Life Cycle Assessment Report: UBC Law Building – Allard Hall

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University of British Columbia

CIVL 498E

April 2, 2012

PROVISIO

This study has been completed by undergraduate students as part of their coursework at the University of British Columbia (UBC) and is also a contribution to a larger effort – the UBC LCA Project – which aims to support the development of the field of life cycle assessment (LCA).

The information and findings contained in this report have not been through a full critical review and should be considered preliminary.

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CIVIL 498E: Life Cycle Assessment Report:

UBC Law Building – Allard Hall

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Date of Submission: *April 2, 2012*

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Abstract

At the end of 2011 the new UBC Law Building, Allard Hall, was completed and opened to the public. This building replaced two older buildings, the Curtis Building and the Curtis Extension. In continuation of adding value to the LCA studies that have been on-going at UBC, another study has been conducted on the new building. A full LCA study has be conducted on Allard Hall, which also includes the environmental impacts from the demolition stage of the pre-existing structures.

Using provided structural and architectural drawings, a building model was created, adhering to LCA ISO standards. Using the Athena Impact Estimator and the TRACI impact assessment method, in conjunction with the quantity take off software, On-Screen Take Off, the input parameters for the project were clearly identified and documented.

The details provided by our analysis include a Bill of Materials, a Summary of the Environmental Impacts separated into assemblies, a Sensitivity Analysis, and a Chain of Custody inquiry. This LCA report also includes a discussion of the building functions and its' functional units, for the purpose of setting references for future similar projects.

The results found show that the dominating materials in the UBC Law building are Batt Fibreglass, Concrete Blocks, Steel Rebar, Fire-Rated Gypsum Board, and 30MPa Concrete, in which Concrete was found to have the most influence on environmental impacts in regards to material used. The manufacturing stage was found to be the most contributing to environmental impacts. Measurements of performance are outlined in the form of functional units, and are intended to be used as a baseline for future project comparisons.

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1.0 Introduction

The UBC Law Building, Allard Hall, was newly constructed and completed in August of 2011. It is named after Peter A. Allard, a law alumnus, to recognize him and his family for their generous support and connection to UBC Law.

This building is intended to be a center for legal education and research, serving as a hub for students and for the legal community to come together. It is the primary building for UBC Law. Before it, two buildings existed: The Curtis Building, and the Curtis Building Extension. These facilities experienced problems with ventilation and moisture, and with them considered as out dated establishments, a drive for a new building was made.

Allard Hall was designed by Diamond and Schmitt Architects and managed by UBC Properties Trust with a budget of approximately $60.0M., At 141,000 square meters, the building aims to provide classroom space, a law library, meeting space, and an auditorium. On top of providing high quality student space, it also boasts an energy savings of 50-60% and achievement of LEED Gold Standard.

Below is a table identifying the primary building characteristics (Table 1). It outlines the key components and summarizes what the building is composed of.

Table 1: Building Characteristics

Structure	Reinforced concrete frame, concrete columns and beams, on suspended concrete slabs
Floors	Basement: Concrete slab on grade; Ground, Second, Third, Fourth Floors: Suspended slabs
Exterior Walls	Reinforced Concrete or Concrete Block
Interior Walls	Steel Stud w/ Gypsum Board
Windows	Standard Glazing
Roof	Steel Roof Deck Z275 Zinc Coated

2.0 Goal and Scope

The Goal & Scope serves as an effective way of documenting the execution of LCA studies. The purpose of defining the Goal of the study is to unambiguously state the context of the study, whereas the Scope details how the actual modeling of the study was carried out. Documenting the current LCA projects provides credible references for the future development of LCA.

For this LCA study report on the new Allard Hall Law Building, the format immediately below has been used to unambiguously outline the details of the parameters outlined in ISO 14040 and 14044.

2.1 Goal of Study

The following section defines the context of LCA study: its intended application, reason of carring, intended audience and Intended comparative assertions.

Intended Application

Describes the purpose of the study

The LCA study is intended to develop a study of the impacts associated with Allard Hall using LCA methods, as well as contribute to the UBC LCA Database.

Reason of carrying

Describes the motivation for carrying out the LCA study

The LCA study project was carried out upon the request of CIVL 498E as an input into the UBC LCA Database. The LCA study of Allard Hall will serve as an effective reference of the overall environmental performance of the new law building—Allard Hall. The study will also be used as a demonstration of the current assessment methods in the development of LCA.

Intended audience

Describes those who the LCA is intended to be interpreted by

The intended audiences are the stakeholders involved in the policy making of sustainable buildings from UBC Sustainable Office, engineers, architects and building users. Governments, investors, and LEED professionals and anyone that is interested in the learning and applying of building LCA are also the group we are communicating with.

Intended comparative assertions

State whether the results of this LCA study are to be compared with the results of other LCA studies

The LCA study is conducted in a transparent and objective way. The prime purpose of this study is to evaluate solely the Allard Hall in its environmental contributions, but comparative studies are also possible. It is critical to consider all aspects of the Goal & Scope to determine whether a studies are comparable.

2. 2 Scope of Study

The following section details the parameters of the models and how they are carried out.

Product system to be studied

Describes the collection of unit processes that will be included in the study

The product system consists of a set of main processes. In this project, the demolition of the previous law building, manufacturing of the building materials, construction, operation, maintenance and end of life of Allard Hall are considered. Each main process involves several unit processes, which are smallest elements considered in the life cycle inventory analysis for which input and output are quantified. The main processes are then modelled to demonstrate the environmental impacts of Allard Hall, based on the quantification of their unit processes by inputs and emits data. As an example, a summary of the construction process, including its unit processes are listed below.

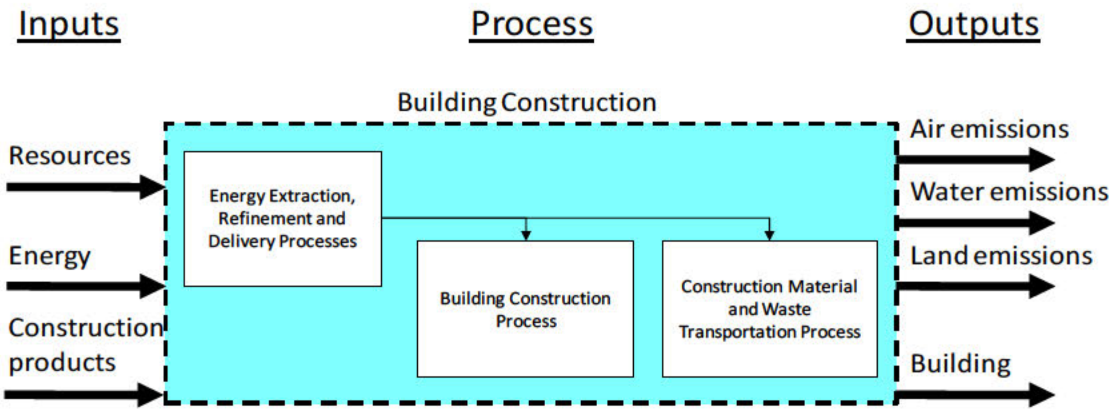

Figure 1: Generic unit processes within Building Construction process by Impact Estimator software

Function of the product system

Describes the functions served by the product focused on in the LCA study.

Allard Hall Building is a multifunctional structure serving both institutional and office feature. The building has a spacious interior for spectacular art pieces and lounge as well as a beautiful atrium on the second floor creating a fascinating view from inside the building. It has large capacity for both classrooms and office areas. While providing an educational environment, this building is also featured in Law Faculty administration offices and general law consulting services. The detailed functional area of Allard Hall is summarized in the Building Function section.

In LCA study of Allard Hall, the main processes summarize the "Cradle to Grave" stages of the building cycle of the study building. The building demolition of the old building ("grave") in particular serves as the site preparation of Allard Hall in the construction process since the excavation activity involves the removal of debris from the deconstructed structures. The construction product manufacturing and building construction process are the "cradle to gate" stage where the building project developed from construction tendering to before user operation. The main service periods of the building project are the operation and maintenance stages. The demolition and recycling of the building wastes are the end-of-life stage of the building project. This is the point where the project is terminated.

Functional Unit

A performance characteristic of the product system being studied that will be used as a reference unit to normalize the results of the study

The functional units used in this study to normalize the LCA results for the Allard Hall include:

- *per generic post-secondary academic building square foot constructed*

System Boundary

Details the extent of the product system to be studied in terms of product components, life cycle stages, and unit processes

The LCA study on Allard Hall covers all stages in the building cycle. Reference data from the previous building LCA study are applied in the construction phase of Allard Hall. In this process, impacts of unit processes such as energy extraction, refinement, delivery process, building demolition process and transportation are considered. The unit processes involved in waste treatment are not included in the study system.

The construction product manufacturing is the production of structural assemblies of the building. In our study, the following are considered:

- Foundations: pad footings and strip footings, both scheduled and special; slabs on grade
- Walls: furring, curtain walls and special interior walls
- Floors: summarized using weighted average
- Columns and beams intersection: scheduled and special
- Roof

Openings and envelopes, and all associated doors and windows, gypsum board and cladding are accounted for in their respective building assemblies. A summary of the system boundary studied in this report is shown in the following schematic diagram.

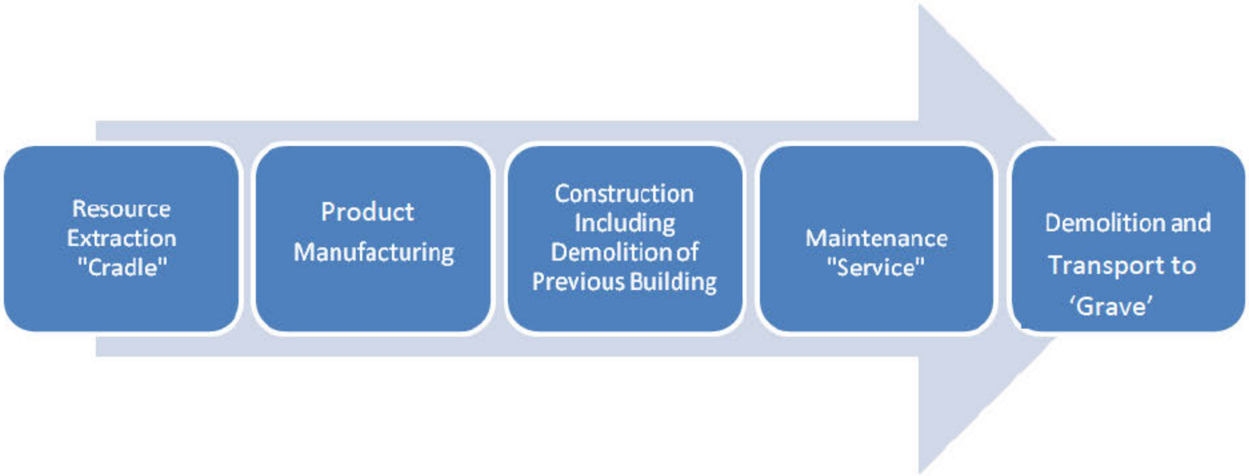

Figure 2: Schematic drawing of system boundary

Allocation procedures

Describes how the input and output flows of the studied product system (and unit processes within it) are distributed between it and other related product systems

In real life, many processes are dynamic which is a source of uncertainty in modelling. They involve different parameters and inputs and they often result in multiple outcomes. The allocation thus becomes very problematic. Sometimes input and outcomes of subsequent life cycle stages are interrelated, and this also creates the difficulty specifically in how to account these elements. The allocation problem of Allard Hall falls into this category as the building demolition serves as an end-of-life stage of the previous building, as well as the early construction stage of the new building.

To solve this problem, we use the cut-off allocation to define that only the direct impacts caused by a product are distributed to that product. In detail, we first determine the impacts of the initial manufacturing of the new building. Then, we determine the impacts of demolition. In our example, the construction of the previous law building does not have direct effect on the Allard Hall project, and thus it is not considered part of the Allard Hall impacts. The demolition process, however, is put into consideration since it is a major part of constructiona.

