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CONTRACTUAL OBLIGATIONS ANALYSIS FOR CONSTRUCTION WASTE MANAGEMENT IN CANADA

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Abstract. Construction industry creates a massive amount of waste, which typically ends up in landfills. Canadian construction industry represents 30% of the total municipal solid waste deposited in landfills. Construction and demolition (C&D) waste has created negative socioeconomic and environmental impacts including contaminating ground water, emitting greenhouse gases, and adding more waste to scarce landfills. Literature is cited rework/waste generation due to ambiguity/errors in construction contract documents. Exculpatory clauses in contract documents are included in contractual agreements to prevent contractor claims, which often cause rework. After an extensive contract documents review, these clauses were categorized in to eight major areas. This paper (1) analyses expert opinions on pre-identified contractual clauses; and (2) introduces recommendations to minimize rework and waste in construction projects. It was found that the clauses related to quality, workmanship, and field quality control/inspection have the most potential to generate construction waste.

Keywords: construction waste, construction waste management, disclaimer clauses, rework, contractual agreements, analytic hierarchy process (AHP), attribute weighing method (AWM).

Introduction

Almost all industries in Canada are influenced by strict environmental regulations. The construction industry is not an exception. The Canadian construction industry is a large contributor of waste materials to landfills. In reality, landfills are rapidly approaching their capacity. As a result, the cost of disposal of waste is rising. In highly populated areas, replacing landfills is difficult due to the public anxiety over social and environmental impacts (The Canadian Construction Association 1992).

Mendis and Hewage (2011) found several incidents of rework initiated due to certain contractual clauses in commercial construction contracts. The same authors mentioned that limited research studies related to the contractual clauses and their impact on rework (and waste) in published literature. Apart from Mendis and Hewage (2011), the authors could not locate any published research study related to the contractual clauses and their impact on construction waste. This paper aims to fill up this knowledge gap by conducting further research and analysis.

The authors reviewed numerous contractual agreements, several project contract documents, and specifications in Canada. Following contractual agreements (in Canada) were carefully reviewed in this research:

– Owner/Contractor agreements;
– Owner/Design-Builder agreements;
– Owner/Construction Manager agreements;
– Design-Builder/Contractor agreement;
– Contractor/Sub contractor agreements;
– Design-Builder/Architect agreements;
– Architect/Consultant agreements;
– Owner/Architect agreements.

It was noted that several clauses in the technical specifications and general conditions in contractual agreements have impacts on generating rework/waste. Such clauses were categorised in to eight major areas – i.e. quality, substitution, workmanship, geotechnical report, submittals/shop drawings, field quality control/inspection, shop finish, and temporary or trial usage/testing. Authors' professional practice also noted several incidents of rework/waste generation due to certain contractual clauses, which have fallen into the identified eight categories.

The overall objective of this paper is to analyse the impacts of standard contractual clauses in generating construction waste and rework in Canada. Data related to this study was collected through literature reviews, interviews, questionnaire surveys, and on-site observations.

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The paper is concluded with suggestions to amend the standard Canadian contract documents, to minimize rework/waste in construction projects. This paper intends to provide suggestions and recommendations to the lawyers, who formulate construction contracts. A future validation study is suggested in this area, once the noted suggestions are implemented in the industry.

1. Background

Riches and Dancaster (2004) stated that the personal judgment which is intended to resolve disputes can be a risk for a project. Terms like "to the satisfaction of architect/contract administrator/engineer" are models for this type of provisions. In addition, implied terms in contracts can cause conflicts or disputes due to misinterpretation in the contract document (Eggleston 2004). Love *et al.* (2009) stated that ambiguous communication, such as not providing clear instruction on what, when, and how a task is to be done, may result rework later. The same phenomenon had been echoed by Love *et al.* (2010), and they revealed that clearly defined working procedures and communications may positively effect in reducing rework and waste. These studies urged the necessity of contract documents with clear instructions.

Jergeas and Hartman (1996) mentioned that the owner's ideas are communicated to contractors through contract clauses mentioned in the bid or contract documents. Poorly written and ambiguous contract documents have a tendency for misinterpretation by the other parties. As per the same researchers, the owners usually incline to contractually transfer responsibilities of numerous project risks to the contractors through disclaimer clauses. These unfair risk allocations in contract agreements create disputes (Powell-Smith, Sims 1990; Bosche 1978; Vidogah, Ndekugri 1997; Loosemore 1999). The most important risks in construction are: 1) construction rework (waste) and modifications; 2) design errors and omissions; 3) change orders; 4) delay damages; 5) overlooked work (assigned to no party); and 6) cost overrun and inaccurate cost estimating (Moazzami *et al.* 2011). Besides, Li and Taylor (2011) recommended that all the stakeholders involved in a project must realize the possible result of having unnoticed rework (waste). They must collaborate towards the final project goal. However, this goal may be achieved by a contractual agreement that do not transfer the responsibilities in unfair manner.

