An Integrated BIM Model to Evaluate the Embodied Energy, Carbon Emissions & Environmental Costs of Construction Material used in the Design of Buildings

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Abstract

Currently, many researchers are looking at efficient ways to reduce energy and carbon emissions of construction materials used in buildings over their life due to its significant environmental impact. Along with operational energy, embodied energies and its associated carbon are substantial contributors in the overall sustainability assessment. The calculation of materials' embodied energy and carbon emissions during the construction stage is a major assessment factor that needs to be considered to measure the environmental impact of materials used in the construction of buildings, which would provide designers with the ability to lower the environmental impact of buildings at the early design stage. Overall, it is rather complicated to compute embodied energy and carbon emissions due to the various factors involved. The tools and methodologies, listed in the literature, are rather imperfect as they tend to overgeneralize. The equipment used, fuel needed, and electricity required for each type of construction material varies from one location to another and thus embodied energy used, and carbon produced will differ for each construction project. Moreover, the method used in manufacturing, transporting and putting in place these materials will have significant influence on their environmental impact. This anomaly has made it difficult to calculate or even benchmark the usage of such factors. This thesis proposes an integrated model aimed at calculating embodied energies, embodied carbon and associated costs generated by construction materials based on such variability. This thesis presents a systematic approach that uses an efficient method of calculation to provide new insight for the selection of construction materials and equipment required to place them for buildings. Such assessment will aid in reducing the environmental impact of construction. The proposed model will be developed in a BIM environment. The quantification of materials' energy is determined over the three main stages of their lifecycle: manufacturing, transporting, and placing. The proposed model will use multiple databases to calculate the energy used by manufacturing, transporting, and placing construction materials. By identifying the machinery required, an accurate calculation is achieved through geospatial data analysis. The proposed model can automatically calculate the distances between the material suppliers and construction sites to increase the accuracy of its outcome. Based on such variables, the proposed model provides designers with a list of equipment as to minimize the embodied energy and carbon produced by materials used in constructing buildings. Additionally, the proposed model has the ability to calculate the environmental cost impact of using specific building materials. Overall, this thesis aims to help researchers and the construction industry in reducing the environmental impact of construction activities through the selection of materials and the determination of machines required to achieve that goal.

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Glossary

BIM	Building Information Modelling
EE	Embodied Energy
EC	Embodied Carbon
CO_2	Carbon Dioxide
LCA	Life Cycle Assessment
LEED	Leadership in Energy and Environmental Design

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Chapter One

Introduction

1.1 General

Overall, the goal of sustainable design is to reduce the environmental impact, and, in such regard, it became apparent that most of the studies performed in the field target the reduction of building operational energy, which is defined as the amount of energy consumed by a building during its operational phase that includes lighting and indoor climate control. Mainly due to its greater environmental impact, most of the studies are targeted at lowering operational energy required by materials through their lifecycles. These studies tend to find ways in which electricity consumption is minimized through equipment, material selection and sunlight utilization. When looking at a building's material lifecycle, it can be inferred that it uses significant amounts of energy. In fact, a significant amount of energy is required in the manufacturing, transporting, and placement of materials during the construction phases of buildings. Furthermore, energy is also required during the rehabilitation and disposal of such buildings. Currently, there are limited studies involved in calculating materials' energy and carbon emissions over their whole lifecycle. A material's lifecycle will involve a cradle to end of life stage. Initially, a material needs to be extracted, manufactured, transported, placed, maintained, and finally disposed of. The energy requirement of such processes is known as embodied energy. Overall, most of the current assessment tools tend to overgeneralize the involved factors. The current practice involves the use of databases created by various studies that contain data related to energy and carbon emissions per unit of material irrespective of the machines involved in the manufacturing, transportation, and placement of construction materials. This causes inconsistencies between the calculation methods. Furthermore, there are limited studies related to the environmental cost implication of the use of embodied energy and carbon production of materials that are used during the construction activities for non-operational stages.

1.2 Research Objectives

As indicated above, calculating the energy required to manufacture, transport, and place materials in a construction site is dependent on many factors. These include the machines, vehicles, and the equipment used along with the fuel and the electricity consumption required by each. Furthermore, the amount of carbon and its associated environmental implication costs produced from manufacturing, transporting, and placing of materials are also dependent on such factors. The currently used practices tend to calculate energy usage and carbonic productions, based on a set of values irrespective of machines, equipment, vehicles, fuel usage and electricity usage. This cause errors in the assessment of Embodied Energy (EE) and Embodied Carbon (EC). Evidently, since assessing the amount of embodied energy, embodied carbon and its associated costs represents an important step in determining the environmental impact of building materials at the preconstruction stage, set of objectives of this study are identified as follows:

- Proposing a methodology that can correctly calculate embodied energy (EE), embodied carbon (EC) and its associated costs for the manufacturing, transportation, and placement of construction material by determining specific machines, vehicles and equipment that will be required by materials in construction of a building.

- Proposing a methodology that will aid in accurately identifying the energy and carbon produced by identifying machines, vehicles and equipment required to manufacture, transport and to place materials used in the construction of a building in order to identify the actual environmental impact of using specific materials as opposed to the current methods.
- Creating an atomized computer model that can use the created methodology to help users quickly determine the embodied energy, carbon and its associated costs early in the design phase
- Creating an atomized computer model that builds on the proposed methodology to suggest methods to reduce embodied energy usage and carbon production in order to reduce the environmental impact of constructing a building. This will enhance the sustainability of building and provide options for the users of the model.

1.3 Research Methodology

The study performed in this thesis will be implemented based on a proposed methodology that aims at satisfying the set objectives. The procedure followed is highlighted below.

1.3.1 Literature Review

An extensive review of the literature will be performed to identify the recent tools and techniques used to quantify the embodied energy, embodied carbon, and environmental costs of materials that are used in constructing buildings. Furthermore, a study will be performed to assess the current techniques used to calculate EE/EC and their associated costs to identify the existing gaps within each. Ultimately, this step is deemed as a vital stage to develop the proposed methodology and to refine the set of objectives.

1.3.2 Data Collection and Inventory Creation

In order to compute the embodied energy, embodied carbon, and environmental costs, data is required to identify the amount of energy needed to manufacture, transport and place materials. In lieu of the above, an extensive effort is put forward to collect information about the materials commonly used in buildings. Subsequently, information will be collected about the means that can be used to manufacture, transport and place such materials. Data about the energy certain manufacturing processes require along with the fuel and electricity required by various vehicles and machines needed to transport and place construction materials will be collected and stored in databases. Information about machines, vehicles, and equipment are obtained from the operational manuals produced by manufacturers. To convert fuel and electricity usage into quantifiable energy, carbon and cost units, conversion values will be collected from Statistics Canada, and the United States Environmental Protection Agency.

1.3.3 Implementation and Integration

Through the literature review, it became apparent that calculating EE, EC and its associated environmental costs for materials used in buildings is a tedious task. Furthermore, the currently used practices tend to use average values that disregard the manufacturing, transportation and placement method. This will cause inaccurate calculations and therefore the assessment of the environmental impact is not properly done. To solve such issues, a methodological model will be developed to accurately calculate EE, EC and its associated costs through four major stages. Those include calculating the EE for manufacturing, calculating the EE of materials through transportation, calculating EE of materials in placement, and calculating the EC and costs for each of the material used in a building. Through each module, a set of submodules will be created to assess the different machines, equipment and vehicles that can be used for each type of material. Based on the manufacturing, transportation, and placement method identified, the model will calculate the EE, EC and the associated costs of any material that is used in a building design. Once the methodology required to accurately calculate EE, EC and its associated cost is developed, the model will be integrated in an atomized computer model that will assist users in determining the sustainability of materials used in a conceptual building design. The model will use the BIM platform to extract materials and perform analysis. To help users in reducing the environmental impact of buildings, the computer model is enhanced to suggest the methods for manufacturing, transportation and placement that will reduce the environmental impact of created designs.

1.4 Thesis Organization.

This thesis consists of six chapters. The contents of each section are briefly explained below.

Chapter One: Introduction

This section presents an introduction into the scope and background of this thesis.
Furthermore, a brief description of each chapters is presented.

Chapter Two: Literature Review

There are many ways to assess the sustainability of buildings. One of the major factors involves the assessment of embodied energy and carbon used during the construction of buildings. This chapter overviews the methods involved in embodied energy and carbon assessments. This includes the use of preset values in inventories created by different researchers irrespective of the manufacturing, transportation or placement methodology. Using such inventories results in errors in computing energy and carbon production especially since those are parametric values based on many variables. This chapter also presents the methods used to quantity the environmental implication costs of energy usage.

Chapter Three: Research Methodology

This chapter outlines the proposed methodology that will be used in developing the model that will correctly compute the embodied energy, embodied carbon, and the associated environmental costs of materials commonly used in a building. Through identifying the machinery, vehicles, travel distances, and site geographies, this chapter proposes a methodology to address issues in the currently used practices. Overall, this chapter is split into three main sections. The first section includes a methodology proposed to be used to measure the embodied energy of materials commonly used in a building through its cradle to end of construction lifecycle. The second section highlights the way of measuring the embodied carbon production from energy usage, while the third section covers the detailed estimate of environmental cost.

Chapter Four: Model Implementation

This chapter describes the development process of the proposed model and furthermore it presents the developed platform used to calculate embodied energy, carbon and costs. This chapter also entails the model components along with developed capabilities of the computerized model.

Chapter Five: Model Testing

This chapter tests the capabilities of the developed model through a simulation of EE/EC and cost analysis of a residential building project. Furthermore, in this chapter the model is tested to determine its workability while doing the 3D design.

Chapter Six: Conclusions and Future Work

This chapter presents the conclusions of the study in terms of embodied energy, embodied carbon, and environmental costs assessment. Additionally, this chapter presents the benefits of the developed model for sustainable design and its capability to aid in reducing the environmental impact of construction. Ultimately, this chapter presents the benefits of the developed model to aid in achieving sustainable construction early during the design stage as to reduce changes and construction costs. Furthermore, the chapter identifies the research contributions. Additionally, it presents the limitation of the study and identifies the areas in which future development is required for enhancement.

1.5 Summary

This chapter provides a brief description of the research study chapters. Nevertheless, an outlined list of objectives to solve the current problem is presented. This chapter also provides a description of the research methodology that is followed through this study.

Chapter Two

Literature Review

2.1 Introduction

Overall, this chapter presents the importance of calculating EE/EC and social carbon costs of materials used in buildings during the sustainable design stage. Additionally, this chapter presents an overview of the current practices used in calculating EE/EC and environmental costs of materials that are used during buildings' lifecycles. This chapter also provides a critical analysis of the tools currently used. Since it is beneficial to calculate such parameters during the design stage, an overview of the design technologies is studied in addition to how such tools are used in the assessment process.

2.2 Environmental Overview of Construction Practices

Generally, buildings consume about 40% of the overall global energy demand (Dixit et al.2012). This represents a significant portion of the whole global usage, and thus improving efficiency during the construction and operation stages could greatly reduce the environmental impact of this type of structures. Today, the production of energy yields carbon dioxide, which is a substantial contributor to climate change. With the growth of population worldwide, the energy demand is only expected to increase, and thus more carbonic emissions will be generated. Many governmental agencies have realized the importance of tackling this issue, and henceforward many have begun implementing standards to dictate energy usage (Sayegh, 2019). For example, in early 2019, the Federal Government of Canada implemented the carbon tax on major polluters in the country in an effort to create a shift in clean energy usage.

Overall, the issue of reducing carbon emissions from energy production and usage is gaining momentum especially since the world is beginning to feel the effects of global warming. In Canada alone about 7.057×10^{11} Metric tons of CO_2 was produced in 2015 from construction practices alone; this is quite significant (Canada, 2018). Many construction practices require electricity and fossil fuels energy to operate machinery. The by-product of such production is CO_2. When released in the atmosphere, CO_2 acts as a thermal blanket enclosing heat within, and thus resulting in the greenhouse effect. This will cause a rise in the earth's ambient temperature, which can cause severe storms and floods. In addition to that, it can even lead to the disappearance of food chains that humans depend on (Nikulin et al, 2018). To address this issue, it is important to quantify and reduce the CO_2 emissions produced from operating machinery especially during construction. The idea of lifecycle assessment addresses the quantification of both energy and carbonic emissions. The assessment of both carbon emissions and energy consumption can help determine the sustainability of construction materials over their lifecycle, which includes the source of production to disposal. This also allows for comparing the sustainability of different materials. It is worth mentioning that both energy usage and carbonic production are two interrelated values, which possess a directly proportional relationship. Both energy usage and carbonic production can be used the environmental footprint produced from using construction materials (Chau et al, 2015).

Buildings consume energy in embodied and/or operational forms. From a holistic lifecycle approach, energy is required for producing construction materials, transporting them, and placing them in their intended locations. In the post construction stage, energy is required for operational processes such as lighting and heating. Through the closing stages, energy is required for renovation and finally for disposal. The study of all energy used throughout all the phases of a building is known as the lifecycle energy assessment. Energy may be calculated through the determination of electricity used or through the amount of fossil fuels burned at each phase. Currently, emphasis is given to energy used in the operational stages, also known as operational energy. This is due to its larger energy demand, but with the advances in machinery and insulation techniques, the shift is beginning to move towards the energy consumed at other stages. Such energy can be identified as embodied energy. Balouktsi et al. (2016) state that embodied energy represents 10%-15% of the whole lifecycle, but with low environmental initiatives, theoretically embodied energy will present 100% of total energy consumption.

Through every stage in energy usage, CO_2 is also produced. In preconstruction stages, CO_2 is produced from the machines and equipment used in manufacturing, transporting, and placing materials. In post construction, carbon is produced from lighting and HVAC systems. Similar to energy, most of the focus today is aimed at optimizing the carbonic emission optimization during the operational stage, but that trend is beginning to fade due to current technological advances in equipment design such as Energy Star compliant machines. The current trend is shifting to address the carbonic emissions at the preoperational phase of buildings. These carbon emissions are known as embodied carbon. The shift towards green buildings has led many to begin to study ways of tackling the issue of reducing the embodied carbon reduction produced from energy usage in addition to the quantification and comparison means.

There are many challenges involved in calculating or benchmarking embodied energy and carbon. In fact, researchers have different interpretations of the terms. According to Dixit et al. (2012), embodied energy is the amount of energy required by building materials during all processes of production, construction, and final disposal. Similarly, embodied carbon is the amount of carbonic emissions produced by the production, construction, and disposal of materials used in buildings. On the other hand, Gardezi et al. (2014) identify embodied energy as the energy consumed to extract, manufacture, assemble and transport. Similarly, embodied carbon is the carbonic emissions produced in extracting, manufacturing, assembling and transporting materials. To add to the ambiguity, Ariyaratne et al. (2014) define embodied energy as the sum of fuel-related and process-related carbon emissions associated with a building during extraction, manufacturing, transportation, construction, maintenance, refurbishment, and demolition. All such explanations are similar in concept, but the boundaries involved within each of those vary, which causes the embodied energy (EE), and embodied carbon (EC) calculation methods to fluctuate.

Other challenges involved with embodied parameter quantification is the determination of whether the type of energy used is significant in the computational process especially if embodied CO_2 is being assessed (Dixit et al. 2010). Energy is either produced in renewable form or as primary energy made from burning fossil fuels. Since renewable productions have no carbonic emissions, there will be no carbon emissions to account for. The idea of a life cycle assessment is that it is used to assess and eventually reduce environmental effects. Since renewable energy has no effect on climate change, adding such data to the overall computed energy is misleading especially if comparisons are required (Balouktsi et al. 2016). Nevertheless, feedstock energy is another parameter that could cause inconsistencies between the embodied energy and carbon calculation methods. Feedstock energy is the amount of energy possessed in fuels used in the material production. For example, plastics contain some petrochemicals in which energy isn't released. Some researchers have opted to add petrochemicals, and thus further variations exist within the different EE/EC computational techniques (Hammond et al.2008).

Calculating embodied energy and carbon is rather difficult. According to (Dixit et al. 2010), embodied energy and carbon vary from one geographic region to another. Travel distances can add to such factors through the added amount of fuel required. Furthermore, Praseeda et al. (2015) state that embodied energy and carbon also depend on the regional climate and the technology used for extraction, manufacturing, transportation, and construction. This chapter lists and evaluates the difficulties that exist in the current EE quantification methods. Furthermore, it proposes the approaches to be used to address such complications. This chapter also assesses the interrelated EC quantification methods and their calculations and complications.

2.3 Current Embodied Energy Life Cycle Assessment Framework

According to Dixit et al. (2012) the prevalent standard used for EE life cycle assessments is the ISO 14040. ISO identifies LCA as a 4-stage process involving goal and scope definition, inventory analysis, impact assessments, and finally the improvement or interpretation stage. As within the confinements of ISO, researchers have decided to assess embodied energy through the creation of material energy inventories. Data is collected based on selected system boundaries, quality requirements, and most importantly study goals. According to Ariyaratne et al. (2014) there are four main boundaries used to quantify embodied energies. These include cradle to gate; cradle to site; cradle to end of construction; and cradle to grave. The current energy inventories include sets of value to assess each boundary condition.

Cradle to gate is a system boundary in which energy is calculated for materials through extraction and production (i.e. manufacturing processes). Cradle to site is a system boundary in which material energy is calculated for manufacturing along with the transportation required (Balouktsi et al. 2016). Cradle to end of construction is a system boundary for which the energy used is calculated based on manufacturing, transportation, and placement or construction. Overall, it is the energy required by materials until the handing of the project (Balouktsi et al. 2016). Cradle to grave is a boundary in which the energy required by materials is calculated from extraction all the way to disposal. This energy involves all energies from previous boundary systems in addition to maintenance, repair, replacement, refurbishment, demolition, transportation, waste processing, and disposal (Balouktsi et al.2016).

Within each boundary, the energy collection method used to identify the embodied energy of materials could vary. Dixit et al. (2010) identify three methods in which material's EE may be quantified. These include the process modelling method; input/output modelling method; and hybrid energy modelling process.

Process modelling is an energy evaluation method where each material is identified as a final product and then through its set life cycle boundaries, backward and/or forward analysis compute process energies (Crawford et al. 2005; Dixit et al. 2010). Unfortunately, the process modelling method can have imperfections due to the confinements of the established boundary system as some lower stage energies may be overlooked (Dixit et al. 2010). This process is the most common due to its directive approach and ease of implementation.

Input output modelling method (I/O) is an energy evaluation method that uses the interdependence of materials to identify energy usage. The input /output method relies on the idea that material outputs in certain processes can still be inputs required for production and in such perspective, one material production affects another. Moreover, the input/output method analyzes the system from a holistic approach and thus it can allow for high accuracy in primary and renewable energy analysis (Crawford et al. 2005; Dixit et al. 2010). Overall, the process is rather complex as it requires national economics and power production factors to identify each material energy usage.

Hybrid modelling is an energy evaluation method that combines both process and I/O evaluation methods. In cases where it is difficult to compute material embodied energies using I/O models, the process modelling methodology may be used for some materials (Sangwon et al. 2007).

2.4 Embodied Energy Calculation Methods

According to Praseeda et al. (2015) embodied energy assessments are mainly attentive to the energy within the cradle to gate boundary. With the aid of various energy declaration requirements, manufacturers are beginning to release EE information for production, and henceforth many researchers are able to collect such Figures to create extraction and manufacturing EE inventories. Through such databases, embodied energy can be quantified for specific materials per unit mass. Unfortunately, this isn't the case for other sectors involved within a building lifecycle (Praseeda et al.2015). Detailed energy usage information isn't commonly available for transportation, construction, and end of life stages. Calculating EE based on a cradle to gate boundary represents only a portioned amount of the total EE materials possess and thus, a full analysis is required through a cradle to grave boundary. There have been some efforts intended to produce inventories for such parameters, but these results remain estimates as material EEs in cradle to grave boundary greatly vary from one building to another (Praseeda et al.2015). These inventories tend to assume a singular energy value per material regardless of the different factors involved.

To assess a cradle to grave EE, the current practice involves the use of computerized software (Ariyaratne et al. 2014). which allows, for a case-by-case scenario analysis. Unfortunately, some software lack accuracy, especially since they depend on approximating the calculation method. Furthermore, such software is programmed in a way that builds on values presented in current EE inventories. This creates inefficiency especially since inventories are produced only for specific geographical regions, and therefore not all inventories can be used globally. Additionally, EE inventories present inconsistencies in reported values, and thus the selection of a reliable inventory can affect the accuracy of the whole lifecycle embodied energy quantification's process. This is due to the various interpretations deduced from the ISO 14040 standard (Jeswani et al. 2010).

Overall, the assessment of embodied energy involves determining the amount of energy for a total unit of material per stage as defined per the stage boundary. In a cradle to end of construction scenario, the energy for manufacturing, transportation and construction needs to be computed. In manufacturing, energy can be calculated by determining the amount of electricity and fuel required to extract the material from its source and the amount required to transport it from its source to the manufacturing facility. Furthermore, calculating the amount of electricity and fuel required to shape a material into its sellable state is necessary. In transportation, the amount of fuel and electricity vehicles consume to transport materials from a production facility to the construction site needs to be computed. During the construction stage, the energy either in electricity or fuel form needs to be computed to place a material in its intended location. This includes the energy required by cranes, concrete pumps, drill machines, jack hammers, rush coat placers, spray machines, lifting jacks, etc. In order to calculate the total energy, all used forms of electricity or fuel need to be converted into a single comparable unit of measure, which is joules. The summation of all energy joules will equate to the total embodied energy.

2.5 Available Inventories Used to Quantify Embodied Energy

Table 2-1 summarizes the list of major comprehensive inventories available worldwide. The table below tends to include the boundaries used for each inventory together with the energy calculation method. Also, the source of data, regional preferences and the approximate age of collected data are identified. The collection of those inventories and comparison of embodied energy is done through research collected by the authors of this study.

Table 2-1: Embodied Energy Inventories

Identification	**Reference**	**Boundary**	**Carbon Calculation Method**	**Source of Data**	**Date Geography**	**Age of Data**
United States Lifecycle Inventory	NREL.2017	Cradle to gate, Cradle to grave, gate to gate	Process Modelling	EPDs, Case Studies	United States	1988 to date
Athena Institute Lifecycle Inventory	Athena Impact Estimator for Buildings.2003	Cradle to gate, Cradle to end of construction, Cradle to grave	Process Modelling	EPDS, Case Studies	Canada	1993 to date
University of Bath inventory of carbon and energy	Hammond et al	Cradle to gate	Process Modelling	Case Studies and EPDs	United Kingdom	Updated to date

OKOBAUDAT	Federal Ministry for the Environment.2001	Cradle to gate, Cradle to grave	Process Modelling	Mainly EPDs	Germany	Updated to date
Ecoinvent	Ecoinvent.1988	Cradle to grave	Process Modelling	Statistics, EPDs	Switzerland	Updated to date

To analyze the differences in the EE inventories, three materials commonly used in the construction industry are selected. These are cement, aluminum, and steel. Table 2-2 presents the EE for each material derived from different inventories. The results are presented in MJ/kg.

Table 2-2: Embodied Energy Inventory Value Comparisons

Database	**Athena Institute Lifecycle Inventory**	**University of Bath Inventory of Carbon and Energy**	**OKOBAUDAT**
Cement(Portland)	8.34 MJ	4.5 MJ	2.29 MJ
Alum (Hot rolled)	43.9 MJ	155 MJ	147.3 MJ
Steel (Rebar)	17.6 MJ	17.4 MJ	10.71 MJ

As shown in table 2-2, EE for each material presents irregularities. This is due to the material identification method used in each inventory. For example, in the Athena Institute lifecycle inventory, Portland cement is identified as a generic material, while in ÖKOBAUDAT, cement is specified by type. No generic values for EE are present. Similarly, in ÖKOBAUDAT aluminum sheets are identified as a singular item with one production process, but at the University of Bath's, inventory multi processes are identified. Consequently, aluminum will possess different embodied energies per processing method in that inventories. The effect of regional data and the use of sources that quantify energy based on various boundaries tend to create additional inconsistencies. For example, the United States Lifecycle Inventory tends to use the cradle to grave quantifications, while the University of Bath Inventory only uses a cradle to gate. Furthermore, in the Athena Institute Lifecycle Inventory, EE values are based on Canadian industries, and thus electricity usages are different as compared to other inventories. Overall, most inventories seem to use a consistent energy calculation approach, but the factors such as the ones identified above cause variances (NREL, 2017; Athena Impact Estimator for Buildings, 2013; Hammond et al ,2008; Federal Ministry for the Environment,2001; Ecoinvent,1998).

2.6 Embodied Carbon Lifecycle framework

As with the embodied energy, ISO 14040 is also a prevalent standard used to estimate and evaluate embodied carbon (Jeswani et al. 2010). According to Jeswani et al. (2010), lifecycle assessments for all sustainability parameters can be quantified through creating inventories. Such inventories include a per unit quantity, which may be referenced to calculate the total unit output per material. In calculating embodied carbon, the unit tonne of carbon per kg of material studied is collected (Hammond et al, 2008). As defined in ISO 14040, LCA inventories need to be specific to their goals. Furthermore, it is important to define the scope of the inventory. Subsequently, the impact assessment stage and the improvement stages need to be implemented. As with the confinements of ISO 14040, embodied carbon can be assessed with the same inventories used for embodied energy as both embodied carbon and energy inventories satisfy the same goals and scope definition in data collection. Furthermore, they both have a similar impact assessment effect and can be optimized by using the same enhancement procedure. Embodied energy and embodied carbon both have a directly proportional relationship in which if one changes, the other is also affected in a similar way. Commonly, both embodied energy and embodied carbon are existent in the same inventory. Lifecycle energy assessment inventories contain information about all assessment factors specified by the LEED criteria. Furthermore, with reference to ISO 14040 guidelines, embodied carbon is collected and represented in a kg per unit weight.

When collected in embodied CARBON inventories, embodied carbon data are dependent on the boundary assessed for embodied energy. According to Praseeda et al. (2015), the main boundaries of embodied carbon assessment include cradle to gate, cradle to site, cradle to end of construction, and cradle to grave. As within the confinements of energy boundaries, material embodied carbon may also be collected based on the processing modelling method, input/output modelling and hybrid energy modelling. Embodied carbon processing modelling is a method where each material is identified as a final product and then through its life cycle boundaries, backward and forward analysis compute process carbonic emissions. Input/output carbon modelling is a carbonic emission evaluation method that uses the material outputs in process as inputs required for production. In fact, every material affects each other. Hydrid carbon modelling is a carbon evaluation method that combines both I/O and process modelling to calculate embodied carbon per unit material. Based on the boundary conditions set by each inventory, embodied carbon values will differ as to satisfy the inventory goals and scope definitions.

2.7 Embodied Carbon Calculation Methods

Similar to embodied energy, embodied carbon is calculated with the aid of inventories. As with the trend of sustainable buildings, many product manufacturers produce environmental product declaration (EPD) reports. These reports are quite comprehensive in identifying the environmental impact of materials produced. EPD reports of products include the production energy used, carbonic and nitrous footprint, photochemical oxidant pollutant amounts, acidification equivalent amounts, and ozone depletion potentials. Such reports are produced to help buildings become LEED accredited. Through LEED, products can be compared based on EPDs and subsequently points are awarded for using environmentally friendly materials. To accommodate buildings in establishing green accreditations, product manufacturers are releasing such reports as to push their goods as green materials, and furthermore to gain better market shares. This is beneficial for the construction industry as such data may be collected in inventories to assess multiple comparable building materials. There has been substantial effort invested to create inventories (De Wolf, et al 2017). In Canada, Athena Institute (2013) has begun an extensive project to collect such data and create software to calculate embodied carbon. Typically, all existing LCA inventories collect and contain information for both embodied carbon and energy. Again, as indicated with embodied energy, embodied carbon inventories use different boundaries for calculations. This causes variances in existing data within different inventories.

Overall, the assessment of embodied carbon involves determining the amount of carbon per total weight of material per stage as defined per stages boundary. In a cradle to grave scenario, the carbon produced in manufacturing, transportation, and placement used by each material in a building lifecycle needs to be computed. In manufacturing, carbon can be calculated by determining the amount of CO_2 produced by the equipment and machines required to extract a material from its source along with the amount produced by vehicles to transport material from its source to the manufacturing facility. In manufacturing, the amount of CO_2 produced by machinery used to create a material in its sellable shape can be computed. In transportation, the amount of CO_2 produced by electricity and fuel required to transport a material from the gate of a manufacturing facility to the site is calculated. Additionally, in construction, the amount of CO_2 produced by machinery required to place a material in its intended location is calculated. The summation of all CO_2 produced per stage allows for total embodied carbon evaluation.

2.8 Available Inventories to Quantify Embodied Carbon

As explained above, the equivalent embodied carbon is determined by calculating the total CO_2 produced by machines and equipment of each material (Hammond et al, 2008).The boundary condition used in the assessment of each inventory will determine the corresponding CO_2 value presented for each material. From the inventory, the unit weight of CO_2 for each material can be multiplied by the total weight of a material to determine the total embodied carbon produced per stage. Today, many inventories aid in sustainability design calculations, and hence these values dictate the current sustainability evaluation process. Table (2-3) summarizes the list of available embodied carbon inventories. These are the same inventories that are used for embodied energy evaluations. Such inventories collect data for both. The collection of those inventories and comparison of embodied carbon is done through research collected by the authors of this study.

Table 2-3: Embodied Carbon Inventories

Identification	**Reference**	**Boundary**	**Carbon Calculation Method**	**Source of Data**	**Date Geography**	**Age of Data**
United States Lifecycle Inventory	NREL.2017	Cradle to gate, Cradle to grave, gate to gate	Process Modelling	EPDs, Case Studies	United States	1988 to date
Athena Institute Lifecycle Inventory	Athena Impact Estimator for Buildings.2003	Cradle to gate, Cradle to end of construction, Cradle to grave	Process Modelling	EPDS, Case Studies	Canada	1993 to date
University of Bath inventory of carbon and energy	Hammond et al	Cradle to gate	Process Modelling	Case Studies and EPDs	United Kingdom	Updated to date
OKOBAUDAT	Federal Ministry for the Environment.2001	Cradle to gate, Cradle to grave	Process Modelling	Mainly EPDs	Germany	Updated to date
Ecoinvent	Ecoinvent.1988	Cradle to grave	Process Modelling	Statistics, EPDs	Switzerland	Updated to date

As shown with embodied energy, the different boundary conditions will cause the values of embodied carbon to fluctuate. Not all inventories use the same boundary conditions. This could cause issues in exact quantification. Furthermore, many inventories use a single value in quantifying the cradle to grave embodied carbon. This causes errors in exact embodied carbon calculation. Embodied carbon is a parameter that is dependent on the machinery, equipment, and vehicles used. When the production, transportation, and placement methods change, the embodied carbon value will also change. This isn’t the case for the inventories used in embodied carbon evaluation. When machines and vehicles change for each material, the fuel and electricity will also change causing embodied carbon values to become affected. This is the case for construction sites at different locations where machines, vehicles, and travel distances vary.

2.9 Quantification of Lifecycle Environmental Costs

Undoubtedly, the concern for embodied carbon and energy is derived from the fact that such parameters affect humans negatively. Overall, to accurately quantify environmental impacts of materials, it is important to quantify the negative costs of every material usage to the environment. Such values are estimated by calculating the loss in terms of monetary value from the production of a single unit of either carbon or energy to society. Generally, all construction activities require energy and specifically every material requires embodied energy. The production of embodied energy yields carbonic emissions. Subsequently, every unit weight of emissions will lead to reduced agricultural productivity, increased flood damage, and worsened health and mortality (Fang, et al 2018). Such effects will require money to fix. To rectify the situation, newer more expensive technologies will be required to maintain agricultural products, cattle, and poultry. Furthermore, as the climate begins to change, more medicine and hospitalized care will be required for citizens especially in cases resulting from global warming induced flooding and hurricanes. All such actions will require increased funding. In an effort to assess these costs, the concept of social carbon cost (SSC) has been developed. The amount to money required to offset the negative effects of carbonic productions is known as environmental carbon cost and alternatively the social carbon cost.

According to Environment and Climate Change Canada (2019), SSC is the estimated marginal external cost of a unit emission of carbon dioxide, based upon the future damage that unit will inflict through its contribution to the greenhouse effect and the resulted global warming.

There are many countries that use such Figures to assess the cost of carbon. Examples include USA, Canada, Ireland, Britain, and Australia (Rickie et al 2018). Recently in Canada, the Federal Government has begun implementing carbon tax at a rate of $20 CAD per tonne of carbon. Currently, the social carbon cost estimation in Canada is at $34.1 CAD per tonne of carbon production. It is predicted the number will increase to reach $45.1 CAD per tonne in the year 2020 (Environment and Climate Change Canada, 2019).

Social carbon costs are calculated by using integrated assessment models (IAMs). Integrated assessment models are platforms that boot together information from different disciplines into one framework in order to understand interactions between different elements in societies. The different disciplines include economics, model energy systems, agricultural systems, geographical systems, behavior statistics, climate systems, etc. By combining and comparing different disciplined information, models can understand the effect on changes, decisions, and choices on the system as a whole and more specifically the effect on society. In terms of carbon cost, the IAM can tend to create a cost benefit analysis where the reduction of carbon will determine the cost of savings in societies. IAM can also help determine the effect of a policy on society. Overall, there are 3 main models; these include DICE, PAGE and FUND. DICE, the Dynamic Integrated model of Climate and the Economy, is a model that depends on the idea production will produce emissions that cause an increase in temperature. In fact, as temperature decreases, environmental damage will minimize. The model assumes the variable factors that will control this include investments in physical capital and emission reduction.

As a result, the model assumes a perfectly elastic relationship between the study variables and the output (Duan, et, al, 2018). FUND is The Climate Framework for Uncertainty, Negotiation and Distribution integrated assessment model of climate change. FUND was originally set-up to study the role of international capital transfers in climate policy, but it soon evolved into a model studying impacts of climate change in a dynamic context (Anthoff et al 2016). Presently, it is used by many European countries to study the effect of climate change and climate policy for environmental agreements (Ortiz et al 2009). FUND links scenarios and simple models of population, technology, economics, emissions, atmospheric chemistry, climate, sea level, and impacts (Ortiz et al 2009).

Developed in the United Kingdom, PAGE is another IAM used in the industry. PAGE is a stochastic-based model in which 31 of its key input variables are defined not by a single value, but rather, as a probability distribution comprised of a range of possible values. For each such variable, a minimum, maximum, mean, and mode is defined (Hope, 2006). PAGE considers the damage to the environment from:

- Costs of damages to economic activity caused by climate change,
- Costs of non-economic damages caused by climate change,
- Costs of large-scale discontinuities, and
- Impact of mitigation (costs of mitigation measures less reduction in damage resulting from mitigation measures).

All such variables are used to create a cost benefit relationship to assess the social carbon costs.

To calculate the environmental costs of materials used in the construction industry, this proposed study will consider the social carbon cost per ton in Canada and use it to calculate the total cost implication of all materials used for buildings through its embodied lifecycle stage. As the study region is directed towards Canada, the social carbon cost will be based on the studies performed by the Canadian Environment and Climate Change Department (CECC, 2019), which values have been recently published. Currently, the CECC uses the DICE model as a base to calculate the cost implication of a single carbonic tonne (Canada, 2019). The values are highlighted above. Based on the study boundaries, the total environmental costs can be identified. Since these values are the common means of calculating environmental costs, it is only sound to build on such practices and improve. According to Tian (2019), once SCC are calculated, manual estimations are used for quantifications. This is a tedious task especially if many materials require assessment. Buildings use over 110 type of materials over their lifecycles and calculating the environmental impact of each is rather time-consuming (Athena, 2013). Overall, this proposed study will consider the SCC as the environmental costs for using materials.

2.10 BIM Platform

BIM tools, such as Autodesk Revit, is CAD based platforms in which engineers can create 3D models with detailed metadata. These include properties such as price, volume and material makeup. Consequently, such tools allow for detailed cost and material quantity takeoffs. BIM concepts give engineers, from different disciplines, the ability to create multiple models and then the ability to superimpose them to identify clashes. All such properties have driven the industry to adopt BIM tools as their major design tool. Overall, a BIM model is considered as a space in which a building can be conceptualized. If external design tools are required, bi-directional transfers can be performed to import and export information. Today, design software such as Etabs, Staad, and Tekla all have the capability to exchange data with BIM tools.

The BIM platform is ideal for EE and EC assessments especially if it is used during the design stages. Currently, EE and EC analyses are performed after the completion of detailed designs. According to Ariyaratne et.al. (2014), this is due to the lack of knowledge that designers have with regards to EE and EC quantifications. In practice, completed models are send to sustainability consultants whom in return adjust the building structure to match criteria specified in green rating programs. Unfortunately, these programs possess ambiguities in terms of EE and EC assessments. For example, LEED, a sustainability green building rating system, gives additional credits to buildings in which materials of low EEs are used, but no specific number is identified (Dixit et al.2012). Furthermore, LEED doesn't identify how to quantify EE and EC energy. In such perspective, consultants are able to adjust the design without completely accounting for all the lifecycle EE. For example, a limited number of aluminum window frames may be altered to include wood as a way of acquiring the points specified for the use of low EE/EC materials. This is a flaw; consultants may take advantage of these to overcome the requirements. Designs are based on certain budgets and resources, and thus any small change performed after the design completion may cause a drastic change in the cost and structural requirements. It is beneficial to address EE during the design stage. Through new software available that are associated BIM tools, EE/EC for singular and grouped materials may be identified at the design stage. This also allows for the modification of materials within the assigned budget.

Presently, there is a number of models intended to quantify lifecycle EE/EC energy. One issue involved with the use of computerized software is the need to manually enter materials for the assessment. This is the case for tools such as SimaPro and OpenLCA. This issue can be solved if calculation tools are used within the BIM Environment. One example is the Tally Environmental Impact Tool. This tool is one of the most comprehensive tools produced for LCA. As this tool starts to operate, the lists of materials used in the model are identified. Users are then prompted to select the details required for each item identified in the project. To clarify, a wall in BIM tool might be constructed with concrete but in reality, concrete has certain strengths, which need to be clarified for the Tally's tool. Users are required to select such parameters to accurately calculate EE/EC. Tally uses a cradle to grave boundary to assess EE/EC. Through the selection of alternative materials, comparison tables can be used to select low EE/EC options. Overall, this model addresses the issue of early EE/EC quantification, but again the results are approximated. Unfortunately, the tool does not use exact distances, nor the actual equipment used by each material in a specific project. Tally quantifies EE/EC based on the average values required and produced by a material for transportation, construction, maintenance, rehabilitation and disposal.

Ultimately, the literature indicates the need for developing an integrated model required to target the existing gaps. Such a model can help designers better estimate the energy required during the construction stages. The creation of an automated model that benefits from the BIM environment would greatly help designers assess the sustainability of buildings early in the design phase.

2.11 Summary

This chapter described in detail the importance of calculating EE/EC and costs during the sustainable design. Furthermore, this chapter presented the different approaches and tools available for such assessment. From the literature, it seems apparent that many of the currently used tools are inaccurate, and a more precise methodology is required. Additionally, this chapter provided an overview of the currently used tools during the design phases. The usage of BIM could greatly enhance sustainability assessments. The full integration of BIM and sustainability assessments could significantly enhance any sustainability assessment method. This part of the research was an integral component that leads to the creation of an innovative methodological approach to solve and enhance the EE/EC and social carbon costs assessments.

Chapter Three

Methodology

3.1 Introduction:

This chapter discusses the methodology of developing an integrated model aimed at efficiently calculating embodied energy, carbon and environmental implication costs along with suggesting alternatives to reduce energy consumption and carbon production in the design phase. The model requirements are established from the comprehensive literature review along with the characteristics of the model. The development methodology is divided into two stages. These are the conceptual modelling stage and the model physical implementation stage. At the conceptual modelling stage, the system requirements, the system components, the dataflow, and the system modules are explained. Whereas in the implementation stage, database requirements are identified, and a practical implementation of the model is presented encompassing the full model components and workflow. In this chapter, the conceptual modelling is explained.

3.2 System Requirements:

As seen in the literature, accurately quantifying both embodied energy and carbon for materials in building lifecycles is rather difficult. The current process involves setting boundaries and using average per unit values for each material quantification. The calculations are based on values obtained from databases. Again, these databases use a single average per weight/volume value for transportation, construction, operation, and disposal regardless of distances equipment/machines used by each material. This develops errors in the calculation process. In calculating environmental costs, each material needs to be identified and then calculated for the total. Furthermore, the exact vehicles, machines, distances traveled, fuel, and electricity used by machines in the construction of a specific building will greatly affect the energy required and carbon produced for each type of material used in that building. In an effort to accurately calculate the EE, EC, and environmental costs for a cradle to grave boundary of construction materials used in a building during its lifecycle, a model will be created that will provide a sequential logic to calculate the EE required to manufacture, transport, and place materials. Furthermore, a sequential logical model is created to assess EC and its associated environmental costs for manufacturing, placing, and transporting construction materials. Based upon the identified gaps that exist within the published calculation methods, the model will encompass a list of specifications and requirements. These include:

- Accurately calculating the embodied energy for construction materials used for buildings through the cradle to end of construction lifecycle,
- Accurately calculating the embodied carbon for construction materials used through the cradle to end of construction lifecycle,
- Accurately calculating the environmental cost implication of construction materials through the cradle to end of construction lifecycle,
- Proposing methods to reduce environmental impacts of buildings through material selection, equipment optimization, and construction method selection

Additionally, the model will be characterized as:

- Accurate and Information intensive; since different databases will be available to store a vast amount of information about material, equipment and machinery. Such information allows for accurately assessing the environmental footprints of materials used in construction
- Practical; it can be used to assess any construction project.
- Efficient; it can be used to assess the sustainability of construction buildings early during the design stage.
- Modular; it is built in a module format as to allow for future expansion.
- Flexible; it can be used by engineers with limited knowledge of design and/or construction experience.
- Proficient; can quickly calculate and assess scenarios by applying tools using the computer-based language c# to provide quick and accurate results.
- Integrated; Benefits from the latest design technologies, specifically BIM platforms, applied by the construction industry during the design phases and can use information from such tools to calculate energy usage and carbon production.

3.3 Model's Components and Architecture

The developed model consists of components designed in a modular format, incorporating six modules: The Manufacturing EE (Embodied Energy) Calculation Module, Transportation EE Calculation Module, Placement EE Estimation Module, Manufacturing EC (Embodied Carbon) & Carbon Cost Calculation Module, Transportation EC & Carbon Cost Calculation Module, and the Placement EC & Carbon Cost Calculation. All Modules share a Database Management system that contains ten databases which are: the Cradle to Gate Manufacturing

Database; Truck Vehicle Database; Hauler Vehicle Database; Concrete Mixer Database; Stationary Crane Database; Mobile Concrete Pump Database; Stationary Concrete Pump Database; Stationary pumping Machine Database; Concrete Bucket Database; and Cradle to Gate Carbon Emissions Database. Information from those databases feed information for each module that allow for the assessment of materials. The functions and data flow performed within each model's component or module are described in the upcoming sections. Figure 3-1 shows the overall model's components and architecture.

Overall, based on the design inputs, the created modular system will guide the user through the process of calculating the EE, EC and carbon environmental implication costs as well as the social carbon cost of a proposed building for the cradle to end of construction lifecycle. Furthermore, a methodology to reduce and optimize the EE and EC will be developed. In the Manufacturing EE Calculation Module, the EE required to manufacture materials needed by a proposed conceptually designed building will be calculated. In the Transportation EE calculation Module, the amount of energy required to transport material from its origin to the place of construction will be determined. In the Placement EE Calculation Module, the amount of energy required to place materials in its intended location will be determined. Similarly, in the Manufacturing EC & Carbon Cost Calculation Module, the carbon produced from manufacturing materials required by a proposed building design will be calculated. Furthermore, in the Manufacturing EC & Carbon Cost Calculation Module, the monetary environmental implication cost of carbon produced from manufacturing materials produced from the design of a proposed building will be calculated. In the Transportation EC & Carbon Cost Calculation Module, the amount of carbon produced from the process required to transport material from its origin to the place of construction will be determined.

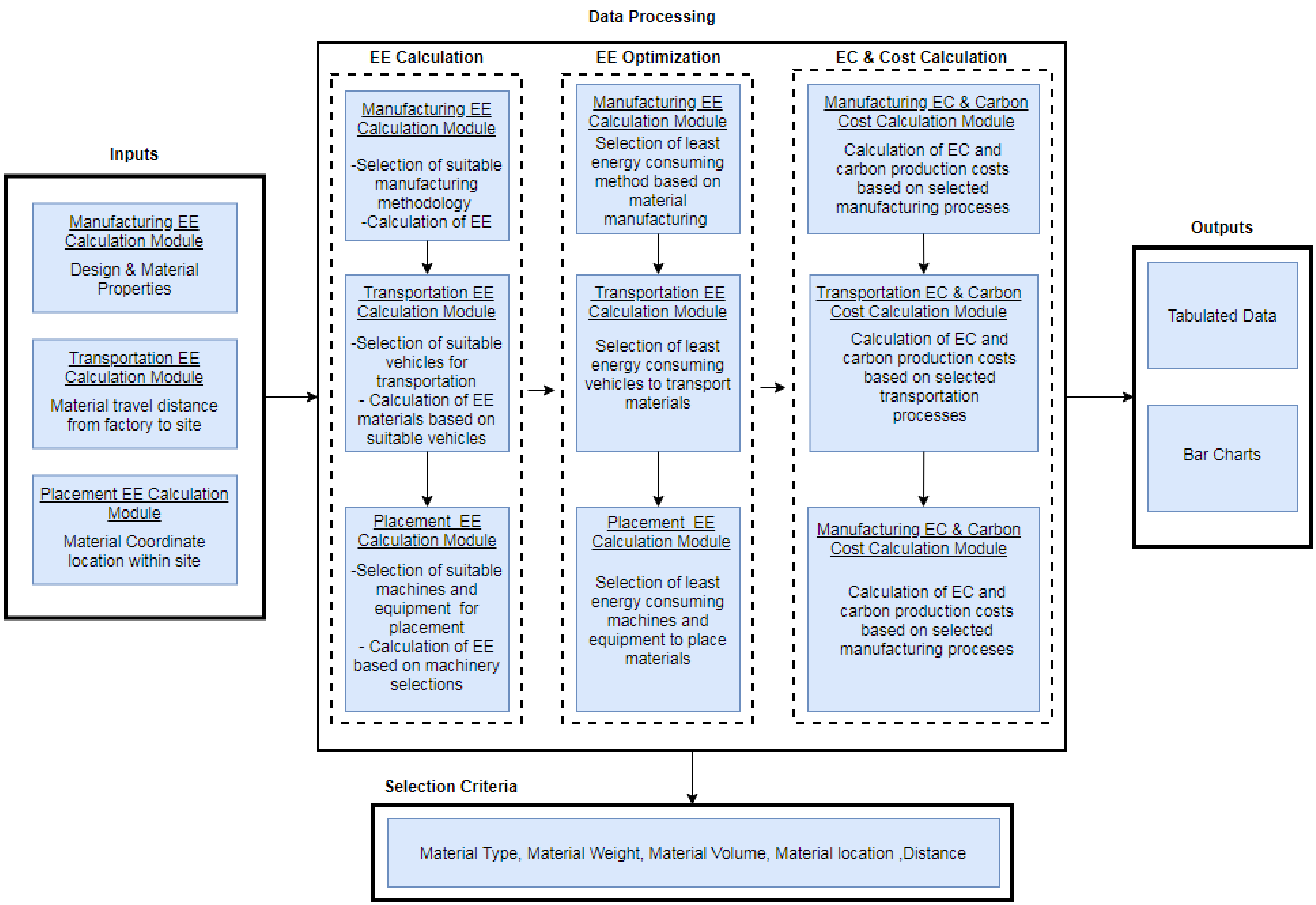

Figure 3-1: Overall Model Architecture

Also, in the Transportation EC & Carbon Cost Calculation Module, the monetary environmental implication cost of carbon produced from the process required to transport material from its origin to the place of construction will be determined. In the Placement EE & Carbon Cost Calculation Module, the amount of carbon produced from activities to place materials in its intended location can be determined. Nevertheless, in the Transportation EC & Carbon Cost Calculation Module, the monetary environmental implication cost of the amount of carbon produced from transportation activities required to place materials in its intended location will be determined.

The calculation methodology for each module is based on a set of inputs in which a suitable manufacturing, transportation, and placement method is selected to calculate EE, EC and costs. By identifying the manufacturing, transportation and placement equipment and processes, the accuracy of the calculation procedure is greatly enhanced. The process will involve a sequential logic, in which, the EE required by materials will be calculated in the Manufacturing, Transportation and Placement EE Calculation Modules and then the EC and the associated carbon production costs is calculated through the Manufacturing, Transportation and Placement EC and Carbon Cost Calculation Modules. In the Manufacturing EE Calculation Module, the energy required to produce a single material will be determined by retrieving the energy required to produce a single material through a specific factory process, then the total of all energy required to manufacture all materials can be identified. In the transportation EE calculation module, the suitable transportation vehicles required to transport materials based on their type will be identified and the energy required to transport materials based on different suitable vehicles will be calculated. Based on the least EE required to transport specific materials through suitable vehicles, the model will assist the user in identifying the least energy consuming vehicles and in return calculate the optimized EE. In the Placement EE Calculation Module, the equipment required for placing materials based on their type will be identified and the energy required to place materials based on different equipment options will be calculated. Based on the least EE required, the model will assist the user in identifying the least energy consuming machines to calculate the optimized EE. In the Manufacturing EC & Carbon Cost Calculation Module, the amount of carbon dioxide produced from the manufacturing process identified in the EE calculation stage will be calculated. Based on carbon produced from processes required to manufacture materials, the monetary environmental implication costs of carbon for manufacturing materials will also be determined. In the EC Transportation EC & Carbon Cost Calculation Module, the model will assist the user in identifying the embodied carbon produced by using the vehicles identified in the transportation EE Calculation Module. Additionally, the environmental impact costs of producing carbon will be identified. In the placement EC Calculation Module, the model will assist the user in determining the carbon produced by machinery and equipment selected in the placement EE calculation module. Additionally, the environmental impact costs of producing carbon through placing materials using suitable transportation vehicles will be identified. The overall selection of manufacturing, transportation, placement equipment, vehicles and production machinery will depend on the type of the material, the weight, the volume, and the location of each material to be used in the proposed design structure. This is explained in detail in the upcoming sections. Different modules will be created for solid and liquid materials since the transportation and placement methods for each type differ greatly and hence the material EE, EC, and cost will differ. EE, EC, and costs will be determined by using the suitable machines, vehicles, and equipment for each type of material.

3.4 Database Management System

A database management system will be created to store ten databases that contain vital information to assess EE, EC, and environmental costs. The databases will be the Cradle to Gate Manufacturing Database; Truck Vehicle Database; Hauler Vehicle Database; Concrete Mixer Database; Stationary Crane Database; Mobile Concrete Pump Database; Stationary Concrete Pump Database; Stationary pumping Machine Database; Concrete Bucket Database; and Cradle to Gate Carbon Emissions Database.

Databases represent the basis for all EE/EC and environmental cost calculations. In lieu of the ISO 14040 standards for lifecycle assessments, all calculations need to be based on databases where the goal and study parameters are defined. The identified is to calculate the EE/EC and environmental cost. With regards to the study parameters, the study parameters involve the determination of EE/EC and cost for the cradle to end of construction stage.

In the cradle to grave manufacturing database, the amount of energy required to extract and manufacture 185 different types of materials will be stored. These are based on values presented in the Athena lifecycle database and they will represent the most common materials used in buildings. Necessary data will be extracted from the Athena Impact Estimator, which is the latest version of the software produced by Athena Institute in Canada. That data is regularly updated whenever an update is released from the producer. Nonetheless, this database contains the density for each material. With regards to the use of the Athena lifecycle database information as the basis for manufacturing EE calculation stages, it is apparent that the cradle to gate databases presented in the literature seems to use a rather consistent approach. Specifically, the databases possess errors if used in cradle to end of construction boundary. If such databases are used within the correct geographical region and if they are used only for cradle to gate EE/EC calculations, there are lower chances of inaccuracies. In such cases, the EE/EC for extraction and manufacturing can be used as a baseline for the cradle to gate lifecycle assessment. This idea is derived from the fact that factories tend to use repetitive processes. Unlike buildings where locations, construction methods, maintenance cycles, and disposal approaches vary, plants are rather stationary and rarely change their techniques. They are not dependent on the transportation and construction processes, thus EE/EC for manufacturing and extraction are rather constant for different buildings. Furthermore, the concentrated research for cradle to gate boundaries and the continuous improvements in data collection methods all suggest these values to be reliable within the cradle to gate boundary (Athena,2013). Since Athena databases are created for the Canadian industry, it is only appropriate to use such data.

In the concrete mixer database, information for a total of nine concrete ready-mix trucks will be collected along with their maximum payload volume and fuel usage per unit distance. Furthermore, in the crane database, information will be collected for thirty cranes. For each, the maximum payload, boom length, and the electricity required for placing materials will be stored. In the mobile pump database, information will be collected for two mobile concrete pumps commonly used in the construction industry. For each, the boom length will be recorded, and the amount of fuel required per pumped volume of concrete will be noted. Nevertheless, in the concrete bucket database, a total of thirty-four buckets used to place concrete will be identified. For each, the volume and weight will be identified. As for the stationary pumping machine database, a total of fifty-two machines will be evaluated; for each, the maximum pumping pressure and flow rate will be stored. Moreover, the electricity usage for each machine is determined. Such databases provide the basis for EE quantification. As to calculate the embodied carbon emissions, the final database identified as cradle to gate carbonic emissions database contains information about the emissions produced by the production of a single unit of all the materials identified in the cradle to gate manufacturing database. These values have been collected from the Athena lifecycle database. They contain information about the emissions produced for single units of 185 materials commonly used in the construction industry. In the truck database, information for a total of 178 vehicles will be collected. These include pickups, flatbed trucks, and tipper trucks. For each vehicle, the maximum load weight and payload volume will be identified and also the fuel consumption per distance of each is recognized and noted in the database. In the hauler database, a total of 135 hauler trucks will be identified along with their maximum payload weight and fuel consumption per unit distance. Furthermore, the maximum payload volume and fuel usage per unit distance for multiple vehicles will be identified.

For transportation vehicles, the data will be collected through surveying three construction companies in Canada. These companies have requested that they remain anonymous as to protect their operational edge in business. In cases where actual on-site vehicle information isn't available; vehicle operational manuals and supplier brochures will be used to extract data. Such information is readily available on supplier and seller websites. Overall, information about fuel or electricity usage for different transportation vehicles will be collected and the average usage per unit distance for different haulers, trucks and concrete mixers were analyzed and stored in the transportation databases. Such data will be used to calculate embodied energy and subsequently the embodied carbon of such vehicles. In terms of placement, data about machines and equipment will be collected from operational manuals produced by different manufacturers. The data was collected to determine electricity per usage for cranes and stationary pumps. Furthermore, information about the fuel usage will be collected for pumps per unit volume of placement. Such data may be used to convert usage values to both EE and EC in MJ to calculate the EE, EC and environmental costs.

3.5 Information Dataflow

As previously mentioned, calculating EE/EC and environmental implication costs requires accurate information. Furthermore, to select suitable transportation for materials and placement machinery, a range of options need to be available for the model to assess the energy, carbon, and costs required by each material. The model will require a structured data flow to feed such information. The information data flow within the model is presented in Figure 3-2. The model data flow will require two sets of data feeding processes. The first is the retrieval of data from databases and the second is feeding the processed data into subsequent modules. The process of calculating EE/EC and associated costs in each module is explained in the succeeding sections.

