

**CONTRACTUAL OBLIGATIONS ANALYSIS FOR CONSTRUCTION WASTE  
MANAGEMENT**

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR  
THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

The College of Graduate Studies  
(Civil Engineering)

THE UNIVERSITY OF BRITISH COLUMBIA  
(Okanagan)

August 2011

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## **ABSTRACT**

Construction industry creates a massive amount of waste which typically ends in landfills. Canadian construction industry generates 25% of the total municipal solid waste deposited in landfills. Construction and demolition (C&D) waste has created negative socioeconomic and environmental impacts including ground water contamination which accumulates toxicity to human/animal food chain, emission of greenhouse gases, and adding more to scarce landfills. Literature cited that construction waste can be generated due to deficiencies and loopholes of contract documents. Current research noted several clauses in the project manuals of commercial construction, which have potentials to generate construction waste during the project construction phase. Those clauses were categorised in to eight major areas. This research is intended to (1) analyse expert opinions collected through a questionnaire survey, (2) analyze on-site observations on waste generation in construction projects due to pre-identified contractual clauses, (3) evaluate contractual clauses of Canadian, American and Australian contractual agreements in terms of the potential for generating construction waste and (4) introduce suggestions for better contractual agreements to minimize/avoid construction waste. Analytical Hierarchy Process (AHP) and Attribute Weighing Method (AWM) were utilized to evaluate and prioritize the expert opinions on contractual clauses in terms of waste generating potential. It was found that the clauses related to quality, workmanship, and field quality control / inspection have the most potential to generate construction waste.

## **PREFACE**

A version of Chapter 3, 4 and 6 (conference paper) in this thesis has been published in CSCE 2011. The full version of Chapter 3, 4 and part of chapter 6 has been submitted to the Canadian Journal of Civil Engineering as a journal article titled “Contractual Obligations Analysis for Construction Waste Management in Canada”. The paper was written by Daylath Mendis under the supervision of Dr. Kasun Hewage. A journal article based on Comparative Studies of Contract Document (Chapter 5) is under preparation. This project was approved by the Behavioural Research Ethics Board Okanagan under the minimal risk amendment (UBC BREB NUMBER: H10-01000).

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## **ABBREVIATIONS**

ACSIM	The Army Assistant Chief of Staff for Installations Management
A/E	Architectural and Engineering
AIA	American Institute of Architect
AHP	Analytic Hierarchy Process
AS	Australian Standard
AWM	Attribute Weighing Method
BDC	Building Deconstruction Consortium
BMRA	The Building Materials Reuse Association
Ca.G.B.C	Canada Green Building Council
CCA	Canadian Construction Association
CCDC	Canadian Construction Documents Committee
CCA	Chromated Copper Arsenate
C&D	Construction & Demolition
CI	Construction Initiative
CMRA	The Construction Materials Recycling Association
CR	Consistency Ratio
CRD	Construction, Renovation and Demolition
CSC	Construction Specifications Canada
COTR	Contracting Officer's Technical Representative
CQC	Contractor's Quality Control

DCP	Development Control Plan
DMM	Decision Making Model
EPTOX	Extraction Procedure Toxicity Method
GC	General Conditions of Contract
HVAC	Heating, Ventilation, and Air-Conditioning
HP	High Potential Clauses
HUD	US Department of Housing and Urban Development
ICI	Industrial, Commercial & Institutional
LEED	Leadership in Energy and Environmental Design
LP	Low Potential Clauses
MBAWA	Master Builders Association of Western Australia
MEP	Multiple Extraction Procedure
MOE	Ministry of the Environment
NSERC	National Sciences and Engineering Research Council of Canada
NB	Net Benefits
NSW	New South Wales
O/T	Over Time
PCBs	Polychlorinated Biphenyls
PCM	Pairwise Comparison Matrix
SCD	Standard Construction Document
SPLP	Synthetic Precipitation Leaching Procedure
TB	Total Benefits
TC	Total Cost

TCLP	Toxicity Characteristic Leaching Procedure
USEPA	United States Environmental Protection Agency
WET	Waste Extraction Test
WMP	Waste Management Plan

## LIST OF SYMBOLS

B1	Purchasing price of new materials
B2	Transportation cost of new materials
B3	Cost of landfill to dump /recycle facilities the old materials
B4	Cost of labour
B5	Benefit of having well written contract document
B6	Benefit of reducing vehicle pollution
B7	Benefit of avoiding traffic congestion
B8	Benefits of avoiding road crashes
B9	Fuel externalities
B10	Reduced roadway cost
B11	Noise pollution
B12	Global warming cost
B13	Tipping fee & leachate, gas and monitoring costs
B14	Property depreciation, landfill site, adjacent properties
C1	Quality clauses
C2	Substitution clauses
C3	Workmanship clauses
C4	Geotechnical report clauses
C5	Submittals/Shop drawings clauses
C6	Field quality control/Inspection clauses
C7	Shop finishes clauses

C8	Temporary or trial usage/testing clauses
CO1	Cost of consultancy fee (legal fee) for removing, changing and adding clauses
CO2	Cost of delays while implementing new contract language
CO3	Cost of employing additional professionals to inspect frequent design changes, coordinate stakeholders to check the changes before construction starts
CO4	Cost of learning curve effects
D1	Extra to contract amount
D2	Cost of additional staff to achieve the work (site staff)
D3	Cost of architectural and engineering staff
D4	Cost of temporary protection
D5	Overtime premium
D6	Heat and equipment
D7	Cost of fuel
Kg	Kilogram
Km	Kilometer
Pb	Lead
Veh	Vehicle
W	Weights

## ACKNOWLEDGEMENTS

I would like to thank everyone who has contributed to my thesis and related studies. I want to express my sincere appreciation particularly to the following individuals.

First of all, I would like to express my heartfelt gratitude to the driving force behind my research – my supervisor, Dr. Kasun Hewage. I am reflecting, with enormous respect and admiration, on your immeasurable guidance, wisdom, inspiration and motivation that influenced my career. I thank you wholeheartedly for your generosity with your time and energy and your unselfish deeds on my behalf. I am forever grateful for the support, leadership, communication, public relations, and teamwork training provided during my career at the University of British Columbia.

To my committee members, Dr. Rehan Sadiq and Dr. Shahria Alam in the School of Engineering at the University of British Columbia/ Okanagan, for their helpful comments and inputs, I am especially grateful.

I would like to express my heartfelt gratitude to my friends Gamini Balasuriya and Anupama Gannoruwa. Without their commitment, a master's degree would have not been possible.

I would like to pay my heartiest gratitude to Mr. Phil Long, Senior Project Manager at Stuart Olson Dominion Construction, for his support as he was an integral part of this research.

I would also like to thank Ms. Joanna Wrzesniewski, Barrister and Solicitor, for her valuable positive feedback on my research which helped to increase the certitude on the legal prospective of my research.



I would like to acknowledge the contributions of the following associations and individuals whose contributions have significantly shaped the content of this thesis: Ms. Bridget Rivera (Manager, Contract Documents Marketing Education – American Institute of Architect), Mr. Salinda Perera (New South Wales Government of Australia), Mr. Jason Mallhi (Senior Project Coordinator, Stuart Olson Dominion Construction, Canada), Mr. David Roche, (Development Manager, UBC Properties Trust), Mr. Lorne Antle (Project Manager, UBC Properties Trust ), Mr. Paul Krzywicki (Project Manager, Yellowridge Construction Ltd., Canada). Mr. Mike McLean, Director and Mr. Charles Anderson, Contracts & Administration Manager (The Master Builders Association of Western Australia), Ms. Jodie Law (Secretary, Housing, Legal & Contracts - Queensland Master Builders Association, Australia), and Mr. Zack Watkins (Chief Estimator, Ledcor Construction Limited, Canada).

Last, but not least, I greatly acknowledge the invaluable support of my wife, Chamalee and my beloved children, Dinushika and Omindee.

**Dedication**

**to**

**My wife, Chamalee, and beloved children, Dinushika and Omindee**

# **1 INTRODUCTION**

## **1.1 Background**

Almost all industries in Canada have been influenced by strict environmental regulations. Changes are being done to the operational strategies and methods of these industries due to government regulations and public concerns, the Canadian construction industry is not an exception. The Canadian construction industry is a large contributor to waste material in landfills. As a reality today, landfills are rapidly approaching their capacity and most of them have been closed since they do not meet necessary environmental standards. As a result, the cost of disposing waste is rising. In highly populated areas, replacing landfills is difficult due to public anxiety over social and environmental impacts (The Canadian Construction Association, 1992).

Jergeas & Hartman (1996) reported that the construction industry is known to have set up procedures for administrating contract documents including technical specifications and drawings. Usually, the general contractor is asked to submit a bid to the owner for executing the construction work. The success or failure of this procedure is mainly depended on the skills of design professionals and other experts. These experts have to diligently communicate the design concepts and owner's ideas to the contractors. Generally, owner's ideas are communicated to contractors through contract clauses mentioned in the bid and contract documents. Poorly written and ambiguous contract documents have a tendency for misinterpretation by the project stakeholders.

Limited research related to the contractual clauses and its impact on construction waste have been reported in the literature review. This research project reviewed over two hundred project contract documents and specifications in commercial construction in Canada, United States of America, and Australia. It was noted that Australian contractual agreements deviate from that of the North American, since several contractual clauses in Australian contract documents have justifiably transferred the responsibility to the consultant/owner and have exempted the contractor liability.

For example:

(1) .....where the Owner provides the Drawings and Specification, the Owner expressly warrants that the said Drawings and Specification are accurate in each and every particular.....

(Master Builders Association of Western Australia: Cost Plus Contract 2007),

(2)..... Should it appear in excavating for footings and/or services that the site will not support the Works as designed, then the Contract may be terminated without liability.....((Master Builders Association of Western Australia; Medium Works Contract – 2007).

It is clearly noted that the organization which prepares the contractual documents, tried to transfer more risk to the other parties. This can be clearly justified by observing the contractual agreements made by the New South Wales Government of Australia, which represents mostly the owner; and Queensland Master Builders Association of Australia, which represents mostly the contractor. It is evident that the potential to create construction waste highly depended on the degree of risk transfer through contractual clauses. The party who transfers risks to another party does not generally consider the possibility of creating construction waste due to certain biased contractual clauses.

While literature cited the risk transfer, ambiguity and disputes of the contractual agreements, there is a potential to create construction waste due to the above mentioned deficiencies and ambiguity/vagueness of the contract documents.

It was noted that several clauses in the technical specification and general conditions of construction contracts have negative impacts on generating construction waste. Further, several incidents of waste generation due to certain contractual clauses were noted during the professional practice and on-site observations.

## **1.2 Major Issues**

Following are the specific research questions emerged in this project.

- a) How to identify the types of waste as per each trade in a construction projects?
- b) What are the sources, stages, or areas of the construction process that generate construction waste?
- c) Are any of these wastes generated due to deficiencies in contract documents?
- d) Is it possible to amend the Canadian contract documents to avoid potential construction wastes?

## **1.3 Research Objectives and Approach**

The overall objective of this research project is to suggest amendments, deletions, and additions to the standard Canadian contract documents to minimize/avoid construction waste in commercial construction projects.

Following are specific objectives of these results:

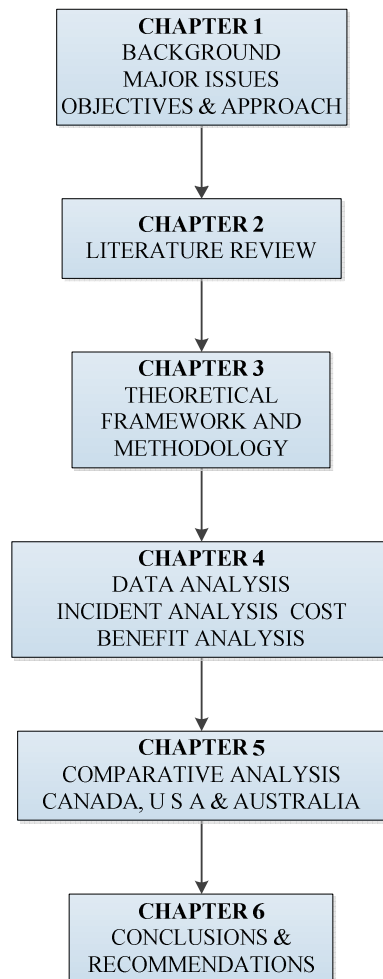
- a) Identify the potential contractual clauses, which could generate waste, from the standard contractual documents.

- b) Compare the contractual agreements from other countries with the Canadian contracts in order to identify state of the art practices to reduce construction waste.
- c) Provide a set of recommendations to avoid/minimize waste in each identified clause of contract documents.

A comprehensive literature review was conducted to be familiar with the clauses in contract agreements of different parts of the world. Construction field observations, interviews, and questionnaire surveys were used as the other main research tools in this research project.

### 1.4 Thesis Organization

This thesis consists of six chapters with the following contents:



**Figure 1.1:** Thesis organization

## **2 LITERATURE REVIEW**

Literature review encompasses issues related to contractual agreements related factors such as design, constructability, planning and controlling etc. It also briefly highlights environmental issues related to construction waste. Finally, waste management practices, type of waste, waste management initiatives and current drives related to Canada, United States of America and Australia are discussed.

### **2.1 Construction Waste and Contractual Agreements**

Construction projects turned out to be more complex and required more sophisticated contract documents as owners stipulated large-scale projects with higher venture value in today's globalized market. Contractual clauses are required to avoid ambiguity of the contractual agreements (Hibberd and Newman, 1999). Appearance of disputes can have noteworthy impacts on the accomplishment of the work and on contractual parties. (Semple et al., 1994; Cheung, 1999)

Companies consult lawyers in the contract preparation stage (Michel, 1998). Implied terms in contracts can cause conflict or dispute due to misinterpretation in the contract document (Eggleston, 2004). Some contracts can create frequent disputes (Fenn et al., 1997). To avoid construction claims and disputes, good understanding of the contractual terms is required (Semple et al., 1994). Personal judgment which is intended to resolve disputes can be a risk for the project. Terms like "to the satisfaction of architect/contract administrator/engineer" are examples for this type of provisions (Riches and Dancaster, 2004). Proper interpretation of contractual documents is vital to avoid misunderstanding (Eggleston, 2004). The interpretation

of contract language can cause difference of opinion (Dilts, 2005). Unfair risk allocations in the clauses can create disputes (Powell-Smith and Sims, 1990; Bosche, 1978; Vidogah and Ndekugri, 1997; Loosemore, 1999). Loosemore (1999) stressed the importance of minimizing the risk of dispute.

Hartman et al. (1998) conducted a survey to study risk allocation and risk dispersion of seventeen contractual clauses in the Canadian Construction Document Committee 2 (1982) document. The survey resulted in two key findings; i.e. (1) if the contractors and owners disagree with each other regarding a contractual clause, a well understood standard contractual clause will resolve the problem. (2) In the case of disparity, circumstances on a particular project should be determined. In the case of large disparity, discussion should be conducted before signing the contract.

As per Jergeas & Hartman (1996), owners are inclined to contractually transfer responsibility for numerous project risks to the contractors through disclaimer clauses. To cover such risks, contractors add extra premiums for their bid prices. Thus the bid pricing turns out to be inflated.

Jergeas (1995) presented two examples of disclaimer clauses used in Canadian contract documents which include:

(1) “....., the contractor shall not have any claim for compensation for damages against the owner for any stoppage or delay from any cause whatsoever.”

This clause is written to stop the contractor for claiming any compensation from delays originated by owner or owner’s representatives by whatever proceedings.

(2) “The bidder is required to investigate and satisfy himself of everything and every condition affecting the work to be performed and the labour and material to be provided, and it is



mutually agreed that submission of bid shall be conclusive evidence that the bidder has made such an investigation.”

This clause is written to avoid the contractor from claiming unforeseen events such as adverse soil conditions. In this situation, the owner transfers the burden of both site and sub-soil investigation to the contractor’s side.

## **2.2 Construction Waste and Pre-Construction Stage**

Ekanayake and Ofori (2004) reported that errors and incomplete contract documents at the commencement of a project contribute to construction waste. Gavilan & Bernold (1994) identified design and detailing errors and design changes as significant sources of creating construction waste. Faniran and Caban (1998) ranked design and detailing errors as the number one source for generating construction waste. In addition, Poon (2007) noted that the last minute design changes to satisfy the client requirements cause demolition of new construction, which creates Construction & Demolition (C&D) waste. To minimize this problem, design concepts should be finalized as much as possible during the early project stages.

Bossaink and Brouwers (1996) found that the limited knowledge of construction and constructability during the project design stage, is the main reason for waste generation. These researchers also mentioned several other ways that can cause construction waste, such as errors in contract documents, starting construction with incomplete documents, design changes during construction, designer unfamiliarity of products, and problems with specifications related to the quality. Osmani et al. (2007) reported two main contributing factors for construction waste: (1) the waste minimization is not a priority requirement during the project design stage, although initial design decisions contribute to one third of the construction waste, and (2) lack of interest from the clients’ side in waste minimization.

Ekanayake and Ofori (2000) found that avoiding waste in the designing stage is the best way to address the problem. They further said, design errors and related problems create significant amount of waste and the field construction professionals have minimal control over it. Ekanayake and Ofori (2000) ranked designers' inexperience, design during the project construction stage, lack of data to determine construction methods, and inadequate knowledge of sequence of construction activities, as the most important factors for construction waste. Appropriate clients' project procurement systems, based on contractors' input on activity sequence, should be promoted to help the decision making process during the design stage, to avoid unnecessary extra and re-work during the construction stage. Contractors must be well informed about feasible cost savings in reducing construction waste and the adverse effects of construction waste on the environment. Project clients should also be convinced on advantages of waste minimization and environmental protection (Ekanayake and Ofori, 2000).

### **2.3 Construction Waste and Site Waste Minimization Strategies**

In a recent, study Ekanayake and Ofori (2004) reported waste minimization strategies at construction site can be divided into two categories: (1) planning and (2) controlling. Planning strategies is the best practice to minimize waste and these include procure material, design, construction scheduling, and site layout. Controlling strategies include delivery and handling of materials, security, storage waste accounting, recordkeeping, safety, education, and maintenance of machinery. Proper management of materials plays a major role in site waste reduction (Ekanayake and Ofori, 2004).

### **2.4 Construction Waste and Environmental Issues**

Yahya and Boussabaine (2006) stated that construction waste has a considerable impact on the environment and construction can be introduced as one of the main environmental

polluters. Measurement of the sustainability of construction activities is vital. Guthrie et al. (1999) mentioned the possibilities of enormous environmental and economic benefits of minimizing construction waste. Tam et al. (2006) demonstrated that resource depletion, land use, various waste generating activities, environmental pollution, and land deterioration are the main factors affecting the sustainable environment. Mills et al. (1999) mentioned that although the construction industry is a major generator of avoidable waste, it has been slow to adopt environmental friendly practices. Poon et al. (2001) stated that the timing is the contractors' top priority and they naturally tend to complete the project within the shortest time rather than paying attention to the environment. Teo and Loosemore (2001) stated that the modern developments, resources exhaustion, increasing pollution level, global warming, and population growth have become alarming factors for educated public and legislative to bring construction industry to an environmental responsible position.

However, Mills et al. (1999) noted, that landfilling has shown to be an easy and cheap solution to its extravagant practices. Peng et al. (1997) found that many strategies to minimize C&D waste have been already proposed and those range from recycling waste, reducing waste at the source, and reusing. Snook et al. (1995) mentioned that the economic benefits of construction waste minimization and recycling as selling of waste materials and reduction in removal cost to landfills. Lam (1997) stated that waste minimization and recycling increase the competitiveness of the contractors bid and improve the public image. However, very few contractors act in environmental friendly manner and use recycled construction materials. Boonie et al. (2010) demonstrated that the C&D debris diversion from landfills is an achievable goal and it is beneficial from the sustainable point of view. During the demolishing process, C&D materials and secondary products can be recycled and reused with effective planning and technologies. This diversion of

C&D products from the landfills will have great positive impacts on sustainable future including energy production, virgin material extraction, and reduced global warming (Boonie et al., 2010).

Table 3.1 shows advantages of diverting waste from landfills with respect to the triple bottom lines of sustainability – i.e. economic, environmental, and social.

**Table 2.1:** Advantages of diverting waste from landfills: Federation of Canadian Municipalities (2009)

<b>ECONOMIC BENEFITS</b>	<b>ENVIRONMENTAL BENEFITS</b>	<b>SOCIAL BENEFITS</b>
Stop building new landfills	Less energy usage than virgin materials.	Improved quality of life in adjacent communities.
Reduced cost of transportation for remote landfill sites.	Reduction of greenhouse gases and toxic substances generation in landfills.	Reduced pollutants and improved health.
Fewer numbers of landfill sites.	Reduced incineration activities.	Sustainable behaviour of built environment.
Creating more jobs with recycling process.	More land for agricultural and resources conservation.	

Hirshfeld et al. (1992) estimated that tipping fee, leachate, gas and monitoring costs, property depreciation, opportunity cost of landfill site and opportunity cost of adjacent properties add up to \$ 66.40 per ton of solid construction waste.

Guerrero et al. (2009) stated that the construction site and environs are mainly affected due to construction activities. These impacts can be negatively impact to soil, groundwater, and air. Groundwater and surface water may be polluted by runoff and infiltration. Soil also can be affected with pollutants by leaving waste on the ground. Using wood as a packaging material can harm the natural forests which are already scarce (Guerrero et al., 2009).