Doloi *et al.* (2011) have found that the substandard contracts; hence, rework due to changes, as a significant factor that delays projects. Love *et al.* (2008) mentioned that errors are inevitable in contract documentation. As per the general practice, the same researchers stated that the errors in contract documentation are assumed to be identified by the contractors/subcontractors. The same researchers concluded that the most significant factor influence cost and time overruns in construction is rework (waste), which typically expresses itself in the form of changes and errors. Further, Hwang *et al.* (2009) have found that owners incline to report rework (sources of waste) more as constructor's errors/omissions, and contractors more frequently point the need for rework to design errors/omissions. Hwang *et al.* (2009) recommended developing a tracking system for controlling constructor's errors/omissions for owners; design changes for contractors; and owner changes and design errors/omissions for both owners and contractors. As per the same authors, the processes of reviewing shop drawings, site inspections, and checking the drawings and the contract documents for errors should be a part of this process; then, the consultants are bound to take the responsibility of the work they have reviewed and inspected.

Love (2002) concluded that clients' demand to cut the time available for design and premature production of contract documentation impact the quality of contract documentation. As a result, errors and omissions of contract documentation may cause rework (and waste). The same fact had been echoed by Love and Sohal (2003), and they have found that the consultants only work on a project for the time they had budgeted for their fee. As a result, dimensional errors and omissions happen during the construction phase, particularly at the interface between subcontract trades.

Change orders and rework are more common in fast-track projects than regular projects. Currently, fast-track projects lack in sufficient specific provisions and clauses in contract agreements that reasonably assign risks between stakeholders. In fast-tracking, incomplete drawings and specifications in bid packages, submitted to subcontractors or trade contractors, cause inevitable rework and changes in the next stages of projects (Moazzami *et al.* 2011).

Ahzahar *et al.* (2011) stated that the quality of site supervision has a key impact on the overall performance and productivity of construction projects. Bossink and Brouwers (1996) mentioned that problems in specifications, related to the quality, as a key reason for waste generation. Insufficient supervision is believed to be another reason for rework and waste. These statements can be justified by reviewing the Canadian contractual clauses, which are written to assure the quality of work. The exculpatory clauses are written to mention that; continuous checking of quality is not a requirement of the consultant; the decisions on the quality of work are based on the consultant's judgement; and quality of the work is strictly under the responsibility of the contractor regardless of the consultant tested the work or not (CCDC 2-2008). Moreover, less attention to quality assertion may result in decrease in quality assertion efficiency, which would result in some errors passing undetected, and being approved as correctly completed work. Then the defective work that is accepted is referred as undiscovered rework (Li, Taylor 2011).

Lu and Yuan (2010) mentioned that fast designs and inadequate market information create more design changes. The same researchers stated that improving the coordination among designers, and close coordination among designers and contractors are all helpful in reducing design changes. In addition, Love and Sohal (2003) have found that poor coordination and incorporation between design team members obstruct the information flow. Moreover, Lu and Yuan (2011) stated construction and demolition waste management is a multidisciplinary effort, which requires coordination of different disciplines, including the legal profession.

Fayek *et al.* (2003) reported that frequent rework incidents occur in construction projects to correct errors initially happened in the fabrication yard. These errors could have been avoided by a sound shop drawing checking process. Bossink and Brouwers (1996) noted that the limited knowledge in construction and constructability, during the project design stage, is the main reason for waste generation. Lu *et al.* (2011) found that a certain amount of concrete waste was generated due to the use of pre-fabricated concrete piles, which were made with a standard length.

As noted above, literature cited errors, deficiencies, risk transfer, ambiguity, and disputes in contractual agreements cause rework. In addition, this research proved the potentials to create rework (and construction waste) due to the unfair disclaimer clauses.

2. Methodology

A pilot study was conducted in the initial phases of the research to determine the epistemological approach of this research. Identified clauses in the Canadian contract documents were classified as shown in Table 1.

