Applying lean construction principles to waste management and identifying minimisation opportunities to inform the industry

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Appling Lean Construction principles to waste management and identifying minimisation opportunities to inform the industry.

The New Zealand Construction Industry similar to overseas treads suffers from poor productivity compared with other industries such as manufacturing and operational type organisations. The input produces far less finished production or output than other industries.

A large proportion of input involved in this production is actually not present in the completed product. Research has confirmed only 10 to 15% of the input is resulting in confirmed and visible out-put. As an industry this is wasteful, unproductive and unsustainable. There are many reasons for this disparity and it has been the basis of many studies and research papers. One of the common themes emerging is, building construction is project based and under a normal tendering situation is driven by a client seeking the best outcome, quality, time, safety for the least price. This process is counter-productive and very wasteful.

Research by Egan 1998 reported that tendering was not a practical procurement solution suggesting a move away from this process into a more collaborative construction situation to increase productivity. Over the years various researchers have explored the methods that have resulted in positive increases in productivity in manufacturing to seek some guidance. The most common methodology supporting these increases is adopting the Lean Thinking Principles developed in early 1950s.This report will investigate if Lean principles would result in less wasteful activities and therefore support an increase in productivity within the construction industry.

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1. ABSTRACT

1.1. Identifying the problem

The New Zealand Construction Industry similar to overseas treads suffers from poor productivity compared with other industries such as manufacturing and operational type organisations. The input produces far less finished production or output than other industries. There are many reasons for this disparity and it has been the basis of many studies and research papers. One of the common themes emerging is, building construction is project based and under a normal tendering situation is driven by a client seeking the best outcome, quality, time, safety for the least price.

In 1998 Egan reported that tendering was not a practical solution suggesting a move away from this process into a more collaborative construction situation. Over the years various researchers have explored the methods that have resulted in huge leaps in productivity in manufacturing to seek some guidance. The most common methodology supporting these increases is adopting the Lean Thinking Principles developed in early 1950s by the Toyota Car Company.

1.2. Purpose and objective of this research

One of the reasons behind poor productivity is processes which result in a high percentage of negative output e.g. items not evident in the finished item. This is normally defined as waste output compared with positive output items which are part of the completed production. According to recent studies in the USA, Scandinavia and UK, the building industry produces waste of:

- up to 30% rework; hidden
- labour is used at only 40-60% of potential efficiency; -hidden
- accidents can account for 3-6% of total project costs; -hidden
- and at least 10% of materials are wasted. -visible

These figures confirm that only a small percentage is actual visible materials (10%), a large proportion of the waste (up to 90%) is hidden but is crucial to completion of the end product.

Plenty of scope exists for improving efficiency and quality simply by taking waste out of construction. To aid the understanding of the extent of waste in the industry requires an examination of the processes carried out in completing a construction project. We are fortunate to have access to two local refurbishment projects to support our report with current data. The analysis will be limited to the waste removed from site in the demolition stages in preparation for the refurbishment and not the general ongoing building site rubbish.

Possible solutions will be put forward after detailed analysis of Lean Thinking Principles with a view to minimising and eliminating waste from the process.

Minimising waste ultimately leads to minimal disposal requirements!

2.INVESTIGATING THE PROBLEM OF CONSTRUCTION WASTE

2.1 The Current situation in New Zealand

A study under taken by Aziz and Hafez (2013) found that over the past 40 years, the productivity of the construction industry has been declining worldwide.

In New Zealand, we are subjected to the same trend, however current research has concentrated on the last twenty to thirty years as records were not necessarily available before this period. "Low productivity levels for at least twenty years in New Zealand's construction industry have only realised any improvement by increasing hourly inputs, (averaging only 0.2% increase per annum)" (Bosnich & Kestle, 2015, p. 1). The overall effect of this is perhaps significantly due to our population size and the related production capacity. (Bosnich & Kestle (2015) wrote: lifting productivity in the construction industry is essential for the benefit of all New Zealanders as announced by Minister Joyce in the NZ sector report in 2013.

Buildings play are an important social focus of our existence (*Sustainable steel council, 2013*)

- People spend an estimated 90% of their lives in and around buildings, this can be either at their place of residence, their work or at social gathering or occasion.
- Quality of life is directly related to the built environment in which people live, work and play. Peoples achievements are often related to the types of buildings they are associated with.
- At work, performance, productivity and staff retention are strongly linked to the quality of the working environment. The end user requirements are always at the forefront of all buildings project design in today's market.

This was further supported by the 2013 New Zealand Sector Report by Joyce which confirmed that the NZ construction industry has a significant influence on the well-being and GDP of the whole country (Bosnich & Kestle, 2015). Statistics confirm that $35 billion revenue is produced annually by the industry which has a fundamental role in the overall economy; approximately 170000 people are employed including trades and professions which is 7.6% of the total work force in New Zeeland; the industry is the fifth largest sector in the economy and produces a nominal 6.3% of GDP (Bosnich & Kestle, 2015).

The industry also has a serious environmental focus (Sustainable steel council, 2013)

- Globally, 40% of all energy and material resources are used to build and operate buildings;
- 40% of greenhouse gas emissions come from building construction and operation;
- Construction and demolition activities are responsible for 40% of total waste generated worldwide;

Improving productivity requires effort from many aspects, such as: time, deliberate choices, patience and perseverance, and supported by ongoing analysis of data and evidence as advised by Bosnich and Kestle (2015). The smallest sustainable productivity growth can have big impact on the industry and employees. However, an important aspect of

considering productivity increases is they should not result in a detrimental increased environmental impact.

2.2 Definition and quantification of waste

To understand the extent of waste in the construction industry requires a close examination of which parts of the transition process are in fact not evident in the finished product. Waste is "Anything that is different from the absolute minimum of materials, machines, and labour necessary to add value to the product" (Alarcon, 1997, p.378). Womack and Jones (1996) define waste as "...any human activity that absorbs resources but creates no value." The definition developed by Walbridge-Aldinger (2000) better conforms to construction production; waste is defined "...as anything that takes time, resources or space but does not add value to the product or service delivered to the customer."

A relatively narrow view of waste in the construction industry believes "waste is directly associated with the debris removed from the site and disposed of in landfills" (Formoso, De Cesare & Isatto, 2002, p.317). The reason behind this is perhaps that material waste is relatively easy to see, it is left over after the production is complete and can readily be quantified. This is also supported by Aziz and Hafez's (2013) who stated that most studies on waste tend to focus on waste of materials, however they did acknowledge that this is only part of the resources involved during a construction process. Waste is generated on construction projects during every phase of the project life cycle from concept to final demolition. This study will concentrate on the minimisation and management of waste at the demolition stages of a project.

"Investigations of the construction production process indicated that construction activities are typically only 10 percent value adding (VA). If a contractor could improve the VA portion to just 15 or 20 percent, the lean contractor would have a significant competitive advantage" (Diehmann, Krewedl, Balonick, Stewart, & Won, 2004). Evidence suggests that Construction and Demolition (C&D) waste may represent up to 50% of all waste to landfills in New Zealand and the majority of waste to clean fills or C&D dumps. That means that up to 1.7 million tonnes of C&D waste is sent to landfills every year and similar amounts to clean fills" (REBRI, 2014).