Wadanambi et al. (2008) conducted extensive experiments to test lead (Pb) contents of the leachates of municipal solid waste landfills. The toxicity characteristic leaching procedure

(TCLP) and the synthetic precipitation leaching procedure (SPLP) were adopted. The test was conducted for samples taken from municipal waste management landfills. The test results were in the range of 8.3 mg/L to 20.6 mg/L of Pb and these values exceeded the maximum allowable limit (5 mg/L). This research provided evidence to prove that construction waste leaches toxic chemicals into landfills.

Anderson et al. (2001) have conducted an ecotoxicological risk assessment for concrete with admixtures. Admixtures with thiocyanate and resin acids were subjected to the study. Thiocyanate leaching was tested by ion chromatography and resin acid leaching was examined by solid-phase extraction. The study revealed the emission rate of these two chemicals in a landfill environment. Thiocyanate is a toxic chemical which has acute and chronic effects. Resin acid is subjected to bioaccumulation in aquatic organisms.

Townsend et al. (2004) conducted standard experiments to determine the leaching of arsenic, chromium, and copper in chromated copper arsenate (CCA) treated wood from construction debris. TCLP, SPLP, extraction procedure toxicity method (EPTOX), waste extraction test (WET) and multiple extraction procedures (MEP) were performed. The test results from regular municipal waste landfill and construction debris were compared. WET gave a higher metal content from construction debris and other tests gave the similar results (arsenic concentration is five times higher than the TCLP and copper and chromium concentrations are ten times higher than the TCLP). Eleven of thirteen samples gave test results for arsenic exceeding TCLP threshold value (5 mg/L) published by United States Environmental Protection Agency (USEPA).

## **2.5 Construction, Renovation and Demolition (CRD) Waste: Canadian Provincial and Municipal Regulations**

The construction waste management sector is regulated by provincial and municipal regulations. Construction and demolition materials account for a large percentage of the waste stream. There are regulations imposed in some parts of Canada to avert these materials from landfills and stop dumping illegally. Municipalities often manage or control CRD waste management practices at the municipal level. Many municipalities all over Canada have by-laws in place outlawing the landfilling of specific CRD material (e.g. drywall etc.). The requirements change by location across the country (Public Works and Government Services Canada, 2011).

### **2.5.1 Municipal By-laws**

Municipalities which operate municipal landfills decide what materials can be landfilled and what by-laws and regulations need to be enforced. The municipal requirements regarding landfill bans should be checked prior to each project. The project team should confirm that disposal companies remove the materials to permitted facilities (Public Works and Government Services Canada, 2011).

### **2.5.2 Rules and Regulations**

As a goal, the Canadian Council of Ministers of the Environment adopted the reduction of wastes in Canada by 50% by the year 2000 in October 1989. As an accomplishment, National Packaging Protocol broadcasted in April 1990 to reduce the waste from packaging by 50 % by the year 2000. Packaging contributes for 30% of the waste stream and represents the main single element in landfills. Dedicated to meeting the 50% reduction target, the federal government, in collaboration with provincial and territorial governments, the private sector and community

groups, promote the Rs of waste management. The federal government has also undertaken the following steps (The Canadian Construction Association, 1992):

- By 1993, establish standards and regulations to reduce waste from packaging materials. They will be employed in the event that voluntary government and industry actions do not achieve the 1992 waste reduction target of 20% as set out in National Packaging Protocol
- By 1994, for other components of the waste stream, develop national standards, codes, policies and regulations for
- Support technological innovations aimed at waste reduction, recycling and reuse
- Support community action through an expansion of the Environmental Partners Fund Program
- Provide information to individuals and business through new programs such as the Canadian Environmental Citizenship Program and ongoing programs such as the Environmental Choice Program
- Commit the federal government to reduce waste from its own operations by 50% by the year 2000
- Expand the National Waste Exchange Program with the objective of making it self-sufficient by the year 2000. The purpose of the program is to improve market opportunities for the reuse and recycling of industrial and large volume wastes
- Establish an Office of Waste Management to co-ordinate federal programs under the National Waste Reduction Plan with participation from the provinces, territories, businesses, non-government groups and women's organizations. This office will also provide national coordination and issue regular progress reports.

The government take further action to lessen the generation of hazardous wastes and guarantee the safe transportation and disposal of hazardous wastes in Canada. These actions will include:

- By 1992, developing a computerized tracking system to monitor the movement of hazardous wastes in and out of Canada, which will allow Canadian industry to participate more easily in international market opportunities to recycle these products
- By 1996, destroying all Polychlorinated Biphenyls(PCBs) under federal jurisdiction and establishing mobile incinerators in Atlantic Canada, Quebec and Ontario
- By 1996, in co-operation with the provinces, completing regulations and guidelines for the safe management of hazardous waste streams, including reduction, reuse, recovery, recycling, transportation, storage and disposal
- Supporting technology aimed at reducing, recycling and reusing hazardous wastes, or their safe destruction

### **2.5.3 Provincial Initiatives**

Some provinces have also taken special actions to fast-track waste reduction in their own jurisdictions. The following contains examples of some initiatives started by the provinces:

- Develop markets for recyclables
- Make information available on the costs of establishing and operating a recycling business and on market information
- Encourage industry, municipal governments, institutions and others to implement policies to recycle waste materials, to promote energy conservation and to purchase products made from recycled materials



- Undertake studies to determine the social and economic feasibility of household and other solid waste separation schemes, including a study of the type and amount of recyclable materials in solid wastes from all sources
- Promote the development of provincial public education and awareness campaign to address the benefits of recycling
- Develop programs to gather and disseminate recycling information to the public, recyclers, municipalities, institutions and industry
- Establish cost-sharing arrangements with municipalities, institutions, industry and others to encourage recycling through the implementation of waste separation programs and facilities
- Provide financial assistance or incentives respecting recycling initiatives
- To carry out, fund or promote research respecting recycling
- Set standards for recyclable materials
- Provide technical assistance to carry out recycling programs

The most outstanding example of provincial action in the area of waste management consists of the Ontario regulatory measures that were adopted to achieve reduction goals. Although Ontario has commenced many of the above-noted initiatives, it decided to control special measures to quicken further waste reduction in its territory. These, certainly, represent the most inclusive methods conceived to-date. They are revealing of what may lie ahead in waste management regulations (The Canadian Construction Association, 1992).

#### **2.5.4 The Ontario Initiative (Cited from The Canadian Construction Association, 1992)**

In April 1992, the Ontario Environmental Protection Act was amended for the purpose of permitting execution of regulatory measures to reach waste reduction targets. These amendments

allow the Minister of the Environment specific powers to control waste generators with respect to four actions. These are:

- The preparation of waste audits and implementation of waste reduction workplans
- The establishment and operation of a source separation system
- The establishment and operation of a composting system
- The creation of standards for a municipal waste management cost accounting system

Under these new rules, construction and demolition industries will be accountable for completing waste audits and waste reduction workplans and creating source separation programs. These rules will apply for projects where fifty individuals or more are employed. The rules call for all Industrial, Commercial & Institutional (ICI) waste generators which meet the least criteria to make and implement waste audits and waste reduction workplans, including

- Examine and evaluate waste management practices, from generation to final disposal, including opportunities for at source reduction, waste separation, recycling efforts and marketing of recovered materials
- Maintain waste audit records and a completed form on site for inspection by an official of the Ministry of the Environment or of the local municipality
- Conduct an annual review of previous waste audits and prepare a report which will be kept on file for inspection by an official of the Ministry of the Environment or of the local municipality
- Prepare a workplan based on the most recent waste audit. The workplan and a completed form shall be kept on file for inspection by an official of the Ministry of the Environment or the local municipality
- Continuously display the workplan in the workplace so that all employees may read it

### **2.5.5 Ontario's 3Rs Regulations**

In 1994, the Ontario Ministry of the Environment (MOE) approved the 3Rs Regulations. Regulations 102/94 and 103/94 are applicable to construction and demolition projects consisting of one or more buildings with a floor area larger than 2,000 m<sup>2</sup>. Regulation 102/94 requires the following

- The completion of an on-site waste audit that identifies the amount and nature of the waste that will be generated;
- The development of a waste reduction workplan that outlines specific achievable diversion options for reduction, reuse, and recycling;
- The implementation of the waste reduction workplan;
- The documentation of the waste audit and workplan results on forms provided by the MOE or forms that have been designed in the same general format
- The retention of a copy of the audit and workplan documents on file for five years from completion of the project.

Regulation 102/94 requires that the waste audit be conducted and the workplan completed before the beginning of the CRD project. Regulation 103/94 requires the following:

- The implementation of a source separation program for the reusable and recyclable materials listed in Regulation 102/94;
- The specification of facilities that are sufficient for the collection, sorting, handling and storage of these materials;
- The communication of the source separation program and its successes to employees, patrons, and tenants
- Reasonable effort in ensuring that the separated waste is reused or recycled

The project team should inquire with provincial environment authorities to find all relevant environmental regulations. The federal government follows to the Ontario 3Rs Regulations as they represent best practices in the industry (Public Works and Government Services Canada, 2011).

### **2.5.6 The Waste Audit**

The aim of a construction, renewal, or demolition waste audit is to find the types and quantities of waste materials that will be formed during the project. The Ontario 3Rs Regulations recognise materials that must be comprised in the waste audit.

In the case of construction projects:

- Brick and Portland cement concrete
- Corrugated cardboard
- Unpainted drywall
- Steel (e.g. ductwork, frames, studs)
- Wood (including painted, treated, or laminated wood)

In the case of demolition projects:

- Brick and Portland cement concrete
- Steel; and
- Wood (not including painted, treated, or laminated wood)

However, there are often significant quantities of other materials that can also be included in the waste audit. These include:

- Rigid plastic, plastic film, and polystyrene packaging
- Wooden shipping pallets
- Doors and hardware

- Thermal insulation
- Ceiling tiles
- Architectural hardware such as curtain rods
- leftover paint
- Carpeting, and hardwood flooring
- Window glass

All of these materials can be quantified using specifications, floor plans, interviews and/or, site visits. In the case of some projects, i.e. the demolition of old buildings, floor plans may not be obtainable. When this occurs, it may be necessary to cut away sections of surface materials, such as gypsum and ceiling tile, to verify internal parts such as joists, insulation, and sound baffles. Based on the total building dimensions, structural components and assembly, material quantities are usually estimated in units of volume. But waste diversion is usually stated in units of weight. The material volumes to weights can be converted by conversion factors during the auditing process. Conversion factors can be found in the Ontario 3Rs Regulations and in architectural and engineering journals. (Public Works and Government Services Canada, 2011).

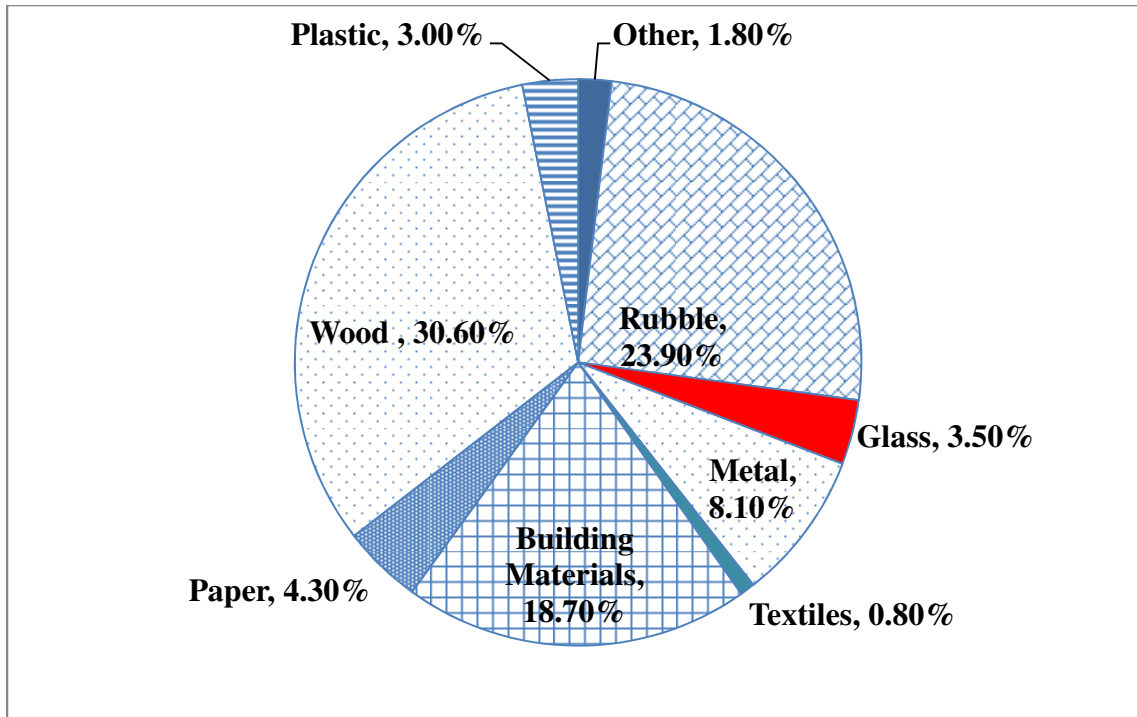
### **2.5.7 Waste Stream Analysis**

Environment Canada estimates that 9 million tons of construction and demolition wastes are created annually. This amount accounts for 1/3 of solid waste stream of the country. For the most part, construction wastes are largely inactive. The major problem is that the waste is bulky, hard to compress and is taking up more and more room in overstrained and limited municipal landfills (The Canadian Construction Association, 1992).

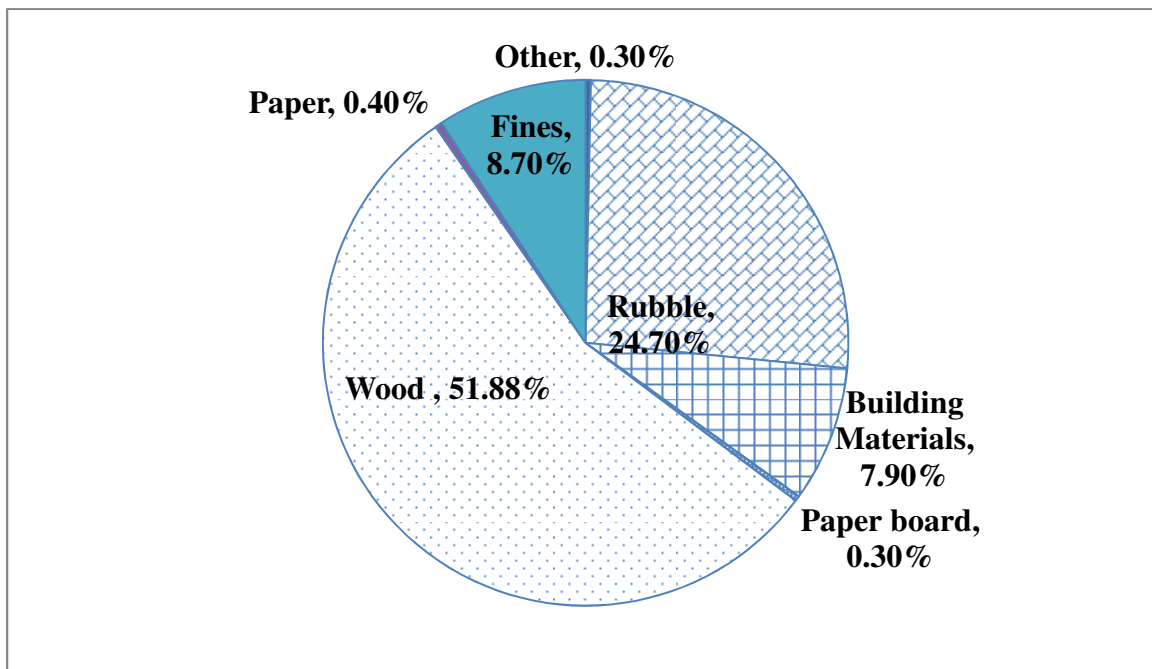
**Table 2.2:** The materials that comprise construction waste: The Canadian Construction Association (1992)

Waste Type	Contents
Rubble	Dirt, bricks, cinder blocks, concrete
Asphalt	Roads, bridges, parking lots
Tar-based materials	Shingles, tar paper
Ferrous metals	Pipes, roofing, flashing, steel
Non-ferrous metals	Aluminum, copper, brass, stainless steel
Harvested wood	Stumps, tops, limbs
Untreated wood	Framing, scraps
Treated wood	Plywood, pressure-treated, creosote treated, laminates
Plaster	Sheetrock, gypsum, drywall
Glass	Windows, doors
Plastic	Vinyl siding, doors, windows
White goods	Appliances
Appliances	Contaminants Lead-based paint, asbestos, fibreglass, Lead-based

There is not much information available on the type and volume of waste that is generated in the construction industry. There is a study that involved taking samples of wastes generated from various commercial and residential structures at different points in their building, demolition or renovation. The results indicated that wood and rubble were the two major constituents of construction/demolition wastes. The following pie charts recap the information that was gathered during the project (The Canadian Construction Association, 1992).



**Figure 2.1:** Construction waste composition: The Canadian Construction Association (1992)



**Figure 2.2:** Demolition waste composition: The Canadian Construction Association (1992)

In most jurisdictions, construction and demolition materials have been categorized into two categories: acceptable and non-acceptable. In general, the waste that landfills accept is divided in the following ways.

**Table 2.3:** Acceptable and non-acceptable waste for landfills: The Canadian Construction Association (1992)

Acceptable	Non-Acceptable
Brick, cardboard, clean earth, concrete, electrical wiring, ferrous materials ,furniture & household Appliances, glass, gypsum, nails, road materials, roofing materials, wood	Asbestos, food waste, hog fuel and sawdust, liquid or semi-solid wastes, putrescence wastes, special wastes: toxic, explosive, corrosive, treated wood

However, a number of municipalities (primarily in Ontario) have approved regulations that curb construction materials to be disposed of at landfill sites. The aim is to get rid of these products from the waste stream and to enforce the approval of methods to reuse or recycle them. Ontario and British Columbia are the only provinces where some construction materials are banned from landfill sites. The table below lists several municipalities that have taken action in this specific area (The Canadian Construction Association, 1992).

**Table 2.4:** Banned materials and respective municipalities: The Canadian Construction Association (1992)

	Cardboard	Tires	White Goods	Wood	Leaves	Metal	Construction Demolition	Drywall
Ajax	x	x	x	x	x	x		x
Kingston	x	x			x		x	
Ottawa	x							
North Simcoe	x	x	x	x		x		x
Toronto	x	x	xx		x			x
Vancouver					x			x
Victoria								x



### 2.5.8 Waste Management

There are several problems involved in effective construction/demolition waste reduction and diversion management

- By nature the construction industry is segmented; in its great majority, it is comprised of small firms
- Sites are limited in space
- There are a lack of established recycling/reuse markets

However, since supported by governments, the first step for effective waste management is to include the 5Rs in its operations. The table below provides information as to their applicability.

**Table 2.5:** 5R and its applicability: The Canadian Construction Association (1992)

Method	Activity
Reduction	order less material, use more durable material
Reuse	use building materials again in their original forms
Recycle	make new products from waste building materials
Resource recovery	Reclaim recyclable components from waste stream by separating them
Residual Management	dispose of what remains in a safe manner

The 5Rs contain the design process which plays a key role in shaping construction waste.

A number of concerns have been established to reduce potential waste at this level.

- Selection of durable and recyclable materials
- Selection of recycled or used materials
- Selection of materials with low embodied energy and made with manufacturing processes with lower environmental impact

On-site material management techniques need to be established to reduce the amounts of waste. The following procedures are recommended.

- Prefabricate common elements at central locations
- Optimize construction scheduling
- Encourage on-site reuse of cut-offs
- Separate recyclable materials

The greatest significant aspect to achieve effective waste management is the collaboration of employees. An educational package should be set up so that all employees clearly realize the procedures. Moreover, it is critical that an official company regulation be established and enforced on all projects. In this way new construction practices would ultimately develop part of the normal work procedures. The following recommendations have been established to support contractors in their day-to-day operations (The Canadian Construction Association, 1992).

- Standardize methods of cost estimating waste management into your projects.
- Study the costs of waste disposal by type of construction. This will identify the projects that require improved waste management practices.
- Pre-plan waste handling procedures before a project begins.
- Discuss waste management in terms of responsibilities, practices and initiatives at project meetings. Include all trades and subcontractors involved in the project.
- Review subcontract provisions to ensure clarity regarding responsibilities for waste management.
- Involve your work force in all your environmental efforts.
- Follow-up by making subcontractors and employees aware of what is expected to be wasted and how to reduce that waste.

- Provide clear and dry storage areas for your building materials.
- Use more prefabricated components.
- Minimize offcuts, and work with your suppliers to obtain materials that are specific to your needs.
- Reuse offcuts whenever possible. Plan storage areas for different waste materials. Practice waste separation.

### **2.5.9 Code of Practice**

The Canadian Construction Association requests its members to implement the following code of practice in their day-to-day tasks for the aim of protection and improving our environment (The Canadian Construction Association, 1992).

