements, lack of trust/information sharing, limited customer focus, price-based selection and inefficient use of emerging and existing technologies (Bankvall et al, 2010; Doran and Giannakis, 2011; Khalfan and maqsood, 2012; Petrovic-Lazarevic et al, 2006; Shin et al, 2011). Issues such as lack of co-ordination and communication amongst supply chain actors has been said to be a limiting factor in the successful uptake of SCM in the construction industry (Bankvall et al, 2010). The construction sector has been described as being fragmented, highly reliant on short-term contracting work, unreliable supply of materials, and often resulting in long and costly project overruns (London and Siva, 2012; London and Kenley, 2001; Vidalakis et al, 2011). All of which mean there are significant inefficiencies in the Australian construction industry (CSIRO, 2001). A fragmented supply chain and resultant inefficiencies have been stated as a barrier to the Australian construction industry competing internationally (Petrovic-Lazarevic et al, 2006).

'The development of integrated supply delivery solutions have not been extensively recognised in the Australian residential sector. Ad hoc examples and applications by some major building companies have seen some limited success. However, this has not been diffused throughout the sector and thus has had little real impact on overall sector performance and individual company competitiveness. Whole-scale industry improvement requires a concerted effort to undertake a stepwise change. A key to the solution is to investigate successful examples of integrated supply chains which have resulted in productivity and/or innovation performance improvements' (London and Siva, 2012).

The following Blueprint was developed and partially tested for the Qld government for the supplier group strategy map. It attempts to identify portfolio and project based activities.

