2.0 LITERATURE REVIEW

2.1 Introduction

C&D waste generation is inevitable in construction industry all over the world. Site waste is not brought from elsewhere and dropped to the site. All categories of waste are generated at site out of raw materials brought to the site which has monetary value. There is an estimated allowance for waste in each and every raw material in construction. If the allocated limits are exceeded, project will lose. Most of developed countries and qualified construction organizations have identified this problem and introduced waste management policies to save their money and prevent environmental pollution.

Literature review help us to study the type of waste, causes for waste and C&D waste management practices in other countries and Sri Lanka too.

2.2 C&D waste management practices in other countries

Weight of the problem is to be identified initially. Some of research findings are given below about volume of C&D waste and its sources.

C&D waste has become one of major environmental problem in many municipalities. C&D waste is voluminous and take up a lot of capacity if they are disposed at landfills (Faniran and Caban, 1988; Kibert,1994). In Hong Kong, between 1991 and 2000, the amount of C&D waste produced annually by local construction activities increased by more than 75% from about 7.7MnTons to 13.7Mn Tons(EPD,2000)

Below table shows some data collected by Poon, Ann, and Jaillon(2003) in Hong Kong in their research done for construction waste.

Table 2.1 - Waste generation in Hong Kong (Poon, Ann, and Jaillon, 2003)

Waste Percentage of various trades for public and private buildings in Hong Kong

Trade	Material	Waste Percentage %	
		Public construction	Private construction
Concrete	Concrete	3 -5%	4-5%
Formwork	Timber	Fabricated form wk used	100%
Reinforcement	Steel bars	3-5%	1-8%
Masonry	bricks and blocks	3%	4-8%
Drywall	fine aggregate	3%	-
Wall plastering	Plaster	3%	4-20%
Ceiling plastering	Plaster	3%	4-20%
Wall tiling	Tiles	8%	4-10%
Floor tiling	Tiles	6%	4-10%
Toilet fittings	sanitary fittings	6%	1-5%
Kitchen fittings	kitchen joinery	1%	1-5%

It can be observed that public construction projects produce smaller amount of waste than private construction projects. This can be attributed to the adoption of low waste technologies such as large panel or fabricated steel form work, pre-cast concrete elements, well trained staff etc in public projects. They further reveal that some of construction wastes are due to design variations governed by following factors.

- Last minute client requirement
- Complex design
- Lack of communication between designers, contractors and engineers
- Lack of design information
- Unforeseen ground conditions
- Long project duration

But this statement is controversial in Sri Lankan context and discussed in chapter 4.

Table 2.1 - Waste generation in Hong Kong (Poon, Ann, and Jaillon, 2003)

Waste Percentage of various trades for public and private buildings in Hong Kong

Trade	Material	Waste Percentage %	
		Public construction	Private construction
Concrete	Concrete	3 -5%	4-5%
Formwork	Timber	Fabricated form wk used	100%
Reinforcement	Steel bars	3-5%	1-8%
Masonry	bricks and blocks	3%	4-8%
Drywall	fine aggregate	3%	-
Wall plastering	Plaster	3%	4-20%
Ceiling plastering	Plaster	3%	4-20%
Wall tiling	Tiles	8%	4-10%
Floor tiling	Tiles	6%	4-10%
Toilet fittings	sanitary fittings	6%	1-5%
Kitchen fittings	kitchen joinery	1%	1-5%

It can be observed that public construction projects produce smaller amount of waste than private construction projects. This can be attributed to the adoption of low waste technologies such as large panel or fabricated steel form work, pre-cast concrete elements, well trained staff etc in public projects. They further reveal that some of construction wastes are due to design variations governed by following factors.

- Last minute client requirement
- Complex design
- Lack of communication between designers, contractors and engineers
- Lack of design information
- Unforeseen ground conditions
- Long project duration

But this statement is controversial in Sri Lankan context and discussed in chapter 4.