Field observations were very important in this type of research, since it gives the practical validity for the study. In this research, four commercial construction projects in British Columbia, Canada were observed for a 10 months period. The total construction costs of the observed projects were \$68 million, \$31 million, \$42 million, and \$15 million (Canadian dollars). "Construction Project Management" delivery method was used in all of these projects.

During regular site visits, all the visible waste items and relevant sources of waste were identified. Investigations and inquiries were conducted to determine whether these waste items were generated due to deficiencies in the contract documents. In addition, "what-if" analysis was conducted to check the possibilities of avoiding waste by amending the current contract documents. Important conclusions and recommendations were drawn from this process, and they are included in the conclusions and recommendations section of this paper.

In addition to observations, one of the nonprobability sampling methods – expert sampling method – was used to collect data from open-ended discussions/interviews and questionnaires surveys. By combining random sampling and expert sampling methods, external validity concerns were addressed. Expert sampling method – a specific subcase of purposive sampling – is the best way to elicit the views of persons who have experience and insight into the field (Trochim 2000). Two hundred and nine questionnaires were disseminated to randomly selected consulting/construction/architectural companies in Canada. Initially, the questionnaire was sent in MS Word format; then, it was sent in pdf format (pdf fillable forms). Finally, the "Survey Monkey" web facility was used, since some of the participants expressed their desire to participate in an online survey. The response rate was about 22% with all three methods. Table 2 shows the sample distribution of the participants of questionnaire survey and open-ended discussions/interviews. The majority of the respondents were construction professionals, who directly manage construction projects. These professionals (i.e. project managers, project coordinators) are the first-hand users of construction agreements in construction settings.

An interview usually took about 30–45 minutes for a single participant. Fifteen interviews were conducted. The interview questions are in the Appendix 1. The results of open-ended discussions/interviews are also presented in the conclusions and recommendations section of this paper. Research participants were asked to prioritize the contractual clause categories, given in Table 1, in terms of waste generating potential. These categories have been indicated, individually and in a pairwise manner, in the parts 1 and 2 of the questionnaire. With this process, the required rankings and pairwise comparisons were obtained. The final values were taken by averaging all questionnaires that individually pass the consistency test. Attribute weighing method (AWM) and group decision method were used to rank the selected contractual clause categories. Moreover, risk ratio was also calculated by using AHP to highlight risks of the contractual clause categories that have the maximum potential to create construction waste. Clause prioritization was conducted to justify the urgency for changes/modifications or deletions in contract clauses. Figure 1 summarizes the research methodology and activity plan.

3. Data analysis methods

As mentioned above, pre-identified contractual clauses were prioritized with expert opinions. Group decision method and Attributed Weighted Method (AWM) were used as prioritization tools. Using these two parallel measures, convergent validity – parallel-forms reliability can be achieved. Moreover, this procedure eliminates the sources of errors caused by biases (Trochim 2000).

3.1. Application of analytical hierarchy process (AHP) and group decision method

Figure 2 illustrates the hierarchical structure of the AHP. The crux of AHP is to rank the potential contractual clauses in terms of generating construction waste. The AHP hierarchy has three levels: i.e. 1) Level 1 – potential of contractual clauses on generating construction waste was set as the goal; 2) Level 2 – eight categories of con-

Table 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 of 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 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. 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.
6	Field quality control, Inspection	a) 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. 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 manner, 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. 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.
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.

tractual clauses were defined as multiple criteria; and 3) Level 3 – two alternatives were defined as potential to generate waste (the eight categories have positive influence on creating construction waste) and no waste (the eight categories do not have positive influence on creating construction waste).

Table 3 shows seven point intensity scale used for pairwise comparison of criteria in AHP/group decision method. Although Saaty (1990) has used 1–9 scale, this research used 1 to 7 scale instead of 1 to 9 scale to simplify the ranking procedure. This strategy helped the respondents to have less cognitive burden, when they answered the survey. Survey participants used a 7 point scale to compare the contractual clause categories, where 1 and 7 represented extremely more important categories, when compared to one another, and 4 represents equally important category. These ratings have been converted to the seven point intensity scale for AHP/ group decision method. Ex: Rating 1 and 7 in the questionnaire is equivalent to 7 in the seven point intensity scale used in AHP/group decision method.