In the Manufacturing EE's calculation module, information about the energy required to produce a single type of materials is attained from the cradle to gate manufacturing database. Based on such values, the total EE required to manufacture all materials is calculated. Once done, the transportation EE module will require information from each of the truck vehicle database, the hauler vehicle database and the concrete mixer database. Based on the material type, a suitable vehicle is selected for each material for transportation and therefore the total EE required is calculated. For the placement EE module, the required data is obtained from each of the Stationary crane database, mobile concrete pump database, stationary concrete pump database, stationary pumping machine database, and concrete bucket database. Based

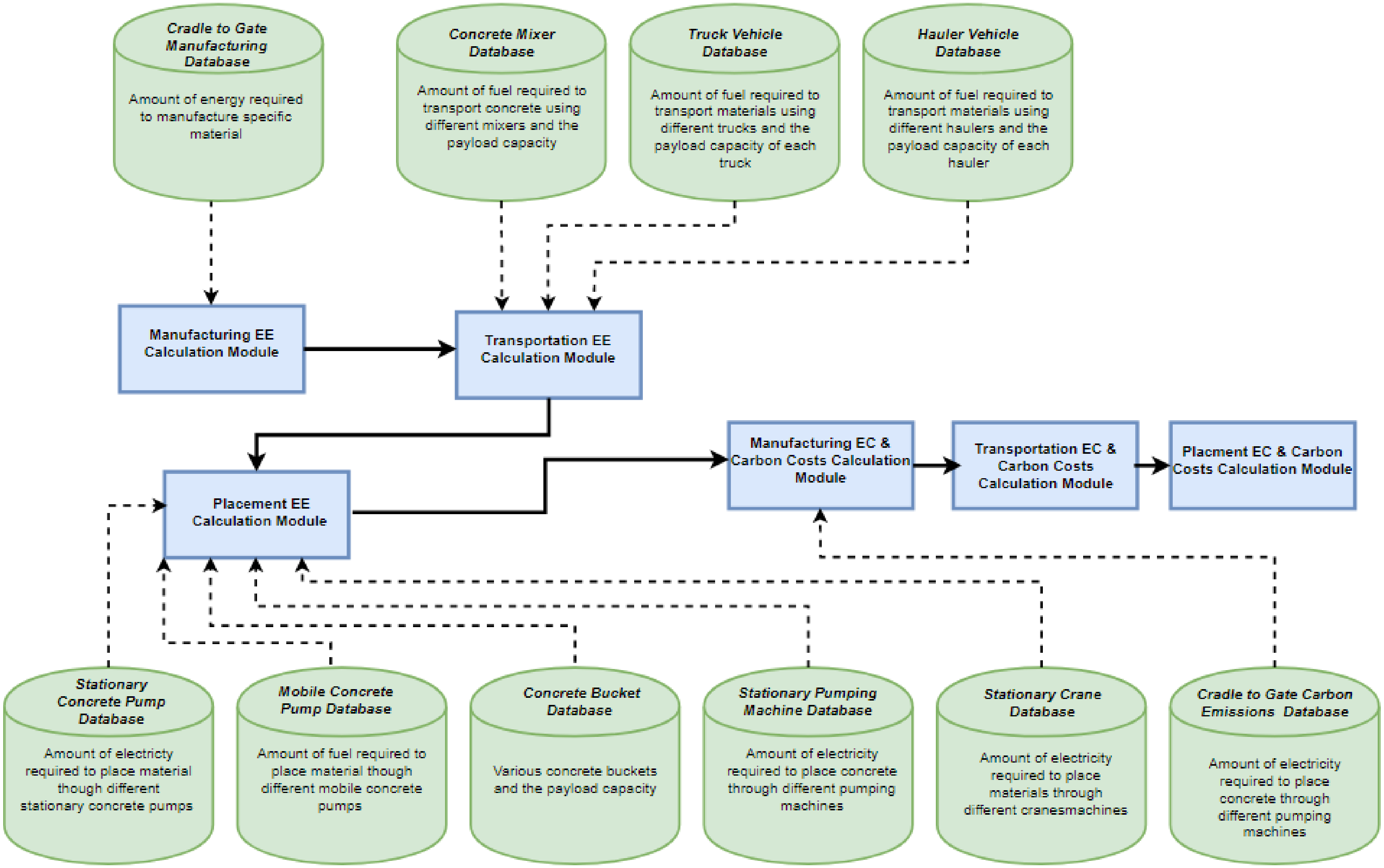

Figure 3-2: Overall Model Dataflow

on the type of material, suitable equipment and machines are selected to place each material in its intended location. Nevertheless, for the manufacturing EC and carbon costs calculation module, the necessary information is transferred from the manufacturing EE calculation module. In the manufacturing EE calculation module, the manufacturing process has been identified for each type of material.

Such information is transferred to the manufacturing EC and costs calculation module. Additionally, the amount of carbon produced by the manufacturing process of each material is required. This is attained from the cradle to gate carbon emissions database. Using such data, the EC for manufacturing materials required by each process per construction material used in buildings can be calculated as well as their associated carbon implication cost. For the transportation EC and carbon costs calculation module, processed information will be transferred from the transportation EE calculation module. In the transportation EE calculation module, suitable vehicles required to transport materials are selected. Furthermore, the selected vehicles have been optimized to minimize energy usage in the EE calculation module. Information about the selected vehicles for each type of material will be transferred to the transportation EC calculation module. The carbon produced from using those vehicles will be calculated in the transportation EC calculation module. The calculation is based on a set of equations created based on the electricity and fuel used by each of the selected vehicle per material. Similarly, for the placement EC and carbon costs calculation module, the machine and equipment selections from the placement EE calculation module will be transferred to the placement EC calculation module. Through a set of specified equations, the electricity and fuel used per selected machine for each material will be converted to a weighted value for carbon produced per machine per material.

3.6. Manufacturing EE Calculation Module

The goal of the manufacturing EE calculation module is to calculate the energy required to manufacture construction materials used during the design of buildings. To asses such energy, the manufacturing embodied energy module represents the stage in which EE for materials are quantified for the cradle to gate boundary. To quantify cradle to gate EEs for materials, information about each material within a building needs to be retrieved from the cradle to gate manufacturing database. This database contains EE information for various materials, and therefore the proposed methodology will provide information about the energy required to produce those materials per weight of each material used in the building. Based on the material used, the energy per unit weight for commonly used materials will be obtained from the database. In addition, information about the materials will be presented in volume, and hence, to calculate EE, the total weight per material will be required. The information about the density for each material will be recorded in the cradle to gate manufacturing database. To calculate the EE required by the materials, the total weight for each material, will be calculated using the following equation,

$$Mass = Density\ x\ Volume \qquad \textbf{\textit{Equation 3-1}}$$

Densities of materials will be retrieved from the database. Such calculation will be performed to find the mass of all materials used in creating the building model. Once completed, the total EE per material can be identified using the following equation:

$$\sum EE = \sum(EE_{PER\ UNIT\ WEIGHT\ \ FROM\ MANUFACTURING\ EE\ DATABASE} \times M_{TOTAL\ PER\ VOLUME\ \ OF\ MATERIAL}) \qquad \textbf{\textit{Equation 3-2}}$$

The total EE for manufacturing will be calculated through the summation of the values. To optimize the EE, substituted materials will be used and the same process will be repeated.

3.7 Transportation EE Calculation Module

After the energy required to manufacture materials is calculated, it will be necessary to calculate the EE required for the transportation. The amount of energy required to transport materials from their assembled location to the site needs to be calculated in this stage. To quantify the energy required for transportation, each material needs to be assigned to a transportation method. Materials can be classified as either liquid or solid. Based on those categories, liquid materials will be transported using concrete mixers while solid materials may either be transported using trucks or haulers. The concrete mixer database contains information about fuel usage for different types of concrete mixers per mile. The total fuel used to transport liquid materials can be identified and can be used to compute the energy for every concrete mixer that will be used to transport concrete. Accordingly, the concrete mixer per concrete type that need the least energy consumption can be identified. On the other hand, the truck vehicle database and hauler database both contain information about the fuel usage of the different trucks and haulers per mile. The fuel used to transport solid materials will be computed in order to calculate the total energy per solid material. Assessing multiple vehicles for both the solid and liquid transportation will allow the model to suggest the best energy transportation modes. To accurately quantify EE, the distance required for transporting a material from its assembled or produced location to the construction site is required. Initially, the location of the suppliers for each material and the proposed building location can be identified. Such information will help calculating the distances between the material producer and the building location, and thus the total fuel per vehicle will be assessed. Nonetheless, the databases associated with this module contains information about the payload capacity of each vehicle. Such information will aid in determining the number of trips required and the vehicle that is capable of transporting variant materials. This will aid in calculating the total fuel required per material per vehicle. To calculate the energy usage, it is important to calculate fuel used. The amount of fuel will be converted based on conversion factors identified in the United States Lifecycle Database (NREL.2017). Below is a summary of the conversion attributes used by the United States Lifecycle Database:

Table 3-1: Energy conversion factors used by the United States Lifecycle Database

Unit	Energy thermal unit conversation
1 Joule	0.000947817 Btu
1 Ton of Coal	19,622,000 Btu
1 kilowatt-hour	3,412 Btu
1 Cubic foot of Natural gas	1,028 Btu
1 Barrel of Crude oil	5,800,000 Btu
1 Gallon of Diesel fuel	137,381 Btu

Overall, to assess the EE required for transportation, four different submodules are created within the transportation EE calculation module. These are: the concrete mixer EE calculation submodule; the truck EE calculation submodule; the hauler EE calculation submodule; and finally, the solid material transportation EE optimization submodule. Initially, the module will assist users in calculating the energy required to transport concrete by using concrete mixers in the concrete mixer EE calculation submodule. Information about concrete mixers is obtained from the concrete mixer database. Furthermore, concrete mixers with the least energy consumption can be identified. Subsequently, in the truck EE calculation module, the energy required to transport solid materials through trucks will be calculated.

Information about the trucks is obtained from the truck database. These include the fuel usage and payload capacities per truck. The weight of each material is computed by the manufacturing EE calculation module, which will be used to select suitable transportation vehicles. From the extracted information, the maximum truck's payload weight and material size will be used to select the suitable trucks that are capable of hauling variant solid materials. Nevertheless, the fuel consumption per kilometer per selected vehicle will be extracted to calculate the energy consumption. In the hauler EE calculation module, the energy required to transport solid materials transportation by using haulers will be calculated. The information will be obtained from the hauler database in addition to the hauler's maximum payload. Nevertheless, the fuel consumption per kilometer per vehicle will also be extracted to calculate the energy usage per suitable vehicles per material. The module will identify the haulers that are suitable to transport solid materials and hence the energy required per the selected vehicles can be calculated. This module can identify the most energy efficient haulers to transport all the solid materials. Since solid materials can be transported by trucks or haulers, an optimization module is needed to select the most energy efficient solid transportation method for each solid material. In some cases, solid materials may be too large to be transported by using trucks, and thus the most suitable method is to use haulers. On the other hand, solid materials maybe small in size and hence trucks will be the most suitable transportation method to minimize energy usage. In the solid material transportation EE optimization submodule, vehicles with the least energy consumption will be identified to transport each solid material. Figure 3-3 shows the transportation EE calculation module's architecture.

3.7.1 Concrete Mixer EE Calculation Module

The goal of the concrete mixer EE calculation module is to calculate the energy required to transport concrete. As explained above, once materials have been classified based on their type in the transportation EE assessment modules, their transportation medium will differ. During the concrete mixer EE calculation process, all materials that have been classified as ready-mix concrete will be assigned to concrete mixers as means of transportation. In construction sites, concrete cannot be transported in a single combined batch since its setting time is assigned as two hours, since buildings are constructed through stages where it is laid through a floor-by-floor sequence. Moreover, concrete mixers cannot transport concrete with different strength at the same time because it will ruin the mixture.

To simulate this scenario, all type of concrete with the same strength and elevation can be grouped together by the module, and hence such group may be transported together. Once grouping is completed, the hauling distance based on available roads to transport each grouped material is required. Through the use of google maps, the module will assist the user in determining the travel distance for each group. Once all distances have been determined for each group, information from the concrete mixer database is required. The concrete mixer databases contain information about multiple concrete mixers. Furthermore, information about the fuel per mile and the payload capacity of multiple option of concrete mixers is available.

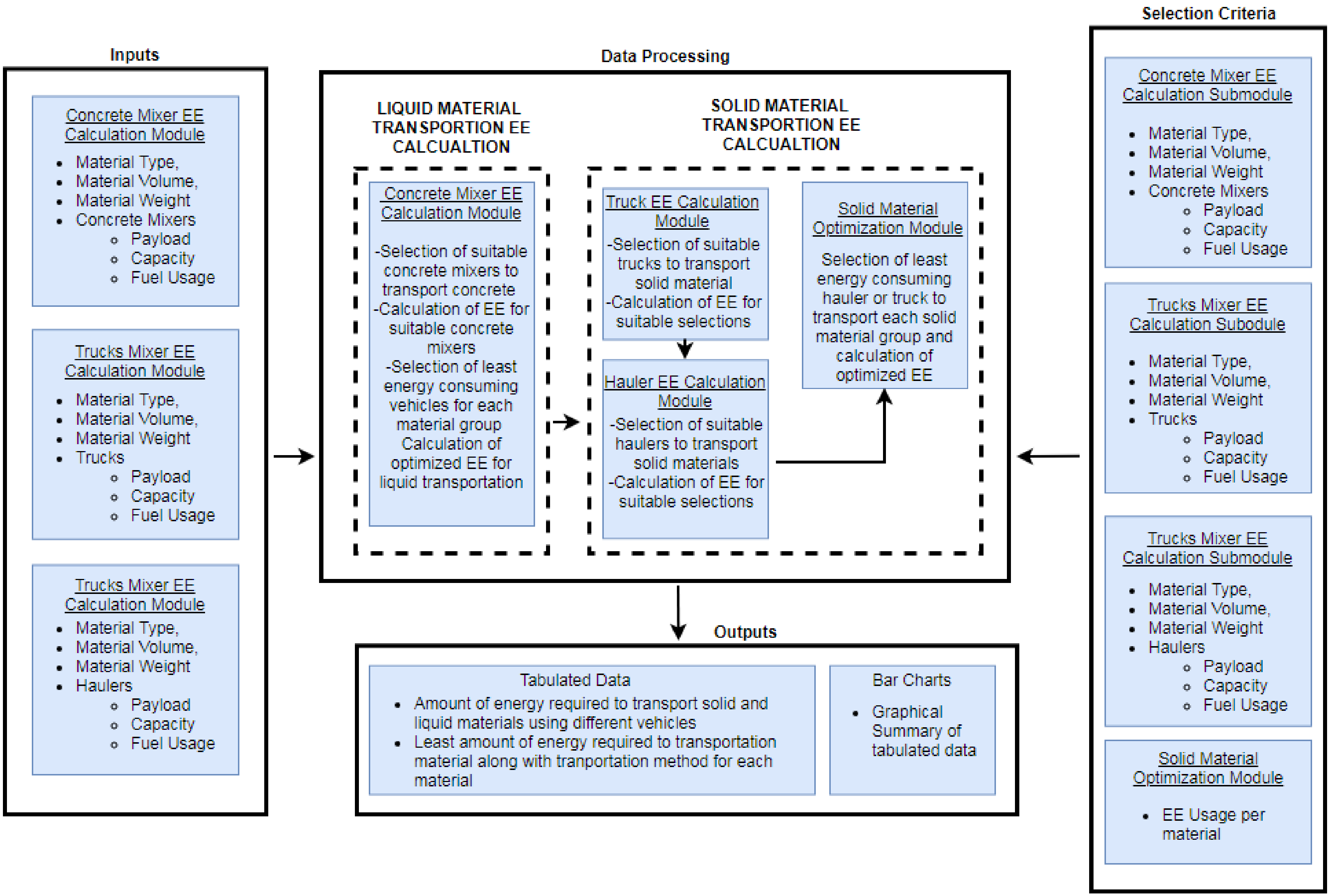

Figure 3-3: Transportation EE Calculation Module's Architecture

For each group, the amount of fuel per grouped material is required. Also, the number of trips required to transport a group of materials is required. The module will assess the use of all concrete mixers in the database. Based on each iteration, the module will calculate the number of trips required to transport each group of materials and in return it will calculate the number of trips required by each concrete mixer to transport each group per mixer. This is performed by dividing the vehicle payload by the group volume. The total amount of fuel that the trucks consume to transport each grouped material will be calculated based on the following equation:

$$Total\ Fuel\ Consumption\ (\text{Ltrs}) = MPG_{TRUCK} * (2.352144) * (Distance) * Number_{\ trips}$$

Equation 3-3

Based on the values provided by the USEPA lifecycle conversion factors, the following equation will be used to determine the energy from the fuel usage (NREL.2017).

$$EE_{TRUCK} = Fuel\ consumption * 3.8290344$$ ***Equation 3-4***

Once the EE for each group is calculated for multiple mixer iterations, the least EE consuming truck for each group will be identified. Similarly, the vehicles required for all liquid transportation will be identified.

3.7.2 Truck EE Calculation Module

In the truck EE module, the materials other than liquid materials are identified. For such materials, the transportation's method can either be trucks or haulers. The same materials will be tested to identify the trucks and haulers' capability to carry each item. In some cases where materials are small, it will be more efficient to use smaller trucks that have lower fuel consumption. On the other hand, some smaller trucks have space and payload limitations and hence such hauling method become unsuitable. To test such scenarios, the module will assess both the conditions to carry solid materials, and the EE required for the transportation of solid material. To begin, the module will calculate the EE required to transport materials using trucks. Initially, the module will use the building location, which was identified at the concrete mixer processing stage. Next, the module groups together the materials of the same type. To reduce EE, the same supplier will be considered for each grouped materials. The module will request from the user to identify the supplier locations of each grouped materials. The module will then connect to google maps to determine the exact travel distance for each grouped family. Once completed, the module will then connect to the truck vehicle database to attain all the trucks available for assessment. Subsequently, the module will check the capability of each truck to carry each individual item which is within each of the groups of materials. Trucks are checked against the weight and volume restrictions. According to MTO (2019), the maximum allowable height for transporting materials on highways is 4.25m. Furthermore, each material is checked against all trucks available in the truck database to identify if the weight of any of the grouped materials exceeds the truck allowable payload. Additionally, the model will consider the material, regardless of the shape, in an imaginary box in which the material can be checked against the vehicle volume restrictions. In such a case the box's dimensions are known and accordingly, the dimensions of the largest box are compared to the dimensions of the truck to ensure it fits. In cases where restrictions occur, the truck is considered ineligible. Once all eligible trucks are identified, the number of trips required for every truck for every group of materials is identified. Throughout the process, the number of trips required to move every group by each eligible truck is determined. For the number of trips, the module uses an optimized workflow to determine the arrangement pattern used to stack irregular materials over the truck's bed. This is done by dividing the total volume of the truck by the volume of the largest imaginary box. This will determine the number of items that would be loaded on the truck. Accordingly, the total number of items to be hauled is divided by the number of items per trip to calculate the total number of trips per vehicle. Once the number of trips is identified, the module will identify the total fuel consumption required by each eligible vehicle for each grouped materials. By connecting to the truck database, the unit fuel usage per mile will be identified and is used to determine the total fuel usage. To calculate the fuel usage of each suitable truck, the following equation will be used:

$$Total\ Fuel\ Consumption\ (Ltrs) = MPG_{TRUCK} * (2.352144) * (Distance) * Number_{\ trips} \quad \textbf{\textit{Equation 3-}}\ 5$$

Once all the necessary calculations are completed, the module will identify the EE for each truck for each group. The following equation will be used to do so:

$$EE_{TRUCK} = Fuel\ consumption * 3.8290344 \quad \textbf{\textit{Equation 3-6}}$$

Those equations have been created based on the conversion values identified by NREL (2017) and used for converting diesel fuel usage to Energy in MJ. Next, the module will recommend the truck with the least energy consumption as the best vehicle for the transportation of each material's group. In some instances, no trucks are available for transporting the groups of material. This is due to weight and height restrictions. In such a case, those groups will only be transported using haulers.

3.7.3 Hauler EE Calculation Module

Once all non-concrete material groups have been evaluated against eligible trucks in the truck EE calculation module, the same groups of materials need to be evaluated against hauler's transportation. Typically, the term hauler refers to vehicles that have a detachable loading trailer. In the hauler EE calculation module, the same process will be repeated as for the truck EE assessment. The only difference lay in the weight restrictions and volume. The maximum height remains fixed to 4.25m while the weight is based on each hauler's maximum payload. In terms of volume, no restriction prevails since trucks are able to transport bulky materials that are only governed by the hauler's engine power and material's payload. Once all the haulers are tested for all groups of materials, the module will identify the hauler with the least energy consumption for each group to be transported.

3.7.4 Solid Material EE Optimization Module

To compare the EE for both the trucks and haulers used for the groups of solid materials, the module will compare the energy consumption for the suitable trucks and haulers that are capable of carrying each grouped material. The goal of this module is to determine the least energy consumed for transporting each solid material group, either by using trucks or haulers. Based on the determined values of EE, the module will assist users in determining the least EE non-liquid transportation method per solid material group. For materials with no eligible trucks, haulers will be the selected method of transportation.

3.8 Placement EE Calculation Module

To quantify the energy required to place a material in its intended location, the quantification of the energy required placement of two types of materials is required. These include the assessment of placement energy for either liquid or solid material. Overall, in the material placement EE modules, the energy required to place a material is calculated based on the machines used, the location and the travel distance for each material on the site. For liquid material placement, concrete arrives to the site by concrete mixers. Upon their arrival, they will head to a pumping station and thereafter concrete will be placed on site. To place the concrete on site, a mobile concrete pump may be used. On the other hand, a stationary pump or even a concrete bucket attached to a crane are alternative methods. To identify the energy required for this process, the location must be identified since machines used for placement consume energy based on efficiency. Machines consume energy based on material volumes and nevertheless material weights. To identify the energy required for the placement of liquid materials, different methodologies can be selected. These include either using mobile pumps or stationary pumps or even concrete buckets. Based on the various methodologies the suitable machines required for each methodology will be identified and accordingly the energy based on fuel or electricity will be determined. To identify the least energy required, the least energy consuming machines will be identified.

For solid material placement, materials are transported to a building location either by haulers or trucks. Once arrived, they will either be stored in storage or get offloaded and directly placed on site. To identify the energy required to place solid materials by using cranes, locations must be identified especially since the cranes used for placement consume energy based on the travel distance. Cranes use energy based on the material’s volumes, material weights, and travel distance required either from the storage locations or from the trucks. Through the material placement EE calculation process, exact cranes are used to determine the placement energy as well as the least energy consumed by a crane is identified. As in the transportation EE assessment module, the material placement method involves the processing of the energy required to place both the solid and liquid materials separately. For each, a set of submodules will be created to assess the different methods of placement for the solid or liquid to evaluate the energy required by each of the placement methods. For the liquid material placement EE process, six submodules will be created. These are: mobile concrete pump placement EE calculation sub-module; bucket concrete material EE calculation sub-module; stationary pump EE calculation sub-module; mobile pump and concrete bucket EE calculation sub-module; mobile pump and concrete stationary pump EE sub-module; and liquid material placement EE comparison sub-module. As for the solid material placement, an independent sub-module will be created. A final sub-module named as the crane optimization module will also be created to select the most suitable crane for placing both the liquid and solid material. Figure 3-4 shows the dataflow process within the module components.

Since concrete, which is a liquid material, can be placed by different methods, it is vital to asses those methods in order to determine the one with the least energy consumption for placement. In terms of liquid placement, the mobile concrete pump placement EE calculation module will assist users in determining the energy required to place concrete by using mobile concrete pumps. Once the material locations are identified, concrete pumps with suitable boom lengths will be selected. Once completed, the energy required for concrete placement through each suitable pump will be calculated and in return the pump with the least energy consumption will be identified. Such methodology will optimize the energy usage. In terms of the dataflow for the mobile concrete pump placement EE calculation module, information about the concrete pumps will be obtained from the mobile concrete pump database. Mainly the boom length and the fuel usage per unit of each suitable pump will be obtained. In the bucket concrete material EE calculation module, the amount of energy required to place concrete by using buckets and stationary cranes will be determined. By selecting cranes with suitable boom lengths that are able to reach all materials in a construction site, the energy required to place concrete through suitable buckets and cranes will be determined. Based on the suitable cranes and buckets, the combination (crane and bucket) that will require the least energy required to place liquid materials for placement is identified. In terms of dataflow, the concrete bucket concrete material EE calculation module will obtain necessary information from the stationary crane and the concrete bucket database. From the stationary crane database, information about various cranes are obtained. This includes the crane boom's lengths, maximum payloads, and electricity usage. From the concrete bucket database, information about various concrete buckets will be obtained. This include the bucket weights and maximum carrying volume. Such values assist the module to determine the energy usage required to place concrete through this process. In the stationary pump EE calculation module, the amount of energy required to place the concrete through stationary pumping machines will be determined In this module, the process involves two machines, the actual pumping arm and the pumping machine required to lift the concrete to higher floors. The module will evaluate the location of the concrete material and accordingly it will assist users in selecting the pumps that are capable to reach the concrete at its location in addition to selecting suitable pumping machines.

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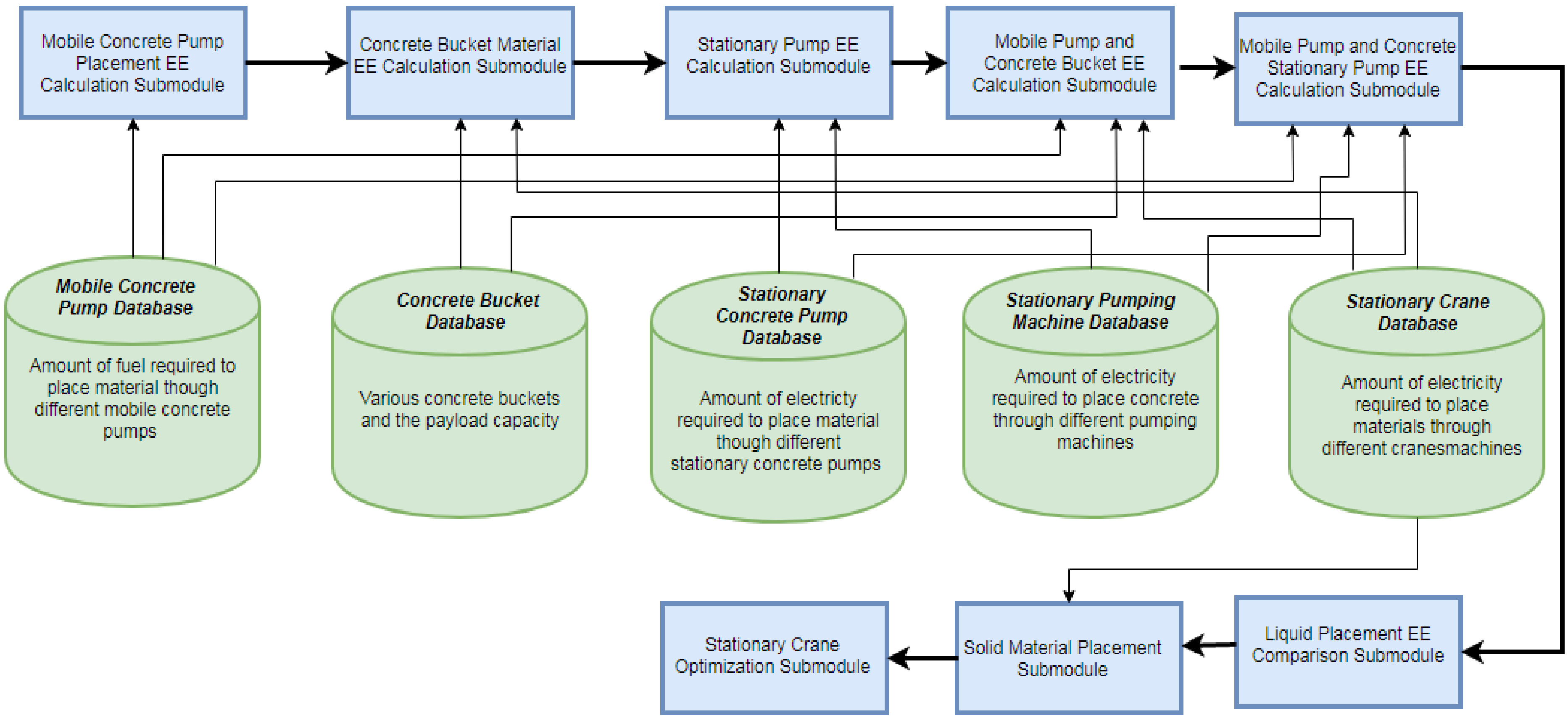


Figure 3-4: Placement EE Calculation Dataflow within Model Components

Based on the selections, the module will calculate the energy required to place the concrete through the various suitable combinations of machines and therefore, the module can assist users in identifying the machine with the least energy consumption. The data required for this module is obtained from stationary concrete pump and stationary pumping machine databases. Mainly, the boom lengths for various arms will be extracted and the electricity usage per concrete volume will be extracted from the stationary crane database. The maximum reachable pumping height and electricity usage per pumping concrete volume will be extracted from the stationary pumping machine database. Such information will aid in the determination of suitable machines and their energy usage when placing concrete by using this method. In the mobile pump and stationary concrete pump EE calculation submodule, the energy required to place concrete by using both mobile pumps and stationary pumps will be calculated. At some instances, mobile pumps might not be able to reach all the locations in a building and thus a supportive method is required to place concrete. For such scenarios the mobile pump and the stationary concrete pump are module is created. In this module, concrete is classified by groups in which materials that are capable of being placed through mobile pumps will be identified. For such groups the same process followed in the mobile concrete pump placement EE calculation module will repeated to determine the energy requirements. For the remaining items, the materials will be processed in a similar way as identified in the stationary pump EE calculation module to determine the energy required to place concrete by using stationary pumps and pumping machines. Using the same optimized mobile pumps and stationary pumps identified in the mobile concrete pump placement EE calculation and stationary pump EE calculation modules, the total optimized EE will be calculated for concrete placement in this module. This module will be processed if all concrete materials items cannot be placed through the mobile concrete pump placement EE calculation submodule. In the mobile concrete pump EE calculation module, the module will identify such irregularities and continue the EE computation by disregarding such materials. In cases where mobile cranes are not sufficient to place concrete, a different alternative method will be used. This is the use of a combination of mobile pumps along with concrete buckets attached to cranes. To assess the energy required to place materials through this method, the mobile pump and concrete bucket EE calculation submodule will be created. In this module, materials will be classified into groups in which materials that will be capable of being placed through mobile pumps will be identified. For such groups the same process used in the mobile concrete pump placement EE calculation module will be repeated to determine energy requirements. For the remaining items, the materials will be processed through the same methodology identified in the concrete bucket EE calculation module to determine the energy required to place concrete through stationary pumps and pumping machines. Using the same optimized mobile pumps and stationary cranes and buckets identified in the mobile concrete pump placement EE calculation and the concrete bucket EE calculation submodule, the total optimized EE is calculated for concrete placement in this module. Overall, the module will process information through the mobile pump and stationary pump EE and mobile pump and concrete bucket EE calculation modules if no mobile pumps are able to place all concrete materials in its intended location.

As a final submodule for the liquid placement, the liquid placement EE comparison submodule will compare the EE required to place concrete through the different placement processes. The module will suggest to users the process that has the least energy consumption to place liquid material. In cases where mobile pumps are not sufficient to place all concrete materials in its intended location, the energy computations from the mobile concrete pump EE calculation module are disregarded.

Once all the least energy required to place liquid materials is identified, the module will subsequently assess the energy required to place solid materials. In terms of solid placement, a singular module will be created. This is the solid material assessment module. In this module the energy required to place solid materials by using cranes will be determined. By selecting cranes with suitable boom lengths that able to reach all the locations of materials in a construction site, the energy required to place solid materials will be determined. Based on suitable cranes, the least energy required to place solid materials for placement are identified. In terms of dataflow, the module will obtain information from the stationary crane database. From this database, information about various cranes will be obtained. This includes the crane boom lengths, maximum payloads, and electricity usage as to allow the module to identify the suitable cranes and calculate the energy usage per suitable crane. The module will assist users in determining the most suitable crane and in return the least energy required to place materials by using different selected cranes.

In the crane optimization module, the most suitable crane to minimize the energy usage for both liquid and solid materials will be identified. In some cases, the process that involves liquid placement will identify the use of a certain stationary crane as being the method with the least energy required for placement, while to place solid material a different crane will be identified. In such case, this module will identify the crane suitable to place both solid and liquid materials. The assessment of energy for liquid and solid materials will be repeated through the selection of such crane. Should both cranes identified in the liquid and solid energy assessment deem suitable to place all materials, the assessment of energy is repeated for both liquid and solid materials through each selected crane. The module will identify to users the crane that minimizes the energy if used for both liquid and solid placement. The goal of this module is based on practicality. It is difficult to change stationary cranes just to place concrete and then to place solid materials through the construction cycle of a building.

3.8.1 Mobile Concrete Pump Placement EE Calculation Module

The goal of the mobile concrete pump placement EE calculation module is to identify the amount of energy required to place concrete for a building using mobile concrete pumps. To carry out such a process, the module will initially connect to the mobile concrete pump database and attain all available mobile pumps. Furthermore, the module will attain the building geometry. Accordingly, the module will then identify the locations to place the pump to pump concrete to a specific building. When casting concrete, the pump may be placed at corner points of a building as to cover the maximum span. As for the module, an additional distance buffer of 5 meters will be added to each identified point. For the module, this is the minimum acceptable placement location for the pump. According to OSHA (2019) and YMCHSB (2019), the minimum safety distance required for concrete pump placement is 3 meters from any obstruction and in such regard, to allow additional distance for concrete mixers to navigate, an additional 2 meters has been added. Once the pumping locations are identified, the module will assess the ability of pump booms to cover the site layout from the identified pumping locations. By comparing the boom length of each crane to half the perimeter length of the largest side of the building, the cranes with boom lengths greater than half the perimeter length in addition to the buffer distance, are selected. The module will select the successful pumps. Next, the module will calculate the fuel used for each eligible pump for all concrete placement by using the following equation:

$$Total\ Fuel\ Consumption\ (Ltrs) = Unit\ Fuel\ Usage\ _{Pump} * Volume\ _{Concrete}\ \text{-} \qquad \textbf{\textit{Equation 3-7}}$$

The fuel usage per m^3 for each pump is attained from the mobile concrete pump database. Once the fuel usage for every eligible pump is calculated, the EE for each pump required to place all concrete is calculated by using the following equation:

$$EE_{TRUCK} = Fuel\ consumption * 3.8290344 \qquad \textbf{\textit{Equation 3-8}}$$

Those values have been calculated according to the USEPA lifecycle database conversion values (NREL, 2019). Once all EE for all eligible pumps are computed, the module will identify the pump with the least energy consumption and present it users. In some instances, the pump boom is able to cover all the horizontal distances of lower floors, but not in the upper floors. As the building begins to rise, additional vertical distance is required by the pump boom to reach the same concrete locations as for the lower floors. For such cases, the module will perform a floor-by-floor analysis for the concrete items to determine if the selected pumps can reach their location. If those are not able to reach the upper floors but can occupy lower ones, the unattainable materials will be lifted with the aid of and a crane bucket or a stationary pump mounted on the building site to complete the casting process. Such materials are indicated to users.

3.8.2 Concrete Bucket Material EE Calculation Module

The same concrete materials will be assessed to determine the required energy to place concrete based on the use of concrete buckets. To place concrete materials using concrete buckets, cranes are required. In the concrete bucket material EE calculation module, the module will primarily require information from two databases. These include the stationary crane database and the concrete bucket database. From the stationary crane database, all available cranes are retrieved including their boom lengths, maximum tip carrying capacities, and trolley and hoist speed during operation. From the concrete bucket database, different buckets are retrieved including their weight and carrying capacities.

Initially, the module will require the proposed crane location. The module will assist users by proposing a list of possible locations for the crane placement. The module assists the user in selecting options based on the site logistics plan. The positions have been identified based on the study performed by Zahra et al. (2017). According to Younis et al. (2018), cranes must be placed in locations that aid in covering the whole building area and also aid in minimizing potential collision areas. Specifically, the cranes can be placed at positions with a space buffer of eight meters from the corner points. According to OSHA (2019), the minimum distance the crane needs to be away from an obstruction is three (3) meters. Since the concrete pump will be placed five meters away from the building corner points, adding an additional three meters will place the crane at a distance of 8 meters from the building. After the suitable crane's location is selected, the module will propose the most suitable bucket for concrete casting; this is the biggest bucket from the concrete bucket database as it will minimize the number of trips required to cast a certain element on site and nevertheless will minimize the EE. Next, the module will determine the eligible cranes to cast all concrete elements on site. For each crane, the module will determine if the boom length is sufficient to reach all the concrete locations from the specified crane's location. Furthermore, the module will determine if the weight of a fully loaded bucket is less than the maximum weight that each crane can carry at its tip. For cranes, the maximum payload will differ based on the location of the carried weight. The least weight payload is at its tip, and hence this tip's weight payload will be considered for comparison. Once the eligible cranes are identified, the model will determine the number of trips required by the selected crane and the required bucket to cast every element on site. This is done by using the following equation:

$$Number_{Trips} = \frac{Total_{Volume}}{Concrete\ Bucket\ Volume} \qquad \textbf{\textit{Equation 3-9}}$$

After the number of trips is computed, the EE of each suitable crane required to cast all materials will be calculated. To calculate EE, the amount of electricity each crane requires should be known. The electrical usage for cranes is calculated based on time and power. Distance and speed are required to calculate the time the crane requires to reach a material from its specified station (concrete pump station). Cranes have three movement variations. Those include vertical movement (hoist movement); boom rotation movement; and the horizontal movement (trolley movement).The distance of movement for each component should be determined while the movement speed of each component for each suitable crane will be retrieved from the stationary crane database in order to calculate the energy. Once this is attained, the distance of each movement will be divided by the speed required for each specific function in order to compute the total time. To calculate electricity, the crane database, which contains information about the power usage per hour will be used. Since time will be computed, the module will calculate the power usage for each material based on the usage time of each component. Once the total power is calculated, the EE will be calculated by using the following equation, which is taken from the electricity to energy conversion factors identified by the EPA lifecycle database:

$$EE_{Crane} = Total\ Electrical\ Power\ * 3.59985 \qquad \textbf{\textit{Equation 3-10}}$$

Finally, once all EE's are calculated for each eligible tower crane and bucket, the module will identify the crane with the least energy consumption and propose it to the user.

To calculate the power required for each crane for each concrete material, three power consumptions are required. Those include the power required by the hoist; the trolley; and the boom. The movement of each component will be calculated to determine the power required to move materials upwards by the hoist, horizontally by the trolley and rotationally through the boom. Initially, the module requires three distances, those are the distance from the concrete collection station to the tower crane (Distance B); the distance between the tower crane and the material (Distance A); and the distance between the material and the pumping station (Distance C). Figure 3-5 displays the distances in a typical site layout plan.

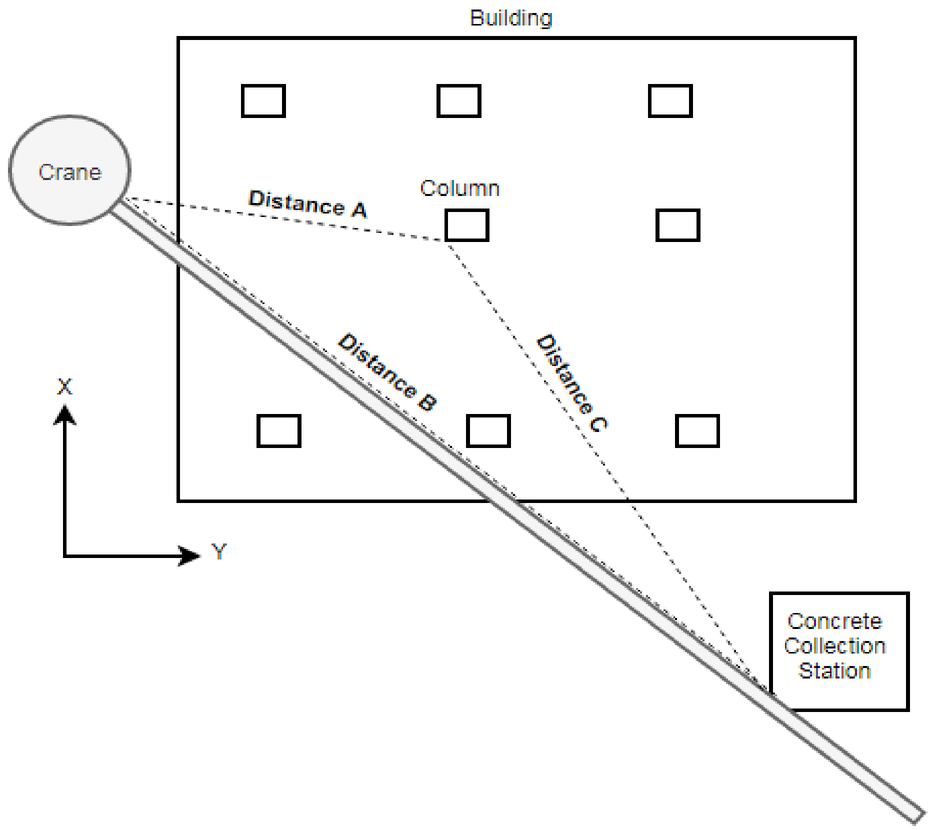


Figure 3-5: Distance Representation for Concrete Bucket EE Calculation Module

The coordinates of each of the crane location; the concrete collection station, and the place where the concrete will be located are inputted into the model. The model obtains the location of design elements from the design model, while the location of the crane and the concrete collection station are selected by the user. The selections are selected based on the suggested locations presented by the model. These are based on the rules established for the suitable location of the concrete collection station and the crane. Since the position of the crane, the concrete collection station and the column will be selected and is identified in the x and y plane, the distances A, B, and C, can be calculated by finding the distance between 2 points. For distance A, the distance between the crane location and the location of an element in the design can be found using the equation:

$$\sqrt{(X_2 - X_1)^2 + \ (Y_2 - Y_1)^2} \qquad \textbf{\textit{Equation 3-11}}$$

Where (X_1, Y_1) are the coordinates for the first point and (X_2, Y_2) is the coordinate of the second point. This equation is used because the coordinates of the two points are known by the model. The same formula can be used for distance B and distance C. In equation 3-11, X values represent the horizontal position of the endpoints with reference to the origin coordinate in the design, while Y values represent the vertical position of the endpoint in the two-dimensional plane. To determine distance A, the module will use the coordinates for the crane location and the intended location in which concrete will be placed. For distance B, the module will use the coordinates for the crane location and the concrete collection station. For distance C, the module will use the coordinates for the concrete collection station and the intended location for concrete placement. Accordingly, the module will calculate distances A, B, and C.

When all distances are computed, the module needs to determine the swing required for the crane to move from the storage to the material. This can be donated as angle (F) This will allow the module to determine the time required for swing movements. This will be computed using the following equation.

$$Cos^{-1}\frac{(-C^2+B^2+A^2)}{2AB}$$ ***Equation 3-12***

Next, the module will determine the swing distance (Distance J) for each material from the storage by using the following equation:

$$Distance\ A * F^0(Radians)$$ ***Equation 3-13***

Once this is completed, the module will determine the trolley distance for each material between the collection location to its intended placement. This is done by using the following equation:

$$Abs\ [\,Distance\ A - Distance\ B]$$ ***Equation 3-14***

Next, the vertical distance each material will need to move from the storage location to its intended location will be computed. This is done using the following equation:

$$Abs\ [\,Coordinate\ Z2 - Coordinate\ Z1]$$ ***Equation 3-15***

Z1 and Z2 values represent the vertical coordinate in which the material is located and the vertical coordinate of the location in which the material needs to be placed. The distance between the coordinates will be denoted as Distance K. Figure 3-6 denotes the distance in an illustrative diagram.

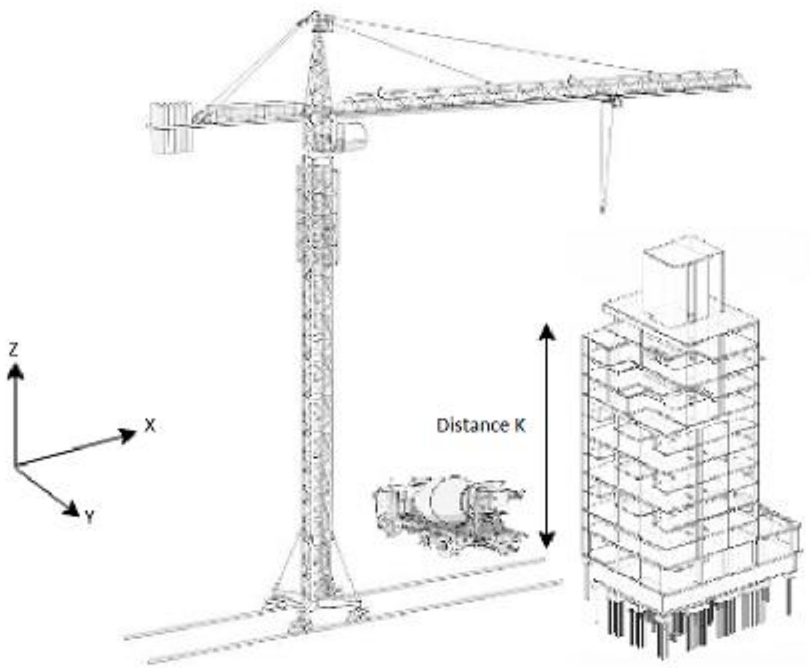


Figure 3-6: Vertical Distance Representation for Concrete Bucket EE Calculation Module (Wilson,2020; Photos, S., & Machinery, C.,2020).

the time required to lift each concrete bucket from the collection point to the material's intended location (time T1). This is done by using the following equation:

$$\frac{Distance\ K)}{Hoist\ Speed_{Crane\ Inventory}} \quad \textbf{Equation 3-16}$$

Next, the module will calculate the time for trolley movement for each material (time T2). This is done by using the following equation:

$$\frac{Distance\ H}{Trolley\ Speed_{Crane\ Inventory}} \quad \textbf{Equation 3-17}$$

Subsequently, the time for swing movement for each material (time T3) is calculated by using the following equation:

$$\frac{Distance\ J}{(3.14 * Crane\ RPM_{From\ Inventory} * (\ Boom\ Length_{Crane})^2} \quad \textbf{Equation 3-18}$$

Next, the module will determine the power consumption of the hoist, trolley, and crane swing movement by using their wattage multiplied by the times t1, t2, and t3. The wattage in Kilowatts will be extracted from the stationary pump database for each component of each crane. Once all power consumptions are identified, the module will calculate the EE for each crane by multiplying the total power usage by a conversion factor of 3.59985, and the number of trips required by each material based on the volume of the bucket. The total energy for each crane will be calculated in MJ. Similar procedure is repeated for the suitable cranes and the module will identify the crane the least energy consumption.

3.8.3 Stationary Pump EE Calculation Module

In the stationary pump EE module, the amount of energy required to place the concrete by using mounted or tower pumps will be calculated. To calculate the least energy required to place concrete by using stationary pumps, the module will need to consider two machines. Those are stationary concrete pumps and pumping machines that lift concrete from the pumping station to their indented locations. In this module, multiple stationary pumps and pumping machines are assessed to determine the EE required to place concrete by using a combination of such machines. Initially, the module will identify locations in which stationary pumps can be placed. Based on the selected locations, the module will compare the boom lengths of multiple pumps to the covered area and determine the suitable pumping machines based on the building's height. Knowing the suitable machines, the energy required to place all the concrete items will be identified. To extract information about machines, the module will connect to both the stationary pump inventory and the stationary pumping machine inventory. From the machine pump inventory, the module will extract information about different stationary pumps along with their manufacturer, model, type, power usage in kwh, maximum pressure they can handle, and the flow rate per hour. From the stationary concrete pump inventory, the different pumps' information is extracted along with their boom lengths, model types, and power usage in kwh.

To calculate the EE required to place concrete by using stationary pumps, the module will initially require the number of pumps required to cover the site. To do so, the module will begin by extracting the length of the pump with the least boom from the stationary concrete pump database. The module will then multiply the boom length by π to determine the area covered by the selected pump. Where π is equal to 3.1416. To determine the number of pumps required to cover the site, the total horizontal area will be divided by the area the selected pump can cover. Once completed, the module will identify to users the locations in which to place stationary pumps can be placed. This is based by equidistantly identifying coordinates in which pumps can be placed. In some cases, the suggested locations will have obstructions within the structural model. For example, slabs with no structural openings will be present and hence the suggested location will not be applicable. To solve this issue, users will be given the option to change locations. Once the module obtains the new locations, the module will check if the placement of stationary pumps in the new locations will be enough to cover the site. Should the locations deem insufficient, the user is notified of the need to change the locations. The module will also allow the user to add additional pumps in order to cover the areas that the pumps cannot reach from the selected locations.

Once all the information is entered by users and the module has verified the eligibility of the users' input, the module will run analysis to determine the stationary pumps and machines from the databases that can be used to place concrete based on height requirements. Placing concrete using stationary pumps will require machines with specific pressure requirements.

As the number of floors in a building increase, the pressure required to pump concrete will also increase. The module will initially determine pumps and machines capable to satisfying the pressure requirements. The module will determine the maximum pressure required for placing concrete in a building using the pressure chart created by Viraj et al, 2014. Figure 3-7 display the chart created by Viraj et al, 2014 in which the pressure required to pump concrete at specific heights is summarized. Initially, the module will identify the highest elevation of all concrete materials. According to the height, the required pressure is attained from the pressure chart. Subsequently, the module will identify pumps and machines that have the capability providing the flow pressure to place all concrete items. Once all eligible stationary pumps and machines are identified, the module will calculate the amount of electricity each pump and each machine require. This is done by first determining the total volume of concrete materials and then determining the amount of time required to pump all concrete based on different pump and machine combinations. From the databases, the maximum flow rate per hour for each pump and pumping machine will be determined. Since the rate per hour is attained, the total time for pumping concrete is determined by dividing the flowrate by the total concrete volume.

Once completed, the total power consumption will be calculated by multiplying the amount of kilowatt hour by the total time for each pump and pumping machine. The summation of the power required by eligible pumps and machines required to cast all concrete elements will be determined. Accordingly, once all power consumptions are identified, the module will calculate the EE by multiplying the total power usage with a conversion factor of 3.59985. After all EE is calculated for each eligible pump and machine combined the least EE pump and machine will be determined.

Height In meter	Distance In Meter									
	10	20	30	40	50	60	70	80	90	100
	Pressure In bar									
10	54	54.6	55.2	55.8	56.4	57	57.6	58.2	58.8	59.4
20	57	57.6	58.2	58.8	59.4	60	60.6	61.2	61.8	62.4
30	60	60.6	61.2	61.8	62.4	63	63.6	64.2	64.8	65.4
40	63	63.6	64.2	64.8	65.4	66	66.6	67.2	67.8	68.4
50	66	66.6	67.2	67.8	68.4	69	69.6	70.2	70.8	71.4
60	69	69.6	70.2	70.8	71.4	72	72.6	73.2	73.8	74.4
70	72	72.6	73.2	73.8	74.4	75	75.6	76.2	76.8	77.4
80	75	75.6	76.2	76.8	77.4	78	78.6	79.2	79.8	80.4
90	78	78.6	79.2	79.8	80.4	81	81.6	82.2	82.8	83.4
100	81	81.6	82.2	82.8	83.4	84	84.6	85.2	85.8	86.4
110	84	84.6	85.2	85.8	86.4	87	87.6	88.2	88.8	89.4
120	87	87.6	88.2	88.8	89.4	90	90.6	91.2	91.8	92.4
130	90	90.6	91.2	91.8	92.4	93	93.6	94.2	94.8	95.4
140	93	93.6	94.2	94.8	95.4	96	96.6	97.2	97.8	98.4
150	96	96.6	97.2	97.8	98.4	99	99.6	100.2	100.8	101.4
160	99	99.6	100.2	100.8	101.4	102	102.6	103.2	103.8	104.4
170	102	102.6	103.2	103.8	104.4	105	105.6	106.2	106.8	107.4
180	105	105.6	106.2	106.8	107.4	108	108.6	109.2	109.8	110.4
190	108	108.6	109.2	109.8	110.4	111	111.6	112.2	112.8	113.4
200	111	111.6	112.2	112.8	113.4	114	114.6	115.2	115.8	116.4

Figure 3-7: Pressure Required to Pump Concrete based on height (Viraj et al, 2014)

3.8.4 Mobile Pump and Concrete Stationary Pump EE Calculation Module

As indicated in the Mobile Pump EE placement calculation module, mobile pumps have limitations in terms of height. Concrete elements in tall buildings cannot be casted by using mobile cranes, and hence a supportive method is required. In the mobile crane EE calculation module, all materials that are casted by using mobile pumps are calculated. The remaining materials will be grouped to be later assessed. In this module, the energy required to place materials in their intended locations will be calculated for cases where mobile pumps cannot be completely used for all materials. Two processes are involved. In this module, the initial EE is reached from the mobile pump EE module for materials that can be casted using mobile pumps. The remaining materials will be processed using the concrete bucket EE module. The same process is applied to unattainable materials in the concrete bucket EE module. The same crane is used, and the remaining materials are assessed based on the processing rules established in the concrete bucket EE calculation module. Once this is complete, the summation of energy in mega joules for both the mobile pump and concrete bucket will be calculated to determine the EE from both stages. This process is performed only for cases where the concrete pump is not able to completely reach all items within the building boundary.

3.8.5 Mobile Pump and Concrete Bucket EE Calculation Module

As indicated in the Mobile crane EE calculation module, mobile pumps have height reach limitations. Stationary pumps are used an alternative to the process where the use of both mobile pumps and concrete buckets, in the mobile pump and concrete bucket EE calculation module. For the materials where, mobile pumps cannot completely cast all the required elements, the combination of mobile pump and stationary pump is a suitable alternative. In this module, the energy required to cast elements by using both mobile and stationary pumps will be calculated. The EE required to cast materials by using mobile cranes will be attained from the mobile pump EE calculation module. As for materials that cannot be casted by using mobile pumps, they will be grouped and sent to the stationary pump EE module for processing. In the stationary pump EE calculation module, the materials will be assessed by applying the same identified rules in the module by using the same stationary pump determined to be the machine that has the least EE consumption. The stationary pump has already been optimized to find the least embodied energy. As indicated in the mobile pump and concrete bucket stage, this module is only processed when the mobile concrete pump is inadequate and cannot reach all the concrete elements within a building site.

3.8.6 Liquid Placement EE Comparison Module

Once all the processes of calculating liquid EE placement are completed, the module will compare the different processes to determine the method with the least EE consumption. These include comparing EE placement by using concrete mobile pump, placement using concrete bucket attached to cranes, placement using stationary concrete pump and, if required, placement using mobile pump and stationary pumps, and placement using mobile cranes and concrete buckets. The module will provide users with the least EE process for placing concrete and hence the optimized energy required to place concrete for a proposed building during its design.

3.8.7 Solid Material Placement EE Calculation Module

To calculate EE for solid material placement, a singular module will be created. This is the solid placement using stationary cranes. In this module, the amount of energy required to transport materials from the storage or offloading location to the material's intended location by using cranes will be calculated. Cranes use energy in the form of electricity, for three main actions. Those are vertical movement using the hoist; the rotational movement required by the crane; and horizontal movement required by the trolley to move the material from storage to its intended location. Each movement has a motor function that uses energy based on the distance, and thus the module will identify such distances to calculate EE. All this information will be extracted from the stationary crane database. Moreover, the rate of rotation required for a crane to complete a full 360-degree turn will be extracted from the database. This will aid in determining the energy consumed during the rotational movements. Unlike concrete placement by using buckets, solid materials cannot be split, and hence this module will not have a multiple number of trips required for each material's transportation. For each material, a singular trip is required for solid material placement. Initially, the module will collect information about the materials that are classified as solid. Mainly, these are materials that have been transported using trucks and haulers. Once completed, the module will determine the maximum weight that needs to be carried along with the maximum horizontal distance between the stored materials and the identified crane location. The maximum weight required is the weight of the heaviest singular solid item. The module will then extract the information for all cranes that are stored in the stationary crane database and will then compare them with the weight and boom length requirements. Acceptable cranes are selected. A comparison will be done for the crane boom length and the maximum tip allowable weights against the placement requirements. Next, the module will remove the materials that have weights less than 23 kilograms as these can be carried manually. Based on OSHA, this is the maximum allowable weight that can be carried by laborers on sites. This classification will aid in reducing the energy consumption. For the remaining materials, the module will calculate the electricity that each acceptable crane requires to transport the materials from their identified storage location to their indented place within the site. To start, the module will identify the locations in which cranes can be located along with the potential offloading or storage locations. The designer will select the location preference, and the module will use such information to assess the capability of each extracted crane to satisfy the weight and length criteria. In terms of location's selections, the same criteria used in the concrete placement using bucket module will be used in this module. Furthermore, the same equations will be used to calculate the electricity and EE for each eligible crane. The only difference will be in multiplying the energy required by the number of trips since it is only a singular trip for each material. Nevertheless, the concrete collection point will be identified as the storage location. Subsequently, the module will run an analysis to determine the amount of electricity each crane requires to transport all solid materials. The most energy efficient crane will then be identified. The total electrical power used by the crane to transport all required materials will be converted to an energy unit represented as Mega joules. Once completed, the module will identify the crane with the least energy consumption to place solid materials and hence the module will identify the optimized energy required to place solid materials.