- Adopt a waste management policy to be implemented on all projects
- Promote this policy to all employees and partners
- Select durable products in the purchase of construction materials
- Minimize the purchase of materials to meet the required amounts only
- Adopt techniques that will minimize construction wastes
- Reuse all possible waste products on site
- Implement source separation on site for recycling purposes
- Identify markets of recycled goods
- Identify potential users of waste materials
- Use landfill sites only where no other options are available

### **2.5.10 The Role of Waste Management in LEED Canada**

The Canada Green Building Council (C.a.G.B.C) is accountable for substituting the US LEED rating systems to Canadian construction practices, regulations, and climates. The Mission

of CaGBC is Lead and increases the conversion to healthy green buildings, high-performing, homes and communities throughout Canada. The Council works to:

- Change industry standards,
- Develop best design practices and guidelines;
- Advocate for green buildings, and
- Develop educational tools to support its members in implementing sustainable design and construction practices (Brydon, 2011)

Key Elements to Sustainable Building Design in waste management practices are waste management reduction, recycling content, existing building reuse (Brydon, 2011).

a) Role of Waste Management in LEED -Design

- Re-Use -Avoid removal
- Material selection - Recycled content
- End of lifecycle disposal - On site re-use and salvageable or recyclable
- Enabling source separation - Design features that promote recycling and on site composting and biodegrading

b) Role of Waste Management in LEED –Project Planning

Having included the following features it develops a comprehensive waste management plan:

- Comply with LEED standards to earn waste management credits
- Document waste management compliance
- Include appropriate specifications in construction documentation
- Market the jobsite recycling program to trade

c) Role of Waste Management in LEED –On Site

This procedure includes the following steps:

- Managing construction and demolition waste on the jobsite by Policing trades and sub trades and collect documentation and maintain LEED templates
- Setting up an efficient jobsite recycling center using multiple bins with large signage and directional signage on large sites
- Recycling new construction waste
- Conducting an on-site audit to assess demolition waste
- Reusing existing materials including asphalt, brick, concrete, insulation, structural steel, wood, glass, and more

d) LEED Canada Rating scheme and rating for construction waste management

- LEED Canada 2009 (June 2010):- Replaces LEED® Canada NC Ver. 1.1, new construction and major renovation, Incorporates previous version of LEED Core and Shell, construction waste management (encourage to divert construction and demolition waste, divert from landfill or incineration, re-direct recyclables and re-useable resources, 1 point for 50% process and 2 points for 75% process), Materials Re-Use (1 point for 5% process and 2 points for 10% process)
- LEED Canada for Homes (April 2009):- New Homes and gut retrofits, for construction Waste reduction up to 3 points
- LEED Canada for Commercial Interiors: - Interior design (encourage to divert construction and demolition waste, divert from landfill or incineration, re-direct recyclables and re-useable resources, 1 point for 50% process and 2 points for 75% process), Materials Re-Use (1 point for 5% process and 2 points for 10% process)
- LEED Canada for Existing Buildings: - Operations and Maintenance

- LEED Canada for Neighbourhoods (late 2011):- Community planning and design (Solid Waste Management Infrastructure: Include at least 4 of following 5 i.e. recycling station hazardous waste drop off, composting site, recycling containers per block or 800 ft, Recycle or salvage 50% non-hazardous construction / demolition debris

## **2.6 Construction Waste Management Practices in Australia**

All three levels of government in Australia and many private organisations have sanctioned the use of Waste Management Plans as contributing to a more environmentally friendly construction industry (Hardie et al., 2007).

### **2.6.1 Federal Government**

One of the initial initiatives motivating the process of waste management was the WasteWise Construction Program established by the Department of the Environment which was carried out between 1995 and 2001. This program was a partnership between the Commonwealth government and major companies and associations from the building and construction industry who had volunteered to be involved. Waste Reduction Guiding principles were formed by the program in 2000. The guiding principles indicated as best practice both a Waste Management Plan (WMP) for a construction project all together, in addition to WMPs for individual sub-contractors. A number of case studies were carried out indicating considerably improved rates of recycling of many materials and these case studies were broadcasted nation-wide (Hardie et al., 2007).

### **2.6.2 State Government**

At the National government level, the New South Wales Waste Minimisation and Management Act 1995 generally provided a state-wide framework for waste minimisation. Regional Waste Boards were begun to focus on numerous industries. A top level of construction

activity heading up to the ‘green’ Olympic Games performed in Sydney in 2000 sustained a focus on waste minimisation. The 1995 Act was switched by the Waste Avoidance and Resource Recovery Act of 2001, which established Resource NSW, in lieu of the earlier NSW Waste Boards and the State Waste Advisory Council (Hardie et al., 2007).

In 2003, Resource NSW was merged into the NSW Department of Environment and Heritage. One of the total results of these law-making changes has been that in New South Wales, the practice of procurement development authorization for building works now generally needs the proposal of a Waste Management Plan. The Waste Management Plan can take various practices depending on the size of the building project and the approval authority (body approving the application). Nevertheless, a particular kind of WMP is vital for almost all non-residential projects which cause the necessity of a development approval. Same rule time frames are replicated in the other states (Hardie et al., 2007).

The Victorian Government established EcoRecycle Victoria in 1996. EcoRecycle published a “Waste Wise Construction and Demolition Kit” in 2004 which comprised of waste minimisation plans. In 2005 the Victorian Government published a “Towards Zero Waste Strategy”. In 2005, EcoRecycle Victoria combined with the Sustainable Energy Authority of Victoria to make Sustainability Victoria. There seems to be some concern among committed recyclers in both NSW and Victoria about the obvious reduction of the priority given to waste minimisation as verified by stand-alone waste authorities being combined with larger, less targeted bodies (Hardie et al., 2007).

The Queensland State Government presented the “Waste Management Strategy for Queensland” in 1996. This tactic indicated a waste recovery program for any government building developments (Hardie et al., 2007).

In 1996, the Australian Capital Territory carried out “No Waste by 2010 - A Waste Management Strategy for Canberra”. In 1999, the “Development Control Code for Best Practice Waste Management” started. Zero Waste South Australia was created in 2003 to help local councils in waste planning and to establish regional waste management policies. There have been equivalent progresses in the other states and territories (Hardie et al., 2007).

### **2.6.3 Local Government**

Local government institutions have started their own initiatives. In 1995, the Western Sydney Regional Organisation of Councils established a standard Waste DCP (Development Control Plan) as a way for reducing construction and demolition waste during building projects. Most local councils have created their own favoured format of WMP to be submitted with an application for Development Approval. There is little consistency in format or content required. Most of the councils with preferred practices have extensive waste policies. A new example is the Council of the City of Sydney’s extensive Policy for Waste Minimisation, including Waste Management Plan templates for the demolition phase, construction phase and use of operational phase (Hardie et al., 2007).

### **2.6.4 Other Organisations**

The establishment of various evaluation systems for buildings has added further motivation to the move to WMPs. The Green Building Council of Australia was formed in 2002 and introduced the Green Star Environmental rating for buildings shortly after. Globally other green building councils are evolving under the good start of the World Green Building Council established in 1998. As the above conversation recommends, WMPs have developed the standard ways of regulating construction waste minimisation in Australia. Though, they seem to have been extensively accepted despite the little objective assessment of their efficiency as a way



to attain better ways of reuse and recycling in the industry. In the meantime, significant incentive still exists to avert waste from landfill and some of the forces of such a change are itemized in the following section (Hardie et al., 2007).

### **2.6.5 Current Drivers**

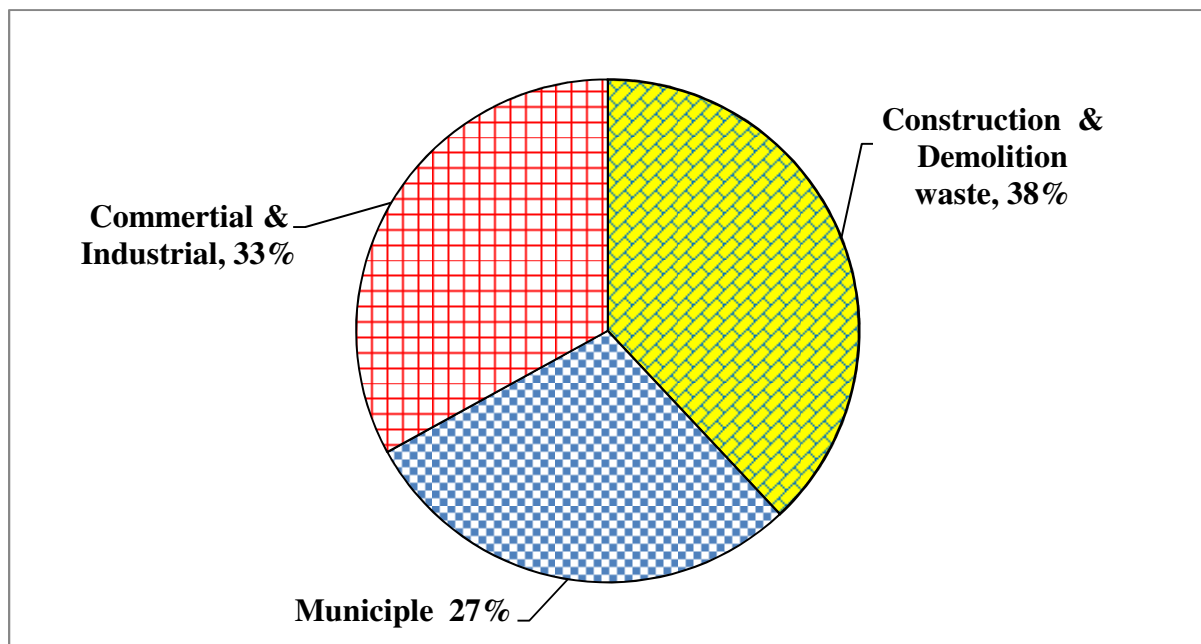
Increasing waste taxes are presently providing a motivation to divert waste from landfill predominantly in the more highly colonized states. Generally, prospective cost effects of reducing waste are proving to be greater as the cost of disposal to landfill increases. Some of the rates exposed represent severe growths over latest years and the NSW government, in specific, appears to be using the price mechanism to drive improved reuse and recycling. Together, though, as the price of landfill is increasing there is a development in the use of the various green rating systems for commercial buildings. Progressively companies are looking for to be listed on sustainable and ethical indexes and there is a subsequent desire for 'green buildings'. This movement is also verified in the current federal Productivity Commission's Public Investigation into Waste Generation and Resource Efficiency (Hardie et al., 2007).

### **2.6.6 Solid Waste Generation in Australia by Waste Stream**

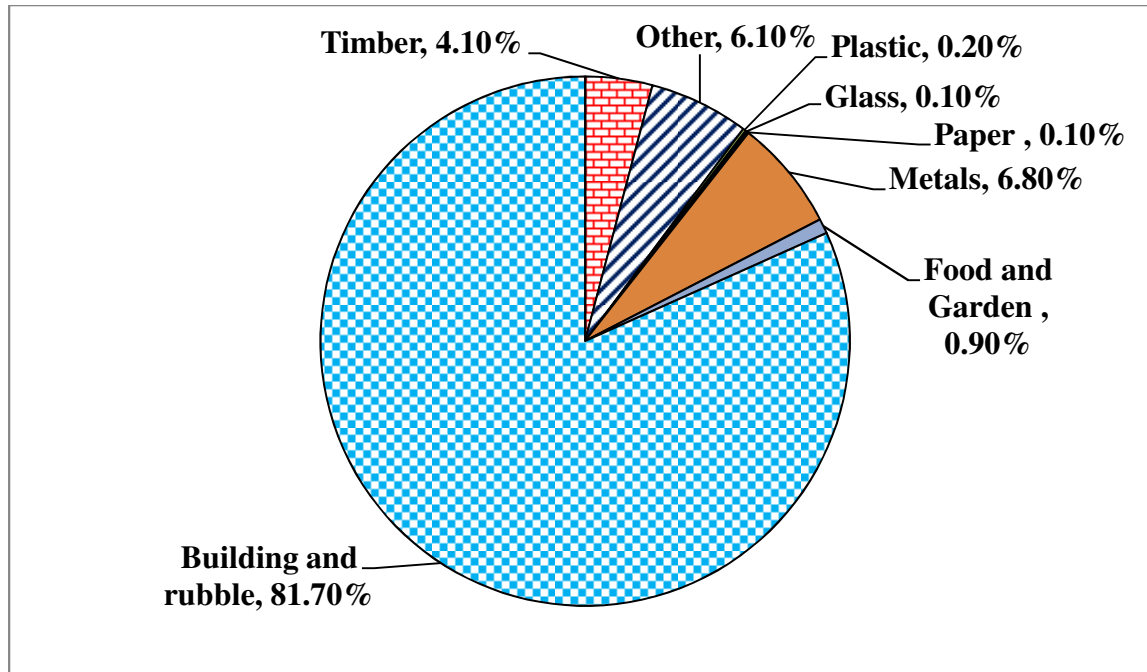
In latest years, industries have also paid strong attention to waste minimisation. As an example, the Australian Institute of Building has circulated both a Corporate Statement of Commitment to waste reduction and a Waste Minimisation Code of Practice for members. In the same way, the list of standards for deciding the annual Professional Excellence Awards currently contains waste minimisation. As per the above conversation, it is visible that the issue of construction waste figures obviously on the public agenda, and Waste Management Plans have been obligatory for most construction projects since the mid 1990's. In spite of the extensive use

of WMPs in their many formats there is very little research into their effectiveness with regard to realising their major aims (Hardie et al., 2007).

Australia produced around 43.8 million tonnes of solid waste or around 1,629 kilograms of waste per person in 2006-07. Of this amount, 29% came from municipal sources, 33% from the commercial and industrial segment, and 38% from the construction and demolition segment. Municipal waste contains domestic waste and other council waste (e.g. beach, parks and gardens, streets) (Hardie et al., 2007).



**Figure 2.3:** The composition waste generated in Australia: Australian Bureau of Statistics (2010)



**Figure 2.4:** The composition of construction and demolition waste generated in Australia:

Productivity Commission, Waste Management (2006)

## 2.7 Construction Waste Management in The United States of America

In 1998, the U.S. EPA valued that yearly 136 million tons of construction-related waste which is 25% to 40% of the national solid waste stream, is created in the U.S. A 2003 update indicate a rise to 164,000 million tons annually which accounts for 9% of construction waste, 38% of renovation waste, and 53% of demolition debris. EPA also estimates that only 20% of C&D waste is being recycled. This proposes a huge potential for development. It also suggests an important resource is available for future use (Napier, 2011).

### **2.7.1 United States Environmental Protection Agency's (EPA) Goals for C&D Reduction and Utilization**

As per United States Environmental Protection Agency (2011), C&D materials are resources that can be used in more effective ways than disposal. In working with C&D materials, EPA's objectives are to:

- Characterize, measure, and increase knowledge and understanding of the C&D materials stream;
- Promote research and development on best practices for C&D materials reduction and recovery;
- Foster markets for construction materials and other recycled materials that can be incorporated into building products;
- Work with key players in the construction, remodelling, and demolition industries to implement more resource-efficient practices; and
- Incorporate C&D materials issues and projects into broader “green building” programs.

#### **a) EPA Partnerships and Programs**

EPA is actively working on C&D materials issues through a number of activities (United States Environmental Protection Agency, 2011)

##### **i. WasteWise Building Challenge**

WasteWise is an EPA voluntary partnership program that helps US establishments decreasing their solid waste, helping both their bottom line and the environment. In 2002, WasteWise started a building challenge that challenged partners to reduce, reuse, and recycle C&D materials and buying recycled-content building products.

## ii. Green Scapes

An EPA program that helps environmentally favourable landscaping practices for huge land-use activities such as shopping centers, recreational amenities (e.g., golf courses, public gardens ,ski resorts, pleasure parks),highways, large universities, and military setting ups.

## iii. Green Buildings

EPA supports a wide range of programs that promote Green Building. An important element of Green Building is the reuse or recycling of C&D building materials. EPA's Sector Program looks for industry-wide environmental improvements through inventive activities engaged with a number of industrial and service sectors, including the Construction Sector. "Green construction" is a significant emphasis of this site. The Construction Industry Compliance Assistance Center offers clarifications of environmental rules for the construction industry and links to comprehensive information, including state regulations and other resources.

## iv. The Building Deconstruction Consortium (BDC)

EPA is operational with the Army's Construction Engineering Research Lab, the University of Florida's Center for Construction and Environment, the United States Department of Agriculture Forest Products Lab, and Habitat for Humanity to show, record, and distribute best practices for the deconstruction for reuse and recycling of the pieces of Army buildings

### **2.7.2 Best Management Practices**

How waste management, or waste diversion, is accomplished, and to what extent, must be governed by specific project necessities and circumstances. Several issues contribute to a total waste diversion strategy (Napier, 2011).

#### a) Waste Management Planning

Waste management should be an important part of a project development. Each of the major project stakeholders (the Owner, their Architectural and Engineering (A/E), Construction Management consultant, the Contractor or Subcontractors) engage in waste management to some degree throughout the project. At first, the Owner and their A/E must establish waste minimization goals and define what levels of diversion are attainable and realistic under the project's conditions (Napier, 2011).

#### b) Facility Design

As per Napier (2011), the contractor is accountable for the methods, means, sequences, techniques and techniques of construction, which include waste disposal techniques. However, the A/E's design team can contribute to waste decrease by numerous methods. These include:

- Observing Value Engineering principals, performing multiple functions with one material rather than requiring multiple materials to perform one function, designing to optimize systems' and components' use and avoiding extraneous materials that do not contribute to function.
- Efficiency in area and volume. If less material is required by the design, less waste is generated at the jobsite.
- Observing standard material and product dimensions and locating features "on module" to the extent possible to reduce cutting and special fitting, which creates scrap.
- Where possible, selecting construction systems that do not require temporary support, shoring, construction aids, or other materials that will be disposed of as debris during the project.

- Where possible, selecting materials that do not rely on adhesives, which require containers and create residue and packaging waste. Furthermore, adhesives inhibit salvage and recycling at the end of the component's or building's life.
- Where possible, reducing requirements for applied finishes, laminates, coatings, adhesives, and the associated scrap, packaging, and waste and selecting materials with integral finishes.
- Where possible, avoiding materials which are sensitive to damage, contamination, environmental exposure, or spoilage on-site, which increase the potential for jobsite waste.

#### c) Construction Contract Requirements

The owners and their contract management consultant must define how their waste management goals represent in the contract documents and merged into the project. Numerous provisions are relevant to the project's total waste reduction performance (Napier, 2011).

##### i. Fundamentally three methods to represent waste reduction necessities in the contract documents

- Describe the waste reduction goals and rely on the contractor's own initiative to achieve them. This may be effective if the owner and contractor share a good working relationship, and encouraging the contractor is sufficient for them to "do the right thing."
- Specify definitive minimum waste and debris diversion criteria. This is commonly incorporated into the demolition specification as a numerical criterion, such as "divert from landfill disposal a minimum of 75% of the non-hazardous construction waste generated at the jobsite."

- Develop incentives to reward the contractor. This may be implemented as an award-type incentive based on the diversion rate, or by including options in the bid schedule for each of several ranges of diversion rates.
- ii. Need the Contractor to submit a C&D Waste Management Plan. Usually, the Plan comprises the following
- Name of individual(s) responsible for waste prevention and management.
  - Actions that will be taken to reduce solid waste generation.
  - Description of the regular meetings to address waste management.
  - Description of the specific approaches to be used in recycling/reuse.
  - Waste characterization; estimated material types and quantities.
  - Name of landfill and the estimated costs, assuming no salvage or recycling.
  - Identification of local and regional reuse programs.
  - List of specific waste materials to be salvaged and recycled.
  - Estimated percentage of waste diverted by this Plan.
  - Recycling facilities to be used.
  - Identification of materials that cannot be recycled or reused.
  - Description of the means by which any materials to be recycled or salvaged will be protected from contamination.
  - Description of the means of collection and transportation of the recycled and salvaged materials.
  - Anticipated net cost or savings.

Several examples of C&D Waste Management Necessities and Plans are delivered in additional resources, below.



iii. Need the contractors to record their actual waste diversion performance during the project life. So the waste management plan should also include progress reporting techniques to record actual diversion and cost relevant to every diversion and cost estimate.

vi. As the recognized plan is a part of the contract document, it should be merged into the contractor's quality control and owner's quality assurance procedures. Some public owners do not approve their progress payments until updated actual diversion reports are submitted.

v. Retain debris and waste materials for the contractor, and permit the contractor to increase the economic benefits. These comprise cost averting through reduced debris tipping costs, incomes from salvaged and recycled materials, and cost averting by using materials taken from the jobsite back into the project.

#### d) Jobsite Waste Reduction

As per Napier (2011), there are number of ways to divert construction waste or demolition debris at the jobsite. The following practices are common.

- i. Up to 10-12% of construction waste is packaging materials. While protecting new materials, the contractor can direct their subcontractors and suppliers to reduce unnecessary packing and packing.
  - Purchase materials in bulk where possible. Avoid individual packaging for volume purchases.
  - Use returnable containers and packing materials
  - Reuse non-returnable containers on the jobsite to the maximum extent possible.

Develop one-hundred-and-one-uses for plastic barrels, buckets, and tubs.

- Give away non-returnable containers. Contact local and community organizations (schools, youth groups, community service groups, Habitat for Humanity, others similar).
- ii. Use scrap instead of cutting new materials. Instruct subcontractors and trades to save scrap at cutting and fabricating locations. Save paints and liquids from empty containers; avoid disposing of useable materials
- iii. Working in smaller lots should reduce the requirement to throw out expired or spoiled materials. Ensure volatile materials, and materials which degrade when exposed to heat, cold, or moisture are secure from spoilage and are not wasted.
- iv. Recycle damaged parts, products, and materials, or take apart them into their basic materials for recycling.
- v. Create a return or buy-back plan with suppliers. Alternatively, unused, or used but useable materials and products can be sold, salvaged or used materials can be taken to retail outlets. Aids to a non-profit outlet are usually tax-deductible.
- vi. The contractor may contract with a C&D recycling firm which receives mixed debris. At the recycling site, concrete and masonry rubble are separated into aggregate products. The residual debris is typically crushed or shredded, then carried along a pick line for categorization and recycling. C&D waste recyclers usually define their fees as "competitive" with landfill removal, which means a modest savings over usual landfill tipping fees. This method typically succeeds a very high diversion rate. However, clean wood is often sold for boiler fuel, and some agencies do not permit incineration as diversion.