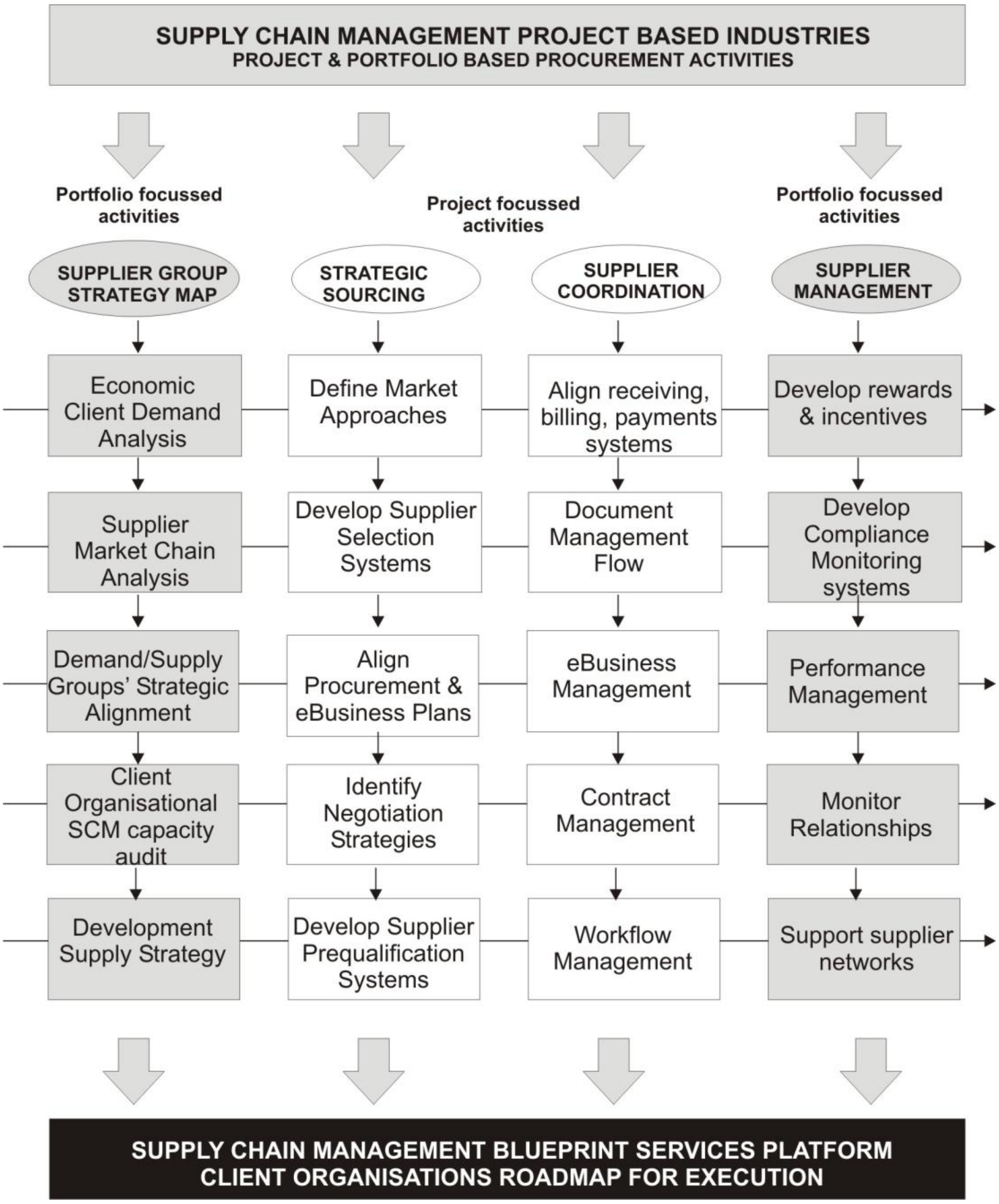

Figure 3 Blueprint Supply Chain Management project based industry (London, 2008)

4.0 SCM and waste minimisation in the residential sector

There has been an explosion of interest in the area of green or sustainable supply chain management with more than 300 publications produced in the last 15 years in this area (Seuring, 2012). Not all of these publications are directly related to the construction industry or more specifically the residential construction sector, however, it does provide an indication of the growing significance of this topic area.

A generic definition of sustainable supply chain management is provided by Seuring and Muller (2012) as "*the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of sustainable development ie economic,* *environmental and social, which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria*".

Past work in sustainable SCM has tended to focus on external elements rather than the firm's internal elements such as resources and capabilities (Gold et al, 2010). Effective sustainable SCM requires flexible interaction between various supply chain actors as well as a long-term approach between the different actors underpinned by mutual dependency (Hult et al, 2007; Spekman et al, 1998).

4.1 Integrated SCM

Integrated supply chains are increasingly being recognised as a win-win approach to achieving waste minimisation in construction. In discussing the potential of greening the construction supply chain in Singapore, Ofori (2000, p. 204) suggested a number of actions or initiatives including:

- Education: develop expertise in SCM within industry, train purchasing officers in key aspects of green procurement including performance evaluation and monitoring, increase knowledge of relevant environmental issues among construction practitioners

- Case studies: document successful local and overseas examples of green procurement in construction, disseminate case studies using appropriate media

- Support and promotion: government should provide direct support through its procurement policies and procedures, offer incentives to support clean production processes and practices, generally promote environmental responsibility among all construction agencies, enterprises and practitioners

- Best practices and award: distil and disseminate best practices in green procurement, institute an annual competition to recognise excellence in green procurement as an adjunct to the existing award in the broad area of the environment

Whilst SCM can help to effectively green the construction supply chain in Singapore, Ofori (2000) indicates that a number of major challenges need to be overcome including conceptual problems of designing the appropriate supply chain and practical issues associated with entrenched business practices and attitudes and lack of knowledge about SCM and its benefits.