Gavilan M. and Bernold E. (1994) produced a paper to the American Society of Civil Engineers (ASCE) about C&D waste and they revealed C&D waste is dominated 23% of total solid waste. In USA (Apotheker,1990) old C&D landfills are quickly being filled and space for new ones is growing scarce. New knowledge about the toxicity of certain construction materials such as treated lumber has caused a remarkable damage to the ground water. In spite of these alarming conditions, very little detailed knowledge currently exists about the origins and distribution of C&D waste. The combination of these factors warrants that present waste management methods in construction be reevaluated. Origins of construction waste should be studied to determine the most effective methods for dealing with these wastes at their source.

2.2.1. Causes for C&D Waste

There are many reasons for waste generation in construction projects. Some research findings are given below to identify main causes for waste.

Gavilan and Bernold(1994) documented 5 major causes for waste generation.

1. Due to design errors – Design and detailing errors are the result from mistakes in engineering. If materials are purchased based on wrong design specifications, waste may result if they cannot be resold or returned to the vendor. The builder's only option may be to dispose the materials. Moreover, if the builder already installed the material and is forced to take the flawed portion of the structure apart, he may not be able to salvage the materials and waste may result.
2. Procurement errors – Mistakes can result in one of three material conditions; over-shipment, under-shipment and mis-shipment. They are usually caused by miscommunication either within the builder's organization or between builder and the vendor.
3. Handling of materials – Improper handling or storage of construction materials can be a reason for generating waste. Materials may be damaged during fabrication, packaging, loading or delivery.
4. Operation errors – Especially in building construction, the operations necessary to build the structures which are closely related to generate waste. Poor workmanship may be caused by unskilled labour, inadequate tools and equipment and poor working conditions. Acts of God

include calamities during the construction phase such as earthquakes, work site accidents, poor weather conditions, cyclones etc.

5. Residual – Given present building techniques, some waste from construction processes is inevitable. This waste includes leftover material scraps from cutting material into shorter pieces to fit the design. Residual also includes pallets, packaging and un-reclaimable non-consumables such as sheet piles that cannot be recovered.

Faniran, O.O. and Caban, G (1998) described in a paper article of "minimizing waste on construction project sites" that 5 main causes for waste generation during the construction phase. They are design changes, leftover material scraps, waste from packaging and non reclaimable consumables, design/ detailing errors and poor weather conditions.

Pilot survey results were emphasized that above described causes for waste are applicable to Sri Lankan context too and deeply discussed in chapter 4.

2.2.2. C&D waste minimization

Minimization of waste generation is the first step of C&D waste management. There are some researchers and organizations were involved in waste minimization processes and below given some results.

Macozoma & Benting(1999) described waste minimization program under several topics such as *reduction, reuse, recovery* and *recycling*. The reduction of waste begins with the design of a structure. Conservative design and aesthetic can result in unnecessary large volume of waste. Proper storage of materials on site can save lot of materials from ending up in the waste stream without use. It further mentioned that construction industry can contribute to waste reduction by implementing a construction site management plan on projects.

- Prior to construction - waste reduction can be implemented in the design phase by avoiding conservative design.
- During construction - measures that can be included waste management plans, construction industry performance tools, waste audits, waste separation, monitoring etc.

There are cases that the design specifications do not agree with the market available dimensions causing large amount of off-cuts during construction (Poon, Ann, and Jaillon,2003).

Their study revealed that many designers were aware of their leading roles in minimizing waste but they were restrained by many factors. Client's requirements, cost effectiveness and aestheticism were their prime concerns. These factors certainly limit the designers from implementing measures to reduce waste in the downstream construction processes. It is further recommended following actions to reduce C&D waste in construction sites.

- Inform the suppliers about the construction process requirements and order the materials in good time for the whole site
- Adopt just-in-time ordering and to ensure materials arrive on site when they are needed, thereby avoiding damage while store on site and additional moving of materials
- Order appropriate material sizes to minimize cutting, and order appropriate quantities to avoid excess
- Carefully inspect the goods when they arrive to the site in order to minimize losses arising from poor packaging
- Prepare suitable vehicles or delivery plants for transporting materials from the storage area to the workplace to make minimum damage
- Avoid double handling - the points of unloading should be the final point of stacking area
- Designate central areas for cutting and storage. So reusable pieces can easily be located
- Fix the storage area in a position that is convenient for operators to draw materials
- Provide appropriate protection for different categories of goods during storage and stacking
- Whenever possible, packaging materials should be returned to the supplier for reuse

It further described that the contractor should develop effective material control and handling strategies, which include educating the workers on waste minimization and communicating with the supplier. The site worker should be made aware of the environmental problems caused by waste and the value of the material which they are working and handling.