- vii. The contractor may contract with different recycling firms which deal with specific materials, besides a general waste mover. This requires the contractor, subcontractors and tradespersons to separate waste, deposit it in the suitable containers, and guard against contamination by other materials. The significant factor to effective jobsite separation is to place containers in the path of least disturbance to the workforce, training the workforce to observe separation carried out, and regulating the jobsite to avert pollution. The construction process provides itself to on-site separation. As trades enter and leave the jobsite, each produces a comparatively homogeneous waste stream, provided the exact tasks and the materials. When the recyclable materials are separated, the recycling firms usually offer a greater price for the material (if the contractor transport), or a lower transport rate (if the recycler transport). Instead, the contractor can contract with a waste transporter who provides containers for recyclable materials and debris, and transport all materials as a one service.
- viii. The waste diversion prospective in a demolition situation is great. The building construction type and project schedule are the two key elements in defining what and how to save, reuse, and/or recycle. Consider the following mentioned facts.
- Create the project schedule to include salvage, reuse, or recycling. The quality and quantity of materials saved is a direct function of time presented for save.
  - Prior to demolition, save as much useable material and parts as the schedule allows. Windows and doors, architectural millwork, wood flooring, electrical fixtures, cabinetry, mechanical equipment plumbing fixtures etc. that can be separated and removed and can be saved and reused. When creating the C&D Waste Management Plan, identify the most reachable and valued materials.

- Concrete and masonry waste can be recycled to make aggregate. This on-site procedure can be done with mobile equipment, or rubble can be transported to a permanent recycling facility. Preferences can change between demolition contractors and recyclers about whether the building should be cleaned before to demolition, leaving only concrete and reinforcing to be crushed, or demolished complete, and the debris sorted as part of the concrete crushing process. Then consider how the recycled concrete aggregate can be used, what recycled concrete aggregate products are most useful, and how to use rubble to produce these products. If aggregate materials are obligatory for the project, site recycling can give these materials at a cheap net cost. The Construction Materials Recycling Association (CMRA) can deliver information on methods and service providers.
- Wood without lead-based paint and not treated with an arsenic-based protective, or polluted with a hazardous or toxic material can be shredded into organic matter, composted, or chiselled for boiler fuel. This can be done on-site or off-site. If organic matter or compost is necessary for the project, shredding on-site can provide at a cheap net cost.
- Structural steel and metals are almost generally recycled.
- Old growth timber is a valued material and usually required for delicate removal process.
- Several class of dimensional timber can also be valuable. Wood framed buildings can be partly or completely deconstructed. Although this is required an additional labour, cost averting and the value of the materials can balance original cost. The

Building Materials Reuse Association (BMRA) can offer information on deconstruction and used building materials selling businesses.

- If the alternative salvage, reuse, or recycling options are not possible, mixed demolition debris can be transported to a C&D debris recycling facility, as explain above.

### **2.7.3 Emerging Issues**

Few areas are facing a lack of C&D landfill space. However, the rise in tipping fees (especially in the Northeast and the Northwest); rules without C&D materials from landfills, the reducing of the numbers of C&D landfills in the U.S. (26% fewer between 1990 and 2002), and more hard standards for new landfill design, predict landfill disposal of C&D waste will be considerably more costly in the future. The construction, engineering, architectural, and waste management businesses are becoming more thoughtful to C&D waste decrease. Public responsiveness for waste reduction and recycling has risen to direct C&D waste diversion. Public organizations are encouraging through rule, or needing by law or regulation, waste diversion in public and private construction. Many organizations have developed resources such as best practice guides to facilitate waste diversion at the project level. Additionally, the U.S. Green Building Council's LEED rating system's MR-2.1 and MR-2.2 credits offer motivation to reduce waste in "green building" design and construction. The development in architectural salvage and used building materials selling industries, and C&D recyclers are additional indications that building material salvage and recycling have become a significant section of the construction industry (Napier, 2011).

#### **2.7.4 Relevant Codes and Standards**

As per Napier (2011),

##### **a) Industry Standards**

- Green Seal—standard on recycled paint
- U.S. Green Building Council, Leadership in Energy and Environmental Design (LEED) Rating System Material Resource Credits MR-2.1 & MR-2.2

##### **b) Government Standards**

- Department of the Army Assistant Chief of Staff for Installations Management (ACSIM)

##### **c) Requirements for Sustainable Management of Waste in Military Construction, Renovation, and Demolition Activities**

- Department of Defense Integrated (Non-Hazardous) Solid Waste Management Policy.
- Executive Order 13423, "Strengthening Federal Environmental, Energy, and Transportation Management", Office of the Federal Environmental Executive
- Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance, Office of the Federal Environmental Executive
- Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding
- Technical Guidance for Implementing the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings (Executive Order 13423)

#### **2.7.5 Construction Initiative**

The US Environmental Protection Agency's (EPA) Construction Initiative (CI) is a combined, public-private area effort to intensify the recycling and reuse of industrial materials in building and transportation construction projects through the country. It is a branch of EPA's

Resource Conservation Challenge, a nationwide program that offers improved urgency to the Agency's idea of reusing, reducing, and recycling valued materials. The initial process increases alertness of the prospective value and unique capabilities of these materials to substitute virgin materials in many construction practices. To achieve this goal, EPA is engaging with the Federal Highway Administration and the Industrial Resources Council (included agents from seven industry associations), to deliver technical help to building owners, real estate investors, general contractors, architects, and transportation officers. (United States Environmental Protection Agency, 2011)

### **2.7.6 Green Building and the Construction Initiative**

As per United States Environmental Protection Agency (2011), sustainable or Green structure is the practice of building and using healthier and more efficient models of construction, maintenance, renovation and operation. Designing with manufacturing materials is a main element of green building and can receive points in green building certification programs. (i.e. the US Green Building Council's Leadership in Energy and Environmental Design (LEED) green building rating system)

**Table 2.6:** Industrial materials recycling and LEED® credits

<b>Industrial Materials Recycling and LEED® Credits</b>	<b>Points</b>
Using construction and building products containing recycled content	1-2
Reusing building materials and products	1-2
Diverting C&D materials from disposal	1-2
Using materials extracted, processed, and manufactured locally	1-2
Total Possible Points	8

Green construction can comprise a range of other sustainability divisions, including water stewardship, air quality, Green procuring, recycling and energy efficiency. The Construction

Initiative works in cooperation with other EPA programs that backing these areas. The Destiny USA project is also a leading model of the kind of multimedia assistance.

#### **2.7.7 Other Federal Programs Related to C&D Materials (United States Environmental Protection Agency, 2011)**

a) US Air Force Center for Environmental Excellence

Contains several resources for C&D debris management and planning with resources, references and for C&D Waste Management.

b) US Army Corps of Engineers Construction Engineering Research Laboratory

Carried out research on how to decrease C&D at army installations.

c) United States Department of Agriculture Forest Products Laboratory

Carried out widespread research into the salvage of wood from the C&D stream.

d) US Department of Housing and Urban Development (HUD)

Explores the worthiness of deconstruction practices to the housing industry.

e) Geological Society of America's Construction Waste Management Database

Comprises information on companies that transport, process and collect recyclable debris from construction projects. Formed in 2002 by Geological Society of America's Environmental Plans and Safety Division to stimulate waste removal.

f) US Department of Transportation, Federal Highway Administration

Supply information about recycling concrete and asphalt in highway construction.



### **3 THEORETICAL FRAMEWORK AND METHODOLOGY**

This chapter illustrate the theoretical framework and methodology of the research project.

#### **3.1 Methodology**

Literature reviews, construction field observations, interviews, and questionnaire surveys were used as the main research tools in this research project.

- a) Literature reviews: A comprehensive literature review was conducted to be familiar with the current body of knowledge and to obtain insight into waste minimization debate in construction. More focused efforts were made to understand construction waste origins and its relationship to the deficiencies in the contract documents. In addition to peer-reviewed articles, several contract agreements and specifications were carefully examined. Contract clauses of each of these documents, which have potentials to generate construction waste, were carefully identified. Those clauses were classified into eight categories. Most of the said clauses were found in the general conditions of contract agreements and the division 1(general requirement) of construction specifications developed by the Construction Specifications Canada (CSC). Identified clause categories are shown in Table 3.1.

**Table 3.1:** Eight categories of potential contractual clauses

No.	Category	Sample Clauses
1	Quality	a. Should any dispute arise as to quality or fitness of product, decision rests strictly with consultant based upon requirements of contract documents. b. Replace materials less than specified quality or as designated by architect and relocate work incorrectly installed as determined by architect.
2	Substitution	There is no obligation on the part of the consultant or owner to accept proposed substitutions. Acceptance of proposed substitutions by owners does not relieve the contractor's responsibility under the contract.
3	Workmanship	Decisions as to quality or fitness of workmanship in case of dispute rest with the consultant, whose decision is final.
4	Geotechnical report	The report, by its nature, cannot reveal all conditions that exist or can occur on the site. Should sub surface conditions be found to vary substantially from those indicated in the soil report, changes in the design and construction of foundations will be made accordingly with resulting credits or expenditures accruing to the owner.
5	Submittals, Shop drawings	a. Consultant's review does not relieve contractor of his responsibility for accuracy of shop drawings. This review of the shop drawings shall not, in any way, relieve the contractor from complying with all requirements of the contract documents. b. Field verify all building and site dimensions prior to any fabrication and installation of equipment or materials. No contract revisions will be considered for failure to verify these dimensions on site. c. Any review of shop drawings is for the sole purpose of ascertaining conformance with the general design concept. This review shall not mean approval of detail design inherent in the shop drawings, responsibility for which shall remain with the contractor submitting same and as such review shall not relieve the contractor of responsibility for errors or omissions in the shop drawing or of responsibility for meeting all requirements of the contract documents. The contractor is responsible for dimensions to be confirmed and correlated at the job site, for information that pertains solely to the fabrication processes or to techniques of construction and installation and for coordination of the work of all sub trades.

**Table 3.1 Cont.:** Eight categories of potential contractual clauses

No.	Category	Sample Clauses
6	Field quality control, Inspection	<p>a .Field service by the consultant or his representative do not in any way relieve the contractor of his responsibility to carry out the work per the contract document and contract drawings.</p> <p>b. Contractors work will be inspected periodically by the Engineer solely for the purpose of determining general quality of work, and not for other purpose. Guidance will be offered to the contractor in interpretation of plans and specifications to assist them to carry out work. Inspections and directives given to contractor does not relieve contractor and his agent, servants and employee of their responsibility to erect and install work in its parts in a safe and workmanlike, and in accordance with the plans and specifications, nor impose upon the Engineer any responsibility to supervise or oversee erection or installation of any work. The location, arrangement and connection of equipment and materials as shown on the drawings represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner.</p> <p>c. The location, arrangement and connection of equipment and materials as shown on the drawings represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner.</p>
7	Shop finish	Unfinished work will be listed as deficiencies.
8	Temporary or trial usage, testing	It is agreed and understood, that no claim for damage will be made for any injury or breakage to any part or parts of above due to aforementioned tests, whether caused by weakness or inaccuracy of parts, or by defective materials or workmanship of any kind whatsoever. Supply all labour and equipment for such tests.

For the comparison purposes of Canadian construction contracts with other developed nations, contract agreements and technical specifications from two other developed nations were selected. The selected countries were Australia and United States of America (USA). Australia was selected in this comparative study due to three main reasons:

- (1) Literature noted positive impacts of Australian contractual arrangements in waste reduction.
- (2) Multi-stakeholder considerations in their state contract documents.
- (3) Availability of contractual documents for academic research

Following legal agreements of Canada, Australia and USA were carefully reviewed in this research.

#### Canada

- (1) Owner/Contractor agreements: Stipulated Price Contract (Canadian Construction Documents Committee) CCDC 2(2008), Cost plus contract CCDC 2(1994), Cost plus contract CCDC 3(1998), Unit Price Contract CCDC 4 (1982), Stipulated Price Contract for trade contractor for construction management CCDC 17 (2010),
- (2) Owner/Design-Builder agreements: Stipulated price contract DOC 14
- (3) Owner Construction Manager Agreement: CCA 5(1988), CCDC 5A (2010)
- (4) Contractor/Sub contractor agreements: Stipulated price sub contract CCA 1
- (5) Owner / Architect agreement: Document 7(2005) develop by The Royal Architectural Institute of Canada
- (6) Design-Builder /Architect agreements: DOC 15(2000)

## Australia

(1) Owner/Contractor agreements: Medium Works Contract 2007(Master Builders Association of Western Australia), Commercial building contract – LSC2 (Queensland Master Builders Association), Cost Plus Contract 2007- CP 2007(Master Builders Association of Western Australia), Residential Building Works Contract 2007-RBW 2007(Master Builders Association of Western Australia), Commercial cost plus contract- CPC 07 July 2010 EV1 (Queensland Master Builders Association), Home Building Works Contract- HBW 2007 (Master Builders Association of Western Australia), General Condition of Contract GC21-Edition 1 (New South Wales Government)

(2) Contractor/Sub contractor agreements: Subcontract GC21 (New South Wales Government)

(3) Owner / Consultant agreement: General Condition of Contract GC21-Edition 1 (New South Wales Government)

## United States of America

In USA, American Institute of Architects (AIA) is one of the organizations which produces the standard contract documents for the construction industry. On request, AIA provided the student version of complete set of contract document (A series, B series, C series, D series, E series and G series). The AIA series contain 159 (A series: 39, B series: 42, C series: 38, D series: 1, E series: 2, G series: 37) contract documents.

In Australia, each and every province drafts its own contract documents. Provincial master builders' associations which represent construction organizations produce their own construction documents including contractual agreements. The

specimen contractual agreements from several provincial master builder associations were received (i.e. The Master Builders Association of Western Australia, Queensland Master Builders Association) In addition, New South Wales (NSW) government subcontract (GC21) and New South Wales government general conditions of contract (GC21:Edition 1) documents provided samples of owner focused contract documents. There were practical difficulties in reviewing some of the contract documents since certain organizations were reluctant to issue their contract documents to a third party for a comparative study. Approximately fifteen thousand pages of contract documents were gone through in this comparative study.

- b) On-site Observations: All the sources of construction waste and its relationship to identified contract clauses were observed during the site visits. Four commercial construction projects in Kelowna, British Columbia were observed for a ten month period. During regular site visits, all the visible waste items and relevant sources were identified. Investigations and inquiries were conducted to check whether waste items were generated due to deficiencies in the contract documents. A detailed situation analysis was then conducted to identify the possibilities to revise / modify or delete particular contract clauses. Open-ended discussions with the site professionals were conducted in each instance of noting a waste item to understand possible contractual deficiencies.
- c) Interviews: If the reasons for waste generation were not directly related to the selected clauses, but still originated due to the loopholes of the contract documents, a separate inquiry was conducted. Moreover, open ended discussions/interviews were conducted with site professionals (project managers, site superintendents, and project coordinators)

to collect expert opinions to eliminate construction waste, which were originated due to deficiencies in the contract documents.

- d) Questionnaire surveys: Questionnaires were used to evaluate and prioritize the selected clauses in terms of the generating potential of construction waste. The prioritization was done to justify a change/modification /or deletion of particular clauses on priority basis. The comparative weights required for pair-wise comparisons were obtained through an expert opinion survey. Over two hundred questionnaires were disseminated in three rounds to top consulting/construction/ and architectural companies in Canada. The snow ball method was used to recruit research subjects to the questionnaire surveys. Firstly, the questionnaire was sent in Microsoft Word format. Secondly, it was sent in pdf format (pdf fillable forms).Thirdly, the SurveyMonkey web facility was used since some of the participants expressed their desire to participate in an online survey. The response rate was about 15% with all three methods.

Table 3.3 shows the sample distribution of demographic information of the participants in the questionnaire survey.

**Table 3.2:** Demographic information of the participants

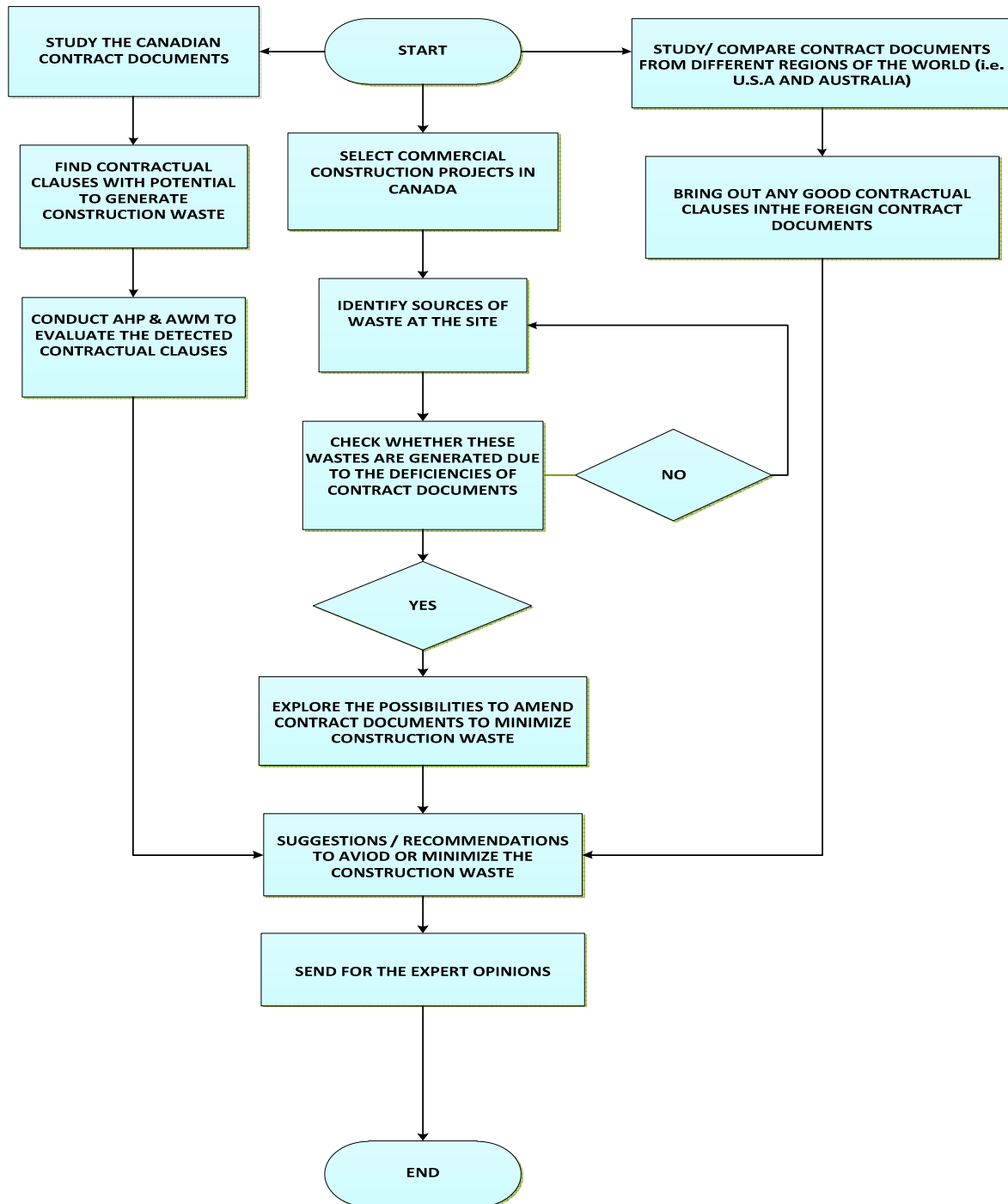
Factor	Number
Type of construction	Residential : 3
	Industrial : 4
	Commercial :12
	Heavy highway : 9
	Institutional (other) : 7
Job title	Project Mangers :12
	Site Superintendent : 1
	Construction Manager : 2
	Operations Manager : 2
	Development Manager : 1
	Project Coordinator : 3
	Director : 1
	General Manager : 1
	Architect : 1
	Structural Engineer : 2
	Division Manager : 1
	Sustainable Manager : 1
	Environmental Manager : 1
	Field Engineer : 1
	Access Planner : 1
Range of working experience in construction	8 years to 45 years with an average of 25 years.

Research participants were asked to prioritize the factors given in Table 4.1 and Table 4.2. The overall ranking values for analysis were taken by averaging individual ranking values of each participant. These values were used to evaluate alternatives in AHP and weights in AWM.



### 3.2 Research Framework

The following flow chart (Figure 3.1) summarizes the research methodology and activity plan.