LCIA methodology and types of impacts

State the methodology used to characterize the LCI results and the impact categories that will address the environmental and other issues of concern

The primary impact assessment method used in the Allard Hall LCA study is the mid-point impact assessment methodology developed by the US Environmental Protection Agency (US EPA), the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2.

The impact categories selected and the units used to express them (i.e. category indicators) are listed below.

- Global warming potential – kg CO_2 equivalents
- Acidification potential – H^+ mol equivalents
- Eutrophication potential – kg N equivalents
- Ozone depletion potential – kg CFC^{-11} equivalents
- Photochemical smog potential – kg NOx equivalents
- Human health respiratory effects potential – kg $PM_{2.5}$ equivalents
- Weighted raw resource use – kg
- Fossil fuel consumption – MJ

Interpretation to be used

Statement of significant issues, model evaluation results and concluding remarks

Detailed discussion of uncertainty, sensitivity and functional units are included in the results section. Remarks and suggestions are given in the discussion section as well as the conclusion section.

Data requirements

Explicit statement of all data sources used to measure, calculate or estimate information from in order to complete the study of the product system

The raw data source used in the study is the structural drawing set provided by Diamond Schmitt Architects. Data use includes basic dimensional measurements of the structural elements, specific material use and design loads. Data are further modified by assumptions in the final modelling process.

Assumptions

Explicit statement of all assumptions used by the modeller to measure, calculate or estimate information in order to complete the study of the product system

Two types of assumptions are used in this study. The first is in the quantity takeoff process where we determined building characteristics and material specifications. The second is in the data input of the Impact Estimator modelling, where some data have to be modified to align with input requirements.

The details of the assumptions are stated in the Model Development section of this report. A full assumption document is available in the appendix.

Value choices and optional elements

Details of the application and use of normalization, grouping, weighting and further data quality analysis used to better understand the LCA study results

Value choices and optional elements are not considered in this study for two reasons. First, comparative study is not the goal of this report, and thus the data do not have to be further adjusted. Second, this report provides sufficient documentation of the execution of the study, and thus the data are justified and the analysis results are acceptable.

Limitations

Describe the extents to which the results of the modelling carried out on the product system accurately estimate the impacts created by the product system defined by the system boundary of the study

The extent of how the LCA study is carried out largely depends on the system boundary that is defined in the previous sections. The cut-off method applied in this study defines that the waste treatments, including reuse, recycling of the wastes are excluded from the study, thus is limited in scope.

Last but not least, the Athena life cycle inventory (LCI) database reflects the average level of the North American industry. This needs to be taken in to consideration, as the actual upstream effects may differ from the industry average. This limitation is caused by the lack of participation of manufacturers in LCA.

Data quality requirements

Qualitative and quantitative description of sourced data used in the LCA study, as well as the methods used to collect and integrate missing data

The sources of data used in the development of this LCA study are from the courtesy of Diamond Schmitt Architects. The information given in the drawing was relatively accurate, but there is still some ambiguity involved for some assemblies. The accuracy of the quantity takeoff relates to the modeling in the Impact Estimator which estimates a bill of materials from building characteristics provided to it by the user. A detailed breakdown of the building characteristics input into the IE are presented in the appendix.

Quality of the outcome data depends on the quantity takeoff and characterization process that is built in the Impact Estimator since all the calculation parameters and calculation procedures are provided by the software's own database. We dedicated our best efforts in measuring, but some human errors are inevitable. The study of the database is not included in the scope of this study.

Type of the critical review

A review of the methods, data, interpretations, transparency and consistency of the LCA study- to be included in the LCA report

This study is conducted in a transparent and communicative way so that it is readily available for any third party who is interested in life cycle assessments to review and comment. However, a review is not included in this report.

Type and format of the report required for the study

Statement of the type and format follow by the report

This report followed the final report outline provided by Rob Sianchuk - the instructor of CIVL 498E. This project is carried out under in the UBC Civil Engineering department.

3.0 Model Development

The purpose of this section is to demonstrate how the model used in our analysis was developed. This is important because it explains how one may recreate our model, and will include a breakdown of what work was done and the assumptions that were made.

3.1 Structure and Envelope

3.1.1 Material Take Off Development

The software used for conducting material quantity take off was On-Screen Takeoff 3. This software is able to quantify materials in several different ways, including area conditions, linear conditions, and count conditions. Using the structural drawings and these conditions, the total amount of building material is estimated.

Area conditions are used primarily for the floors, pad footings and roof. The Athena Impact Estimator requires the span and width parameters, which essentially requires of us the total floor and roof areas. When measuring the floor areas, beams and columns are overlapped, but footings and wall are not.

Linear conditions were used to perform takeoffs of walls and strip footings. Beyond the linear condition obtained, the height and thickness of the wall or footing was determined. Care must be taken to account for thickness of the slabs involved and avoid double counting. When the condition is being used, it snaps to planes at 0°, 90°, and 15° intervals in between. An option also exists to account for slope, though there was no cause to use it in this project.

The count condition is used for columns, beams, doors, and windows. Columns and beams structures were analyzed in a joint condition with the slabs because they are evenly distributed throughout the floor area, supporting the upper structures. Therefore, the only information needed to analyze columns and beams is the, the number of beams and columns, floor area, bay and span size of the columns.

Not all functions of the software are used. The main intent is to find inputs for use in the IE. Basic quantities (areas, length, count) are recorded and in the notes section, information regarding key properties is to be shown. Specific nomenclature is also used when operating the software, to allow for a consistent and smooth transition into the use of IE. The assemblies are defined as one of the following: foundation, walls, columns/beams, floors, roofs, or extra basic material. The assemblies are then labeled dependant on their type (ex. Concrete Suspended Slab) and a unique characteristic (ex. 2.4KN LL) to distinguish from other similar assemblies.

When doing quantity take offs, the main challenge is deciding on what assumptions to use, as the structural drawings are very detailed and elaborate. Research is done to ensure logical assumptions are considered, and notes of these assumptions are clearly made.

3.1.2 Material Take Off Assumptions

Various assumptions were required to be made in order to complete the analysis for the Allard Hall Law building. The detail of the provided structural drawings was great; however, certain key properties required by the Athena Impact Estimator were not listed, such as percent fly ash content. In this section, we identify the significant assumptions that were made and how we accounted for them.

Data input in Impact Estimator are in imperial form. Metric data have to be approximated to match with the imperial data selection. Structural components such as foundation, columns and beams are made of reinforced concrete, and thus we assume the property of concrete to be consistent, unless otherwise specified.

Footings

Several assumptions are made in the data input stage of the modeling. All measurements taken using Onscreen Takeoff for slabs do not overlap with footings and walls, but do overlap columns and beams. For any foundation types, dimension needs to be modified if the width is larger than 500mm (19.68 in). This requires the adjustment of length or depth to maintain the volume of material. For the slabs on grade, the interior and exterior ones have 20MPa and 32MPa, respectively. They are approximated as 3000Psi and 4000Psi in the modeling. Because of the imperial unit, rebar sizes have to be approximated too. Typically, 10M rebar correspond to #4, 15M rebar correspond to #5 and 20M rebar correspond to #6 in the model. Reinforced members with rebar size larger than 20M are assumed to be #6.

Walls

All cast in place concrete walls were assumed to be made of 30MPa concrete. Actual walls varied from 25 to 40MPa, 30MPa was used for balance. Flyash percentage for the concrete mix was not specified, so the “average” input in the impact estimator was used. All concrete reinforcement was taken as #15M (the lowest value allowed by the impact estimator). Most reinforcement was actually #10M with very few #20M bars in the larger shear walls. Walls thicker than 300mm had to have their lengths adjusted to obtain the correct volume of concrete (the impact estimator limits concrete wall thicknesses to either 200mm or 300mm). Simple math was used to do this.

Retaining walls were ignored because landscape drawings were unavailable.

Interior wall heights were taken as the floor height minus the thickness of the slab. The slab was assumed to be 200mm thick in all areas. For interior partition walls, a steel stud thickness of 25Ga was used when unknown. Insulation was referred to only as “Batt Insulation,” so the impact estimator input “Fiberglass Batt” was used as a surrogate. The plans also referred to “gypsum board 16mm type X” and “16mm fire code C.” The closest input in the impact estimator was “gypsum fire rated type X 16mm.”

Reinforcement for concrete block walls was unknown, so the input #10M was used. Insulation type for the exterior partition walls was unknown (and referred to only as “semi-rigid insulation.” The input “polystyrene expanded” was used. An air and water barrier was specified for exterior walls but the type was unknown. “Polyethylene 3 mil” was used. The glazing type was unknown, so “standard glazing” was used. Some exterior partition types (specifically W1.1 and W3.1) consisted only of an outer envelope covering over a structural concrete wall rather than the usual concrete block wall. Because these structural walls were already counted and an envelope can't be added without backing, the equivalent length of section of structural wall was removed and re-added with the W1.1 and W3.1 envelope types.

The type of wood used for the forum sliding doors and the wood panel balcony were unknown, so the extra material basic material input in the Impact Estimator was use for "cedar wood bevel siding".

Columns and Beams

Columns and beams are not modeled individually. Together with the contribution area, they are considered as a joint member in the modeling. These members are generally considered as having an even distribution in the floor plan, while in real life, building designs intentionally have irregular patterns of column placing for aesthetic reasons. The dimension of the columns and beams are not considered. Rather, this modeling process takes the floor plan as a whole study target, and only the numbers of columns and beams are counted. The exact data for live load are calculated as a weighted average of the designing load plan of that floor, and it is also approximated in the model due to limited selections in the IE.

Floors

The floors in the building are all either suspended slabs or slab on grade. Much of the data required by the Athena Impact Estimator is provided by the detailed structural drawings. Due to how specific the options are, however, for concrete strength, and live load, numbers had to be rounded, in some cases significantly.

The concrete strength of slab on grade was specified as 20MPa or 32MPa for interior and exterior, respectively. For input into IE, the values of 3000psi and 4000psi were used in place. When modeling the suspended slabs, all of them had a specified strength of 30MPa, which was also inputted into IE as 4000psi.

The live loading throughout the building was provided not only in the general notes of the structural drawings, but also with a live load map. This enabled us to easily separate the building into the different zones when measuring the floor areas. Due to limitations in IE however, we were not able to input all of the information available to us, as only values of 50psf, 75psf, and 100psf were accepted. Observed numbers ranged from 50psf to 200psf, and they were rounded to the closest available value.

Another important parameter not disclosed in the provided structural drawings was the % fly ash content. The assumption was made that an average value was used, and this was inputted for all slabs on grade and suspended slabs.

The parameter span length is the distance between columns and walls. In order to have a resulting single value for this parameter, a weighted average was calculated based on column layouts. The floors were broken down into sections where column spacing was consistent, and based on the area of space taken, an average span was found to describe a single type of slab.

Roof

The roof of the building consists of two classifications: Suspended Concrete Slab, and Steel Joist. As the roof is stepped, it begins to appear on the third floor in some areas, but is predominantly only on the roof. However, a quantity take off was taken for all roof areas.

The Roof Suspended Slab, as with the other slabs is assumed to have an average % fly ash concentration. The concrete strength, as previously specified is 30MPa, to be inputted as 4000psi. The live load of the roof was noted as 2.4KN in the drawings, and as such an input of 50psf is used. The span length was calculated as similar to the spans of the other suspended slabs.

The other aspect of the roof is the Steel Joist Decking. Not as much detail as required by IE, is provided by the structural drawings. What was retrieved however was the joist size of W250X22. The deck thickness was listed as 38mm, due to the upper bound in IE being 19mm, 19mm was used. Many other parameters were required, but not described in the drawings, and typical values were assumed: No decking Type, 18 Gauge Steel, and Joist spacing of 24.

Greater details about the assumptions made for the entire model can be found in Appendix B (IE Input Assumptions Document). Specific information such as the calculations made and methods used for our assumptions will be available.