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

Table 2. Demographic information of the participants whose answers passed the consistency

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.	

$$C_{ij} = \begin{pmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} & C_{17} & C_{18} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} & C_{26} & C_{27} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} & C_{37} & C_{38} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} & C_{47} & C_{48} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} & C_{57} & C_{58} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} & C_{67} & C_{68} \\ C_{71} & C_{72} & C_{73} & C_{74} & C_{75} & C_{76} & C_{77} & C_{78} \\ C_{81} & C_{82} & C_{83} & C_{84} & C_{85} & C_{86} & C_{87} & C_{88} \end{pmatrix}. \quad (1)$$

Equations (2a) and (2b) represents C_{ij} as:

$$C_{ij} = \frac{\sum_{k=1}^{n} s_k}{n}, \quad (2a)$$

where: $i \neq j$; S_k = weight calculated from a single participant (whose answer passed the consistency test) of the expert opinion survey; and n = total no. of participants whose data with the required consistency (from the questionnaire survey).

$$C_{ij} = 1, \quad (2b)$$

where $i = j$.

Equation (3) shows normalized weights of PCM (W):

$$W = \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ w_8 \end{pmatrix}. \quad (3)$$

Equation (4) shows one element of $W(W_i)$ as:

$$W_i = \frac{\left(C_{i1} \times C_{i2} \times \cdots\cdots C_{i8}\right)^{1/8}}{\sum_{i=1}^{8}\left(C_{i1} \times C_{i2} \times \cdots\cdots C_{i8}\right)^{1/8}}. \quad (4)$$

Then two alternatives should be evaluated against each and every criterion. Eqn (5) shows the illustrated example for criteria no. 1 (category 1):

	Waste	No Waste
Waste	A_{11}	A_{12}
No Waste	A_{21}	A_{22}.

(5)

Equations (6a) and (6b) represents A_{ij} as:

$$A_{ij} = \frac{\sum_{k=1}^{n} T_k}{n}, \quad (6a)$$

where $i \neq j$.

$$A_{ij} = 1, \quad (6b)$$

where $i = j$.

T_k = weight calculated from a single participant (whose answer passed the consistency test) of the expert opinion survey, n = total no. of participants whose data with the required consistency (from the questionnaire survey). Then Eqn (7) shows the matrix for category 1(M1), and Eqns (8a) and (8b) shows its elements.

$$M1 = \begin{pmatrix} A_1 \\ A_1^* \end{pmatrix}; \quad (7)$$

$$A_1 = \frac{\left(A_{11} \times A_{12}\right)^{1/2}}{\left(A_{11} \times A_{12}\right)^{1/2} + \left(A_{21} \times A_{22}\right)^{1/2}}; \quad (8a)$$

$$A_1^* = \frac{\left(A_{21} \times A_{22}\right)^{1/2}}{\left(A_{11} \times A_{12}\right)^{1/2} + \left(A_{21} \times A_{22}\right)^{1/2}}. \quad (8b)$$

Thus Matrix A (Eqn (9)) contains the matrices (M1 to M9) of eight criteria (all clauses categories), and it represents relative contribution between two alternatives towards the eight criteria.