Also, it is necessary to consider other forms of hidden wastes incurred during production, such as those which did not result in adding value for the client. This was investigated by Alarcon (1997) who measured waste in terms of their costs, efficiency of processes, equipment and personnel. He found that cost can be measured easier than other efficiency based factors which are not always possible.
This was also expanded by Song and Liang (2011) who studied waste in project-level contractor coordination and operation level construction performance.
They concluded that if production lead to a value loss situation it could be directly related to wasted productivity.

Kosela 1992, as cited in Aziz & Hafez, 2013 summarised construction waste and value loss as being attributable to these factors.

Quality of works; the lack of a suitable Quality Assurance and Quality Control Plan. Lack of a suitable plan and benchmarking meant that material or system failures were only evident after a time of operation or use. Repairs or replacement at this stage incur considerably expense as theoretically the item has already being paid for once as originally installed which is the owner's responsibility. However, the necessary repairs or replacement are not a cost which the client should reasonably be expected to pay, this is now at the installers or providers cost.

- *Constructability*; The non-consideration in the design stage of the following construction phase. This is now extremely important as contract risk considerations and time frames become tighter in the current market. As implied by Egan 1998 the tendering situation of expecting the best possible outcome for the least cost is largely responsible for project failures.
- *Material management*; The ineffective handling and procurement of materials. This can be handled better as explained later in this report.
- *Non-productive time*; The inclusion of time in the production cycle which is not adding value for the client. This can be handled better as explained later in this report.
- *Safety issues*. Not implementing a suitable Health and safety plan to conform to the Regulatory requirements. This can be handled better as explained later in this report.

Hidden waste is also clarified by Aziz and Hafez (2013) confirming the main classification of waste based on Formoso et al. (2002) study as following: These are from Lean Construction.

- *Overproduction*; Producing more than is required
- *Substitution*; Changing material selection to standard other than specified
- *Waiting time*; Non-productive time on the critical activities
- *Transportation*; In effective loading, movement or pathways
- *Processing;* In effective processes
- *Inventories*; too much stock or inventory
- *Movement*; More movements or motions than are required to complete a task
- *Production of defective products*; Deflects are wasteful and involve cost to fix
- *Others*. Under-utilisation of talent.
  None of these nine activities could be considered as adding value to the end product or process.

According to Alarcon (1997) waste in the industry can be better identified if dividing them into three activity groups associated with flows, conversions, and management activities:

- *Activities associated with flows:*
- *Activities associated with conversions:*
- *Activities associated with management activities:*
  If the task is broken down into these distinct sections, flow, conversion, management it is easier to apply each one of the nine points in the previous section and clearly identify the problem areas.

  Analysis of the works as presented by Kosela, Aziz, Hafez, Formosso and Alarcon above confirms that most of these ideas concerning the hidden waste in

production when applied to the construction industry are in fact lean thinking ideas.

In summary, creating an efficient control system or model to quantify waste and performance has been a challenge for the construction industry for many years, but if the hidden waste is carefully addressed, progress is certainly achievable and will satisfy the need to address the related sections of waste which are not immediately visible. "Investigations of the construction production process indicated that construction activities are typically only 10 percent value adding (VA) (Diehmann, Krewedl, Balonick, Stewart, & Won, 2004) The balance in some cases is waste of various types.

2.3 Waste Minimisation and Management

Having established that the construction industry produces more than its fair share of waste and much of it is unseen we will now consider which is the most effective means of disposal. Currently, the Waste Minimisation Act places responsibility for waste management and minimisation on the council rather than on the generators of waste (Auckland City Council, 2018). As there is a lack of reasonable data available in the BOP area to provide effective guidance, the Draft Auckland Waste Management and Minimisation Plan 2018 will be used as a base line.
This also supports the realisation of the size of the issue 80% compared with the 51% including other residual land rubbish reported by local councils in 2010 and yet to be updated. It may also be assumed that this local figure could include other commercial streams as they are not detailed in Figure 1. The local councils appear to be aware of this as they have stated "due to increases in building activity since this survey, we are probably sending more construction and demolition waste to landfill now than in 2010. We are planning to measure the exact amount with a new survey in late 2016" (Tauranga District Council, 2018). However, the 2018 report figures do not appear to have been updated.

As cities grow, so does the production of waste, particularly from the construction and development sectors. Due to the cost and scarcity of suitably located land, it is becoming common to see existing buildings repurposed. The existing building 1950-1980 is stripped of all interior and exterior finishes and services leaving just the concrete or steel structure. This is then structural strengthened to conform to new Seismic requirements. Followed by any further structural alterations, upgraded services, new interior finishes and a new curtain wall façade. This is the case of our two study case projects both older building due for major upgrades, and strip out and repurpose to suit modern requirements was the selected way forward.
It is also possible to add additional floors onto existing concrete structures with structural steel now. In some cases, the building height has been increased by ten storeys. Records in

Auckland demonstrate that combined with other commercial waste streams this repurposing Construction and demolition waste can amount to 80% of the total waste to landfill. The council is currently following a strategy of encouraging "business and industry to find ways to reduce commercial waste and divert waste materials into new economic activities." (Auckland City Council, 2018, p 6).
The cost of land is also leading to some existing buildings being totally demolished and a new structure erected on the site. This greatly adds to the quantity of waste requiring deposal.
This process of part demolition and upgrade refurbishment applies to the two-case study Bay of Plenty building for this report.

The Auckland city council has recognised that Partnerships with communities, businesses are critical to dealing with this large issue (80%). As domestic collection services become business as usual the council can reprioritise their internal resources to focus on opportunities for waste minimisation within commercial waste streams.

The council suggests the following reasons a business could benefits from this incentive:

- reducing waste disposal costs
- a high level of client satisfaction could enhance your company's image and encourage repeat business
- winning contracts for projects that specify waste reduction procedures
- innovation and challenges can help to attract and retain employees."

It should be noted however, it is not yet technically or economically feasible to divert all materials from landfill. There is no viable method for reusing or recycling many of the products in use today, and the environmentally friendly products that will replace them haven't yet been invented.

The available data from the local council which amounts to 51%, construction and demolition and other residual landfill rubbish would suggest that the figures need to be updated to reflect a better appreciation of the full extent of the issue (80% in Auckland)

With up to date confirmation of the size of the C&D waste locally, it would be possible to be guided by the Auckland City plan to improve our situation considerably. The Auckland City Council who are pursuing a "Zero Waste" policy, do admit that they accept it is not yet technically or economically feasible to divert all materials from landfill. There is no viable method for reusing or recycling many of the products in use today, and the environmentally friendly products that will replace them haven't yet been invented.