4.0 Results and Interpretation

This section provides the results from the building model, showing the impact measures as outputted from the Athena Impact Estimator. The results are categorized into the used assembly groups, and discussion of these attained values is provided. The effects of uncertainty and sensitivity are also explored, and the chain of custody for the material found is inquired and commented on.

4.1 Inventory Analysis

Before looking at the environmental impacts, it is first important to look at the material that is being modeled. The IE creates a list of material based on the assembly inputs. One of the outputs produced is a Bill of Materials, listing the total amount of all materials and the assembly group using it.

Table 2: Bill of Materials

Construction Material	Unit	Assembly Group					Building Total
		Foundation	Walls	Columns and Beams	Floors	Roof	
#15 Organic Felt	m2		2233				2233
3 mil Polyethylene	m2		2768.3392				2768.339
5/8" Fire-Rated Type X Gypsum Board	m2		25704.0231				25704.02
5/8" Regular Gypsum Board	m2		6511.9641				6511.964
Air Barrier	m2		2768.3392				2768.339
Aluminum	Tonnes		42.3318				42.3318
Batt. Fiberglass	m2 (25mm)		43466.9237				43466.92
Cedar Wood Bevel Siding	m2		760.1536				760.1536
Cold Rolled Sheet	Tonnes		0.5129				0.5129
Commercial(26 ga.) Steel Cladding	m2		456.7021				456.7021
Concrete 20 MPa (flyash av)	m3	292.0775					292.0775
Concrete 30 MPa (flyash av)	m3	1497.6054	1280.0123	469.4726	2025.572	420.9769	5693.639
Concrete Blocks	Blocks		34717.3679				34717.37
EPDM membrane (black, 60 mil)	kg		2751.059				2751.059
Expanded Polystyrene	m2 (25mm)		14011.3077				14011.31
Galvanized Sheet	Tonnes		6.2225				6.2225
Galvanized Studs	Tonnes		42.7567			77.0185	119.7753
Glazing Panel	Tonnes		205.5112				205.5112
Hollow Structural Steel	Tonnes			3.4291			3.4291
Joint Compound	Tonnes		32.1521				32.1521
Metric Modular (Modular) Brick	m2		2151.7593				2151.759
Mortar	m3		726.0972				726.0972
Nails	Tonnes		2.3625				2.3625
Natural Stone	m2		514.1651				514.1651
Paper Tape	Tonnes		0.369				0.369
Rebar, Rod, Light Sections	Tonnes	5.3976	133.0627	173.8924	114.0167	22.3913	448.7607
Screws Nuts & Bolts	Tonnes			3.0623		1.1321	4.1944
Small Dimension Softwood Lumber, kiln-dried	m3			3.7693			3.7693
Solvent Based Alkyd Paint	L			10.0225			10.0225
Standard Glazing	m2		1365.4443	492.5246			1857.969
Water Based Latex Paint	L			579.2532			579.2532
Welded Wire Mesh / Ladder Wire	Tonnes	2.5455					2.5455

To help analyse this information, the top five materials with the largest contribution to the building are identified. These have been noted as the Batt Fibreglass, Concrete Blocks, Steel Rebar, Fire-Rated Gypsum Board, and 30MPa Concrete.

The most common of these is both the 30MPa concrete and the rebar. This is because every basic assembly uses poured concrete. There is heavy use of concrete in the floors, but the rebar is used predominantly in the beams and columns as much more capacity is expected to be required in those elements. The concrete type listed (30MPa w/ average flyash) was assumed when modeling. As previously discussed, a higher range of concrete types is expected, but due to input limitations, have been simplified into this one major type.

The next materials most used appear solely in the wall's assembly. The main structural element of the walls is assumed to be concrete blocks. With the amount of wall elements present in the building, there is no surprise that this number is very high. Another major component of the walls is the use of fire-rated gypsum and batt fibreglass. Though there were many assumptions stated for the quantifying of the walls assembly, the materials were modelled very accurately. There were no major limitations requiring substitution in the model inputs.

4.2 Impact Assessment

4.2.1 Impact Category

In this LCA study, a total of eight impact categories are tested as the outcome of the modelling. These are global warming potential, acidification potential, eutrophication potential, ozone depletion potential, photochemical smog potential, human health respiratory effects potential, weighted raw resource use and fossil fuel consumption. A brief description of the eight categories is provided below.

Global warming potential: a reference measure of how much a product has contributed to the global warming issue. It is expressed as an equivalent mass of CO_2. Greenhouse gases (eg. CH_4, NO_x) other than CO_2 are converted to the same unit. The Impact Estimator has a sectional approach corresponding to each life cycle stages and the global warming potential is then summed in the outcome table.

Acidification potential*:* measures a more regional impact that affects human health when high level of NO_x and SO2 are detected. Acid rains are one of the concerns from acidification. The air and water emission from the product are calculated for acidification potential. It is expressed as an equivalent weight of H^+.

Eutrophication potential: the extent of surface waters contamination by nutrients that are previously scarce. When such nutrient is added to a water body, fast proliferation of aquatic photosynthetic plants can be resulted. High level of eutrophication can quickly deplete oxygen so that other creatures can die from lack of oxygen and decompose to pollute the water. Eutrophication is measured by equivalent weight of N.

Ozone depletion potential: measures the contribution to reduce the thickness of ozone layers within the stratosphere due to CFCs, HFCs, and halons emission. The ozone depletion potential of each of the contributing substances measured as equivalent weight of CFC-11.

Smog Potential: impact from air emission from industry and transportation causing photochemical smog. It is measured as equivalent weight of NO_x.

Human health respiratory effects potential: Particulate matters of various sizes (PM10 and PM2.5) have a considerable impact on human health. It is defined as the number one cause of human health deterioration due to its impact on the human respiratory system, such as asthma and bronchitis. This is measured as equivalent weight of PM 2.5.

Weighted raw resource use: measures the relative effects of different resource extraction activities. The Athena Sustainable Materials Institute surveyed a number of North America resource extraction activities and evaluate the study target based on this average. It is expressed in kg.

Fossil fuel consumption: energy including all direct and indirect energy is accounted. They are used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. This impact category captures the indirect energy from the unit processes (processing, transporting, converting and delivering) in the main process. Fossil fuel consumption is reported in mega-joules (MJ).

A summary of impact category measurements per square foot area (finished) by life cycle stages is listed in the follow table.

Table 3: Environmental Impact Results for All Impact Categorises

Life Cycle Stage	Process	Global Warming Potential	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Material	kg CO2 eq	476557.76	1308844	623841.611	231465.41	247403.05	**2888112.009**
	Transportation	kg CO2 eq	14297.179	30311.88	18439.5884	6880.4852	4744.6361	**74673.76435**
	Total	kg CO2 eq	490854.9	1339156	642281.199	238345.9	252147.7	**2962786.053**
Construction	Site Preperation	kg CO2 eq	-	-	-	-	-	**312315.4505**
	Material	kg CO2 eq	10409.417	25211.8	29536.2479	7.1911985	6650.268	**71814.92008**
	Transportation	kg CO2 eq	21767.349	76774.63	25124.4076	6651.7381	6910.9598	**137229.0797**
	Total	kg CO2 eq	32176.77	101986.5	54660.6554	6658.929	13561.23	**209044.0506**
Maintenance	Material	kg CO2 eq	0	309796.5	0	0	0	**309796.468**
	Transportation	kg CO2 eq	0	18221.49	0	0	0	**18221.4866**
	Total	kg CO2 eq	0	328017.9	0	0	0	**328017.93**
End-of-Life	Material	kg CO2 eq	12799.774	15919.11	15264.3763	4700.689	4789.4037	**53473.35203**
	Transportation	kg CO2 eq	10762.46	16629.52	12462.9322	3288.9159	2848.7686	**45992.59177**
	Total	kg CO2 eq	23562.23	32548.63	27727.3086	7989.605	7638.172	**99465.9426**
Operating Energy	Annual	kg CO2 eq	0	0	0	0	0	**0**
	Total	kg CO2 eq	0	0	0	0	0	**0**
Assembly Total			546593.9	1801709	724669.163	252994.434	273347.1	3911629.122

Life Cycle Stage	Process	Ozone Layer Depletion	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Material	kg CFC-11 eq	0.00096	0.002103	0.0011493	0.000266506	0.000239	**0.004718281**
	Transportation	kg CFC-11 eq	6.00E-07	1.3E-06	7.74E-07	2.86E-07	1.99E-07	**3.16299E-06**
	Total	kg CFC-11 eq	0.001	0.002103	0.00115	0.000266792	0.0002392	**0.00475947**
Construction	Site Preperation	kg CFC-11 eq	-	-	-	-	-	**243787.4004**
	Material	kg CFC-11 eq	0	7.7E-10	0	3.41E-12	0	**7.73411E-10**
	Transportation	kg CFC-11 eq	8.90E-07	3.11E-06	1.03E-06	2.73E-07	2.87E-07	**5.58809E-06**
	Total	kg CFC-11 eq	9.00E-07	3.01E-06	1.03E-06	2.73E-07	2.87E-07	**5.49909E-06**
Maintenance	Material	kg CFC-11 eq	0	0 00031	0	0	0	**0.000310388**
	Transportation	kg CFC-11 eq	0	7.43E-07	0	0	0	**7.43138E-07**
	Total	kg CFC-11 eq	0	0 00031	0	0	0	**0.000310431**
End-of-Life	Material	kg CFC-11 eq	5.80E-07	7.2E-07	6.88E-07	2.12E-07	2.16E-07	**2.41524E-06**
	Transportation	kg CFC-11 eq	4.40E-07	6.82E-07	5.10E-07	1.35E-07	1.17E-07	**1.88333E-06**
	Total	kg CFC-11 eq	1.00E-06	1E-06	1.20E-06	3.46E-07	3.32E-07	**3.88047E-06**
Operating Energy	Annual	kg CFC-11 eq	0	0	0	0	0	**0**
	Total	kg CFC-11 eq	0	0	0	0	0	**0**
Assembly Total			0.0010019	0.002418	0.00115223	0.000267411	0.0002398	243787.4054

Life Cycle Stage	Process	Acidification Potential	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Material	moles of H+ eq	162808.71	583503.9	213699.41	79482.82408	66305.139	**1105799.987**
	Transportation	moles of H+ eq	6056.2442	12910.18	7673.0676	2632.482448	1994.1039	**31266.07509**
	Total	moles of H+ eq	168865	596414.1	221372.5	82115.30653	68299.243	**1137066.105**
Construction	Site Preperation	moles of H+ eq	-	-	-	-	-	**255191.5918**
	Material	moles of H+ eq	5299.2448	13006.22	15376.646	4.006653704	3472.6094	**37158.72282**
	Transportation	moles of H+ eq	6904.6822	25023.71	7924.1328	2150.941394	3370.3287	**45373.79375**
	Total	moles of H+ eq	12203.93	38029.92	23300.78	2154.948048	6842.938	**82532.51878**
Maintenance	Material	moles of H+ eq	0	176849	0	0	0	**176848.9653**
	Transportation	moles of H+ eq	0	5911.795	0	0	0	**5911.795368**
	Total	moles of H+ eq	0	182760.7	0	0	0	**182760.7407**
End-of-Life	Material	moles of H+ eq	709.64439	882.5864	846.28674	260.6153486	265.53386	**2964.666744**
	Transportation	moles of H+ eq	3394.4162	5244.85	3930.735	1037.304599	898.48474	**14505.79099**
	Total	moles of H+ eq	4104.061	6127.437	4777 022	1297.919947	1164.0186	**17470.4589**
Operating Energy	Annual	moles of H+ eq	0	0	0	0	0	**0**
	Total	moles of H+ eq	0	0	0	0	0	**0**
Assembly Total			185172.991	823332.2	249450.302	85568.17453	76306.2	1675021.389