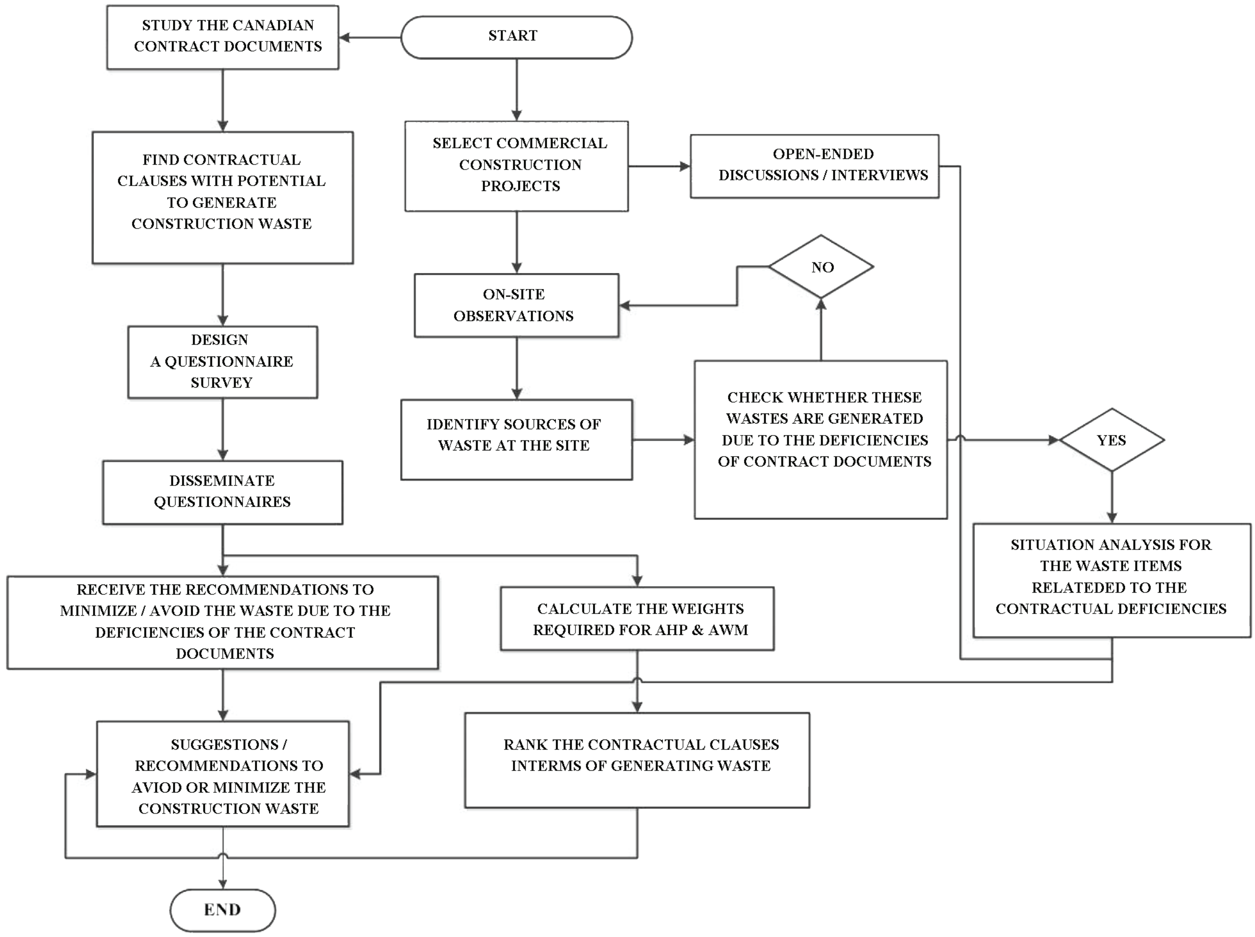

Fig. 1. Theoretical framework

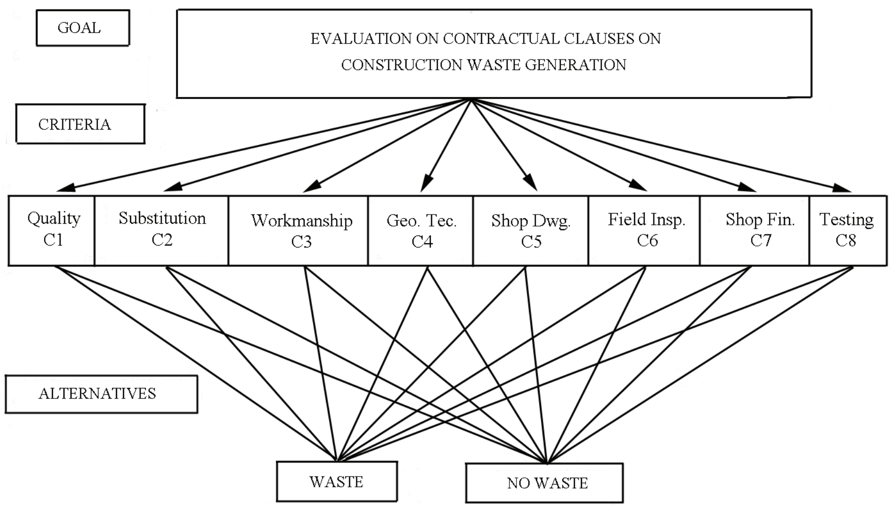

Fig. 2. Hierarchical structure of AHP

Table 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

$$A = \begin{pmatrix} A_1 & A_2 & A_3 & A_4 & A_5 & A_6 & A_7 & A_8 \\ A_1^* & A_2^* & A_3^* & A_4^* & A_5^* & A_6^* & A_7^* & A_8^* \end{pmatrix}. \quad (9)$$

Risk ratio =

$$\begin{pmatrix} A_1 & A_2 & A_3 & A_4 & A_5 & A_6 & A_7 & A_8 \\ A_1^* & A_2^* & A_3^* & A_4^* & A_5^* & A_6^* & A_7^* & A_8^* \end{pmatrix} \times \begin{pmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ w_5 \\ w_6 \\ w_7 \\ w_8 \end{pmatrix}. \quad (10)$$