Bruce McDonald and Mark Smithers (1996) revealed in their research report that there are two areas to be considered in C&D waste management. First is to minimize waste generation during the design and procurement phase of building contract and second is the development of on-site techniques for waste minimization.

The hand book published by Environment Authority in Australia, *techniques for reducing construction waste* (1998) revealed several strategies to minimize C&D waste. They are,

- Waste audit
- Waste minimization plan implementing and monitoring
- Management and training
- Site arrangement
- Contracts and purchasing

The first step in developing a waste minimization strategy is to undertake a waste audit to determine the base line for waste minimization plan. Audit those elements of all operations which generate waste such as resource acquisition, administration, commercial activity, construction or demolition. As part of audit

- Assess how the different components of your operation can contribute to waste minimization (eg. Through source reduction, waste avoidance and recycling)
- Identify the location of potential sources of waste material
- Undertake trials to establish benchmarks for waste produced by operational components (eg. Cost of disposal, volumes and weight)
- Identify waste minimization performance indicators
- Set up processes to monitor and audit performance indicators ensuring appropriate records are kept so that performance can be monitored and adjusted
- Explore the best available waste minimization techniques applicable to operations in your organization

Waste minimization plan implementing and monitoring will involve encouraging and promoting a waste minimization culture within the organization. To do this it needs to make a significant investment in establishing procedures, training, revamping contracts, promoting waste minimization, educating employees and subcontractors and monitoring and reporting on your progress. Once identify the waste minimization performance indicators and determined the logistical needs for introducing waste minimization measures, establish new organizational responsibilities for managing site waste minimization and appoint coordinators to oversee the process. A waste minimization plan to be prepared before the commencement of each project and some guide lines are as follows.

- Document the expected waste types on the project under current practices, estimated cost and method of waste collection and removal
- Set out steps to take to reduce those waste or keep them to a minimum, reuse/ recycle/ recover method, use recycled products, dispose of waste that cannot be reduced/ reused/ recycled
- Out line the members of the industry who can support to do this
- Develop waste minimization manuals to bring about the above actions
- Commit to operational targets for waste avoidance and minimization (promote competition between different parties of the organization or develop reward system or contest to achieve targets)
- Set realistic goals for waste minimization, recognizing existing barriers and developing strategies to overcome these barriers over time.
- Within the plan, adopt the following waste minimization measures for the project which are practical and cost effective
  1. order exact quantities of materials
  2. develop new purchasing arrangements with suppliers to minimize waste in acquiring resources and arrange them to take back
  3. incorporate recycled materials or products into project where recycled materials meet performance specifications
  4. find out markets for recyclable materials or recyclers willing to take recoverable waste
  5. provide collection facilities for recyclables on the site by installing clearly labeled containers
  6. confine all litter within the site boundaries and control run-off of sediment resulting from activities on the site
  7. sell, exchange or give away recyclable materials which cannot be used in the site
  8. develop new contractual arrangements with sub-contractors which require them to comply with organization's waste minimization plan and take responsibility for sorting, collection, removal and use of waste including packaging and protection materials
  9. dispose any waste that cannot be reused and recycled in accordance with the legislation, regulations and policies of local authorities

10. train project personnel and staff in the principles of waste minimization to ensure awareness and compliance with waste minimization practices
11. monitor and report by documenting the total volume and cost of actual waste removed or avoided at the site
12. investigate and implement innovative ways of dealing with site specific waste management problems

Above literature shows various practices followed by some countries for minimization of C&D waste. Most of them are very much related to Sri Lankan context. But some are very difficult to implement because some construction organizations in Sri Lanka are not up to the standards of developed countries.