3.8.8 Crane Optimization Module

In this module, the most suitable crane to minimize the energy usage for both liquid and solid materials will be identified. In some cases, the process identified in the liquid placement EE comparison module identifies the use of a certain stationary crane as being the one the most energy efficient placement method while for solid material placement another crane is identified. In such case, this module will identify the crane that can be used for both solid and liquid material to minimize the energy usage. Initially the crane that is suitable to place both liquid and solid materials needs to be identified. Subsequently, the assessment of energy for liquid and solid materials placement assessment modules is repeated to select such a crane then the one with the least energy consumption will be selected. Figure 3-8 illustrates the processing steps of the module. Initially, the module will identify whether the liquid placement EE comparison module proposes the use of a stationary crane. If cranes are not required for liquid placement, the processing of this module is not required. While, if the liquid placement EE comparison module suggests the use of a stationary crane, the crane optimization module will be required. Initially, the module will identify if the crane selected to minimize energy usage in the solid material placement module is suitable to place liquid materials. If it is, the concrete bucket material EE calculation module, and the mobile pump and concrete bucket EE calculation module (if required) needs to be reassessed by using the newly identified crane. Subsequently the liquid placement EE comparison module needs to be reassessed to determine the least energy consumption process based on the crane selections. Next the module will assess if the crane suggested by the old output from the liquid placement EE comparison module is suitable to place solid materials. If deemed acceptable, the module will reassess the energy required to place solid materials through the solid material placement EE calculation module by using the identified crane. The module will tally the EE required to place both solid and liquid materials through the different scenarios and then it will assist users in determining the crane that can be used solely for the construction process in which the least placement energy is required. The goal of this module is based on practicality, and hence a single crane selection for the whole construction process is required.

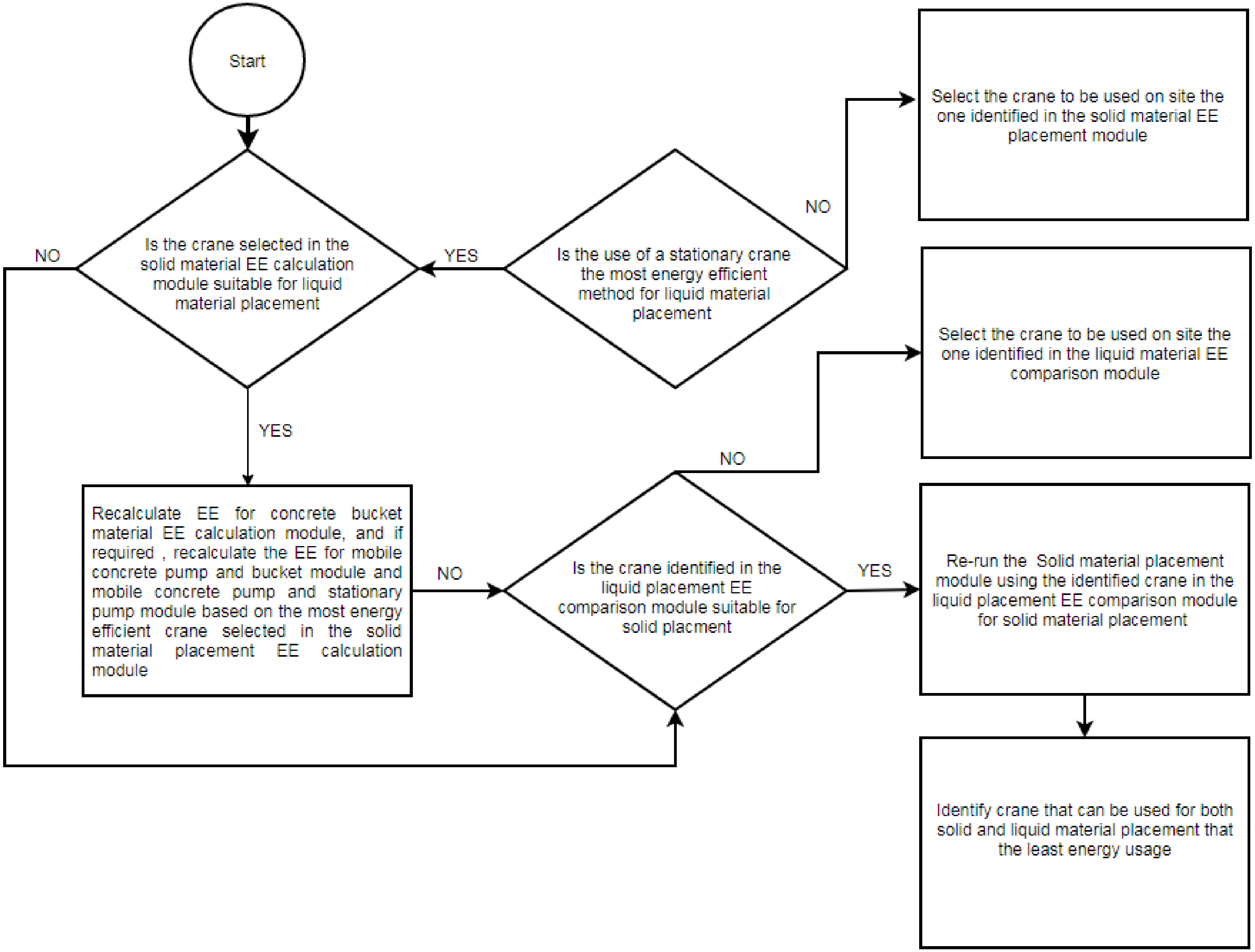


Figure 3-8: Optimization Module Flowchart

3.9 Manufacturing EC & Carbon Costs Calculation Module

The goal of the manufacturing EC and carbon calculation module is to calculate the carbonic emissions along with the associated carbon costs that are produced from the process required to manufacture the materials used during the conceptual building design. To quantify the cradle to gate ECs and cost for materials, a singular module is required. This is the manufacturing EC and carbon cost calculation module. In the Manufacturing EE calculation module, EE for all manufacturing processes have been calculated and the production processes have been identified. As established from the literature presented in this paper, EE and EC are two interrelated sustainability assessment factors that may be used side-by-side to measure the environmental footprint of materials. These factors present a direct relationship in which if one increases, so does the other. Since, EE have been optimized to achieve the least attainable values based on the machine and equipment's usages in the Manufacturing EE Calculation Module, the same resources will also yield the least carbonic production. To calculate the EC produced, the module will obtain the amount of carbon produced from the production of a single unit of material using the factory production process selected from the manufacturing EE calculation module from the cradle to gate carbon emission database. Moreover, the volume and weight of each material is obtained from the Manufacturing EE Calculation Module. Using the equation one can calculate the EC:

$$Total\ EC = EC_{PER\ UNIT\ WEIGHT}\ x\ Total\ Volume_{materials} \qquad \textbf{\textit{Equation 3-19}}$$

The total carbon produced by each material is identified. A summation of all the ECs produced from the materials will yield the total carbon produced in tons. To calculate the total carbon environmental implication costs the following equation will be used.

$$Total\ EC\ Cost_{Manufacturing} =$$

$$Unit\ Cost_{Carbon\ per\ ton}\ x\ Total\ Unit\ Weight\ _{EC\ produced} \qquad \textbf{Equation 3-20}$$

The unit cost of carbon per ton is obtained from the data publicly available for the social carbon costs issued by the Canadian Federal Public Published Data for the year of 2019. This value varies every year. Therefore, the module will be designed to accept different values depending on the year in which the project's construction will occur. The module system architecture is shown in Figure 3-9.

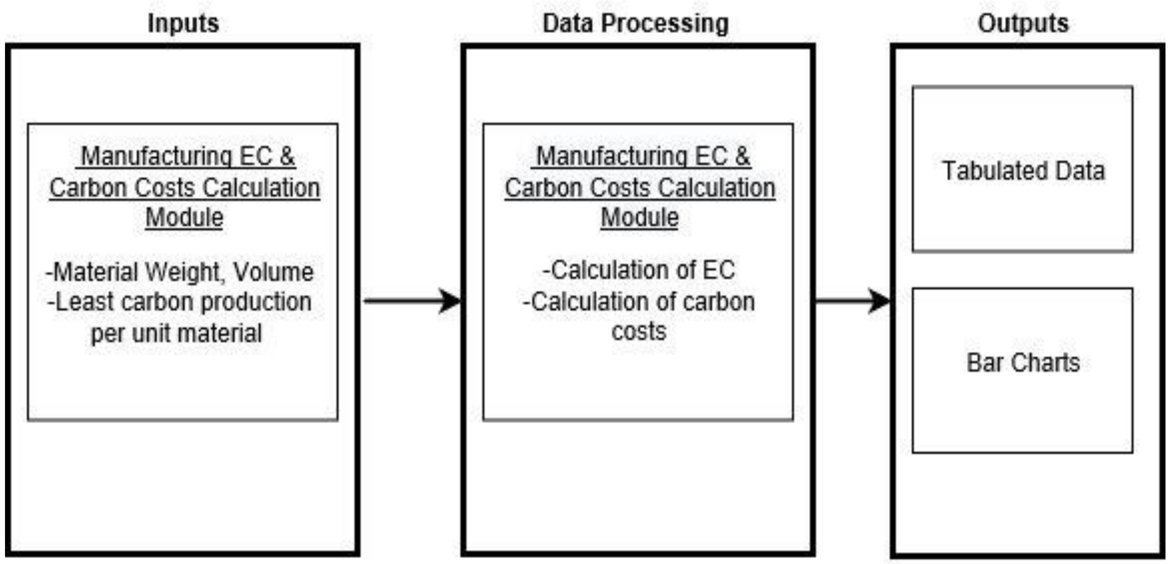


Figure 3-9: Manufacturing EC & Carbon Costs Calculation Module Architecture

3.10 Transportation EC & Carbon Costs Calculation Module

The goal of the transportation EC and carbon calculation module is to calculate carbonic emissions along with the associated carbon costs produced from the process required to transport materials used in designing the building at the conceptual stage. These will be based on fuel usage. Materials can be classified as solid or liquid. For the liquid materials, concrete mixers will be used. For the solid materials, trucks or haulers will be used. In the transportation EE calculation module, the most energy efficient vehicle required to transport each material will be identified. Using the vehicles that are suitable for each material, the energy consumed by each vehicle will determine the carbonic production each vehicle will produce when transporting each material. To calculate EC for transportation, the amount of carbon dioxide produced from using one unit of fuel is required. In a study performed by UK's Department for Environment, Food and Rural Affairs Environment, a thorough analysis was carried out to establish the equivalent amount of carbon dioxide produced while consuming fuel per kilometer. Although the amount of carbon produced is based on study parameters performed in the United Kingdom, the amount of carbon produced from the fuel usage can be used as to identify the carbon produced fuel used by vehicles in Canada. (Tgagtakis et.al ,2019), (Transport Canada, 2019). This is because the engines used in vehicles in the United Kingdom are identical vehicle engines used in the Canadian construction industry. The difference lays in the fuel required for heating. Since the module will calculate CO2 based on fuel usage, the heating will be accounted by calculating the amount of fuel each vehicle will use. The amount of fuel required takes into account the climate control requirements in transportation vehicles.

From the values obtained by the UK's Department for Environment, Food and Rural Affairs Environment, the average use of diesel will yield 0.1979 kg CO2 per kilometer. In an effort to calculate EC production and costs of material used in a certain building, the module will revert back to the transportation EE calculation module. The module will extract the least EE consuming vehicles required for transportation and the transportation distances for each material. Once established, the module will use the following equation to identify the carbon emissions produced by each material used within a building (Carbon trust, 2019).

$$Embodied\ Carbon\ Produced_{per\ vehicle} =$$

$$Total\ Distance_{travelled\ in\ KM}\ \ x\ 0.1979\ Kg\ C0_2\ per\ KM \qquad \textbf{\textit{Equation 3-21}}$$

When the carbonic emissions produced by each machine is computed, a summation of all those values will yield the total embodied carbon produced. To identify the social carbon cost produced, the equation 3-20 will be used to identify embodied carbon costs for transporting materials.

3.11 Placement EC & Carbon Costs Calculation Module

The goal of the placement EC and carbon cost calculation module is to calculate carbonic emissions along with the associated carbon costs produced from the process required to place materials used in the design of a building. Those will be based on fuel or electricity usage. The optimal machines for each type of material placement will be identified in the placement EE calculation module, and hence the same machines will be used for embodied carbon analysis.

Placing materials will require the use of machines that either use fuel or electricity. For example, mobile pumps will use fuel, but cranes will require electricity. In order to calculate the CO_2 production per machine, this module will identify the machines selected from the previous modules in which EE is calculated for placement and accordingly the module will calculate the CO_2 produced by each machine's fuel or electricity usage.

With regards to the calculation of carbon produced from electricity usage, a thorough analysis has been performed by Tgagtakis et.al, (2019) to identify the values for CO_2 produced from the use of electricity from the grid in the United Kingdom. Such values will be used to compute CO_2 production based on the machine electrical usage for Canada. Such values can be used for the Canadian industry by accounting for changes in the production methodology. The

United Kingdom generates 28% of its electricity through renewable and clean energy resources, while Canada generates about 60% through renewable resources (Natural Resources Canada, 2019), (Natural Statistics UK, 2019). To calculate the amount of carbon produced from electricity generation in Canada, a reduction factor equivalent to 32 % will be used to account for the lower carbonic production from electricity generation in Canada. Clean energy resources produce no carbonic emissions; therefore, those will be removed from the analysis. The value of CO_2 produced per KWH in the UK is 0.537 kg CO_2. For the module, a value equivalent to 0.365 kg CO_2 per KWH will be used to calculate the carbon produced per KWH used.

With regards to the calculation of carbon produced from fuel usage, a value 0.266 kg CO_2 per litre of fuel will be used. According to Tgagtakis et.al, (2019), diesel machines produce an average of 0.266 kg of carbon for every liter of fuel used. Since calculation of carbon production will be based on fuel usage, the same value can be used to equate the amount of carbon produced for machines in Canada.

To start, the module will determine the machines identified in the placement EE calculation module for each material. Once identified, the embodied carbon amount is determined by converting the fuel consumption for pumps or electricity usage for the machines into carbonic emissions in ton. Based on the optimized equipment identified in the placement EE calculation module for each material, this module will identify the energy usage. The amount of fuel or electricity each equipment has already been calculated in the previous modules. For the case of fuel usage, the following equation will be used to convert energy usage into carbon produced:

$$EC_{MACHINE} = Fuel\ usage * 0.266\ Kg\ \mathrm{C0_2} \qquad \textbf{\textit{Equation 3-22}}$$

For the electricity usage, the following equation will be used (it is used for both the stationary pump and cranes) to convert energy into carbon:

$$EC = Total\ Electricity\ Used_{in\ KWH} * 0.366Kg\ C0_2 *\ Total\ Usage\ Time_{Hours} \quad \textbf{\textit{Equation 3-23}}$$

Once all the CO_2 produced from either fuel or electricity usage is computed for all optimized machines for each material, the module will compute the total CO_2 produced during the placement stage using the following equation:

$$Total\ EC\ Cost_{PLACEMENT} = Unit\ Cost_{Carbon\ per\ ton}\ x\ Total_{\ EC\ produced} \quad \textbf{\textit{Equation 3-24}}$$

3.12 Summary

This chapter described the proposed methodology that will be applied to develop the model. The design methodology involves the creation for an integrated model that will be used for EE/EC and social carbon costs assessments. Mainly, the methodology includes six main modules. These are the Manufacturing EE (Embodied Energy) Calculation Module; Transportation EE Calculation Module; Placement EE Estimation Module; Manufacturing EC (Embodied Carbon) & Carbon Cost Calculation Module; Transportation EC & Carbon Cost Calculation Module; and the Placement EC & Carbon Cost Calculation. All modules share a Database Management system that contains ten databases. These are the Cradle to Gate Manufacturing Database; Truck Vehicle Database; Hauler Vehicle Database; Concrete Mixer Database; Stationary Crane Database; Mobile Concrete Pump Database; Stationary Concrete Pump Database; Stationary pumping Machine Database; Concrete Bucket Database; and Cradle to Gate Carbon Emissions Database. Information from those databases feed information into each module and allow for the assessment of manufacturing, transporting and placing materials. The functions and data flow performed within each system component or module were described. In the manufacturing EE calculation module, a methodology was presented in which the EE for manufacturing materials is calculated. Furthermore, in the transportation EE calculation module, a methodology to calculate the EE required by materials to move from the origin to the construction site is identified. In Placement EE Calculation Module, a methodology to calculate the EE required to place materials in its intended location is identified. Modules are created to analyse the different solid and liquid materials. For each module, explanation of the assessment procedure required to calculate EE/EC and cost for material included in the design of a building for the cradle to end of construction boundary was detailed. This involves the use of different construction methods for each process. Overall, this chapter also identified the methodology required to calculate the EC and environmental costs of the materials by dictating the construction processes required to manufacture, transport and place materials and simultaneously reducing the environmental impacts of buildings. This chapter also explained the reasoning used to establish the calculation procedures and presents a step-by-step approach to accurately calculate EE/EC and costs.

Chapter Four

Model Development

4.1 Introduction

This chapter presents an overview of the model's development in which an atomized computerized tool is created to implement the conceptualized modelling created in the previous chapter. This chapter explains the model development and displays the forms that are used to execute the calculation explained in the methodology chapter. Nevertheless, this stage also displays the capabilities of the model by providing explanation of the inputs, processing buttons, and outputs created by the developed tool forms. This chapter begins by describing the model and then goes further to describe the steps and modules required to complete the assessment of EE/EC and costs for any BIM model. This chapter provides a step-by-step guide to develop model.

4.2 Model Development

As concluded from the literature, accurately quantifying both the embodied energy and carbon for materials used in building is rather difficult. The current process involves setting boundaries and using average per unit values for each material. The calculations are based on values obtained from databases. Again, those databases use a single average per weight/volume value for transportation, construction, operation, and disposal regardless of the distances equipment/machines used for each material. This creates errors in the calculation process. While calculating environmental costs, each material needs to be identified and then amount of carbon produced from activities such as manufacturing, transportation, and placement needs to be identified. According to the total amount of carbon produced, the total cost required to rectify the effects of the carbonic production can be calculated. To accurately calculate EE, EC, and environmental costs for a cradle to grave boundary of materials used during the designed of a structure, the model will be developed as a computerized tool that targets the Canadian construction industry. The model is associated within BIM environment. The BIM tool that will be used is Autodesk Revit, which will allow for the creation of a computerized automation tool used to execute the necessary calculations. Since BIM models contain large amounts of data for building material, this information will be extracted to prevent manual data collection when needed for the quantification of EE/EC, which would eliminate data entry needed for the EE/EC quantification. Furthermore, using BIM tool's interoperability properties will allow for reduced design time along with minimized errors. Autodesk Revit was selected due to its common usage as a 3D BIM modelling tool (Salama et al 2019).

A BIM model will be created that host a tool that will automate the process of calculating EE, EC and environmental costs. This model is imbedded into the Revit platform. In such a case, users can easily run the tool for analysis early during the design stage. Once a concept design is created into Revit, the model will allow users to assess the selected materials to determine their environmental impact early during the design stage. Users can also determine the amount of EE/EC and environmental costs for each construction material based on different boundaries. Those include cradle to gate, cradle to site, and cradle to end of construction. To accurately calculate EE/EC, the model can simulate the transportation and construction by suggesting vehicles, cranes and machines that will lead to the least environmental impact per material. Furthermore, the model will be able to exactly identify the travelled distances related to each material. Nevertheless, the distances from storage locations to the item's intended location can be identified. Since the exact electricity and fuel usages can be identified, the accuracy of the computation of EE/EC is greatly improved when compared to the currently used techniques. In cases where there are limitations to the usage of suggested machines, the user can change the vehicles, machines, and equipment based on their availabilities.

To develop the proposed model, the methodology requires the implementation of 6 main modules. These include

1. Manufacturing EE Calculation Module,
2. Transportation EE Calculation Module,
3. Placement EE Calculation Module,
4. Manufacturing EC & Carbon Costs Calculation Module,
5. Transportation EC & Carbon Costs Calculation Module, and
6. Placement EC & Carbon Costs Calculation Module

Initially, the model will extract the material properties from the BIM model. Based on the extracted material's properties, the manufacturing EE calculation module will calculate the energy required to manufacture those materials. Next, through the transportation EE module, the embodied energy required to transport the extracted materials from the production factory to the site are identified. Once complete, during the placement EE assessment stage, the embodied energy required to place the extracted materials on the site is calculated. For every modular process, the user can select the preferences that suit the available equipment. Once all EE optimization have been completed, the embodied carbon and associated costs produced from the manufacturing, transporting and placing of construction materials will be assessed.

Those will be based on optimized machines, vehicles, and equipment that are selected by users in the EE calculation modules. Through the Manufacturing EC and Carbon Costs Calculation Module, the Transportation EC and Carbon Costs Calculation Module EC and Carbon Costs Calculation Module, and the Placement EC and Carbon Costs Calculation Module, the amount of carbon and its associated costs are determined for the manufacturing, transporting and placing activities respectively.

Generally, the proposed model is developed by using a Revit API tool. With the aid of functions presented within the software development kit (SDK), a C# code is written to perform the functional analysis required to quantify EE and ECs for the building design model. Different programming languages can be used; however, C# was chosen due to its compatibility with the BIM tools. The model is created to be embedded within the Revit platform. The algorithm that performs the calculation and analysis as well presenting those to users through forms for analysis are developed in Visual studio environment. All modules' processing will occur through the algorithm, which is coded within visual studio. A file is produced in the format of *.dll, which will contain the programming code required to process the construction materials through the EE/EC and cost modules. This file is connected to Revit platform by using an addin file extension that is produced by Autodesk. Once the connection is created, users can see the developed model inside Revit as plugins. This is shown in Figure 4-1. Generally, all stages of analysis will occur by the model. These include manufacturing, transporting and placing EE/EC quantification and cost analysis. For successful operation, the model will require access to the information stored in the developed databases.

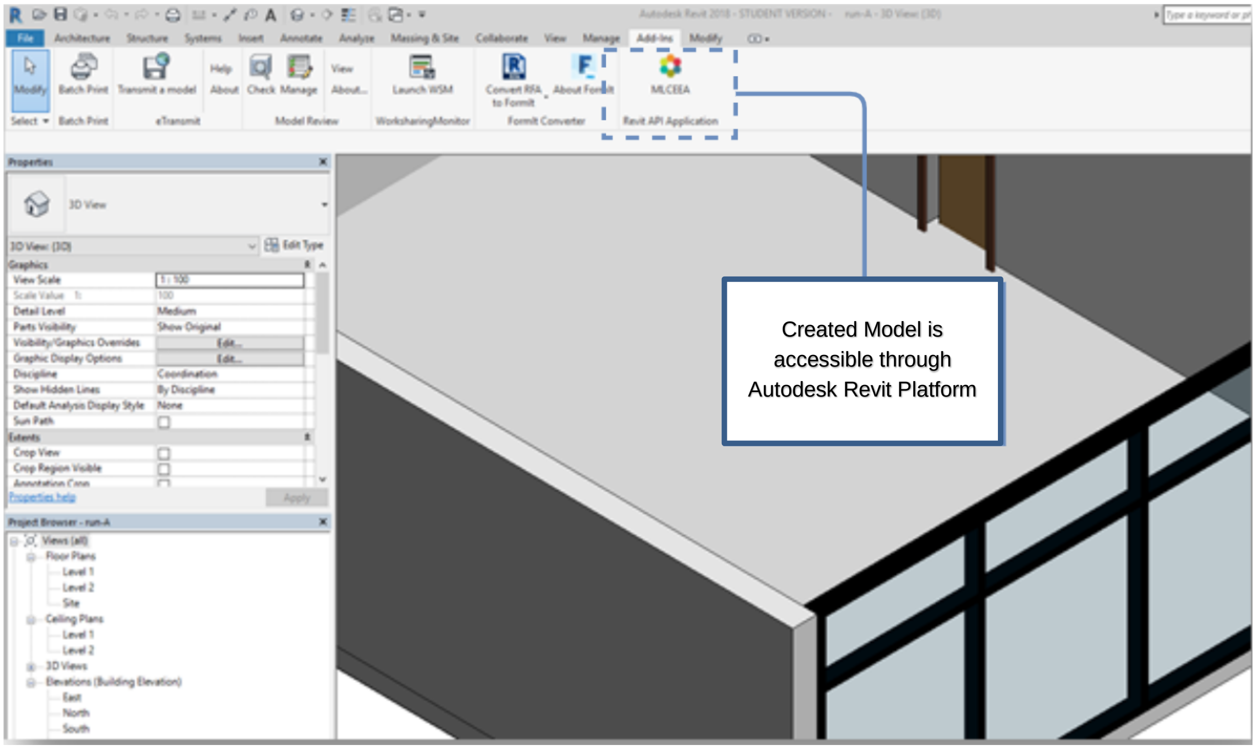


Figure 4-1: Model Accessibility within Autodesk Revit

Connections will be established by using the SQL server and SQL management studio. Through the studio's tool, databases are created within SQL management studio. Those include the different databases previously explained in chapter 3. SQL server instances are used to connect to the databases. For data retrieval, queries are created to extract the correct information from the database for the model operations. Once the SQL server is connected to model, Revit's tool will assess the information by using the created algorithm. The model will continuously connect to a file package created by Visual and SQL studio, and thus it is necessary to keep the addin file connected to the package file path. Reports and value outputs are presented within the model platform. Overall, the model has been designed to appear when an active BIM model file is opened in Revit. Overall, the model will operate over two main platforms. The main operational platform is Autodesk Revit. The second is the SQL exchange server. Data is retrieved from the databases that are stored in the SQL server where the data is processed during the model calculation stages. Furthermore, data is also extracted from BIM Models. Materials are processed through the manufacturing, transporting, and placing EE assessment stages and then processed by the Manufacturing, Transportation and placement EC and Carbon Costs modules to calculate EE/EC and costs required by materials for manufacturing, transporting and placing construction materials that are selected during the design of proposed buildings.

Information is required for each processing module depending on the type of material that has been processed. In terms of data flow for the liquid material processes, material properties are initially retrieved from the BIM design model. Moreover, the manufacturing EE calculation module will acquire information from the cradle to gate manufacturing database, while the transportation EE calculation module will acquire information from the concrete mixer database. In terms of the placement EE's calculation, information is acquired from each of the stationary crane database, pumping machine databases, stationary pump database, the mobile pump database, and the concrete bucket database. For solid materials, the data is extracted from the BIM model, the manufacturing EE module will acquire information from the cradle to gate manufacturing database, while the transportation EE module will acquire information from the truck and hauler databases. As for the placement EE assessment stages, the information is acquired from the stationary crane database. For the Manufacturing EC & Carbon Costs Calculation, Transportation EC & Carbon Costs Calculation Module, and Placement EC & Carbon Costs Calculation Modules, necessary information is attained from the cradle to gate carbon emissions database and the manufacturing, transportation, and placement EE calculation modules respectively.

4.3 Model's Overview

The computerized model is created to target the six main modules. These are the Manufacturing EE Calculation Module, the Transportation EE Calculation Module, the Placement EE Calculation Module, the Manufacturing EC & Carbon Costs Calculation Module, Transportation EC & Carbon Costs Calculation Module, and Placement EC & Carbon Costs Calculation Module. For each corresponding stage, a separate module tab is created within computerized model to perform the necessary assessments. The model is created in a sequential format in which users will have to pass through each module in order to calculate the EE, EC, and cost of construction materials selected in the design model. Each tab is processed by selecting the module by which the processing is required. Those include, Manufacturing EE Calculation Module, Transportation EE Calculation Module, Placement EE Calculation Module, Manufacturing EC & Carbon Costs Calculation Module, Transportation EC & Carbon Costs Calculation Module, Placement EC & Carbon Costs Calculation Module. Figure 4-2 displays the created tabs in the model that correspond to each modular process. Also, Figure 4-2 displays the initial starting screen for the model. The user will need to complete the manufacturing EE assessment through the data collection and manufacturing EE tab. Next, users will have to complete the transportation EE assessment stage by selecting the transportation EE tab. Furthermore, the placement EE assessment needs to be completed in the Placement EE tab. To process the EC and carbon costs calculation the EC MTP tab is used. The EC MTP tab contains the processing modules required for material manufacturing, transportation, and placement EC and the costs assessment. Finally, users need to select the reporting tab to attain a summary of the EE/EC and associated cost for all the processed modules.

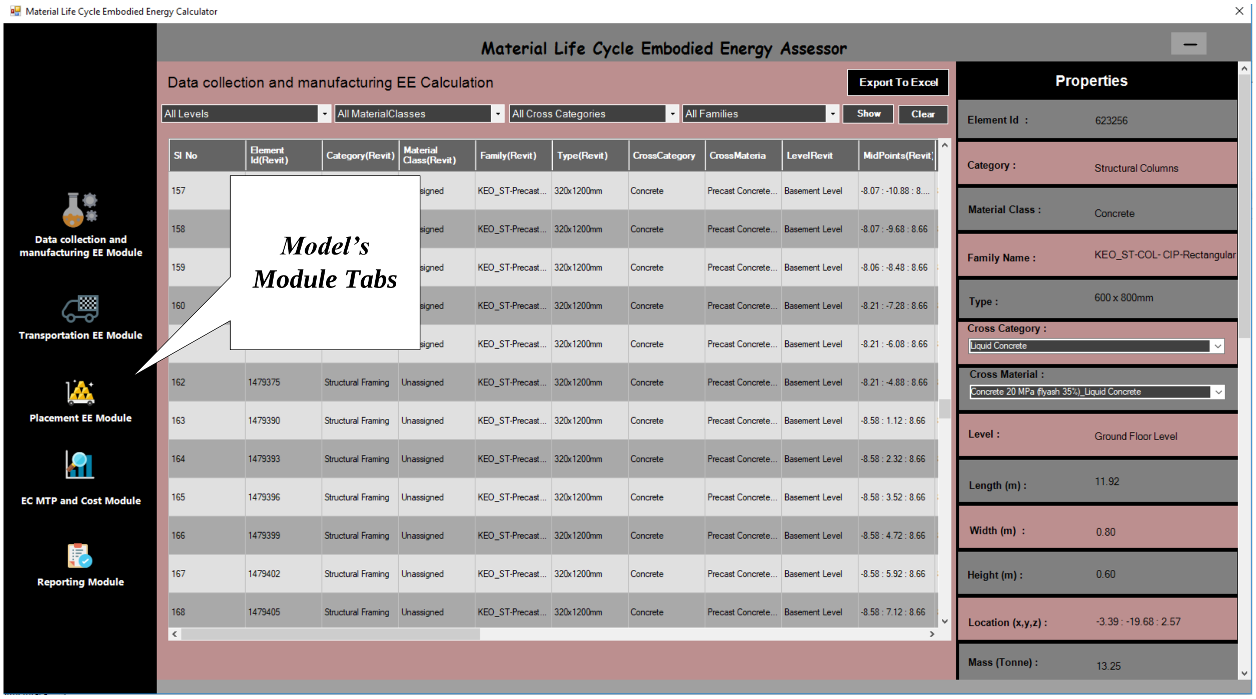


Figure 4-2: Manufacturing EE Calculation Module

4.4 Developing the Manufacturing EE Calculation Module

The manufacturing embodied energy module represents the stage in which EE for construction materials selected during the design of the BIM model are quantified for the cradle to gate boundary. To compute the manufacturing EE, the data collection and manufacturing EE module tab is created within the model. At this stage, the energy required to extract, and manufacture materials is calculated. Specifically, it is the stage in which the energy required to transport materials from the extraction location to the manufacturing facility and the energy required to manufacture the materials in that facility are also computed. To quantify cradle to gate EEs materials, each material of the BIM design model needs to be attained and linked to an entity within the cradle to gate manufacturing database. This database contains EE information for various types of materials and therefore this will allow the model to retrieve the information about the energy per weight of each material. Furthermore, the database contains information about the density of each material. Once the total weight of each material is calculated, the total EE per material is identified. From the literature review, it became apparent that the material weights cannot be directly extracted from BIM models, and therefore they need to be computed by the model. However, the BIM model contains the volume value of each material. This volume is extracted and is used to determine the mass by using the material's densities. To extract material densities, the model will retrieve this information for the material from the cradle to gate manufacturing database. This permits the determination of the mass value. Linking the materials to their corresponding items, represent a crucial part in the quantification process so that the model can retrieve the required information for processing each material. To allow the model to automate the linking process, extracted materials will be categorized. Within the model code of the model, a series of "if then" rules is used. Based on each extracted material category of each item from the BIM model, the model's tool determines the corresponding item from the cradle to gate manufacturing database. Table 4-1 represents the material's categories in BIM model that correspond to which associated item within the database which information needs to be retrieved. Those rules are established based on study presented by Venkatarama et al (2003). Those rules use a probabilistic approach to determine the commonly used items in the database that correspond to the extracted for extracted material's categories. In case users would like to use different materials to the corresponding materials identified in the model, the model allows for different material to be selected in a similar manner the as corresponding material information is extracted from the cradle to gate manufacturing database. Material categories is pre-set within the databases, and thus the model will be able to identify the category relevant to each material and identify it based on its corresponding category in the Revit model.

Table 4-1 Material's Mapping Rules

Revit Material Category	**Cross Material Item from Database**
Concrete	Concrete 20 MPa (flyash 25%) _Liquid Concrete
Unassigned	Concrete 20 MPa (fly ash 25%) _Liquid Concrete
Precast Concrete	Concrete 20 MPa (flyash 25%) _Liquid Concrete
Gas	Fiberglass Frame _Glass and Frames
Generic	Concrete 20 MPa (fly ash 25%) _Liquid Concrete
Glass	Double Glazed Hard Coated Air _Glass and Frames
Liquid	Water _Binder
Masonry	10" Concrete Block _Concrete
Metal	Rebar, Rod, Light Sections _Steel
Miscellaneous	1/2" Fire-Rated Type X Gypsum Board _Gypsum
Plastic	Polypropylene _Plastic
Stone	Marble _Natural Stone
System	Aluminum Cold Rolled Sheet _Aluminum
Wood	Cross Laminated Timber _Wood

Once all the materials have been linked, the model can calculate the total manufacturing EE for the BIM design model.

In terms of operation, the first step includes data collection. This process is performed within the manufacturing EE tab. To identify the information required by the model, the platform shown in Figure 4-3 is created. Through this platform, the model displays all the materials collected from the BIM design model. Those include all liquid and solid materials. Moreover, the model will collect information from the cradle to gate manufacturing database by identifying the corresponding materials and their category from the cradle to gate manufacturing database to the one collected from the BIM design model. This is done by using the mapping rules previously established. Once completed, the model determines the masses of the materials and the unit parameters of each material from their corresponding densities stored in the database. Each material available in the BIM design model has unique characteristics. Those include Element ID, Category, Level and Location coordinates. Such data is extracted from the model and presented to users. To allow for better display functionalities, a filter has been created to allow the users to display extracted materials-based material class, cross referenced category, family and material's position. Once all volumes and the corresponding database materials have been identified by the model, the model will calculate the total EE for each material that is part of the BIM model. This is based on the mapped rules and connections established in the data collection process. All this is done automatically by the model. The information of the data collection stage is used to calculate the manufacturing EE for each material. Overall, the same platform screen created for the data collection is also used for this stage. Figure 4-4 displays the output columns created for such calculation within the model.

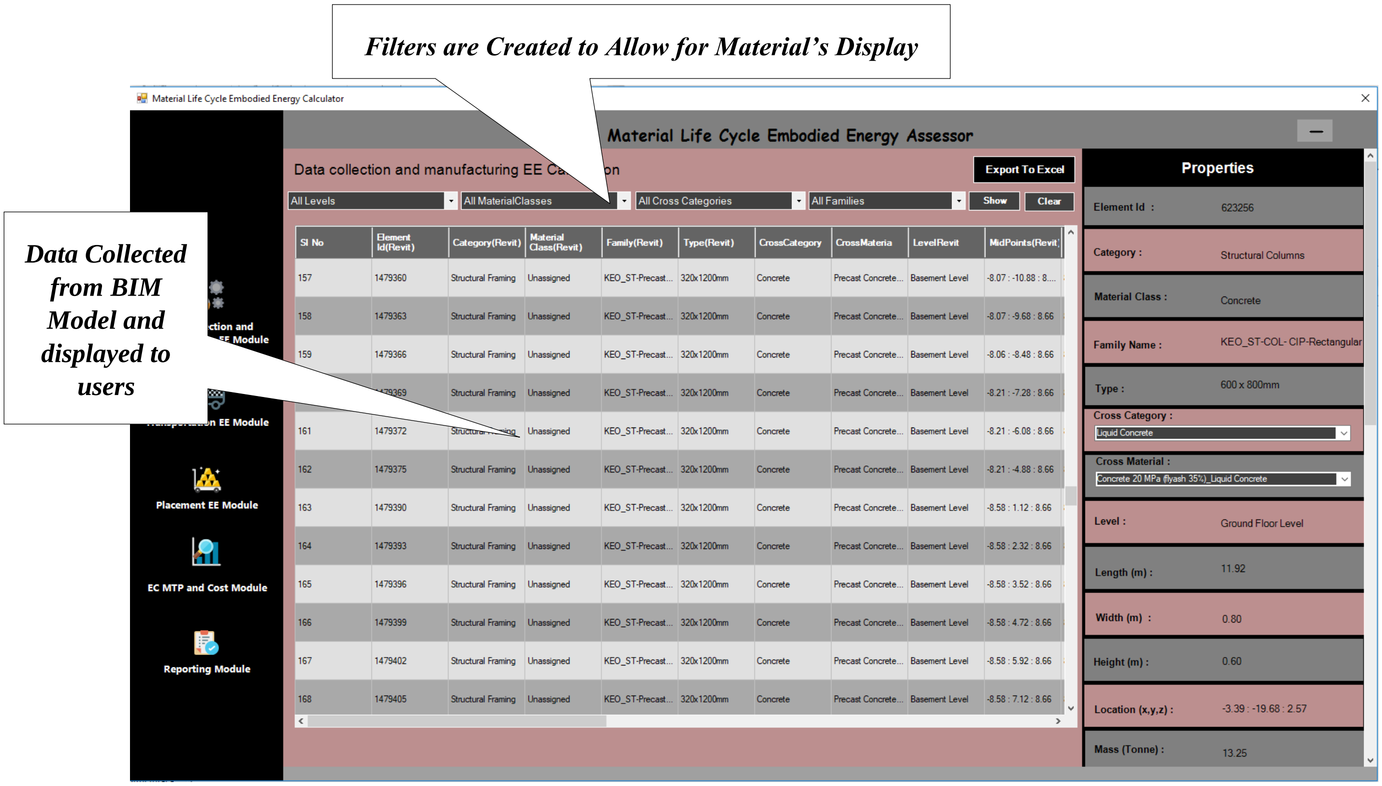


Figure 4-3: Material Manufacturing EE Assessment Form

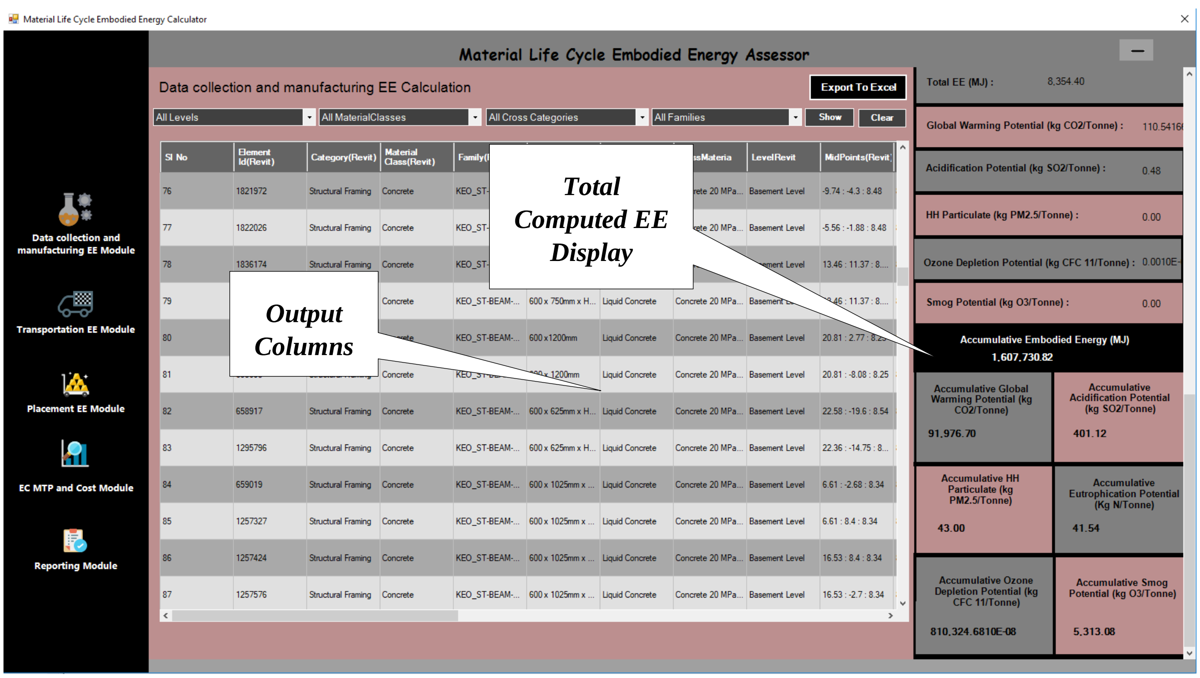


Figure 4-4 Output for Material EE Calculation Module

Additionally, at this stage the platform is designed to allow the user to change selected materials based on preferences. The drop-down menu presented on the side of the model gives the user the ability to change materials and subsequently the individual material EEs are reiterated. This is shown in Figure 4-5.

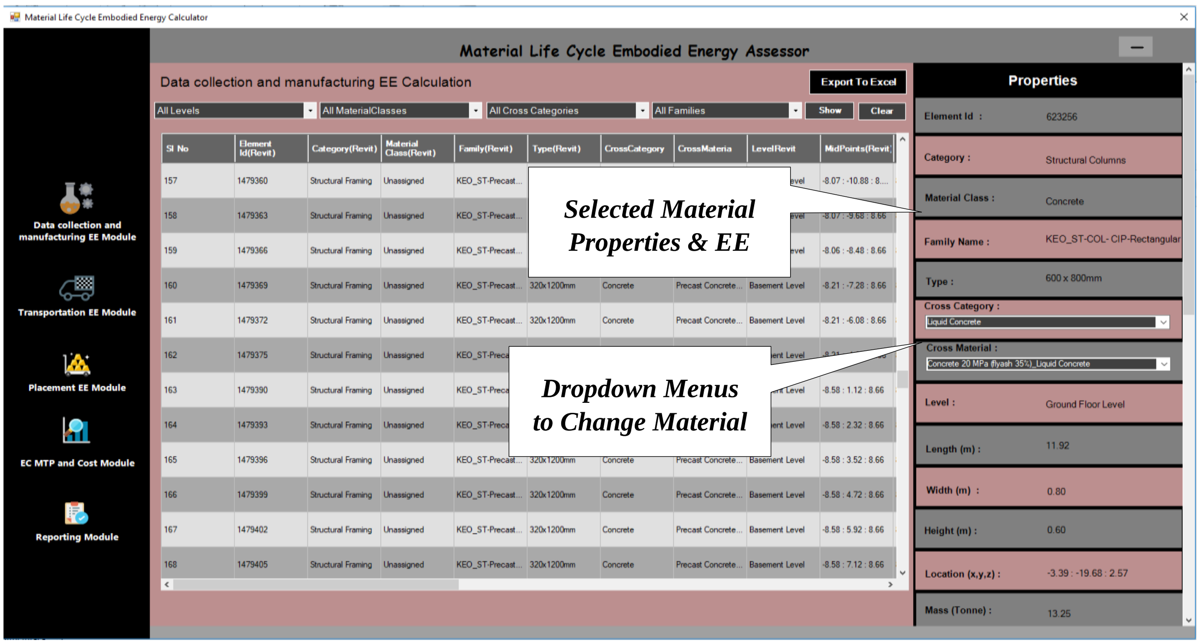


Figure 4-5 Changing Material Ability within Model through the Dropdown Menu

By selecting a material from the output list, users can select an alternative material from the drop-down menu selection list. Two drop down menus are created. In the first dropdown menu, users will need to identify the category of the material that users would like to replace. Once selected, a list of materials based on the selected category will appear. This functionality will ease the process of selecting alternative materials from the EE manufacturing database. Through such a process, users will define the materials that the model will need to display to users rather than displaying the list of materials that are stored in the database. Since the model is developed to automatically iterate changes, users can run multiple scenarios as to reduce the manufacturing EE’s values. Once users’ selections are completed, the model will display the total cumulative EE at the right-side panel presented in the model. It is worth mentioning that both solid and liquid materials are processed together at this stage. Figure 4-5 displays the output screen that is created for this module Once users are satisfied with the model results, they can move to the transportation module.

4.5 Developing the Transportation EE Calculation Module

After the energy required to manufacture materials is determined, the model will move to process the transportation embodied energy module tab. The amount of energy required to transport a material from its assembled location to the construction site is calculated in this module. To quantify the energy required for transportation, the model assigns to each material a transportation method. Based on the assigned categories, liquid materials are assigned to concrete mixers while solid materials will either be transported using trucks or haulers. Overall, the concrete mixer database contains information about the fuel usage for different concrete mixers per mile, accordingly the total fuel used to transport liquid material is identified and is used to compute the consumed energy of every suitable vehicle available in the database against the materials used. Similarly, both the truck vehicle database and hauler database contain information about fuel usage for different vehicles per mile. The total fuel used to transport every solid material is identified and is used to compute the energy for every vehicle in the database. To accurately quantify EE, the distance required for transporting a material from its assembled or created location to the construction site is automatically calculated using Google maps. The model will ask users to identify the location of the suppliers for each material’s group as well it asks for the construction location. Users may enter the locations in any form they typically use in Google Maps. Such information allows the model to exactly identify the distance between the material producer and the construction location. Applying the Google distance matrix API, the model can determine the travel distance for a matrix of origins and destinations by using a specialized URL path (Google API, 2019). Such process generates an XML file that is readable through the .NET application. At this stage, the model can automatically retrieve the travel distance for each material. Fuel for each type of transportation vehicle is calculated based on the running distance between the factory and the site, as well as and furthermore the number of trips that correspond to the capacity of the different selected vehicle.

In order to calculate the EE required for transportation, the transportation module tab needs to be selected users. Once selected, this module requires the processing of two different type of materials, which are solid and liquid materials. In order to simulate the two processes, two submodules are developed into the transportation EE module tab. Those are the liquid material transportation stage and the solid materials transportation stages. Users can simulate the processes separately by using the two created sub platform screens. Figure 4-6 displays the submodules tab created into the transportation EE module tab. Users will have to select and process each submodule in order to move to the placement EE module.

Figure 4-6: Transportation Module Material Processing Stage Selection

4.5.1 Liquid Material Transportation Submodule

To determine the transportation EE for the liquid material, a singular submodule is developed. This is the liquid transportation EE submodule. In it, the energy required to transport concrete by using concrete mixers is identified. Furthermore, the least EE required to transport concrete based on selected machines is identified. In this submodule a set of forms are created to allow users identify the locations and the materials in order to allow the model to determine the most suitable transportation method that is required for liquid transportation. First, users need to process this submodule by selecting the created liquid material EE icon as shown in Figure 4-6. Users are then prompted by the model to select the location of the construction site from the platform screen created in Figure 4-7. For the model to determine the geographical location of the site, a google map screen is presented to users to identify the coordinates. Users can either select the construction location manually or they can use the keyword option in the model. This location is used by all the modules as being the site location.

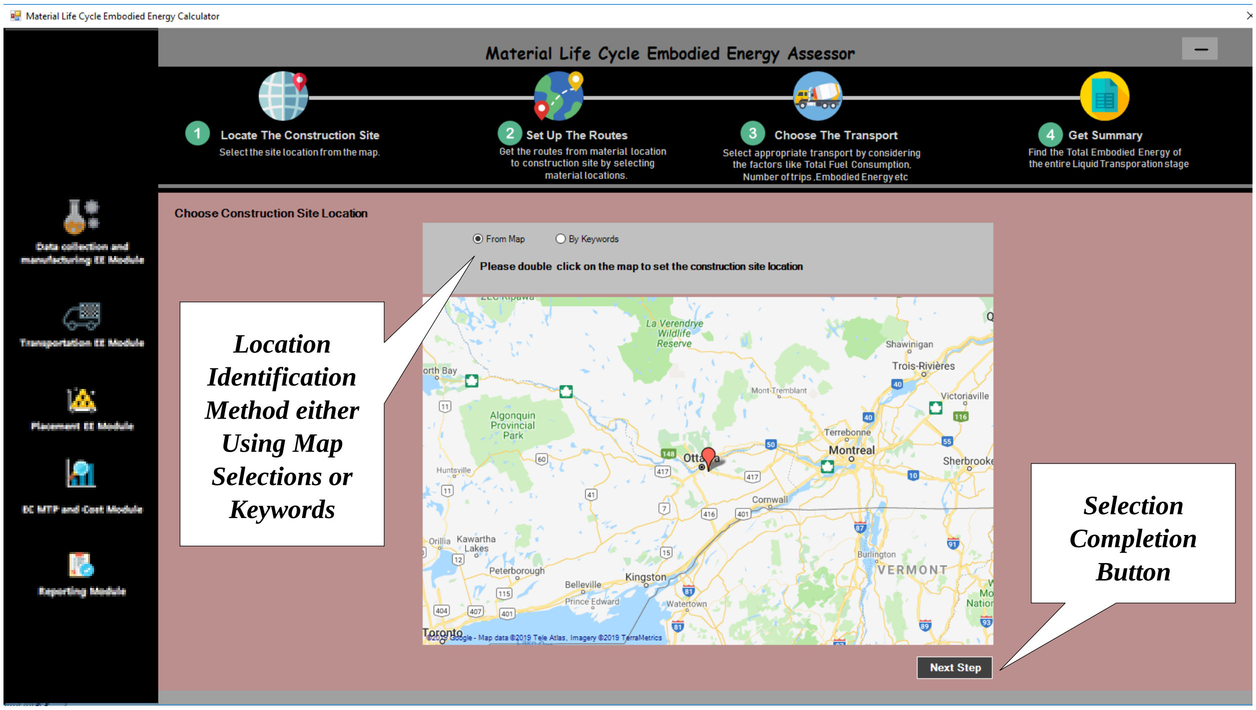


Figure 4-7: Liquid Material EE Assessment Stage Site Location Selection Platform

Once completed, the model needs to identify the concrete material and subsequently, determine the travel distance for each material to reach the site. In order to process this, a new platform screen is created allowing users to input the location of each concrete material type. Overall, this screen displays a list of the grouped materials along with a supportive google maps tool for the users to identify material locations. The groups are created based on their type and elevation. The elevation indicates the level on which each material is located in a building. This grouping methodology is followed because concrete will be transported to the site in batches depending on the casting sequence. In such perspective, concrete that will be casted at different levels is transported to site in different batches. This will affect the transportation process. The created form is shown in Figure 4-8. Once the location of every group is selected, the enter button is selected to verify the material's manufacturing location. To specify that the coordinates of the material's manufacturing location are identified by the model, an indicator is created. Such an indicator turns green when a specific grouped material location is identified by the google maps data retrieval function of the model. The created indicator is shown in Figure 4-8. To move to the next stage, users can select the "Next Step" from the created form as shown within Figure 4-8. Once all inputs are identified by users, the module will assess the vehicles to transport concrete groups. For each group, the module determines the fuel required to transport each group per suitable vehicle. Accordingly, the module identifies concrete mixer per group that has the least fuel consumption.

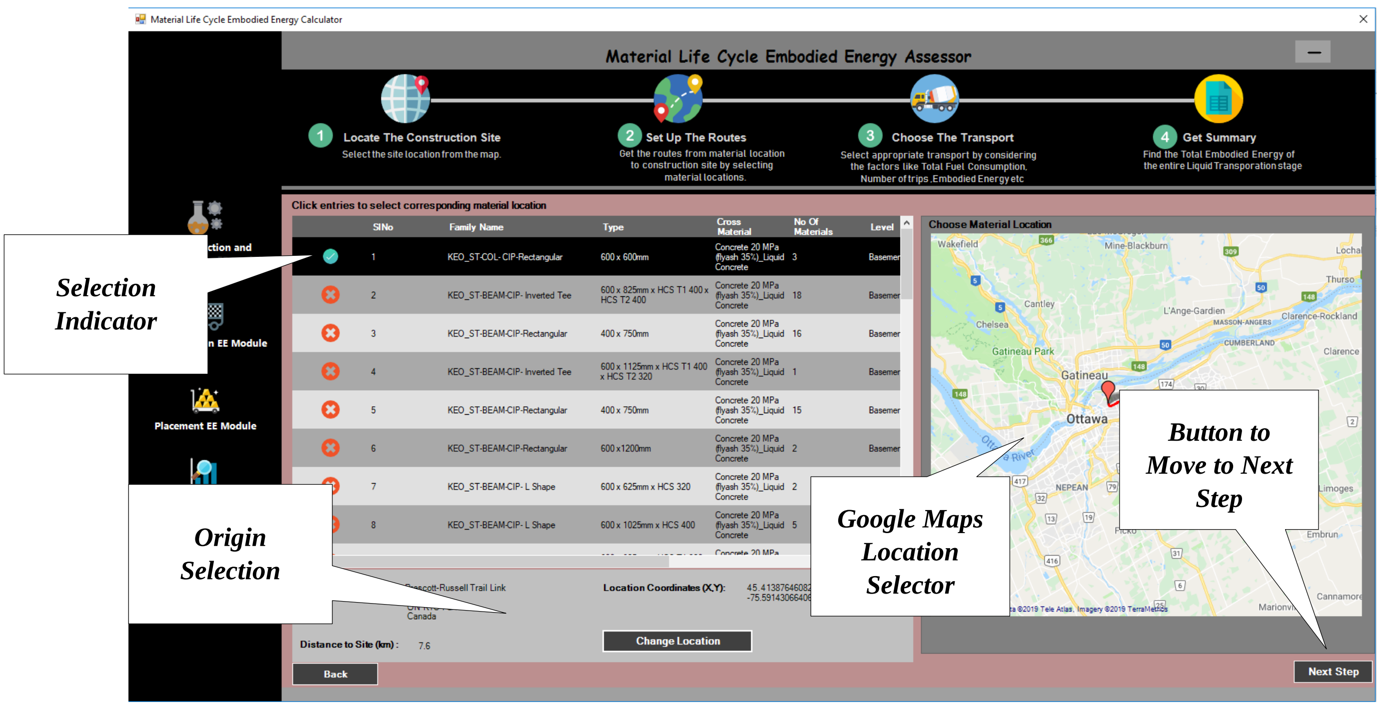


Figure 4-8: List of Grouped Materials Along with a Supportive Google Maps Tool to Allow Users Identify the Material Origins

Once the most energy efficient vehicle is identified, the calculations are displayed in a new form. This is shown in Figure 4-9. This platform screen presents users with information about the fuel usage of the selected concrete mixers along with information about their capacities and number of trips required by each vehicle and individual EE calculated values. All fuel usage calculations are based on the running distance, volumes and payload equations identified in chapter 3. Since vehicle restrictions may occur, a drop down, selection pane is created to allow users change the selected vehicles based on their availability. Once all selections are finalized, users may proceed to the next step all in which the developed platform reiterates EE values based on the changes performed by users.