In Eqn (10), Multiplication of W (Eqn 3) and A (Eqn 9) gives the risk ratio between potential to generate Waste and No Waste. The risk ratio between Waste/No Waste 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. Attribute weighing method (AWM) to rank the contractual clauses

The contractual clauses categories (shown in Table 1) were ranked as per the average values of the questionnaire survey results. 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, and R8; and n can be taken as number of categories. Then weights (W) can be calculated as per Eqn (11) (rank reciprocal weights):

$$W = \frac{1/R_i}{\sum_{k=1}^{n} 1/R_k}. \quad (11)$$

4. Results

Results of the questionnaire surveys, field observations, and interviews are presented in the following section.

4.1. Questionnaire survey analysis with group decision method (pairwise comparison)

The eight categories of contractual clauses indicated in Table 1 were defined as multiple criteria. These eight categories were included in Table 4, and they were arranged in a pairwise manner. These pairs were compared by the survey participants. The summarized results of pairwise comparisons of questionnaire surveys are shown in Table 4. The values of Table 4 were calculated by taking the average of all the responses that passed the consistency test, individually. 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 example, the value 4.13 in the first raw of Table 4 is the average value for all pairwise comparisons between quality vs. substitution taken from all the questionnaires that individually passed the consistency test (i.e. quality is 4.13 times more important than substitution in terms of generating construction waste).

Notations C1 to C8 represent the clauses categories (Ref. Table 5).The Consistency ratio (CR) of PCM was 0.0603 (CR < 0.1). As per Saaty (1990), PCM has the required consistency. By checking the consistency, internal consistency reliability and inter-rater or inter-observer reliability (in terms of reliability) can be achieved (Trochim 2000). Table 7 shows normalized weights of PCM and ranking of clause categories. Normalized weights of PCM, W (Eqn (3)) were determined as per Eqn (4).

Thus, final ranking among eight clause categories can be illustrated as **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 clauses and field quality & inspection clauses respectively. Quality, workmanship, and field quality& inspection clauses have 27.18%, 25.54%, and, 9.86% of weights respectively. Geotechnical report, substitution clauses, and shop drawings contain intermediate level of risks; and shop finish and testing account clauses have a low risk level.

4.2. Questionnaire survey analysis with AHP

Matrix A (Eqn (9)) contains the matrices of eight criteria (all clause categories), and it was calculated as per Eqns (5), (6a), (6b), (7), (8a), (8b), and (9).

As per Eqn (10), the ratio between Waste and No Waste (Risk ratio) is:

= 1.58/ 0.32;

= 4.92.

AHP sensitivity analysis was performed to observe the changes in the relative weights (of the criteria), which influence the final risk ratio. A sample calculation is shown in Table 6, and the relative weight of the each criterion was increased by 30% each time. The sensitivity analysis shows that changes to the three contractual clause categories with highest potential/risk to generate construction waste, has an upward movement. Changes to the other six contractual clause categories with lower

Table 4. Pairwise comparison for clause categories

Symbol	Pairwise comparison category	Average value
C12	Quality vs. Substitution	4.13
C13	Quality vs. Workmanship	1.36
C14	Quality vs. Geotechnical report	4.39
C15	Quality vs. Submittals/Shop drawings Clauses	3.84
C16	Quality vs. Field quality control/Inspection	1.68
C17	Quality vs. Shop finish	3.92
C18	Quality vs. Temporary or trial usage/testing	3.79
C23	Substitution vs. Workmanship	0.43
C24	Substitution vs. Geotechnical report	1.46
C25	Substitution vs. Submittals/Shop drawings	0.47
C26	Substitution vs. Field quality control/Inspection	1.56
C27	Substitution vs. Shop finish	2.07
C28	Substitution vs. Temporary or trial usage/testing	1.49
C34	Workmanship vs. Geotechnical report	4.28
C35	Workmanship vs. Submittals/Shop drawings	4.02
C36	Workmanship vs. Field quality control/Inspection	2.90
C37	Workmanship vs. Shop finish	3.98
C38	Workmanship vs. Temporary or trial usage/testing	4.18
C45	Geotechnical report vs. Submittals/Shop drawings	2.15
C46	Geotechnical report vs. Field quality control/Inspection	1.46
C47	Geotechnical report vs. Shop finish	2.20
C48	Geotechnical report vs. Temporary or trial usage/testing	2.14
C56	Submittals/Shop drawings vs. Field quality control/Inspection	1.83
C57	Submittals/Shop drawings vs. Shop finish	2.48
C58	Submittals/Shop drawings vs. Temporary or trial usage/testing	1.49
C67	Field quality control/Inspection vs. Shop finish	3.69
C68	Field quality control/Inspection vs. Temporary or trial usage/testing	3.88
C78	Shop finish vs. Temporary or trial usage/testing	1.52