2.2.3. JIT concept for waste reduction

About three decades ago, the idea for the JIT (Just In Time) concept was first mooted by Taiichi Ohno, former Executive Vice President of Toyota Motor Corporation (Lim and Low, 1992)

Low Sui Pheng and Stephanie K.L.Tan (1997) of National University in Singapore have done a case study of a private condominium project to check possibility of JIT implementation to reduce waste in construction projects. The JIT concept has been established in the manufacturing sector for many years, but the concept is relatively new for the construction industry.

The successful implementation of JIT is depending on supplier flexibility, user stability, total quality management and employee commitment plus team work. Through the elimination of waste, JIT aims to improve product quality and productivity. Waste is considered as non-value adding to an activity. In any operation, it compromises motion and work. However, only work is a value adding activity. Hence motion is regarded as a form of waste. Waste include over production of components and products, delays in materials and information, material transportation, unnecessary processing, excess stocks, unnecessary human activities and defects in materials and information. The six principles of JIT used to overcome the above problems are as follows.

1. Elimination of waste – The fundamental philosophy of JIT is to eliminate waste. Under the JIT concept, construction waste can be classified in to the following categories
    - Waste from over-production
    - Waste from delays

- Waste from transportation
- Waste from unnecessary processing
- Waste from excess inventory
- Waste from unnecessary motion
- Waste from defects

2. The KANBAN or pull system – Organizations produce on demand. Hence no over stock but only buffer stock has to be maintained.
3. Uninterrupted work flow – Rationalization and simplification of the production process are necessary.
4. Total Quality Control (TQC) – In order to achieve zero inventory, errors and defective components must be eliminated in each task. Total quality management (TQM) concern, JIT is a sub set of TQM which strives for continuous improvement. This improvement is achieved when the elimination of waste which does not add value to the process or activity.
5. Employee involvement – As noted earlier, the success of JIT implementation is depend on the great extent of team work and commitment of every employee.
6. Supplier relations – Building a good supplier – user relation is no longer a choice but a necessity. An organization must treat suppliers as long term business partners, so that the quality of materials delivered will always be maintained at a high standard. This would greatly reduce paper works, inventory levels and storage space.

Although JIT is a good concept in manufacturing, there are some draw backs when implementing in the construction industry in Sri Lanka. As an example,

- Roads are closed for few hours or few days due to security reasons – if materials are not received to the site, scheduled task may not be able to complete on time and hence progress will retard. Some times workers will idle and make money lose. Some times supplier has to find alternative roads to the site which are hardly accessible or greater distance to travel than estimated. Hence cost will be increased and required quantity will not be delivered. Some times alternative roads are not suitable to travel for long vehicles such as ready mixed concrete trucks.
- Scarcity of materials – There are some situations that supplier cannot cope up the demand because materials are not freely available or demand to meet customer call.

But there are some merits in implementing of JIT concept to the construction industry in Sri Lanka. As we know most of Colombo projects are very congested due to limited space and no sufficient space to stock materials. JIT is a more effective method for such situations. Ready mixed concreting is done under this concept. Required quantity of materials reached to the site on time in good quality will reduce C&D waste generation. Ultimate effect of the JIT is "Zero Inventory" if possible to maintain which gives much flexibility to the cash flow of the project. So JIT has both merits and de-merits in construction industry.

2.2.4. Reuse of waste

Reuse has been introduced as the second step of C&D waste management process by many authors. A significant portion of the C&D waste generated could be reused in construction sites but subjected to some constraints including tight time schedule, transport cost, operational cost etc.(Macozoma and Benting, 1999).

CIRIA (Construction Industry Research and Information Association) report for waste management described reuse of timber as follows

- Reuse of timber for shuttering
- Sell timber if possible
- Investigate any potential local users of waste timber – advertise in local papers
- Give it to local community groups to use as fire woods or any other means
- Investigate sending timber to wood processing plant for chipping

2.2.5. Recycle of waste

Recycling of C&D waste has gradually gained wide acceptance in developed countries due to

- Increased awareness of the public and industries about limited natural resources available
- Scarcity of land for developments
- Environmental implications of C&D waste
- Government support
- Realization of C&D waste recycling is an untapped market

The environment concerns that go along with construction waste recycling is noise and dust generating. Location of the plant must be away from residential areas and noise barriers must be erected where necessary. Dust collectors also have to be provided.