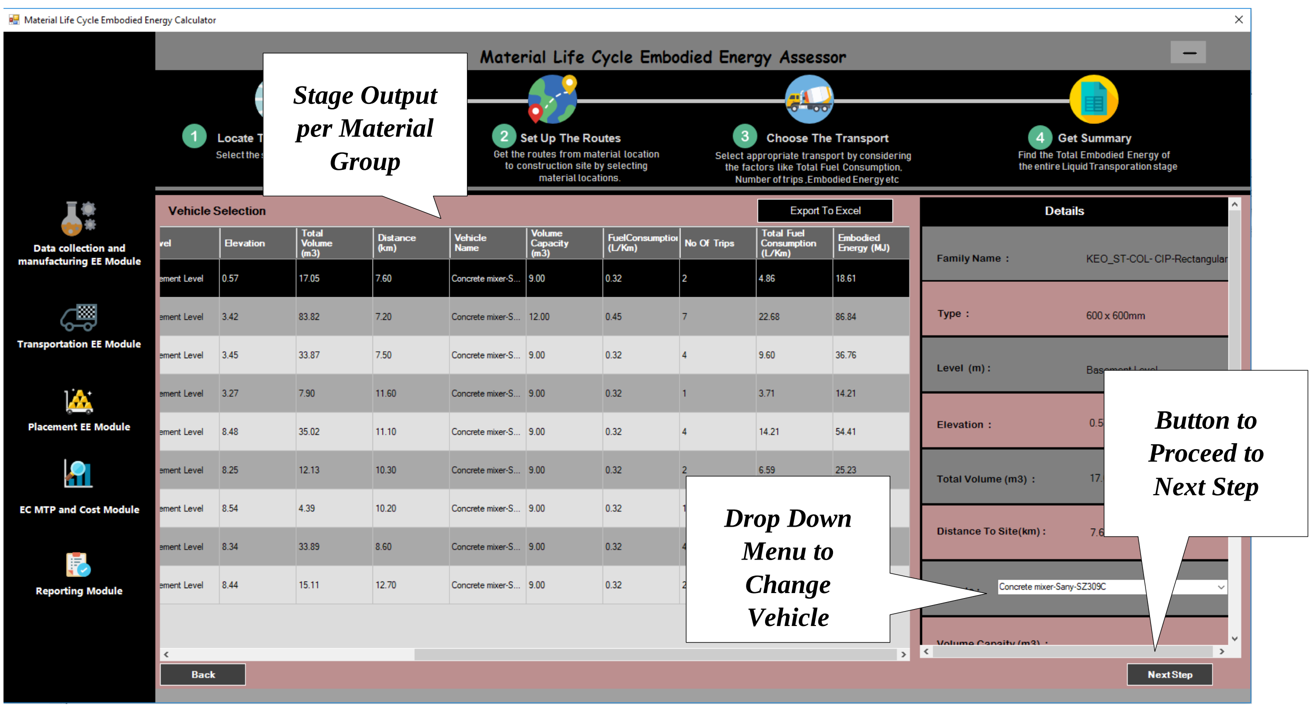


Figure 4-9: Output from the Liquid Material Transportation Submodule

Once users accept all values, the model will accumulate the total EE energy used for all materials group to determine the optimized EE required to transport the concrete materials. To show such values, a new platform screen is created that shows the total calculated energy for all. To reach this screen, the next step button imbedded in the platform screen in figure 4-9 needs to be selected. The summary screen is shown in Figure 4-10. Once the process is completed, users will need to select the finish button to move to the main transportation module screen.

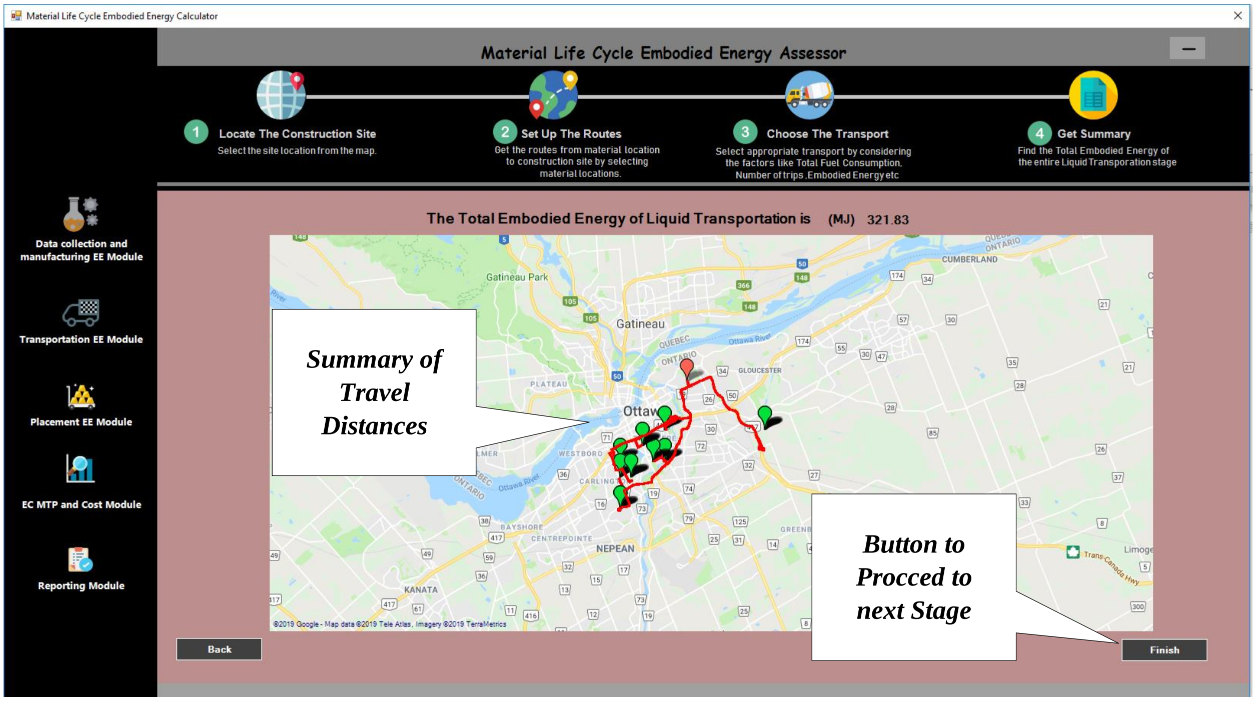


Figure 4-10: Summary Output for the Liquid Material Submodule Stage

4.5.2 Solid Material Transportation Submodule

To determine the solid material transportation EE, the solid material submodule is created. In terms of operations, a set of platform screens are created to allow users identify the locations and the materials needed by the model to determine the most suitable transportation method required for the transportation of the solid material. Once users complete the liquid EE computation, the model will direct users to the screen created in Figure 4-8. At that stage, users need to select the non-liquid transportation EE sub module. Two different methods are used for transportation, which include the use of trucks or haulers. To simulate those two processes, two submodules are created to be part of the non-liquid material transportation module. Those include the truck submodule and hauler submodule. Since solid materials are transported by either vehicle, a comparison submodule is also created to identify the vehicle with the least energy consumption for transporting solid materials, which can either be trucks or haulers. Figure 4-11 shows the three submodules created inside the non-liquid material transportation assessment module. The submodules include the truck submodule, the hauler submodule and the comparison submodule. Overall, the amount of energy required to transport solid materials by trucks is determined by the truck submodule. Similarly, the amount of energy required to transport the same materials using haulers is determined by the hauler submodule. The comparison module determines the least amount of energy required to transport solid materials along with the suitable vehicle.

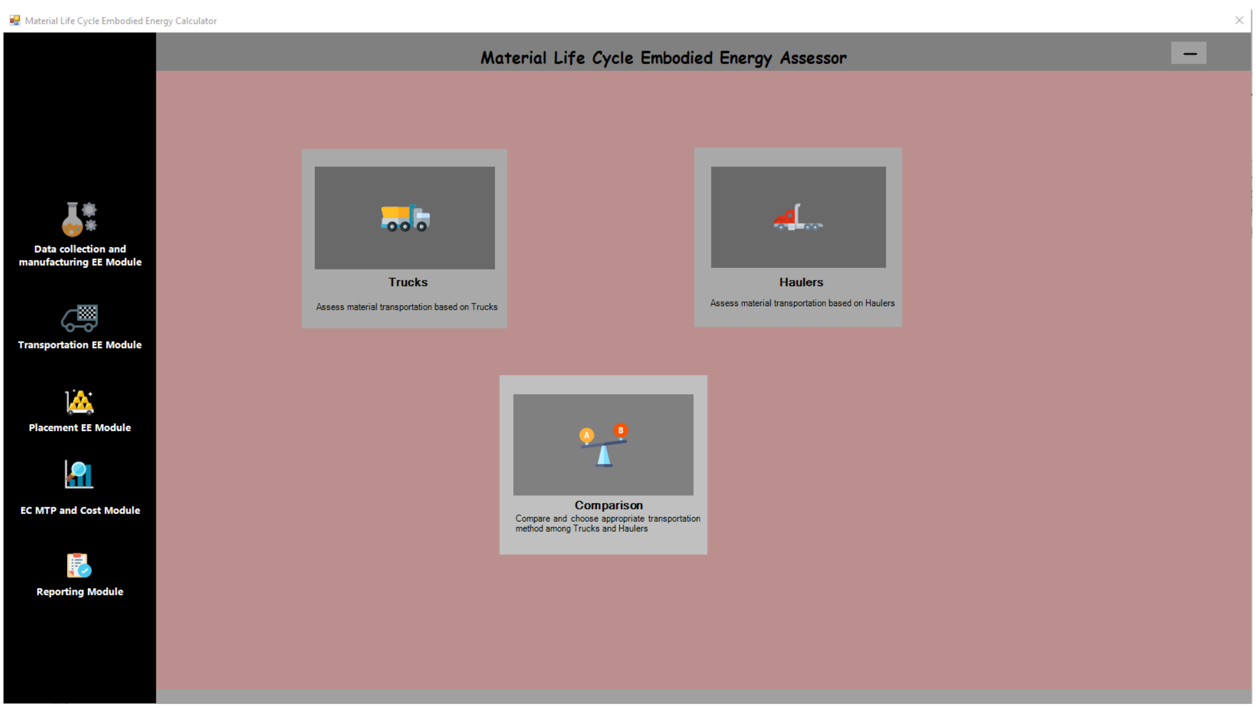


Figure 4-11: Solid Materials Transportation EE Assessment Submodules

First, users will need to select the truck module. To process the EE required to transport solid material using trucks, users are presented with a platform screen that displays a list of all family groups of solid material. Furthermore, the model needs to determine the distances each material group requires to reach the site and hence a new platform screen is created to allow users to input the origins of each material. This platform is shown in Figure 4-12.

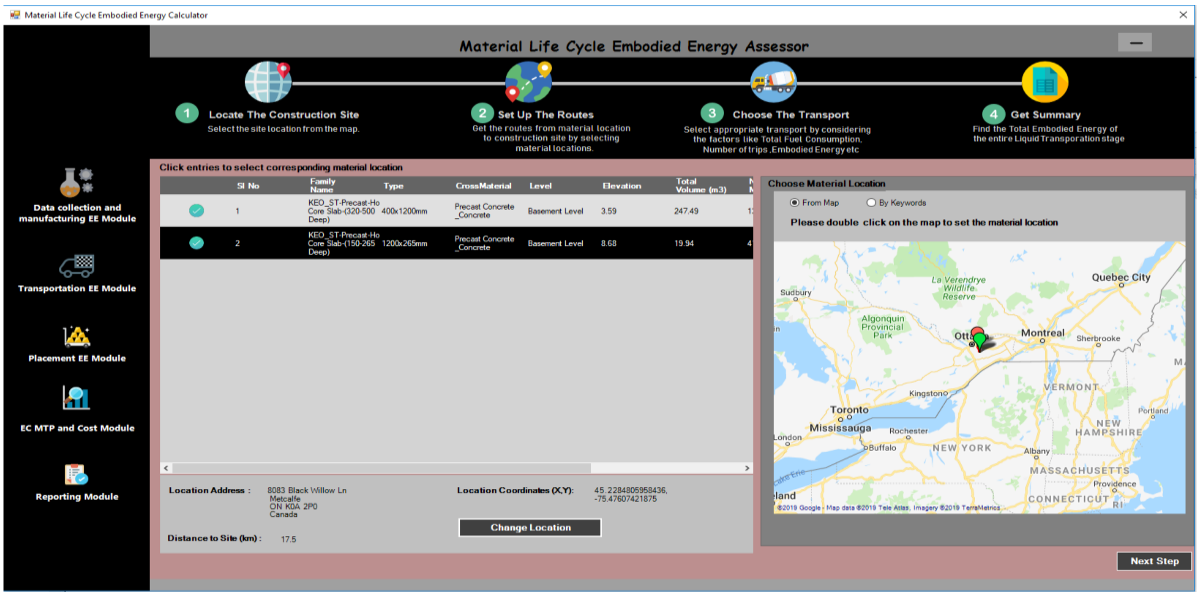


Figure 4-12: Platform Screen Created to Allow the User to Input the Origins of Each Material

Again, users can select the locations by using keywords similar to the case of the google maps application for the liquid material EE transportation calculation module. Once the location of every material group is selected, users need to select the next step button to verify the origin selection. To simplify the selection, materials from the same family, and type are grouped and displayed. Those items are also grouped based on the rules established in chapter 3. Once users select the material's origin for each grouped material created, an indicator specifies if the origin coordinates are identified by the model and the distance is retrieved from google maps.

Once all the materials' origins are obtained, the model identifies the suitable trucks to transport each grouped item. Overall, the selection is based on the weight, volume and payload's rules as identified in chapter 3. Based on the energy consumed by each suitable truck for each group, the most energy efficient trucks are identified. Accordingly, the model will accumulate the total EE energy required to transport materials by those trucks. To show such values, a new platform screen shows the total calculated values. Figure 4-13 displays the form used to display the output. That form displays to users, information about the most energy efficient concrete mixer, the fuel usage of suitable vehicles, capacities and number of trips required by each vehicle, and the individual EE calculated values for each group to transport solid materials. If all trucks available in the database are unable to carry a specific material due to size or weight restrictions, the model indicates that no trucks are available and thus the only vehicle to transport a specific material is a hauler.

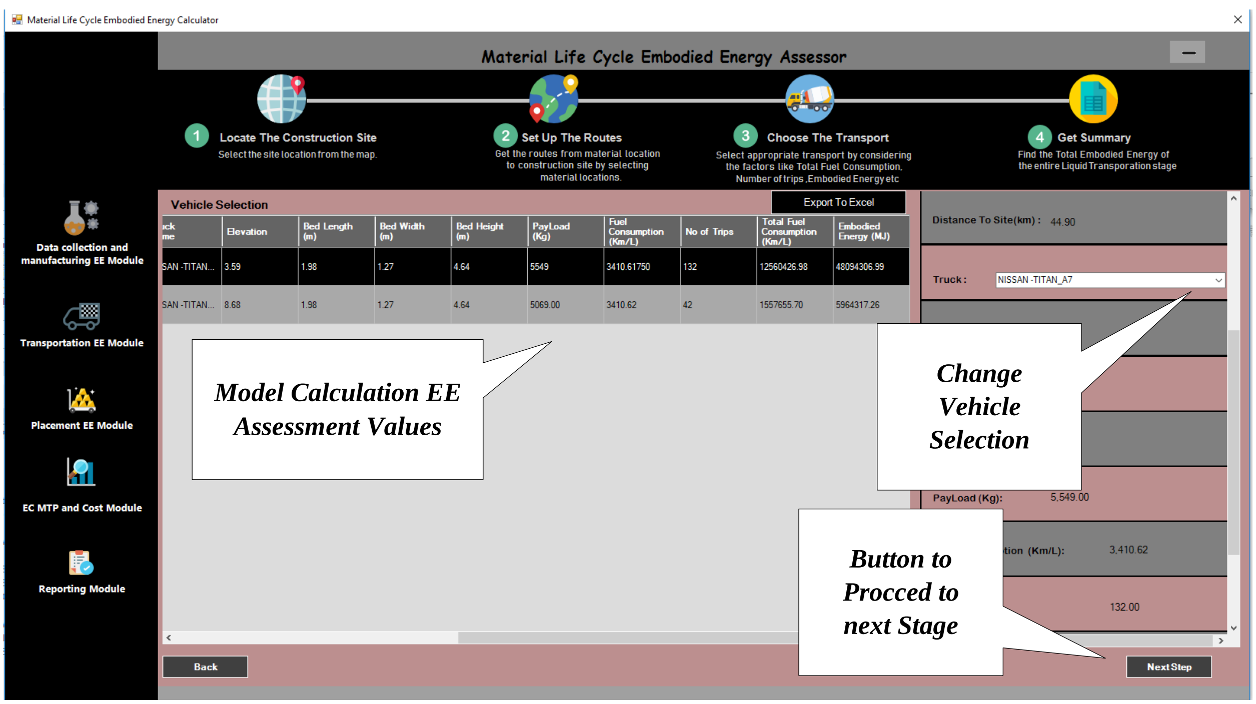


Figure 4-13: Platform Screen Indicating the Most Suitable Truck Is Identified to Transport Each Grouped Item

Overall, the selection is based on the weight, the volume and the payload rules identified in chapter 3. Once the vehicles with the least energy consumption are selected, the optimized accumulative energy is calculated. This is done by accumulating the least energy required to transport each material group. To show the total accumulative EE, a new form is created. The summary screen for the EE required by materials to be transported through trucks is shown in Figure 4-14. To reach this screen, the next step button imbedded into the output screen as presented in Figure 4-13 needs to be selected.

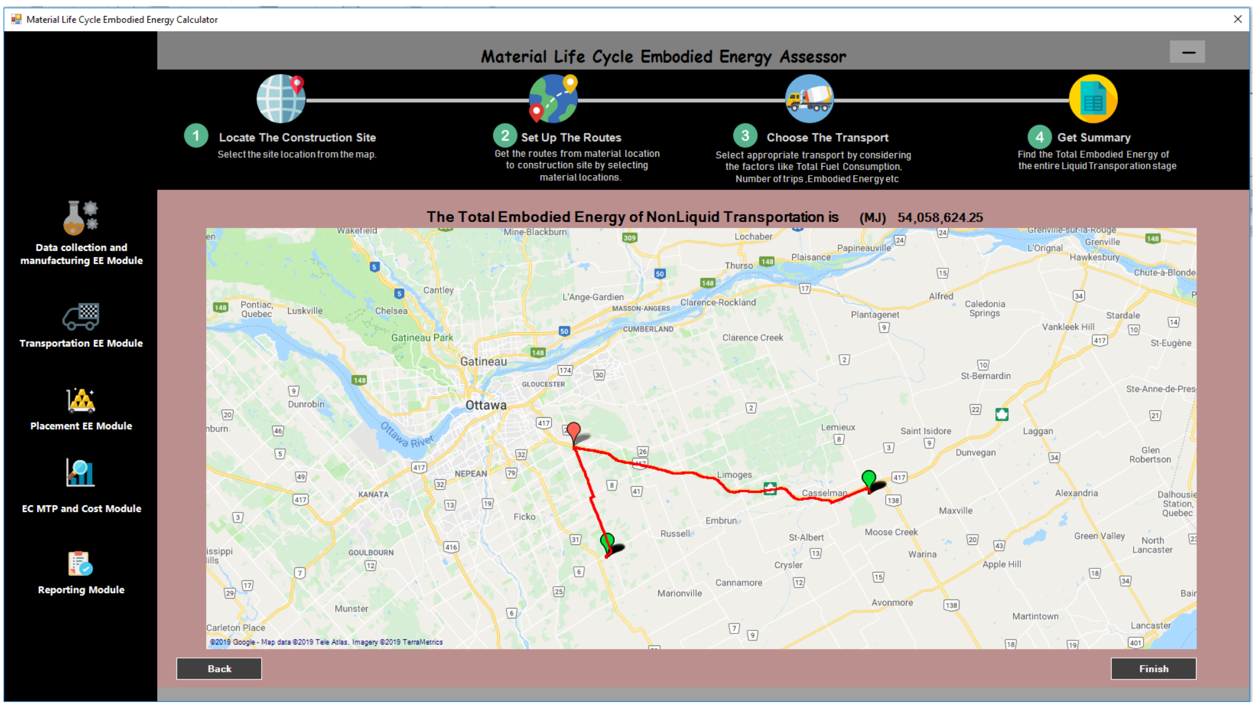


Figure 4-14: Solid Material EE Assessment Using the Trucks Submodule

Once all the calculated EE, which are required by materials using trucks is completed, users returned to the solid material transportation EE assessment submodule displayed in Figure 4-11. At that stage, users need to select the hauler module to reassess the EE of solid materials if transported by haulers. In the hauler module, users are presented with a platform screen, which again displays a list of families for all grouped materials. At that stage, the model needs to determine the travel distances for each material by using haulers to reach the site from its origin. For that case, a new platform screen is created allowing users to input the origins of each material. That platform is shown in Figure 4-15. Yet again, users can select the locations based on keywords similar to the one used in google maps or select the item from the map. Once the origin of every item is selected, the next step button can be chosen to verify the origin selection. To simplify the selection process, materials from the same family and type are grouped and displayed. Those items are also grouped based on the rules established in chapter 3. Once users select the material origin, an indicator will specify if the origin coordinates are identified by the model. The reason for this process to be repeated is to provide users the ability to simulate multiple scenarios by changing the material origins and hauler's types.

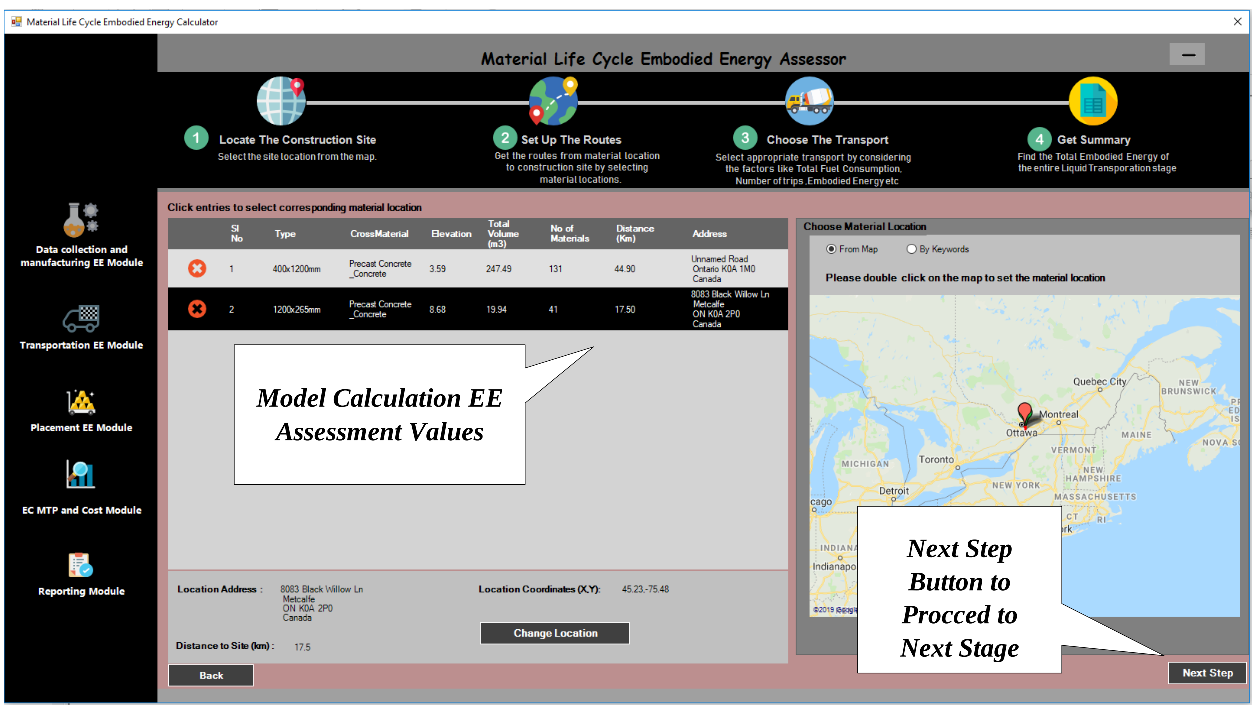
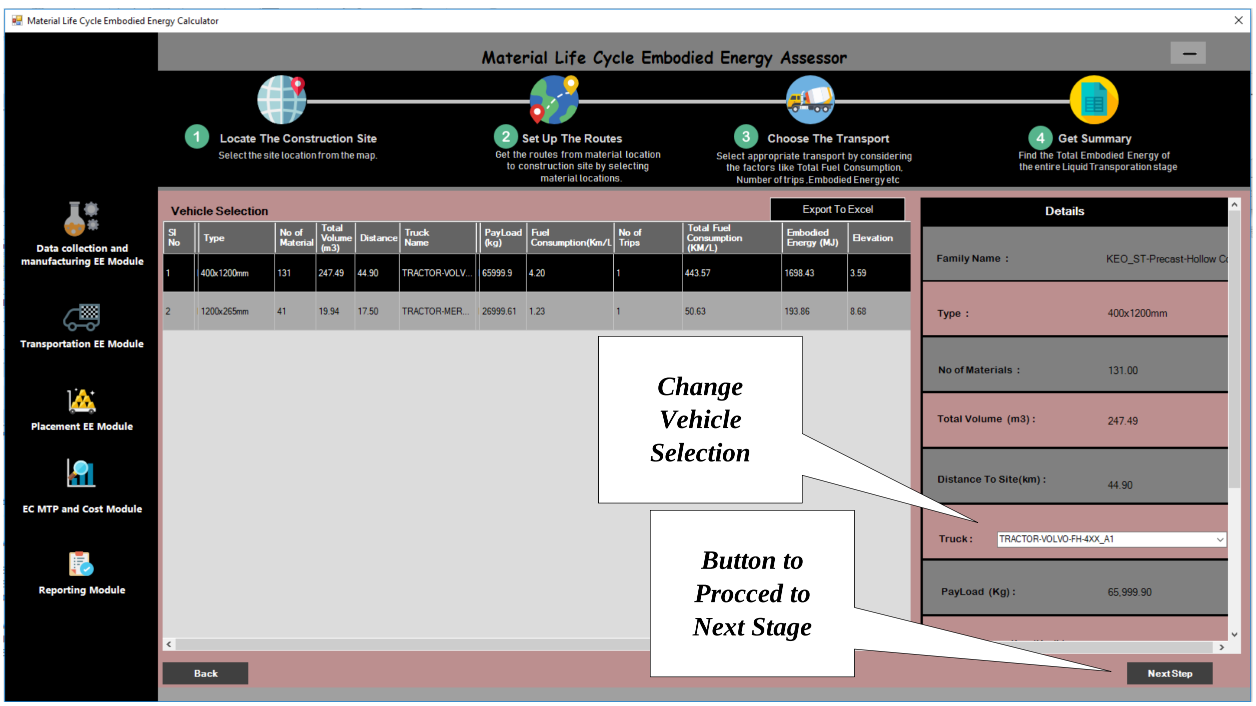


Figure 4-15: Platform Screen to Allow the User to Input the Origins of Each Material

Next, a new platform screen is created and is shown to users in which the most energy efficient hauler is identified to transport each grouped item. Figure 4-16 displays that output screen. This is based on the distance, and the volumes and the payload rules identified in chapter 3. Since vehicle restrictions may occur, a drop down, selection pane is created to allow users change the vehicle selection based on availability. Once all selections are finalized, user may proceed to the next step in which the developed platform will reiterate EE values based on the changes performed users. Furthermore, that platform screen will present the user with information about the fuel consumed by the selected vehicle, capacities and number of trips required by each vehicle and individual EE calculated values.



Sl No	Type	No of Material	Total Volume (m3)	Distance	Truck Name	PayLoad (kg)	Fuel Consumption(Km/L)	No of Trips	Total Fuel Consumption (KM/L)	Embodied Energy (MJ)	Elevation
1	400x1200mm	131	247.49	44.90	TRACTOR-VOLV...	65999.9	4.20	1	443.57	1698.43	3.59
2	1200x265mm	41	19.94	17.50	TRACTOR-MER...	26999.61	1.23	1	50.63	193.86	8.68

Figure 4-16: Platform Screen in Which the Most Suitable Hauler Is Identified to Transport Each Grouped Item

After all values are accepted users, the model accumulates the total EE energy used for all materials. To show such values, a new platform screen is created to show the total calculated and optimized EE for haulers. That screen is shown in Figure 4-17.

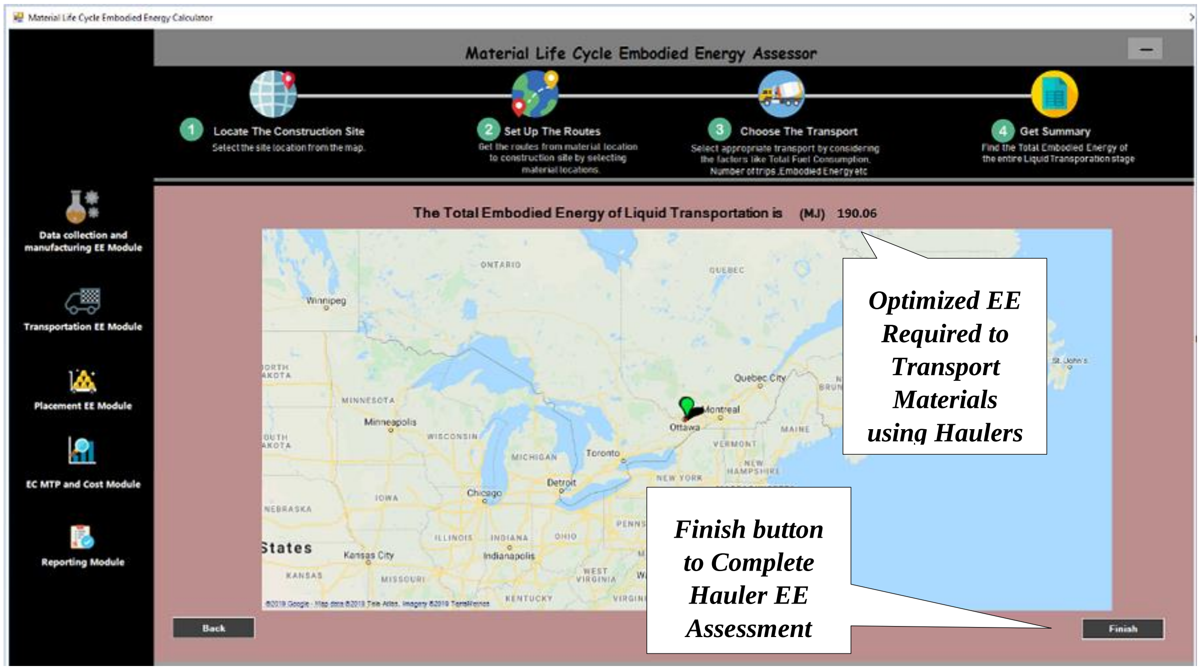


Figure 4-17: Platform Screen to Show the Total Calculated and Optimized EE for Haulers

To attain that screen, the next step button imbedded into the output screen presented in Figure 4-17 needs to be selected. Once the process is completed, users can select the finish button and are returned to the screen displayed in Figure 4-18. After both the truck and hauler submodules are applied, users are required to compare the EE values by using the comparison submodule. Users need to select the comparison module to complete this process. Once selected, this submodule will display a screen revealing all grouped materials along with the EE required to transport materials by using both trucks and haulers. The model displays the transportation method that requires the least energy consumption as the selected option; the selected option may be either by haulers or trucks for each grouped solid material.

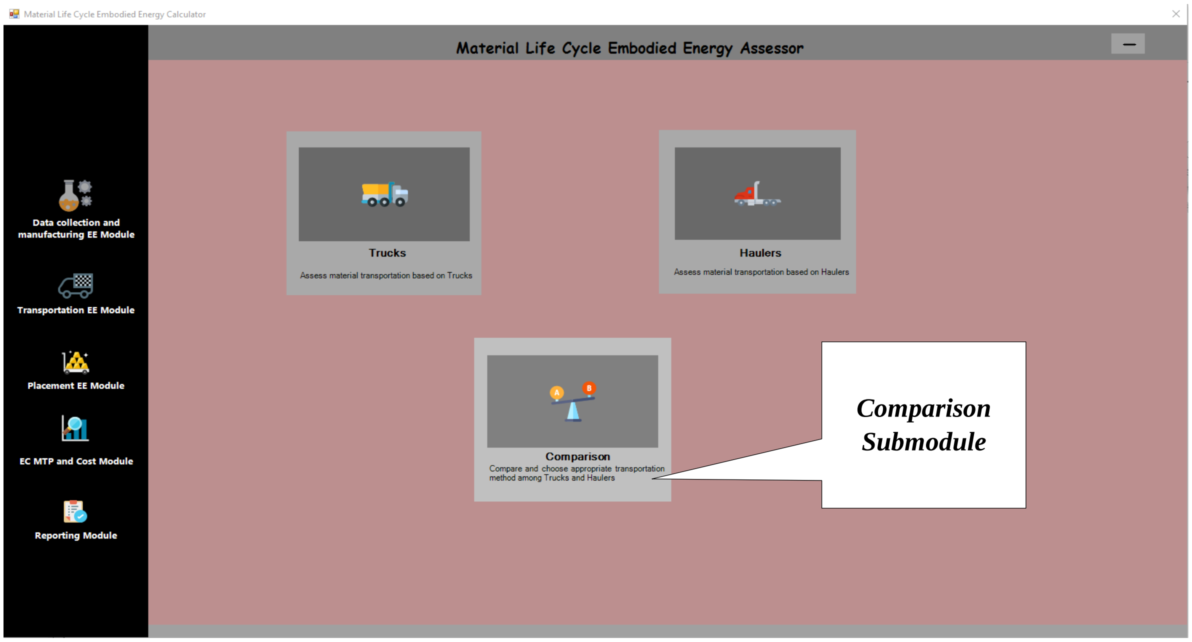


Figure 4-18: Solid Materials Transportation EE Assessment Submodules

Figure 4-19 displays the referred platform in this stage. If users want to select a transportation method different than the suggested one, they can do so by changing the selection box. The total EE will be reiterated.

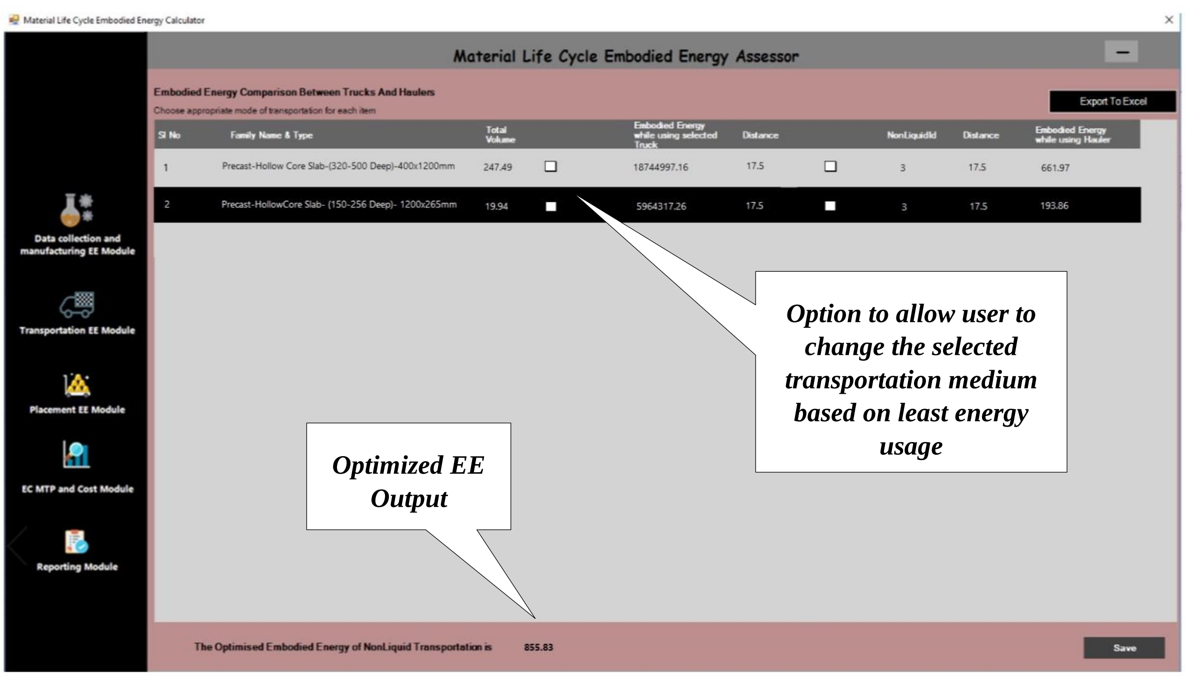


Figure 4-19: Platform Used to Compare All Processed Materials for Different Transportation Methods and Select the Least Energy Consuming Method

4.6 Developing the Placement EE Calculation Module:

To calculate the EE required for placement, a placement EE module tab is developed. That module requires to process two different type of materials. Those include solid and liquid materials. For that reason, two submodules are developed, which are the liquid material placement stage submodule and the solid materials placement stage submodule. Since different cranes can be used for placing in the solid and liquid material, a third submodule is created to select the optimized tower crane. Such a selection is vital as it is difficult to change a tower crane during the construction of a project. First, users will select the placement EE module tab. Subsequently, users are required to begin with the liquid material placement stage to assess the energy required to do this task. Once completed, users will need to move to the solid placement EE assessment stage. Here the energy required to place solid materials is determined. Finally, users will need to process the crane optimization stage in order to select the appropriate crane and reiterate energy values. Users need to select and process each module and its associated submodules to move to the EC MTP and cost modular tab.

To access the placement EE sub modules, users will need to select the placement EE submodule tab as presented in Figure 4-20 and afterward the other submodules.

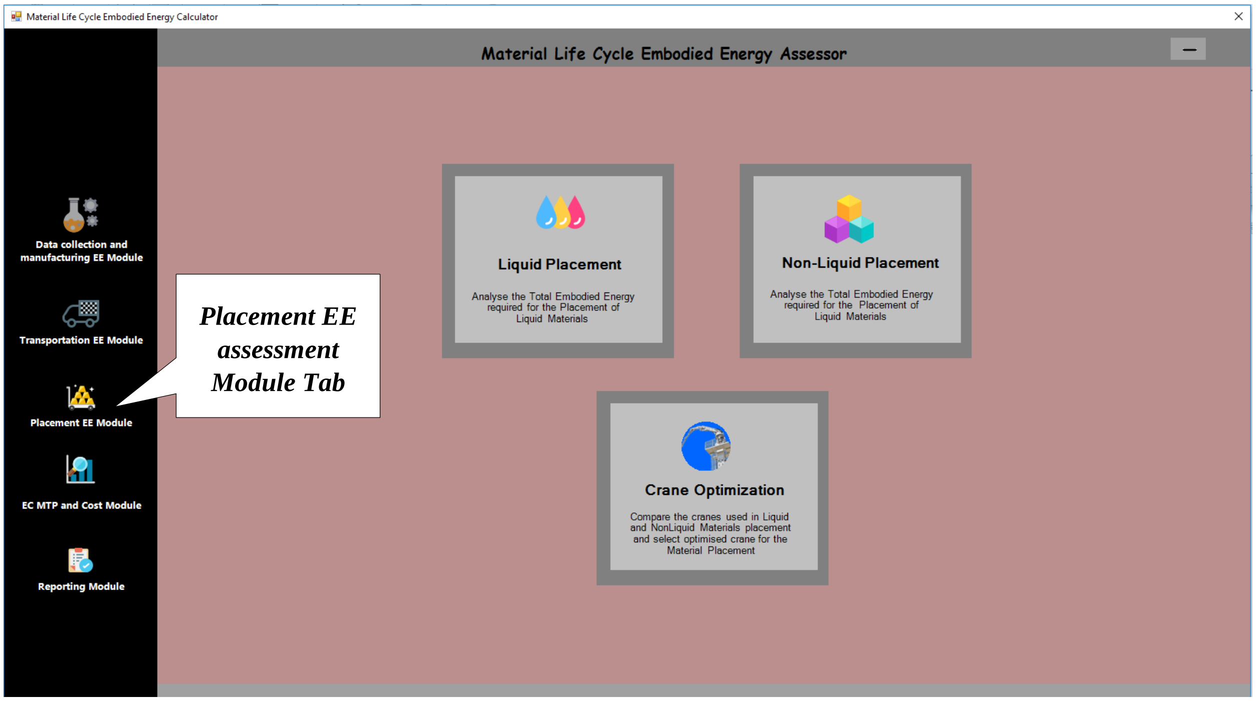


Figure 4-20: EE Calculation Submodules Required the Processing for The Energy Required for Placing Materials in Their Intended Location Within Sites.

4.6.1 Liquid Material EE Placement Submodule

To assess the liquid placement EE submodule, three main submodules are considered, which are the mobile concrete pumping stage submodule, bucket placement stage submodule and stationary concrete pumping stage submodule. Those represent the process in which concrete may be placed. Each submodule assesses the placement by using a different concrete placement method. Assessing all three submodules allows the model to determine the energy required in case of using mobile pumps, concrete buckets or stationary concrete pumps. Figure 4-21 displays the created submodules. Additionally, a comparison submodule is created to indicate the placement method that requires the least energy.

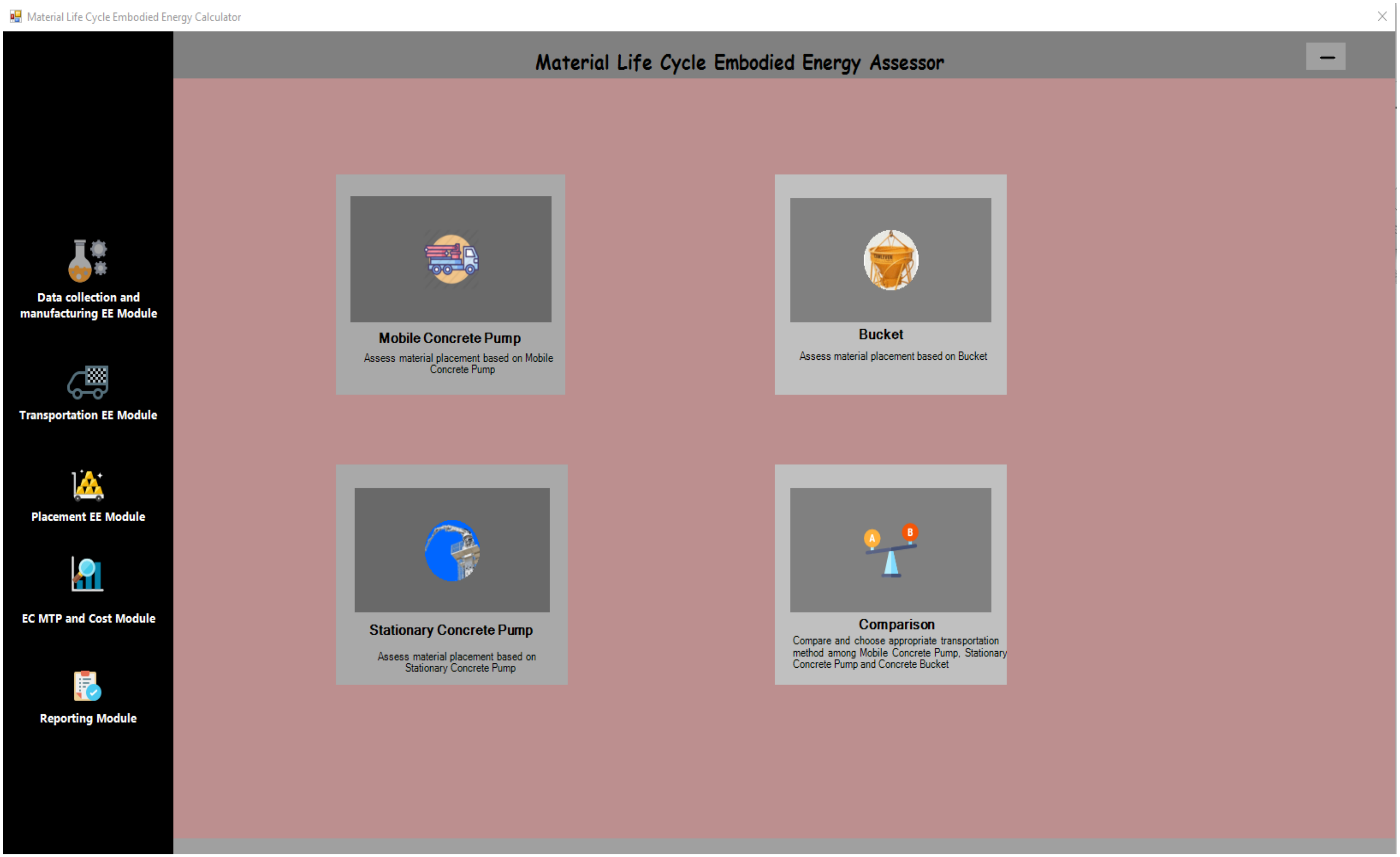


Figure 4-21: Created Submodules for the Liquid Material EE calculation Stage

The model requires two additional modules, which are the mobile pump and concrete bucket EE calculation module and the mobile pump and stationary pump EE module. In case the mobile concrete pump submodule is not able to place all the concrete materials in place due to the available restrictions on the concrete pump boom length, the model will assess the mobile pump and concrete bucket along with the mobile pump and stationary pump before moving to the liquid material EE comparison stage. The mobile pump and concrete bucket EE calculation submodule and the mobile pump and stationary pump EE calculation submodules are performed by the model in the background. Since those submodules require no manual data entry and are not always required. The additional submodules will be automatically computed in the model background. If required, the mobile pump and concrete bucket EE calculation modular stage and the mobile pump and stationary pump EE calculation modular stage are performed after users complete the stationary concrete pump EE assessment submodule. Accordingly, the determined values from the submodules are considered in the liquid material EE comparison (optimization stage) submodule.

Users will need to process the mobile concrete pump submodule and subsequently they need to process the bucket stage, the stationary concrete pump stage and finally the process comparison stage in order to assess the liquid material EE placement.

4.6.1.1. Concrete Mobile pump submodule

The concrete mobile concrete pump submodule represents the stage in which the energy required to place concrete by using mobile pumps is determined. First, all the concrete items available in the BIM design model are identified. According to the coordinates attained along with the pumping machine location, the model will determine the mobile pumps suitable to place concrete floor by floor. Accordingly, the model identifies the energy required by the different concrete pumps for each floor and therefore the machine with the least energy consumption is identified. To calculate energy, the pumps with suitable boom length are identified. Pumps with boom lengths capable of reaching the center of the building from the casting locations are selected. The geographical locations in which the pump can be placed in reference to a building are identified in chapter 3. For each selected pump, the module will display the coordinates of the casting location required to place all concrete elements. Since concrete of the same strength and elevation can be casted together, the model groups such material and displays it to users. By using the form created in figure 4-22, the model displays the energy required to cast different concrete groups through different pumps.

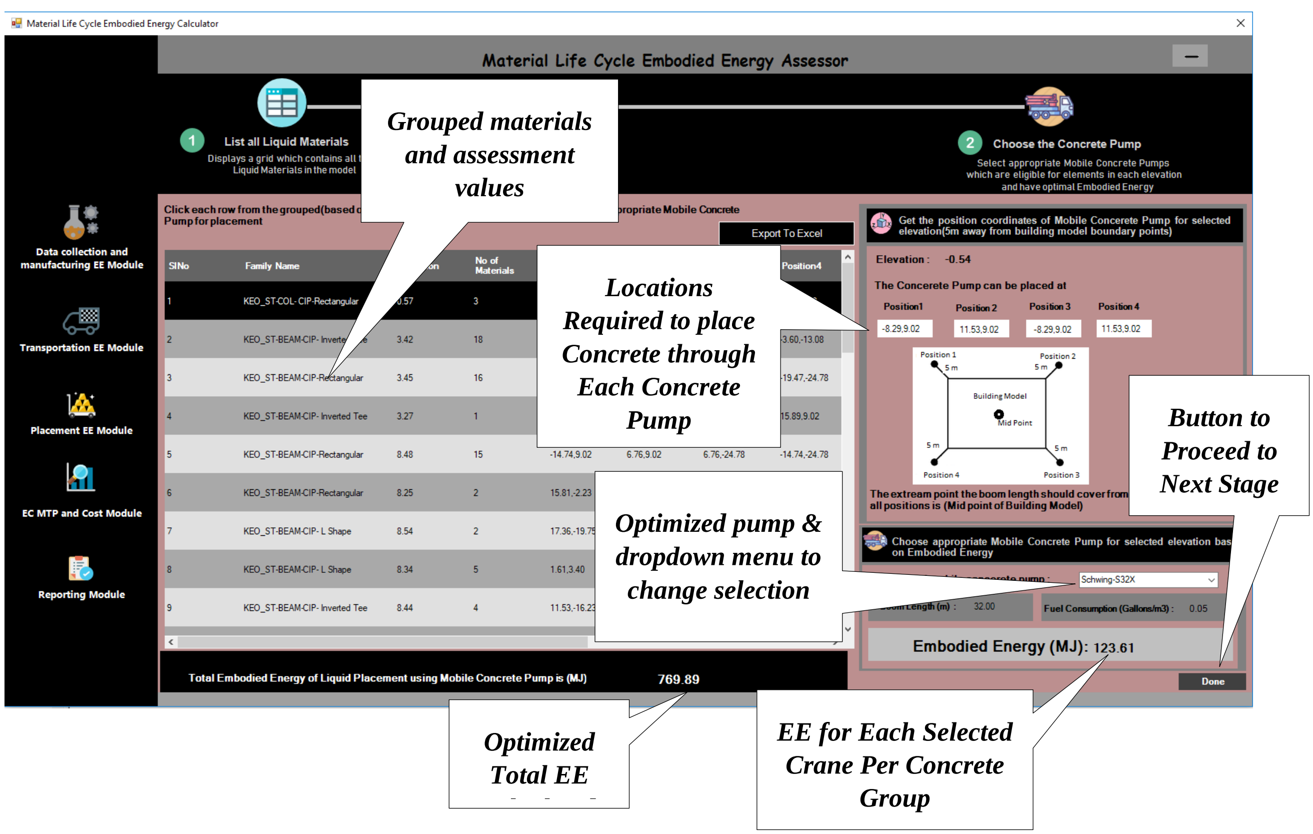


Figure 4-22: Mobile Concrete Pump Submodule Form

The pump that consumes the least energy to cast all concrete groups is identified by the model. Accordingly, the total energy to cast all concrete materials through the identified pump is calculated. Initially, users need to select the mobile concrete pump submodule as shown in Figure 4-21. Subsequently, the model automatically computes the optimized energy values and displays them in the form shown in Figure 4-22. Should the user want to change the least energy consuming pump selected, a drop-down menu is presented which will allow the user to select from a list of pumps that may be used as a replacement. Once changes occur, the values for the EE assessment is reiterated and new energy calculations are displayed in the developed platform. Overall, when the user is satisfied with the selections, the done button may be selected in order to return the user to the screen displayed in Figure 4-21.

4.6.1.2 Concrete placement using bucket Submodule

In order to calculate the EE for placing liquid materials by using buckets, a set of forms are created in the model. Once the concrete bucket submodule is selected, users are presented with a form as displayed in Figure 4-23. In that form, users' inputs are required to determine the energy needed to place materials using buckets. First, the module will require two important factors, which are the location of the tower crane and the location where the concrete is offloaded by concrete mixers. In lieu of the above, the created form is developed as part of the module to ask users identify such variables. Users are presented with set of lists of the possible locations based on the BIM design model. The bucket required for placement should then be identified. Through the module form, users are prompted to select their options from a list of preconfigured values. The created form also displays a list of the concrete buckets that may be used. Based on the site conditions and availability, users can select the bucket type. By default, the largest bucket is selected by the model. Once all necessary values are selected,

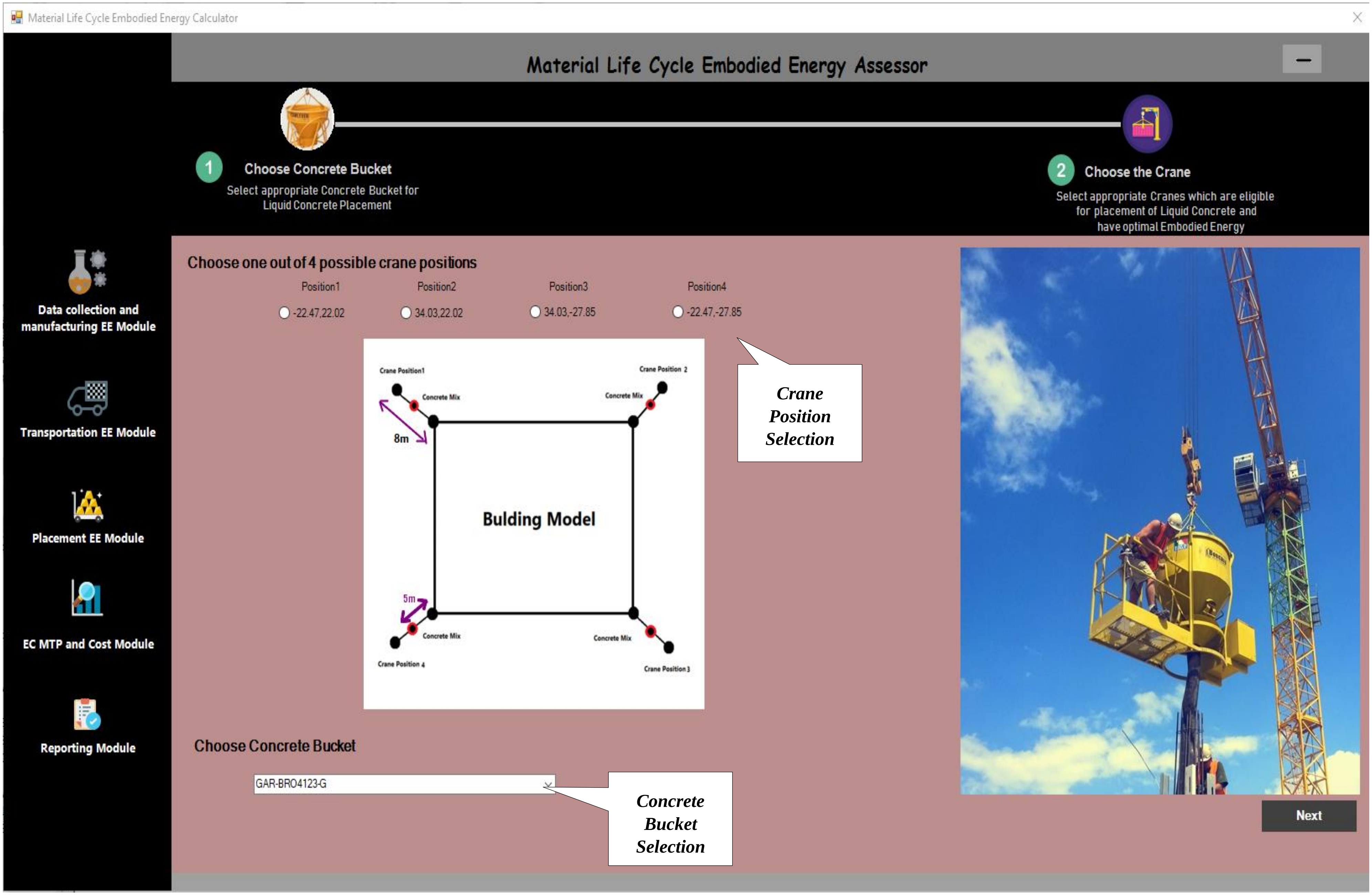


Figure 4-23: Concrete placement using bucket Submodule Initial Platform Screen

users may move to the next step. This is done by selecting the next button at the bottom right hand corner of the model. Once users select the next button, a new form is displayed, as shown in Figure 4-24. In that form, a list of all the grouped liquid materials is presented along with details about their location. At this stage, the model processes multiple cranes to determine the one with the least energy consumed per material. This is based on the required distance to move the concrete from its offloading station to its intended placement location in the site. Information about the electricity usage is identified as well. Overall, the developed platform shows details about the crane used. Information such as trolley speed, hoist wattage, number of bucket trips per material group and boom length are also provided. Afterwards, the module calculates the least energy consumed by the selected crane to place all concrete. Users have the ability to change the optimized crane selection. Should a specific crane become unavailable during construction, users are presented with a list of cranes that may be used to place all the liquid materials. Should the selection change, the model recalculates values and presents them to users with their modified embodied energy. Once users are satisfied with the results, they move to the next stage by selecting the done button. The model then displays the submodule screen to allow users to move to the concrete placement using the stationary crane stage.