As an indication of the quantities of and the breakdown of construction and demolition wastes in NZ, consider the follow information from REBRI (2014) Christchurch City Council Target Zero Construction Waste Reduction Project:
A Typical construction waste skip, measured by weight confirmed the following;

- Wood and particle board – 20%
- Plasterboard – 13%

- Concrete and bricks – 12%
- Metal – 5%
- Packaging (cardboard and plastic wrap) – 5%
- Others (sweepings, other plastic, soil, green waste, glass, fixtures, etc.) – 45%

It can be argued that diversion to landfill of C& D waste which could be recycled is not discouraged by the fee structure. The current fees for general rubbish to a transfer station is approximately $240.00 per tonne in most cities, however it is debatable if this cost of dumping is sufficient to cover the likely cost of manually sorting one tonne of demo rubbish into recyclable items. It should also be realised that this material once sorted has very little if any resale value. There also appears to be minimal incentive for commercial enterprises to actively invest in developing new resource recovering infrastructure.

REBRI (2014) have also put forward these suggested avenues of reduction, which have been expanded to normal suit normal site conditions.

1. Plan to reduce waste at the start of a project, as with any good plan ,reduction in the early stages is easier to monitor and mitigation actions are more effective if instigated at the earlier rather than latter!
2. All staff and subcontractors need to follow the waste management systems .The plan and its implementation should form an integral part of the ongoing situation of managing the sub-contractor and your own staff.
3. Order just-in-time delivery of products, this saves double handling and reduces the need for unproductive storage space. Always attempt to load from delivery vehicle to its final point of installation.
4. Liaise with suppliers and subcontractors about the latest methods for product installation
5. Keep waste materials separate for recycling and reuse. Mixed heaps of recyclable items are very labour intensive to sort and make the task of recycling uneconomical, resulting in mixed recycling items being redirected to land fill.
6. Set up a single waste storage area, this makes far better use of the limited space available on most sites
7. Accept that different waste types occur at different stages. Left over concrete is rare at the finishing stages of a project.
8. Encourage reuse of off-cuts, scraps and so on, reusable metal fixings for concrete. Reuse treated boxing timber for noggs in framing.
9. Keep a current list of recycling operators, this help considerably when odd materials are sorted to be recycled.
10. Have incentives to encourage reuse ,recycling,

A significant part of implementing Lean is in education of the various stakeholders involved in a project .Construction personnel have for a long time focused their attention on the transformation of activities, with little attention given to the flow of activities, leading to uncertain flow processes, increased upstream variability, expansion of non-value-adding activities, and reduction of output value. Understanding of 'waste' has been typically associated with the quantity of waste of materials on-site." The hidden waste elements are not necessarily considered as they get in the way of construction progress. Equally a lot of waste is designed into buildings by poor consideration of materials available sizes and the

simple set out of building grids. It would be also be advantageous for designers and consultants to consider simple lean ideas with a view to designing for minimal waste. These items should all be considered when formulating a Waste Management and Minimisation Plan for Project.

There is plenty of scope for improving efficiency and quality simply by taking waste out of construction.

As explained in previously researched data the industry traditionally has

a. Labour being used at only 40-60% of potential efficiency;
b. Accidents can account for 3-6% of total project costs;
c. Up to 30% rework;
d. 10% of materials are wasted. (Egan, 1998, as cited in Sarhan,2014)

Experience would suggest that demolition would be at the higher end of the suggested range of both item a and b due its dangerous nature, labour intensity and piece meal nature (55% item a and 5% item b)

Supporting the theory that up to 60% of the production effort put into demolition may in fact be unseen and result in negative output. It could therefore be assumed that unlike new production up to 40% of the effort will actually result in a positive or a value added outcome.eg demolition waste material to be taken to disposal.

Having established that the construction industry produces more than its fair share of waste, we will now consider if the 10% as reported (TCC 2010) is a reasonable assumption today. As there is a lack of reasonable data available in the BOP area to provide effective guidance, the Draft Auckland Waste Management and Minimisation Plan 2018 (AWMMP2018) will be used as a base line.

Currently, the Waste Minimisation Act 2008 places responsibility for waste management and minimisation on the council rather than on the generators of waste. However, in other cities construction and development combined with other commercial waste streams amount to 80% of the total waste to landfill (Auckland City Council, 2018). The council has realised that with a responsibility of this magnitude (80%), the risk is better owned by those that are best able to handle it: the producers. The council is therefore currently following a strategy of encouraging “business and industry to find ways to reduce commercial waste and divert waste materials into new economic activities.” (Auckland City Council, 2018, p 6). Councils have recognised that partnerships with communities, businesses are critical to dealing with this large issue (80%). As domestic collection services (20%) become business as usual, the council can reprioritise their internal resources to focus on opportunities for waste minimisation within commercial waste streams.

. With up to date information, ACC has put forward the following reasons a business could benefit from improved waste minimisation and management planning:

- reducing waste disposal costs;
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- winning contracts for projects that specify waste reduction procedures;
- innovation and challenges can help to attract and retain employees.

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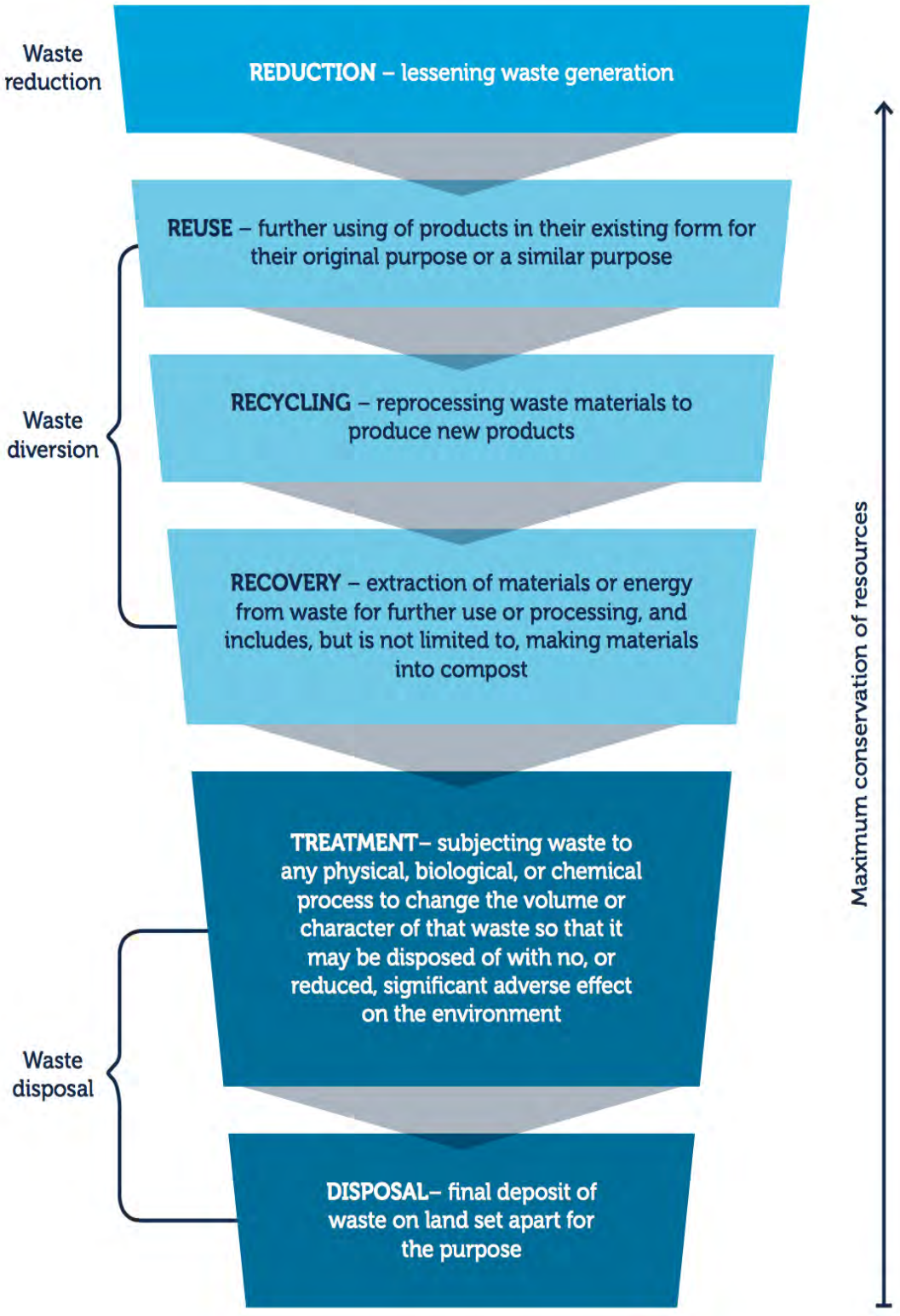