Life Cycle Stage	**Process**	**Eutrophication Potential**	**Assembly Group**					**Building Total**
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	
Manufacturing	Material	kg N eq	119.58395	475.0918	284.677362	268.44263	137.27404	**1285.069778**
	Transportation	kg N eq	6.3806571	13.60522	8.07698352	2.7589617	2.1000861	**32.92190732**
	Total	kg N eq	125.9646	488.697	292.754346	271.2016	139.3741	**1317.991625**
Construction	Site Preperation	kg N eq	-	-	-	-	-	**243797.6123**
	Material	kg N eq	4.2359811	12.44689	15.3631491	0.0013368	3.4694001	**35.51675513**
	Transportation	kg N eq	7.1553007	25.97876	8.20858627	2.2318724	3.5748299	**47.14934517**
	Total	kg N eq	11.39128	38.42565	23.5717354	2.233209	7.04423	**82.66610041**
Maintenance	Material	kg N eq	0	98.3034	0	0	0	**98.3033988**
	Transportation	kg N eq	0	6.135455	0	0	0	**6.1354554**
	Total	kg N eq	0	104.4389	0	0	0	**104.43885**
End-of-Life	Material	kg N eq	0.4872624	0.606009	0.58108503	0.1789461	0.1823233	**2.035626233**
	Transportation	kg N eq	3.2068171	4.954984	3.71349517	0.9799759	0.8488282	**13.70409987**
	Total	kg N eq	3.69408	5.560992	4.29458021	1.158922	1.031151	**15.73972521**
Operating Energy	Annual	kg N eq	0	0	0	0	0	**0**
	Total	kg N eq	0	0	0	0	0	**0**
Assembly Total			141.04996	637.1225	320.620661	274.593731	147.44948	245318.4487

Life Cycle Stage	**Process**	**Smog Potential**	**Assembly Group**					**Building Total**
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	
Manufacturing	Material	kg NOx eq	2407.628849	5436.85	2972.67	834.89976	700.61031	**12352.65856**
	Transportation	kg NOx eq	139.8628437	298.3954	176.892	60.162042	46.035029	**721.3473017**
	Total	kg NOx eq	2547.491693	5735.735	3149.6	895.0618	746.6453	**13074.53381**
Construction	Site Preperation	kg NOx eq	-	-	-	-	-	**244021.3165**
	Material	kg NOx eq	117.4222664	314.03	377.082	0.0311297	85.127203	**893.6925991**
	Transportation	kg NOx eq	154.2012182	560.4162	176.863	48.132042	78.011182	**1017.623614**
	Total	kg NOx eq	271.6234846	874.4062	553.94	48.16317	163.1384	**1911.271227**
Maintenance	Material	kg NOx eq	0	1704.85	0	0	0	**1704.85015**
	Transportation	kg NOx eq	0	132.4161	0	0	0	**132.4161271**
	Total	kg NOx eq	0	1836.996	0	0	0	**1836.9963**
End-of-Life	Material	kg NOx eq	9.118635687	11.341	10.8744	3.348799	3.4119999	**38.09483459**
	Transportation	kg NOx eq	75.76163618	117.0649	87.732	23.152109	20.05372	**323.7643384**
	Total	kg NOx eq	84.88027186	128.3649	98.606	26.50091	23.46572	**361.8177749**
Operating Energy	Annual	kg NOx eq	0	0	0	0	0	**0**
	Total	kg NOx eq	0	0	0	0	0	**0**
Assembly Total			2903.995449	8575.502	3802.146	969.72588	933.24942	261205.764

Life Cycle Stage	**Process**	**Human Health Respiratory Effects**	**Assembly Group**					**Building Total**
			Foundation	**Walls**	**Floors**	**Columns & Beams**	**Roof**	
Manufacturing	Material	kg PM2.5 eq	1115.465923	5653.788	1395.6896	447.5113	374.96	**8987.414929**
	Transportation	kg PM2.5 eq	7.35757296	15.68687	9.3165438	3.1873626	2.4219765	**37.97033063**
	Total	kg PM2.5 eq	1122.823496	5669.475	1405.006	450.6987	377.382	**9025.385146**
Construction	Site Preperation	kg PM2.5 eq	-	-	-	-	-	**243800.5617**
	Material	kg PM2.5 eq	4.80005525	14.61644	17.408945	0.003789	3.9313943	**40.76062186**
	Transportation	kg PM2.5 eq	8.299907588	30.11463	9.5230281	2.5876833	4.1118031	**54.63705278**
	Total	kg PM2.5 eq	13.09996284	44.73107	26.93197	2.591472	8.043197	**95.39767084**
Maintenance	Material	kg PM2.5 eq	0	4135.226	0	0	0	**4135.226479**
	Transportation	kg PM2.5 eq	0	7.113116	0	0	0	**7.113115664**
	Total	kg PM2.5 eq	0	4142.34	0	0	0	**4142.339624**
End-of-Life	Material	kg PM2.5 eq	0.675570225	0.840208	0.8056516	0.2481017	0.252784	**2.822315797**
	Transportation	kg PM2.5 eq	4.079325056	6.303131	4.7238596	1.2466069	1.0797766	**17.43269915**
	Total	kg PM2.5 eq	4.754895282	7.143339	5.529511	1.494709	1.332561	**20.25501564**
Operating Energy	Annual	kg PM2.5 eq	0	0	0	0	0	**0**
	Total	kg PM2.5 eq	0	0	0	0	0	**0**
Assembly Total			1140.678354	9863.689	1437.46748	454.784881	386.75776	257083.9392

Life Cycle Stage	Process	Weighted Resource Use	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Material	ecologically	4681726.493	5959314	5481213.2	1.00E+06	1.00E+06	**18122254.08**
	Transportation	ecologically	5893.247672	13341.85	7470.3157	2581.9	2010	**31297.31759**
	Total	ecologically	4687619.741	5972657	5488684	1.00E+06	1.00E+06	**18148960.89**
Construction	Site Preperation	ecologically	-	-	-	-	-	
	Material	ecologically	3582.772549	8088.649	10218.498	0.5231	2301.3	**24191.7431**
	Transportation	ecologically	6898.229827	25125.54	7908.2456	2156.6	3587.2	**45675.81314**
	Total	ecologically	10481.00238	33214.19	18126.74	2157	5888	**69866.93155**
Maintenance	Material	ecologically	0	375857.8	0	0	0	**375857.7775**
	Transportation	ecologically	0	5881.674	0	0	0	**5881.67379**
	Total	ecologically	0	381740.2	0	0	0	**381740.2213**
End-of-Life	Material	ecologically	4623.127183	5749.794	5513.3124	1697.8	1729.9	**19313.93369**
	Transportation	ecologically	3387.635488	5234.374	3922.8829	1035.2	896.69	**14476.78205**
	Total	ecologically	8010.762671	10984.16	9436.195	2733	2627	**33791.12144**
Operating Energy	Annual	ecologically	0	0	0	0	0	**0**
	Total	ecologically	0	0	0	0	0	**0**
Assembly Total			4706111.506	6398596	5516246.94	1004890	1008515	18638949.12

Life Cycle Stage	Process	Fossil Fuel Use	Assembly Group					Building Total
			Foundation	Walls	Floors	Columns & Beams	Roof	
Manufacturing	Material	MJ	2925493.9	13281380	5.00E+06	3567604.4	2630148.4	**27404627.07**
	Transportation	MJ	251455.31	569954.5	318651	109980.12	85811.914	**1335852.881**
	Total	MJ	3176949	13851335	5.00E+06	3677585	2715960	**28421829.38**
Construction	Site Preperation	MJ	-	-	-	-	-	**1237027.74**
	Material	MJ	154573.19	348694.4	440861	21.335051	99285.666	**1043435.611**
	Transportation	MJ	292797.98	1067017	335631	91570.961	153233.77	**1940251.029**
	Total	MJ	447371.2	1415712	8.00E+05	91592.3	252519.4	**3007194.918**
Maintenance	Material	MJ	0	1548943	0	0	0	**1548943.13**
	Transportation	MJ	0	249748.8	0	0	0	**249748.755**
	Total	MJ	0	1798692	0	0	0	**1798691.9**
End-of-Life	Material	MJ	196342.09	244191.1	234148	72106.202	73467.041	**820254.453**
	Transportation	MJ	143773.39	222150.1	166490	43935.92	38056.086	**614405.5077**
	Total	MJ	340115.5	466341.3	4.00E+05	116042.1	111523.1	**1434021.952**
Operating Energy	Annual	MJ	0	0	0	0	0	**0**
	Total	MJ	0	0	0	0	0	**0**
Assembly Total			3964435.7	17532081	6200000	3885219.4	3080002.5	36194546.18

The environmental impacts of Allard Hall are strongly related to the material manufacturing, energy consumption and emissions. From the tables above, Allard Hall contributes most in fossil fuel consumption and weighted resource use because the mass concrete use. It also contributes a considerable amount to global warming potential and acidification potential. The global warming potential reflects the building's concrete emission and emission related to its energy use, which is moderate. Its contributions in other impact categories are not significant.

4.2.2 Uncertainty

Service Life - We are making a very rough estimate of the service life of this building. Construction at UBC occurs at a rapid rate, and as we've seen by the building that was on site before Allard Hall was constructed, buildings are often torn down before their expected life expires.

Methods and Tools used in Modeling - There is uncertainty inherent in the programs used to model the building. Several assumptions had to be made to determine surrogate materials in cases when the actual construction material did not have a matching input available in the impact estimator.

Collection - The fact that the people responsible for performing detailed quantity takeoffs are students with little field experience may be a source of inaccuracy. This is especially true when making a comparative assertion with other campus buildings. With no background in the software and in some cases, no background reading structural plans, the level of detail and accuracy may be highly inconsistent from one project to the next.

Inaccurate Data - Energy use data presents uncertainty due to seasonal variations in temperature, waning building maintenance, and changes in occupancy will all contribute to shifts in energy use. Also, because this is a new building, no history is available and only a rough estimate of this number can be assumed.

No Data - There were cases when the exact building material was unknown and an educated guess was made. In cases where large quantities or particularly harmful substances were involved, this may be a source of significant uncertainty.

Impact Assessment - Any uncertainty involved with impact assessment is directly related to the limitations of the impact assessment software. The impact assessment is generated automatically, and the accuracy of emission impacts, characterization factors, etc. is based on Athena's databases.

4.2.3 Sensitivity Analysis

A sensitivity analysis is essential for accurately interpreting the output results from IE in the design of a building. As previously discussed, there are uncertainties that we encounter when modeling such a large scale project. Certain quantities are expected to not be completely accurate, and the methods used to calculate impacts may differ amongst other analysis methods. This fact once again emphasizes the importance of documenting the procedures of a LCA, but also leads us into the question of: What kind of changes will happen due to our uncertainties?

One way we can look at this aspect, is by measuring the sensitivity of the building's material. The top five materials, as previously identified in the inventory analysis, were further analysed for sensitivity. The quantity of each material was changed by a % of weight, and the differing environmental impacts outputted by IE were noted. Below is a figure illustrating the changes observed when increasing, individually, each of the top five materials by 10%.