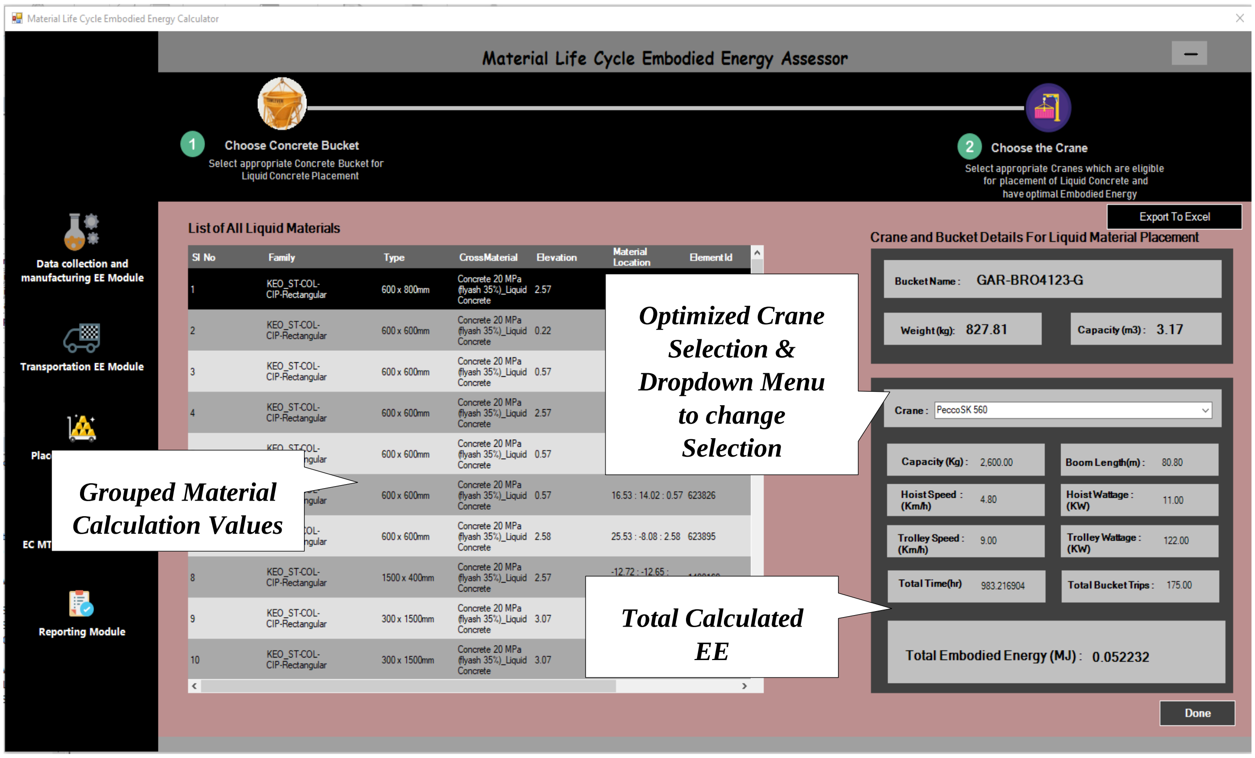


Figure 4-24: Concrete placement using bucket Submodule Output Platform Screen

4.6.1.3 Concrete placement using stationary concrete pump Submodule

Once the liquid material placement stage using concrete buckets is completed, users determine the energy required to place concrete by using the stationary concrete pump submodule. This stage is embedded into the liquid material placement that is in the placement EE module. In this stage users needs to select the stationary pump submodule. Thereafter, the locations of the concrete pumps need to be identified. For that reason, a form is created for users to use when selecting the locations. Since concrete pumps are required to be placed inside shafts, the model will suggest the location coordinates which can be verified by users based on site the obstructions. Figure 4-25 displays the developed platform. Once users select the locations, a check is performed by the submodule in the model to identify if all the site areas are covered.

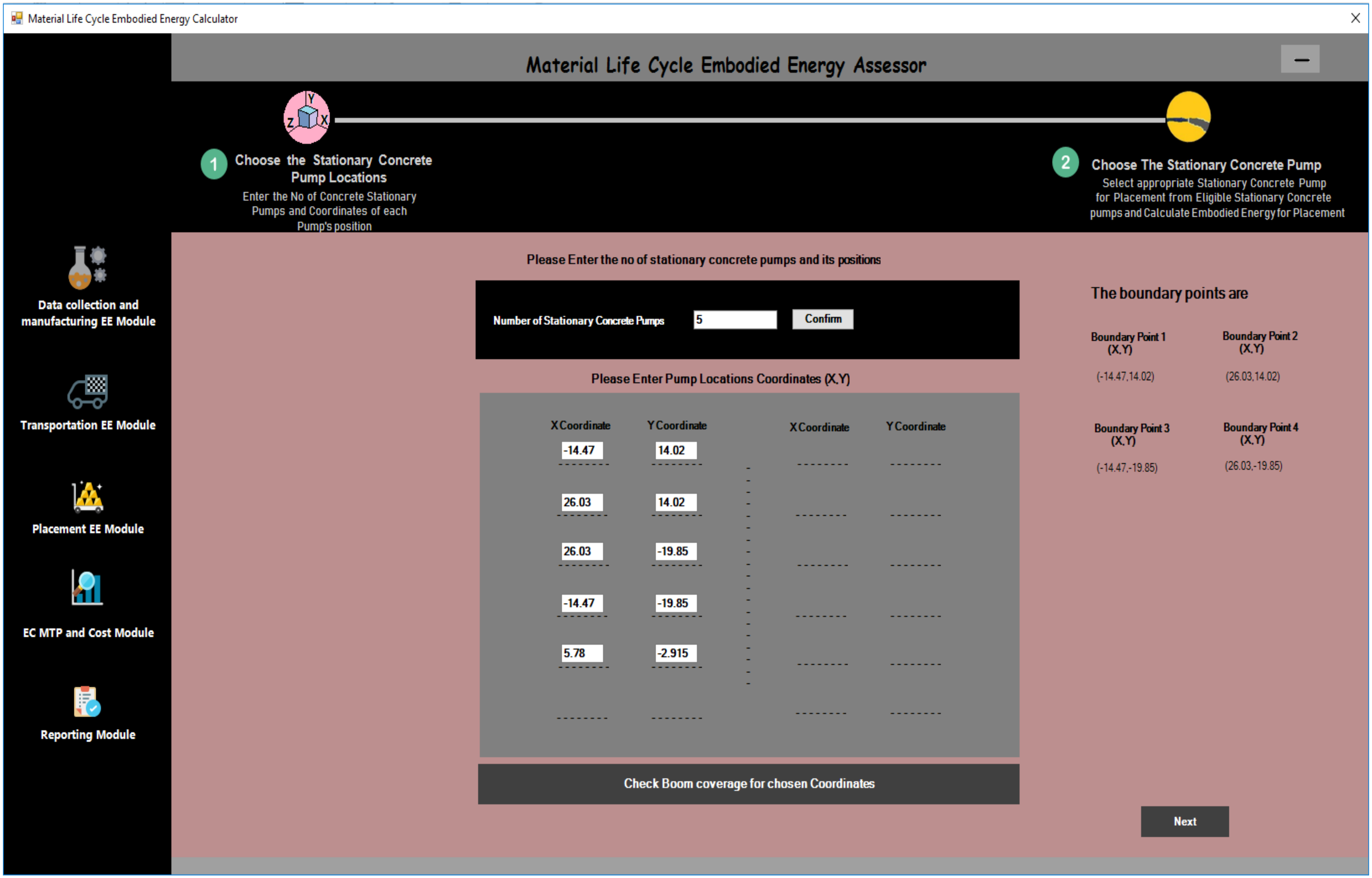


Figure 4-25: Stationary Concrete Pump Location Selection Screen

This is done by comparing the largest boom diameter covered area with the building's area. Specifically, the model checks the coverage by comparing the diameter covered by the greatest boom length of the pumps that are available in the database against the covered site areas. Once the locations are verified, a new form is presented to users. Figure 4-26 displays that form. Based on the selected locations, the model determines the available pumps to cast concrete to all locations on the site. The model collects and displays all liquid materials that are part of the BIM design model. Furthermore, the model collects and displays the material locations, elevations and types. When all this information is collected, a form function runs through multiple scenarios to determine the combination of pumping machine and crane that have the least energy consumption. Based on that selection, the platform presents users with the accumulated EE that is required to place liquid materials by using stationary pumps. Of course, users have the ability to change the optimized equipment selection. Should a specific machine become unavailable, users are presented with a list of alternative pumps and pumping machines that can be used to place all the liquid materials in the building based on the pressure, height and boom length's requirements. If the selection changes, the model recalculates the values and presents users with the modified embodied energy. Once users are satisfied with the results, they move to the next stage by selecting the done button. The model then displays the submodule screen to allow users to move to the comparison EE liquid material assessment stage.

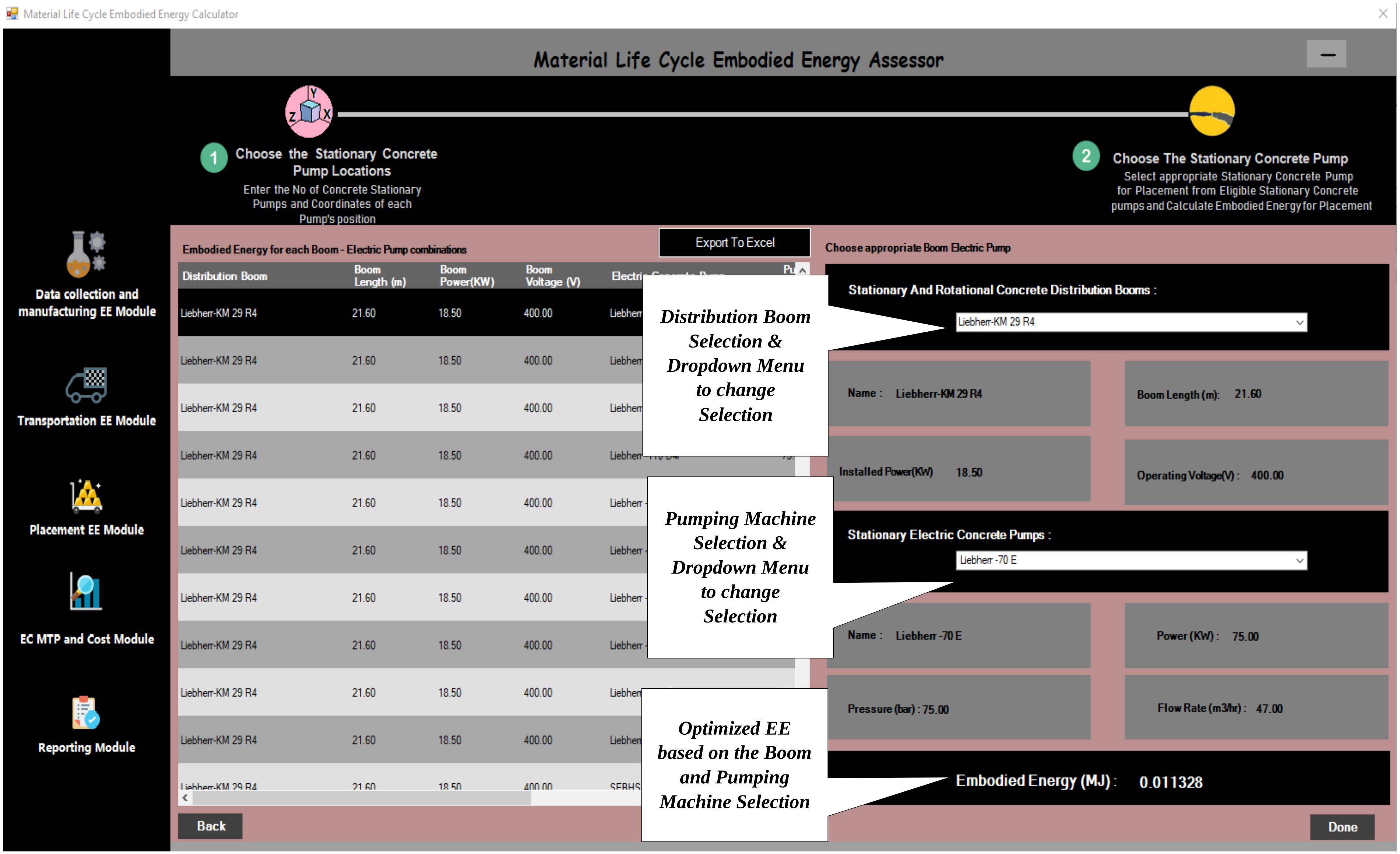
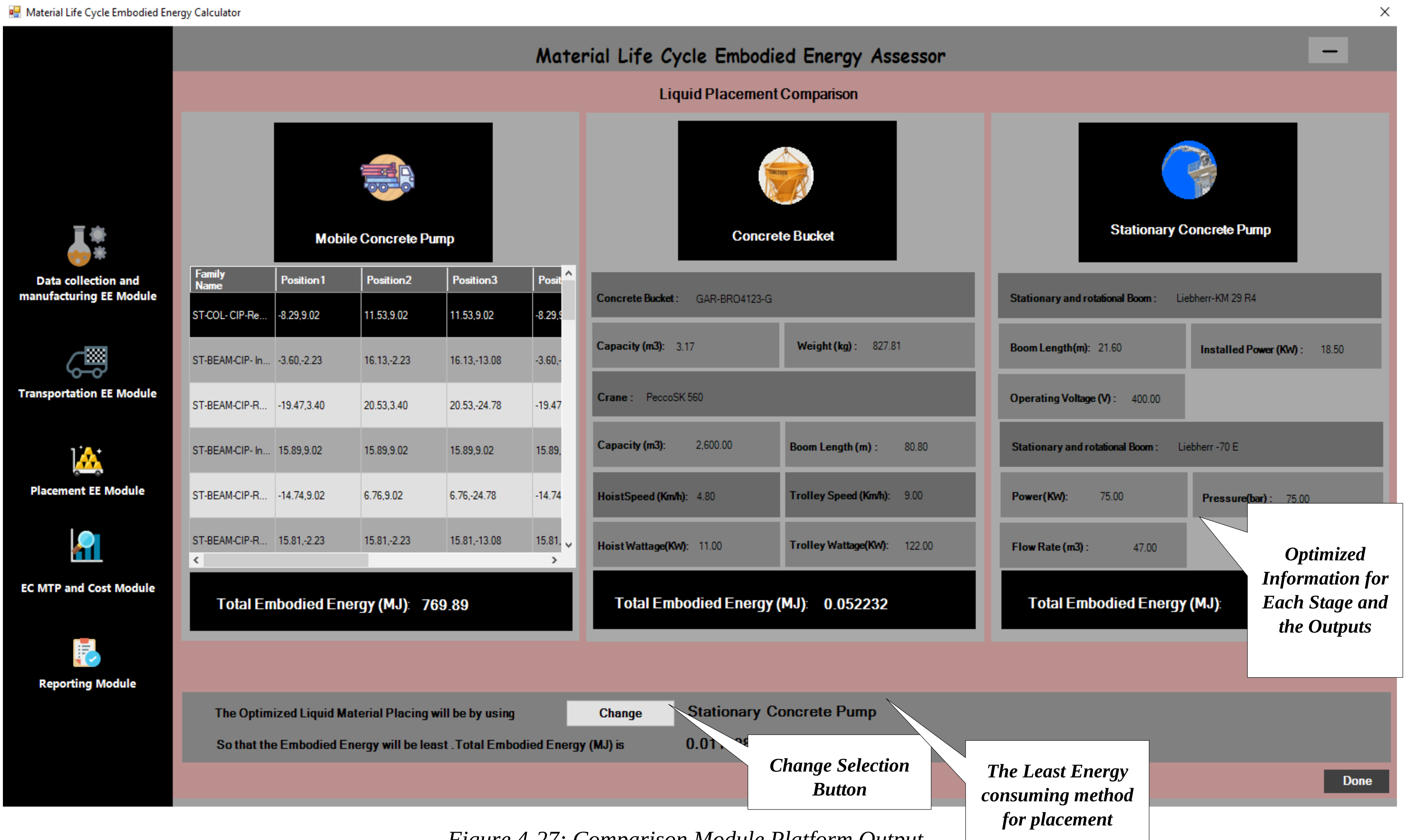


Figure 4-26: Stationary Concrete Pump EE assessment Stage Output

4.6.1.4 Comparison Module

Once the EE for liquid materials placement using different methodologies has been calculated, the model to compares and suggests the least EE method for liquid placement. This is displayed in Figure 4-27. In the comparison submodule, the energy required to place concrete by using mobile concrete pumps, concrete buckets, stationary concrete pumps, mobile concrete pump and buckets, and mobile concrete pump and stationary concrete pump stage is displayed. If the mobile pump and bucket and mobile pump and stationary modules are processed, information for those are also displayed. Subsequently if those modules are not required, the created form only displays information and energy calculations required for mobile concrete pumps, concrete buckets, and stationary concrete pumps submodule. The model identifies the least energy consumption method and indicate it to users. This is done by comparing the overall EE values calculated from the placement of liquid material assessment stages based on the optimized energy usage. Information about the pump, bucket, tower crane, and stationary tower crane for each method that have the least energy consumption is displayed. Other values, such as electrical usage and equipment parameters are also displayed. At this stage, the model will indicate the process that will require the least EE as shown in figure 4-27.The different types of energy are displayed by the model so that the user can manually compare the different results. If users want to change the least EE selection, a change button is created. Through that button, users select the preferred method of placement and in return the model recalculates the EE required to place liquid materials. The selections of equipment usages remain the same as considered in the previous stages, but users may change the placement methodology. Once the process is completed, users select the close button in order for the model to revert users to the main placement tab form.



Family Name	Position1	Position2	Position3	Posit
ST-COL- CIP-Re...	-8.29,9.02	11.53,9.02	11.53,9.02	-8.29,9
ST-BEAM-CIP- In...	-3.60,-2.23	16.13,-2.23	16.13,-13.08	-3.60,-
ST-BEAM-CIP-R...	-19.47,3.40	20.53,3.40	20.53,-24.78	-19.47
ST-BEAM-CIP- In...	15.89,9.02	15.89,9.02	15.89,9.02	15.89,
ST-BEAM-CIP-R...	-14.74,9.02	6.76,9.02	6.76,-24.78	-14.74
ST-BEAM-CIP-R...	15.81,-2.23	15.81,-2.23	15.81,-13.08	15.81,

Figure 4-27: Comparison Module Platform Output

4.6.2 Solid Material EE Placement Submodule

Since solid materials are mostly placed in their intended location by using cranes, a singular module is created to identify the crane that has the least embodied energy consumption to place solid materials. Figure 4-28 displays the platform created for such process. Once all liquid material placement modules are completed, users will need to select the solid materials assessment submodule, as shown in Figure 4-20. Once selected, the model begins processing the solid materials to identify the EE required for their placement. At start, the model selects all the materials that their weight is greater than 23 kg. The module displays the listed the solid materials. Next, it is necessary to identify the crane's position i.e. the location where the tower crane will be placed and also the storage location. The model identifies a list of suggested locations that users can select from. This is displayed in Figure 4-28. Once completed, users move to the calculation stage in the model by selecting the next button which is provided at the lower right-hand corner of the created form. Based on the selected parameters, the model identifies the most energy efficient crane and displays it to users. Furthermore, the model calculates the minimum embodied energy required to place solid materials by using the identified crane. Within the created platform, the model displays the individual energies required to place each material. Additionally, information about the materials locations, electrical usage, time required, and power required by both the boom and the trolley per suitable cranes are shown. Based on the least energy consumption crane, the module identifies the most energy efficient crane. The model allows users to change the crane selection. A list of possible cranes is displayed in a drop-down menu from which users can select their preferences and accordingly the EE will be recalculated. This is shown in Figure 4-29.

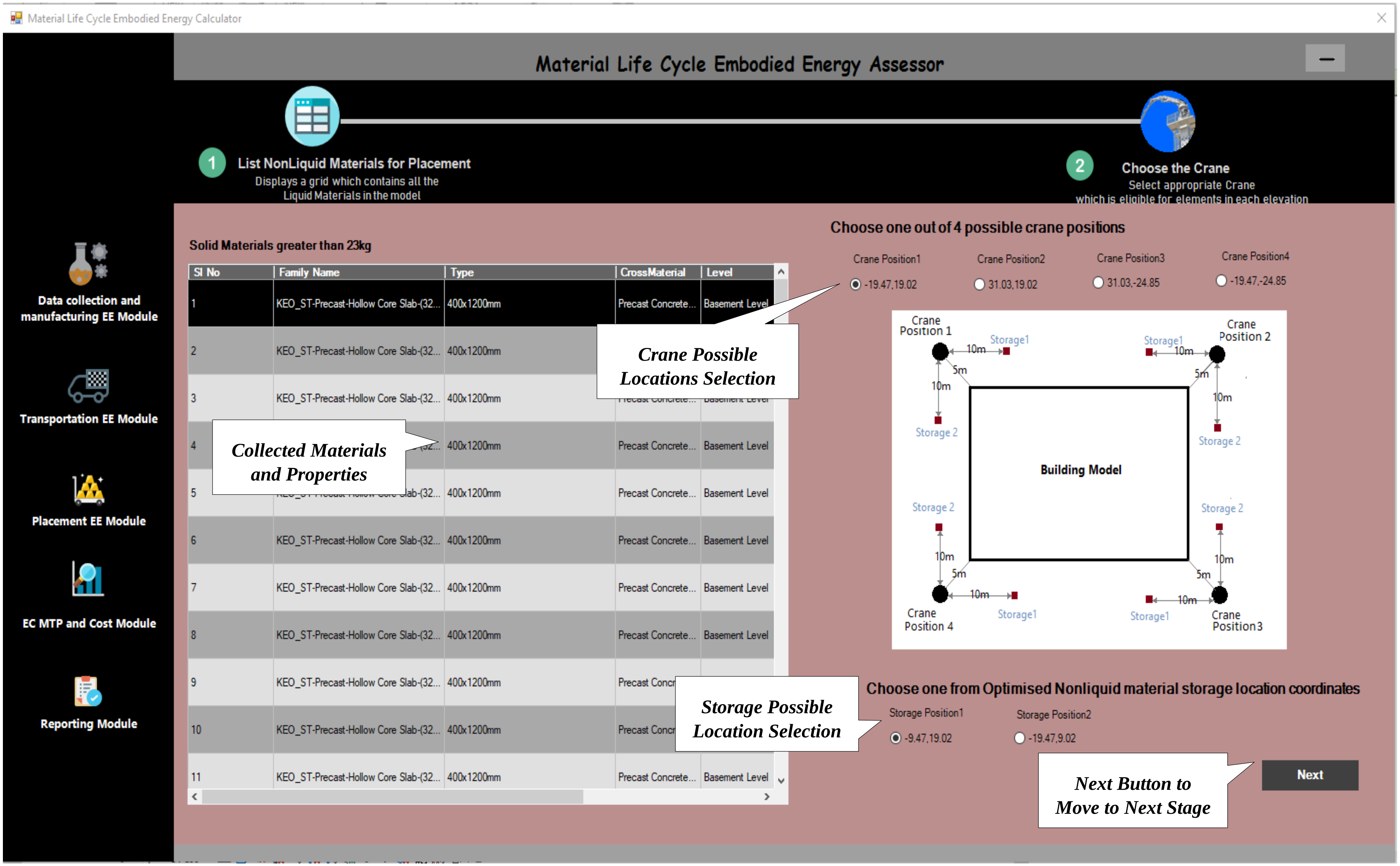


Figure 4-28: Solid Material EE Placement Assessment Module Initial Platform Screen

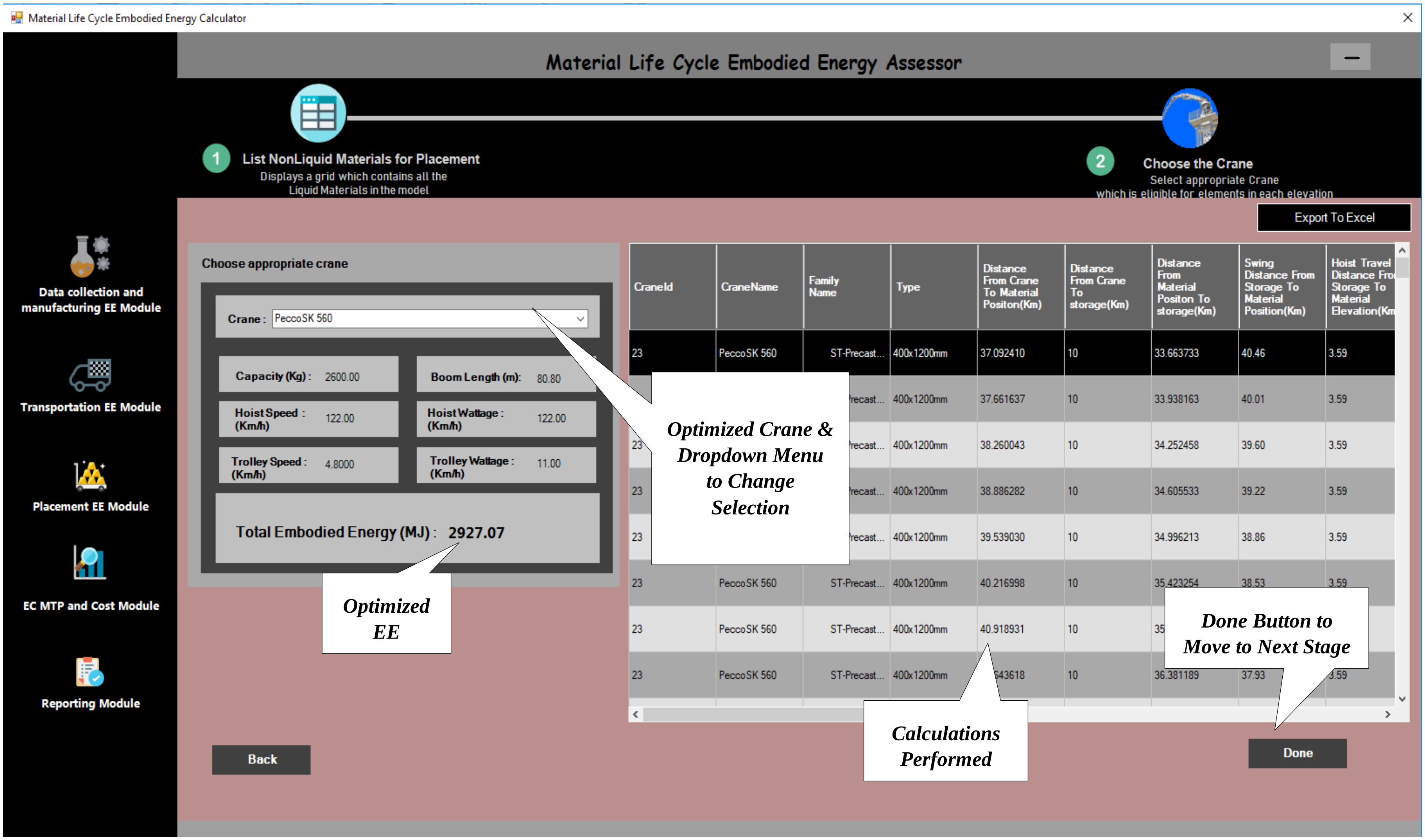


Figure 4-29: Solid Material EE Placement Module Output

Once users are satisfied with the results, they can select the done button in which the user is returned to the main placement form as displayed in Figure 4-30.

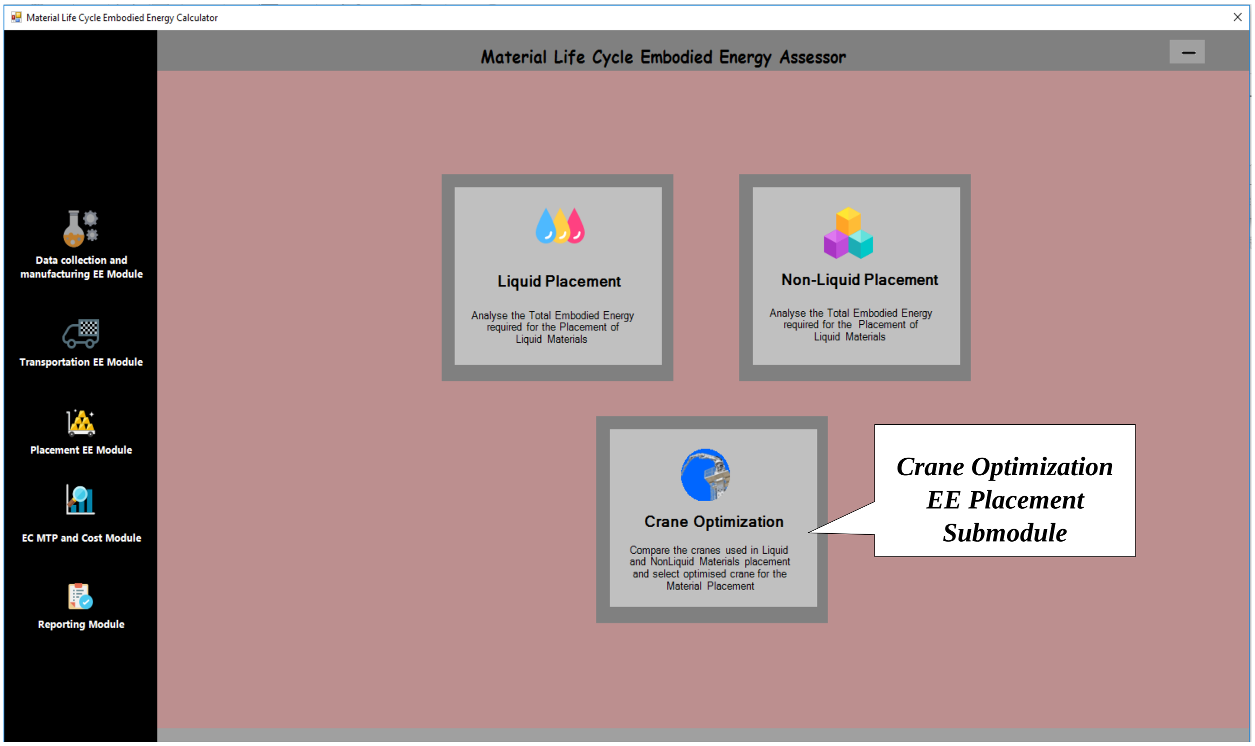


Figure 4-30: EE Calculation Modules Required the Processing for The Energy Required for Placing Materials in Their Intended Location Within Sites.

4.6.2.1 Crane Optimization EE Placement Submodule

As a final stage in calculating the total embodied energy for placing the materials, the model needs to identify the most optimized stationary crane from both the liquid and solid material stages. The most optimized crane from the liquid and solid placement stages may be different depending on the calculation for each stage. Additionally, using different cranes on the site is rather expensive and it is an ineffective practice. Such an activity tends to waste valuable time required for construction. To solve this issue, a platform submodule is created to identify a single energy efficient crane. This is placed as a submodule into the placement process tab.

To reach this process users select the crane optimization submodule as shown in Figure 4-30. Once selected, a screen is shown to analyze the selections. The selection is based on two options: the crane identified as the most energy efficient in the placement modules and the crane that is the most energy efficient from the solid material placement module. If users opt to change those selections from the dropdown selection menus, the selected cranes will be selected. Figure 4-31 displays a screenshot of the analysis output. The model selects the crane with the least energy consumption and presents it to users as the best option to be used during the construction process. Overall, the embodied energy is recalculated for each stage that requires the crane and the results are displayed to users. It is worth mentioning that if the least energy consumption method from the liquid placement EE modules does not involve cranes, then the optimized crane for the calculation is the one selected from the solid material EE placement module. Once this stage is completed users need to select the EC MTP and Cost Module to move to the next processing stage

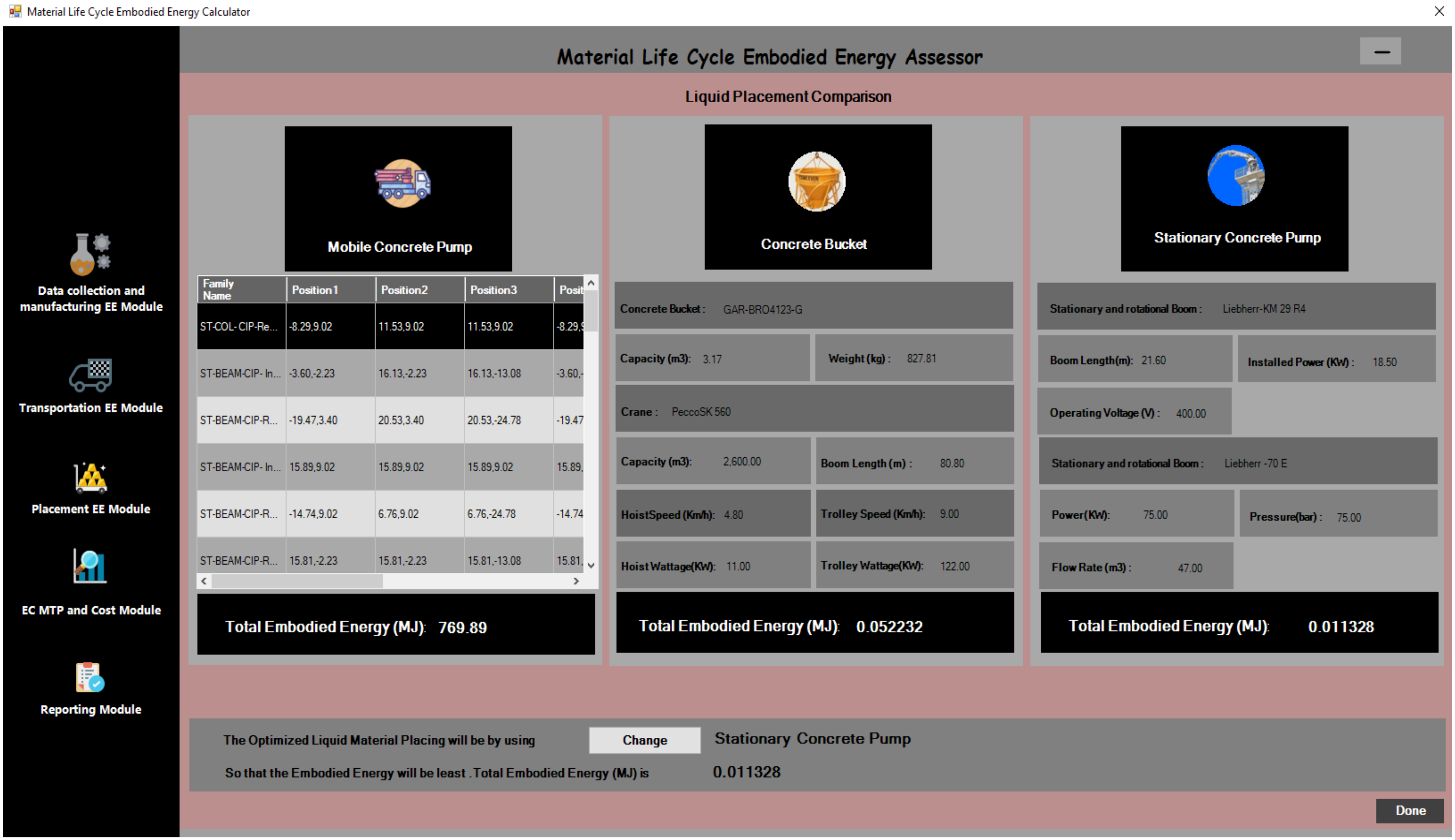


Figure 4-31: Crane Optimization Analysis Output Screen

4.7 Developing the EC MTP and Cost Calculation Module

In order to calculate the EC and Environmental costs required for manufacturing, transporting, and placing, the EC MTP and Cost module tab is developed. Since this module is created to target three modules (The Manufacturing EC & Carbon Costs Calculation Module, The Transportation EC & Carbon Costs Calculation Module, and The Placement EC & Carbon Costs Calculation Module), three submodules are developed within the EC MTP and Cost module. Those are the Manufacturing EC and cost analysis submodule, Transportation EC and Cost Analysis submodule, and the Placement EC and Cost Analysis submodule. Once the EC MTP and Cost module is selected, users are presented with a platform screen that displays all the submodules that users need to use. Figure 4-32 displays these modules. Furthermore, at that stage users need to identify the social carbon cost as identified by the natural resources department for the year at which the model is run. Once this value is inputted, users select and process the submodules embedded into the EC MTP and Cost module.

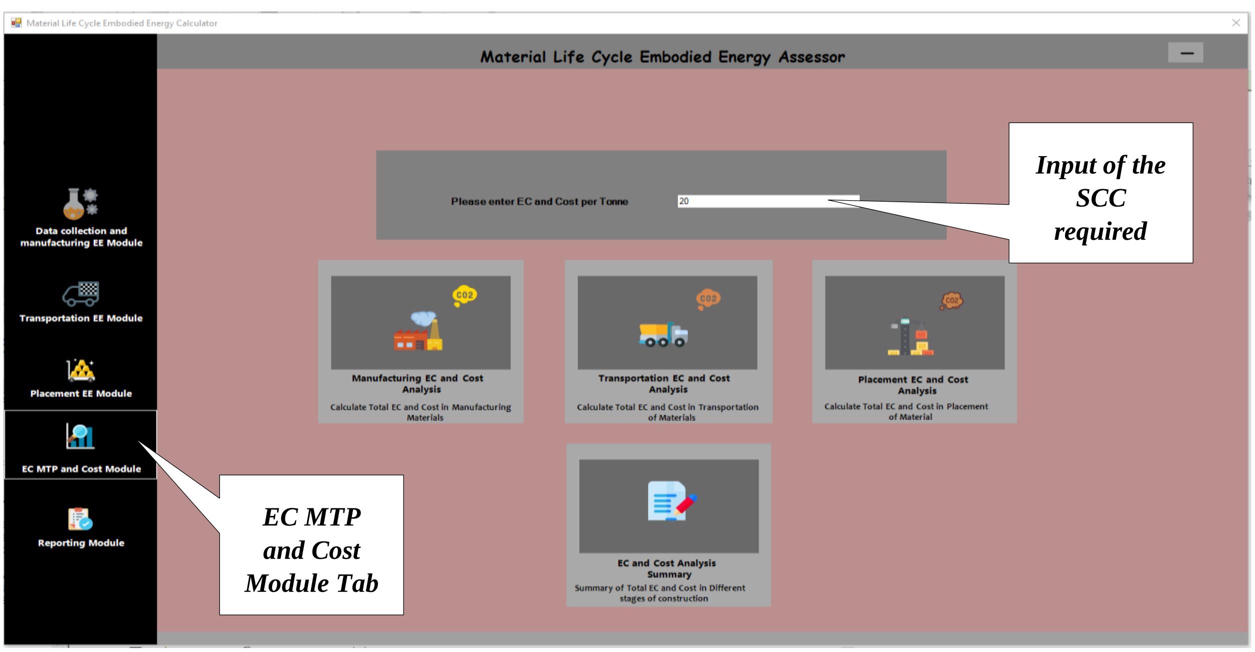


Figure 4-32: EC MTP and Cost Sub modules

4.7.1 Manufacturing EC and Cost Analysis Submodule

First, the EC and total social carbon cost from the manufacturing stage needs to be calculated. This includes both liquid and solid materials. Once users select the Manufacturing EC and cost analysis submodule, the model collects all the materials included in the BIM design model. Based on the identified materials and based on the selections from the manufacturing EE calculation stages, the total EC is calculated. The model connects to the cradle to gate EC emissions database. From the manufacturing EE calculation stages, each material that is part of the BIM design model is linked to a corresponding material from the database and then the model determines the unit carbon produced by each material. In this submodule, a platform screen is created to show the total embodied carbon produced by manufacturing each material as well as the total EC produced. Based on the total EC, the total cost is displayed to users. Figure 4-33 displays the created platform for this process. Moving to the next stage is attained by using the done button so users return to the initial platform screen as displayed in Figure 4-32. Once selected users will need to select the Transportation EC and Cost Analysis.

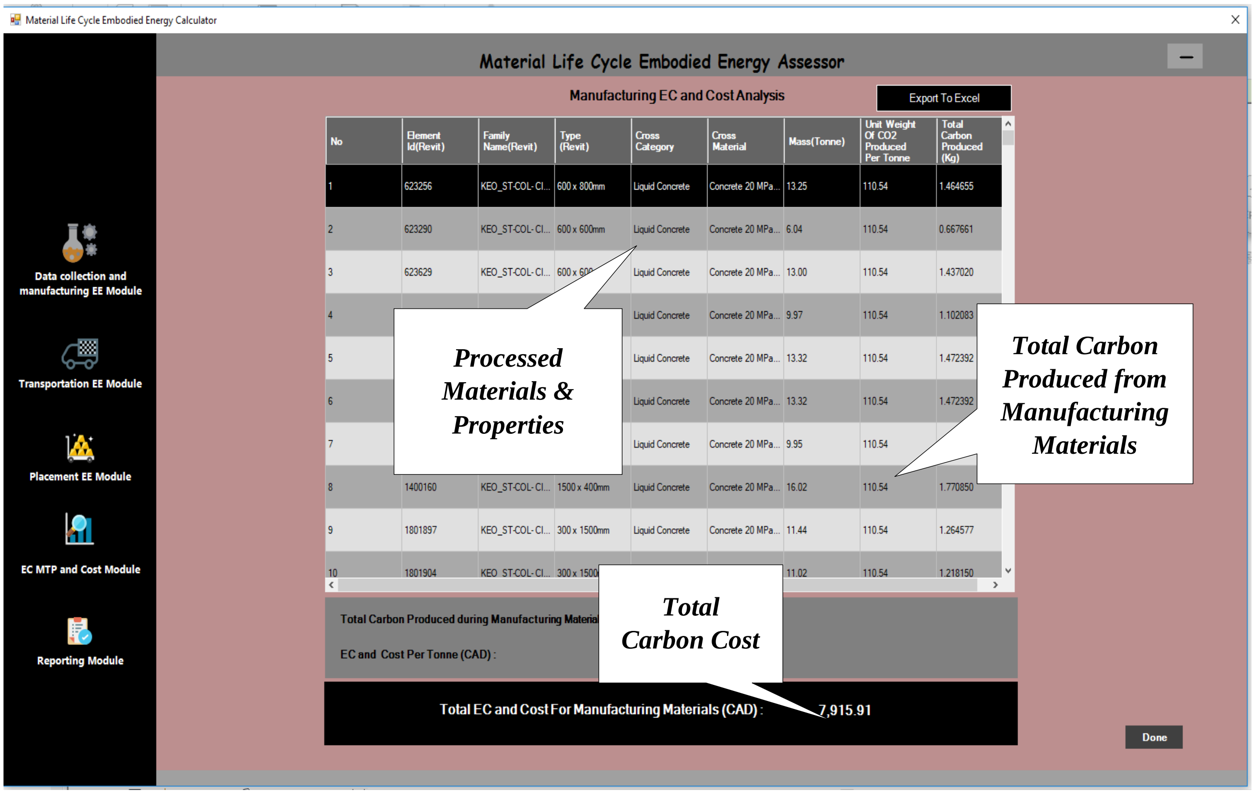


Figure 4-33: Manufacturing EC and Costs Assessment Platform

4.7.2 Transportation EC and Cost Analysis Submodule:

In order to calculate the EC and Environmental costs required for transportation, two submodules are created, which include the liquid material transportation EC and cost submodule and the Solid Material Transportation EC and cost module. Once the Transportation EC and Cost Analysis is selected, a platform screen is presented to users from which they select the processing submodules. The platform screen is presented in Figure 4-34. Users need to process both submodules to move to the placement EC and cost submodule.

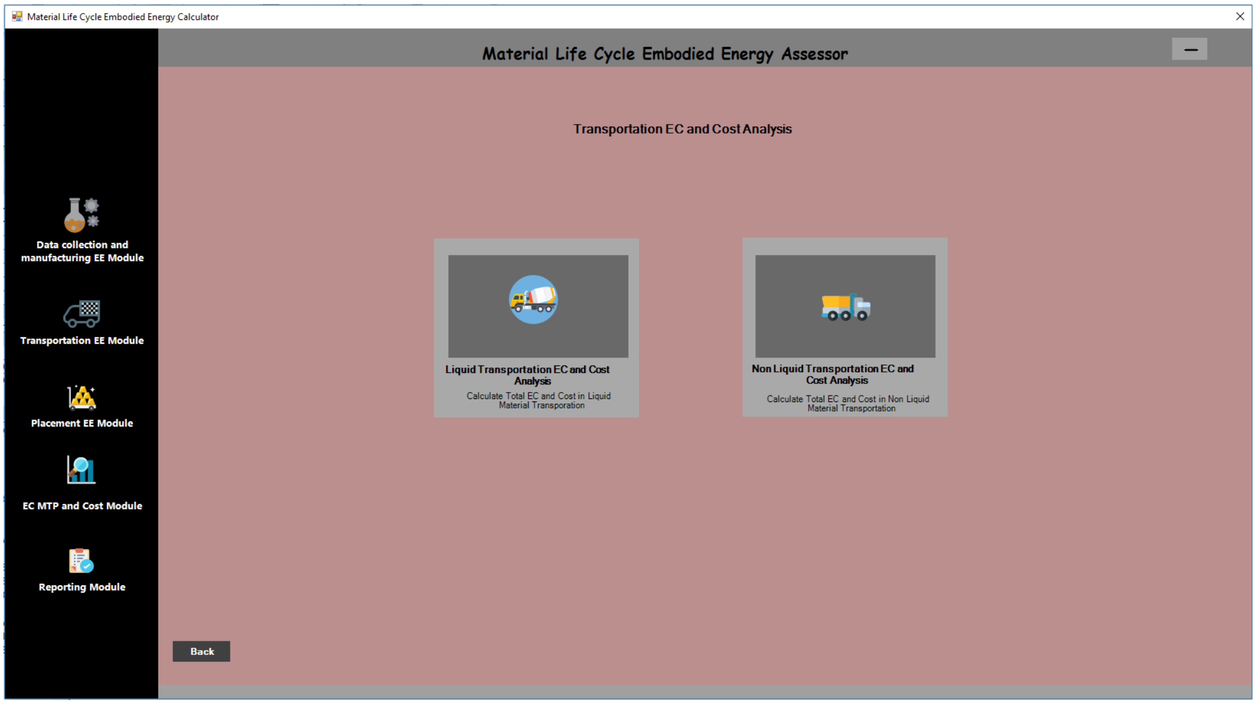


Figure 4-34: Transportation EC and Costs Submodules

4.7.2.1 Liquid Material Transportation EC and Cost Analysis Submodule

To start, the liquid material transportation EC and cost analysis submodule needs to be selected. Once selected, a new platform window appears allowing users to identify the embodied carbon and environmental cost requirements for transporting liquid materials. In the liquid material EE transportation module, the transportation methods have been optimized. The selected vehicles from the EE calculation stages are used to identify the EC and costs. In the created platform, as shown in Figure 4-35, the model uses the equation 3-2 identified in chapter 3 to calculate the EC based on the fuel used and the travel distances required to transport the liquid materials. The model shows the EC for each liquid material group and finally the total SCC that is required for such transportation. The materials that are processed in the transportation EE assessment stage are considered for the EC and cost assessment. For users to move to the next stage, they have to select the done button which will return them to the main Transportation EC and Cost Analysis screen.

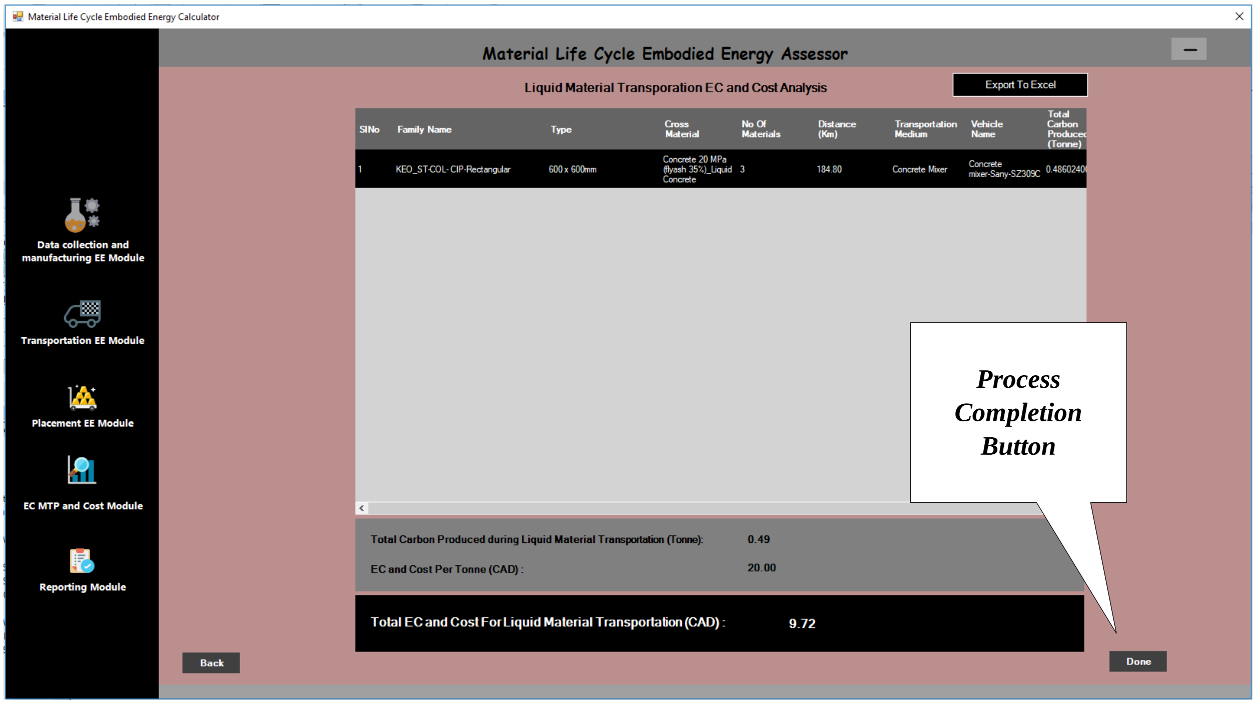


Figure 4-35: Liquid Material EC and Costs Assessment Platform for Transportation

4.7.2.2 Solid Material Transportation EC and Cost Analysis Submodule

Once the liquid material transportation EC and cost analysis submodule is completed, users need to identify the embodied carbon and environmental costs requirements for transporting solid materials. To accommodate such process, a platform screen is created to facilitate this process. Figure 4-36 displays this screen. In the solid EE transportation calculation module, the transportation methods have been optimized. The selected vehicles from the EE calculation stages is used to identify the EC and costs. In the created platform, as shown in Figure 4-36, the model will use the equation 3-21 identified in the chapter 3 to calculate the EC based on fuel usage and travel distances required by vehicles to transport the materials transportation.

Overall, the selected vehicle for each material may be either trucks or haulers depending on the user’s selection. At this stage, the model shows the EC required for each solid material group and finally the total SCC required for such transportation. Users can move to the next stage, by clicking on the done button, which is created to allow users to return to the main Transportation EC and Cost Analysis screen. Once all transportation EC and costs are completed, the done button has to be clicked so users return back to the main EC MTO and Cost Module screen as shown in Figure 4-32. At this stage, users are required to select the Placement EC and Cost Analysis submodule to proceed to the next stage.

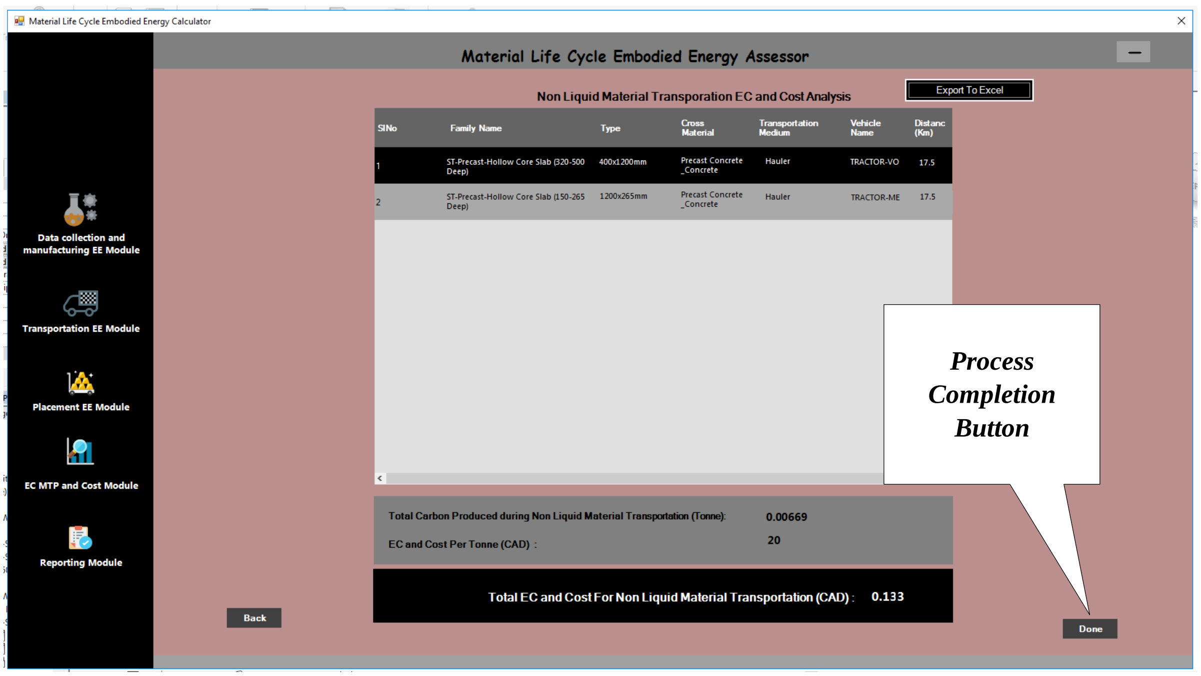


Figure 4-36: Solid Material EC and Costs Assessment Platform for Transportation

4.7.3 Placement EC and Cost Analysis Submodule

In order to calculate the EC and Environmental costs required for placing the materials, two submodules are created, which include the liquid material placement EC and cost submodule and the Solid material placement EC and cost module. Once the placement EC and Cost Analysis is selected, a new platform screen is presented to users from they can select the processing submodule. The platform screen is presented in Figure 4-37. Users need to use both submodules to move to the total EC and cost summary submodule. Once the Placement EC and Cost Analysis Submodule is selected the created platform is presented to users.

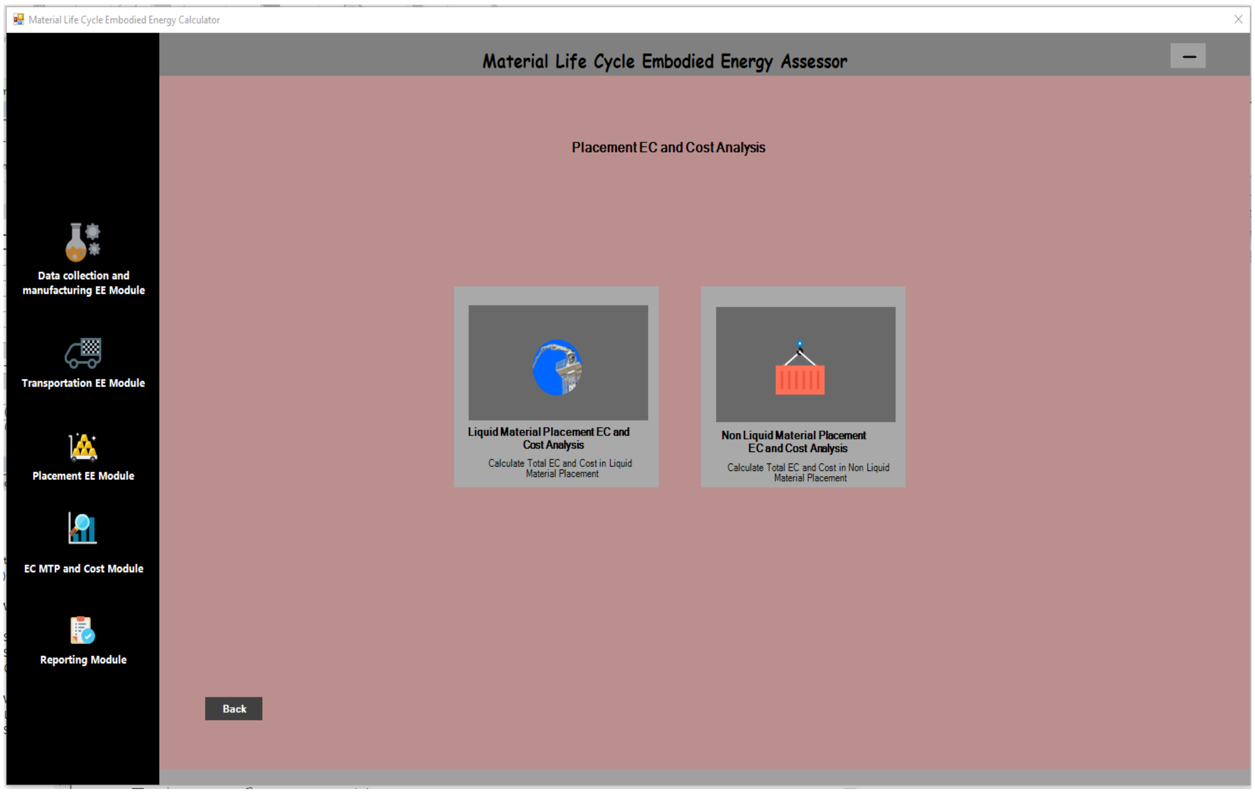


Figure 4-37: EC and Costs Assessment Submodules for Placing Materials

4.7.3.1 Liquid Material Placement EC and Cost Analysis Submodule

It is important to calculate the EC and environmental costs produced from placing the liquid materials. Users need to select such process to calculate those values. Once the liquid material placement EC and cost analysis submodule is selected, a new created platform will appear allowing users to calculate the liquid material EC and cost produced from placing the material.