According to Zu and Zhou (2011) construction firms seeking to implement green supply chain management should consider their management and choice of suppliers in terms of how the collaboration with the supplier can contribute towards greening the supply chain. Furthermore, "green" SCM involves examining the whole life cycle of a project. A framework for strategy development for firms seeking to introduce sustainable SCM was proposed by Kang et al (2012). The framework included five key perspectives:

- Leadership for knowledge sharing
- Innovation for product and process corresponding to the lifecycle of sustainable supply chain
- Integration of operations by the supply chain and its components
- Improvement along with the management lifecycle of process
- Compliance of socioeconomic requirements and governmental regulations

In a study to explore the waste minimisation strategies utilised in high profile construction projects in the UK (Dainty and Brooke, 2004), it was identified that a wide range of waste minimisation techniques are currently being employed by large construction organisations. The study revealed that the three most effective waste management solutions employed by construction firms include:

1. the development of alliances with suppliers and recycling companies by forming relationships with suppliers and secondary users of waste materials
2. increased use of off-site fabrication to control waste and damage
3. use of standardisation to improve buildability and reduce the quantity of off-cuts

Dainty and Brooke (2004, p. 27) pointed out that the two of the three most popular strategies revolve around ways to avoid waste at the source and deal with waste as it is produced on-site, which suggests that there is scope to remove waste throughout the design and specification project phases within what is terms "waste minimisation partnerships". Through the development of integrated waste management strategies project stakeholders can work together to achieve significant improvements in waste management performance. A key to the solution is to embed the importance of waste minimisation as a key performance criteria throughout the supply chain whereby all project stakeholders need to be committed to waste management as part of an integrated supply chain. This aligns well with the national policy developed by Building Research Establishment in 2006 and discussed in the first section of this report on Waste in Construction.

4.2 SCM & waste minimisation in the residential sector

While this review has presented a number of articles and research regarding SCM and the construction sector, there is little attention to waste reduction and avoidance in the residential construction sector. While there is limited focus within the research addressing waste reduction and avoidance in the construction industry from a SCM perspective, one emerging discussion in this area is with regards to pre-fabrication of dwellings (Eriksson, 2010). Eriksson (2010) discusses the benefits of 'lean construction' as a method of SCM. While focusing primarily on the economic and labour efficiencies achievable, he touches upon the fact that such an approach would also lead to a reduction of material waste. However this point is not discussed in detail. However, London and Kenley (2001) in their review of SCM and its application in the construction industry, highlight that there are issues with lean construction. For example while lean production had been embraced by the auto industry, it was criticised for the negative impact it had on workers.

Another more recent article discussing SCM and pre-fabrication (or modular) construction is that by Doran and Giannakis (2011). The authors argue that although there is increasing engagement with SCM from the construction industry, there are still inefficiencies and further work is required. They discuss the benefits of offsite versus onsite construction. They discuss the role which SCM can play with regards to offsite construction. Again, this is more focused upon economic and time efficiencies but they do state that waste material reduction is a benefit of modular construction although there is little real data to evidence this and the waste may simply be shifted from site operations to a more controlled environment.

In the UK's government's, 20 year construction waste reduction strategy, it was identified that a move towards factory produced building will reduce construction waste and that this type of construction will play an important role in the future in reducing construction waste (BRE, 2006). However, while such examples seem to be pushing for the benefits of prefabrication in the construction industry, others drawing upon SCM argue that onsite construction allows for greater outcomes through the ability for more flexibility and questions the gains in efficiency of prefabrication (Bankvall et al, 2010).

The discussion of waste reduction in the SCM and construction literature is primarily in regards to wasted economic, time and labour rather than wasted materials (Eriksson, 2010). An holistic approach to waste avoidance and reduction is required whereby we must examine upstream decisions and behaviour in the supply chain as the problem of waste although evident at the site in many cases is not the root cause of the problem. Some key reasons why waste materials are generated can be attributed to the following:

- design sub-optimisation [as evidenced by simple matters such as cut bricks and plasterboard sheets etc]
- ordering inaccuracy through lack of skills and adequate documentation provided to project procurement officers
- wastage through ordering inaccuracy due to low confidence levels in the design and design development documentation
- incorrect usage of materials onsite and poor management and construction technique skills
- site reworks due to a range of factors including design changes, poor constructability, poor workmanship and client changes
- site ground conditions and associated preparation [cut and fill poorly engineered] as well as contaminated soil
- over packaged construction materials

Clearly participants at each phase of the project can provide input into solving the problems of wastage - specifically the concept and developed design functions [architectural, civil engineering and environmental engineering], tendering and procurement functions and pre-site preparation and onsite construction operational functions. In the housing sector these various functions are internal to the organisation as well as outsourced externally. A SCM framework will begin to solve such problems at each of the 5 cascading levels:

- intra-organisational function;
- inter functionional,
- inter-organisational,
- supplier network and
- regional clustering.