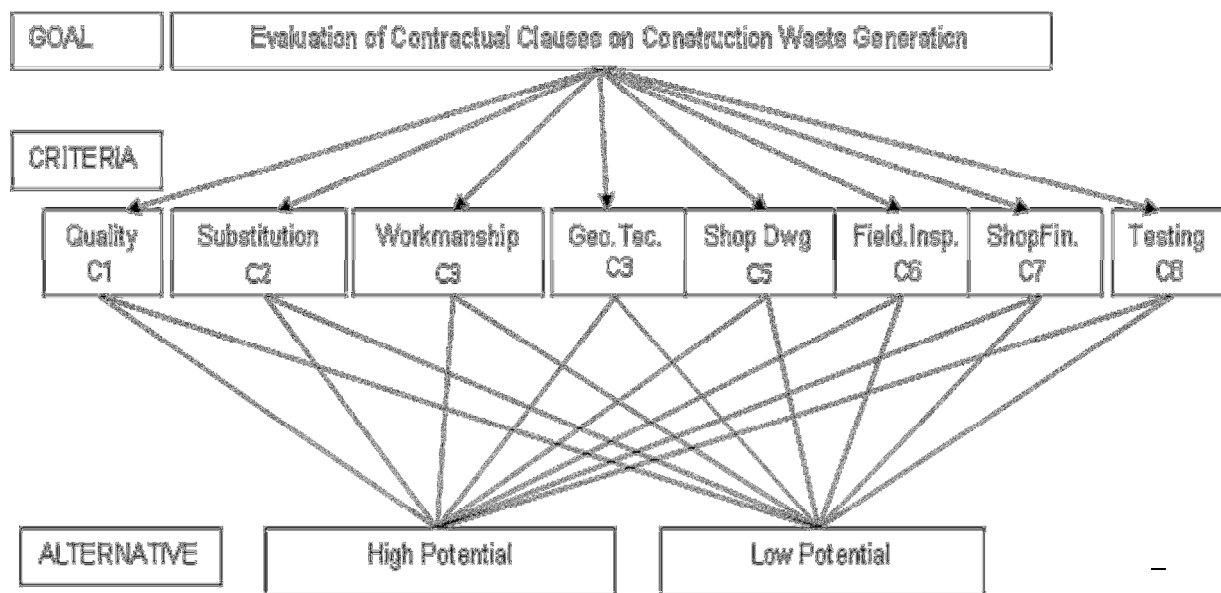


**Figure 3.1:** Graphical interpretation of the research framework

Applications of Analytical Hierarchy Process (AHP) and Attributed Weighted Method (AWM) in contract clause prioritization are described below.

### 3.2.1 Application of Analytical Hierarchy Process (AHP)

Figure 3.2 illustrates the hierarchical structure of the AHP. The crux of AHP is to evaluate the potential clauses, in terms of construction waste generation. The AHP hierarchy has three levels: i.e. 1) Evaluation of contractual clauses on construction waste generation was set as the goal (level 1), 2) In the middle (level 2), eight categories of contractual clauses were defined as multiple criteria, and 3) the two alternatives were defined as high potential and low potential to generate construction waste.



**Figure 3.2:** Hierarchical structure of AHP

Table 3.3 shows the seven point intensity scale used for pairwise comparison of criteria in AHP.

Survey participants used the rating scale of 1 -7 to compare the contractual clause categories where 1 and 7 represent extremely more important categories when compared to one another and 4 represents equally important category. For an example if the contractual clause categories

(indicated in table no 3.1) in column A is extremely more important than the contractual clause categories (indicated in table no 3.1) in column B the survey participant should rank this situation as rank 1 since this is the extremely important case. On the other hand if the contractual clause categories (indicated in table no 3.1) in column B is extremely more important than the contractual clause categories (indicated in table no 3.1) in column A the survey participant should also rank this situation as rank 1 since this is also the extremely important case. (Refer part 2 in Appendix 2) Those ratings have been converted to seven point intensity scale for AHP process. Then rating 1 and 7 in the questionnaire is equivalent to 7 in seven point intensity scale used in AHP.

**Table 3.3:** Relation between rating scale and equivalent seven point intensity scale of pairwise comparison matrix

RATING IN THE QUESTIONNAIRE	1	2	3	4	5	6	7
SEVEN POINT INTENSITY SCALE	7	5	3	1	3	5	7

In AHP, pairwise comparison matrix (PCM) for eight criteria,  $C_{ij}$  is defined as:

$$C_{ij} = \begin{pmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} & C_{17} & C_{18} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} & C_{27} & C_{28} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} & C_{37} & C_{38} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} & C_{47} & C_{48} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} & C_{57} & C_{58} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} & C_{67} & C_{68} \\ C_{71} & C_{72} & C_{73} & C_{74} & C_{75} & C_{76} & C_{77} & C_{78} \\ C_{81} & C_{82} & C_{83} & C_{84} & C_{85} & C_{86} & C_{87} & C_{88} \end{pmatrix} \quad (3.1)$$

Equation 3.2a and 3.3b represents  $C_{ij}$  as

$$C_{ij} = \frac{\sum_{i=1}^n S_i}{n} \quad (3.2a)$$

(Where  $i < j$  and  $i > j$ ,  $S_i$  = Weight calculated from a single participant of the expert opinion survey and  $n$  = no of participant for the survey)

$$C_{ij} = 1 \quad (\text{Where } i = j) \quad (3.2b)$$

Equation 3.3 shows normalized weights of PCM (W)

$$W = \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ w_8 \end{pmatrix} \quad (3.3)$$

Equation 3.4 shows one element of W ( $W_i$ ) as

$$W_i = \frac{(C_{i1} \times C_{i2} \times \dots \times C_{i8})^{1/8}}{\sum_{i=1}^8 (C_{i1} \times C_{i2} \times \dots \times C_{i8})^{1/8}} \quad (3.4)$$

Then two alternatives were evaluated against each and every criterion. Equation 3.5 shows the illustrated example for criteria no 1(category 1).

$$\begin{array}{cc}
 & \text{High potential} & \text{Low potential} \\
 \begin{pmatrix} \text{High potential} \\ \text{Low potential} \end{pmatrix} & \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} & 
 \end{array} \quad (3.5)$$

Equation 3.6a and 3.6b represents  $A_{ij}$  as

$$A_{ij} = \frac{\sum_{i=1}^n T_i}{n} \quad (\text{Where } i < j \text{ and } i > j) \quad (3.6a)$$

$$A_{ij} = 1 \quad (\text{Where } i = j) \quad (3.6b)$$

$T_i$  = Weight calculated from a single participant of the expert opinion survey,  $n$  = no of participant for the survey.

Then Equation 3.7 shows the potentiality matrix of category 1 and Equation. 3.8a and 3.8b shows its elements.

$$\text{Potentiality matrix} = \begin{pmatrix} A_1 \\ A_1^* \end{pmatrix} \quad (3.7)$$

$$A_1 = \frac{(A_{11} \times A_{12})^{1/2}}{(A_{11} \times A_{12})^{1/2} + (A_{21} \times A_{22})^{1/2}} \quad (3.8a)$$

$$A_1^* = \frac{(A_{21} \times A_{22})^{1/2}}{(A_{11} \times A_{12})^{1/2} + (A_{21} \times A_{22})^{1/2}} \quad (3.8b)$$

Thus Matrix A (Equation 3.9) contains the potentiality matrices of eight criteria (all clauses categories) and it represents relative contribution between two alternatives towards the eight criteria.

$$A = \begin{pmatrix} A_1 & A_2 & A_3 & A_4 & A_5 & A_6 & A_7 & A_8 \\ A_1^* & A_2^* & A_3^* & A_4^* & A_5^* & A_6^* & A_7^* & A_8^* \end{pmatrix} \quad (3.9)$$

$$\text{Risk ratio} = \begin{pmatrix} A_1 & A_2 & A_3 & A_4 & A_5 & A_6 & A_7 & A_8 \\ A_1^* & A_2^* & A_3^* & A_4^* & A_5^* & A_6^* & A_7^* & A_8^* \end{pmatrix} \times \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ w_8 \end{pmatrix} \quad (3.10)$$

Equation (3.10), Multiplication of W (Equation 3.3) and A (Equation 3.9) gives the risk ratio of High Potential clauses (HP) and Low potential clauses (LP). The risk ratio between High Potential clauses (HP) / Low potential clauses (LP) gives an indication of overall tendency of generating construction waste with respect to all the clauses. In addition, it is possible to rank the clause categories by considering the normalized form of PCM (W) since PCM can be considered as a group decision method.

### 3.2.2 Attribute Weighing Method (AWM) to Rank the Contractual Clauses

The categories of contractual clauses can be rank as per the average values from the questionnaire and survey results (Shown in Table 4.2). As per Stillwell et al 1981, attribute weights can be calculated and clauses can be ranked. These ranks can be taken as R1, R2, R3, R4, R5, R6, R7, R8 and n can be taken as no of categories. Then weights (W) can be calculated as per Equation 3.11 (rank reciprocal weights).

$$W = \frac{1 / R_i}{\sum_{k=1}^n 1 / R_k} \quad (3.11)$$

## **4 DATA ANALYSIS**

The data analysis conducted under questionnaire surveys, observations, and interviews are presented below.

### **4.1 Questionnaire Surveys on Contractual Clauses**

Questionnaire survey results were analyzed with AHP and AWM.

#### **4.1.1 Questionnaire Survey Analysis with AHP**

The summarized results of the pair-wise comparisons and prioritizations in questionnaire surveys are shown in Tables 4.1 & 4.2. The values of Table 4.1 were calculated by taking the average of all the responds. It represents the relative importance of contractual clauses in terms of generating construction waste. Therefore these average values directly provide the input values for the elements of the PCM. For an example, the average value 4.13 in the first raw of Table 4.1 means, it is the average value taken from the all questionnaire responses for pair-wise comparison between quality vs. substitution (i.e. quality is 4.13 times important than substitution in terms of generating construction waste).



**Table 4.1:** Pairwise comparison for clause categories

SYMBOL	PAIRWISE COMPARISON CATEGORY	AVERAGE VALUE
C <sub>12</sub>	Quality vs. Substitution	4.13
C <sub>13</sub>	Quality vs. Workmanship	1.36
C <sub>14</sub>	Quality vs. Geotechnical report	4.39
C <sub>15</sub>	Quality vs. Submittals/Shop drawings	3.84
C <sub>16</sub>	Quality vs. Field quality control/Inspection	1.68
C <sub>17</sub>	Quality vs. Shop finish	3.92
C <sub>18</sub>	Quality vs. Temporary or trial usage/testing	3.79
C <sub>23</sub>	Substitution vs. Workmanship	0.43
C <sub>24</sub>	Substitution vs. Geotechnical report	1.46
C <sub>25</sub>	Substitution vs. Submittals/Shop drawings	0.47
C <sub>26</sub>	Substitution vs. Field quality control/Inspection	1.56
C <sub>27</sub>	Substitution vs. Shop finish	2.07
C <sub>28</sub>	Substitution vs. Temporary or trial usage/testing	1.49
C <sub>34</sub>	Workmanship vs. Geotechnical report	4.28
C <sub>35</sub>	Workmanship vs. Submittals/Shop drawings	4.02
C <sub>36</sub>	Workmanship vs. Field quality control/Inspection	2.90
C <sub>37</sub>	Workmanship vs. Shop finish	3.98
C <sub>38</sub>	Workmanship vs. Temporary or trial usage/testing	4.18
C <sub>45</sub>	Geotechnical report vs. Submittals/Shop drawings	2.15
C <sub>46</sub>	Geotechnical report vs. Field quality control/Inspection	1.46
C <sub>47</sub>	Geotechnical report vs. Shop finish	2.20
C <sub>48</sub>	Geotechnical report vs. Temporary or trial usage/testing	2.14
C <sub>56</sub>	Submittals/Shop drawings vs. Field quality control/Inspection	1.83
C <sub>57</sub>	Submittals/Shop drawings vs. Shop finish	2.48
C <sub>58</sub>	Submittals/Shop drawings vs. Temporary or trial usage/testing	1.49
C <sub>67</sub>	Field quality control/Inspection vs. Shop finish	3.69
C <sub>68</sub>	Field quality control/Inspection vs. Temporary or trial usage/testing	3.88
C <sub>78</sub>	Shop finish vs. Temporary or trial usage/testing	1.52

The values of the average rating in Table 4.2 were calculated by taking the average values of all the responds of questionnaire surveys. The same values can also be used for calculating weights in AWM.

**Table 4.2:** Ranking of clause categories in terms of potential/influence on generating construction waste

CATEGORY	CLAUSE CATEGORY	AVERAGE RATING OVER GENERATING CONSTRUCTION WASTE
C1	Quality	5.81
C2	Substitution	4.06
C3	Workmanship	6.23
C4	Geotechnical report	3.58
C5	Submittals/Shop drawings	3.58
C6	Field quality control/Inspection	5.26
C7	Shop finish	2.58
C8	Temporary or trial usage/testing	4.65

Table 4.3 shows the elements of Pairwise comparison matrix (PCM). These elements of PCM for eight criteria were taken from Table 4.1 (questionnaire survey data). Notations C1 to C8 represent the clauses categories (Ref. Table no. 4.2).

**Table 4.3:** Pairwise comparison matrix (PCM) for the eight criteria

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1.00	4.13	1.36	4.39	3.84	1.68	3.92	3.79
C2	0.24	1.00	0.43	1.46	0.47	1.56	2.07	1.49
C3	0.74	2.34	1.00	4.28	4.02	2.90	3.98	4.18
C4	0.23	0.69	0.23	1.00	2.15	1.46	2.20	2.14
C5	0.26	2.12	0.25	0.47	1.00	1.83	2.48	1.49
C6	0.59	0.64	0.35	0.68	0.55	1.00	3.69	3.88
C7	0.26	0.48	0.25	0.45	0.40	0.27	1.00	1.52
C8	0.26	0.67	0.24	0.47	0.67	0.26	0.66	1.00

The Consistency ratio (CR) of PCM was 0.06039. As per Saaty (1990), when  $CR < 0.1$  PCM has the required consistency. Table 4.4 shows normalized weights of PCM and ranking of clause categories determined by the group decision method. Normalized weights of PCM, W (Equation 3.3) were determined as per Equation 3.4.

**Table 4.4:** Normalized weights of PCM and ranking of clause category

CATEGORY		NORMALIZED WEIGHTS	WEIGHTS %	RANK
Quality	C1	0.271759299	27.18%	1
Substitution	C2	0.089959277	9.00%	6
Workmanship	C3	0.255382627	25.54%	2
Geotechnical report	C4	0.095276561	9.53%	4
Shop drawings	C5	0.092826937	9.28%	5
Field quality& Inspection	C6	0.098565112	9.86%	3
Shop finish	C7	0.048175232	4.82%	7
Temporary trial & Testing	C8	0.048054955	4.81%	8

Thus complete ranking among eight clause categories are **C1 > C3 > C6 > C4 > C5 > C2 > C7 > C8**. As per the analysis, Quality clauses have the highest potential/risk to generate construction waste. The second and third priorities are Workmanship and Field quality & inspection clauses respectively. Quality, Workmanship, and Field quality& Inspection clauses have 27.18%, 25.54%, and, 9.86% of weight, respectively. Geotechnical report, Substitution clauses, and Shop drawings contain intermediate level of risk and Shop finish and testing account clauses have a low level risk. Matrix A (Equation 3.9) contains the potentiality matrices of eight criteria (all clauses categories) and it was calculated as per Equations 3.5, 3.6a, 3.6b, 3.7, 3.8a, 3.8b and 3.9.

As per equation 3.10 the ratio between High potentiality and Low potentiality

$$= 1.583366771 / 0.32165308$$

$$= 4.922591673$$

As per AHP analysis, all high potential contractual clauses (Quality, Workmanship and Field quality & Inspection) have **4.922** times high risk of creating construction waste than low potential clauses (Substitution, Geotechnical report , Shop drawings, Shop finish and Temporary trial & Testing).

#### 4.1.2 Questionnaire Survey Analysis with AWM

Questionnaire survey data on the clauses categories (in Table 4.2) have been used to rank (Table 4.5) by considering average rating of each category.

**Table 4.5:** Ranking of clause categories sorted weights in the order of their magnitudes

CLAUSES CATEGORY	RANK (USED SURVEY DATA)	$1/R_i$	WEIGHTS (AS PER EQUATION 3.11)	PERCENTAGES %
C3	1	1.00	0.36578013	36.57%
C1	2	0.50	0.18289006	18.29%
C6	3	0.33	0.12192671	12.19%
C8	4	0.25	0.09144503	9.14%
C2	5	0.20	0.07315602	7.32%
C4	6	0.15	0.05627386	5.63%
C5	7	0.15	0.05627386	5.63%
C7	8	0.14	0.05225430	5.23%
TOTAL			1.00	100%

Thus complete ranking among eight clauses is **C3 > C1 > C6 > C8 > C2 > C4, C5 > C7**. As per this result, workmanship clauses have the highest potential/risk to generate construction waste. The second and third priorities are taken by quality clauses and field quality & inspection clauses respectively. Quality, workmanship, and field quality& inspection clauses have 18.29%, 36.57%, and 12.19% of weight, respectively. Temporary trial & testing, and substitution clauses contain intermediate level of risk. Shop drawings, shop finish and geotechnical reports account for low level of risk.

Having considered both analyses, following three clauses categories can be ranked as top priority clauses.

- Clause category no 1: Quality Clauses
- Clause category no 3: Workmanship Clauses
- Clause category no 6: Field quality control, Inspection Clauses

They have the highest potential or risk of generating construction waste. Moreover, AHP results proved high potential contractual clauses have 4.922 times the risk of creating construction waste than low potential clauses. Thus the attention should be paid to revised, alter or removed these high potential / risk contractual clauses from contract documents.

#### **4.2 On Site Observation and Interviews (Incident Analysis)**

During site visits multiple evidences related to construction waste were found. The following section analyzes six such selected incidences. The reason (source) behind all of the following incidences was poor coordination among stakeholders, design professionals, construction manager, and sub-contractors.

##### **Incident 1:**

Observation:

Parapet wall height of the roof was increased to accommodate roof insulation layers. Composite Aluminum panels and moisture barrier, gypsum boards and steel studs were among the construction waste.

Interview:

The project manager and site superintendent stated that it happened due to the lack of coordination among subcontractors. Construction professionals were urged to impose a

contractual clause to highlight the obligatory requirement for the coordination during pre-construction and construction phase to avoid such incidents.

Related contractual clauses:

Related clauses can be identified as the Clause category no 6 part 3 and Clause category no 5 (Ref: Table 3.1). As per the contractual agreement, each and every sub-contractor is committed to complete the work regardless of the responsibility of the fault. Moreover, the owner and consultant are protected through contractual clauses such as the location, arrangement and connection of equipment and materials as shown on the drawings represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner (Clause category no 6 part 3 ) and it creates a huge potential to create construction waste.

### **Incident 2 & 3:**

Observation:

The part of the floor slab has been removed to accommodate new plumbing ducts. Concrete and mixed construction waste was recognized as construction waste.

Interview:

The project manager and project coordinators stated that it happened due to the lack of coordination among subcontractors and designers (structural and mechanical). The project manager highlighted the need to impose a contractual clause to build the obligatory requirement for the coordination throughout the life cycle of the project to avoid the incidents like this.

Related contractual clauses:

Related clauses can be identified as Clause category no 6 part 3 and Clause category no 5 (Ref: Table 3.1). As per the contractual agreement, each and every sub-contractor is committed to complete the work regardless of the responsibility of the fault. Moreover the owner and consultant are protected through contractual clauses such as Clause category no 6 part 3 and it creates a huge potential to create construction waste.

#### **Incident 4 & 5:**

Observation:

A part of the concrete slab has been removed to accommodate new floor drains. Concrete and mixed construction wastes were recognized as construction waste.

Interview:

The project manager stated that it happened due to lack of coordination among subcontractors and designers (structural and Mechanical). The project manager highlighted the need to impose a contractual clause to build the obligatory requirement for the coordination among designers and sub-contractors throughout the life cycle of the project avoid such incidents.

Related contractual clauses:

Related clauses can be identified as Clause category no 6 part 3 and Clause category no 5 (Ref: Table no 3.1). As per the contractual agreement, each and every sub-contractor is committed to complete the work regardless of the responsibility of the fault. Moreover, the owner and consultant are protected by contractual clauses such as such as Clause category no 6 part 3 and it creates a huge potential to create construction waste.

## **Incident 6:**

### **Observation:**

A part of the steel slab (steel joists, cross bracings and metal sheets) has been removed to accommodate new HVAC facilities. The construction waste of this incident was mixed construction waste and structural steel.

### **Interview:**

The project manager stated that above incident happened due to lack of coordination among subcontractors and designers (structural and HVAC). The project manager highlighted the need to impose a contractual clause to have an obligatory requirement for the coordination among designers and sub-contractors throughout the lifecycle of the project to minimize such incidents.

### **Related contractual clauses:**

Related clauses can be identified as Clause category no 6 part 3 and Clause category no 5(Ref: Table 3.1). As per the contractual agreement, each and every sub-contractor is committed to complete the work regardless of the responsibility of the fault. Moreover, the owner and consultant are protected through contractual clauses such as Clause category no 6 part 3 and it creates possibility to create construction waste.



**Figure 4.1:** Wasted steel joists, cross bracings and metal sheets



### 4.3 Cost Benefit Analysis of Revising Contractual Obligations

The Cost benefit analysis was done to analyze net benefits, which can be achieved by avoiding construction waste generated due to the deficiencies of contract documents and contractual clauses. This analysis was based on reported six incidents in section 4.1. Cost benefit analysis was done to evaluate cost and benefits of removing, adding, and revising the contract documents /contractual clauses.

Net benefits (NB) can be calculated as:

$$NB = TB - TC \quad (4.1)$$

Total benefits can be considered as an addition of several components (TB).

Following are the components of TB

Purchasing cost of new materials	=	B1
Transportation cost of new materials	=	B2
Cost of landfills to dump the old materials	=	B3
Cost of labour	=	B4
Benefit of having well written contract document	=	B5

B5 can be considered as addition of several components

They are:

Extra to contract amount	=	D1
Additional staff to achieve the work (Site superintendent etc.)	=	D2
Architectural and engineering staff to attend	=	D3
Temporary protection	=	D4

O/T Premium	=	D5
Heat and equipment	=	D6
Fuel	=	D7

Then:

$$B5 = D1 + D2 + D3 + D4 + D5 + D6 + D7 \quad (4.2)$$

Values D1 to D7 were taken as normally distributed ( $\mu$ ,  $\sigma$ ) and B5 can be calculated by Equation 4.3.

$$B5 = \mu_{D1} + \mu_{D2} + \mu_{D3} + \mu_{D4} + \mu_{D5} + \mu_{D6} + \mu_{D7} \quad (4.3)$$

Where  $\mu_{Di}$  is mean value of  $i^{\text{th}}$  component.