Figure 2: Waste hierarchy. (Source: *AWMMP 2018)*

The ‘waste hierarchy’ chart Figure 2 confirms the underpinning ideology that reducing, reusing, recycling and recovering waste is preferable to disposal. Also, the objective is not restricted to reduction of the quantity, steps are also required to prevent the incorrect materials being placed in landfill and the associated environmental issues.
In general, focusing on actions towards the top of the waste hierarchy can reduce the costs at lower levels. Environmental impacts are also often reduced by focusing on opportunities at the higher levels. However, relative costs can vary significantly depending on factors such as disposal and transport costs applicable to various waste materials. This is one of the barriers summarised late, it is often more expensive to use recycled materials than the original product

Figure 3 illustrates the different ways waste products from Construction and demolition activities could possibly be repurposed to avoid ending up in landfill.

Current available data (2017) reveals that local councils sent close to 90,000 tonnes of waste to landfill in 2014/15. This waste included a significant quantity of material that, if separated, could be recycled and put to beneficial use. Decisions to recycle or compost are made at an individual household level.” Since 2010 (when the first Plan was adopted) there appears to only minor progress made toward achieving the previous vision to “promote efficient waste management practices that minimise environmental harm towards minimal waste.

The local city council (2018) states in the Waste Management & Minimisation Plan that ensuring that we are dealing with waste in the best way possible, by maximising

opportunities to reduce, reuse, recycle and compost, and seeking to achieve our vision of 'minimising waste to landfill' is a challenging task and one that will not be undertaken overnight.

Any potential change will be undertaken carefully and in stages over the next few years. After analysing the current waste services, and the nature of the industry and waste management infrastructure, the joint Waste Assessment concluded that it would be challenging for Council to achieve a significant reduction in the amount of waste to landfill under the current ownership, governance and operational arrangements. (TCC2010)

What we're sending to landfill (TCC, 2018):

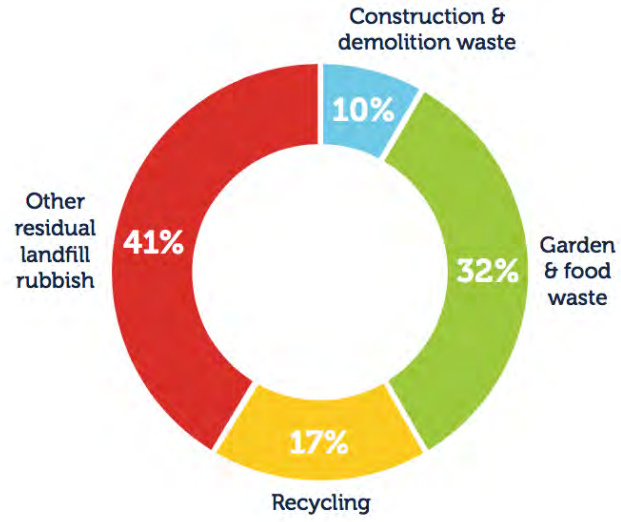

Figure 3: Percentage composition of material disposal to land ll. This 2010 data appears in the 2018 report unchanged

Current data from TCC WMMP 2018 confirms that each week, we are sending nearly

- 190 tonnes of paper and cardboard,
- 30 tonnes of plastic,
- 60 tonnes of glass to landfill that could instead be recycled using collections already available in Tauranga.

We're also sending approximately

- 400 tonnes of food and garden waste to landfill each week that could be composted instead, and used by the horticulture and agricultural industries in the Bay of Plenty.

Application of the formulas from figure 1 confirm that this chart is very much out of date

There is a lot of building activity in Tauranga, the two case study buildings produced many tonnes of C&D waste See Appendix 1 but the contractors struggled to find suitable local methods to recover, reusable or recyclable materials such as concrete, glass, timber, etc. This was also complicated by the fact that there did not appear to be any contractual

requirement to do anything rather than" business as usual."ie Do what is the normal situation but recycle if at all possible!
Also, due to increases in building activity since the 2010 survey, we are probably sending more construction and demolition waste to landfill. This reinforces the need to do more than we currently do as it is in all stakeholder's best interest.

The local council accepts this is the case and have preparing an Action Plan, which also includes reviewing the targets and actions from the 2010 WMMP.
The proposed plan.
Investigate, plan and upgrade and extend the Resource Recovery Park (RRP) to offer improved waste management and minimisation e.g. accommodating additional material streams on a case by case basis (e.g. construction and demolition materials, hazardous waste etc.), waste minimisation centre or learning hub, reuse centre etc. --- This upgraded Park would process 10,000 tonnes of waste per annum from 2019/20 onwards.
The principle soft target would be the categorisation of waste into these sections,

- Reduction
- Reuse:
- Recycling
- Recovery
- Treatment:
- Disposal (summarised definition):
- Construction and demolition waste (C&D):
  Complete with a plan and process to effectively deal with each category in an ecological and sustainable manner.

Also, Solid waste objectives which would be:

- effectively collect and deliver waste to landfill;
- reduce the quantity of waste to landfill;
- reduce the quantity of harmful waste to landfill; and
- increase diversion of waste for reuse, recovery, or recycling.