Different participants will exert varying degrees of influence at each level of the supply chain. The causes and the current practices of volume residential house builders need a closer examination as they shall provide the aligned objectives between the organisations and their designers, subcontractors and suppliers when developing a supplier group strategy. In the broader Australian construction sector, as well as the volume housing construction organisations, these supply chain management activities have had limited attention.

5.0 Conclusion

There has been increasing research interest in the area of sustainable supply chain management. Significantly though much less attention has been paid on the investigation of integrated supply chain management for construction waste minimisation or avoidance in the residential housing industry. Given the increasing costs charged for construction waste disposal and recycling and limited landfill capacity; innovative approaches to avoiding and reducing waste by housing construction organisations has never been more urgently needed.

There has been some limited ad-hoc success of SCM integration into the construction industry in Australia and internationally (London and Siva, 2012). However, there remains a dearth of research, understanding and application of SCM in the Australian construction sector. This is even more so the case with regards to SCM and waste reduction and avoidance in the construction sector specifically.

This review has identified various policy level approaches in various countries and interesting data for benchmarking purposes in our study. The sources and causes of materials waste research is useful as it highlights clearly the role of various supply chain participants. Various strategies in supply chain management and sustainability research also provides a contribution to developing organizational and project level strategies to frame our study. There is no research that specifically investigates the development of individual and organizational capability in relation to exploring an holistic supply chain approach to waste minimization although this is clearly on the agenda of numerous governments. There appears to be useful organizational supply chain management level strategies that we can build upon but little action research case study oriented material that has been evaluated within house building organisations in Australia or internationally. Our study is well placed to make a practical and theoretical contribution to the field of waste minimization using supply chain management strategies.

6.0 References

Aloini, D., Dulmin, R., Mininno, V., & Ponticelli, S. (2012). Supply chain management: a review of implementation risks in the construction industry. *Business Process Management Journal, 18*(5), 735-761.

Bankvall, L., Bygballe, L. E., Dubois, A., & Jahre, M. (2010). Interdependence in supply chains and projects in construction. *Supply Chain Management, 15*(5), 385-393.

Bell N. (1998) Waste minimization and resource recovery. The environmental design guide, vol. 2. Canberra: Gen 21, Royal Australian Institute of Architects

Benton, W. C., & McHenry, L. F. (2010). *Construction purchasing & supply chain management*. New York: McGraw-Hill.

BRE. (2006). Developing a strategic approach to sonctruction waste. 20 year strategy draft for comment. Garston, Watford: BRE.

Brooks, K., Adams, C. and Demsetz, LA (1994). Germany's construction and demolition debris recycling infrastructure: what lessons does it have for the U.S? Sustainable Construction, Proceedings of the 1st Conference CIB TG16, C.J. Kibert (ed). Centre for Construction and Environment, Gainesville, 647-656

Bygballe, L. E., Jahre, M., & Swärd, A. (2010). Partnering relationships in construction: A literature review. *Journal of Purchasing and Supply Management, 16*(4), 239-253. doi: 10.1016/j.pursup.2010.08.002

Bossink, B. and Brouwers, H. (1996) Construction waste: quantification and source evaluation, Journal of Construction Engineering and Management, Vol. 122, No. 1, pp. 55-60

CIRIA (1995). Waste Minimisation and Recycling in Construction – A Review. London: Construction Industry Research and Information Association (CIRIA) Special Publication.