Then following Externalities (intangible benefits) were taken into account.

Benefits of reducing vehicle pollution	=	B6
Benefits of avoiding traffic congestion	=	B7
Benefits of avoiding road crashes	=	B8
Fuel Externalities	=	B9
Reducing roadway costs	=	B10
Noise Pollution	=	B11
Global warming cost	=	B12
Tipping fee & leachate, gas and monitoring costs	=	B13
Property depreciation, landfill site, adjacent properties	=	B14

Direct cost can be categorised in the following sub headings (TC).

Cost of consultancy fee (legal fee) for removing, Changing and adding clauses = CO1

Cost of delays while implementing new Contract language = CO2

Cost of employing additional professionals to inspect frequent design changes,  
coordinate stakeholders to check the changes before construction starts = CO3

Cost of learning curve effects = CO4

$$TC = CO1 + CO2 + CO3 + CO4 \quad (4.4)$$

As per the site staff CO4 was negligible.

Then:

$$TC = CO1 + CO2 + CO3 \quad (4.5)$$

Values TC was taken as normally distributed ( $\mu$ ,  $\sigma$ ) and TC can be calculated by Equation 4.6.

$$TC = \mu_{CO1} + \mu_{CO2} + \mu_{CO3} \quad (4.6)$$

Where  $\mu_{COi}$  is mean value of  $i^{th}$  component.

TB can be expressed as:

$$TB = B1 + B2 + B3 + B4 + B5 + B6 + B7 + B8 + B9 + B10 + B11 + B12 + B13 + B14 \quad (4.7)$$

Equation no. (4.1) can be expressed as:

$$NB = [(B1 + ..... + B14) - (\mu_{CO1} + \mu_{CO2} + \mu_{CO3})] \quad (4.8)$$

Calculating the Benefits (B1 to B14)

The following values of B1 to B4 were provided by site staff of the visited construction site.

Purchasing price of new materials B1 for all incidents = \$ 11,233.30

(Transportation cost of new materials B2 included in material prices)

Cost of landfill to dump /recycle facilities the old materials B3 for all incidents = \$ 6,687.95

Cost of labour B4 = \$ 9,136.00

As per the collected data from the site visit, the following were noted as additional cost to the general contractor and if the observed construction projects had a properly written contract document with appropriate contractual clauses, these additional costs would be avoided. It can be taken as the benefit of having proper contract documents (B5). The breakdown of costs are as follows:

**Table 4.6:** Factors and values contributing to the benefit of having well written contract document

COMPONENT		MEAN( $\mu$ )	SD( $\sigma$ )
Extra to contract amount	D1	150,000	10,000
Additional staff to achieve the work (site staff)	D2	400,000	10,000
Architectural and Engineering staff	D3	200,000	10,000
Temporary protection	D4	30,000	1,000
O/T Premium	D5	200,000	10,000
Heat and Equipment	D6	60,000	1,000
Fuel	D7	30,000	1,000

As per Equation 4.3:

Benefit of having well written contract document (B5) = \$1,070,000

In calculating vehicle externalities, all the values were calculated as per:

- a) Vehicle usage for new material delivery to the construction site (within 50 km)
- b) Vehicle usage for transporting waste material to the landfill at Glenmore (10 km)
- c) Vehicle usage for transporting waste material to the recycle facilities ( facilities at Surrey and Vancouver area),400 km

For illustration purposes, calculations for Incident 1 are shown.

As per (Litman, 2005), cost of vehicle pollution is taken as 0.025/Veh/km.

Benefit of reducing vehicle pollution B6 = \$11.25

As per (Litman, 2005), cost of traffic congestion is taken as 0.030/Veh/km.

Benefit of avoiding traffic congestion B7 = \$13.30

As per (Litman, 2005), cost of road crashes is taken as 0.025/Veh/km.

Benefit of avoiding road crashes B8 = \$11.25

As per (Litman, 2005), cost of fuel externalities is taken as 0.025/Veh/km.

Benefit of avoiding fuel externalities B9 = \$11.25

As per (Litman, 2005), cost of roadway costs is taken as 0.010/Veh/km.

Benefit of considering roadway costs B10 = \$ 4.50

As per (Litman, 2005), cost of noise pollution is taken as 0.010/Veh/km.

Benefit of reducing Noise Pollution B11 = \$ 3.38

As per Lemp et al (2008), cost of global warming is taken as 0.08/Veh/km.

Benefit of reducing global warming cost B12 = \$ 36.00

Total waste of six incidents (kg) = \$67145

As per Hirshfeld et al (1992), cost of tipping fee & leachate, gas and monitoring is taken as \$ 54.00 / ton.

Benefit of reducing tipping fee & leachate, gas and monitoring costs (B13) = \$ 3996.80

As per Hirshfeld et al (1992), cost of property depreciation, landfill site, adjacent properties is taken as \$ 12.40 / ton.

Benefit of reducing property depreciation, landfill site, adjacent properties (B14) = \$ 917.80

**Table 4.7:** Summarized values of total benefit calculation

<b>BENEFIT TYPE</b>		<b>COST/\$</b>
Purchasing price of new materials	B1	11,233.30
Transportation cost of new materials(included in B1)	B2	0.00
Cost of landfill to dump /recycle facilities the old materials	B3	6,687.95
Cost of labour	B4	9,136.00
Benefit of having well written contract document	B5	1,070,000.00
Benefit of reducing vehicle pollution	B6	56.25
Benefit of avoiding traffic congestion	B7	67.50
Benefits of avoiding road crashes	B8	56.25
Fuel externalities	B9	56.25
Reduced roadway cost	B10	22.50
Noise pollution	B11	16.90
Global warming cost	B12	180.00
Tipping fee & Leachate, gas and monitoring costs	B13	3,996.80
Property depreciation, landfill site, adjacent properties	B14	917.80
<b>Total Benefits(TB)</b>		<b>1,102,427.50</b>

According to the site staff, Total Cost (TC) can be considered as:

Mean Value ( $\mu$ ) = \$ 50000.00

Standard Deviation ( $\sigma$ ) = \$ 1000.00

As per Equation 4.6:

TC = \$ 50,000.00

Then:

Using equations (4.1), Net Benefit (NB) can be determined as \$ 1,052,427.50.

## **5 COMPARATIVE STUDIES OF CONTRACT DOCUMENTS**

The objective of this chapter is to compare and contrast contractual clauses of Canadian, American, and Australian contractual agreements in terms of the potential for generating construction waste and suggest amendments to minimize/avoid construction waste. All the selected construction documents were analyzed under eight categories described in Table 3.1. As mentioned, potential to create construction waste due to the nature of contract clauses is the base criteria for the following analysis.

### **5.1 Analyzing Contractual Clauses Under Eight Categories Mentioned in Table 3.1**

#### **5.1.1 Quality**

##### **Canada:**

- “Unless otherwise specified in the Contract Documents, products provided shall be new. Products, which are not specified shall be of a quality consistent with those specified and their use acceptable to the Consultant” (CCDC2 – 2008, Clause no: GC 3.8.2).
- “Should any dispute arise as to quality or fitness of product, decision rests strictly with consultant based upon requirements of contract documents” (Project Manual/CCDC2 – 2008).
- “Replace materials less than specified quality or as designated by architect and relocate work incorrectly installed as determined by architect” (Project Manual/CCDC2 – 2008).

As per above clauses, quality should be “acceptable” to the consultant.



### **United States of America:**

- “The Design-Builder may visit the site at intervals appropriate to the stage of the Contractor’s operations to become generally familiar with and to keep informed about the progress and quality of the portion of the Work completed. However, the Design-Builder shall not be required to make exhaustive or continuous on-site inspections to check the quality or quantity of the Work. The Design-Builder shall neither have control over or charge of, nor be responsible for, the construction means, methods, techniques, sequences or procedures, or for the safety precautions and programs in connection with the Work, since these are solely the Contractor’s rights and responsibilities under the Contract Documents, except as provided in Section A.3.3.1” (Design - Builder /Contractor Agreement, Terms and Conditions: AIA, A142- 2004/Exhibit A, Clause no: A.2.3).

According to this clause, continuous checking of quality is not a requirement of the design - builder.

### **Australia:**

- “The Contractor shall, if requirements as to quality assurance are so stated in the Contract, Any such quality system shall be used only as an aid to achieving compliance with the Contract and to document such compliance. Such system shall not relieve the Contractor of the responsibility to comply with the Contract” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no: 30.1)
- “Where the Contract allows for the substitution of materials or standards of workmanship which are equal to or the equivalent of those specified, the question of their similarity and quality or equivalence shall be determined by the Superintendent” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no: 30.1)

- “The Contractor remains responsible for quality of the Works carried out under this Contract even though the Superintendent may have had such work tested or otherwise indicated that such work is in accordance with the Contract or otherwise acceptable” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no: 30.2)

According to these clauses:

- (1) The quality of the work is strictly under the responsibility of contractor whether the consultant approved or not.
- (2) Decision of the quality is strictly based on the superintendent’s (consultant’s) judgment.

### **Suggestions:**

According to the Canadian and Australian documents, quality of work should be approved by the consultant. However, these clauses do not specify a timeframe for such approvals. American documents emphasize continuous checking of quality; however, it is not a strict responsibility of the consultant (design-builder). As per all these contractual clauses, in general, the contractor is the party who is responsible for the quality of the work regardless of the testing and inspection of the consultant. This concept has a good chance to create construction waste since as per these clauses the consultant/owner can reject the completed work. To minimize such situations, a contract clause should be introduced to fairly distribute the responsibilities of quality inspection among the contractor and the consultant. More consultant involvement with real time quality checking is needed to reduce rework and waste. Such a contractual clause was not written in any of the countries analyzed in this study.

### **5.1.2 Substitution**

#### **Canada:**

- “There is no obligation on the part of the consultant or owner to accept proposed substitutions. Acceptance of proposed substitutions by owners does not relieve the contractor’s responsibility under the contract” (Project Manual/ CCDC2 – 2008).

As per this clause, acceptance of substitution does not guarantee that it will not be rejected in the future and substituted material may be demolished /dumped later, thereby creating construction waste.

#### **United States of America:**

- “The Contractor warrants to the Design-Builder that materials and equipment furnished under the Contract Documents will be of good quality and new unless otherwise required or permitted by the Contract Documents, that the Work will be free from defects not inherent in the quality required or permitted by law or otherwise, and that the Work will conform to the requirements of the Contract Documents. Work not conforming to these requirements, including substitutions not properly approved and authorized, may be considered defective. The Contractor’s warranty excludes remedy for damage or defect caused by abuse, modifications not executed by the Contractor, improper or insufficient maintenance, improper operation, or normal wear and tear and normal usage. If required by the Design-Builder, the Contractor shall furnish satisfactory evidence as to the kind and quality of materials and equipment” (Design - Builder /Contractor Agreement, Terms and Conditions: AIA, A142- 2004/Exhibit A Clause no: A.3.5).

According to this clause, substitution, which is not approved by consultant may be considered as defective regardless of its quality.

**Australia:**

- “Where the Contract allows for the substitution of materials or standards of workmanship, which are equal to or the equivalent of those specified, the question of their similarity and quality or equivalence shall be determined by the Superintendent” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no: 30.1).

As per this clause, decision of the substitution is strictly based on the superintendent’s (consultant’s) judgment.

**Suggestions:**

Canadian documents state that the consultant or the owner does not guarantee the acceptance of the substitution, whereas Australian and American documents do not have such a clause. In general, contractor is the party who is responsible for the substitution of the work and the acceptance depends on the decision of the consultant. This concept is critical for the completed work and there is a good chance to create construction waste since the consultant/owner may reject the completed work. To avoid such situation, a contract clause may be written to approve the proposed substitution before the substitution has taken place (construction begins). The acceptance or rejection criteria should be clearly defined by the contract document with a clause. This type of contractual clause does not seem to exist in any of the countries under the study.

**5.1.3 Workmanship****Canada:**

- “Decisions as to quality or fitness of workmanship in case of dispute rest with the consultant, whose decision is final” (Project Manual/ CCDC2 – 2008).

- “The Contractor shall promptly correct defective work that has been rejected by the Consultant as failing to conform to the Contract Documents whether or not the defective work has been incorporated in the Work and whether or not the defect is the result of poor workmanship, use of defective products or damage through carelessness or other act or omission of the Contractor” ..... (CCDC2 – 2008, Clause no: GC 2.4.1).

As per these clauses, decision of the workmanship is strictly based on the consultant’s judgment.

#### **United States of America:**

- “The Contractor shall promptly correct defective work that has been rejected by the Consultant as failing to conform to the Contract Documents whether or not the defective work has been incorporated in the Work and whether or not the defect is the result of poor workmanship, use of defective products or damage through carelessness or other act or omission of the Contractor” (Design - Builder /Contractor Agreement, Terms and Conditions: AIA, A232- 2009 General conditions of the contract for construction, Construction Manager as adviser, Clause no:12.2).

The consultant’s decision is crucial and consultant’s decision can be bounded by the phrase “failing to conform to the requirements of the contract documents”. It does not explain what the conformation requirements are.

- “Except as otherwise required by the Contract documents or provided by any special warranties furnished there under, CONTRACTOR shall promptly and properly repair, replace, restore, or rebuild, as OWNER determines, any finished Work in which defects of materials or workmanship may appear or damage may occur because such defects for a period of three (3) calendar years commencing on the Date of Substantial Completion”

(The City of Indianapolis Storm water Design and Construction Specifications Manual 2001)

Here the owner determines the defects of the workmanship.

**Australia:**

- “The Contractor shall use the materials and standards of workmanship required by the Contract. In the absence of any express requirement elsewhere in the Contract to the contrary, the Contractor shall use suitable new materials. Where the Contract allows for the substitution of materials or standards of workmanship which are equal to or the equivalent of those specified, the question of their similarity and quality or equivalence shall be determined by the Superintendent” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no: 30.1).

As per this clause, decision of the quality is based on the superintendent’s (consultant’s) judgment.

These clauses were quoted from commercial cost plus contract general conditions.

“On expiration of the Defect Liability Period, the Contractor is to give the Owner a final claim in accordance with Clause 14, certifying the balance of all monies claimed by the Contractor arising out of, or in connection with, the Contract” (General Conditions of Commercial Cost plus Contract, Queensland Master Builders Association, Clause no: 26).

“Costs of making good defects and faults which are not due to materials or workmanship not in accordance with this Contract.” (General Conditions of Commercial Cost plus Contract, Queensland Master Builders Association, Clause no: 30.2).

Decision can be bounded by the phrase “in accordance with this Contract”.

**Suggestions:**

Having referred to the above mentioned contractual clauses from three countries, it is clearly apparent that the consultant /owner has the key role to determine the acceptance of the workmanship of the work provide by the contractor. A phrase like “failing to conform to the requirements of the contract documents” and “in accordance with this contract” transfer the contractual agreements in to a gray area. There should be a pre-defined standard by explaining how the consultant or owner takes the decisions related to workmanship of certain building components (i.e. as per the technical specification of relevant work packages). Otherwise the contractor or owner may take the advantage of vague language and it may trigger changes to the completed work, which creates construction waste.

**5.1.4 Geotechnical Report****Canada:**

- “If the Owner or the Contractor discovers conditions at the Place of the Work which are: Subsurface or otherwise concealed physical conditions which existed before the commencement of the Work which differ materially from those indicated in the Contract Documents; or Physical conditions, other than conditions due to weather, that are of a nature which differ materially from those ordinarily found to exist and generally recognized as inherent in construction activities of the character provided for in the Contract Documents, then the observing party shall give Notice in Writing to the other party of such conditions before they are disturbed and in no event later than 5 Working Days after first observance of the conditions” (CCDC2 – 2008, Clause no: GC 6.4.1).
- “If the Consultant finds that the conditions at the Place of the Work are not materially different or that no change in the Contract Price or the Contract Time is justified, the

Consultant will report the reasons for this finding to the Owner and the Contractor in writing” (CCDC2 – 2008, Clause no: GC 6.4.3)

As per these contractual clauses, the parties determine the work may change if sub surface conditions are found to vary substantially from those indicated in the initial soil report. Excavating deeper than the expected depth (mentioned in the drawings) does not fall in to the extra category unless it is a material change. Therefore the contractor may be instructed to excavate deeper creating more soil waste without being paid additional monies it tends to create more construction waste. On top of that there is no indication which party (owner or contractor) should provide the geotechnical report.

**United States of America:**

- “If the Contractor encounters conditions at the site that are (1) subsurface or otherwise concealed physical conditions that differ materially from those indicated in the Contract Documents or (2) unknown physical conditions of an unusual nature, that differ materially from those ordinarily found to exist and generally recognized as inherent in construction activities of the character provided for in the Contract Documents, the Contractor shall promptly provide notice to the Owner and the Architect before conditions are disturbed and in no event later than 21 days after first observance of the conditions. The Architect will promptly investigate such conditions and, if the Architect determines that they differ materially and cause an increase or decrease in the Contractor’s cost of, or time required for, performance of any part of the Work, will recommend an equitable adjustment in the Contract Sum or Contract Time, or both. If the Architect determines that the conditions at the site are not materially different from those indicated in the Contract Documents and that no change in the terms of the Contract is



justified, the Architect shall promptly notify the Owner and Contractor in writing, stating the reasons” .....(AIA, A 201- 2007 General conditions of the contract, Clause no: 3.7.4).

As per this contractual clause, the architect is the person who decides the claim and the architect’s decision seems to be final (unless challenged in courts) among the immediate project participants.

- “The Owner shall furnish services of geotechnical engineers, which may include test borings, test pits, determinations of soil bearing values, percolation tests, evaluations of hazardous materials, seismic evaluation, ground corrosion tests and resistivity tests, including necessary operations for anticipating subsoil conditions, with written reports and appropriate recommendations” (AIA, C 191 Exhibits A – 2009, Clause no: 3.7.4).

As per this clause the owner should provide the geotechnical engineer’s service.

#### **Australia:**

- ”Where the Drawings and Specification indicate the nature of the ground below the surface of the site and/or the depth to which excavations will have to be made to provide footings or foundations or services, then any extra work caused by conditions being other than those indicated in the Drawings and Specification or caused by the necessity to excavate to a greater extent than that so indicated shall be deemed to be a variation” (Master Builders Association of Western Australia; Medium Works Contract – 2007, Clause no: 25).
- “Should it appear in excavating for footings and/or services that the site will not support the Works as designed, then the Contract may be terminated without liability on either side except that the Builder shall be entitled to be paid the actual cost to him of his work up to the date when it was ascertained that the site would not support the Works” (Master

Builders Association of Western Australia; Medium Works Contract – 2007, Clause no: 25).

- “Where the Drawings and Specification indicate the nature of the ground below the surface of the site or the depth to which excavations will have to be made to provide footings or foundations or services, then any extra work caused by conditions being other than as indicated or caused by the necessity to excavate to a greater extent than indicated is a variation” (Master Builders Association of Western Australia; Cost Plus Contract – 2007, Clause no: 22).
- “Where the Drawings and Specification indicate the nature of the ground below the surface of the site and/or the depth to which excavations will have to be made to provide footings or foundations or services, then any extra work caused by conditions being other than as indicated is a variation” (Master Builders Association of Western Australia; Resident building Work Contract – 2007, Clause no: 24).

As per these clauses, requirement of extra work does not relate to sub-surface material, rather it is related to the excavation depth. It allows defining “extra to contract” without considering the material mentioned in the geotechnical report. Deeper excavation than the contract specified is enough to claim for extras to the contract. Termination of contract can be done when the previous design does not support the current site condition.

- The Contractor warrants that it has examined the Site and surrounds and satisfied itself through its own investigation as to the condition and characteristics which may be encountered on, in or under the Site (including sub-surface conditions) and as to the further geotechnical or other information for the Site that may be required to be obtained by the Contractor; and made its own assessment of the risks, contingencies and other

circumstances which might affect the Works and has allowed fully for these in the Contract Price. (New South Wales government general conditions of Contract, GC21: Edition 1, Clause no: 40).

As per this clause the principal (owner) transfer the risk of subsequence of what is mentioned in the geotechnical report. The contractor should not rely on the information provided by the principal. The contractor is required to do its own site investigation and was required to obtain its own assessment. Therefore, the principal or consultant can change the scope of work (foundation design) without considering what is mentioned in the geotechnical report provided by the contractor. The principal can change foundation (type, dimensions or location of certain footings etc.) in the middle of the construction period due to unexpected sub surface condition. These types of situations have potential to create construction waste.

### **Suggestions:**

In Canada and United States of America, the contractor can claim additional soil work as extra only if the subsurface materials differ from that contemplated by the contract document. Australian document made by Master Builder Association allows the contractor to make additional claim when deeper excavation is required and it does not specify as to the type of material under excavation. As per New South Wales government (Australia) contract document, the contractor should conduct his or her own soil investigation. However the contract document of Master Builders Association from Australia and the contract document of other two countries do not have such directions.

The owner or the principal can transfer the risk generated by the geotechnical report. Contractor may include more contingencies on the bid price to cover the risk which result is a

higher contract price. Ultimately, the owner or the principal is the party who bears the higher cost.