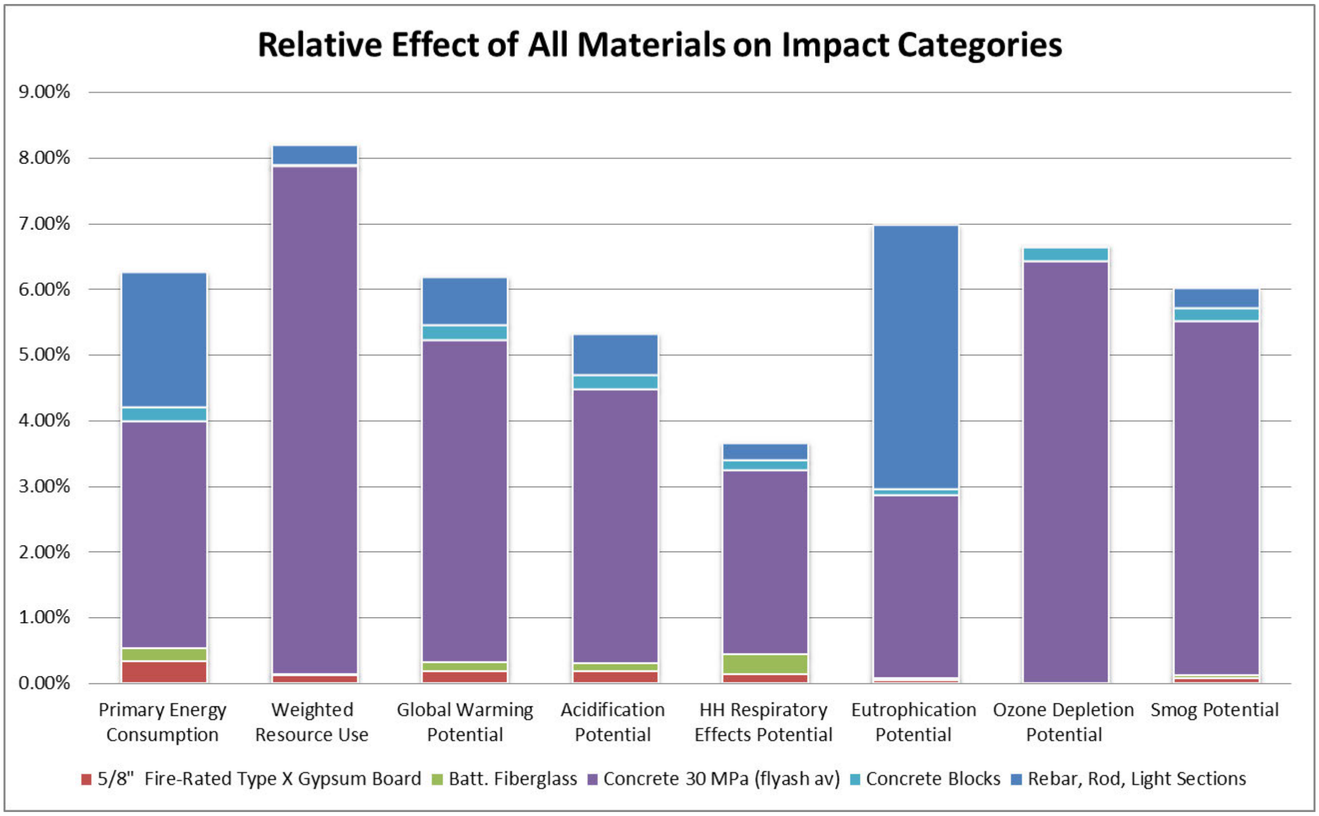

Figure 3: Relative Effect of Top Five Materials on Environmental Impact Categories

An obvious first observation is the dominance of concrete in the graph. In almost every category, concrete has the largest effect on the environmental impact categories, with a 7.72% increase in weighted resource. Other properties can also be extracted, such as that concrete contributes the most impact towards ozone depletion, and rebar use contributes most heavily to eutrophication.

Other materials have very minute impacts, resulting in observed differences less than 1.0%. This is telling us that at the least, any quantifying of these material take offs are not absolutely reliant on full accuracy. There is some leniency in both human error, and the assumptions made. The other more impactful materials should be measured more in depth however, to ensure the most realistic model.

This data is also revealing that the most sensitive category to material quantity is the weighted resource use. This can easily be linked to the fact that much of the building makes use of concrete, which is also a fairly dense material. The categories of eutrophication and ozone depletion are also very responsive to material changes in the building. That being said, decisions in detailing of the main components will make significant differences on the value of those impact categories.

4.2.4 Chain of Custody Inquiry

The specific materials used in this building project have a significant effect on the environmental impacts. As seen in the sensitivity analysis, a change in material of only 10% can alter impact categories at the building scale sufficiently enough, to make a material's full profile valuable in assessment.

To get a better understanding of what kind of impact material choice can have on a project, different materials were traced back to their extraction origins. This enables us to envision the traveling required for a material to reach its final destination.

For our case study, we traced the Steel Decking used in the Allard Hall Law Building. The structural drawings specified the use of VicWest brand decking, or something similarly approved. Assuming that the building contractors did indeed use decking as specified, information of local VicWest providers was inquired. In the below table, information regarding the chain of custody is summarized.

Table 4: Chain of Custody Inquiry

Material	**Life cycle stage**	Company Name	Date of contact	Latitude of facility	Longitude of facility	Transportation mode to facility	Transportation mode from facility
Steel Decking	Extraction	Wabush Mine	-	50.21896	-66.3833		Water
	Steel Manufacturing	Dofasco	-	43.26851	-79.8445	Water	Rail
	Decking Manufacturing	Vicwest	28-Mar-12	49.14484	-123.002	Rail	Truck
	Construction	UBC Properties Trust	24-Mar-12	49.26903	-123.253	Truck	-

VicWest in Delta, BC was able to provide us with a complete material tracing for the steel they manufacture. This factory, based in Vancouver, imports steel from Hamilton, Ontario, from a large steel Manufacturer, Dafasco. Furthermore, this Ontario based manufacturer imports its raw material from several different mines, located across America, but predominantly from within the province in Quebec. Raw materials are transported via water, and rail. The short distances across land are handled by truck, including the transportation from manufacturing to the building site.

Somewhat surprisingly, information about material extraction for steel in Canada was very easy to find. Due to the increasing use of LEED design in North America, for a product such as steel, this information is essentially required to be publicly available. If a manufacturer wants to stay competitive, and with designers wanting to achieve LEED standards, being able to provide a full material profile is necessary to allow clients to reach their goals.

4.2.5 Functions and Impacts

Building Functions

Allard Hall Building is a multifunctional structure serving both institutional and office functions. The building has a spacious interior for spectacular art pieces and lounge as well as a beautiful atrium on the second floor creating a fascinating view from inside the building. It has large capacity for both classrooms and office areas. While providing an educational environment, this building also provides the Law Faculty administration offices and general law consulting service space. The detailed functional areas of Allard Hall is summarized below.

Table 5 Functional Area

Starewells/Halls/Atriums	35944	26.81%
Office/Office Spaces	29979	22.36%
Library	27169	20.27%
Classroom	13154	9.81%
Mechanical Rooms	12044	8.98%
Study/Research/Prep/Computer Lab Rooms	6975	5.20%
Washrooms/ Locker Rooms	4302	3.21%
Storage Rooms	2269	1.69%
Auditorium/Lecture Halls	2210	1.65%
Testing Labs	0	0.00%
Total	134046	100%

Functional Units

A functional unit is a measure of performance for a product or building undergoing an LCA. It is a reference unit that expresses impacts per amount of delivered performance by the product system. In the case of a building, the main use is occupancy. Several options of how to express occupancy are available, but the most fitting one will take the purpose (study space, office space, and storage space) of the building into account.

The law building is clearly an academic building, but its use is split between study space for students and office space for law faculty. Large portions of space are reserved for the law library as well, which is useful to both students and faculty. Because of the mixed use nature of this building, several potential functional units exist, including:

Per generic floor area – impacts are divided by the square footage of the whole building.

Per library area – impacts are divided by the square footage reserved study spaces and book stacks

Per office area – impacts are divided by the square footage reserved for administration and staff use

Per classroom area– impacts are divided by the square footage reserved for holding lectures

Table 6: Table of Examined Functional Units

		Per Functional Area (/ft2)			
	TOTAL Impact	Generic Floor Area	Library Floor Area	Office Area	Classroom Area
Fossil Fuel Consumption MJ	35035360.51	261.3681909	1289.534415	1168.663415	2280.354
Weighted Resource Use kg	19479125.56	145.3167238	716.9614474	649.7590168	1267.842
Global Warming Potential (kg CO2 eq)	3599313.656	26.85133205	132.4786947	120.0611647	234.2693
Acidification Potential (moles of H+ eq)	1419829.795	10.59210864	52.25918491	47.3608124	92.41277
HH Respiratory Effects Potential (kg PM2.5 eq)	13283.37754	0.099095665	0.48891669	0.443089414	0.864578
Eutrophication Potential (kg N eq)	1520.836358	0.01134563	0.055976899	0.050730056	0.098987
Ozone Depletion Potential (kg CFC-11 eq)	0.00504887	3.76652E-08	1.85832E-07	1.68414E-07	3.29E-07
Smog Potential (kg NOx eq)	17184.39744	0.128197764	0.632500182	0.573214498	1.118485

In the above table, the total building impacts are divided by the different functional units used in our analysis. The generic floor area is useful because it allows us to see the impact of the entire building as a whole, in units of measurement that can be immediately compared to other buildings. However, as previously stated, all buildings are not valued equally for simply, their floor space. What the floor space is used for is also an essential parameter to know. It is for that reason, aside from total floor area, the functional units of library space, office area, and classroom are chosen. For example, one is able to assess the building in its ability to provide book stacks in relation to environmental impact.

The value of this type of functional unit breakdown is for when comparing to other buildings of different size. This new UBC Law building now has a clearly defined and measured value for environmental impact, separated into different categories for purpose. From this point, it can now be compared to other projects that have had an LCA conducted.

5.0 Conclusion

A life cycle assessment on the new UBC Law Building, Allard Hall, was conducted and the resulting environmental impacts were assessed. A number of significant values have been discovered, including a bill of materials to display the assumed construction materials used in analysis:

- This revealed to us that the likely top 5 represented materials used in the building were Batt Fibreglass, Concrete Blocks, Steel Rebar, Fire-Rated Gypsum Board, and 30MPa Concrete.
- From this a sensitivity analysis was also done, which demonstrated the dominating influence concrete has on the overall building impact, with as much of a 7.72% increase in weighted material use, when independently increased by 10% in weight. The environmental impact categories are not particularly sensitive to the other materials, except for Eutrophication Potential, which is significantly influenced by a change in rebar quantity.
- When looking solely at the overall environmental impacts and the building's life cycle, it is shown that the cycle with the biggest contribution is material manufacturing. Of all stages of the life cycle, this is one that needs the most attention if one wishes to reduce emissions. The greatest impacts come in the form of fossil fuel consumption and weighted resource, and this attributed to the extensive use of concrete.
- A Chain of Custody Inquiry was done and the results showed that steel decking used in the Allard Hall building originated from Eastern Canada, due to the lack of Iron Ore mines on the West Coast, and also due to the large steel manufacturing plants in Ontario. This transportation is not over extensive, but is still important to consider when looking at possible improvements.
- The functional units for this building were taken as square footage of floor area, in the form of generic, library, office, and classroom space. The values attained are to be used as a baseline to compare other similar buildings in terms of performance using the aforementioned building uses.

All of the data that has been collected is to be added to the UBC Building Database. This information is intended to be used as reference in the future, so that quantifiable comparisons can be made.