Table 5. 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 6. AHP sensitivity analysis

Category		Risk ratio	Change
Quality	C1	5.0032	Upward
Substitution	C2	4.8804	Downward
Workmanship	C3	4.9840	Upward
Geotechnical report	C4	4.9186	Downward
Shop drawings	C5	4.8979	Downward
Field quality & Inspection	C6	4.9319	Upward
Shop finish	C7	4.8793	Downward
Temporary trial & Testing	C8	4.8770	Downward

Table 7. 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

Table 8. Ranking of clause categories sorted weights in the order of their magnitudes

Clauses category	Rank (used survey data)	1/Ri	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%

potential/risk to generate construction waste, has a downward movement.

4.3. Questionnaire survey analysis with AWM

The eight categories were individually ranked.

The questionnaire survey data of Table 5 has been used to rank the contractual clause categories, considering the average ranking of each category. Table 8 illustrates the final results.

Thus, final ranking among eight clauses can be shown as **C3 > C1 > C6 >C8 > C2 > C4, C5 > C7.** Workmanship clauses have the highest potential/risk to generate construction waste. The second and third priorities are quality clauses and field quality & inspection clauses, respectively. Quality, workmanship, and field quality & inspection clauses have 18.29%, 36.57%, and 12.19% of weights respectively. Temporary trial and testing, and substitution clauses contain intermediate risk levels. Shop drawings, shop finish, and geotechnical report account for low level of risks.

5. Discussion

This study critically analysed the most common contract documents in Canada for its potential to generate construction waste. The research project discussed in this paper provides valuable contributions to the body of knowledge by identifying and prioritizing the most influencing contract clauses, which have potentials to create construction waste. During an extensive literature review, authors did not locate any published studies (or statistics) in technical journals or reputed web sites, which examined the influence of contractual clauses/agreements in generating construction waste, in Canada or any other part of the world. In addition, this study concluded key focus areas that need immediate attention of construction managers and legal professionals. Further, this study might motivate the construction industry to create fair contractual documents which have less potential to create rework and waste. In addition, this paper demonstrated an application of the decision making theories (AHP and group decision making method and AWM), in the contract administration area, to quantify professionals' views.

Ranking several factors in a given time may create a heavy cognitive burden on the decision maker. Thus, a method by which a complete ranking can be obtained, from a set of pairwise judgement, is the preferred approach. Therefore, the group decision method is recommended over AWM. On top of that, the group decision method offers a valuable tool for testing the consistency of the evaluation measures. Judgments can be affected by availability heuristics and social influences of the decision maker. Taking a large number of samples, bias can be minimized; however, it can't be completely avoided.

Despite the method of analysis, the top 3 clauses categories, which influence construction waste generation, remained the same. It is interesting to note that AHP sensitivity analysis follows the exact pattern shown in the group decision method (done by pairwise comparison). There is no impact on the scale for the results between two methods.

6. Limitations and future research

This research reviewed and analysed most influential categories of contractual clauses, which have potentials to create construction waste; however, there are many other minor areas which may have a cumulative impact on waste generation. In addition, this research is limited to the Canadian contract documents. A wide range of contractual models and standard contracts are used in the world. Contract documents can be changed from region to region, country to country, and even province to province within the same country. The views and analysis discussed in this paper are strictly limited to the analysed contract documents. It is suggested to conduct further research to analyse contractual clauses in different regions of the world to identify global attention areas to reduce construction waste. Such research projects may reveal contractual conflicts in multi-national construction projects, which ultimately create rework and construction waste. Further research is also recommended to identify fair risk allocation in contract documents among contractors, owners, and other key project stakeholders. Such approach may positively influence to reduce construction rework and waste. Finally, this research project revealed the importance of collaborative studies among legal and construction professionals. Such synergy in future research may help to create more practical and sustainable construction contract documents.

Conclusions and recommendations

As per the analysed expert opinions, with group decision method and AWM, it can be concluded that the following three contractual clause categories have the maximum potential to create construction waste:

1) Category 1 (Quality);
2) Category 3 (Workmanship);
3) Category 6 (Field quality control and Inspection).