Cheng, J. C. P., Law, K. H., Bjornsson, H., Jones, A., & Sriram, R. (2010). A service oriented framework for construction supply chain integration. *Automation in Construction, 19*(2), 245-260. doi: 10.1016/j.autcon.2009.10.003

Christopher, M. (1992). Logistics and Supply Chain Management Strategies for Reducing Costs and Improving Services, Pitman, London.

Cooper, M. C., & Ellram, L. M. (1993). Characteristics of supply chain management and the implications for purchasing and logistics strategy. *The International Journal of Logistics Management, 4*(2), 13 - 24.

Cox, A., Ireland, P., & Townsend, M. (2006). *Managing in construction supply chains and markets*. London: Thomas Telford.

Craven, D., Okraglik, H. and Eilenberg, I. (1994) Construction waste and a new design methodology, Sustainable Construction, Proceedings of the 1st Conference CIB TG16, C.J. Kibert (ed). Centre for Construction and Environment, Gainesville, 89-98

Crittenden, B. and kolaczkowski, S. (1994) Waste minimisation: a practical guide, Rugby, Warwickshire: Institution of Chemical Engineers

CSCMP (2013). CSCMP Supply Chain Management Definitions. Retrieved 08/01/2013, from http://cscmp.org/aboutcscmp/definitions.asp

CSIRO. (2001). Building and construction industries supply chain project (domestic). Canberra: Commonwealth Scientific and Industrial Research Organisation on behalf of Department of Industry, Science and Resources.

Dainty, A. and Brooke, R. (2004) Towards improved construction waste minimisation: a need for improved supply chain integration?, Structural Survey, Vol. 22 Iss: 1, pp. 20-29

Doran, D., & Giannakis, M. (2011). An examination of a modular supply chain: a construction sector perspective. *Supply Chain Management: An International Journal, 16*(4), 260-270.

DSEWPC. (2011). *Construction and demolition waste guide - recycling and re-use across the supply chain*. Canberra: Commonwealth of Australia.

Duran X, Lenihan H, O'Regan B. (2006) A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland. Resources, Conservation and Recycling, 46(3):302–20.

EPA (1998). Construction and Demolition Waste Action Plan. NSW, Environment Protection Authority.

Eriksson, P. E. (2010). Improving construction supply chain collaboration and performance: a lean construction pilot project. *Supply Chain Management: An International Journal, 15*(5), 394-403.

Faniran, O.O. and Caban, G. (1998), "Minimising waste on construction project sites", Engineering Construction and Architectural Management 5, Vol. 2, p. 183.

Formoso, C., Isatto, E. and hirota, E. (1999) Method for waste control in the building industry, Proceedings IGLC-7, 7th Conference of the International Group for Lean Construction, Berkeley, CA, 26-28 July

Formoso, C. T., & Isatto, E. L. (2011). *Three Theoretical Perspectives for Understanding Inter-firm Coordination of Construction Project Supply Chains* (Vol. 11).

Gavilan, R. and Bernhold, L. (1994) Source evaluation of solid waste in building construction, Journal of Construction Engineering and Management, ASCE, 120, 3, pp. 535-555

Gold, S., S. Seuring, P. Beske, Sustainable supply chain management and interorganizational resources: a literature review, Corporate Social Responsibility and Environmental Management 17 (4) (2010) 230–245.

Graham, P. a. S., G. (1996). "Construction waste minimisation for Australian residential development." Asia Pacific Construction Management Journal **2**: 14-19.

Greenwood, R. (2003) Construction Waste Minimisation: Good Practice Guide, Centre for Research in the Built Environment(CRiBE), Welsh School of Architecture, Cardiff, UK, retrieved at 10/01/2013 from http://wales.gov.uk/desh/publications/housing/constructwastemini/guide.pdf?lang=en

Hong-Minh, S. (2002). *Re-engineering the UK private house building supply chain.* University of Wales Cardiff. Retrieved from http://www.uni-mannheim.de/mateo/verlag/diss/hong-minh/hong-minh.pdf

Hyder Consulting (2011) Construction and demolition waste status report, Management of construction and demolition waste in Australia, Report prepared for the Department of Sustainability, Environment, Water, Population, Communities - Queensland Department of Environment and Resource Management,