Recycled materials can be used as a raw material to produce some other construction components but due to many reasons it is very difficult to develop a market.

Evia O.W. Wong and Robin C.P (2004) revealed in their research done in Hong Kong, most of customers are reluctant to purchase recycled raw materials due to following reasons

- Higher price (44%)
- Lower quality (15%)
- Quality is not reliable (4%)
- Limited choices in market (17%)
- Not up to the standard (10%)
- Supply is not stable (10%)

As described above, price is the main factor to be considered in marketing of recycled products. In this case government support is needed to reduce prices by providing necessary capital on machineries, infrastructure and technology. But quality improvement has to be done within the scheme.

Pedrozo (2000), Dep. of Civil Engineering in Brazil has done a technical viability study to check the ability of use recycled materials for concrete production and he concluded that recycled materials can be used with a reasonable quality. This material can be considered as a viable alternative to minimize natural resources use and to improve lifetime of disposal sites.

Standards have to be updated to maintain the quality of recycled materials or products. Some countries have amended existing specifications and standards to accommodate the use of recycled materials in construction. In some cases, new specifications have been prepared.

Eg. BS 6543: the use of industrial by products and waste materials in buildings and civil engineering.

ASTM C33-82: Standard specification for concrete aggregate

Department of Transport in U.K. has included in its "Specification for Highway Works" the use of crushed concrete as granular fill for a wide range of applications including drainage works, earthworks and road base and sub-base materials(Mulheron,1988)

In Japan, in order to promote the use of recycled construction waste, recently enacted legislation to use recyclable resources to the extent technically and economically possible (Clean Japan Centre, 1991).

While maintaining the quality of recycled materials, it is necessary to look for marketable products or any other usage.

The research done by Federal University of Bahia, Brazil (2002) regarding recycling of C&D waste, revealed 3 methods of usage of recycled C&D wastes

1. Production of *soil-cement* bricks using processed debris – The use of processed debris to produce bricks with soil-cement is clearly a good alternative solution for environmental problems and it also has the benefit of producing a low cost construction material.
2. Application of processed debris in base and sub-base of roads – This kind of recycling requires very simple technology and it uses large amounts of materials.
3. Production of mortar and concrete using additions of processed debris – The equipment crushes the debris so that it can be used as aggregates in the production of mortar and non-structural concrete.

Concrete is the most important item to be recycled and CIRIA report has described four steps to recycle waste concrete

1. Crushing of concrete – Different type of crushers produce different grade of materials.
2. Before demolishing a concrete structure in a building remove any internal furnishings and fittings to avoid contaminate with crushed concrete
3. Store concrete waste in a designated place and make sure every one knows that nothing else should be dumped there
4. Segregate the concrete waste. Keep it separate from masonry, timber and other wastes.

Lawrance(2001), Senior Manager of Tri-mix Pte Ltd in Singapore has revealed that 2-3% of ready mix concrete is identified as waste out of total concrete production. Recycling plant has been installed in their premises to recycle waste concrete and reuse them for concreting. Thus they save lot of money and run the plant in environmental friendly.

Poon C.S.(1996) of Hong Kong Polytechnic University has mentioned in his report, simple plants such as hydraulic hammers and backhoes are needed for crushing of C&D waste other than the sorting procedures. He has emphasized to have short term and long term plans to manage C&D waste as follows,

- Government should in collaboration with the construction industry, set up intermediate waste sorting plants and the sorted waste can be used as fill materials at public disposal sites.
- Suitable provisions should be included in Government funded projects to specify on-site sorting of waste
- Appropriate legislation should be developed to control the disposal of demolition waste
- A suitable charging scheme should be introduced for waste disposal at landfills
- Specific clauses should be incorporated into the government's general conditions of contract to specify the disposal arrangement of demolition waste
- Government departments, especially the works departments should conduct evaluation of the reuse of recycled aggregates.

Above discussed all C&D waste management methods such as reduction, reuse, recycling etc are to be included in a plan to implement in project level. This waste management plan has several factors to be considered and responsibilities of different parties.