This platform is shown in Figure 4-38. From the EE liquid material placement calculation module, the placement methods and equipment have been optimized and selected. The selected machines from the EE calculation stages are used to place the liquid materials and in return the model uses those to identify the EC and costs. In the created platform, as shown in Figure 4-38, the model will use the equations identified in chapter 3 to calculate the EC based on the fuel and electrical usage which are calculated in the EE calculation stages. Those are equations 3-22; 3-23;3-24. Furthermore, the travel distances required for moving a material from its storage location to its intended location is considered. Overall, at this stage, the model shows the EC required for each group of liquid material and finally the total SCC required for their placement. Users can move to the next stage by clicking on the done button that will return them to the main Placement EC and Cost Analysis screen. At this stage users are required to select the solid material Placement EC and Cost Analysis submodule to proceed to the next stage.

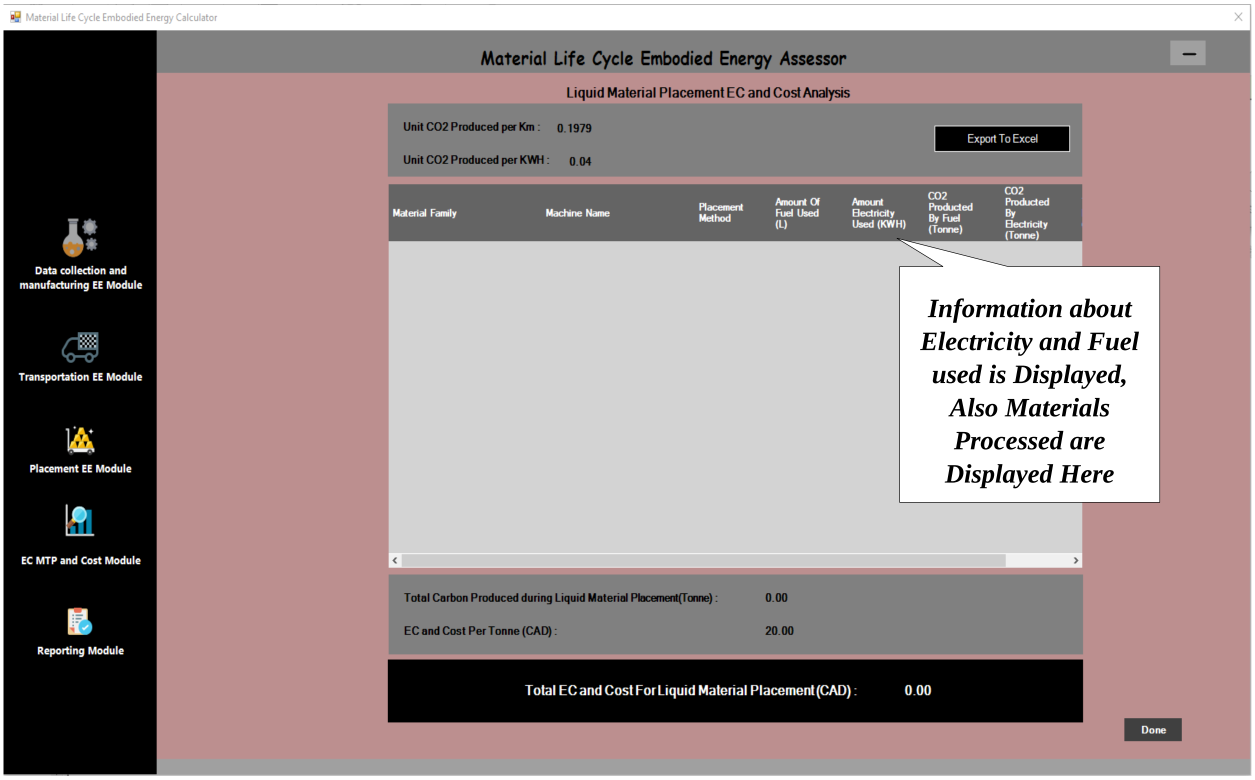


Figure 4-38: Liquid Material EC and Costs Assessment Platform for Placement

4.7.3.1 Solid Material Placement EC and Cost Analysis Submodule

To calculate the EC and environmental costs produced from placing solid materials, a new submodule is created. To access this process, users need to select the Solid Material Placement EC and Cost Analysis Submodule embedded in the Placement EC and Cost Analysis Submodule. Once the newly created platform appears, users are able to see the value of the solid material EC and cost produced from the material's placement. This platform is shown in Figure 4-39. Again, from EE solid material placement calculation module, the placement methods and equipment have been optimized and selected. The selected machines from the EE calculation stages are used as the machines needed to place solid materials and in return the model uses those to identify the EC and costs. In the created platform, as shown in Figure

4-39, the model uses equations 3-23 and 3-24 identified in the chapter 3 to calculate the EC based on fuel and electrical usage calculated from the EE calculation stages. Furthermore, the travel distances required for moving a material from its storage location to its intended location is considered. At this stage, the model shows the EC required for each group of solid material group and finally the total SCC required for such placement. Since a combination of energy sources are used, EC carbon produced from electricity and fuel usage are identified. Users can move to the next stage, by clicking on the done button that will return them to the main Placement EC and Cost Analysis screen. As a subsequent step, users are required to select the EC and cost summary sub module to move to the next processing stage.

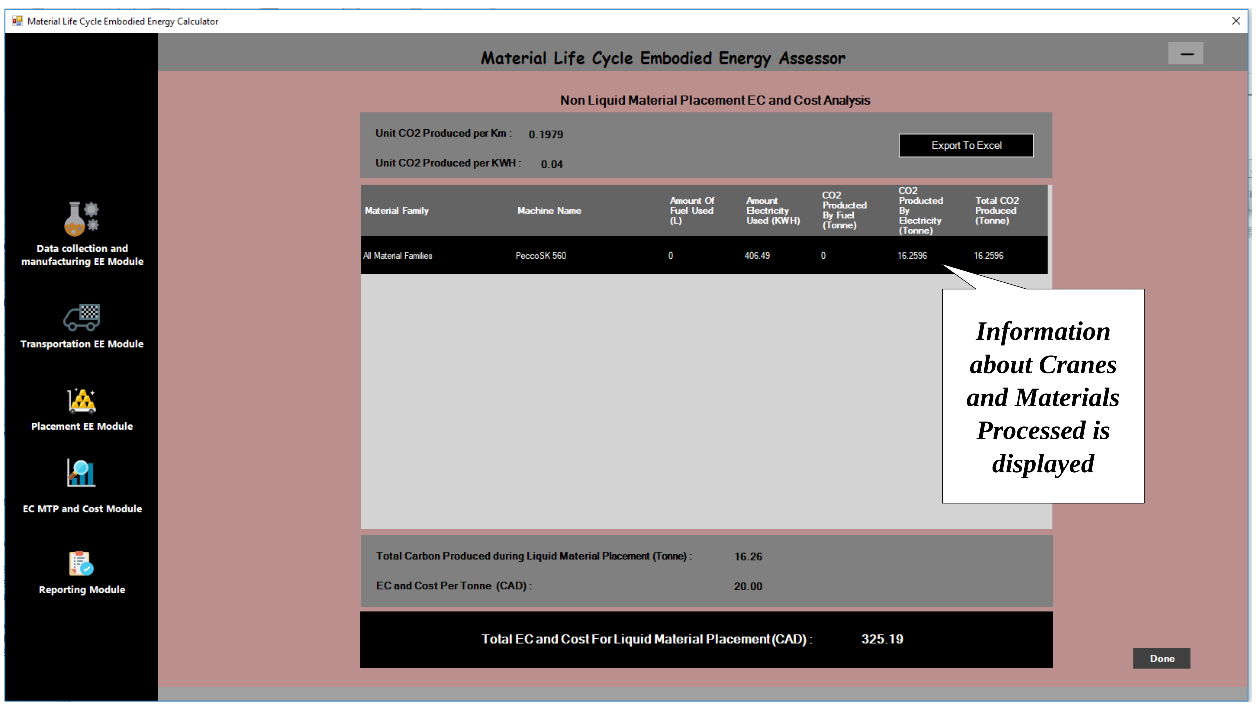


Figure 4-39: Solid Material EC and Costs Assessment Platform for Placement

4.7.4 EC and Cost Analysis Summary Submodule

Once all the EC and costs have been analyzed for the manufacturing, transporting and placing stages, it became apparent that a summary screen is required to display an overview of the values presented for the completed EC MTP and cost module tab. With such consideration, a new screen is created to show the total EC produced from this tab. Once users complete the processing of all EC and costs analysis, they can select the summary EC and cost analysis submodule as presented in Figure 4-32. Additionally, when selected, a new platform screen is shown as displayed in Figure 4-40. Overall, this screen will show a summary that indicates the EC produced from the machines, vehicles and equipment used for manufacturing transporting and placing along with the social carbon cost required based on the embodied carbon produced by each stage. The total carbon costs required for the construction of the full project are also displayed.

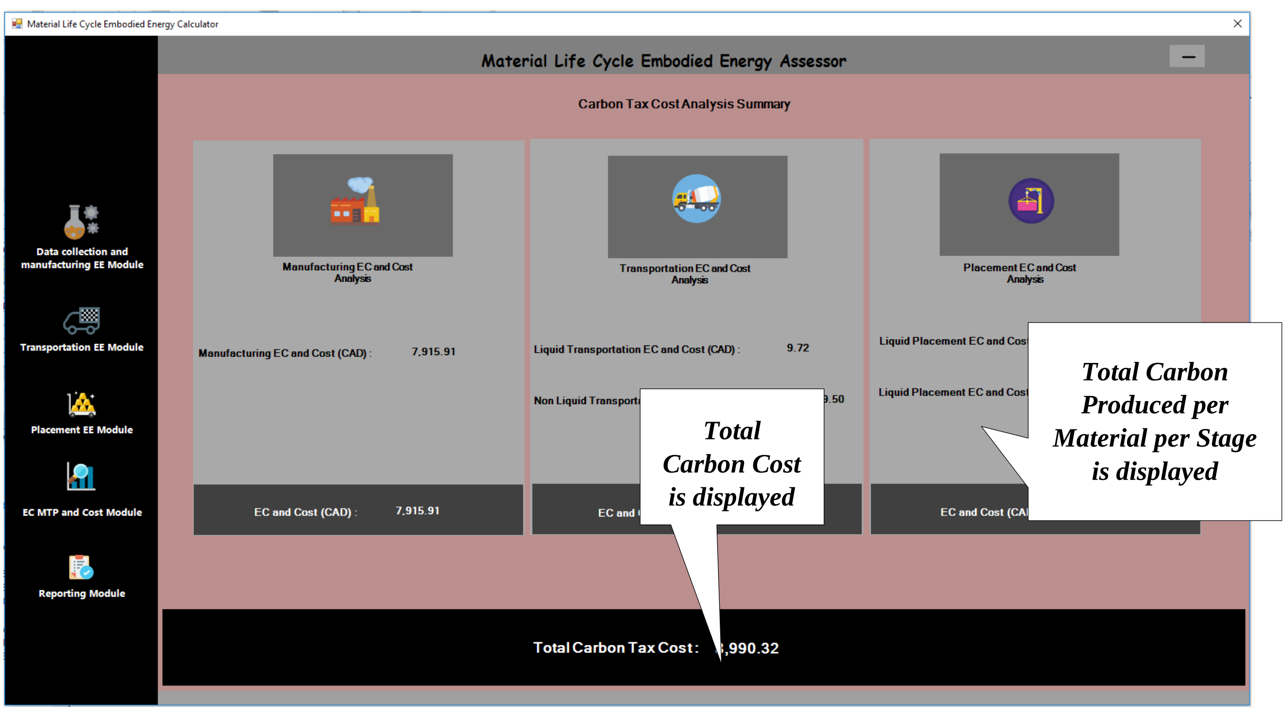


Figure 4-40: Summary EC and Cost Analysis Sub Module Output

4.8 Developing the Reporting Module

After all the processing stages are completed, the final stage is to display summaries and reports for all those stages. which include the EE, EC and costs for all manufacturing, transportation and placement stages for both solid and liquid materials. For that a reporting module tab is created. Once the EC and Cost Analysis summary sub module is completed, users can move to the Reporting Module by selecting the Reporting Module tab. Once the reporting module tab is selected, a new form is developed, which appears within the model. This is shown in Figure 4-41. Overall, this page will show the total EE required for manufacturing, transporting and placing the solid and liquid materials based on the optimized construction methods and equipment. Furthermore, the total EC required for manufacturing, transporting and placing for the combined solid and liquid materials based on the optimized construction methods and equipment are shown. Since exporting tables that contain information presented at each stage is important, two buttons are created, which are the "Export Embodied Energy Summary in Excel" and the "Export EC and EC and Cost Summary in Excel Button." When selecting the "Export Embodied Energy Summary in Excel," the model generates a set of summary reports for the EE stages. Overall, thirteen excel files are created. One for each sub process performed in the model for EE computation stages. Those include EE processing for manufacturing, transporting, and placing for both liquid and solid materials along with the EC and carbon cost assessments for both liquid and solid materials. In each, all the information shown in the model pages is displayed in a table format. Additionally, bar charts graphs are created into each excel file, showing the EE per material per used equipment. All excel files are created as CVS excel files. If users opts to change any of the selected machines, equipment or vehicles, that change will be considered in the calculation and the summaries are regenerated and presented based on the new selections. In case the crane usage needs to be optimized, the cranes that are suitable for all stages in which the least energy consumption is considered and thus the reporting module shows the data based on such optimization. When selecting the "Export EC and EC and Cost Summary in Excel" button, the model generates a set of summary reports for the EC and cost stages. Seven excel files are created; one for each subprocess performed for the EC and cost computation stages. Those include processing for manufacturing, transportation, and placement for both liquid and solid materials. All the information shown in the model forms are displayed in those files. For each file, a bar chart graph is created that shows the EC per material per equipment usage and the total EC cost per process. All machinery and equipment selections have been finalized in the EE stages and thus such selections are used for the summaries in the EC and cost reporting module. Figures 4-42 and 4-43 display a sample report produced in cvs format used by the model. It is worth mentioning, that, an "export to excel" button is created that allows users to export an individual report for the process at which users are currently working on.

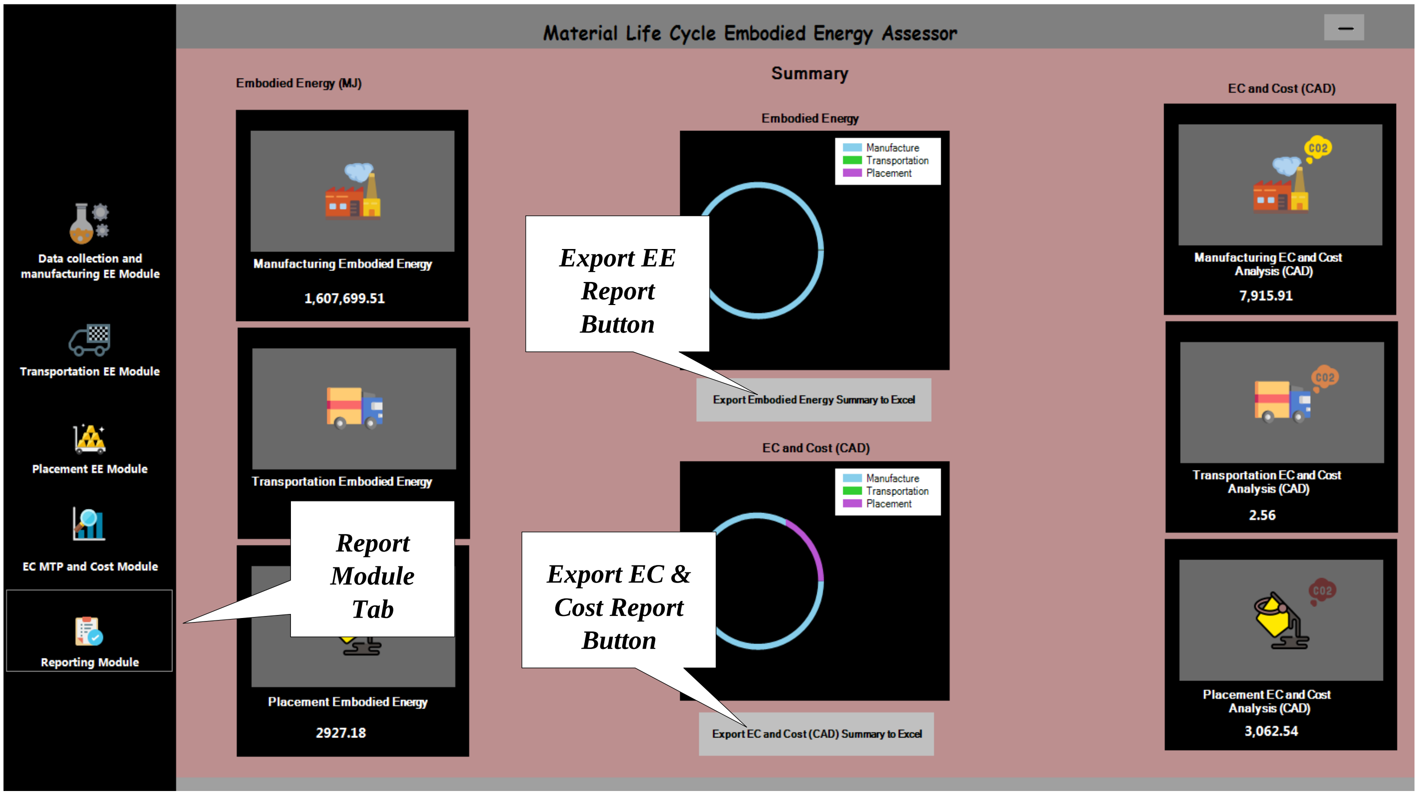


Figure 4-41: Reporting Module Output Platform

Family Name	Elevation	No of Materials	Position1	Position2	Position3	Position4	Concrete Mobile Pump Name	EE (MJ)
ST-COL- CIP-Rectangular	0.57	3	-8.29,9.02	11.53,9.02	11.53,9.02	-8.29,9.02	Schwing-S32X	123.61
ST-BEAM-CIP- Inverted Tee	3.42	18	-3.60, -2.23	16.13, -2.23	16.13, -13.08	-3.60, -13.08	Schwing-S32X	123.61
ST-BEAM-CIP-Rectangular	3.45	16	-19.47,3.40	20.53,3.40	20.53, -24.78	-19.47, -24.78	Schwing-S32X	123.61
ST-BEAM-CIP- Inverted Tee	3.27	1	15.89,9.02	15.89,9.02	15.89,9.02	15.89,9.02	Schwing-S32X	57.28
ST-BEAM-CIP-Rectangular	8.48	15	-14.74,9.02	6.76,9.02	6.76, -24.78	-14.74, -24.78	Schwing-S32X	57.28
ST-BEAM-CIP-Rectangular	8.25	2	15.81, -2.23	15.81, -2.23	15.81, -13.08	15.81, -13.08	Schwing-S32X	57.28
ST-BEAM-CIP- L Shape	8.54	2	17.36, -19.75	17.58, -19.75	17.58, -24.60	17.36, -24.60	Schwing-S32X	31.83
ST-BEAM-CIP- L Shape	8.34	5	1.61,3.40	20.46,3.40	20.46, -7.68	1.61, -7.68	Schwing-S32X	31.83
ST-BEAM-CIP- Inverted Tee	8.44	4	11.53, -16.23	11.53, -16.23	11.53, -16.23	11.53, -16.23	Schwing-S32X	31.83

Figure 4-42: Output Report Table Produced from the Liquid Material Using Concrete Pumps EE Assessment Stage

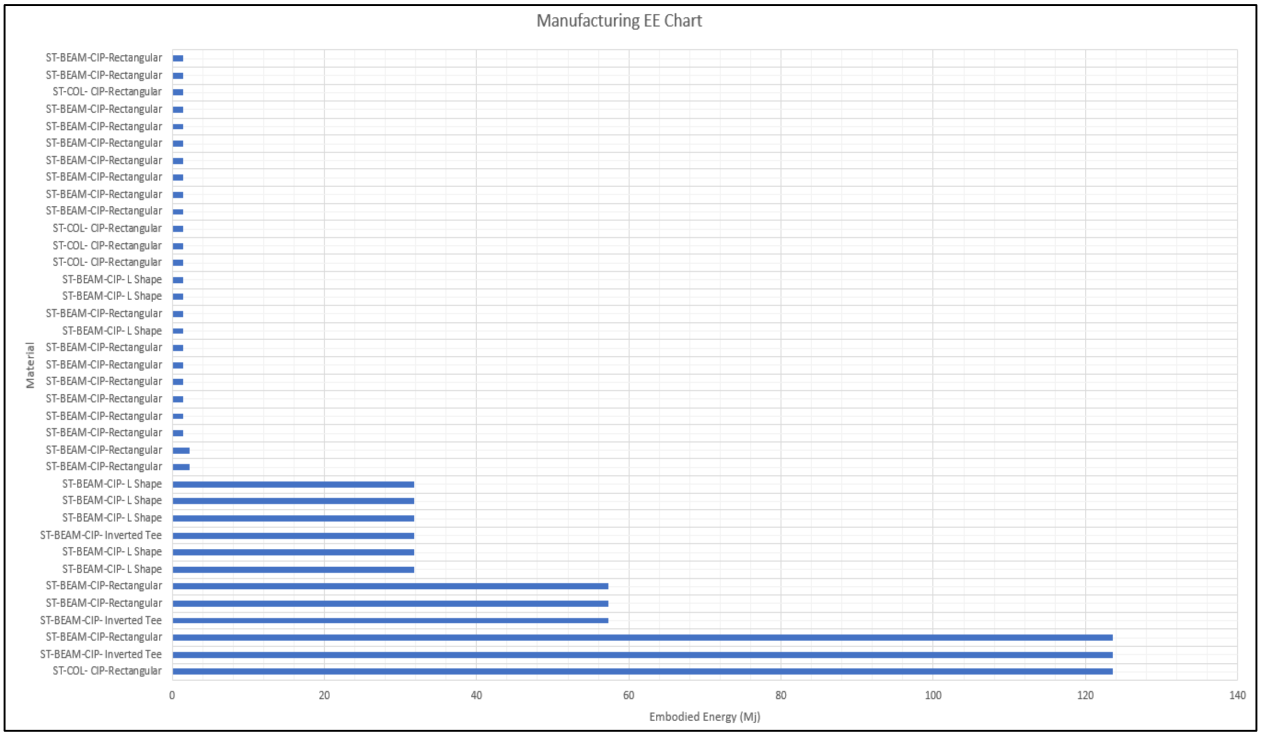


Figure 4-43: Output Report Graph from the Material Manufacturing EE Calculation Stage

4.9 Summary

This chapter presented an overview of the model's development. Overall, the model is used to calculate EE/EC and costs for cradle to end of construction boundary. Through the use of visual studio, an API model was created and embedded within the BIM tool (Revit). The created model connects to the created databases through a compatible sql server. Such capabilities allow for the model to extract and analyze the EE/EC and cost required by materials for any building. Furthermore, this chapter presented the multiple platform screens created for each stage of the model. Forms were created to calculate the EE for manufacturing, transporting and placing materials. Furthermore, additional forms were created to calculate EC and environmental costs required for manufacturing, transporting, and placing materials. Through every stage, considerations were given to the material type. Either being solid or liquid and hence different processing modules were created. Based on the method, machine, vehicle and equipment required by each material, the EE/EC and costs for every stage are processed separately. For every platform screen, the calculation capabilities are presented, and an explanation of the process flow along with the selection capabilities of the model is displayed. Once the processing and selection of the EE/EC are complete, a series of output reports are presented based on the method, machine, vehicle and equipment selected by the model which accounts for changes by users.

Chapter Five

Model Testing

5.1 Introduction

This chapter presents the process used to test the model's capabilities. Due to the created methodology, it is difficult to compare the results of the developed model to other tools currently used to assess EE and EC. The quantification method is dependent on the manufacturing process, the vehicles used for transportation and furthermore the equipment used for placement. Additionally, the geographical locations of both the construction site and the manufacturing plant affect the quantification process. The currently used assessment tools disregard this fact. In light of this, the purpose of this chapter is to test the workability of the model in terms of input, output and the analysis performed by the model. To test the assessment of calculating the EE/EC and costs, a two-story residential apartment building is selected for that purpose. The building represents a preliminary structural design of a multipurpose building that will be built. The conceptual data is obtained from a well-known design consultancy firm operational in Canada. For the purpose of the model testing, a multiuse plot in downtown Ottawa is selected and the building is to be built for the year 2019. The preliminary data about the materials and the building dimensions are available. These were obtained from the design and build contractor handling the project. Overall, the proposed building gross area is 1,662.3 square meters with axis dimensions equal to 46.175 and 36 metres. The building is shown in Figure 5-1.

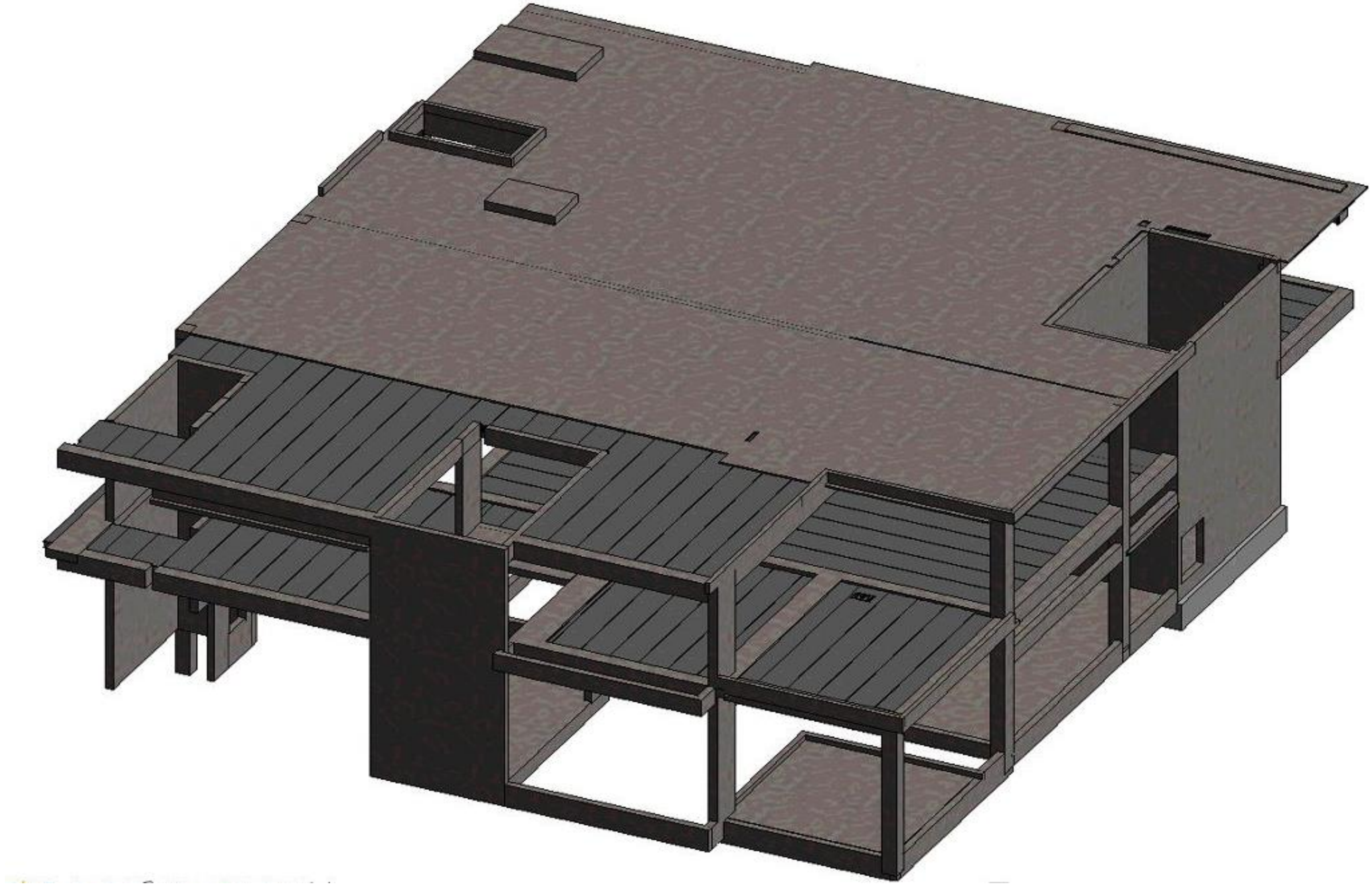


Figure 5-1: Proposed Building Model

To test the model, the process will involve two stages. The first involves comparing the model against the conceptual data available and the second involves simulating the EE/EC and its associated costs assessment through the developed model. The simulation involves checking the operational function of the model tool by verifying the google maps distance calculations and checking the ability of the tool to retrieve information from databases and process the correct information to calculate EE/EC and its associated environmental costs.

Since the model will attain information from the BIM design model, it is important to compare the available data to the data collected by the model. For the first stage, the data is available about the building size, the preliminary superstructure design components and the superstructure quantities that are being developed for this project. Prices are not available due to the confidentiality of such data. Figure 5-2 displays the available information for the model in a tabular format. The attained BIM design model contained elements for which information is not available. In lieu of this fact, the obtained model is modified to remove the elements for which information is not available.

		BILL OF QUANTITIES					BILL NO 2
ITEM REF	ITEM	Quantity	UNIT	Volume	UNIT	UNIT RATE	TOTAL PRICE
	SUPERSTRUCTURE						
	Reinforced concrete using ordinary portland cement,well punnedaround reinforcment bars between formwork						
A	Column Walls	10	#	50.47	m3	N/A	N/A
B	Beams	108	#	322.79	m3	N/A	N/A
C	Hollow Core Slab (256 -150)	41	#	19.4	m3	N/A	N/A
D	Hollow Core Slab (320-500)	131	#	247.49	m3	N/A	N/A

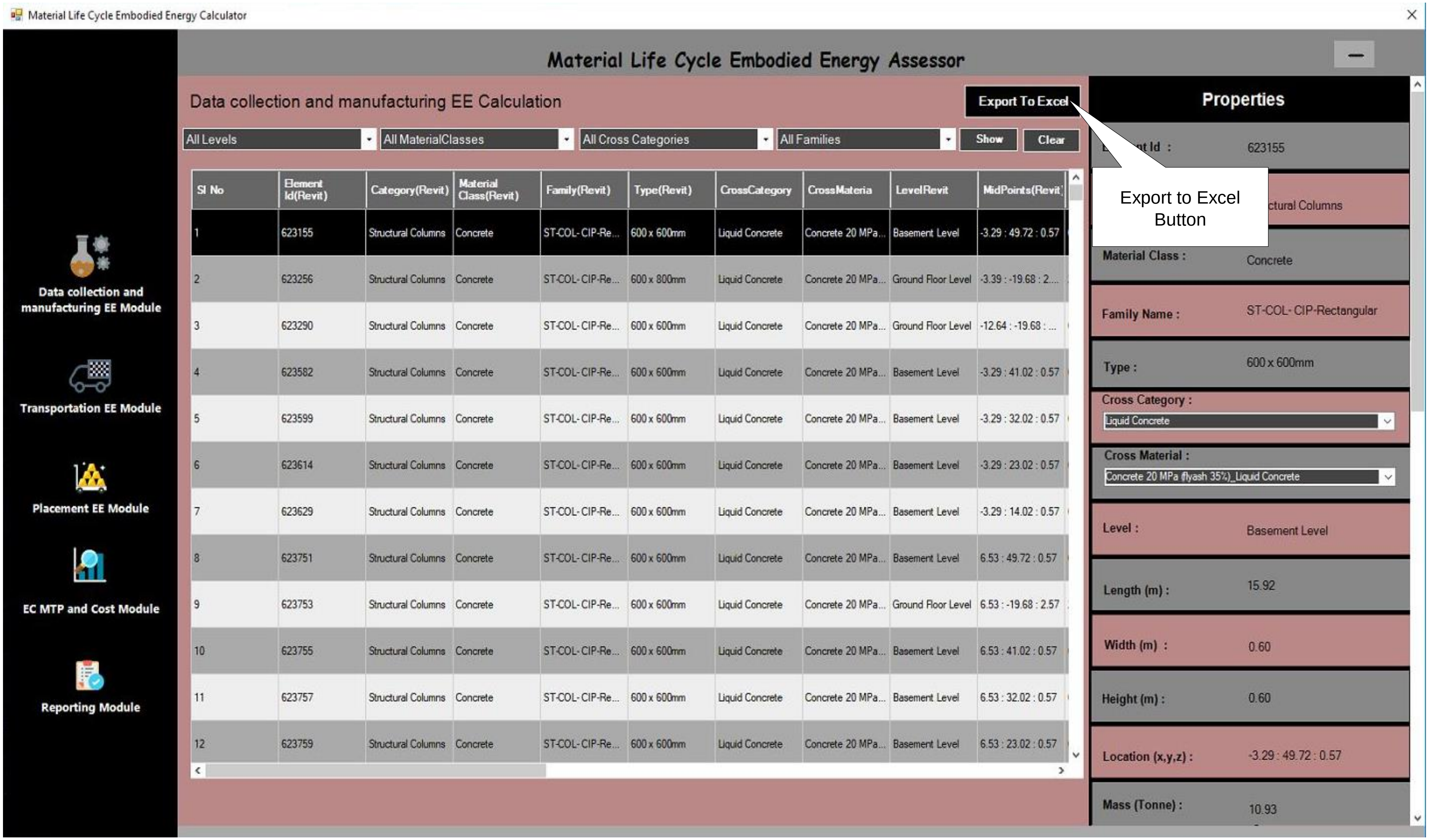
Figure 5-2: Preliminary Design Data Available

The concrete strengths and the type of the material are included the BIM design model. This includes information about whether the structural members are cast in situ or precast. Such information will enable the model to determine if the materials are considered solid or liquid.

5.2 Testing Process

To test the model, the BIM design file is imported into Revit. In Revit, the EE and EC evaluations are performed by running the developed model against the established BIM design. As an initial step, the model begins by extracting information about Element ID, Material Category, Material Class, Material Family, Material type, Material locations, and Material volumes. Figure 5-3 displays the materials collected from the design model. A total of 291 material elements are collected.

In order to validate the material collection process, values presented from the available data are compared to the total volume of materials extracted from the model. The total volume of concrete items collected from the model is 640.15 m^3. When compared to the obtained data, it is apparent that the model can collect all items available from the BIM design model. The materials extracted by the developed model are exported to excel and there the total volume of materials is identified. After the model collects information about the different materials available in the BIM design model, the model is required to connect each material to a corresponding item from the database. The model will automatically connect materials to the corresponding DB item using SQL server connection. As represented in chapter 4, a set of rules have been established for this connection. To verify the accuracy of the results, a visual



Sl No	Element Id(Revit)	Category(Revit)	Material Class(Revit)	Family(Revit)	Type(Revit)	CrossCategory	CrossMateria	LevelRevit	MidPoints(Revit)
1	623155	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 49.72 : 0.57
2	623256	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 800mm	Liquid Concrete	Concrete 20 MPa...	Ground Floor Level	-3.39 : -19.68 : 2...
3	623290	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Ground Floor Level	-12.64 : -19.68 : ...
4	623582	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 41.02 : 0.57
5	623599	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 32.02 : 0.57
6	623614	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 23.02 : 0.57
7	623629	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 14.02 : 0.57
8	623751	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 49.72 : 0.57
9	623753	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Ground Floor Level	6.53 : -19.68 : 2.57
10	623755	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 41.02 : 0.57
11	623757	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 32.02 : 0.57
12	623759	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 23.02 : 0.57

Figure 5-3: Data Collection from the Model

verification is performed to check if all items are linked to the correct corresponding material according to the set rules. Figure 5-4 shows the output connections created by the model. The reporting tables in the Appendix show the detailed output for the materials collected and the corresponding material each item is connected to. As a sample for visual verification, item 623256 is a cast in place structural column identified in the design model. According to the developed model, the item is identified as liquid concrete and is cross referenced to the material “Concrete 20 MPa”. This indicates that the correct cross referencing is done by the model.

Once all items are connected, the model runs through a set of phases to calculate EE, EC and costs for manufacturing, transportation, and placement. In the manufacturing stage, the EE required to create materials is determined. To start, the model begins by identifying the mass of each material extracted. To calculate the mass, equation 3-1 is used. To compute manufacturing EE, the amount of energy required by a single unit of material is multiplied by the total mass of elements present in the design model. The energy required to manufacture a single corresponding element is obtained from the manufacturing EE database. Accordingly, the total mass is multiplied by the energy and the model computes the total energy required to produce each element.

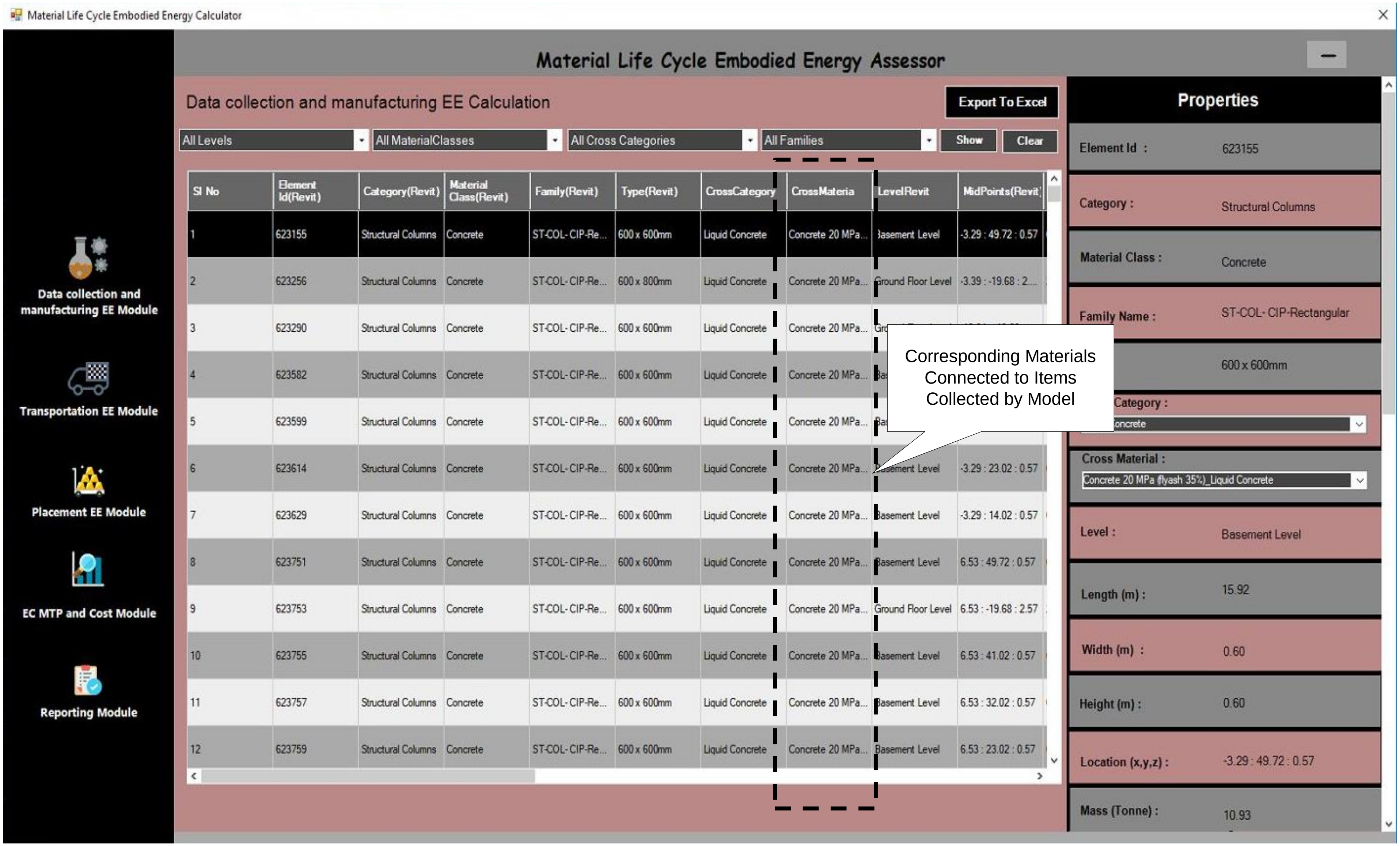
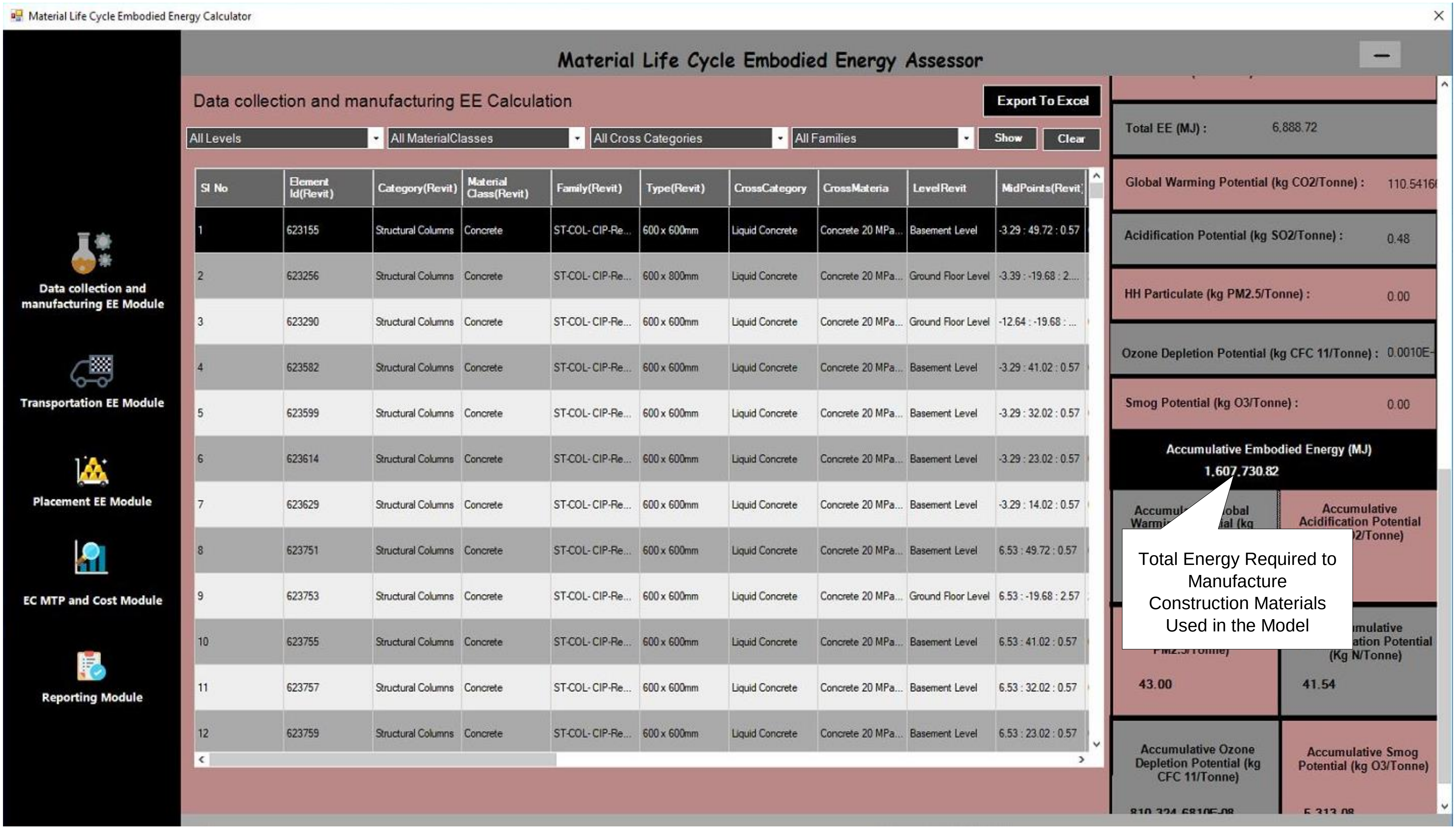


Figure 5-4: Connecting Collected Materials to corresponding Items by Model

Figure 5-5 shows the calculated energy output presented by the model. A summation of the energy required to produce each element leads to the energy required for the model. The total manufacturing EE for the design model is 1,607.73 GJ.

In order to verify the results, a manual check is done to test every material using the corresponding material from the inventory. The materials, volumes, and corresponding materials displayed in the developed model are exported into excel. Next, the density of each corresponding material is obtained from the manufacturing EE database. By multiplying the density and the volume, the mass of each material in the design model is calculated. Next, the energy required to manufacture the corresponding material identified by the developed model is noted in excel. By multiplying the energy and mass, the total energy required to manufacture elements presented in the model are calculated.

A sample calculation is shown in table 5-1 for a singular material element extracted from the model and the calculation process is executed in excel. As calculated, the total energy required to produce element 623256 is 8336.41 MJ. This value is correctly calculated by the model. A full list of the materials collected, their weights, and energy requirements are presented in the report produced by the model in the Appendix.



Sl No	Element Id(Revit)	Category(Revit)	Material Class(Revit)	Family(Revit)	Type(Revit)	CrossCategory	CrossMateria	LevelRevit	MidPoints(Revit)
1	623155	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 49.72 : 0.57
2	623256	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 800mm	Liquid Concrete	Concrete 20 MPa...	Ground Floor Level	-3.39 : -19.68 : 2....
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4	623582	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 41.02 : 0.57
5	623599	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 32.02 : 0.57
6	623614	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 23.02 : 0.57
7	623629	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	-3.29 : 14.02 : 0.57
8	623751	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 49.72 : 0.57
9	623753	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Ground Floor Level	6.53 : -19.68 : 2.57
10	623755	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 41.02 : 0.57
11	623757	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 32.02 : 0.57
12	623759	Structural Columns	Concrete	ST-COL- CIP-Re...	600 x 600mm	Liquid Concrete	Concrete 20 MPa...	Basement Level	6.53 : 23.02 : 0.57

Figure 5-5: Manufacturing EE Assessment Stage Output for Model

Table 5-1: Sample Element Manual Calculation Using Inventory Values

Element ID	**Material Classification**	**Cross Material from Inventory**	**Volume of Material from Revit Model (m^3)**	**Density for Material from Inventory (Ton/m3)**	**EE per unit mass of element from inventory (MJ/ton)**	**Mass of Material calculated (Ton)**	**Manufacturing EE material element (MJ)**
623256	Concrete	Concrete 20MPa	5.70	2.32	630.40	13.25	8336.41

Once the manufacturing EE module is complete, the model will move to the transportation stages. The model will begin at the concrete mixer EE calculation module. In the model, materials are initially classified as either liquid or solid materials. To verify the correct use of the filter within the model, a manual comparison is applied to check if all the liquid materials are collected. The total volume of liquid materials filtered from the model and the available conceptual data are compared. Figure 5-6 presents the material filter used by the model for the liquid transportation EE assessment stage.

Overall, the model will list all liquid materials in a grouped format. The remaining solid elements will be displayed in the solid transportation modules. These are the trucker and hauler modules which will be tested at a later stage in this chapter. All liquid materials will be transported using concrete mixers.

In the liquid material transportation EE assessment stage, the liquid materials of the same family and elevation are obtained. To check the accuracy of the data filtering process, the

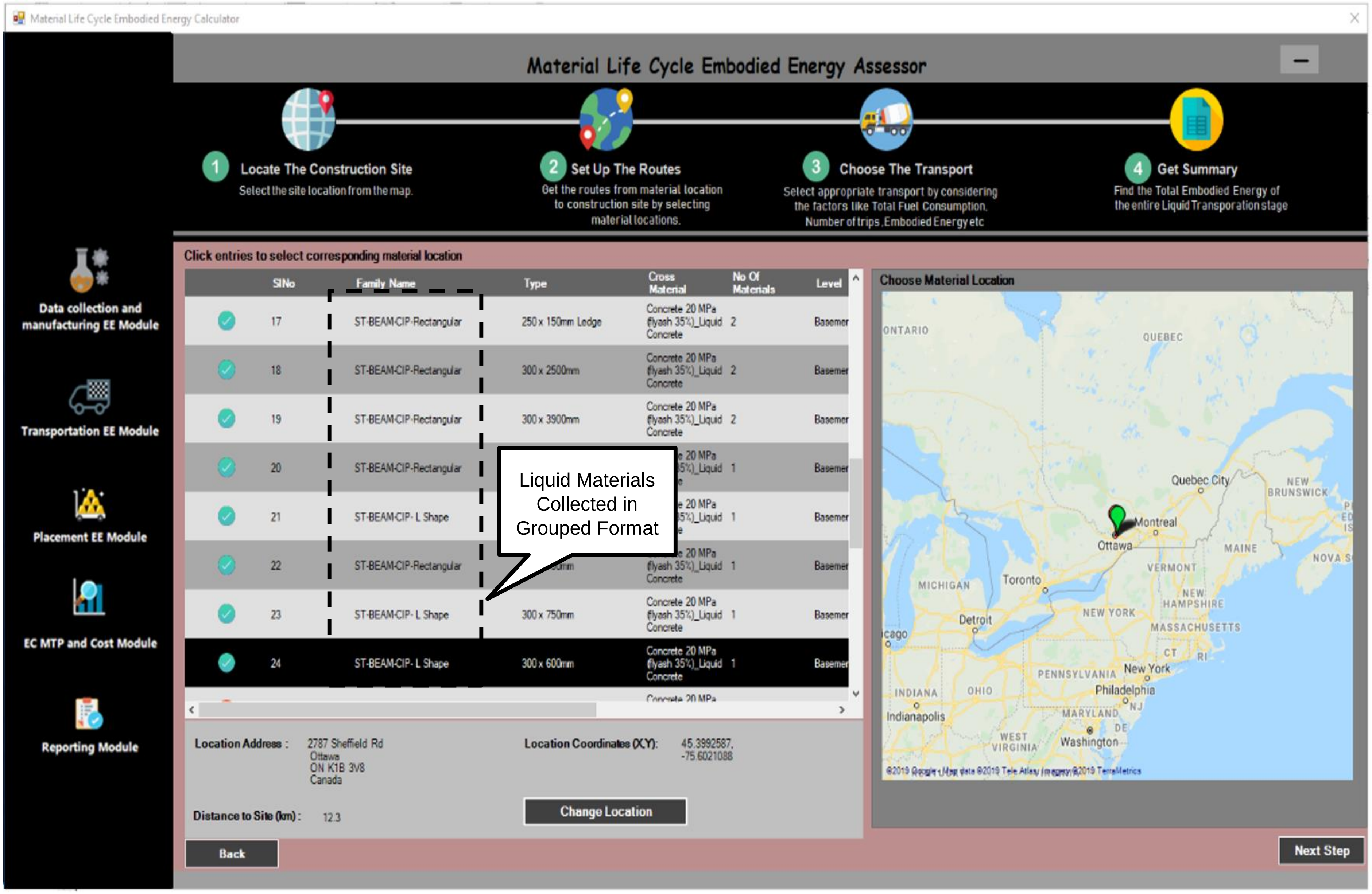

Figure 5-6: Transportation EE Assessment Material Collection Output from Model

liquid materials groups displayed in the model are exported into excel. Additionally, the volume of each grouped element is also exported. Accordingly, the summation of the total volume of materials collected is calculated in excel. The volume of materials collected by the model is 373.26 $m^{3.}$ This is the total amount presented by the available conceptual data and the computation using excel. The liquid materials from the preliminary available data are columns and beams. These elements will be casted in place and hence those are delivered to site in liquid form. The volumes from both the data and the model match indicating that all items have been accounted by the developed model for liquid materials.

In the liquid material transportation EE assessment stage, the distance between the concrete mixing facility and the site is required. This will allow for the calculation of the fuel usage which is required to calculate EE. To calculate the distance required to transport materials, the model will first connect to google maps. Since the proposed location of the new building is downtown Ottawa, the following postal code is used: K1N5A7. The closest cement batch plant is located at K1B3V8. For the design model, it is assumed that all liquid materials originate at a single source and hence the only distance required is the distance between the factory and site. To check the distance calculation tool within the model, values from google maps are compared to values produced from the model. From google maps, the distance between the construction site and the batch plant is identified as 11.2km. Figure 5-7 presents the values from google maps through the manual implementation.