Hult, G. T. M., Ketchen, D. J., & Arrfelt, M. (2007) Strategic supply chain management: Improving performance through a culture of competitiveness and knowledge development. Strategic Management Journal, 28(10);1035–1052

Kang, S., Kang, B., Shin, K. K., Kim, D. and Han, J. (2012) A theoretical framework for strategy development to introduce sustainable supply chain management, The 2012 International Conference on Asia Pacific Business Innovation and technology Management, Procedia - Social and Behavioural Sciences 40, 631-635

Khalfan, M., & Maqsood, T. (2012). Supply chain capital in construction industry: coining the term. *International Journal of Managing Projects in Business, 5*(2), 300-310.

Khalfan, M., & McDermott, P. (2006). Innovating for supply chain integration within construction. *Construction Innovation: Information, Process, Management, 6*(3), 143-157.

Lathin, D. (2001), "Lean manufacturing", American Society for Quality Journal, December, pp. 2-9.

Lawson (2013). White Paper: Lean Manufacturing Retrived at 10/01/2013 from http://www.lawson.com/lpod/white+paper/english/6218

Liker, J.K. (2004), The Toyota Way - 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill, New York, NY.

Lim, K. (2005) Causal model for management of subcontractors in waste minimisation, PhD thesis, National University of Singapore

Lingard, H., Graham, P. and Smithers, G. (2000) Employee perceptions of the solid waste management system operation in a large Australian contracting organisation: implications for company policy implementation, Construction Management and Economics, Vol. 18, No. 4, pp. 383-393

Ling, F and Lim, M (2002) Implementation of a Waste Management Plan for Construction Projects in Singapore, Architectural Science Review, Vol. 45, No. 2, pp. 73-81

London, K. (2008). *Construction supply chain economics*. London: Taylor & Francis.

London, K., & Siva, J. (2012). Housing supply chain model for innovation. Melbourne: Australian Housing Supply Chain Alliance.

London, K. A., & Kenley, R. (2001). An industrial organization economic supply chain approach for the construction industry: a review. *Construction Management and Economics, 19*(8), 777-788. doi: 10.1080/01446190110081699

Lönngren, H.-M., Rosenkranz, C., & Kolbe, H. (2010). Aggregated construction supply chains: success factors in implementation of strategic partnerships. *Supply Chain Management: An International Journal, 15*(5), 404-411.

Maloney, W.F. and Federle, M.O. (1993), "Practical models for organizational assessment", Journal of Management in Engineering, Vol. 9 No. 1, pp. 64-81.

McGeorge, W. D., Palmer, A., & London, K. (2002). *Construction management: new directions*. Oxford: Blackwell Science.

McGrath C, Anderson M. (2000) Waste minimizing on a construction site. Building Research Establishment Digest, 447.

Mills TH, Showalter E, Jarman D. (1999) A cost effective waste management plan. Cost Engineering, 41(3):35–43.

Mincks, WR (1994) The construction contractor's waste management plan: optimising control and cost, Sustainable Construction, Proceedings of the 1st Conference CIB TG16, C.J. Kibert (ed). Centre for Construction and Environment, Gainesville, 765-774

Meng, X. (2010). Assessment framework for construction supply chain relationships: Development and evaluation. *International Journal of Project Management, 28*(7), 695-707. doi: 10.1016/j.ijproman.2009.12.006

Nystuen, T. (2002). Big results with less. *Quality Progress*, October, pp.1-9

O'Brien, W. J., Formoso, C. T., Vrijhoef, R., & London, K. A. (2009). *Construction Supply Chain Management Handbook*. London: CRC Press. Taylor and Francis Group.

Ofori, G. (2000) Greening the construction supply chain in Singapore, European Journal of Purchasing and Supply Management, Vol. 6, No. 3-4, pp. 195-206

Parker, V. (2003). Burt's bees implementation of production process. *Ttibune Business News*, Nos. 1-3, pp. 2-4

Petrovic-Lazarevic, S., Matanda, M., & Worthy, R. (2006). Supply chain management in building and construction industry: Case of Australian residential sector: Monash University.