Appendix A: IE Input Document

Assembly	Assembly Type	Assembly Name	Input Fields	Input Values	
				Known/Measured	IE Inputs
1.0 Foundations	1.1 Concrete Slab On Grade				
		1.1.1 SOG_100mm_Exterior			
			Length (ft)	57.78	57.78
			Width (ft)	57.78	57.78
			Thickness (in)	4	4
			Concrete (psi)	4000	4000
			Concrete flyash %	-	Average
		1.1.2 SOG_100mm_Interior			
			Length (ft)	154.98	154.98
			Width (ft)	154.98	154.98
			Thickness (in)	4	**4**
			Concrete (psi)	3000	3000
			Concrete flyash %	-	Average
		1.1.3 SOG_200mm_Interior			
			Length (ft)	54.42	54.42
			Width (ft)	54.42	54.42
			Thickness (in)	8	**8**
			Concrete (psi)	3000	3000
			Concrete flyash %	-	Average
	1.2 Concrete Footing				
		1.2.1 Footing_F1			
			Length (ft)	49.2	49.2
			Width (ft)	4.9	4.9
			Thickness (in)	17.7	17.7
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.2 Footing_F2			

			Length (ft)	70.85	70.85
			Width (ft)	5.90	5.90
			Thickness (in)	19.68	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.3. Footing_F3			
			Length (ft)	52.48	57.73
			Width (ft)	6.56	6.56
			Thickness (in)	21.65	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.4 Footing_F4			
			Length (ft)	135.79	176.53
			Width (ft)	7.54	7.54
			Thickness (in)	25.58	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.5 Footing_F5			
			Length (ft)	9.84	16.73
			Width (ft)	9.84	9.84
			Thickness (in)	33.46	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#8	#6
		1.2.6 Footing_F6			
			Length (ft)	17.71	17.71
			Width (ft)	2.95	2.95
			Thickness (in)	9.84	9.84
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#4	#4
		1.2.7 Footing_SF1			
			Length (ft)	555.39	555.39
			Width (ft)	1.97	1.97

	Thickness (in)	9.84	9.84
	Concrete (psi)	4351	4000
	Concrete flyash %	-	average
	Rebar	#5	#5
1.2.8 Footing_SF2			
	Length (ft)	420.43	462.47
	Width (ft)	6.56	6.56
	Thickness (in)	21.65	19.68
	Concrete (psi)	4351	4000
	Concrete flyash %	-	average
	Rebar	#8	#6
1.2.9 Footing_SF3			
	Length (ft)	54.15	70.39
	Width (ft)	8.20	8.20
	Thickness (in)	25.58	19.68
	Concrete (psi)	4351	4000
	Concrete flyash %	-	average
	Rebar	#8	#6
1.2.10 Footing_SF4			
	Length (ft)	57.72	57.72
	Width (ft)	4.92	4.92
	Thickness (in)	13.78	13.78
	Concrete (psi)	4351	4000
	Concrete flyash %	-	average
	Rebar	#6	#6
1.2.11 Footing_1500mm_LowerFloor			
Lower floor @ Elevator Pit	Length (ft)	54.42	163.26
	Width (ft)	21.33	21.33
	Thickness (in)	59.04	19.68
	Concrete (psi)	4351	4000
	Concrete flyash %	-	average
	Rebar	#10	#6
1.2.12 Footing_250mm_LowerFloor			

			Length (ft)	3.28	3.28
			Width (ft)	3.94	3.94
			Thickness (in)	9.84	9.84
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#4	#5
		1.2.13 Footing_400mm_GroundFloor			
			Length (ft)	40.10	40.10
			Width (ft)	52.48	52.48
			Thickness (in)	15.74	15.74
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.14 Footing_750mm_GroundFloor			
			Length (ft)	48.25	48.25
			Width (ft)	9.84	9.84
			Thickness (in)	19.68	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#8	#6
		1.2.15 Footing_400mm_GroundFloor			
			Length (ft)	8.20	8.20
			Width (ft)	4.92	4.92
			Thickness (in)	15.74	15.74
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#5	#5
		1.2.16 Footing_500mm_GroundFloor			
			Length (ft)	14.76	14.76
			Width (ft)	4.92	4.92
			Thickness (in)	19.68	19.68

			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#6	#6
		1.2.17 Footing_1500mm_Ground Floor			
			Length (ft)	56.25	168.75
			Width (ft)	6.56	6.56
			Thickness (in)	59.04	19.68
			Concrete (psi)	4351	4000
			Concrete flyash %	-	average
			Rebar	#8	#6
2.0 Walls	2.1 Cast in Place				
		2.1.1 Wall_Cast-in-Place_200mm_Basement			
			Length (ft)	863.00	863.00
			Height (ft)	13.70	13.70
			Thickness (in)	7.87	8
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.2 Wall_Cast-in-Place_300mm_Basement			
			Length (ft)	233.00	233.00
			Height (ft)	13.70	13.70
			Thickness (in)	11.81	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.3 Wall_Cast-in-Place_400mm_Basement			
			Length (ft)	41.00	54.68
			Height (ft)	13.70	13.70
			Thickness (in)	15.75	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average

			Rebar	#15M	#5
		Opening	Type	Door	Door
			Number	1	1.000
			Material	Hollow Metal	Steel Interior Door
		2.1.4 Wall_Cast-in-Place_450mm_Basement			
			Length (ft)	72.00	108.03
			Height (ft)	13.70	13.70
			Thickness (in)	17.72	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		Opening	Type	Door	Door
			Number	1	1
			Material	Wood	Hollow Core Wood Interior Door
		2.1.5 Wall_Cast-in-Place_600mm_Basement			
			Length (ft)	15.00	30.00
			Height (ft)	13.70	13.70
			Thickness (in)	23.62	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.6 Wall_Cast-in-Place_1000mm_Basement			
			Length (ft)	7.00	23.34
			Height (ft)	13.70	13.70
			Thickness (in)	39.37	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.7 Wall_Cast-in-Place_200mm_Main			
		(see assumptions)	Length (ft)	619.00	430.00
			Height (ft)	12.47	12.47
			Thickness (in)	7.87	8

	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#15M	#5
2.1.8 Wall_Cast-in-Place_300mm_Main			
	Length (ft)	855.00	855.00
	Height (ft)	12.47	12.47
	Thickness (in)	11.81	11.81
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#15M	#5
2.1.9 Wall_Cast-in-Place_400mm_Main			
	Length (ft)	166.00	221.38
	Height (ft)	12.47	12.47
	Thickness (in)	15.75	11.81
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#15M	#5
Opening	Type	Door	Door
	Number	4	4
	Material	Wood	Hollow Core Wood Interior Door
2.1.10 Wall_Cast-in-Place_450mm_Main			
	Length (ft)	289.00	433.62
	Height (ft)	12.47	12.47
	Thickness (in)	17.72	11.81
	Concrete (psi)	-	4000
	Concrete flyash %	-	average
	Rebar	#15M	#5
Opening	Type	Door	Door
	Number	5	5
	Material	Wood	Hollow Core Wood Interior Door
2.1.11 Wall_Cast-in-Place_600mm_Main			
	Length (ft)	57.00	114.00
	Height (ft)	12.47	12.47

			Thickness (in)	23.62	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.12 Wall_Cast-in-Place_1000mm_Main			
			Length (ft)	28.00	93.34
			Height (ft)	12.47	12.47
			Thickness (in)	39.37	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.13 Wall_Cast-in-Place_300mm_5thFloor			
			Length (ft)	19.00	19.00
			Height (ft)	16.40	16.40
			Thickness (in)	11.81	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		2.1.14 Wall_Cast-in-Place 400mm 5thFloor			
			Length (ft)	29.00	38.67
			Height (ft)	16.40	16.40
			Thickness (in)	15.75	11.81
			Concrete (psi)	-	4000
			Concrete flyash %	-	average
			Rebar	#15M	#5
		Opening	Type	Door	Door
			Number	1	1
			Material	Hollow Metal	Steel Interior Door
		2.1.15 Wall_Cast-in-Place_450mm_5thFloor			
			Length (ft)	63.00	94.53
			Height (ft)	16.40	16.40
			Thickness (in)	17.72	11.81
			Concrete (psi)	-	4000

			Concrete flyash %	-	average
			Rebar	#15M	#5
		Opening	Type	Door	Door
			Number	1	1
			Material	Hollow Metal	Steel Interior Door
	2.2 Partition Walls				
		2.2.1 Interior_Partition_P1_Basement			
			Length (ft)	30.00	30.00
			Height (ft)	13.70	13.70
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm type X / 2	Gypsum Fire Rated Type X 5/8"
			Material/Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	1	1
			Material	Hollow Metal	Steel Interior Door
		2.2.2 Interior_Partition_P2_Basement			
			Length (ft)	149.00	149.00
			Height (ft)	13.70	13.70
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16

		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm type X / 3	Gypsum Fire Rated Type X 5/8"
			Material/Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	6	6
			Material	Wood	Hollow Core Wood Interior Door
		2.2.3 Interior_Partition_P4_Basement			
			Length (ft)	75.00	75.00
			Height (ft)	13.70	13.70
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	(2x) 1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm type X / 2	Gypsum Fire Rated Type X 5/8"
			Material / Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	184	184
		2.2.4 Interior_Partition_P1_Main			
			Length (ft)	1,050.00	1,050.00
			Height (ft)	12.47	12.47
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none

			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm type X / 2	Gypsum Fire Rated Type X 5/8"
			Material/Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	47	47
			Material	Wood	Hollow Core Wood Interior Door
		2.2.5 Interior Partition P2 Main			
			Length (ft)	4,869.00	4,869.00
			Height (ft)	12.47	12.47
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm type X / 3	Gypsum Fire Rated Type X 5/8"
			Material/Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	197	197
			Material	Wood	Hollow Core Wood Interior Door

2.2.6 Interior_Partition_P3_Main			
	Length (ft)	349.00	349.00
	Height (ft)	12.47	12.47
	Wall Type	-	Non Load Bearing
	Stud Weight	-	Light (25Ga)
	Sheathing Type	none	none
	Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
	Stud Spacing (in)	16	16
Envelope	Category	Gypsum Board	Gypsum Board
	Material/Number	16mm type X / 1	Gypsum Fire Rated Type X 5/8"
	Material/Number	16mm Fire Code C / 2	Gypsum Fire Rated Type X 5/8"
Envelope	Category	Insulation	Insulation
	Material	Batt Insulation	Fiberglass Batt
	Thickness (mm)	92	92
Opening	Type	Door	Door
	Number	3	3
	Material	Wood	Hollow Core Wood Interior Door
2.2.7 Interior_Partition_P4_Main			
	Length (ft)	387.00	387.00
	Height (ft)	12.47	12.47
	Wall Type	-	Non Load Bearing
	Stud Weight	-	Light (25Ga)
	Sheathing Type	none	none
	Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
	Stud Spacing (in)	16	16
Envelope	Category	Gypsum Board	Gypsum Board
	Material / Number	16mm type X / 2	Gypsum Fire Rated Type X 5/8"
	Material /	-	

			Number		
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	184	184
		Opening	Type	Door	Door
			Number	8	8
			Material	Wood	Hollow Core Wood Interior Door
		2.2.8 Interior_Partition_P5_Main			
			Length (ft)	146.00	146.00
			Height (ft)	12.47	12.47
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm Fire Code C / 2	Gypsum Fire Rated Type X 5/8"
			Material / Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	4	4
			Material	Wood	Hollow Core Wood Interior Door
		2.2.9 Interior_Partition_P6_Main			
			Length (ft)	256.00	256.00
			Height (ft)	12.47	12.47
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none

			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	24	24
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm Fire Code C / 1	Gypsum Fire Rated Type X 5/8"
			Material / Number	25mm for elevator, fire resistant	Gypsum Fire Rated Type X 5/8"
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	64	64
		2.2.10 Interior_Partition_P9_Main			
			Length (ft)	148.00	
			Height (ft)	12.47	
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 6	1 5/8 x 6
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm Type X / 2	Gypsum Fire Rated Type X 5/8"
			Material / Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	152	152
		Opening	Type	Door	Door
			Number	4	4
			Material	Wood	Hollow Core Wood Interior Door
		2.2.11 Interior_Partition_P10_Main			
			Length (ft)	84.00	
			Height (ft)	12.47	

			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 6	1 5/8 x 6
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm Type X / 3	Gypsum Fire Rated Type X 5/8"
			Material / Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	152	152
		Opening	Type	Door	Door
			Number	2	2
			Material	Wood	Hollow Core Wood Interior Door
		2.2.12 Interior_Partition_P3_5thFloor			
			Length (ft)	48.00	
			Height (ft)	16.40	
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm type X / 1	Gypsum Fire Rated Type X 5/8"
			Material/Number	16mm Fire Code C / 2	Gypsum Fire Rated Type X 5/8"
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92

		Opening	Type	Door	Door
			Number	5	5
			Material	Hollow Metal	Steel Interior Door
		2.2.13 Interior_Partition_P5_5thFloor			
			Length (ft)	49.00	
			Height (ft)	16.40	
			Wall Type		Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material / Number	16mm Fire Code C / 2	Gypsum Fire Rated Type X 5/8"
			Material / Number	-	
		Envelope	Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	92	92
		Opening	Type	Door	Door
			Number	1	1
			Material	Hollow Metal	Steel Interior Door
		2.2.14 Interior_Partition_P6_5thFloor			
			Length (ft)	10.00	
			Height (ft)	16.40	
			Wall Type	-	Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 2 1/2	1 5/8 x 3 5/8
			Stud Spacing (in)	24	24
		Envelope	Category	Gypsum Board	Gypsum Board