Thus, priority should be given to amend these high potential/risk contractual clauses in standard Canadian construction contract documents. Contractual clause rewriting is beyond the objectives of this paper.

Poor quality assurance process for completed designs is evident in construction projects. It causes design errors, omissions, and incompatibilities in the final drawings. The completed designs should be reviewed by an expert design team (preferably, a third party) to identify any design errors, omissions, constructability issues, and incompatibilities. Such specific requirement may be included in the standard contractual agreements.

In general, errors and discrepancies in the contract documentation are assumed to be identified by the contractor/subcontractors, regardless of the party that made the contract documents. This practice tends to create rework and waste. The party that prepared the contract documents should be responsible for the accuracy and quality of the documents, and that party should warrant the content of documents to provide accurate information. The consultant's working time on a project is generally depends on fee allocations. This practice may impact the quality of the contract documentation and quality of field inspections.

In addition, ambiguous communication and vague wordings in contract documents create rework/waste. Contract documents should be written in crisp technical language (avoid vague language) by explaining the work acceptance and rejection procedure. It prevents contractual agreements to fall into grey areas, and eliminates confusions and conflicts.

Authors' field observations noted lack of coordination among designers and subcontractors. As a result, construction waste and rework was generated. It is recommended to include a clause in standard contract documents to enforce an obligatory requirement, for coordination among all designers and subcontractors, to avoid conflicting situations. Such coordination should be happen, at least, at major project milestones (e.g. at the end of individual design processes, when issuing the drawings for client's approval, when issuing drawings for building permits, when issuing drawings for construction, when producing shop drawings, and when approving shop drawings).

Moreover, exculpatory contractual clauses that are written for the shop drawing review process should be re-evaluated. It may be done by enforcing equal obligations between the main project parties (i.e. designers, main contractors, and construction managers) who review/approve the shop drawings, and the parties that produce shop drawings (i.e. subcontractors, main contractors). The consultants (engineer/architect) or owner should take the responsibility of what they have reviewed and approved, to minimize potential future changes.

Insufficient and irresponsible supervisions by consultants, under the current contract agreements, create rework and waste (e.g. clause category no. 6). A joint field inspection/testing procedure may be implemented with the contractor and the consultant, at pre-identified intervals, to accept or reject the completed works. A fair distribution of responsibilities of quality inspections among the contractor and consultant is needed to minimize construction waste.

Another noted factor on waste generation is the limited knowledge on constructability during the project design stage. Design engineers should consult all potential project stakeholders (i.e. contractors) for the decisions related to constructability. Such a need should be emphasized in the contract agreements.

Fast-track projects generally start before the completion of designs and contract documents (e.g. construction drawings, contractual agreements, technical specifications). Most construction processes in the "fast-track" approach commence even before the completion of the necessary designs. It is recommended to initiate a contractual obligation, which prevents the start of the construction process, until all essential designs and other contract documents are finalized.

In addition, after completing the final design, a model (computer or physical) may be used to visualize the structure. A client, who does not have a technical background, may not be able to understand and interpret technical drawings and specifications in the standard format. A visual model may help to ensure that the designs have fulfilled all stakeholders' expectations. It is worthy to impose an obligatory requirement to provide such a visualization aid prior to the project construction phase.

At present, the general practice is to copy and paste design details and specification from one contract document to another. This practice has high chances to repeat unrelated design components in new projects. Contract documentation and specifications should always be tailored for specific project requirements.

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Appendix 1

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 (Appendix 1)
2. Contractual Clauses with Potentials to Generate Rework or Waste (Appendix 2)

1. Demographic Information (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 2) are the most important among **all clauses** (all categories in Appendix 2) you should write **"8"** under column 3(the column which indicates the RANK).

PART 2

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

RAW 1: Quality vs. Substitution

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

PART 3

Open-ended questions for the last part of the questionnaire and interviews:

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. Please mention your experience about the relationship between construction waste and deficiencies of contract documents/agreements etc.
   ....
   ....
   ....
   ....
4. Any other comments related to construction waste and contract documents/obligations.
   ....
   ....
   ....

Table 1**.** Ranking of categories in Appendix 2

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	

Table 2. Comparison categories and their ratings

Description	Ratings
Column A is *extremely* more important than column B	1
Column A is *more* important than column B	2
Column A is *moderately* more important than column B	3
Column A is *equally* important as column B	4
Column B is *moderately* more important than column A	5
Column B is *more* important than column A	6
Column B is *extremely* more important than column A	7

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	

Appendix 2

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.

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