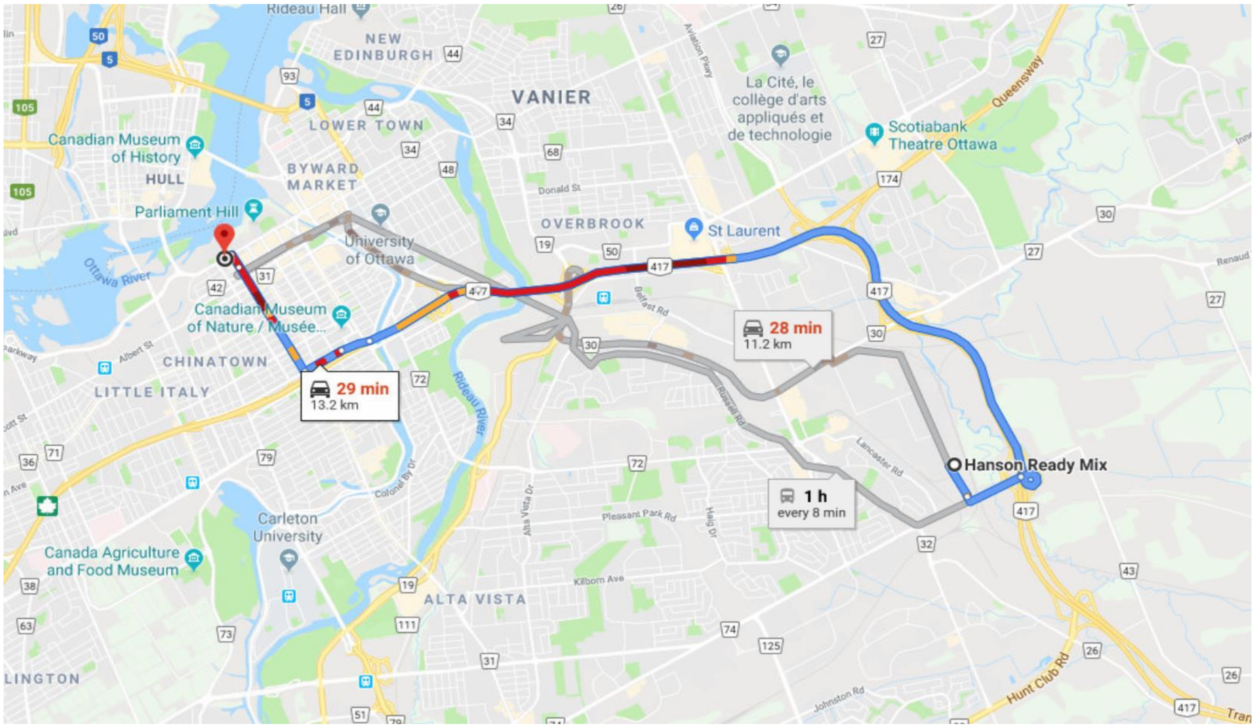

Figure 5-7: Google Maps Distance Verification

From the model, the distance is computed as 12.3km. Figure 5-8 presents the distance output using the model. In lieu of the above, it is conclusive that the distance measuring tool is sufficiently functional indicating that the distance calculator created for the model is functioning properly. The difference in the values is due to the approximation used in pinpointing the two locations (origin and destination). In the model user can select the locations by placing the cursor on a specific point on the map and hence Google maps will identify the closest addresses and determine the distances in between. The manual cursor selection was used in the testing of the model. While when trying to identify the distance between the origin and destination in Google maps, the location was entered by using the addresses and in such regards the distance is slightly different. Once the distances are verified, the model determines the concrete mixers that can transport each grouped item. Accordingly,

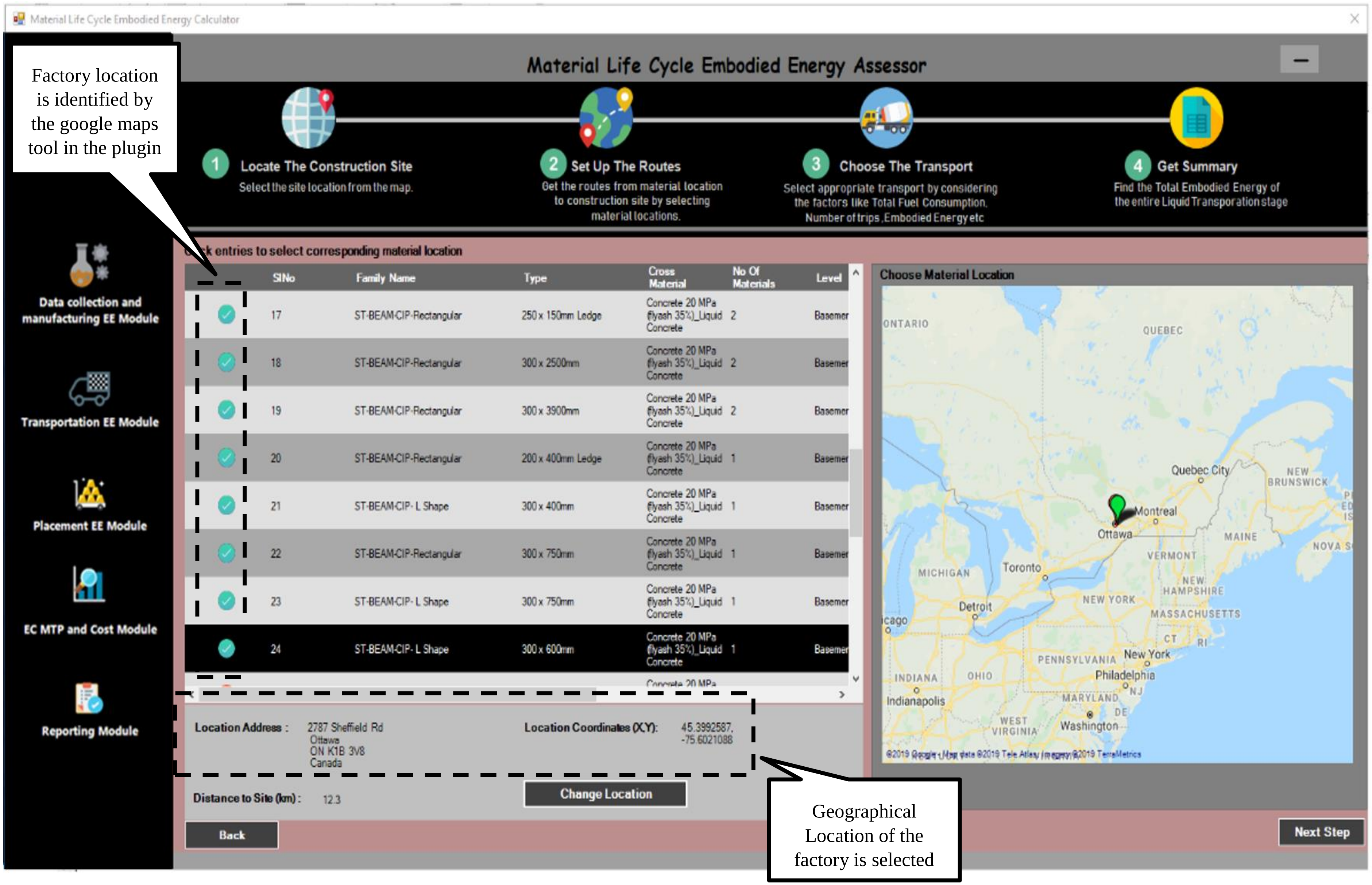

Figure 5-8: Model Origin Verification for Concrete Mixers

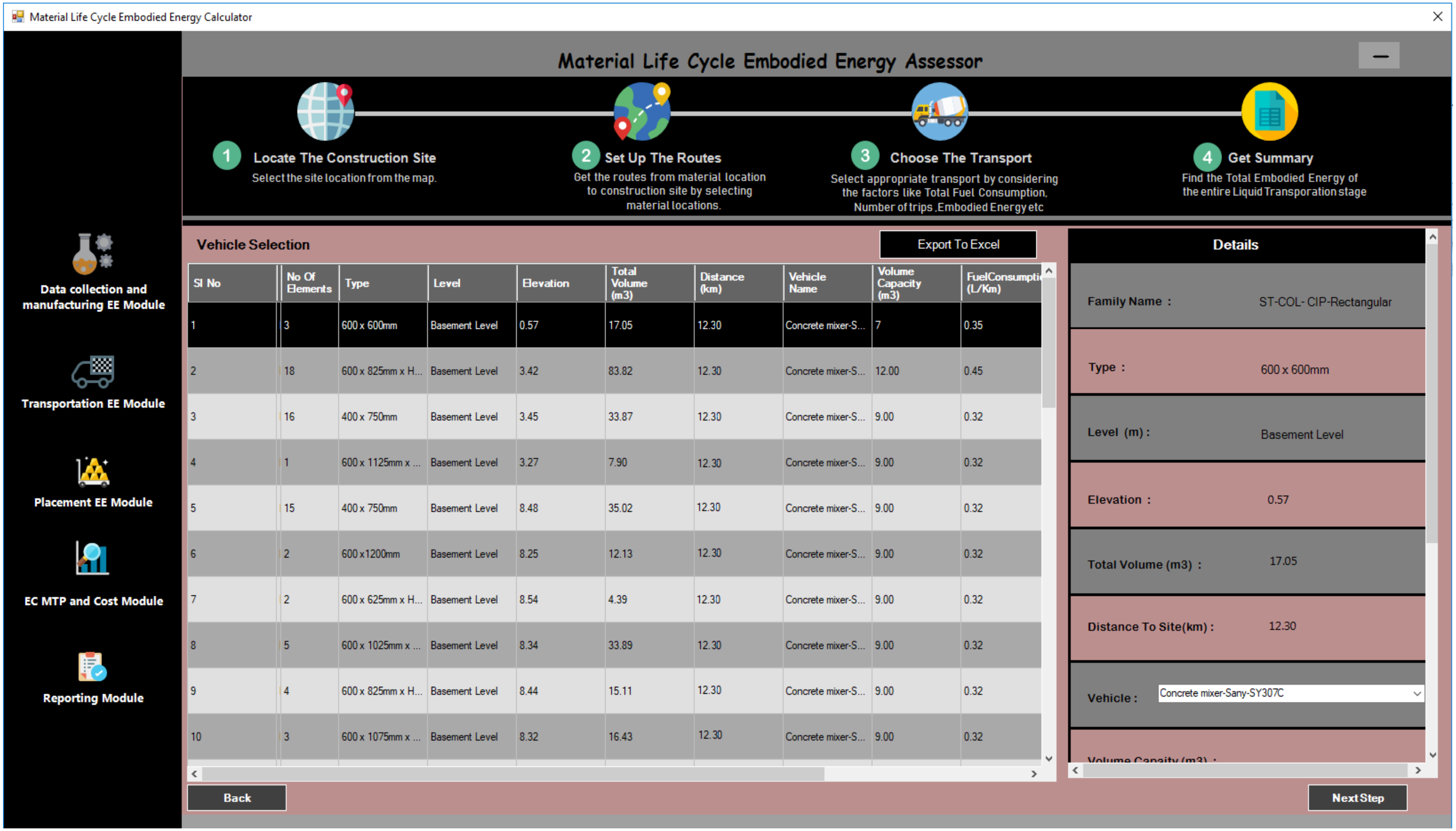

Figure 5-9: Model Output for Mixer Transportation Stage

the amount of fuel required to transport each group using suitable concrete mixers is calculated. These figures are used to compute the energy required to transport materials through different trucks. Figure 5-9 shows the fuel consumption for different groups based on the different suitable trucks.

To verify the EE for liquid material transportation, manual calculations are performed to check the processing methodology of the model. The amount of fuel required by different concrete mixers along with their consumed energy are manually computed. The manual calculations and the model results are compared. Table 5-2 shows a sample calculation performed to verify the correctness of the energy calculation based on fuel usage for a singular material group.

Table 5-2: Sample Manual Calculation of an Individual Grouped Material from the Model

Grouped Family Name	**Elevation**	**Family Volume (m3)**	**Level**	**Concrete Mixer Used**	**Vehicle Capacity (m3)**	**Fuel Consumption (Litres/KM)**	**Number of trips**	**Embodied Energy (MJ)**
ST-COL-CIP-RECTANGULAR	0.57	17.05	Basement	Sani SZ390	9	0.32	2	28.55

This group is “ST-BEAM-CIP-RECTANGULAR. In excel, all material groups, along with the trucks tested by the model, are imported. Accordingly, the amount of fuel for each suitable truck per group is calculated. This is done by multiplying the distance with fuel required. Once the fuel is determined, the fuel is converted into quantifiable energy units. As a manual check for item ST-BEAM-CIP-RECTANGULAR, the energy calculation presented through both the manual calculation and the model equate to 28.55 MJ. This indicates that the model is operational for the liquid material stage. Overall, the total computed EE for liquid material transportation by the model is calculated as 727.75 MJ. Figure 5-10 displays the total computed energy for liquid material transportation. Once the liquid material transportation stage is complete, the model will move to assess the solid transportation EE assessment stage.

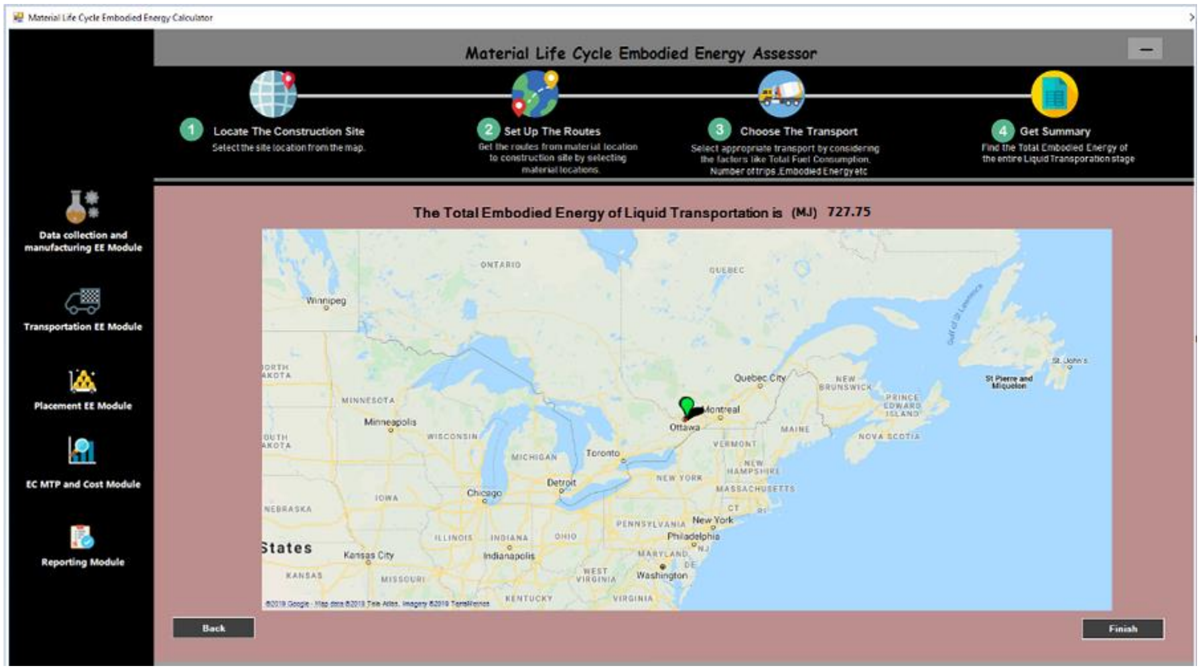

Figure 5-10: Model EE Calculation for Liquid Transportation Stage

In the solid material transportation stage, two processes occur: the truck and hauler transportation EE modules. In the solid material transportation modules, the distance between the manufacturing facilities and the site are also required. This will allow for fuel calculating the usage which are required for EE calculations. To calculate the fuel usage necessary to transport materials, the model first will connect to google maps. At first, the user is required to identify the locations from which materials originate.

To verify the use of the traveled distance tool within the solid material transportation modules, a manual verification of the distance is required. Since the proposed location of the new building is downtown Ottawa, the following postal code is used: K1N5A7. For the design model, it is assumed that all solid materials originate at a single source. It is identified that solid materials will come from a precast factory placed at 17.5 km from the site. A verification check is performed and extracted from google maps. Since the origin postal code K2E 6V2 is used, the total computed distance is 18.2 km. This indicates the functionality of the model.

Once distance calculations are complete, the model will collect the solid materials capable of being carried by the vehicles available from the trucks and hauler inventories. These are done through the truck and hauler EE assessment modules. In some cases, the model will determine the ineligibility of trucks to carry materials due to weight or volume restrictions and in such regard, materials are not shown in their respective stage. In the Solid Material EE Comparison module, the model displays the summary of the truck and haulers that can minimize the EE of materials. Furthermore, the EE for each process is identified. The output from both processes is shown in Figure 5-11.

From the solid material transportation modules, the process of material grouping is completed. The model will group items of the same family in clusters. The idea that materials of the same type will come from the same manufacturer is used. This allows economies of scale in calculating the costs through a reduced number of trips. To verify the correctness of the grouping and collection function for the solid material EE assessment modules, a manual check is performed to determine whether all the solid materials are accounted for in the model after grouping for both stages. This is done by checking the total volume of the grouped materials collected by the solid material comparison stage against the total volume of solid materials from the preliminary BOQ.

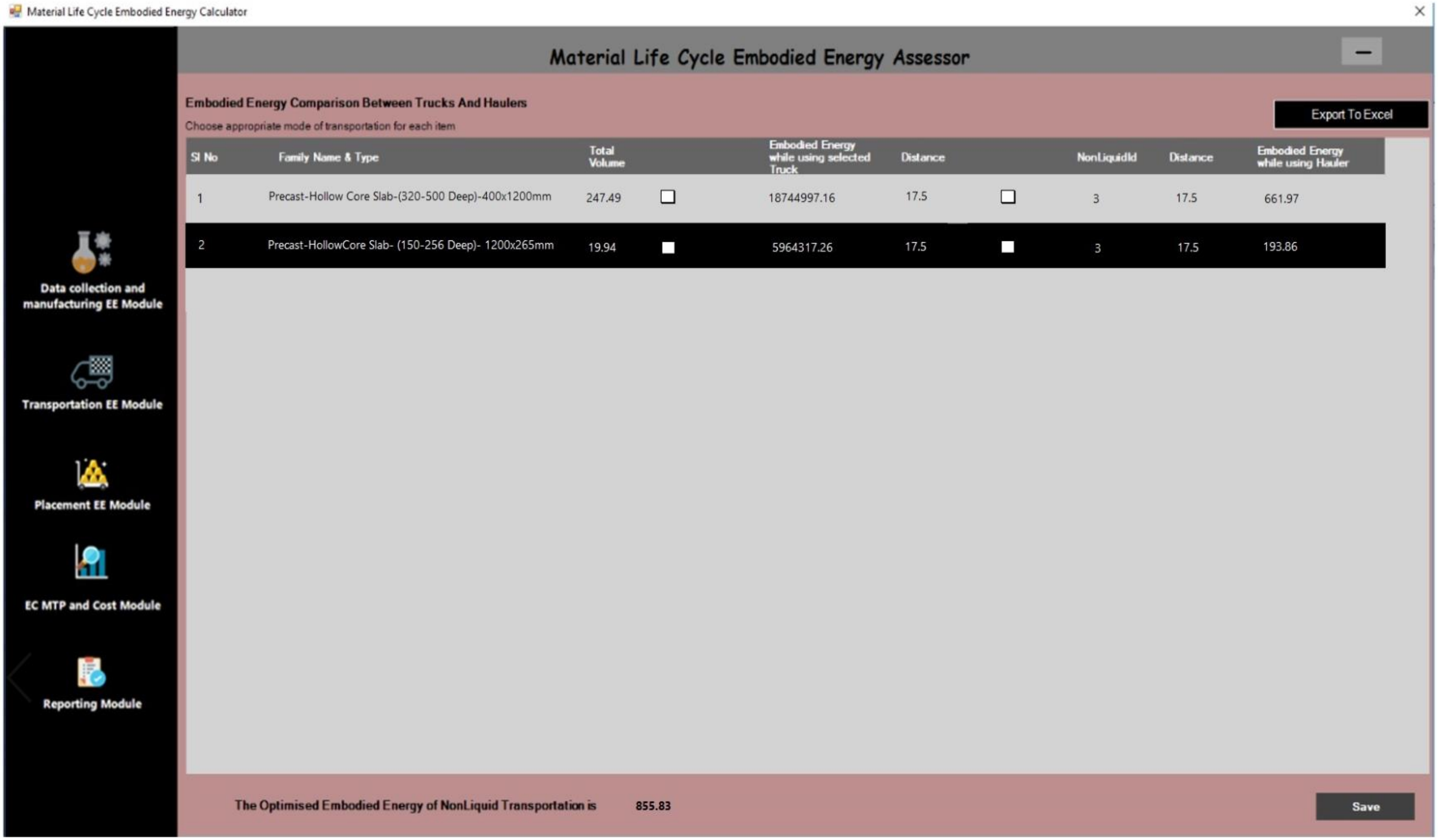

Figure 5-11: Model Comparison Output for Transportation Stage

Tables 5-3 and 5-4 compare the model calculations to the manual calculations. From the comparison, all solid materials are correctly accounted for by the model.

Table 5-3: Model Output for Transportation Stage

Sly No	Family Name of Grouped Materials	Type	Total Volume (m3)
1	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	247.49
2	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	19.94

Table 5-4: Manual Computation for the Volume of Liquid Materials

Non liquid Material Type Manually Determined	Total Volume (m3)
Hollow Core Slabs	267.43

In the solid material comparison module, the model will determine which trucks or haulers are suitable to transport each solid material group. Table 5-5 shows all the grouped solid materials present in the design model including their dimensions and weights.

Table 5-5: Solid Material Transportation EE Calculation Optimized Output

Family Name & Type	Total Volume	Optimized Transportation Vehicle	Least Embodied Energy	Least Energy Consuming Method
ST-Precast-Hollow Core Slab-(320-500 Deep)-400x1200mm	247.49	TRACTOR-VOLVO-FH-4XX_A1	661.97	Hauler
ST-Precast-Hollow Core Slab-(150-265 Deep)-1200x265mm	19.94	TRACTOR-MERC-BENZ-ACTROS-38XX_F4	193.86	Hauler

The model checks the material dimensions to determine the trucks and haulers suitable to carry the largest singular solid material item of each group. Accordingly, the energy is computed.

Through the model, bed space optimization is performed by placing the materials in different orientations. The model will run multiple scenarios to determine if the placed materials on the truck or hauler are possible for the largest material within each group for different vehicles. In many instances, materials are irregular in dimensions, and thus the material orientation is important.

To check the functionality of the solid EE calculation modules, a manual check is performed to ensure the most optimized truck or hauler selected by the model is suitable for the transportation of the solid material groups. From the design model, 2 material groups are obtained. Those are ST-Precast-Hollow Core Slab-(256-150 Deep) and ST-Precast-Hollow Core Slab-(320-500 Deep). From the data collection, it is identifiable that the largest material, for the ST-Precast-Hollow Core Slab-(256-150 Deep) material is item 112111. Nevertheless, the largest material in the ST-Precast-Hollow Core Slab-(320-500 Deep) is element 112224. The greatest height, width and length of the elements are 0.48m, 1.2m, and 11.6m respectively. To check the suitability of the selected vehicle, a check is performed to assess the weight of the greatest solid material against the payload of the selected hauler or truck. Using the greatest material previously mentioned, the greatest weight of each material within the families are 33.176 and 5.601 tons. Using the model, the selected hauler for this material is TRACTOR-VOLVO-FH-4XX_A1. The maximum payload for the selected truck is 66 tonnes. From the comparison, the selected hauler is suitable. From the model the total computed EE for solid materials is 855.83 MJ.

Once the transportation stages are complete, the model will move to determine the placement EE. The process involves the processing of both solid and liquid materials. First, the model will run analysis for the liquid material's placement stages. Through the liquid placement stage, the EE required for liquid material placement using mobile concrete pumps, concrete buckets, and stationary concrete pumps is determined. All materials have been classified as either liquid or solid. The classification process has been verified in the sections presented above. To begin, the process will start with the calculation of EE for concrete placement using the concrete mobile pumps module. In that module, the EE of placing materials using the mobile pump is calculated. That stage is fully automated and requires no manual input. Figure 5-12 represents the model output for that module.

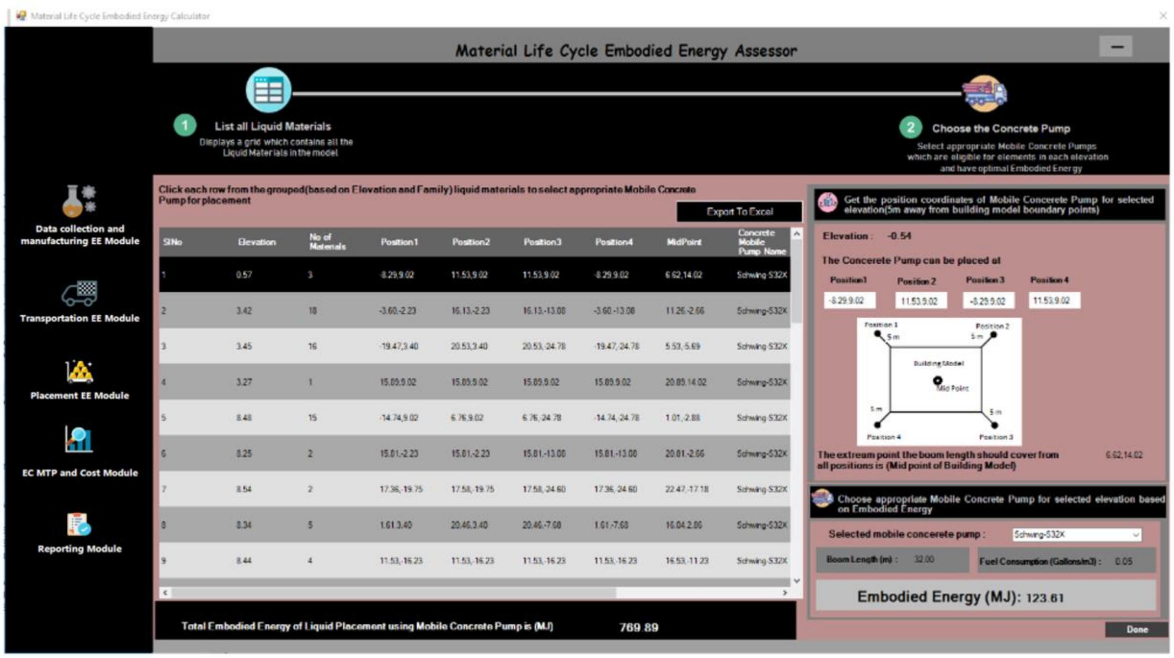

Figure 5-12: Output Platform for Pump Positioning and EE Calculation in the Mobile Pump Module

In order to confirm the correctness of the process, a determination for suitable pumps is required. Using the coordinates extracted from the model, the minimum requirement for the pump boom length is (9.91m). This is determined by calculating the distance to the center point from the corner points of the proposed building. An additional buffer of 5 meters is added to account for the clearance from the pump location to the building edge. Pumps with at least (14.91m) can be used. Furthermore, this is the minimum boom length required to reach the location of every liquid material at a lower floor. To verify the correctness of the calculations presented by the model, a manual calculation is presented in table 5-6. Table 5-6 shows the energy required to place a singular group of material at an elevation of 0.57m.

Table 5-6: Sample Output Extraction of an Individual Item Material from the Model in the Mobile Concrete Pump Module

Family Name	Elevation	Volume (m3)	Concrete Mobile Pump Used	Boom Length (m)	Fuel Consumption (Gallons/m3)	Embodied Energy (MJ)
ST-COL- CIP-Rectangular	0.57	0.62	Schwing-S32X	32	0.031	123.6

A manual verification is presented to check the boom length of the selected pump. Overall, when compared to the values presented by the model, the manual verification indicates the accuracy of the model output. Overall, the results from the model indicate that the total calculated embodied energy for liquid materials using the mobile pumps is 769.89 MJ. Once this stage is completed, the model will move to the concrete bucket EE module.

In the concrete bucket EE module, the EE of placing liquid materials using stationary cranes and buckets is calculated. The minimum EE is calculated by selecting suitable cranes and buckets to minimize the EE. To test the workability of the concrete bucket EE calculation module, a manual simulation will prevail the workability of this stage. Initially in this module, the cranes suitable to cover the site area are determined. Suitability is a factor dependant on the crane location and in such regard a singular position is identified as suggested by the model. The selected coordinates identified as (-22.47, 22.02). Next, to identify suitable cranes, a check is performed to determine the minimum boom length required by cranes. Based on the location of the selected concrete offloading station and the crane location, the estimated minimum required boom length is (56.5m). Based on the identified parameters, a list of cranes is selected. Furthermore, to minimize the number of trips, the bucket (GAR-BRO4123-G) is selected. Based on the selection criteria, the model identified the total EE for this stage as 0.052232 MJ. Figure 5-13 shows the output from the model in which Pecco 560 is the most suitable crane to reduce and achieve the calculated EE.

At the final stage of placing the liquid material, the model will determine the EE of placing a material using concrete pumps and pumping machines. The model will select the machines with the least energy consumption for this stage. To verify the correctness of this stage, a simulation is performed. To begin, the model will suggest possible locations to place stationary concrete pumps. For the design model, the values are (-14.47, 14.02), (26.03, 14.02), (-14.47, -19.85), (26.06, -19.85), & (-5.78, -2.92). Next, it is important to identify the pumps that have suitable booms to cover the building area. Using a manual verification, the coordinates are suitable based on the least boom presented in the inventory.

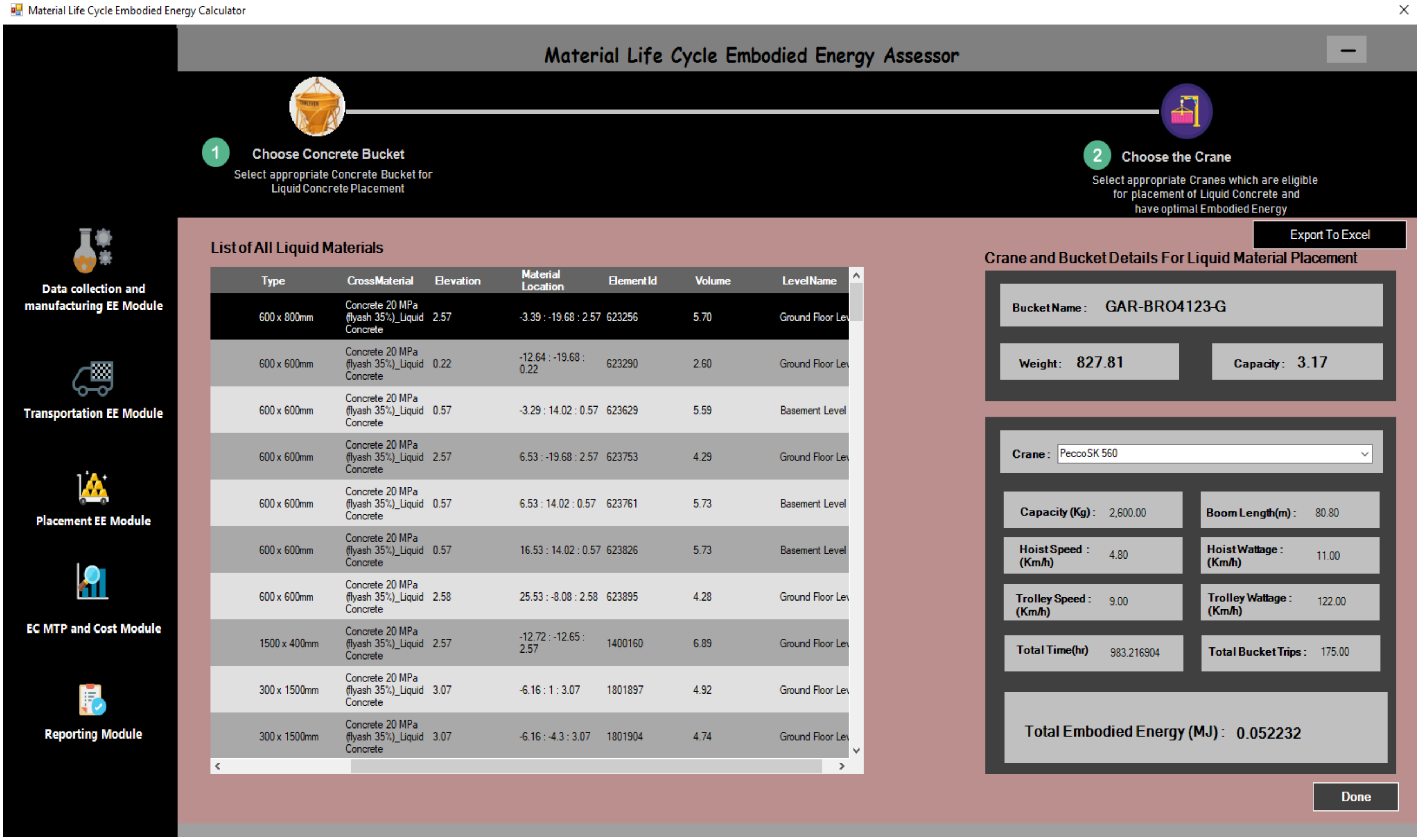

Figure 5-13: Output Platform from the Concrete Bucket Module Calculating EE

This value is 12m. As indicated by the model, the pump locations selected are sufficient. Figure 5-14 shows the model output.

Once complete, the model establishes a list of suitable pumps and pumping machines as per the indicated parameters. Figure 5-15 represents the output from the model. Overall, the EE at this stage indicates that the EE required is 11.378 KJ. From the comparison module, it is apparent that the least energy consumption method of placing concrete is by using the stationary pumps. Once the liquid placement assessment stages are complete, the model will move to determine the EE for solid material placement. In the solid material placement module, stationary cranes are used to place and move materials from their storage or offloading station to their intended location on the site. Therefore, all the properties of each solid material are identified. The model begins by identifying the materials that have a weight less than 23 kg. Those will be removed from the process. It is assumed that such material can be hand carried to reduce the use of energy on the site. Once completed, the model identifies the suitable cranes for the placement process. In reference to the design model, the model suggests a list of possible locations.

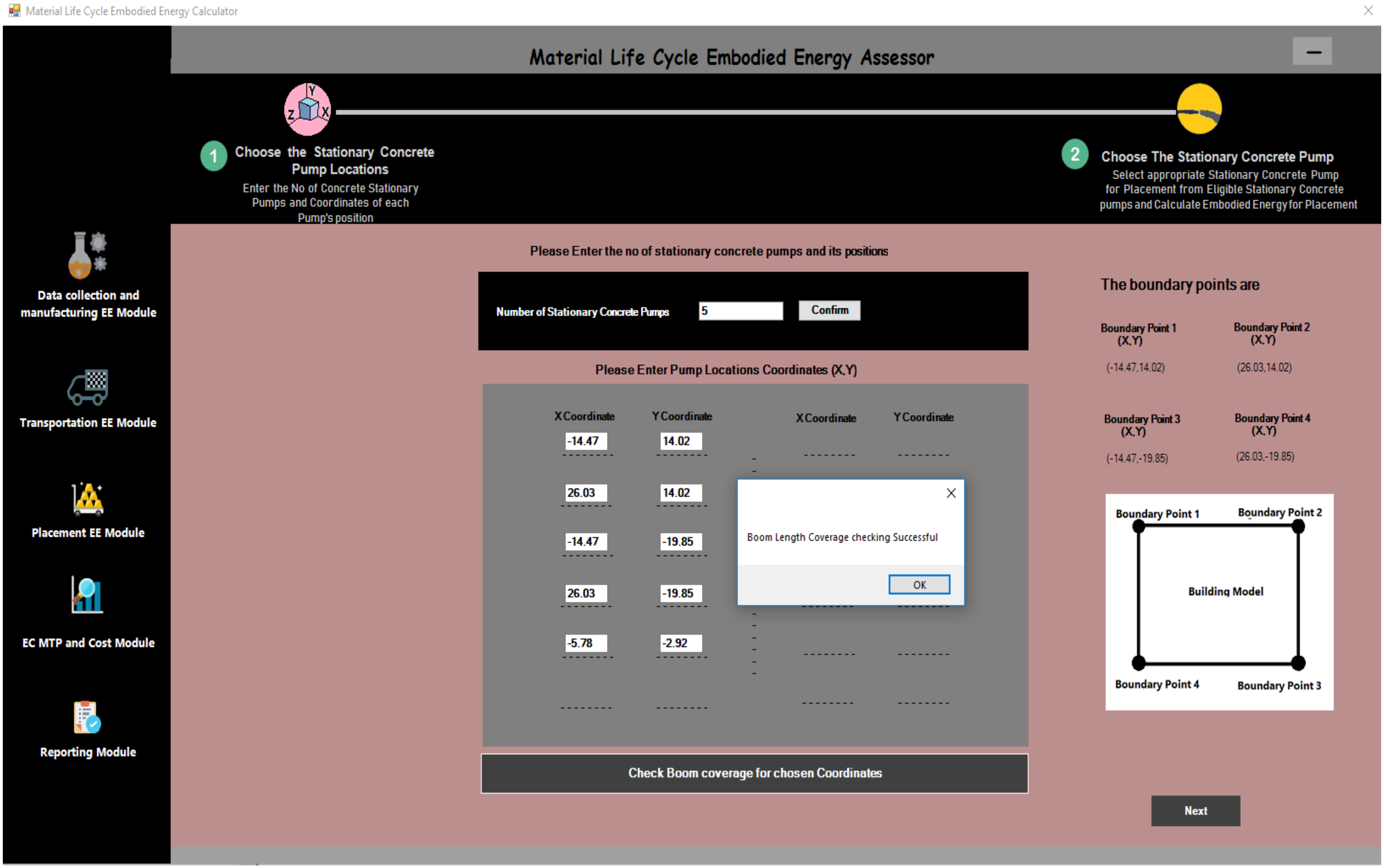

Figure 5-14: Stationary Pump Optimized Location Selection

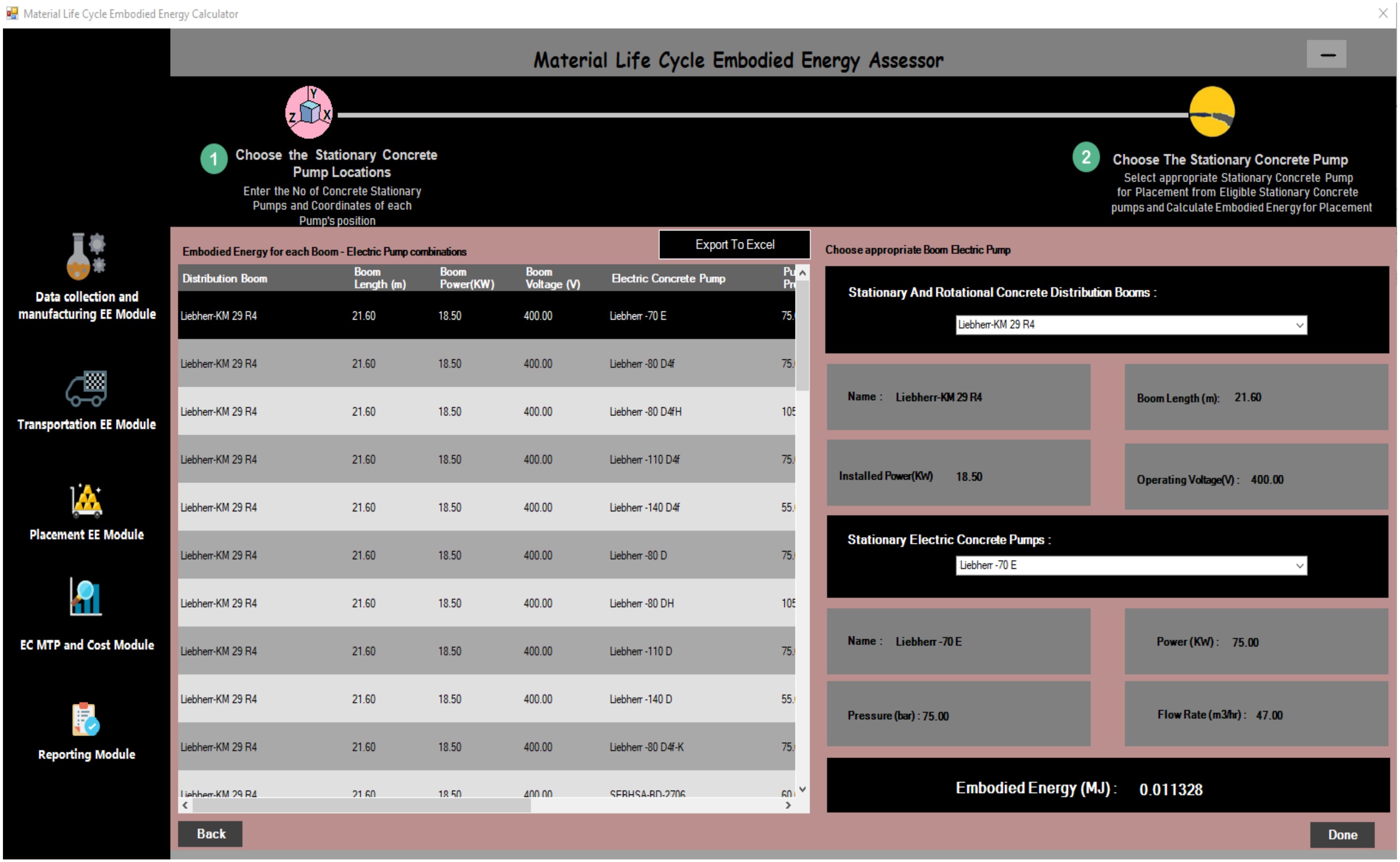

Figure 5-15: Stationary Pump and Machines EE Optimized Output

Figure 5-16 shows the input platform along with the selected parameters. The selected positions are (-19.47, 19.02), and (-9.47, 19.02). Those identify the crane and storage locations. A visual verification is performed to identify the cranes suitable to cover a diametric length equivalent to (45m). Based on the selected positions, the model will begin calculating the electrical usage for swing, trolley and hook movements for multiple cranes. Subsequently, the model will determine the EE of each suitable crane and will then identify the method with least energy consumption. Figure 5-17 displays the output from the model. To verify the findings, a manual calculation is presented for singular material and a singular element. The values are compared to the output presented from the model. Table 5-7 shows the manually calculated results. Those have been calculated by extracting data for the selected crane in the stationary crane inventory and using the equations presented in chapter 3. Those include equations 3-9 to 3-18. Overall, the total EE calculated for the placement using stationary cranes is 2926.63 MJ.

Table 5-7: Placement EE Stage Results Verification Chart

Element ID	**Element Material**	**Family Name**	**Crane Selected**	**Element Location**	**Horizontal Distance required(m)**	**Vertical Distance required(m)**
112296	Precast Concrete	St- Precast-HCS-400*1200	Pecco SK 560	FIRST FLOOR	24.1	3.59
Angular Distance Required (m)	**Time for vertical movement (HR)**	**Time for horizontal movement(HR)**	**Time for angular movement(HR)**	**Trolley Wattage KW**	**Hoist Wattage KW**	**Rotor Wattage KW**
10.8	0.137	5.02	0.3168	11	122	27

Swing angle (rad)	Trolley power consumption (KWH)	Hoist power consumption (KWH)	Crane rotor power consumption (KWH)	Total power usage (KWH)	Total EE (MJ)	
0.31	0.92	0.811	0.01	68.8	6.25	

In reference to the design model, it is apparent that the crane selected for placing the solid material placement is the most efficient option. The total computed EE using the most efficient crane is "Pecco560." Since the same crane is selected for liquid and non-liquid material therefore, additional crane optimizations are not needed. The same crane can be used for both processes.

Once all EE assessment modules are complete, the model will begin determining the social carbon costs for materials. This is based on the machines for each stage. Since both EE and EC are interrelated variables possessing a directly proportional relationship, the same methods, trucks and vehicles used as optimized solutions in EE modules were also used for EC stages. In the embodied carbon modules, the model will determine the amount of carbon produced from manufacturing, transporting and placing materials used in the design model. Those stages also involve calculating the total social carbon cost of each module. A unit social carbon cost of 20$ per ton is inputted into the model. This is required by the model to calculate the total carbon costs. Seeing that the project will be built in Canada, it seemed reasonable to use the current carbon rates established by the Canadian Environmental Agency for the year 2019.

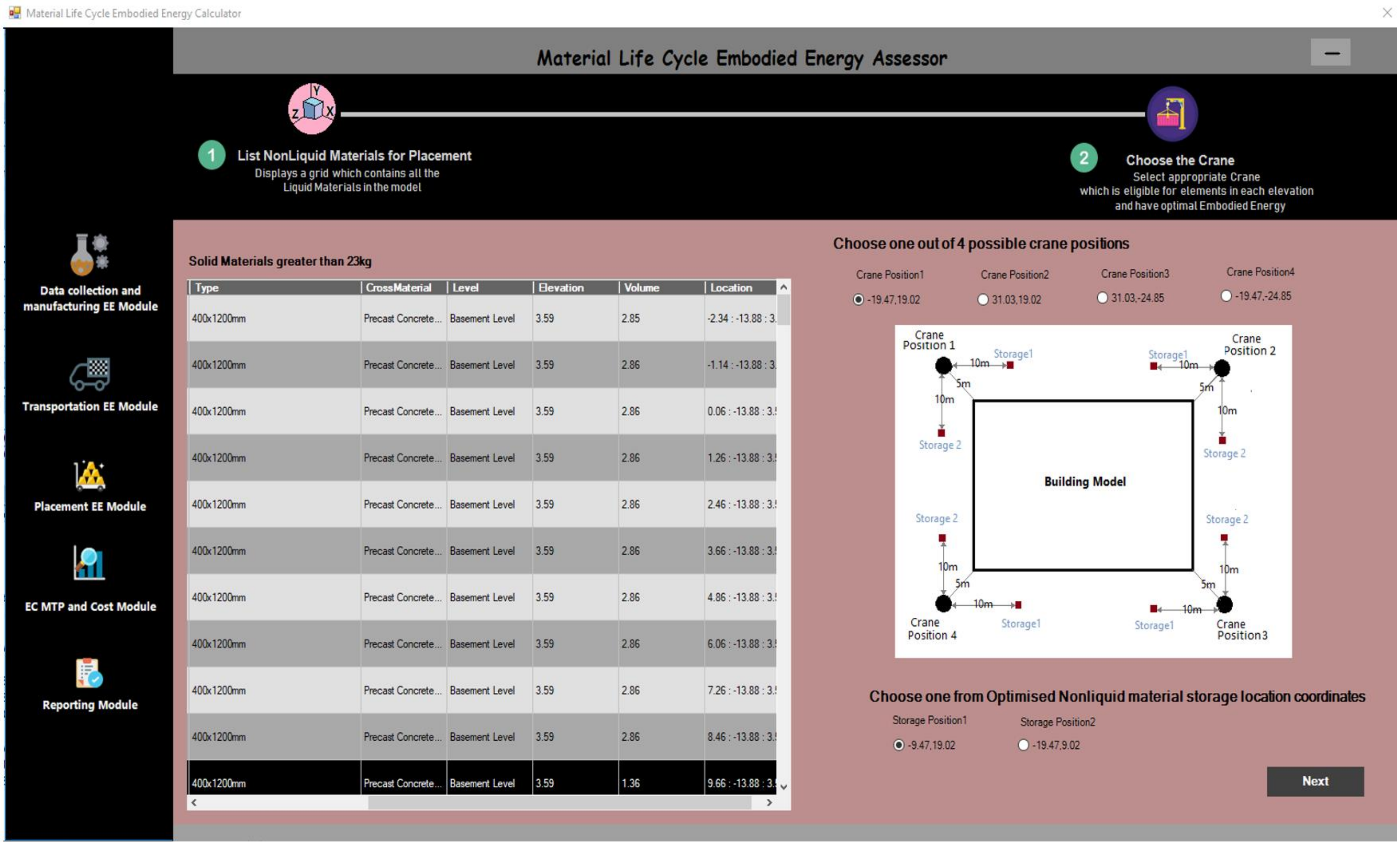

Figure 5-16: Input Platform for Crane Positioning in the Placement Stage

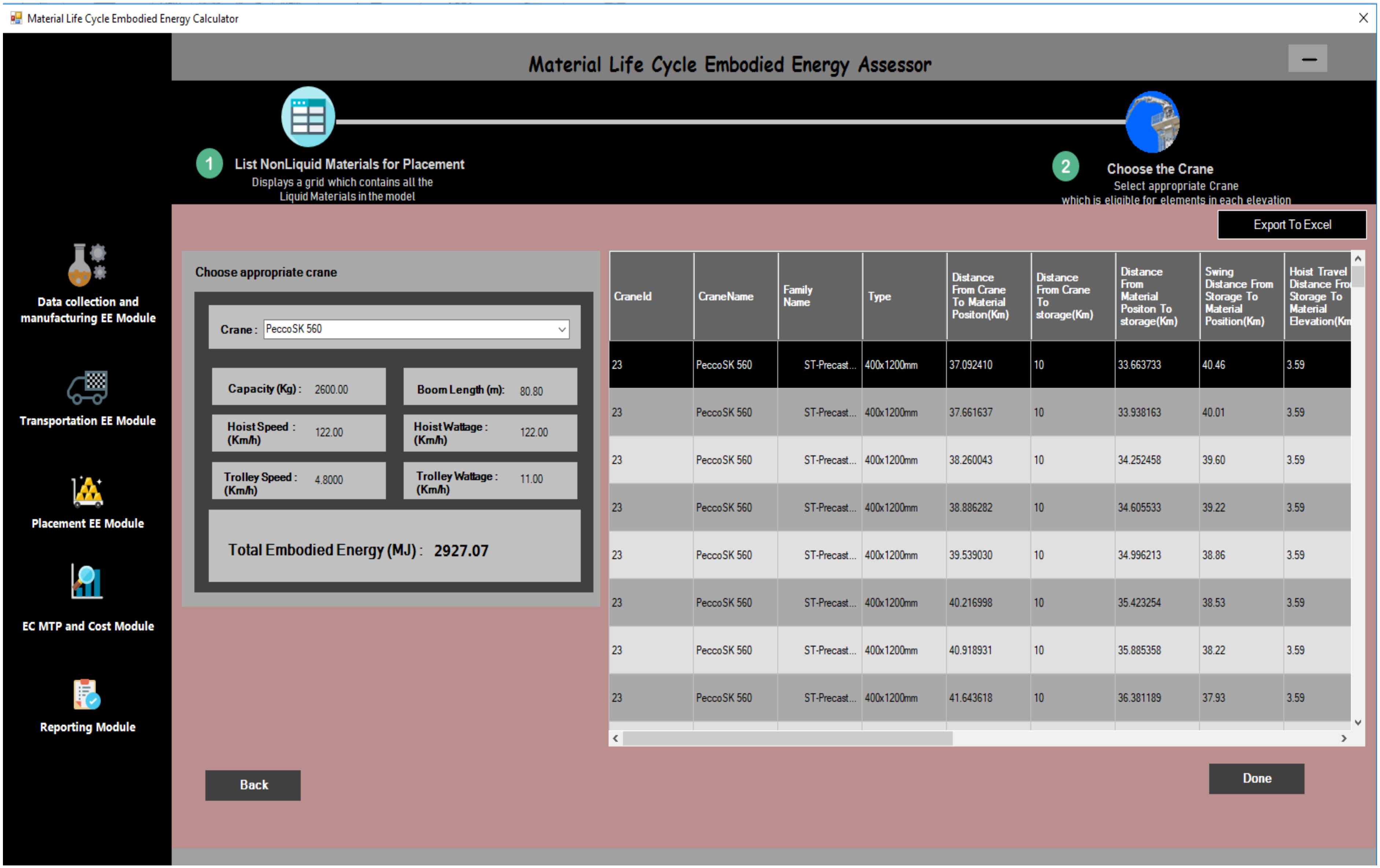

Figure 5-17: Model Output for the EE Placement Optimization Stage

For the manufacturing EC stage, the model will determine the embodied carbon of materials in the design model for both solid and liquid stages. The data previously collected from EE manufacturing stage is used to compute the mass and volumes of each material. Once completed, the individual carbonic emission for each material was computed by multiplying values of the per unit output of each material using the manufacturing EC inventory. Figure 5-18 presents the model's output.

A manual check for the manufacturing material EC calculation module, is performed by comparing the values for singular material against the output from the model. For checking, the element 1802657 is used. The material is liquid concrete. The total element's volume is 1.85. The density of concrete is identified as 2.3 ton/m^3 and thus the total mass is 4.07kg. Using the information from the EC manufacturing inventory, the total EC carbon produced is 0.98kg. When multiplied by the per carbon costs, the total monetary value is $19.6. When compared to the model report output, the value has been verified and equates to 19.6. Overall, from the model, the total carbon produced is determined as 395.80 tonnes and thus the total social carbon cost is $7,915.

Once the manufacturing EC is complete, the model will move to the transportation stages. Using the equation 3-21, it can be determined that the total EC produced for liquid placement is 0.1214 tons. Subsequently, the total social carbon cost is $2.43. Figure 5-19 shows the output from the liquid EC transportation module.

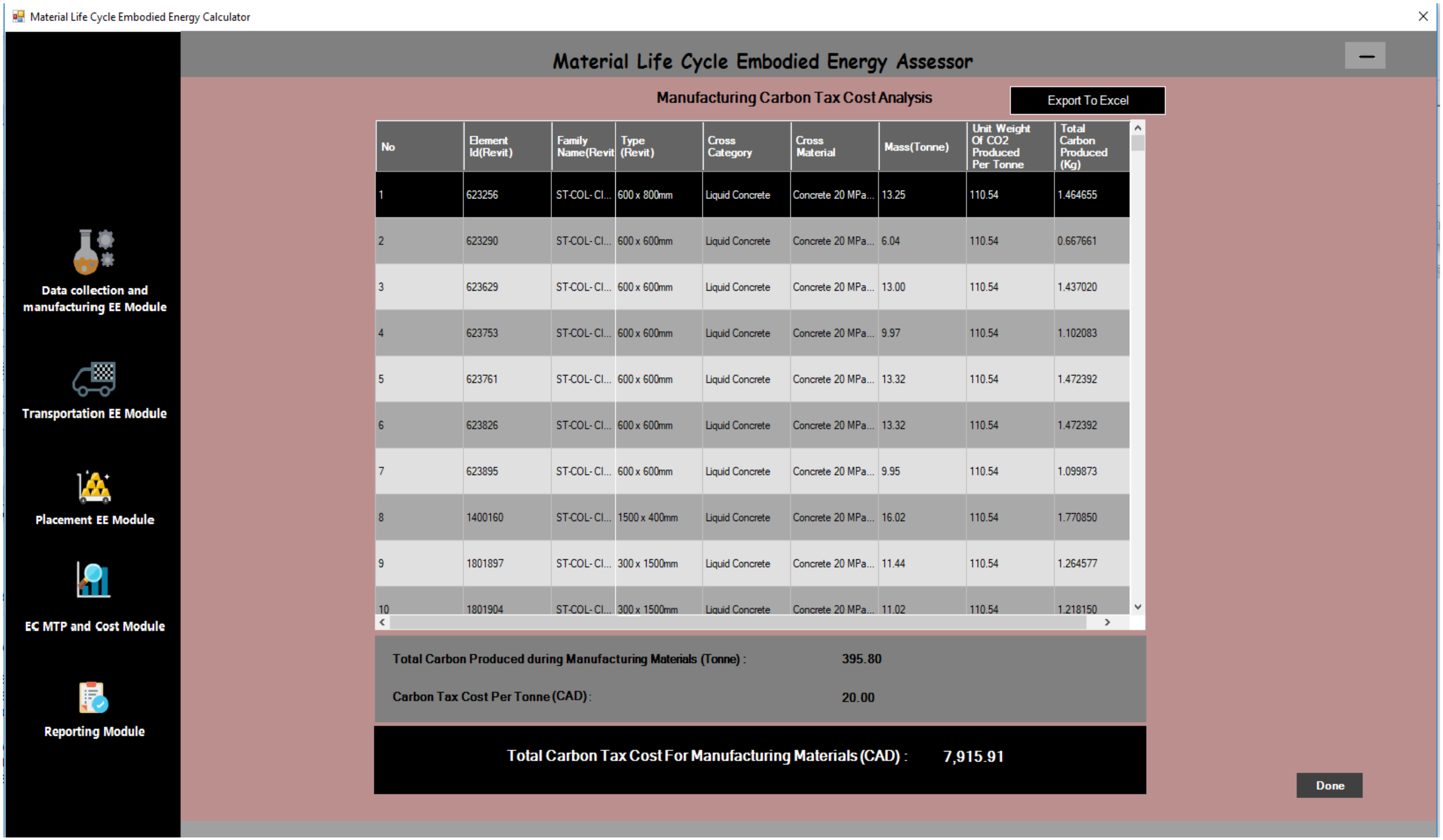

Figure 5-18: Model Output for EC Calculation for Manufacturing Stage

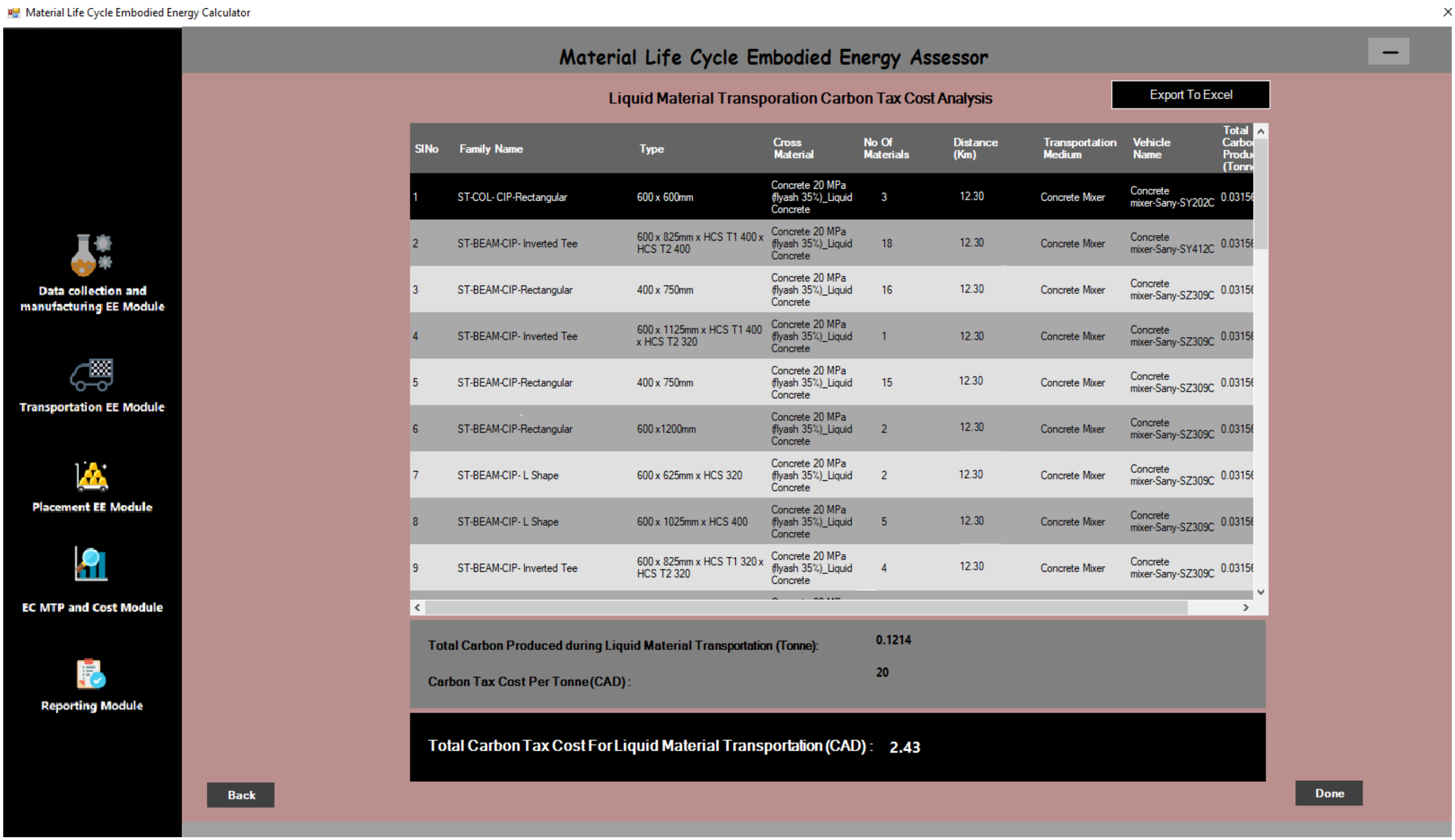

Figure 5-19: Model Output for EC Calculation for Transportation Stage

When the liquid material EC transportation submodule is complete, the model will move to the solid material EC and cost assessment stage for transportation. Using the equation 3-21, it can be determined that the total EC for solid placement is 0.00669 tonnes. Subsequently, using equation 3-20, the total social carbon cost is $0.139, respectively. Figure 5-20 shows the output from the solid material EC transportation stage.