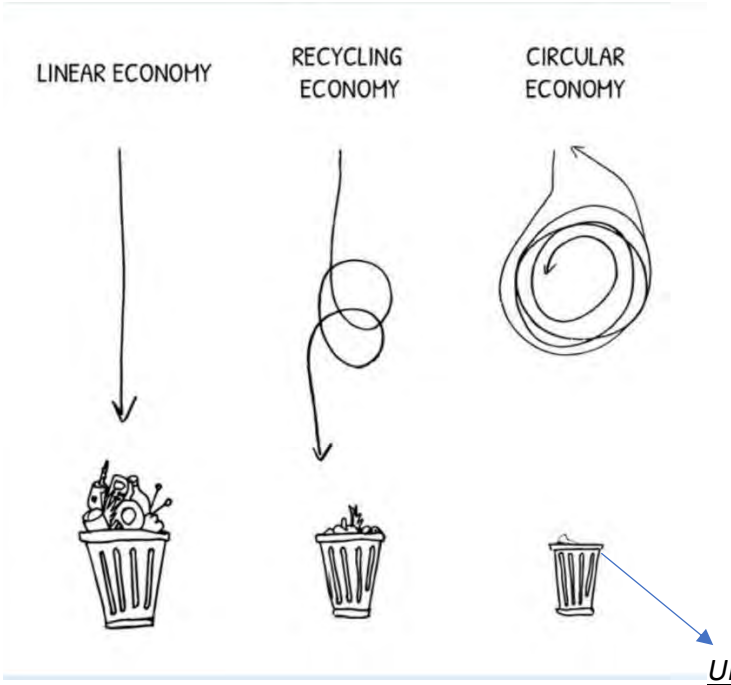

Figure 4: Conceptualising economies and waste

(Source: Pierre-Francois Kaltenbach/ AWMMP 2018)

As demonstrated in figure 4 the ideal progression for waste is to move from the concept of all waste going to the rubbish bin, to some being recycled or reused and hence being diverted from the bin, to all rubbish being divert to another purpose perhaps eliminating the need for a bin completely.

However literature on barriers (CIB, 2014; WALGA, 2013; Boser, Bierma & El-Gafy, 2010; DSEWPC, 2012, as cited in Zou, Hardy, & Yang, 2015) indicates that they are numerous. They include:

- Lack of knowledge about what can be recycled, or about recycling opportunities;
- Contamination of recyclables due to lack of separation or lack of space for separation;
- Lack of markets for the recycled materials;
- Technological barriers in terms of conversion of waste materials to useful ends;
- Cost of recycling processes making products more expensive than that from virgin materials;
- Design for deconstruction has not yet been incorporated into the building process;
- Alternatives to recycling are less costly – landfill gate prices are too low;
- Government policy is not driving recycling;
- Lack of confidence in recycled materials;
- Lack of communication and industry infrastructure;
- Lack of knowledge across industry; and
- Low value/low volume products being landfilled rather than stored for recycling because it is uneconomic to stockpile."

The requirement for materials to meet certain specifications and standards makes it easier to select new product than go through the process of having recycled product certified for use. Utilising recycled material is also in 90% of the cases more expensive than new product so there is little incentive or value in using recycled product. The best use for recycled material appears to be *reuse* as supplements in the manufacture of the new product,

- introducing recycled glass into the manufacture of new glass produces
- introducing recycled steel into the manufacture of new steel items
- including recycled paper and cardboard into manufacture process
- manufacture of fibre glass insulation from recycled flat glass window materials
    - it should be noted however that sometimes due to contaminates in the recycled materials production of a pure new product is not possible.

The councils believes that businesses also have significant opportunities to improve their waste management practices. The council will encourage this through increased education and communication regarding services, and potentially through alterations and/or improvements to services depending on the outcome of the procurement process and bylaw review. This is illustrated by the diagram Figure 5 below which highlights the difference of rubbish recycling being a circular rather than linear opereation.

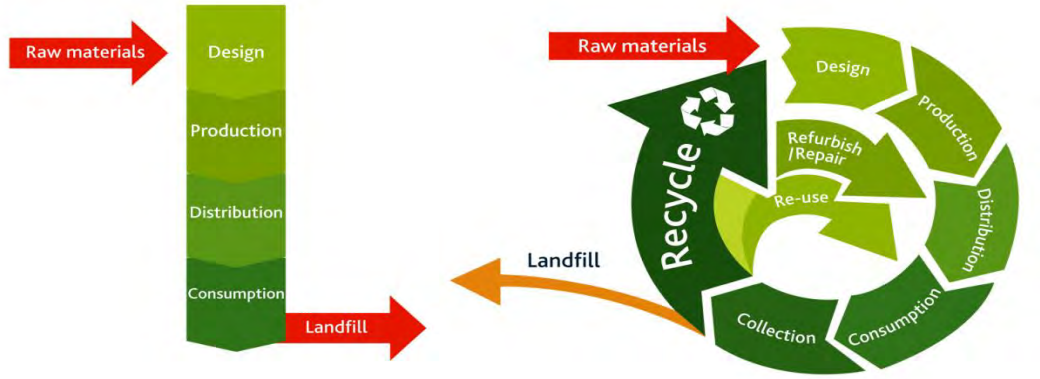

Figure 5: Linear vs Circular economies. (Source: AWMMP 2018)

Figure 5 also suggests that if businesses considered the waste they produce in terms of a circular economy rather than a linear type there is adequate scope to recycle, refurbish, repair and reuse. This is the most desirable result for the environment but proving it is the most economical and sustainable option is still subject to robust debate.
Many opportunities exist for the beneficial reduction and recovery of materials that would otherwise be destined for disposal as waste. Construction industry professionals and building owners can educate and be educated about issues such as beneficial reuse, effective strategies for identification and separation of wastes, and economically viable means of promoting environmentally and socially appropriate means of reducing total waste disposed (Napier, 2015).
Our research confirms it is still the cheapest option to send waste to landfill.

This option was investigated by *The Wasted Opportunities Report 2017*
"New Zealand's levy rate is set at $10 per tonne of waste which is among the lowest of any country with a similar type of levy or tax. Experience from overseas suggests that there are benefits to having a higher rate of levy, and to applying the levy more broadly"
This report puts forward a number of environmental alternatives which would ensure a better return for all parties concerned and encourage people to consider other forms of disposal before Land fill. Land fill should be the last option when all others are avenues have been explored.
It also suggests that" increasing the waste levy could generate up to 9000 new jobs per year." It could even be more if the infrastructure to reprocess materials were built here, rather than having most materials exported, as happens now.
News items last year highlighted a growing mountain, at that stage 4000 Tonnes, of plastic waste which was all banded up in bundles ready to be exported when the proposed market declined to accept any more plastic waste.
As stated by Auckland City council *2018*;
Turning waste into commodities and resources target of "Zero Waste" doesn't mean the end of the waste industry. Rather, it means the services the industry contractors currently supply will change. The focus will change from mainly disposal and minimal reuse to disposal after due consideration of all other forms of waste management. Increasingly, waste businesses will become commodity and resource business skilled at redirecting materials to their next productive use. *Auckland City Council, 2018*.