The clauses which are written to remove the liability of the owner or the principal should be removed and a clause highlighting (validating) the responsibility of the information provided in the contract document by the owner or the principal should be included. This approach may reduce unnecessarily high contract prices and future litigation.

The principal may direct the contractor to conduct a separate geotechnical investigation, however all parties may share their information to fairly share possible risks. The agreed report may be used when taking a decision for the extra work. This approach encourages every party to have responsibility for the changes to the scope of work. Distributed responsibility may reduce construction waste.

### **5.1.5 Submittals, Shop Drawings**

#### **Canada:**

- “Consultant’s review does not relieve contractor of his responsibility for accuracy of shop drawings. This review of the shop drawings shall not, in any way, relieve the contractor from complying with all requirements of the contract documents” (CCDC2 – 2008, GC 3.10, Clause no: 3.10.10).

As per this clause, the consultant does not take the responsibility of own review and the consultant transfers the risk of accuracy of the details mentioned in the shop drawing back to the contractor. The contractor has to take the overall responsibility of field dimensions. Usually the contractor receives the approved shop drawings after a couple of weeks depending on the urgency of the job. Usually the contractor commences the work immediately after receiving the approved drawings. Identification of a change after this point by the consultant or contractor

(change directive, change order, contemplated change notice) creates definite rework. This situation may create construction waste since in most cases the materials had already been fabricated or work had already been completed the consultant does not take the responsibility of such situations due to above mentioned contractual clauses. The field observations in commercial construction projects in Canada verified quite a few such cases.

**United States of America:**

- “The Work shall be in accordance with approved submittals except that the Contractor shall not be relieved of responsibility for deviations from requirements of the Contract Documents by the Architect’s approval of Shop Drawings, Product Data, Samples or similar submittals unless the Contractor has specifically informed the Architect in writing of such deviation at the time of submittal and (1) the Architect has given written approval to the specific deviation as a minor change in the Work, or (2) a Change Order or Construction Change Directive has been issued authorizing the deviation. The Contractor shall not be relieved of responsibility for errors or omissions in Shop Drawings, Product Data, Samples or similar submittals by the Architect’s approval thereof” (AIA, A 201-2007 General conditions of the contract for construction, Clause 3.12.8).
- “The Design-Builder shall review and approve or take other appropriate action upon the Contractor’s submittals required by the Contract Documents, but only for the limited purpose of checking for conformance with information given and the design concept expressed in the Contract Documents. The Design-Builder’s action shall be taken with such reasonable promptness as to cause no delay in the Work or in the activities of the Contractor or separate contractors. Review of such submittals is not conducted for the purpose of determining the accuracy and completeness of other details, such as

dimensions and quantities, or for substantiating instructions for installation or performance of equipment or systems, all of which remain the responsibility of the Contractor as required by the Contract Documents” (AIA, A 142 - 2004/Exhibit A, Clause A.2.3.5).

- “The Design-Builder’s review and approval of the Contractor’s submittals required by the Contract Documents shall not relieve the Contractor of responsibility for compliance with the Contract Documents unless (a) the Contractor has notified the Design-Builder of the deviation prior to approval by the Design-Builder, or (b) the Design-Builder has approved a change in work reflecting any deviations from the requirements of the Contract Documents” (AIA, A 142 - 2004/Exhibit A, Clause A.2.3.6).
- “.....The Architect will review and approve or take other appropriate action upon the Contractor’s submittals such as Shop Drawings, Product Data and Samples, but only for the limited purpose of checking for conformance with information given and the design concept expressed in the Contract Documents.....” (AIA, A 232 – 2009: General Condition of Contract, Clause A.4.2.10).
- “The Work shall be in accordance with approved submittals except that the Contractor shall not be relieved of responsibility for deviations from requirements of the Contract Documents by the Architect’s approval of Shop Drawings, Product Data, Samples or similar submittals unless the Contractor has specifically informed the Construction Manager and Architect in writing of such deviation at the time of submittal and (1) the Architect has given written approval to the specific deviation as a minor change in the Work, or (2) a Change Order or Construction Change Directive has been issued authorizing the deviation. The Contractor shall not be relieved of responsibility for errors

or omissions in Shop Drawings, Product Data, Samples or similar submittals by the Architect's approval thereof" (AIA, A 232 – 2009: General Condition of Contract, Clause A.3.12.8).

After a careful review of the above mentioned clauses, it was noted that the consultant does not take the responsibility of the review and approval. Contractor is not relieved of responsibility for deviations from the contract documents in a later stage.

- "The approval of submittals by the government shall not be construed as a complete check, but will indicate only that the general method of construction, materials, detailing and other information is satisfactory. Approval will not relieve the Contractor of the responsibility for any error which may exist, as the Contractor under the Contractor's Quality Control (CQC) requirements of this contract, is responsible for the dimensions and design of adequate connections, details, and satisfactory construction of all work. After submittals have been approved by the government, no resubmittal for the purpose of substituting materials or equipment will be given consideration unless accompanied by an explanation as to why a substitution is necessary" (Construction Specifications, ATCT & TRACON at McCarran International Airport, Las Vegas, Nevada).
- "Field Measurements: Contractor is to verify that field measurements are as indicated on construction and/or shop drawings before confirming product orders or proceeding with work, in order to minimize waste due to excessive materials" (Construction Specifications, ATCT & TRACON at McCarran International Airport, Las Vegas, Nevada).

As per these clauses, consultant does not take the responsibility of dimensions and field measurement and the risk of errors is transferred to the contractor. Such a situation may create construction waste due to rework in the project construction phase.

- “Shop Drawings, Product Data, Samples and similar submittals are not construction documents. The purpose of their submittal is to demonstrate for those portions of the Work for which submittals are required the way the contractor proposes to conform to the information given and the design concept expressed in the construction documents” (Dane county department of administration Madison, Wisconsin, Clause no:3H).
- “The Contractor shall not be relieved of responsibility for deviations from requirements of the Construction Documents by the Public Works Project Engineer’s approval of Shop Drawings, Product Data, Samples and similar submittals unless the Contractor has specifically informed the Public Works Project Engineer in writing of such deviation at the time of submittal and the Public Works Project Engineer has given written approval to the specific deviation. The Contractor shall not be relieved of responsibility for errors or omissions in Shop Drawings, Product Data, Sample or similar submittals by the Public Works Project Engineer’s approval thereof” (Dane county department of administration Madison, Wisconsin, Clause no:3H).

As per these clauses, shop drawings and submittals are not construction documents and the engineer does not take the responsibility of his or her own review.

### **Australia:**

The authors could not find anything related to the shop drawings or submittals from the reviewed Australian contractual documents.



**Suggestions:**

The Canadian and American contract documents state that the consultants are not liable for the errors in the approved shop drawings. The referred Australian documents do not include this concept in their documents. Authors believe that the consultant (engineer or architect)/owner may be responsible for what they have reviewed and approved, including accuracy of the dimension mentioned in the submittals. If such an approach is adopted, the consultant/ owner will be forced to be more careful in reviewing the shop drawings and any submittals. It may be implemented as multiple checks for the contract documents. In addition, the shop drawings and submittals may be considered as construction documents. Above suggested changes to the current contractual clauses related to the shop drawings and submittals may reduce construction waste significantly.

**5.1.6 Field Quality Control, Inspection****Canada:**

- “Field service by the consultant or his representative does not in any way relieve the contractor of his responsibility to carry out the work per the contract document and contract drawings” (Project Manual/CCDC2 – 2008).
- “Contractors work will be inspected periodically by the Engineer solely for the purpose of determining general quality of work, and not for other purpose. Guidance will be offered to the contractor in interpretation of plans and specifications to assist them to carry out work. Inspections and directives given to contractor does not relieve contractor and his agent, servants and employee of their responsibility to erect and install work in its parts in a safe and workmanlike, and in accordance with the plans and specifications, nor impose upon the Engineer any responsibility to supervise or oversee erection or

installation of any work. The location, arrangement and connection of equipment and materials as shown on the drawings represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner” (Project Manual/CCDC2 – 2008).

- “The location, arrangement and connection of equipment and materials as shown on the drawings represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner” (Project Manual/CCDC2 – 2008).

As per these clauses, consultants do not take the responsibility of their inspections in terms of quality or accuracy of the work done. Consultants may later reject already completed and approved work by referring to these clauses. These types of contract clauses create a considerable potential to generate construction waste.

- “The Consultant may order any portion or portions of the Work to be examined to confirm that such work is in accordance with the requirements of the Contract Documents. If the work is not in accordance with the requirements of the Contract Documents, the Contractor shall correct the work and pay the cost of examination and correction. If the work is in accordance with the requirements of the Contract Documents, the Owner shall pay the cost of examination and restoration” (CCDC2 – 2008, Clause no: GC 2.3).

Again, a consultant’s decision can be bounded by the phrase “not in accordance with the requirements of the contract documents”.

## **United States of America:**

- “The Architect will visit the site at intervals appropriate to the stage of construction, or as otherwise agreed with the Owner, to become generally familiar with the progress and quality of the portion of the Work completed, and to determine in general if the Work observed is being performed in a manner indicating that the Work, when fully completed, will be in accordance with the Contract Documents. However, the Architect will not be required to make exhaustive or continuous on-site inspections to check the quality or quantity of the Work. The Architect will not have control over, charge of, or responsibility for, the construction means, methods, techniques, sequences or procedures, or for the safety precautions and programs in connection with the Work, since these are solely the Contractor’s rights and responsibilities under the Contract Documents, except as provided in Section 3.3.1” (AIA, A 201 – 2007: General Condition of Contract, Clause no: 4.2.2.).
- “On the basis of the site visits, the Architect will keep the Owner reasonably informed about the progress and quality of the portion of the Work completed, and report to the Owner (1) known deviations from the Contract Documents and from the most recent construction schedule submitted by the Contractor, and (2) defects and deficiencies observed in the Work. The Architect will not be responsible for the Contractor’s failure to perform the Work in accordance with the requirements of the Contract Documents. The Architect will not have control over or charge of and will not be responsible for acts or omissions of the Contractor, Subcontractors, or their agents or employees, or any other persons or entities performing portions of the Work” (AIA, A 201 – 2007: General Condition of Contract, Clause no: 4.2.3.)

As per these clauses, site inspection by an architect is to generally familiarize himself /herself with the progress and the quality of work. The architect does not assure the quality of the work process since a continuous inspection is not emphasized. However, the architect holds the authority to reject the inspected work by bounding the contractor to “the requirements of the contract documents”. An architect’s inspection does not necessarily prevent future modifications and rework.

**Australia:**

- “The Contractor shall not be entitled to rely upon any inspections or tests carried out under this clause 31.1, whether such inspection or tests are carried out by the Contractor, the Principal, the Superintendent or by some other person” (Australian Standard, NSW: general conditions of contract, AS 2124—1992, Clause no 31.1).

As per this clause, the contractor cannot depend on the inspection or quality test done by the consultant or the owner. This type of a clause raises the absolute value of such formal inspections. Completed work may be rejected in a later stage, even if the initial result of the test or the inspection is acceptable. There is a potential to generate waste due to this type of clauses.

**Suggestions:**

All the reviewed contract documents in three countries transfer the responsibility of quality inspection to the contractors even though the consultants routinely perform quality inspections. It may be beneficial to conduct joint field tests with contractors and consultants during pre-identified intervals in construction. A contract is suggested clause to emphasize joint quality inspections.

### **5.1.7 Temporary or Trial Usage, Testing**

#### **Canada:**

- “It is agreed and understood, that no claim for damage will be made for any injury or breakage to any part or parts of above due to aforementioned tests, whether caused by weakness or inaccuracy of parts, or by defective materials or workmanship of any kind whatsoever. Supply all labour and equipment for such tests” (Project Manual/CCDC2 – 2008).
- “The Contractor shall pay the cost of making any test or inspection, including the cost of samples required for such test or inspection, if such test or inspection is designated in the Contract Documents to be performed by the Contractor or is designated by the laws or ordinances applicable to the Place of the Work” (CCDC2 – 2008 Clause no: GC 2.3).

#### **United States of America:**

- “Tests, inspections and approvals of portions of the Work shall be made as required by the Contract Documents and by applicable laws, statutes, ordinances, codes, rules and regulations or lawful orders of public authorities. Unless otherwise provided, the Contractor shall make arrangements for such tests, inspections and approvals with an independent testing laboratory or entity acceptable to the Owner, or with the appropriate public authority, and shall bear all related costs of tests, inspections and approvals. The Contractor shall give the Construction Manager and Architect timely notice of when, and where, tests and inspections are to be made so that the Construction Manager and Architect may be present for such procedures. The Owner shall bear costs of (1) tests, inspections or approvals that do not become requirements until after bids are received or negotiations concluded, and (2) tests, inspections or approvals where building codes or

applicable laws or regulations prohibit the Owner from delegating their cost to the Contractor” (AIA 232 -2009, General Conditions of Contract, Clause no:13.5).

- “If such procedures for testing, inspection or approval under Sections 13.5.1 and 13.5.2 reveal failure of the portions of the Work to comply with requirements established by the Contract Documents, all costs made necessary by such failure including those of repeated procedures and compensation for the Construction Manager’s and Architect’s services and expenses shall be at the Contractor’s expense” (AIA 232 -2009, General Conditions of Contract, Clause no: 13.5).

According to the above contractual relations in Canada & United States of America, cost of all the testing is mostly a responsibility of the contractor.

#### **Australia:**

- “The Principal may instruct the Contractor at any time to Test any part of the Works. The Principal must pay for the Tests (as an addition to the Contract Price) if the results of the Tests show full compliance with the Contract. Otherwise, the Contractor must pay” (New South Wales Government GC21, General Conditions of Contract, Clause no: 49).
- “The Contractor must repeat the Tests (at his own cost) of all parts of the Works where Defects have been found, until the results of these Tests, as reported in writing to the Principal, confirm that all Defects have been made good and that the Works comply with the Contract” (New South Wales Government GC21, General Conditions of Contract, Clause no: 49).
- Costs of, and incidental to, testing shall be valued under clause 40.5 and shall be borne by the Principal or paid by the Principal to the Contractor unless:
  1. The Contract provides that the Contractor shall bear the costs .....

2. The test shows that the material or work is not in accordance with the Contract
  3. The test is in respect of Work under the Contract covered up or made inaccessible without the superintendent's prior .....
  4. The test is consequent upon a failure of the Contractor to comply with a requirement of the Contract.....
  5. (Australian Standard General Conditions of Contract, AS 2124—1992, Clause no: 31.7).
- “The Contractor remains responsible for quality of the Works carried out under this Contract even though the Superintendent may have had such work tested or otherwise indicated that such work is in accordance with the Contract or otherwise acceptable” (Australian Standard General Conditions of Contract, AS 2124—1992, Clause no: 31.7).

Referring to the above contractual clauses of Australia, the cost of testing is not the responsibility of the contractor by default. Here initial testing is done at the expenses of the owner when the results of the tests show full compliance with the Contract. When defects have been found the contractor should pay and repeat the tests until the tests show that the material or work is in accordance with the Contract. This is a reasonable approach.

### **Suggestions:**

Canadian and American contract documents state that the contractor should pay the cost of the testing whereas the Australian contract document state that the cost of the testing should be paid by the owner, if the results of the tests show full compliance with the Contract. Having referred to the above contractual clauses used by three countries, authors suggest transferring the cost of testing to the principal or owner unless:

- (1) The test shows that the material or work is not in accordance with the contract

(2) The test is in respect of work under the contract covered up or made inaccessible without the Superintendent's prior approval where such was required

(3) The test is consequent upon a failure of the Contractor to comply with a requirement of the Contract.

It is also suggested that the testing be performed the testing with an independent agency. The suggested approach may eliminate unnecessary and repeated testing by the owner or consultant by creating construction waste.

## **5.2 Additional Contractual Clauses and Suggestions**

Following contractual clauses were also related to construction waste management. These could not be grouped into the main eight categories identified in Table 3.1.

### **5.2.1 Review of Contract Documents and Field Conditions by Contractor**

#### **United States of America:**

- “Because the Contract Documents are complementary, the Contractor shall, before starting each portion of the Work, carefully study and compare the various Contract Documents relative to that portion of the Work, as well as the information furnished by the Owner pursuant to Section 2.2.3, shall take field measurements of any existing conditions related to that portion of the Work, and shall observe any conditions at the site affecting it. These obligations are for the purpose of facilitating coordination and construction by the Contractor and are not for the purpose of discovering errors, omissions, or inconsistencies in the Contract Documents; however, the Contractor shall promptly report to the Architect any errors, inconsistencies or omissions discovered by, or made known to, the Contractor as a request for information in such form as the Architect may require. It is recognized that the Contractor’s review is made in the



Contractor's capacity as a contractor and not as a licensed design professional, unless otherwise specifically provided in the Contract Documents" (AIA 201-2007, General conditions of the contract for construction, Clause no.3.2.2)

- "The Contractor shall check drawings immediately upon their receipt and shall promptly notify the Contracting Officer's Technical Representative (COTR) of any discrepancies. Figures marked on drawings shall be followed. Scale measurements shall be used only if approved by the COTR. The Contractor shall compare all drawings and verify the figures before laying out the work and shall be responsible for any errors that might have been avoided thereby. Review of Contract Documents and Field Conditions: Immediately on discovery of the need for clarification of the Contract Documents, submit a request for information to COTR. Include a detailed description of problem encountered, together with recommendations for changing the Contract Documents" (Construction Specifications, Specifications for New ATCT & TRACON at McCarran International Airport, Las Vegas, Nevada, Clause no:1.5 D ).

**Canada:**

- "The Contractor shall review the Contract Documents and shall report promptly to the Consultant any error, inconsistency or omission the Contractor may discover. Such review by the Contractor shall be to the best of the Contractor's knowledge, information and belief and in making such review the Contractor does not assume any responsibility to the Owner or the Consultant for the accuracy of the review. The Contractor shall not be liable for damage or costs resulting from such errors, inconsistencies or omissions in the Contract Documents, which the Contractor did not discover. If the Contractor does discover any error, inconsistency or omission in the Contract Documents, the Contractor

shall not proceed with the work affected until the Contractor has received corrected or missing information from the Consultant” (CCDC2 – 2008, Clause no: GC 3.4).

As per the above contractual clauses in North America, the contractor is contractually bound to check the drawings and contract documents for errors and inform the consultant of same.

#### **Australia:**

- “The Contractor, in addition to any responsibility to check Principal’s Documents under clause 44 (if applicable), must check the Contract Documents and notify the Principal of any ambiguities, inconsistencies or discrepancies at least 21 days before the Contractor proposes to use them for Design or construction (including procurement, manufacture or fabrication of any part of the Works) or for other Contract purposes.” (New South Wales Government GC21 General Conditions of Contract, Clause no: 42).

As per the Australian provincial government contractual agreement, the contractor is contractually bound to check the drawing for errors and inform the consultant.

- “The owner warrants the accuracy and suitability of contract documents and other documents and data provided to the contractor“(The Master Builders Queensland Commercial building contract, Clause no: 5a).
- “If the Owner is to supply the Drawings and/or the Specification, then without cost to the Builder the Owner must provide the Builder with six copies of the Drawings and/or the Specification as the case may be to enable the Builder to perform the Works and obtain the consents, permits and authorities required. Where the Owner provides the Drawings and Specification, the Owner expressly warrants they are accurate in each and every particular” (Master Builders Association of Western Australia: Cost Plus Contract 2007 Clause no: 4b).

- “If the Owner is to supply the Drawings and/or the Specification, then without cost to the Builder the Owner must provide the Builder with six copies of the Drawings and/or the Specification as the case may be to enable the Builder to perform the Works and obtain the consents, permits and authorities required. Where the Owner provides the Drawings and Specification, the Owner expressly warrants they are accurate in each and every particular. Where the Builder provides the Drawings and Specification, the Builder expressly warrants they are accurate in each and every particular” (Master Builders Association of Western Australia: Residential Building Works Contract 2007, Clause no: 4b).
- “If the Owner is to supply the Drawings and/or the Specification, then without cost to the Builder the Owner shall provide the Builder with six copies of the Drawings and/or the Specification as the case may be to enable the Builder to perform the Works and obtain the consents, permits and authorities required. Where the Owner provides the Drawings and Specification, the Owner expressly warrants that the said Drawings and Specification are accurate in each and every particular. Where the Builder provides the Drawings and Specification, the Builder expressly warrants that the said Drawings and Specifications are accurate in each and every particular” (Master Builders Association of Western Australia: Home Building Works Contract 2007, Clause 4b).

As per the contractual clauses mentioned in this Australian provincial Master Builder Association contractual agreement, the party which is producing contract document should be responsible for the accuracy of the document and that party should warrant the content of the document. It is noteworthy to mention that the Master Builder Associations are composed of construction companies, and they preferred to transfer the risk of errors to the other party. In the

waste management point of view, it is important to get the warranty from the party/organization which makes the contract document (and drawings). The organization which made the drawings is more familiar with its document than any other party.

As per North American contractual agreement, the contractor is contractually bound to check the drawing for errors and report to the consultant. Australian provincial government (NSW) contractual agreement also states the same requirement whereas the contract document produced by the Master Builders Association of Western Australia (MBAWA) clearly states that the party which is producing the contract document should be responsible for the accuracy of the document.