Poon CS. (2007) Reducing construction waste. Waste Management, 27(12):1715–6.

Pryke, S. (2009). *Construction Supply Chain Management* (1 ed.). Chicester: Wiley-Blackwell.

Reddrop A, Ryan C. (1997) Housing construction waste, vol. 2. Canberra: Commonwealth Department of Industry, Science and Tourism

Seuring, S. (2012) A review of modeling approaches for sustainable supply chain management, Decision Support Systems,

Shen LY, Tam VWY, Tam CM, Drew D. (2004) Mapping approach for examining waste management on construction sites. Journal of Construction Engineering and Management, 130(4):472–81.

Sheridan, J. (2000), "Growing with lean", Industry Week, October, pp. 1-5.

Shin, T.-H., Chin, S., Yoon, S.-W., & Kwon, S.-W. (2011). A service-oriented integrated information framework for RFID/WSN-based intelligent construction supply chain management. *Automation in Construction, 20*(6), 706-715. doi: 10.1016/j.autcon.2010.12.002

Slack N, Chambers, S. and Johnston, R. (2001). Operations Management, third edition, Pearson Education Limited, Harlow, England.

Sohal, A. and Eggleston, A. (1994), "Lean production: experience amongst Australian organisations", International Journal of Operations & Production Management, Vol. 14, pp. 1-17.

Spekman, R. E., Kamauff, J. W. J., & Myhr, N. (1998). An empirical investigation into supply chain management: A perspective on partnerships. *International Journal of Physical Distribution & Logistics Management, 28*(8), 630 - 650.

Sustainability Victoria (2010) Towards Zero Waste Strategy Progress Report 2005-2009

Tam VWY, Tam CM. (2008) Waste reduction through incentives: a case study. Building Research & Information, 36(1):37–43.

Tennant, S. and Fernie, S. (2012). An emergent form of client-led supply chain governance in UK construction: Clans. *International Journal of Construction Supply Chain Management 2*(1), 1-16

Teo, M. and Loosemore, M. (2001) A theory of waste behaviour in the construction industry, Construction Management and Economics, vol. 19, No. 7, pp. 741-51

Tucker, S. Seo, S, Johnston, D., Williams, A., Mitchell, P., Watson, P., Jones, D., Newhouse, O, Ambrose, M., Lawther, P., O'Donnell, A. (2005) Waste Minimisation in Construction, Final Report, CRC for Construction Innovation, Icon.Net, Brisbane, Australia.

USEPA (U.S. Environmental Protection Agency). (2002) Waste wise update: building for the future, Available from http://www.epa.gov/wastewise/pubs/wwupda16.pdf.

Vidalakis, C., Tookey, J. E., & Sommerville, J. (2011). Logistics simulation modelling across construction supply chains. *Construction Innovation, 11*(2), 212-228.

Walker, D. (2012). Innovation and value delivery through supply chain management. In A. Akintoye, J. Goulding & G. Zawdie (Eds.), *Construction innovation and process improvement*. Chichester, West Sussex: Wiley-Blackwell.

WCS Market Intelligence. (2008). The blue book: Australian waste industry: 2007/08 industry and market report. North Sydney, N.S.W., WCS Market Intelligence

Womack, J., & Jones, D. (1996). *Lean thinking(1st Edition)*. London: Simon and Schuster UK Ltd.

Yuan, HP, Shen, LY, Hao, JJL and Lu, WS (2011) A model for cost-benefit analysis of construction and demolition management throughout the waste chain, Resources, Conservation and Recycling, 55. pp. 604-612

Zhu, M., and Zou, Z. (2011) Green supply chain management in construction industry, M. Dai (eds), ICCIC 2011 Part 2, CCIS 232, 81-86, Springer-Verlag Berlin Heidelberg.