In conclusion local councils lead the way via their waste minimisation and management plans however rely on the waste material to be sorted at source by the producer. For most generators and supply sources of C&D waste there is no financial incentive to sort rubbish which generally has to be completed manually and is extremely labour intensive.
The fee to dump waste still is the best option for bulk unsorted waste as volume dictates the economics of demolition.

3.INVESTIGATING THE SOLUTION, A LEAN THINKING APPROACH

3.1 Lean Thinking- History and definition

Lean Thinking was developed by the Toyota Car Manufacturing company in the early 1950s as an alternative to the mass production type system being practised by other manufacturing plants worldwide. Their production system developed around the idea it easier to produce repeatable, forecastable results in the controlled environment of a factory which were not subject to outside influences of weather, labour and supply issues. This thinking produced excellent results and was very instrumental in cementing Toyotas position as a leading vehicle manufacturer. *Matt Banna 2017*

Lean Thinking Definition

Lean Thinking can be defined as a production management system which is subject to the following requirements;

(1) *Specify Value*:
Specify value from the customer's own definition and needs and identify the value of activities. Lean sets out methods which enable clear definition of what the end user or customer perceives to be the value of their participation in the project.
(2) *Identify the Value Stream*:
Identify the value stream by elimination of everything, which does not generate value to the end product. This value once identified needs to be put into a logical stream and the flow from one to the next must be clearly defined and understood.

It is also necessary to consider
Value adding activities: Those which convert materials and/or information in the search to meet client's requirements.
Non- value adding activities: Those which are time, resource, or space consuming, but do not add value to the product.

(3) *Flow:*
Ensure that there is a continuous flow in the process and value chain by focusing on the entire supply chain. "Always start with the end in mind" ,the flow should be continuous and should not contain non–value added activities.
(4) *Pull:*
Use pull in the production and construction process instead of push. This ensures continuance of the stream of activities and eliminates the non–value added activities from the stream..

(5) *Perfection:*
Aims at the perfect solution and continuous improvements. There is little to be gained by production which is of the incorrect standard or quality, this results in rework, defective product and wastage. Once we have a lean plan in place we need to constantly monitor the resultant improvements for;
(a) *Effectiveness*: A measure of accomplishment of objectives
(b) *Efficiency*: A measure of utilisation of resources used in accomplishment of objectives
(c) Quality: A measure of conformance with specifications;
(d) Productivity: Theoretically, this is defined as a ratio between output and input, and it is primary measured in terms of cost or increases in percentage.
The lean plan must always be fluid and is subject like any good plan to improvements as production proceeds. Thus ensuring experiential learning to becomes part of the accepted production process.

3.2 Construction Application

The construction industry, according to Aziz and Hafez (2013) over the past 40 years, has suffered from some of the worst productivity figure of any industry. This can be directly linked to the unpredictable nature and risk inherent in construction when compared to manufacturing. Greater scope variation and workflow disruptions are the norm in construction due to location and environment. According to recent studies in the USA, Scandinavia and UK, the building industry produces waste of:

- up to 30% rework which is hidden,
- labour is used at only 40-60% of potential efficiency this is hidden,
- accidents can account for 3-6% of total project costs not visible till occurrence so therefore considered hidden,
- and at least 10% of materials are wasted, this is visible and takes the form of off cuts and left over materials which is diverted to waste bins and then to landfill.

These figures confirm that only a small percentage is actual visible materials (10%), a large proportion of the productivity (up to 90%) is hidden but is crucial to completion of the end product.
It has been proven that manufacturing before 1950 suffered from poor productivity also and as described above the industry trend was reversed by the application of lean thinking principles . It therefore is logical that if Lean has been applied successfully in other industry it should be considered for construction as a means of waste management and reduction.
Lean construction is the continuous process of eliminating waste applied to the construction industry. *Matt Banna 2017* Lean philosophy, broadly defined, can apply to design, procurement and production functions. For example, BIM (Build Information Modelling) is Lean Thinking applied to the design process.

Lean construction was first introduced in 1992, lean production concept has been adapted in the construction industry, and lead to the introduction of TFV production management system:

(T) transformation,

- (F) flow and
- (V) values generation.

"This tripartite view of production has led to the birth of lean construction as a discipline that subsumes the transformation-dominated contemporary construction management" Aziz & Hafez, 2013, p.680

Lean construction management is different to the traditional system in four key areas as summarised by Aziz and Hafez 2013:

- Lean construction has more clear objectives for the delivery process
- The ultimate goal is to maximise project performance
- Concurrent product and process
- Production control is applied at every phase of the project

However it is also important to note that there is no one cookie-cutter approach to Lean, the ideas applied to manufacturing do not automatically fit construction.

They are subject to modification to suit the different requirement that are inherent to the construction process. Many tools have been developed, some adapted from manufacturing and others developed because they did not exist in the then current construction technology. *Matt Banna 2017*

If we consider the principles of lean thinking generally to be

- Meeting or exceeding all customer requirements,
- Focusing on the entire value stream pursuing perfection in the execution of a constructed project.
- It is a philosophy that requires a continuous improvement effort that is focused on a value stream defined in terms of the needs of the customer.
- Improvement is, in part, accomplished by eliminating waste in the process.

To be successful, adoption of Lean Construction should be implemented from the top (*management side*) and driven from the bottom (*the actual people completing the works*.)Becoming lean is a long-term, comprehensive commitment; it amounts to a cultural change for the company. Lean principles must be understood and applied in a context and require a comprehensive understanding of a complex, interacting and uncertain construction system. It must be approached as a system of thinking and behaviour that is shared throughout the value stream which is the entire company from top management to on site workers.

However it must also be considered that local practices in the management construction and demolition wastes often are shaped by the availability of suitable disposal sites, availability of markets for recycling and reuse, capabilities of local workforces and construction businesses to adapt demolition processes for management of wastes

If successfully applied, however, lean has the potential to improve the cost structure, value, attitudes and delivery times of the construction industry

Lean can apply to the enterprise or company level, to the project level and to the individual process level. It also has been clearly broken down into the various individual parts of many industries.

In building Construction and in this report, we will concentrate on the *waste* elements.

Most wastes are controllable, Alarcon (1997) has divided them into three activity groups associated with flows, conversions, and management activities:

1.<u>Activities associated with flows</u>:

- (a*) Resource*:
- (i) Lacking, inefficient distribution, and inadequate transportation of materials;
- (ii) Inadequate and inefficient usage of plant and equipment, and sometimes required equipment is not available; and
- (iii) incorporation and personal attitudes of workers.
- (b) *Information*: this relates to lack of or poor quality of information required, and inadequate delivery of information.