		Envelope	Material / Number	16mm Fire Code C / 1	Gypsum Fire Rated Type X 5/8"
			Material / Number	25mm for elevator, fire resistant	Gypsum Fire Rated Type X 5/8"
			Category	Insulation	Insulation
			Material	Batt Insulation	Fiberglass Batt
			Thickness (mm)	64	64
		2.2.15 Interior_Partition_P23_Basement			
		Opening	Length (ft)	245.00	245.00
			Height (ft)	13.70	13.70
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
			Type	Door	Door
			Number	12	12
			Material	Hollow Metal	Steel Interior Door
		2.2.16 Interior_Partition_P23_Main			
		Opening	Length (ft)	37.00	37.00
			Height (ft)	12.47	12.47
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
			Type	Door	Door
			Number	2	2
			Material	Hollow Metal	Steel Interior Door
		2.2.17 Exterior_Partition_W1_Main			
		Envelope	Length (ft)	1,159.00	1,159.00
			Height (ft)	13.12	13.12
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
			Category	Cladding	Cladding
			Material	Brick (modular metric)	Brick (modular metric)

Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
	Material	Air Barrier	Air Barrier
Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
	Material	Vapour Retarder Membrane	Polyethylene 3 mil
Envelope	Category	Insulation	Insulation
	Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
	Thickness	125	125
Opening	Type	Window	Window
	Number	75	75
	Total Area (ft^2)	2743.800	2743.800
	Frame Type	-	Aluminum Frame
	Glazing Type	-	Standard Glazing
	Fixed / Operable	Fixed	Fixed
2.2.18 Exterior_Partition_W1.1_Main			
Envelope	Length (ft)	109.00	109.00
	Height (ft)	13.12	12.47
	Wall Type	See 1.1.7	
	Reinforcement	See 1.1.7	
	Category	Cladding	Cladding
	Material	Brick (modular metric)	Brick (modular metric)
Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
	Material	Air Barrier	Air Barrier
Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
	Material	Vapour Retarder Membrane	Polyethylene 3 mil
Envelope	Category	Insulation	Insulation
	Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
	Thickness (mm)	125	125
2.2.19 Exterior_Partition_W2_Main			

			Length (ft)	58.00	58.00
			Height (ft)	13.12	13.12
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
		Envelope	Category	Cladding	Cladding
			Material	12mm prefinished wood	Wood Bevel Siding - Cedar
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		2.2.20 Exterior_Partition_W3_5th Floor			
			Length (ft)	188.00	188.00
			Height (ft)	16.40	16.40
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
		Envelope	Category	Cladding	Cladding
			Material	32mm stone veneer	Natural stone
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		2.2.21 Exterior_Partition_W3.1_5thFloor			

			Length (ft)	80.00	80.00
			Height (ft)	16.40	12.47
			Wall Type	See 1.1.7	
			Reinforcement	See 1.1.7	
		Envelope	Category	Cladding	Cladding
			Material	32mm stone veneer	Natural stone
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		Opening	Type	Door	Door
			Number	4	4.000
			Material	Hollow Metal	Steel Exterior Door
		2.2.22 Exterior_Partition_W4_5th Floor			
			Length (ft)	109.00	109.00
			Height (ft)	16.40	16.40
			Wall Type	Steel z-girts	Non Load Bearing
			Stud Weight	Heavy (20ga)	Heavy (20ga)
			Sheathing Type	none	none
			Stud Thickness	200mm	1 5/8 x 8in
			Stud Spacing	600mm	24in
		Envelope	Category	Cladding	Cladding
			Material	prefinished metal cladding	commercial - 26ga
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	100	100
		2.2.24 Special_Exterior_Partition_W1_3400			
			Length (ft)	181.00	181.00

			Height (ft)	11.15	11.15
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
		Envelope	Category	Cladding	Cladding
			Material	Brick (modular metric)	Brick (modular metric)
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		Opening	Type	Window	Window
			Number	11	11
			Total Area (ft^2)	223.700	223.700
			Frame Type	XXX	Aluminum Frame
			Glazing Type	XXX	Standard Glazing
			Fixed / Operable	Fixed	Fixed
		Opening	Type	Door	Door
			Number	2	2
			Material	Glass	Aluminum Exterior Door, 80% Glazing
		2.2.25 Special_Exterior_Partition_W3_600			
			Length (ft)	642.00	642.00
			Height (ft)	1.97	1.97
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
		Envelope	Category	Cladding	Cladding
			Material	32mm stone veneer	Natural stone
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier

			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		2.2.26 Special_Exterior_Partition_W1_50-50			
		Envelope	Length (ft)	286.00	286.00
			Height (ft)	13.12	13.12
			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
			Category	Cladding	Cladding
			Material	Brick (modular metric)	Brick (modular metric)
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		Opening	Type	Window	Window
			Number	170	170
			Total Area (ft²)	1875.900	1875.900
			Frame Type	XXX	Aluminum Frame
			Glazing Type	XXX	Standard Glazing
			Fixed / Operable	Fixed	Fixed
		2.2.27 Special_Exterior_Partition_W1_800			
			Length (ft)	724.00	724.00
			Height (ft)	2.62	2.62

			Wall Type	Concrete Block	Concrete Block
			Reinforcement	-	#4
		Envelope	Category	Cladding	Cladding
			Material	Brick (modular metric)	Brick (modular metric)
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Air Barrier	Air Barrier
		Envelope	Category	Air and Vapour Barrier	Air and Vapour Barrier
			Material	Vapour Retarder Membrane	Polyethylene 3 mil
		Envelope	Category	Insulation	Insulation
			Material	semi-rigid, flexible (polyurethane?)	Polystyrene Expanded
			Thickness (mm)	125	125
		Opening	Type	Door	Door
			Number	2	2
			Material	Glass	Aluminum Exterior Door, 80% Glazing
		2.2.28 Special_Exterior_Partition_FM2_3200			
			Length (ft)	724.00	724.00
			Height (ft)	10.50	10.50
			Wall Type	Curtain	Curtain
			Percent viewable glazing	50	50
			Percent spandrel panel	50	50
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Spandrel Panel
		2.2.29 Special_Exterior_Partition_FM2 3400			
			Length (ft)	461.00	461.00
			Height (ft)	11.15	11.15
			Wall Type	Curtain	Curtain
			Percent viewable glazing	50	50

			Percent spandrel panel	50	50
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Spandrel Panel
	2.3 Furring				
		2.3.1 Furring_F1_Basement			
			Length (ft)	299.00	299.00
			Height (ft)	13.70	13.70
			Wall Type		Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1" metal furring system	1 5/8 x 3 5/8
			Stud Spacing (in)	16	24
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm regular	Gypsum Regular 5/8"
			Material/Number	-	-
		Opening	Type	Door	Door
			Number	5	5
			Material	Hollow Metal	Steel Interior Door
		2.3.2 Furring_F3_Basement			
			Length (ft)	126.00	126.00
			Height (ft)	13.70	13.70
			Wall Type		Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	2 1/2	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm regular	Gypsum Regular 5/8"
			Material/Number	-	-

2.3.3 Furring F1 Main

Envelope	Length (ft)	362.00	362.00
	Height (ft)	12.47	12.47
	Wall Type		Non Load Bearing
	Stud Weight	-	Light (25Ga)
	Sheathing Type	none	none
	Stud Thickness (in)	1" metal furring system	1 5/8 x 3 5/8
	Stud Spacing (in)	16	24
	Category	Gypsum Board	Gypsum Board
	Material/Number	16mm regular	Gypsum Regular 5/8"
	Material/Number	-	-
Opening	Type	Door	Door
	Number	1	1
	Material	Hollow Metal	Steel Interior Door

2.3.4 Furring_F3_Main

Envelope	Length (ft)	3,599.00	3,599.00
	Height (ft)	12.47	12.47
	Wall Type		Non Load Bearing
	Stud Weight	-	Light (25Ga)
	Sheathing Type	none	none
	Stud Thickness (in)	2 1/2	1 5/8 x 3 5/8
	Stud Spacing (in)	16	16
	Category	Gypsum Board	Gypsum Board
	Material/Number	16mm regular	Gypsum Regular 5/8"
	Material/Number	-	-
Opening	Type	Door	Door
	Number	5	5
	Material	Wood	Hollow Core Wood Interior Door

2.3.5 Furring_F4_Main

	Length (ft)	730.00	730.00
	Height (ft)	12.47	12.47

			Wall Type		Non Load Bearing
			Stud Weight	-	Light (25Ga)
			Sheathing Type	none	none
			Stud Thickness (in)	1 5/8 x 3 5/8	1 5/8 x 3 5/8
			Stud Spacing (in)	16	16
		Envelope	Category	Gypsum Board	Gypsum Board
			Material/Number	16mm regular	Gypsum Regular 5/8"
			Material/Number	-	-
		Opening	Type	Door	Door
			Number	21	21
			Material	Wood	Hollow Core Wood Interior Door
	2.4 Curtain Walls				
		2.4.1 Curtain_Wall_FM2_600_lounge			
			Length (ft)	73.00	73.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	85	85
			Percent spandrel panel	15	15
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Panel Spandrel
		Opening	Type	Door	Door
			Number	2	2
			Material	Glass	Aluminum Exterior Door, 80% Glazing
		2.4.2 Curtain_Wall_FM2_800_lounge			
			Length (ft)	94.00	94.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	80	80

			Percent spandrel panel	20	20
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Aluminum Exterior Door, 80% Glazing
		2.4.3 Curtain_Wall_FM2_0_lounge			
			Length (ft)	104.00	104.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	100	100
			Percent spandrel panel	0	0
			Insulation thickness	-	-
			Spandrel panel type	-	-
		2.4.4 Curtain_Wall_FM2_1500_lounge			
			Length (ft)	104.00	104.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	62	62
			Percent spandrel panel	38	38
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Panel Spandrel
		2.4.5 Curtain_Wall_Glass_forum			
			Length (ft)	109.00	109.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	100	100
			Percent spandrel panel	0	0

		Envelope	Insulation thickness	-	-
			Spandrel panel type	-	-
		Opening	Type	Door	Door
			Number	2	2
			Material	Glass	Aluminum Exterior Door, 80% Glazing
		2.4.6 Curtain_Wall_FM2_1200_southwest			
			Length (ft)	182.00	182.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	70	70
			Percent spandrel panel	30	30
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Panel Spandrel
		2.4.7 Curtain_Wall_FM2_2000			
			Length (ft)	309.00	309.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	50	50
			Percent spandrel panel	50	50
			Insulation thickness (mm)	125	125
			Spandrel panel type	glass	Opaque Glass Panel Spandrel
		2.4.8 Curtain_Wall_FM2_Terrace			
			Length (ft)	129.00	129.00
			Height (ft)	13.12	13.12
			Wall Type	Curtain	Curtain
			Percent viewable glazing	100	100

			Percent spandrel panel	0	0
			Insulation thickness	-	-
			Spandrel panel type	-	-
	2.5 Special Interior Walls				
		2.5.1 Forum_Sliding_Doors			
		(extra materials input used)	Length (ft)	127.00	(1249.68 sf)
		(converted to square feet)	Height (ft)	9.84	
			Wall Type	Solid Wood Panel	Cedar Wood Bevel Siding
		2.5.2 Forum_Wood_Panel_Balcony			
		(extra materials input used)	Length (ft)	54.00	(177.12 sf)
		(converted to square feet)	Height (ft)	3.28	
			Wall Type	2 wood panels	Cedar Wood Bevel Siding
		2.5.3 Forum Concrete Balcony			
			Length (ft)	84.00	84.00
			Height (ft)	3.28	3.28
			Thickness (mm)	300.00	300.00
			Wall Type	Concrete	Typical Concrete Values
		2.5.4 Library_Glass_Wall			
		(extra materials input used)	Length (ft)	58.00	(464 sf)
		(converted to square feet)	Height (ft)	8.00	
			Wall Type	Glass	Standard Glazing
		2.5.5 Glass_Guard			
		(extra materials input used)	Length (ft)	1,191.00	1,137.70
		(converted to square feet)	Panel Height (ft)	2.79	2.79