2.2.6. Waste Management Plan

Williams R Mincks (1994) revealed basic elements of waste management plan in his report of "construction contractor's waste management plan". Those are

- Analysis of the project –The first step is to analyze type, amount and timing of the construction waste.
- Plan for the project – Statement of the objectives of the waste management program which contains the strategies and methods for disposing of the waste on the construction projects. It is the statement of the intent of the contractor prior to start of the project. The actual waste management plan as a custom prepared document for the use of the contractor and to submit to the owner, municipality or the regulatory agency. The plan should be a job

related, easy to understand. Goals and objectives of waste management plan of the project are very important. One of the goals is to reduce the waste. An officer should be appointed to implement and monitor the plan.

- Implementation/ Record keeping - As the project progress, the plan needs to be implemented, monitored and shortcomings are to be identified. Like any plan, this plan needs to be flexible, recognizing changes and emerging technologies and methods. New technologies are constantly being developed and applied possibly providing more attractive disposal opportunities. The contractor should be encouraged to explore and use these new alternatives. Some of important facts to be included in the records are description of materials, disposal alternatives, landfill, recycling, amount of waste, date removed from job site, tipping fees, mileage etc.
- Cost tracking/ control – As the plan is implemented, continual cost monitoring and control should be applied to waste management activities as for any construction activity.
- Post project evaluation – Compilation data from the project is helpful in establishing the plan for the next project. The owner and municipality may want a final report indicating their goals were met with the project.

But Spivey (1974) gave a different view on C&D waste management plan. He was among the first construction engineers to see the need for construction waste management systems. He was a pioneer in helping to develop the construction waste management practices. Spivey devised the following four step planning procedure to assist in "optimal disposal".

1. Evaluate the composition and estimate the volume of solid wastes that will be generated(including demolished structures)
2. Determine recycle potential(volume, market, cost and return)
3. Evaluate disposal options available(recycle, burial and incineration)
4. Match disposal options to volume and composition of waste considering economy, environmental protection and resource depletion

Most of above described factors could help in preparation of waste management plan to construction industry in Sri Lanka. There are some responsible parties in the industry for the implementation of waste management plan.

CIRIA report has given Project Manager's Role in waste management as follows

- Co-ordinate 3R initiatives on site
- Gather data about waste on site, keep accurate records on site movement on and off site
- Ensure all site personnel know their responsibilities for site waste management
- Take responsibility for making sure that all waste storage containers are accurately labeled to show site people where to drop specific materials
- Obtain a list of potential buyers/sellers of used or recycled materials in the location of the site. Share this information with your colleagues.
- Encourage all site personnel to use their initiative to come up with ideas of how to reduce, reuse and recycle waste. Set up an "Idea board" where people can record their suggestions for 3R
- Wherever possible try to reuse and recycle waste you have on site before ordering materials
- Inform designers so that waste can be reused and recycled on this site or another site.
- Inform suppliers to take away their own packaging

Above sub-chapter described the C&D waste management practices in some developed countries and most of them are very much useful in developing a "Best practice" for construction industry in Sri Lanka. But it is necessary to study the existing C&D waste management practices in Sri Lanka too.

2.3 C&D waste management practices in Sri Lanka

A.K.W.Jayawardana (1992) has done a research on waste generation of construction projects in Sri Lanka. Construction waste is a common problem in our sites but overnight reduction of wastage is impossible due to various problems and constraints that are present within and outside the construction organizations. He has quoted few reasons for waste in site as follows

- Difficulty in changing wrong attitudes of workers such as lack of job consciousness, lack of motivation, lack of care and indifference which result in complete negligence of waste
- Lack of resources to seriously study the problems, evaluate causes and take remedial measures

- The priority is to complete the project on time and win more projects and no time is available for any waste or cost control. Evaluation is done at the end of project which makes it impossible to monitor the project.

He has observed following wastage of construction items as percentage.