2.<u>Activities associated with conversions</u>:

- *(*a) *Method*: this means that work activities are deficiently designed, the procedures and support are inadequate.
- (b) *Planning*: this is associated with work space and conditions. Limited work space and poor work conditions cause demotivation.
- (c) *Quality of product*: does not meet requirement or unwanted damages to finished work*.*

3.<u>Activities associated with management activities</u>:

- (a) *Decision-making*: this relates to poor allocation of work and distribution of personnel.
- (b) *Ineffective/inefficient supervision*: lack of supervision during production processes.

Waste elements of Lean Construction are, it should be noted that not all of these are applicable to demolition:

- ***Overproduction**:* which means that the quantity production is greater than required. This should not be confused with a wastage allowance. It is common practise to allow for a % wastage factor say 2.5 to 10 %, this compensates for bad workmanship, damages during installation, accidental losses, product failures and incorrect installations. This wastage factor is a normal part of the pricing requirement of a product's supply and installation. Extra materials, labour hours, plant and equipment usage will be costed into the item. The overproduction discussed here is the amount produced over and above this wastage allowance. If there is a surplus of product supplied the cost of the oversupply is mainly the material, other costs like installation labour plant hire and overheads can be minimised as the product is not installed. If material is ordered in for the project the resultant over produced material could be returned to the supplier for a credit, used on another project or in the worst case sent to the land fill. Whichever option is selected, they are all considered as wasteful as they do not add value to the initial project. Other researchers have interpreted Ohno's original concept of production implies that production on a late-start schedule is the ideal. Indeed, from the client's viewpoint, if a late-start schedule could be guaranteed in the face of weather, supplier schedules and other uncertainties, a late-start schedule would minimize work in progress and cash flow requirements.

- *With demolition* it is difficult to over produce as the final disposable waste can be no greater in quantity than the original. Measuring the original quantity and allowing suitable baulking factors will confirm an expected quantity to be carted away from site.
  Demolition is a measurable trade according to NZS4202 but if a schedule of quantities is not supplied it would be up to the contractors to measure the demolition themselves. It is unlikely that *overproduction* would be of concern unless they have under measured in their original take off of quantities.
  Overproduction is not likely to be an issue with demolition contracts.

- ***Substitution**:* wastes caused by substitution of materials. For example: a more expensive material is used to achieve better unnecessary performance; simple tasks allocated to overqualified workers or performed by highly sophisticated equipment/plant; Substitution should always be approached with due care. If the product specified is fit for purpose the only reason for changing it is a cost saving. Clients are obviously reluctant to even consider a substitution if it is not the original specified product and it is not fit for purpose. Generally, when tendering for the bulk of works in a project it is best to price the original project as specified then offer alternatives for the client to consider after. The reasoning supporting this is including an alternative can be considered as a noncompliance tender. It would therefore not be considered.
  For demolition works it is normal to leave the actual methodology up to the individual contractors so any alternative solutions or methods.
  Substitution is not likely to be an issue with demolition contracts.

- ***Waiting time****:* time wasted due to lack of planning in synchronisation, material flow, and pace of work by different groups of equipment. It also refers to the periods of inactivity occurred because a preceding activity did not deliver on time or finish completely. It increases cycle time during which no value-added activity is performed. Proper planning of equipment or people will eliminate waiting because of poor scheduling, production control or unbalanced crew size.
- *For demolition* -to avoid the loss of time due to waiting require very good planning and a constant monitoring of the day by day operations. A large amount of the demolition trade cannot be accurately itemise and measured and experienced contractors will be sure to include a suitable contingency.
- *Waiting time* is therefore a Waste elements of Lean Construction which if handled correctly could have significant effect on the overall project.
- ***Transportation****:* related to wastes produced with material movement on site, for example: double handling, unorganised site pathways, and inadequate equipment or plant. Unnecessary man hours, energy, site space is generated, with the possibility of material wastes during transportation. *Ying and Roberti 2013* found that transportation cost equates to 30% of the total construction costs, and the vehicles loadings are only 50% efficient;
- *In Demolition* transportation is a major issue to be considered and requires adequate planning. Appling leans principles to the demolition transportation could have a very positive effect on productivity.
- ***Processing****:* related to the nature of processing activity, and extra steps taken by people to accomplish their work because of inefficient processes. Elimination of such waste requires changing / improving of construction methodologies;
- *In Demolition* processing is a major issue to be considered and requires adequate planning. Appling leans principles to the demolition process and methodology could have a very positive effect on productivity.
- ***Inventories****:* excessive or unnecessary inventories can cause material wastes: deterioration, losses, robbery and vandalism; and tie up capital;
  Inventories is not likely to be an issue with demolition contracts.
- ***Movement****:* inadequate equipment, ineffective work methods, or poor working place arrangement can cause unnecessary or inefficient movement, thus create waste;
- *Appling leans principles* to the demolition plant and equipment movement could have a very positive effect on productivity.
- ***Production of defective products****:* means wastes caused by product which does not meet quality specifications; "*Production of defective products*: it occurs when the final or intermediate product does not fit the quality specifications."

- *Production of defective* product is not likely to be an issue with demolition contracts
- ***Others:*** waste caused by other factors, for instance: inclement weather, accidents and vandalism.
- These are items deemed to outside the contractor's control and *demolition* would not be outside the influence of such occurrences.

This table highlights how the manufacturing lean ideas can be altered to suit construction

Table 6.1: Comparison of Lean Manufacturing to Lean Construction Waste

Type of Waste	Manufacturing	Construction
1. Overproduction	Production of too many units or parts due to push nature of manufacturing.	Overbuilding a particular aspect of a project, either because it was over- engineered or a process was started before it was really needed.
2. Waiting	Time spent waiting for the next batch of parts to arrive from the previous conversion process. Time spent waiting for a machine to finish.	Time spent waiting for other work crews to finish their particular conversion process so that the next conversion process may begin. Time spent waiting on crew members of a specific team. Time spent waiting for parts or instructions.
3. Transport	Wasted effort to transport materials, parts or finished goods into or out of storage between processes.	Wasted effort to transport building components or tools into or out of job trailers or storage between processes.
4. Extra Processing (Operations)	Doing more work than is required.	Waste associated with rework, re- handling or storage caused by defects in design, fabrication or construction activities.
5. Inventory	Maintaining excess inventory of raw materials, parts in process or finished goods.	Maintaining excess inventory of construction components, equipment or tools.
6. Motion	Waste associated with unnecessary worker/equipment movement between work stations.	Waste associated with unnecessary worker/equipment movement around the construction site.
7. Defects	Repair or rework.	Deficiencies in the finished product that require additional work or rework to correct punch list items.

Diehmann et al,2004

The waste items of Lean construction can also be highlighted by the following chart

Figure 7 Saad Sarhan 2017

These signs are labels for parts of the lean waste process and could be located in appropriate position around a construction site to remind employees of the lean waste items.

If the site was at the demolition stage it would only be necessary to display the appropriated signs with the rest being displayed as construction proceeded.