### **5.2.2 Conformance with Plans and Specifications**

#### **United States of America:**

- “All Work performed, and all materials furnished, shall be in reasonably close conformance with the lines, grades, cross sections, dimensions, and material requirements, including tolerances, shown on the plans or indicated in the specifications. Plan dimensions and specifications values are to be considered as the target value to be complied with as the design value from which any deviations are allowed. It is the intent of the specifications that the materials and workmanship shall be uniform in character and shall conform as nearly as realistically possible to the prescribed target value or to the middle portion of the tolerance range. The purpose of the tolerance range is to accommodate occasional minor variations from the median zone that are unavoidable for practical reasons. When a maximum or minimum value is specified, the production and processing of the Material and the performance of the Work shall not be preponderantly

of borderline quality or dimension” (Standard General Conditions for Construction Contracts, City Of Indianapolis, Clause No: 6.30.2).

As per this clause, the city’s contract document only gives approximate dimension with a target value and tolerance. So there is no exact requirement of the dimensions, material requirement, and workmanship. The contractor should finish work within a reasonable range of quality and workmanship. Rejection of complete work (from the clients’ side) may be difficult due to the range of the values. This clause has lesser potential to create construction waste.

### **5.2.3 General Consultation Responsibilities of the Contractor**

- “Throughout the development of the Contract Documents, the Contractor shall advise the Company on proposed site use and improvements, selection of materials, and building systems and equipment. The Contractor shall also provide recommendations on constructability; availability of materials and labour; time requirements for procurement, installation and construction; and factors related to construction cost including, but not limited to, costs of alternative designs or materials, the Company’s Budget for the Work, and possible cost reductions” (AIA, C 199 – 2010: Exhibit A, Terms and conditions Clause no: 4.2).

According to this clause the contractor should provide the advice on constructability and installation procedure to the stakeholders and the contractor is the right party to make decision on constructability. This approach may reduce the potential to generate construction waste since authors observed that many cases of rework originated due to the lack of knowledge of the designers.

### **5.2.4 Coordination**

- “Coordinate scheduling, submittals, and work of various sections of Specifications to assure efficient and orderly sequence of installation of interdependent construction elements. Verify utility requirement characteristics of operating equipment are compatible with building utilities. Coordinate space requirements and installation of mechanical and electrical work that are indicated diagrammatically on Drawings” (Project Manual of Dane County Department of Administration, Madison, Wisconsin USA, Clause no: 1.6).

It was observed that many incidents of lack of coordination among the contractor and consultant created rework and waste. A clause which highlights a coordinating requirement is vital. Authors suggest similar clauses in other standard construction documents.

### **5.2.5 Material Storage**

- “Storage and Protection: Designate receiving/storage areas for incoming material to be delivered according to installation schedule and to be placed convenient to work area in order to minimize waste due to excessive materials handling and misapplication. Store and handle materials in a manner as to prevent loss from weather and other damage. Keep materials, products, and accessories covered and off the ground, and store in a dry, secure area. Prevent contact with material that may cause corrosion, discoloration, or staining. Protect all materials and installations from damage by the activities of other trades” (Model Specifications for Construction Waste Reduction, Reuse, and Recycling, Triangle J Council of Governments, 1995, Clause no: Part 3A/Execution).

There were several observed incidents of material mishandling, which ultimately created considerable waste. The above clause is useful to minimize such situations.

## **6 RECOMMENDATIONS AND CONCLUSIONS**

As per the data analysis with questionnaire surveys, it can be concluded that following three contractual clauses have the top potential to create construction waste.

- Category 1 (Quality)
- Category 3 (Workmanship)
- Category 6 (Field quality control, Inspection)

It is necessary to attend above three contractual clause categories on priority basis to minimize its potential on generating construction waste. The remedy would be a revision/alternation or completely removal of the clauses. To avoid the six incidents which were reported during the onsite observation, a contract clause to build coordination among stakeholders during pre-construction stage should be imposed. This can be concluded from the onsite interview process.

In terms of construction waste management, none of the countries produced a fully acceptable document. The parties which write the contract documents transferred more risk to the other parties through contract clauses. This practice tends to create construction waste. The risks that are mainly outside the contractor's control should be allocated to the client/consultant.

### **6.1 Recommendations Initiated by Survey Participants and Field Professionals**

The following additional recommendations, based on expert opinions, can be given to improve current waste management practices in commercial construction projects.

- a) During the design stage, each and every sub trade should exchange their designs/constructability views to avoid conflicts during the construction stage. It is

advisable to have a common database of design details and drawings. It is recommended to include a contract clause or clauses to highlight the obligatory requirement for the coordination among the necessary project stakeholders throughout the lifecycle of the project.

- b) Many projects generally start before completing the overall contract documents such as construction drawings, technical specifications etc. Further, most construction processes commence even before completing necessary designs. It is recommended introducing a contract clause not to begin the construction process at least without absolutely necessary designs and other contract documents. In addition, all contract documents should be completed as per the intended purpose of the project without following the typical design. It is safe to have a completed drawing set before the tendering process.
- c) After completing the final design, a model (computer or physical) should be used to visualize the structure. The idea is to check whether the design has fulfilled the stakeholders' expectations such as owner's requests. Especially a client with no technical background may not understand technical drawings and specifications. It is worthy to consider a contract clause to fill the current visualization gap in the industry.
- d) Industry experts suggested consultants to pay for their errors and have reasonable liability on consulting, design, and reports. They suggested a clear contract clause with such information in contract documents.
- e) If possible, the construction team should be involved in the design process to avoid impracticable design output. By a contractual clause, this idea can be strengthened.
- f) Single sources of specification should not be used and they should be always tailored for project requirements.



- g) Nowadays almost all the design and drafting works are done by software packages and designers usually copy the details of old or previous drawings to the current ones. This approach may copy the items which are not relevant to the current project drawings and later these items may be included into the estimates and will be delivered to the site. A proper computer design document procedure enforced through contract documents is advisable.
- h) Contractual clauses imposing penalties for the expedited changes should be created to minimize material waste due to such changes at a later stage.
- i) Once the designs (structural and architectural) are finalized, the completed designs should be checked by the expert design team to catch the design errors, and reimbursement for incorrect designs should be implemented. The drawings and technical specifications should be jointly checked by the consultant. A design meeting should be held prior to construction to ensure all requirements of the stakeholder's are met. The design team should be accountable for the impact attributable to the incomplete design. These concepts can be implemented through contractual clauses as well.
- j) LEED is a popular sustainability rating system that has a great potential to reduce waste by diverting waste into recycling and utilization of sustainable products. Integration of complimentary General Conditions within the LEED scoring template could be considered. Insisting that the contract has bonus clauses that will make the contractor strive to recycle may increase the recycle content, which will ultimately decrease the material waste.
- k) Change order should be processed as soon as possible to avoid wastes in materials already procured or installed.

- l) Insisting bonus clauses that make the contractor strive to recycle those materials that the contractor can on site.
- m) Packing materials should be sent back for recycling.
- n) Scope changes which shift soil or concrete work at ground level during winter conditions should be avoided to avoid rejection of work due to inadequate heating. (i.e. poor/incomplete design).
- o) Cities or provinces should not issue new clauses without consultation with contractors before implementing. A partnership process for creating contract documents should be emphasized.
- p) Clauses such as “in the first instant the contractor / consultant shall look at solution to minimize waste resulting from.....” should be included in the contractual agreements.
- q) Clauses such as “Notify the consultant in writing of any discrepancy in the contract documents prior to proceeding ...” should be avoided since it relieves the consultant responsibility on drawing coordination.
- r) The Owner’s decision to overrule the consultant’s decision may create construction waste. The owner should promote sustainable solutions suggested by consultants

## **6.2 Recommendations Initiated by Comparative Study of Contract Documents**

- a) As per all the contractual clauses of three different countries reviewed in this research, the contractor is responsible for the quality of the work regardless of the testing and inspection of the consultant. This concept has a high potential to create construction waste since the consultant/owner can reject the completed work based on quality. To minimize such situations, a contract clause should be introduced to fairly distribute the responsibilities of quality inspection among the contractor and the consultant. More

consultant involvement in joint quality checking may reduce rework and waste. It may be beneficial to conduct joint field tests with contractors and consultants or to perform the testing with an independent agency. This suggested approach may eliminate unnecessary and repeated testing by the owner or consultant by creating construction waste. It can be done at pre-identified intervals in construction.

- b) In general, contractor is the party who is responsible for the substitution of the work and the acceptance depends on the decision of the consultant. This concept generally creates construction waste since the consultant/owner may reject the completed work due to unacceptable substitution as per their decision. To avoid such situations, a contract clause may be written to approve the proposed substitution before the substitution has taken place (construction begins). The acceptance or rejection criteria should be clearly defined by the contract document with a clause.
- c) Having referred to the above mentioned contractual clauses from three countries, it is clearly visible that the consultant /owner has the responsibility to accept the “workmanship” of the work completed by the contractor. A phrase like “failing to confirm to the requirements of the Contract Documents” and “in accordance with this Contract” transfer the contractual agreements in to a gray area. There should be a pre-defined standard by explaining how the consultant or owner takes the decisions related to workmanship of certain building components (i.e. as per the technical specification of relevant work packages). Otherwise the contractor or owner may take the advantage of vague language and it may trigger changes to the completed work, which creates construction waste.

- d) The clauses which are written to remove the liability of the owner or the principal from the information provided in the contract documents should be removed. In the waste management point of view, it is important to get the warranty from the party/organization which makes the contract document (and drawings). The organization which made the contract documents such as drawings is familiar with its document than any other party. A clause highlighting (validating) the responsibility of the information provided in the contract documents, by the owner or the principal, should be included. This approach may reduce unnecessarily high contract prices and future litigations.
- e) The principal may direct the contractor to conduct a separate geotechnical investigation, however all parties may share their information to fairly share potential risks. The agreed report may be used when taking a decision for extra work. This approach encourages every party to have responsibility for the changes to the work. Distributed responsibility may reduce construction waste.
- f) The consultant (engineer or architect)/owner should be responsible for what he/she has reviewed and approved, including accuracy of the dimension mentioned in the submittals. If such an approach is adopted, the consultant/ owner will be forced to be more careful in reviewing the shop drawings and submittals. It may be implemented as multiple checks for the contract documents. In addition, the shop drawings and submittals should be considered as construction documents.
- g) Transfer the cost of testing to the principal or owner unless;
- I. The test shows that the material or work is not in accordance with the contract.
  - II. The test is in respect of work under the contract covered up or made inaccessible without the consultant's prior approval where such was required.

III. The test is consequent upon a failure of the contractor to comply with a requirement of the contract.

- h) The contract may specify a reasonable range of quality and workmanship depending on the type of work. Rejection of complete work (from the clients' side) could be reduced due to the specified range. Such a clause has lesser potential to create construction waste.
- i) The contractor should provide advices on constructability and installation procedure to other stakeholders since the contractor is the right party to take decision on constructability. This approach may reduce potential to generate construction waste. It was observed in many cases that rework was originated due to the lack of knowledge of the designers and owners on constructability.
- j) New Construction materials should be delivered according to installation schedule and they should be stored in a convenient area in order to minimize waste due to contamination, excessive materials handling and misapplication. There were several observed incidents of material mishandling, which ultimately created considerable waste.

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## **APPENDICIES**

### **Appendix 1: Consent Form**

#### **Consent Form**

**To investigate clauses/sections of contract documents for potentials/loopholes to create Construction waste.**

#### **Principal Investigator:**

Name: Dr. Kasun Hewage, P.Eng.  
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#### **Co-Investigator(s):**

Names: Daylath Mendis  
Phone: 250 869 9470  
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Statistical data gathered in this research may be used in the research thesis of MASc degree. Total confidentiality and privacy of research participants will be protected in any publications and presentations.

#### **Sponsor:**

This research is funded by National Sciences and Engineering Research Council of Canada (NSERC).

#### **Purpose:**

This research project aims to suggest amendments and develop best practices to minimize/avoid construction waste due to deficiencies of contract documents. You are being invited to take part in this research study to share your professional experiences related to contract documents and construction waste. The research participants are construction field professionals and managers.

**Study Procedures:**

The data will be collected through questionnaire surveys, interviews, and observations.

**Questionnaire Survey:** A questionnaire will be sent to construction and consultancy service companies. Questionnaire will take about fifteen to twenty minutes to complete. Construction managers, engineers, architects and field professionals will be requested to answer the questionnaire. Their participation is completely voluntarily. Results of the questionnaire survey will be used to conduct data analysis using Analytical Hierarchy Process (AHP).

**Observations:** Direct observations will be conducted in active construction projects. Observation will be done for six months at three selected construction projects. Number of visits and duration of observations in each project will depend on the volume of construction waste materials. While visiting sites, contract documents of those projects will also be carefully reviewed. All possible sources of construction waste will be observed and analyzed against the clauses of contract documents.

**Interviews:** An interview will take about thirty minutes. The researchers may contact the same professional twice for clarification purposes. Interview questions will be based on their experience levels and familiarity on contract documents. Depending on the availability, one to five professionals will be invited to participate in the study from each site or organization.

This study does not involve any control groups. There will not be any known adverse effects to the participants by participating in this research.

**Potential Risks:**

There are no known risks for the participants by providing their opinions in this research project.

**Potential Benefits:**

Benefits of this research to the construction industry as whole are:

1. Construction companies will be notified the relative importance of the clauses in terms of potentials to generate construction waste.
2. Construction companies will be able to amend construction documents with revised versions of the clauses or/and additional clauses, to eliminate potentials to generate construction waste due to deficiencies of the contract documents.
3. A Decision Making Model (DMM) for the industry for future contract documentation.

**Confidentiality:**

All documents will be identified only by code number and kept in a locked filing cabinet in Dr. Kasun Hewage's office. Subjects will not be identified by name in any reports of the completed

study. All the computer files will be password protected. This will be kept until the thesis is defended then data will be deleted from the database. This is scheduled on July 2011.

**Contact for information about the study:**

If you have any questions or desire further information with respect to this study, you may contact Dr. Kasun Hewage or one of his associates at 1-250-807-8176.

**Contact for concerns about the rights of research subjects:**

If you have any concerns about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at 1-888-822-8598 or the UBC Okanagan Research Services Office at 250-807-8832.

**Copy of the finding of this research:**

If you like to receive a copy of the finding/results of the research please provide your email address below.

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**Consent:**

Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without jeopardy to your employment, class standing, access to further services from the community centre, day care, etc.

Your signature below indicates that you have received a copy of this consent form for your own records.

Your signature indicates that you consent to participate in this study.

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Participant's Signature

---

Date

---

Printed Name of the Participant

## Appendix 2: Questionnaire

Questionnaire

Date:

Number:

Note: All the information will be kept confidential and will not be disclosed to your company or any other persons. It will remain with the University of British Columbia.

### IMPACTS OF PROJECT CONTRACT DOCUMENTS ON REWORK AND WASTE GENERATION

This document consists of two major sections:

1. Questionnaire
2. Appendix 3

#### 1. Demographic Information (Kept confidential):

##### 1.1 Type of construction (Please select as appropriate):

- |                          |   |
|--------------------------|---|
| a. Residential .....     | b. Industrial .....                       |
| c. Commercial .....      | d. Infrastructure and heavy highway ..... |
| e. Other (specify) ..... |   |

##### 1.2 Job title:

.....

##### 1.3 Years of working experience in construction:

.....

## PART 1

Please rank the potentials to generate **Construction waste** under each category of Contract clauses by using **8 point intensity scale**. Use 1 to indicate the least potential and 8 to indicate the most potential.

Please refer the following example:

If you think “**Quality**” clauses (Category 1 in Appendix 3) are the most important among **all clauses** (all categories in Appendix 1) you should write” **8**” under column 3(the column which indicates the RANK).

Table 1: Ranking of categories in Appendix 3.

CATEGORY	DESCRIPTION OF CLAUSES	RANK
1	Quality	
2	Substitution	
3	Workmanship	
4	Geotechnical report	
5	Submittals/Shop drawings	
6	Field quality control/Inspection	
7	Shop finish	
8	Temporary or trial usage/testing	



## PART 2

Please evaluate the relative importance of Contractual Clauses stated in the **Appendix 3** in terms of potential to generate **Construction waste** by filling column C in table 3. Please use the guidance given in table 2.

Table 2: Comparison categories and their ratings.

Description	RATINGS
Column A is <b>extremely</b> more important than column B	1
Column A is <b>more</b> important than column B	2
Column A is <b>moderately</b> more important than column B	3
Column A is <b>equally</b> important as column B	4
Column B is <b>moderately</b> more important than column A	5
Column B is <b>more</b> important than column A	6
Column B is <b>extremely</b> more important than column A	7

### RAW 1: Quality vs. Substitution

If you think Contractual clauses related to “**Quality**” (Category 1 in Appendix 3) are more important than Contract clauses related to “**Substitution**” (Category 2 in Appendix 3) in terms of generating **Construction waste**, you should write “**2**” in column C of the table 3.

Table 3: Comparison table.

RAW NO.	COLUMN A	COLUMN B	COLUMN C
1	Quality	Substitution	
2	Quality	Workmanship	
3	Quality	Geotechnical report	
4	Quality	Submittals/Shop drawings	
5	Quality	Field quality control/Inspection	
6	Quality	Shop finish	
7	Quality	Temporary or trial usage/testing	
8	Substitution	Workmanship	
9	Substitution	Geotechnical report	
10	Substitution	Submittals/Shop drawings	
11	Substitution	Field quality control/Inspection	
12	Substitution	Shop finish	
13	Substitution	Temporary or trial usage/testing	
14	Workmanship	Geotechnical report	
15	Workmanship	Submittals/Shop drawings	
16	Workmanship	Field quality control/Inspection	
17	Workmanship	Shop finish	
18	Workmanship	Temporary or trial usage/testing	
19	Geotechnical report	Submittals/Shop drawings	
20	Geotechnical report	Field quality control/Inspection	
21	Geotechnical report	Shop finish	
22	Geotechnical report	Temporary or trial usage/testing	
23	Submittals/Shop drawings	Field quality control/Inspection	
24	Submittals/Shop drawings	Shop finish	
25	Submittals/Shop drawings	Temporary or trial usage/testing	
26	Field quality control/Inspection	Shop finish	
27	Field quality control/Inspection	Temporary or trial usage/testing	
28	Shop finish	Temporary or trial usage/testing	

### PART 3

1. Have you noticed any other contractual clauses in your current/previous projects which have potential to generate construction waste?

.....

.....

2. Please state your suggestions to change or modify any contractual clauses to minimize construction waste generation.

.....

.....

3. Any other comments related to construction waste and contract documents/obligations.

.....

.....

.....

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.....

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### **Appendix 3: Contractual Clauses with Potentials to Generate Rework or Waste**

The following contractual clauses with the potential to generate rework or waste were found by studying the contract documents of several construction projects.

#### **1. Category 1/Quality**

- I. Should any dispute arise as to quality or fitness of product, decision rests strictly with consultant based upon requirements of contract documents.
- II. Replace materials less than specific quality or as designated by architect and relocate work incorrectly installed as determined by architect.

#### **2. Category 2/Substitution**

- I. There is no obligation on the part of the consultant or owner to accept proposed substitutions. Acceptance of proposed substitutions by owners does not relieve the contractor's responsibility under the contract.

#### **3. Category 3/Workmanship**

- I. Decisions as to quality or fitness of workmanship in case of dispute rest with consultant, whose decision is final.

#### **4. Category 4/Geotechnical report**

- I. The report, by its nature, cannot reveal all conditions that exist or can occur on the site. Should sub surface conditions be found to vary substantially from those indicated in the soil report, changes in the design and construction of foundations will be made accordingly with resulting credits or expenditures accruing to the owner.

#### **5. Category 5/Submittals, Shop drawings**

- I. The consultant's review does not relieve the contractor of his responsibility for accuracy of shop drawings. This review of the shop drawings shall not, in any way, relieve the contractor from complying with all requirements of the contract documents.
- II. Field verify all building and site dimensions prior to any fabrication and installation of equipment or materials. No contract revisions will be considered for failure to verify these dimensions on site.
- III. Any review of shop drawings is for sole purpose of ascertaining conformance with the general design concept. This review shall not mean approval of detail design inherent in

the shop drawings, responsibility for which shall remain with the contractor submitting same and as such review shall not relieve the contractor of responsibility for errors or omissions in the shop drawing or of responsibility for meeting all requirements of the contract documents. The contractor is responsible for dimensions to be confirmed and correlated at the job site, for information that pertains solely to the fabrication processes or to techniques of construction and installation, and for coordination of the work of all sub trades.

## **6. Category 6/Field quality control, Inspection**

- I. Field service by the consultant or his representative do not in any way relieve the contractor of his responsibility to carry out the work per the contract document and contract drawings.
- II. Contractors work will be inspected periodically by the Engineer solely for the purpose of determining general quality of work, and not for other purpose. Guidance will be offered to contractor in interpretation of plans and specifications to assist them to carry out work. Inspections and directives given to contractor does not relieve contractor and his agent, servants and employee of their responsibility to erect and install work in its parts in a safe and workmanlike, and in accordance with the plans and specifications, nor impose upon the Engineer any responsibility to supervise or oversee erection or installation of any work.
- III. The location, arrangement and connection of equipment and materials as shown on the drawings, represent a close approximation to the intent and requirement of the work. The right is reserved by the consultant to make consultant to make responsible changes required to accommodate conditions arising during the progress of the work, at no extra cost to the owner.

## **7. Category 7/Shop finish**

- I. Unfinished work will be listed as deficiencies.

## **8. Category 8/Temporary or trial usage, testing**

- I. It is agreed and understood, that no claim for damage will be made for any injury or breakage to any part or parts of above due to aforementioned tests, whether caused by weakness or inaccuracy of parts, or by defective materials or workmanship of any kind whatsoever. Supply all labour and equipment for such tests. Take responsibility for damage caused by defective materials or workmanship during temporary or trial usage by owner.