			Panel Width (ft)	4.27	
			Panel gap (ft)	0.20	(3174 sf)
			Wall Type	Glass	Standard Glazing
3.0 Columns and Beams	3.1 Concrete Column				
		3.1.1 Column_Concrete_Beam_N/A_Lowerlevel			
			Number of Beams	0	0
			Number of Columns	6	6
			Column Height(ft)	14.37	14.37
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68
			Supported Area(ft2)	387.30	388.00
			Live load (psf)	100.27	100
		3.1.2 Column_Concrete_Beam_Concrete_GroundLevel			
			Number of Beams	20	20
			Number of Columns	43	43
			Column Height(ft)	13.12	13.12
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68
			Supported Area(ft2)	387.30	388.00
			Live load (psf)	113.48	100
		3.1.3 Column_Concrete_Beam_Concrete_Level2			

			Number of Beams	11	11
			Number of Columns	64	64
			Column Height(ft)	13.12	13.12
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68
			Supported Area(ft2)	387.30	388.00
			Live load (psf)	134.72	100
		3.1.4 Column_Concrete_Beam_Concrete_Level3			
			Number of Beams	8	8
			Number of Columns	83	83
			Column Height(ft)	13.12	13.12
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68
			Supported Area(ft2)	387.30	388.00
			Live load (psf)	111.22	100
		3.1.5 Column_Concrete_Beam_Concrete_Level4			
			Number of Beams	13	13
			Number of Columns	87	87
			Column Height(ft)	13.12	13.12
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68

			Supported Area(ft2)	387.30	388.00
			Live load (psf)	53.59	75
		3.1.4 Column_Hollow Structural Steel_Beam_N/A_Level5			
			Number of Beams	7	7
			Number of Columns	31	31
			Column Height(ft)	16.40	16.4
			Bay sizes (ft)	19.68	19.68
			Supported span (ft)	19.68	19.68
			Supported Area(ft2)	387.30	388.00
			Live load (psf)	38.02	50
4.0 Floors	4.1 Concrete Suspended Slab				
		4.1.2 Floor _Concrete Suspended Slab_3.6LL			
			Roof Width (ft)	2618.43	2618.4
			Span (ft)	18.403	18.403
			Concrete (psi)	4000	4000
			Concrete flyash %	-	Average
			Live Load (psf)	75	75
		4.1.3 Floor _Concrete Suspended Slab_4.8LL			
			Roof Width (ft)	2965.05	2965.05
			Span (ft)	19	19
			Concrete (psi)	4000	4000
			Concrete flyash %	-	Average
			Live Load (psf)	100	100

5.0 Roof	5.1 Concrete Suspended Slab	5.1.1 Roof _Concrete Suspended Slab_2.4LL			
			Roof Width (ft)	1280.568	1280.5
			Span (ft)	18.542	18.542
			Concrete (psi)	4000	4000
			Concrete flyash %	-	Average
			Live Load (psf)	50	50
	5.2 Steel Joist Roof	5.2.1 Roof_Steel Joist Roof			
			Roof Width (ft)	3122.83	3122.83
			Span (ft)	18.04	18.04
			Decking Type	-	None
			Decking Thickness (in)	1.5	0.75
			Steel Gauge	-	18
			Joist Type	7/8 x 10	1 5/8 x 10
			Joist Spacing	28	24

Appendix B IE Input Assumptions Document

Assembly	Assembly Type	Assembly Name	Modeling Assumptions
1.0 Foundation			
	1.1 Concrete Slabs On Grade		The strength of the slabs on grade are dependant on being interior or exterior. These are denoted as 20 Mpa for Interior and 32 Mpa for Exterior and are taken in the Impact estimator as 3000psi and 4000psi respectively.
			All Slabs on Grade are assumed to have average content of fly ash.
			All measurements in IE are in imperial form
			All measurements taken using on screen take off for slabs do not overlap with footings and walls, but do overlap columns and beams.
	1.2 Footings		All footings with width larger than 500 mm are assumed to have width equal to 500mm (19.68in.)
			All footing concrete has average fly ash content
			Rebar sizes are assumed as follows: 10M→#4 15M→#5 20M→#6 Rebar sizes larger than 20M will be assumed to be #6.
			All measurements in IE are in emperial form
2.0 Walls			
	2.1 Cast In Place		All walls taken as 30MPA (4350psi). Actual walls were between either 25, 30, or 40. In order to balance out and be conservative, 30 was chosen.
			Flyash percentage not specified, "average" used.
			Slab depth was taken as 200mm (0.656ft) in all locations. Reasonable considering that a majority of the slabs are 200mm and the difference between 200mm and 225mm is negligible

			All reinforcement taken as #15M. Most reinforcement is actually 10M, with very few 20M bars in the larger shear walls.
			Lengths adjusted and 12in. thickness used for impact estimator to achieve equivalen volumes. This may create an overestimation for formwork but is necessary to not underestimate concrete.
		2.1.1 Wall Cast-in-Place_200mm_Basement	
		2.1.7 Wall_Cast-in-Place_200mm_Main	"Main" refers to the 1st to 4th floor, which share similar wall heights and other characteristics.
	2.2 Partition Walls		
		2.2.1 Interior_Partition_P1_Basement (and all other steel stud partition walls unless stated)	Stud thickness unknown, taken as 25Ga. Insulation type unknown, referred to only as Batt Insulation. "Fiberglass Batt" used. Gypsum board 16mm Type X and 16mm Fire code C both taken as "Gypsum Fire Rated Type X 5/8"
		2.2.16 Exterior_Partition_W1_Main (and all other concrete block walls)	Reinforcement unknown, taken as 10M (lowest value allowed by impact estimator). Insulation type unknown, referred to only as semi-rigid insulation. "Polystyrene Expanded" used. Air and water barrier unknown. "Polyethylene 3 mil" used. Glazing type unknown. "Standard Glazing" used.
		2.2.17 Exterior_Partition_W1.1_Main 2.2.21 Exterior_Partition_W3.1_5thFloor	Cladding exists over previously counted structural walls. No assembly used, only envelope.
		2.2.18 Exterior_Partition_W1.1_Main	In order to add cladding without a wall, part of the length of 2.1.7 was removed and added to 2.2.18 to balance out the amount of concrete used.

		2.2.21 Exterior_Partition_W3.1_5thFloor	In order to add cladding without a wall, part of the length of 2.1.7 was removed and added to 2.2.18 to balance out the amount of concrete used. Note, the presence of doors and height differential will make numbers slightly inaccurate.
		2.3.1 Furring_F1_Basement	22mm furring system used and smallest steel stud available is 92mm. Studs placed at 600mm spacing to compensate.
	2.3 Furring		
		2.3.5 Furring_F4_Main	Section on first floor drawing has 11ft of "F5." Doesn't exist in schedule, assumed it was F4 (similar to other furring in the area).
	2.5 Special Interior Walls		
		2.5.1 Forum_Sliding_Doors 2.5.2 Forum_Wood_Panel_Balcony	Type of wood unknown and no applicable input exists. Extra material "cedar wood bevel siding" used.
		2.5.4 Library_Glass_Wall 2.5.5 Glass Guard	Type of glass paneling unknown, extra material "standard glazing" used.
3.0 Columns and Beams			
			Columns and Beams are not summarized as individual structural components. Instead, a set of beam, column and floor intesection is analyzed in the Impact Estimator
			Aeras of each floor are measured based on Onscreen Takeoff.
			All columns and beams concrete has average fly ash content
			Bay sizes and span sized are assumed to be 6m based on their location on the grids in the structural drawings.

			Live load of each floor calculated as an average of the load design of that floor. Exact results are approximated later for input data.
4.0 Floors			
	4.1 Concrete Suspended Slab		All Slabs are noted to be 30Mpa, which is rounded to 4000 psi All Slabs on Grade are assumed to have average content of fly ash. All measurements in IE are in imperial form All measurements taken using on screen take off for slabs do not overlap with footings and walls, but do overlap columns and beams. All spans lengths noted are found using a weighted average calculation. This calculation used the spans observed and averaged the values based on the area these were found. For details of these calculations, please refer to below.
		4.1.2 Floor _Concrete Suspended Slab_3.6LL	The live load of 3.6KN was used for all classroom and office areas as noted on the structural drawings provided
		4.1.3 Floor _Concrete Suspended Slab_4.8LL	A live load of 4.8KN was used for all library areas and other high load areas as noted on the structural drawings provided. Because 4.8KN is the highest live load analysed by IE, this includes Live Loads of 7.2 and 9.8, also noted in the plans.
5.0 Roof			
	5.1 Concrete Suspended Slab		All Slabs are noted to be 30Mpa, which is rounded to 4000 psi All Slabs on Grade are assumed to have average content of fly ash.

			All measurements in IE are in imperial form All measurements taken using on screen take off for slabs do not overlap with footings and walls, but do overlap columns and beams. All spans lengths noted are found using a weighted average calculation. This calculation used the spans observed and averaged the values based on the area these were found. For details of these calculations, please refer to below.
		5.1.1 Roof _Concrete Suspended Slab_2.4LL	The live load of 2.4KN was used for all roof areas as noted on the structural drawings provided
	5.2 Steel Joist Roof		All measurements in IE are in imperial form All spans lengths noted are found using a weighted average calculation. This calculation used the spans observed and averaged the values based on the area these were found. For details of these calculations, please refer to below.
		5.2.1 Roof_Steel Joist Roof	The Joist Size as approximated to be W250X22 based on its description in the drawings
			Deck Thicness was listed as 38mm, but used 19mm in IE due to limitations. All other factors were not provided and were assumed based on typical industry standards

Calculating Weighted Slab Span

Ground Floor	Area Calculation (ft)			Span	% Contribution	Weighted Average Span (ft)
(Slab 3.6KN)	Dimension		Area			
	50	37	1850	50	0.167050431	8.352521559
	71	90	4540	8	0.409950788	3.279606303
	33	19.5	643.5	19.5	0.058106461	1.133075985
	33	20	660	20	0.05959637	1.191927401
	46	19.5	897	19.5	0.080996885	1.579439252
	69	16.5	1138.5	16.5	0.102803738	1.696261682
	69	19.5	1345.5	19.5	0.121495327	2.369158879
			11074.5			19.60199106

	Area Calculation (ft)			Span	% Contribution	Weighted Average Span (ft)
Second Floor	Dimension		Area			
(Slab 3.6KN)	69.5	53.5	3718.25	17.83333	0.312123565	5.566203577
	67	34.5	2311.5	17.25	0.194035802	3.347117584
	53	111	5883	18.5	0.493840633	9.136051709
			11912.75			18.04937287

(Slab 4.8KN) Entire Area has consistent span of 19m.

Use 19m for total area 18222 sf 19 span

Third Floor

Identical to second floor in regards to column spacing and area distribution.

Use the same weighted span

(Slab 3.6KN)	11241	sf	18.04937287
(Slab 4.8KN)	18147	sf	19

Fourth Floor

Identical to second floor in regards to column spacing and area distribution.

Use the same weighted span

(Slab 3.6KN)	14442	sf	18.04937287
(Slab 4.8KN)	12788	sf	19

Fifth Floor

(Slab 4.8KN) Entire Area has consistent span of 19m.

Use 19m for total area 7179 sf 19 span

	Area Calculation (ft)			Span	% Contribution	Weighted Average Span (ft)
(Slab 2.4KN)	Dimension		Area			
	67.5	128	8640	17.83333	0.392762978	7.004273116
	-	-	13358	19	0.607237022	11.53750341
			21998			18.54177653

Roof

Max Allowable span is 5.5m
18.04461942 ft
All Spans were 19m, or greater.

Results	Total Area Used	Average Span
Slab 3.6KN	48670.25	18.40265789
Slab 4.8KN	56336	19.0
Slab 2.4KN	21998	18.54177653
Roof	6566	18.04461942