3.3 Clearly define the lean construction principles

To implement and gain benefit from lean concept, there are principles shall be followed. Aziz and Hafez (2013) have explained these :

- *Specify value*: to specify value from client's point of view, then identify activities which can generate value to the product;
- *Identify the value stream*: this is achieved by eliminating all other activities which cannot generate value to the product. For example, when something goes wrong during the process, stop or change it to eliminate further waste. There are other processes shall be minimised or avoided, such as, miss production, overproduction, transport and storage of materials, movement of labour;
- *Flow*: to ensure a continuous and smooth flow in the process, the flow is yet optimal until client value is specified and value stream is identified;
- *Pull*: Using "pull" instead of "push" in the construction process. This means only produce what is specified at required time and prepare for changes from client;
- *Perfection*: Aims at a perfect end product. The goal is to deliver a product which meets client expectation within agreed timeframe and budget, and in a perfect quality without mistakes and defects.

Azia and Hafez's 2013 expanded the principles that lean construction is to produce unique value for the customer. It focuses on how value is generated rather than how individual activity is managed. This concept is particularly challenging for construction managers who's focus is very much on activities and task based methodologies rather than value streams. It will require a paradigm shift in how coordination and work flow are managed throughout the construction process by construction managers who support project performance. The primary objectives are value to the customer, movement of information of materials to completion. Therefore, to achieve improved results from reducing waste.

4.FINDINGS

Analyse of this report supports the following findings,

- To be an effective means of input of waste minimisation and management into a project it would be more effective if this type of study was carried out before construction actually starts. This would enable the formalisation of a contractual arrangement to support the implementation of a clearly defined waste minimisation and management plan.

- Production of Construction Waste is an inherent part of the majority of all construction processes .

- Production of Demolition Waste is the main part of demolition contracts and requires special consideration due its larger volumes comparted with the normal construction waste.

- A large percentage of the effort required to complete a construction project results in negative output and is non value adding to the end product.

- A large amount of waste can be attributed to the construction process of trying to produce a finished product of factory quality under the constraints of a site environment.

- The process of Waste Minimisation and Management Plan is mainly concerned with the disposal of visible waste which in some instance is as low as 10% of the total waste in the overall process.

- The sorting of this visible waste into other areas of possible disposal, reuse, recycle, refurbish or disposal at land fill dump site, is left up to the contractor.

- The decision of the contractor as to the disposal process undertaken is very much governed by the facilities available both private and those supplied by the local council.

- The incentives available do not support recycling, reuse or repurposing The best business decision is usually demolish in bulk, load out and dump to land fill site.

- Analyse of the two local study projects confirms of a total of approximately 1900 tonnes of demolition rubbish produced 760 tonnes was able to be diverted from landfill to another use.

- A certain amount of waste can be attributed to the choice of project procurement system

- The move to a more collaborative system of early contractor involvement and integrated project delivery, if properly implemented has resulted in better productivity and less waste. Scaffolding these ideas are the principles of Lean Construction.

- Lean thinking enforces the ideology that the customer is of prime importance and concentrates on value added activities. Negative productivity, ineffective management, unacceptable quality, over runs in time and cost are all non- value added activities . Lean Construction proposes methodologies to eliminate these.

- Researched data suggested that of all materials used in site production 10% ends up as left over visible waste. Lean proposes a check list of eight other forms of waste which warrant investigation in the total waste minimisation and management.

- Application of Lean Construction to waste has proven to be effective but needs to be implemented from the top management down and would be difficult to enforce on just one project.

- Becoming lean is a long term comprehensive commitment ,it amounts to a significant cultural change for most businesses. It cannot be approached in a piece meal fashion either it must be approached as a system of thinking and behaviour that is shared throughout the entire value stream.

5.REFERENCE

Alarcon, L. (1997). Tools for the identification and reduction of waste in construction projects. In L. Alarcon (Eds), *Lean construction* (pp. 374-387). Rotterdam, Netherlands: A.A. Balkema.

Auckland Council. (2018). *Draft Auckland waste management and minimisation plan 2018*. Retrieved from https://www.aucklandcouncil.govt.nz/have-your-say/topics-you-can-have-your-say-on/waste-minimisation-management-plan/Documents/draft-auckland-waste-management-minimisation-plan-2018.pdf

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal, 52, 679-695*

Bosnich, A., & Kestle, L. (2015). *How will NZ's construction industry escalate productivity to meet the largest predicted construction demand in decades – is a lean approach one of the magic bullets?*. Asia Pacific Institute of Advanced Research (APIAR). New Zealand, Australia.

Diehmann, J. E., Krewedl, M., Balonick, J., Stewart, T., & Won, S. (2004). *Application of lean manufacturing principles to construction*. Austin, Texas.

Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material waste in building industry: main causes and prevention. *Journal of Construction Engineering & Management, 128*(4), 316-326.

Howell, G., & Ballard, G. (1998). Implementing lean construction: understanding and action. Retrieved from https://www.leanconstruction.org/media/library/id13/Implementing_Lean_Construction_Understanding_and_Action.pdf

Koskela, L. (1992). A*pplication of the new production philosophy to construction, technical repost no 72*, CIFE. Stanford University, CA.

Joyce, H. S. (2013). The NZ sectors report 2013: main report. NZ Government, Wellington. Government Printer, NZ.

Napier, T. (2016). *Construction Waste Management*. Retrieved from Whole Building Design Guide: https://www.wbdg.org/resources/construction-waste-management

Sarhan, S. (2015). *The Concept of Waste as Understood in Lean Construction*. Retrieved from http://leanconstructionblog.com/The-Concept-of-Waste-as-Understood-in-Lean-Construction.html

Song, L., & Liang, D. (2011). Lean construction implementation and its implication on sustainability: a contractor's case study. *Canadian Journal of Civil Engineering, 38* (3), 350-359.

Tauranga City Council. (2018). Waste management & minimisation plan. Retrieved from http://econtent.tauranga.govt.nz/data/documents/plans/waste_management_and_minimisation_plan.pdf

The New Zealand Waste Levy Action Group. (2017). *A wasted opportunity: using the waste disposal levy to create economic & environmental advantage for Aotearoa New Zealand*. Retrieved from http://www.wasteminz.org.nz/wp-content/uploads/2017/06/A-Wasted-Opportunity-NZ-Waste-Disposal-Levy-Summary-Report.pdf

Western Bay of Plenty District Council. (2017). Waste management and minimisation plan 2017. Retrieved from https://www.westernbay.govt.nz/our-council/policies-plans-bylaws-strategies/Documents/WMMP%20Decisions.pdf

Ying, F. & R, H. (2013). *Improving construction logistics.* Retrieved from https://www.buildmagazine.org.nz/assets/PDF/Build-134-80-Research-Improving-Construction-Logistics.pdf

Zou, P., Hardy, R., & Yang, R. (2015). Barriers to Building and Construction Waste Reduction, Reuse and Recycling: a case study of the Australian capital region.
M. Panko and L. Kestle (Eds.). *Building Today - Saving Tomorrow: Sustainability in Construction and Deconstruction Conference Proceedings* (pp. 27-35). Auckland, New Zealand: Unitec Institute of Technology. Retrieved from: www.unitec.ac.nz/epress/