Table 2.3.1 - Wastage on Building Construction Sites (Jayawardane,1992)

Method of wastage	**By**	**Mean %**	**Max %**
Cement wastage during storage	Volume	Not significant	
Cement wastage during handling	Volume	2.9	53.1
Sand wastage during storage	Volume	4.7	44.6
Sand wastage during handling & transport	Volume	4.6	50.0
Combined wastage of sand	Volume	9.3	50.0
Metal wastage during storage	Volume	1.5	20.0
Metal wastage during handling and transport	Volume	3.5	23.1
Combined wastage of metal	Volume	4.9	23.1
Wastage of mortar during transport(using pans)	Volume	2.7	22.1
Wastage of mortar during transport(using wheel Barrows)	Volume	5.2	24.9
Wastage of mortar during transport(using pans shovels)	Volume	4.7	8.3
Wastage of mortar during placing (direct labour)	Volume	6.0	23.9
Wastage of mortar during placing (sub contractor)	Volume	8.3	44.3
Wastage of mortar due to excess thrown away	Volume	3.5	24.9
Wastage of concrete during transport	Volume	2.6	10.2
Wastage of concrete during placing	Volume	2.2	9.1
Wastage of concrete due to excess thrown away	Volume	3.5	23.2
Wastage of bricks during transport and handling	Volume	4.3	52.6
Wastage of bricks during placing	Volume	1.8	20.8
Combined wastage of bricks	Volume	6.1	52.6

According to the figures in above table 2.3.1, it gives clear idea about causes for waste and opportunity for waste reduction in work sites. But the figures given in Max % column are debatable because if any project exists such a big wastage, it would not be profitable.

He has proposed several methods to reduce waste on sites

1. Awareness programs to site staff and workers
2. Bricks and tiles to make standard sizes or design to market available sizes
3. Proper site management, stores management and plant management
4. Introduce bonus system for reduce waste and penalties for people who increase waste
5. Reduction of wastage be considered when negotiating terms with subcontractors
6. Use trained people on sites instead of unskill people. Rules and regulations to impose to control it.
7. Proper material reconciliation system to monitor day by day.
8. Material management, project control, project monitoring tools to be implemented in sites
9. Consultants should be educated to make clear specification of materials and components. Any reject concrete or ready mix to use some other purpose which is not structurally important
10. Prefabricated items to use at sites as much as possible such as pre-cast panels, fabricated structures etc.

Rameezdeen (2007) carried out a research on material wastage in Sri Lankan construction sites and table 2.3.2 indicates some of common materials tend to waste and its percentage by volume.

Table 2.3.2 – Material wastage in Sri Lankan projects (Rameezdeen, 2007)

Material	Waste as a percentage by volume
Sand	25
Lime	20
Cement	14
Bricks	14
Ceramic tiles	10
Timber(form work)	10
Rubble	7
Steel (reinforcement)	7
Cement blocks	6
Paint	5
Asbestos sheets	3

This results shows that material wastage is accountable and precautions have to be taken to reduce waste at site level. Waste percentages are calculated as follows.

Material waste quantity = Store records - Actual material requirement

$$\text{Material Wastage (\%)} = \frac{(\text{Store records - Actual material requirement})}{\text{Actual material requirement}} \times 100$$

Asela Kuluppuarachchi (2006) undergraduate of Open University of Sri Lanka has revealed in his research report that nearly 500 buildings are constructed in Colombo in a year and 250 MT of C&D waste generated and most of them are used for land fills.

The main disposal method of C&D waste in Sri Lanka is landfills and no other specific methods in C&D waste management such as reduce, reuse, recycle followed by the most of industry personnel.

2.4 Summary

Literature studies revealed that C&D waste is a real problem in the construction industry in all over the world and it averaged to 20 – 30% of total waste. Various researches done by various organizations to identify the causes for waste, method for waste minimization, reuse of waste, recycling of waste and finally to develop a waste management plan.

Several causes for waste are described in some literatures which are more applicable to Sri Lankan context. Waste minimization can be done in pre-construction stage and during construction. JIT concept in material procurement is identified as one of latest method for waste reduction.

Heavy equipments are used by developed countries to recycle C&D waste and by-products are used to produce minor construction items. Standards and specifications have been developed by some countries as to motivate recycling of waste and use them as raw materials for other constructions.

Waste management plan basically consists of waste reduce, reuse, recycle and disposal (landfill). Waste auditing, monitoring, people awareness and people training are important factors in developing a waste management plan.