After all EC transportation stages are completed, the model will move to calculate liquid material EC and costs for placing liquid materials. From the previously computed EE optimization modules, the method with the least energy consumption for liquid placement is by using the stationary pump. In their case, the total power usage from that process is 18.50 kwh. Using the equations 3-22,3-23, and 3-24 the total carbonic emissions are 71.55 ton. Furthermore, the total social carbon costs are $1,431.

Once the liquid placement EC is complete, the model will move to the solid material EC and cost assessment for the placement stage. Using equation 3-23, the total EC for solid placement is 81.5769 tonnes. Subsequently, using equation 3-24, the total social carbon cost is calculated as $1,631.54 From the previously computed EE optimization modules, the method with the least energy consumption for solid placement is by using the Pecco Sk560 crane. To verify the results, a manual verification was performed to calculate the amount of carbon and the costs of using Pecco SK560. Overall, the total calculated power usage for the process was calculated as 812.989 KWH. Using equation 3-23 the total carbonic emissions is 81.5769 tonnes. Furthermore, the total social carbon costs for solid materials are $1,631.54 After all EC and cost stages are completed, the model will begin processing the information in the reporting module.

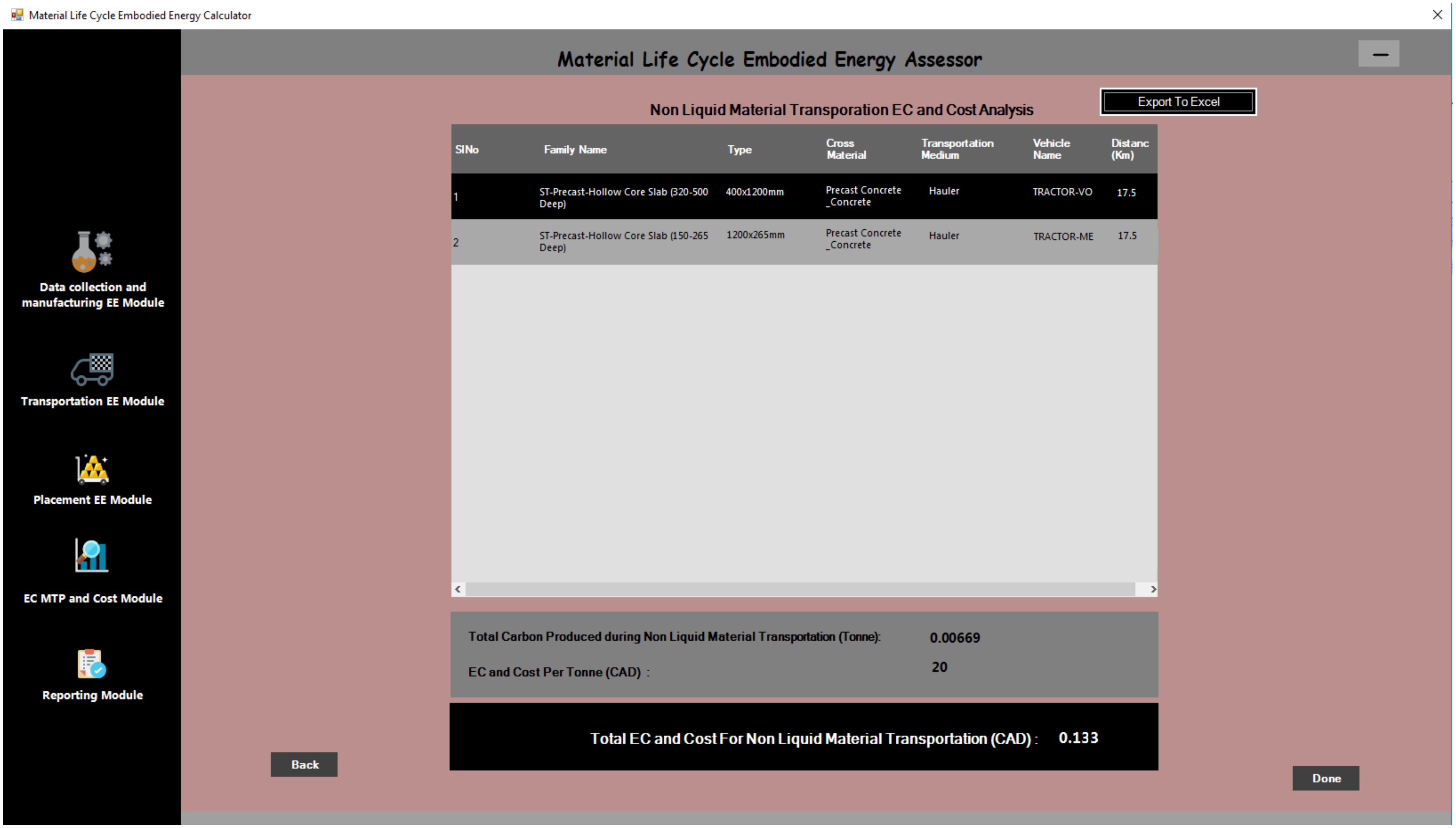

Figure 5-20: Model Output for EC Calculation for the Transportation of Solid Material

Finally, once all processing modules are completed, a summary is displayed in the Reporting module. Figure 5-21 displays summary output from the model. To verify the workability of the reporting module, a visual verification is performed to compare the model's output results to the produced reports. Each report contains information extracted from the model processes and information about energy usage per material per machinery. Furthermore, each report presents a bar chart that summarizes the results. Overall, when compared, the reporting results are identical to the results produced at every stage.

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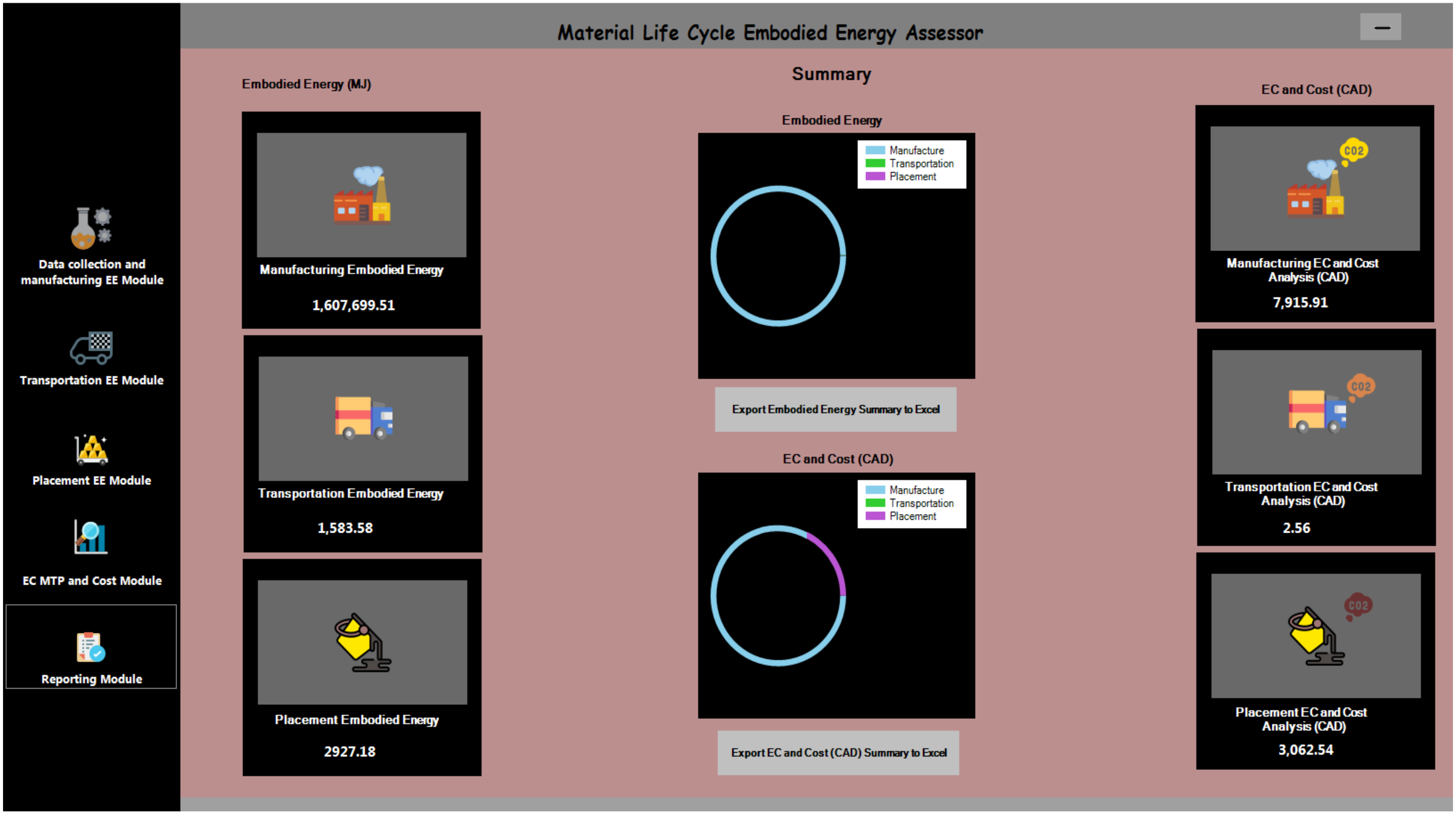

Figure 5-21: Reporting Module Output

5.3 Summary

This chapter provided the sequence for testing the capabilities and the workability of the developed model. By using a real case scenario, the inputs, logical sequence, analysis and output were checked. Series of manual and visual checks were performed to check the workability of the developed model. Overall, the model was able to assess the EE/EC and costs for the materials used in the BIM design model. Furthermore, the model was able to identify the methods, machines, equipment, and vehicles required to minimize the environmental impact of the tested structure. The model was able to connect to the correct databases to retrieve and process information

Chapter Six

Conclusions and Future Recommendations

6.1 Conclusion

This study presented a methodology to calculate the materials' embodied energy, carbon and social carbon costs in a cradle to end of construction boundary. The issue of imprecise EE/EC and cost quantification used in the methods currently available in the literature is addressed by developing a BIM integrated model. Through the selection of equipment and machinery, the developed model can efficiently and accurately quantify the EE/EC and costs of materials commonly used in the design of buildings. The lifecycle stages include manufacturing, transporting, and placing of materials. Overall, dictating the construction process early in the design stages will help in limiting changes required to satisfy sustainable design parameters especially in terms of energy usage. This will prevent huge variation in the costs of the construction stages. Overall, the developed model has many advantages. Probably the most significant is the ability of the model to help assessing the actual environmental impact of new construction and thus to benchmark acceptable impact rates. The developed model can also aid in sustainability studies. It may be used as part of the LEED assessment criteria. Overall, LEED doesn't dictate the use of specific values in the terms of EE/EC usage and assessment. This is due to the current uncertainties in the calculation models presented in the literature. Using use of the developed model, best practices and suggestions are identified to help reduce the environmental impact of construction and by eliminating such ambiguities. Designers and contractors can both identify the machinery required for a sustainable construction process. An important advantage of the model is its ability to identify the total social carbon costs by using specific materials. This function is helpful when identifying the environmental cost impact of new construction practices and in return tax the relevant parties accordingly.

6.2 Research Contribution

The purpose of this study is to develop a model that can reduce the environmental impact of constructing new structures. Furthermore, the goal of this study is to produce a model that can accurately assess the environmental impacts and costs. Overall, the developed model presented a major improvement in the calculation process of both the EE and EC. The model uses proposed resources to calculate EE and EC through optimized methods to reduce the value of each. This is different from the models described in the literature which use a single values per material for EE and EC per unit material regardless of the manufacturing, transportation and placement method. Furthermore, the created databases used to calculate EE, EC and costs hold a wide range of valuable information about resources needed to calculate the fuel, electricity and energy. Ultimately, it was very important to create a model that can be used during the design stage as to perform changes early at the design phase. Moreover, due to the concentrated research on operational energy and the importance of material's embodied energy on the environment, a model is needed to target such embodied energy. Based on the above, the authors of this study opted to create a model that will address such parameters. Due to the momentum of BIM usage during the design phases, it became apparent that a model is needed to incorporate these advances. Furthermore, due the current interest in carbon tax in Canada, there is a need a tool to estimate such pricing. Overall, this research has many contributions that include:

- The creation of an automated tool that uses a systematic methodology to calculate the embodied energy of materials commonly used by buildings through their lifecycles.
- The creation of an automated tool that can calculate the embodied carbon for materials commonly used by buildings through their lifecycles.
- The creation of an automated tool that can precisely calculate the environmental cost implication of materials used by buildings throughout its lifecycle early in the design stages.
- The creation of an automated model that benefits from the current BIM platform used for designing buildings and to accurately calculate embodied energy, embodied carbon, and environmental costs.
- The creation of an automated model that can propose improvements to lower the environmental impacts of materials used in buildings at the design stage.
- The creation of an automated model that can dictate the construction process during the design stages by indicating the vehicles, machines, and equipment that will lower the environmental impact of construction.

6.3 Research Limitation

Overall, this research has the following limitations:

- Since the created datasets will control the quality of the quantification method, more records allow for better results, and thus governmental agency collaboration can greatly help enhance such inventories. Overall, the quality of the quantification process is dependent on the quantity of the collected data. The accuracy of the calculation process used is only as good as the available information.

- Since designers will need to dictate the use of specific machines, vehicles and equipment in order to exactly quantify factors, the current model cannot assess' structures that span beyond sixty-five meters as the study limits the use of a single crane for construction. Furthermore, such machine selections will limit building developers. Having a comprehensive database can greatly help in overcoming this limitation.
- Due to the broad scope of this study, the research is limited to the cradle to end of construction boundary. Adding other activities could require other types of equipment such as screw fasteners, anchoring tools, concreting, etc. which will change the sustainability assessment parameters. Such machines have not been considered in any of the studies, however researchers are currently assessing these for future work. This study targets the preoperational stage.
- The model considers methods as to reduce energy usage to help in reducing the environmental impact but doesn't consider reducing costs. Such limitation is important. Enhancing material usage to reduce energy usage could in return increase the initial investments required.

6.4 Future Expansions:

Overall, the developed model has many uses; however, there is still room for future enhancement and expansion. The following is a list of enhancements for improving the model:

- Adding more processing modules as to allow for a more detailed placement energy usage calculation process. Those can include the placement of steel sections, block work, cable trays, duct insulation, painting etc. Each of such process requires sophisticated equipment that uses specific equipment. Such consideration can greatly enhance the energy calculation and reduction process.
- Adding more modules as to allow the model to calculate the energy and reduce such energy for the cradle to end of life cycle. Adding modules such as maintenance, rehabilitation, and disposal stages rehabilitation, disposal and recycling materials can greatly enhance the significance of the model.
- Creating a cost optimization module for trade-off between construction cost and energy usage. Such module will require the use of artificial intelligence as to understand the cost reduction, aesthetics and energy usage selection parameters and also suggest the list of best materials and equipment, vehicles and machines that are required.
- Update and add more information to the created databases to improve the reliability of the created model output. This can be done by the collaboration between universities and governmental agencies.
- Increasing the area boundary restrictions by allowing the use of multiple cranes in the placement stages.
- Creating an artificial intelligence system that learns the best practices used to identify equipment locations from previously constructed projects. This will allow for better planning as to reduce costs, improve and ease operations all through reducing energy usage.

- Integrating a new module to reduce the number of processing stages required to calculate EE, EC and Environmental costs.
- Identifying the EE, EC and environmental costs of different designs that are considered green through the created model.
- Creating a scoring system, within the model, to identify if a specific building design is sustainably acceptable with regards to EE, EC and environmental costs. Based on the created model, the EE,EC and environmental cost of a design will be determined and accordingly, the model will indicate if EE,EC and costs need to be reduced or are acceptable according to a set tolerable ranges for EE, EC and costs. The tolerable ranges for EE, EC and costs will be based on values determined by identifying the EE, EC and costs of buildings that are currently considered sustainable.
- Comparing values computed for EE and EC for a specific building design using the created model as opposed to calculating the EE and EC using the databases created by researchers. Accordingly the variances between the calculation of EE and EC through use of databases and the model will be compared.

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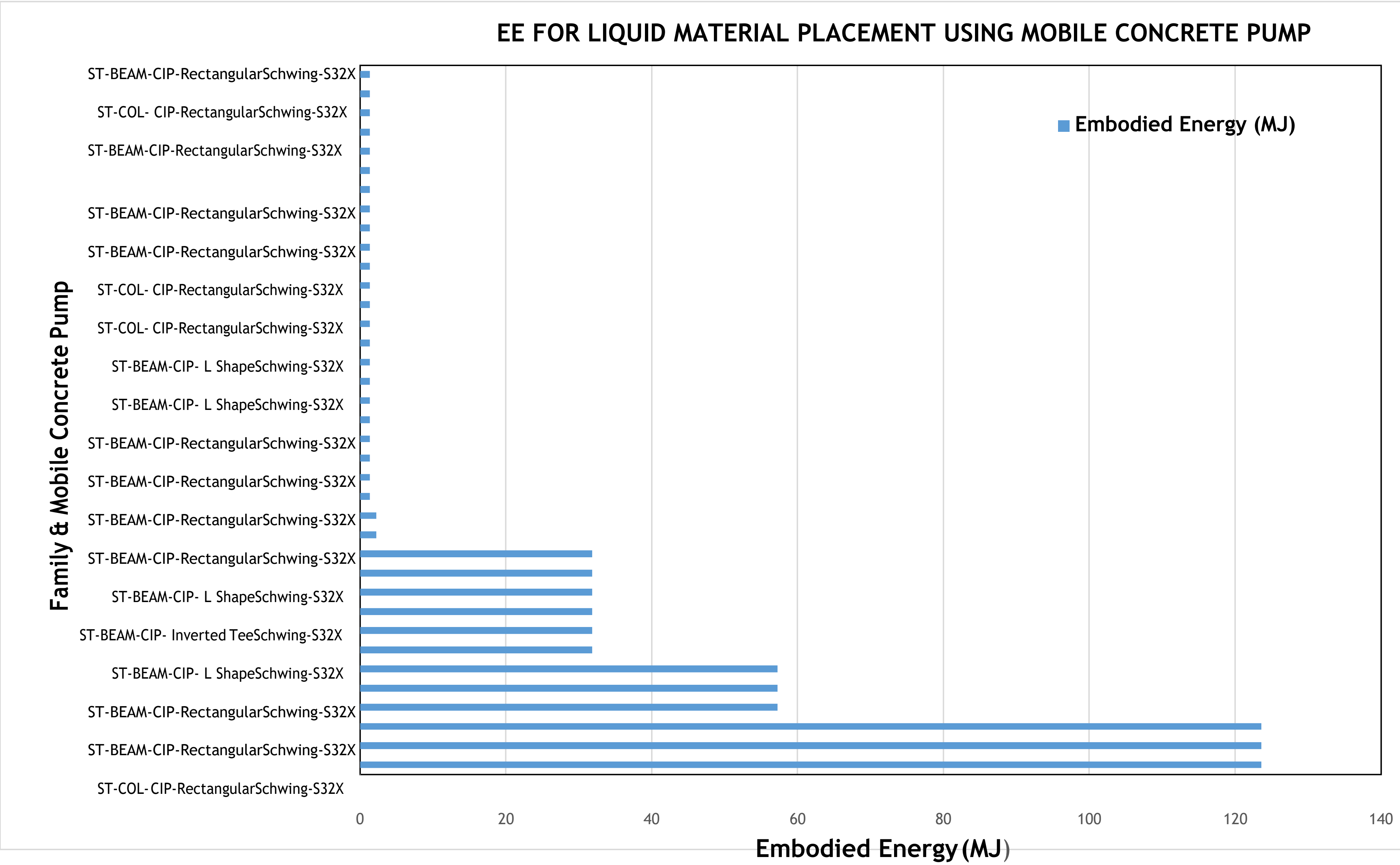
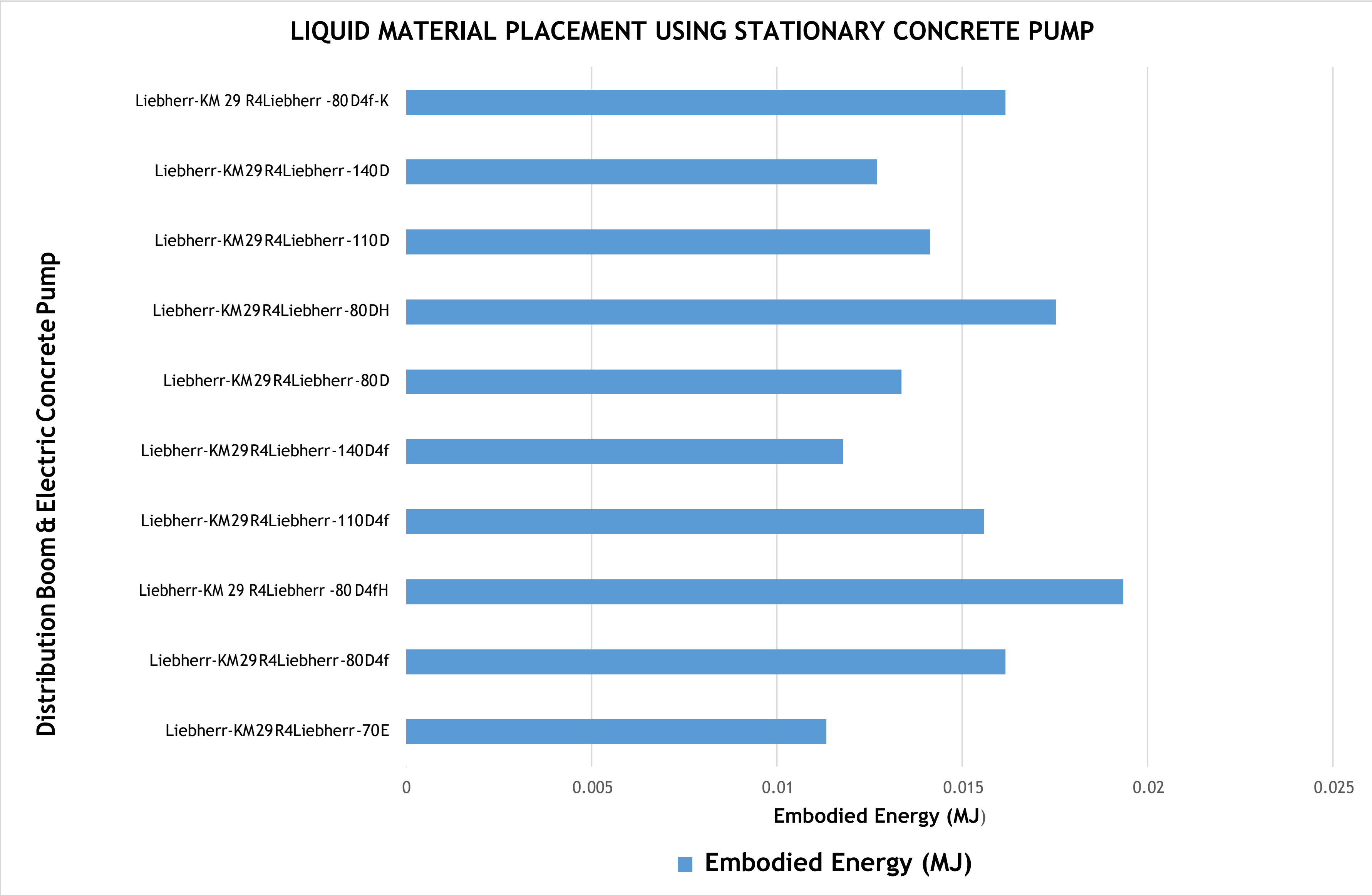
SlNo	Family Name	Elevation	No of Materials	Position1	Position2	Position3	Position4	MidPoint	Concrete Mobile Pump Name	Boom Length (m)	Embodied Energy (MJ)
1	ST-COL- CIP-Rectangular	0.57	3	-8.29,9.02	11.53,9.02	11.53,9.02	-8.29,9.02	6.62,14.02	Schwing-S32X	32	123.61
2	ST-BEAM-CIP- Inverted Tee	3.42	18	-3.60,-2.23	16.13,-2.23	16.13,-13.08	-3.60,-13.08	11.26,-2.66	Schwing-S32X	32	123.61
3	ST-BEAM-CIP-Rectangular	3.45	16	-19.47,3.40	20.53,3.40	20.53,-24.78	-19.47,-24.78	5.53,-5.69	Schwing-S32X	32	123.61
4	ST-BEAM-CIP- Inverted Tee	3.27	1	15.89,9.02	15.89,9.02	15.89,9.02	15.89,9.02	20.89,14.02	Schwing-S32X	32	57.28
5	ST-BEAM-CIP-Rectangular	8.48	15	-14.74,9.02	6.76,9.02	6.76,-24.78	-14.74,-24.78	1.01,-2.88	Schwing-S32X	32	57.28
6	ST-BEAM-CIP-Rectangular	8.25	2	15.81,-2.23	15.81,-2.23	15.81,-13.08	15.81,-13.08	20.81,-2.66	Schwing-S32X	32	57.28
7	ST-BEAM-CIP- L Shape	8.54	2	17.36,-19.75	17.58,-19.75	17.58,-24.60	17.36,-24.60	22.47,-17.18	Schwing-S32X	32	31.83
8	ST-BEAM-CIP- L Shape	8.34	5	1.61,3.40	20.46,3.40	20.46,-7.68	1.61,-7.68	16.04,2.86	Schwing-S32X	32	31.83
9	ST-BEAM-CIP- Inverted Tee	8.44	4	11.53,-16.23	11.53,-16.23	11.53,-16.23	11.53,-16.23	16.53,-11.23	Schwing-S32X	32	31.83
10	ST-BEAM-CIP- L Shape	8.32	3	-8.37,3.25	-8.36,3.25	-8.36,-7.70	-8.37,-7.70	-3.36,2.78	Schwing-S32X	32	31.83
11	ST-BEAM-CIP- L Shape	8.03	1	20.46,-19.00	20.46,-19.00	20.46,-19.00	20.46,-19.00	25.46,-14.00	Schwing-S32X	32	31.83
12	ST-BEAM-CIP- L Shape	3.35	1	-8.36,-18.97	-8.36,-18.97	-8.36,-18.97	-8.36,-18.97	-3.36,-13.97	Schwing-S32X	32	31.83
13	ST-BEAM-CIP-Rectangular	3.52	1	9.94,-19.30	9.94,-19.30	9.94,-19.30	9.94,-19.30	14.94,-14.30	Schwing-S32X	32	2.25
14	ST-BEAM-CIP-Rectangular	8.2	3	-16.48,6.92	-10.33,6.92	-10.33,-6.86	-16.48,-6.86	-8.40,5.03	Schwing-S32X	32	2.25
15	ST-BEAM-CIP-Rectangular	8.19	1	5.79,-22.19	5.79,-22.19	5.79,-22.19	5.79,-22.19	10.79,-17.19	Schwing-S32X	32	1.38
16	ST-BEAM-CIP-Rectangular	3.53	1	-10.56,-6.73	-10.56,-6.73	-10.56,-6.73	-10.56,-6.73	-5.56,-1.73	Schwing-S32X	32	1.38
17	ST-BEAM-CIP-Rectangular	3.55	2	-16.48,6.79	-10.33,6.79	-10.33,6.79	-16.48,6.79	-8.40,11.79	Schwing-S32X	32	1.38
18	ST-BEAM-CIP-Rectangular	7.28	2	-14.70,5.25	-12.03,5.25	-12.03,5.25	-14.70,5.25	-8.36,10.25	Schwing-S32X	32	1.38
19	ST-BEAM-CIP-Rectangular	1.88	2	-14.70,5.25	-12.03,5.25	-12.03,5.25	-14.70,5.25	-8.36,10.25	Schwing-S32X	32	1.38
20	ST-BEAM-CIP-Rectangular	7.38	1	21.03,-18.85	21.03,-18.85	21.03,-18.85	21.03,-18.85	26.03,-13.85	Schwing-S32X	32	1.38
21	ST-BEAM-CIP- L Shape	7.48	1	20.88,-7.97	20.88,-7.97	20.88,-7.97	20.88,-7.97	25.88,-2.97	Schwing-S32X	32	1.38
22	ST-BEAM-CIP-Rectangular	1.75	1	-3.23,-24.83	-3.23,-24.83	-3.23,-24.83	-3.23,-24.83	1.77,-19.83	Schwing-S32X	32	1.38
23	ST-BEAM-CIP- L Shape	1.8	1	3.70,-24.85	3.70,-24.85	3.70,-24.85	3.70,-24.85	8.70,-19.85	Schwing-S32X	32	1.38
24	ST-BEAM-CIP- L Shape	7.73	1	-19.17,0.64	-19.17,0.64	-19.17,0.64	-19.17,0.64	-14.17,5.64	Schwing-S32X	32	1.38
25	ST-COL- CIP-Rectangular	2.57	3	-17.72,-17.65	1.53,-17.65	1.53,-24.68	-17.72,-24.68	-3.10,-16.16	Schwing-S32X	32	1.38
26	ST-COL- CIP-Rectangular	0.22	1	-17.64,-24.68	-17.64,-24.68	-17.64,-24.68	-17.64,-24.68	-12.64,-19.68	Schwing-S32X	32	1.38
27	ST-COL- CIP-Rectangular	2.58	1	20.53,-13.08	20.53,-13.08	20.53,-13.08	20.53,-13.08	25.53,-8.08	Schwing-S32X	32	1.38
28	ST-BEAM-CIP-Rectangular	-2.9	4	-19.07,-13.65	3.85,-13.65	3.85,-24.83	-19.07,-24.83	-2.61,-14.24	Schwing-S32X	32	1.38
29	ST-BEAM-CIP-Rectangular	-3.15	2	-17.79,-21.28	-14.32,-21.28	-14.32,-24.83	-17.79,-24.83	-11.06,-18.06	Schwing-S32X	32	1.38
30	ST-BEAM-CIP-Rectangular	-2.97	3	14.47,-12.98	17.44,-12.98	17.44,-16.18	14.47,-16.18	20.96,-9.58	Schwing-S32X	32	1.38
31	ST-BEAM-CIP-Rectangular	-3.37	5	-3.39,-8.62	12.96,-8.62	12.96,-18.85	-3.39,-18.85	9.78,-8.74	Schwing-S32X	32	1.38
32	ST-BEAM-CIP-Rectangular	-2.75	2	-8.29,-7.78	-8.29,-7.78	-8.29,-19.15	-8.29,-19.15	-3.29,-8.46	Schwing-S32X	32	1.38
33	ST-BEAM-CIP-Rectangular	-3	3	-8.47,3.40	1.53,3.40	1.53,-2.23	-8.47,-2.23	1.53,5.58	Schwing-S32X	32	1.38
34	ST-BEAM-CIP-Rectangular	-3.02	1	-9.42,-24.83	-9.42,-24.83	-9.42,-24.83	-9.42,-24.83	-4.42,-19.83	Schwing-S32X	32	1.38
35	ST-COL- CIP-Rectangular	3.07	2	-11.16,-4.00	-11.16,-4.00	-11.16,-9.30	-11.16,-9.30	-6.16,-1.65	Schwing-S32X	32	1.38
36	ST-BEAM-CIP-Rectangular	-2.67	3	-14.74,-4.00	-10.56,-4.00	-10.56,-9.30	-14.74,-9.30	-7.65,-1.65	Schwing-S32X	32	1.38
37	ST-BEAM-CIP-Rectangular	-0.54	1	-10.56,-6.73	-10.56,-6.73	-10.56,-6.73	-10.56,-6.73	-5.56,-1.73	Schwing-S32X	32	1.38



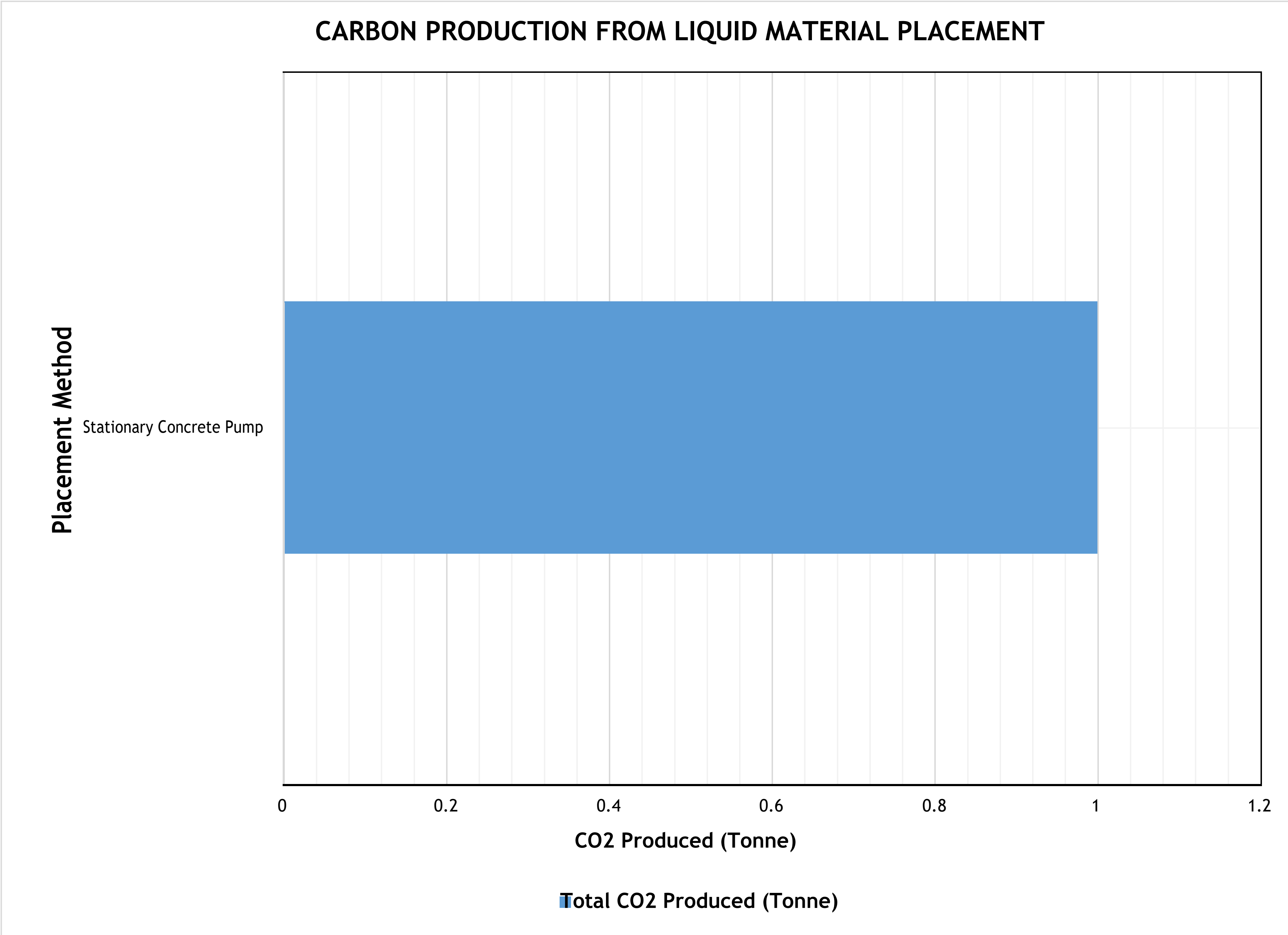
EE FOR LIQUID MATERIAL PLACEMENT USING MOBILE CONCRETE PUMP
Embodied Energy (MJ)
Family & Mobile Concrete Pump
ST-BEAM-CIP-RectangularSchwing-S32X
ST-COL- CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-COL- CIP-RectangularSchwing-S32X
ST-COL- CIP-RectangularSchwing-S32X
ST-BEAM-CIP- L ShapeSchwing-S32X
ST-BEAM-CIP- L ShapeSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP- L ShapeSchwing-S32X
ST-BEAM-CIP- Inverted TeeSchwing-S32X
ST-BEAM-CIP- L ShapeSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-BEAM-CIP-RectangularSchwing-S32X
ST-COL-CIP-RectangularSchwing-S32X
0
20
40
60
80
100
120
140
Embodied Energy (MJ)

Distribution Boom	Boom Length (m)	Boom Power(KW)	Boom Voltage (V)	Electric Concrete Pump	Pump Power(KW)	Pump Pressure(bar)	Pump Flow Rate(m3/hr)	TotalKWH	Embodied Energy(MJ)
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -70 E	75	75	40	3502.875	0.011328
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4f	115	75	43	4996.34884	0.016158
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4fH	160	105	50	5978.24	0.019333
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -110 D4f	160	75	62	4821.16129	0.015591
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -140 D4f	160	55	82	3645.26829	0.011789
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D	95	75	43	4127.4186	0.013348
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 DH	145	105	50	5417.78	0.017521
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -110 D	145	75	62	4369.17742	0.01413
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -140 D	145	55	82	3303.52439	0.012683
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4f-K	115	75	43	4996.34884	0.016158
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -70 E	75	75	40	7005.75	0.022656
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4f	115	75	43	9992.69767	0.032316
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4fH	160	105	50	11956.48	0.038667
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -110 D4f	160	75	62	9642.32258	0.031183
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -140 D4f	160	55	82	7290.53659	0.023577
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D	95	75	43	8254.83721	0.026696
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 DH	145	105	50	10835.56	0.035042
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -110 D	145	75	62	8738.35484	0.028259
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -140 D	145	55	82	6607.04878	0.021367
Liebherr-KM 29 R4	21.6	18.5	400	Liebherr -80 D4f-K	115	75	43	9992.69767	0.032316

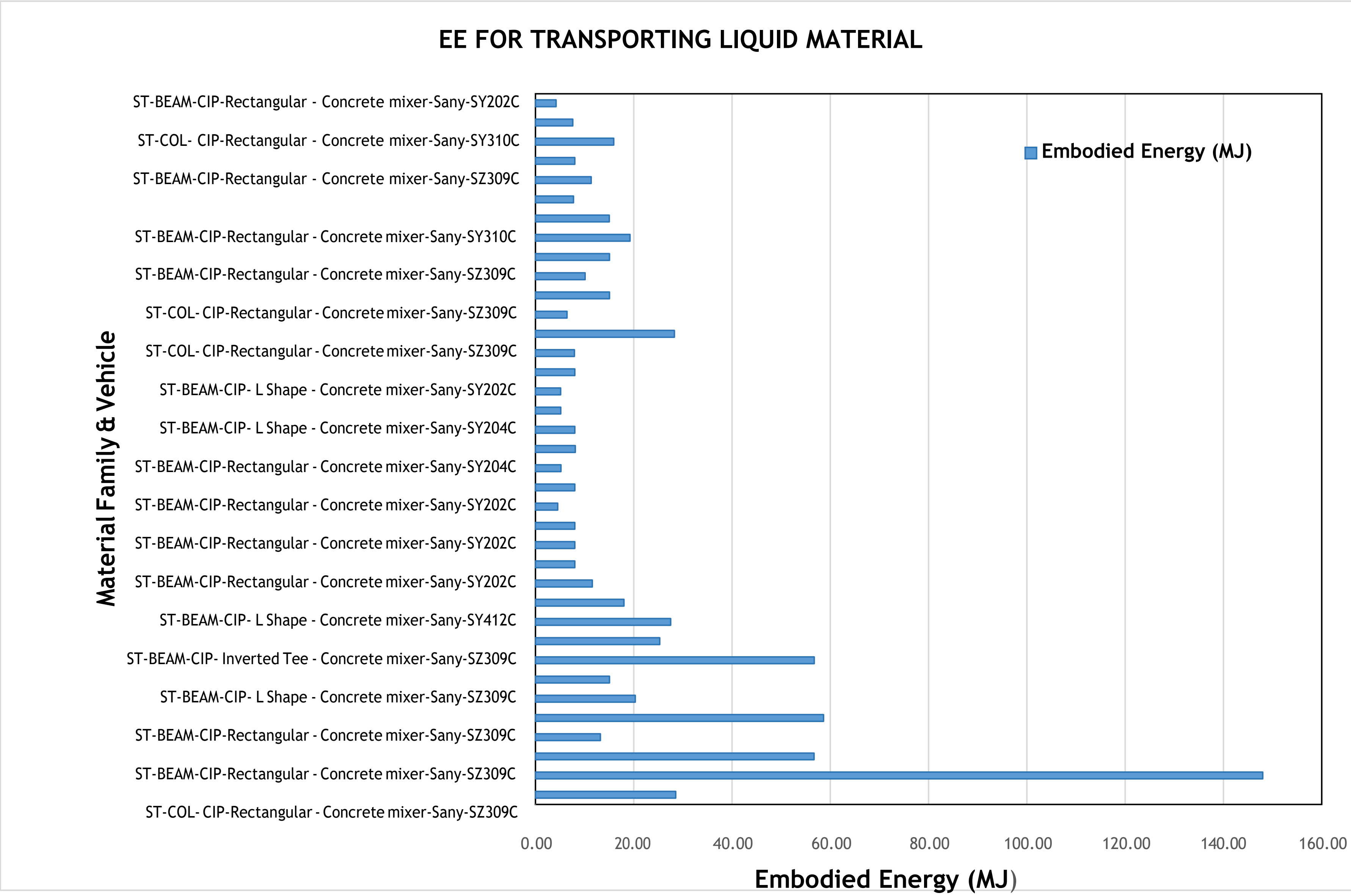

LIQUID MATERIAL PLACEMENT USING STATIONARY CONCRETE PUMP
Distribution Boom & Electric Concrete Pump
Liebherr-KM 29 R4Liebherr -80 D4f-K
Liebherr-KM29 R4Liebherr-140 D
Liebherr-KM29 R4Liebherr-110 D
Liebherr-KM29 R4Liebherr-80 DH
Liebherr-KM29 R4Liebherr-80 D
Liebherr-KM29 R4Liebherr-140 D4f
Liebherr-KM29 R4Liebherr-110 D4f
Liebherr-KM 29 R4Liebherr -80 D4fH
Liebherr-KM29 R4Liebherr-80 D4f
Liebherr-KM29 R4Liebherr-70E
0
0.005
0.01
0.015
0.02
0.025
Embodied Energy (MJ)
Embodied Energy (MJ)

LIQUID MATERIAL PLACEMENT STAGE EC PRODUCTION SUMMARY REPORT

Placement Method	Machine Name	Amount Of Fuel Used (L)	Amount Electricity Used (KWH)	CO2 Producted By Fuel (Tonne)	CO2 Producted By Electricity (Tonne)	Total CO2 Produced (Tonne)
Stationary Concrete Pump	Liebherr-KM 29 R4,Liebherr -70 E	0	18.5	0	71.548	71.548

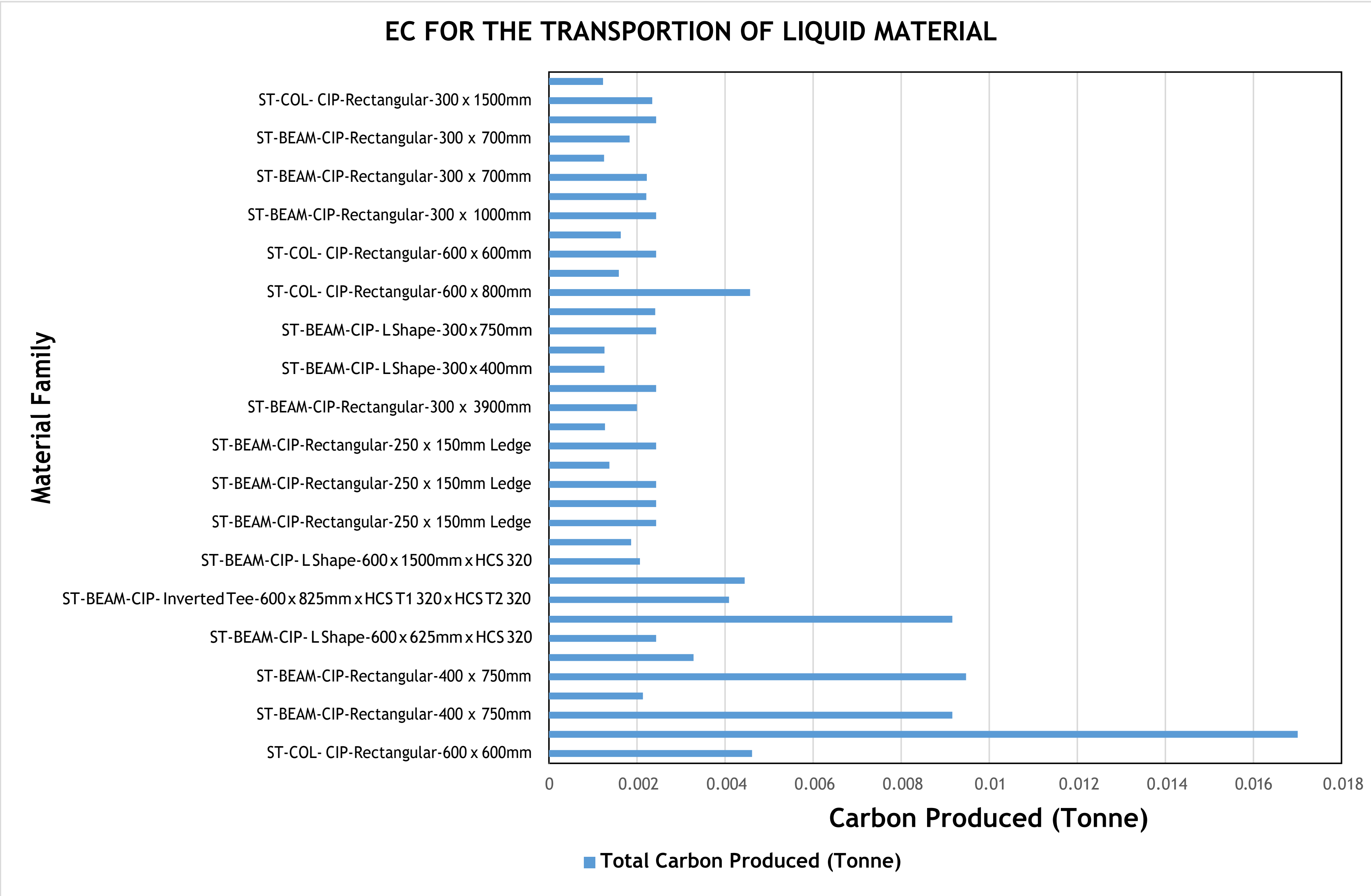

CARBON PRODUCTION FROM LIQUID MATERIAL PLACEMENT
Placement Method
Stationary Concrete Pump
0
0.2
0.4
0.6
0.8
1
1.2
CO2 Produced (Tonne)
Total CO2 Produced (Tonne)

Sl No	Family Name	Type	Elevation	No Of Elements	Total Volume (m3)	Distance (km)	Vehicle Name	Volume Capacity (m3)	FuelConsumption (L/Km)	No Of Trips	Embodied Energy (MJ)
1	ST-COL- CIP-Rectangular	600 x 600mm	0.57	3	17.05	12.3	Concrete mixer-Sany-SZ309C	9	0.32	2	28.55
2	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	3.42	18	83.82	12.3	Concrete mixer-Sany-SY412C	12	0.45	7	148.04
3	ST-BEAM-CIP-Rectangular	400 x 750mm	3.45	16	33.87	12.3	Concrete mixer-Sany-SZ309C	9	0.32	4	56.72
4	ST-BEAM-CIP- Inverted Tee	600 x 1125mm x HCS T1 400 x HCS T2 320	3.27	1	7.9	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	13.23
5	ST-BEAM-CIP-Rectangular	400 x 750mm	8.48	15	35.02	12.3	Concrete mixer-Sany-SZ309C	9	0.32	4	58.64
6	ST-BEAM-CIP-Rectangular	600 x1200mm	8.25	2	12.13	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	20.31
7	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	8.54	2	4.39	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	15.07
8	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	8.34	5	33.89	12.3	Concrete mixer-Sany-SZ309C	9	0.32	4	56.75
9	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 320 x HCS T2 320	8.44	4	15.11	12.3	Concrete mixer-Sany-SZ309C	9	0.32	2	25.30
10	ST-BEAM-CIP- L Shape	600 x 1075mm x HCS 320 -680	8.32	3	16.43	12.3	Concrete mixer-Sany-SZ309C	9	0.32	2	27.51
11	ST-BEAM-CIP- L Shape	600 x 1500mm x HCS 320	8.03	1	10.19	12.3	Concrete mixer-Sany-SY412C	12	0.45	1	18.00
12	ST-BEAM-CIP- L Shape	600 x 950mm x HCS 320	3.35	1	6.9	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	11.55
13	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	3.52	1	0.31	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
14	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	8.2	3	0.47	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
15	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	8.19	1	0.19	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
16	ST-BEAM-CIP-Rectangular	300 x 750mm	3.53	1	1.13	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	4.52
17	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	3.55	2	0.26	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
18	ST-BEAM-CIP-Rectangular	300 x 2500mm	7.28	2	2.1	12.3	Concrete mixer-Sany-SY204C	4	0.21	1	5.19
19	ST-BEAM-CIP-Rectangular	300 x 3900mm	1.88	2	3.28	12.3	Concrete mixer-Sany-SY204C	4	0.21	1	8.11
20	ST-BEAM-CIP-Rectangular	200 x 400mm Ledge	7.38	1	0.88	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
21	ST-BEAM-CIP- L Shape	300 x 400mm	7.48	1	2.08	12.3	Concrete mixer-Sany-SY204C	4	0.21	1	5.14
22	ST-BEAM-CIP-Rectangular	300 x 750mm	1.75	1	2.07	12.3	Concrete mixer-Sany-SY204C	4	0.21	1	5.12
23	ST-BEAM-CIP- L Shape	300 x 750mm	1.8	1	0.95	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
24	ST-BEAM-CIP- L Shape	300 x 600mm	7.73	1	1.98	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	7.93
25	ST-COL- CIP-Rectangular	600 x 800mm	2.57	3	16.88	12.3	Concrete mixer-Sany-SZ309C	9	0.32	2	28.27
26	ST-COL- CIP-Rectangular	600 x 600mm	0.22	1	2.6	12.3	Concrete mixer-Sany-SY204C	4	0.21	1	6.43
27	ST-COL- CIP-Rectangular	600 x 600mm	2.58	1	4.28	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	15.07
28	ST-BEAM-CIP-Rectangular	300 x 1000mm	-2.9	4	6.03	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	10.10
29	ST-BEAM-CIP-Rectangular	300 x 1000mm	-3.15	2	4.06	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	15.07
30	ST-BEAM-CIP-Rectangular	300 x 1600mm	-2.97	3	10.89	12.3	Concrete mixer-Sany-SY412C	12	0.45	1	19.23
31	ST-BEAM-CIP-Rectangular	300 x 700mm	-3.37	5	9.12	12.3	Concrete mixer-Sany-SY310C	10	0.35	1	15.03
32	ST-BEAM-CIP-Rectangular	300 x 700mm	-2.75	2	4.62	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	7.74
33	ST-BEAM-CIP-Rectangular	300 x 700mm	-3	3	6.77	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	11.34
34	ST-BEAM-CIP-Rectangular	300 x 1250mm	-3.02	1	0.74	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	8.01
35	ST-COL- CIP-Rectangular	300 x 1500mm	3.07	2	9.66	12.3	Concrete mixer-Sany-SY310C	10	0.35	1	15.92
36	ST-BEAM-CIP-Rectangular	300 x 700mm	-2.67	3	4.54	12.3	Concrete mixer-Sany-SZ309C	9	0.32	1	7.60
37	ST-BEAM-CIP-Rectangular	300 x 700mm	-0.54	1	1.05	12.3	Concrete mixer-Sany-SY202C	2	0.17	1	4.20


EE FOR TRANSPORTING LIQUID MATERIAL
Embodied Energy (MJ)
Material Family & Vehicle
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY202C
ST-COL- CIP-Rectangular - Concrete mixer-Sany-SY310C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY310C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-COL- CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-COL- CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-BEAM-CIP- L Shape - Concrete mixer-Sany-SY202C
ST-BEAM-CIP- L Shape - Concrete mixer-Sany-SY204C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY204C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY202C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY202C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SY202C
ST-BEAM-CIP- L Shape - Concrete mixer-Sany-SY412C
ST-BEAM-CIP- Inverted Tee - Concrete mixer-Sany-SZ309C
ST-BEAM-CIP- L Shape - Concrete mixer-Sany-SZ309C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-BEAM-CIP-Rectangular - Concrete mixer-Sany-SZ309C
ST-COL- CIP-Rectangular - Concrete mixer-Sany-SZ309C
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Embodied Energy (MJ)

EC FOR PRODUCTION FOR THE TRANSPORTATION OF LIQUID MATERIALS SUMMARY REPORT

SlNo	Family Name	Type	Cross Material	No Of Trips	Transportation Medium	Vehicle Name	Distance (Km)	Total Carbon Produced (Tonne)
1	ST-COL- CIP-Rectangular	600 x 600mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.0046114
2	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	Concrete 20 MPa (flyash 35%)_Liquid Concrete	7	Concrete Mixer	Concrete mixer-Sany-SY412C	12.3	0.017002677
3	ST-BEAM-CIP-Rectangular	400 x 750mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.009160593
4	ST-BEAM-CIP- Inverted Tee	600 x 1125mm x HCS T1 400 x HCS T2 320	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.00213666
5	ST-BEAM-CIP-Rectangular	400 x 750mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.009471626
6	ST-BEAM-CIP-Rectangular	600 x1200mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.00328072
7	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.00243417
8	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.009166002
9	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 320 x HCS T2 320	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.004086701
10	ST-BEAM-CIP- L Shape	600 x 1075mm x HCS 320 -680	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.004443713
11	ST-BEAM-CIP- L Shape	600 x 1500mm x HCS 320	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY412C	12.3	0.002067016
12	ST-BEAM-CIP- L Shape	600 x 950mm x HCS 320	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.001866197
13	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
14	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
15	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
16	ST-BEAM-CIP-Rectangular	300 x 750mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.001375306
17	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
18	ST-BEAM-CIP-Rectangular	300 x 2500mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY204C	12.3	0.001277939
19	ST-BEAM-CIP-Rectangular	300 x 3900mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY204C	12.3	0.001996019
20	ST-BEAM-CIP-Rectangular	200 x 400mm Ledge	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
21	ST-BEAM-CIP- L Shape	300 x 400mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY204C	12.3	0.001265768
22	ST-BEAM-CIP-Rectangular	300 x 750mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY204C	12.3	0.001259683
23	ST-BEAM-CIP- L Shape	300 x 750mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
24	ST-BEAM-CIP- L Shape	300 x 600mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.002409828
25	ST-COL- CIP-Rectangular	600 x 800mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.004565421
26	ST-COL- CIP-Rectangular	600 x 600mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY204C	12.3	0.001582211
27	ST-COL- CIP-Rectangular	600 x 600mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.00243417
28	ST-BEAM-CIP-Rectangular	300 x 1000mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.001630894
29	ST-BEAM-CIP-Rectangular	300 x 1000mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.00243417
30	ST-BEAM-CIP-Rectangular	300 x 1600mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY412C	12.3	0.002209009
31	ST-BEAM-CIP-Rectangular	300 x 700mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY310C	12.3	0.002219963
32	ST-BEAM-CIP-Rectangular	300 x 700mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.001249541
33	ST-BEAM-CIP-Rectangular	300 x 700mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.001831037
34	ST-BEAM-CIP-Rectangular	300 x 1250mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.00243417
35	ST-COL- CIP-Rectangular	300 x 1500mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY310C	12.3	0.002351408
36	ST-BEAM-CIP-Rectangular	300 x 700mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SZ309C	12.3	0.001227904
37	ST-BEAM-CIP-Rectangular	300 x 700mm	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1	Concrete Mixer	Concrete mixer-Sany-SY202C	12.3	0.001277939


EC FOR THE TRANSPORTION OF LIQUID MATERIAL
Material Family
ST-COL- CIP-Rectangular-300 x 1500mm
ST-BEAM-CIP-Rectangular-300 x 700mm
ST-BEAM-CIP-Rectangular-300 x 700mm
ST-BEAM-CIP-Rectangular-300 x 1000mm
ST-COL- CIP-Rectangular-600 x 600mm
ST-COL- CIP-Rectangular-600 x 800mm
ST-BEAM-CIP- L Shape-300 x 750mm
ST-BEAM-CIP- L Shape-300 x 400mm
ST-BEAM-CIP-Rectangular-300 x 3900mm
ST-BEAM-CIP-Rectangular-250 x 150mm Ledge
ST-BEAM-CIP-Rectangular-250 x 150mm Ledge
ST-BEAM-CIP-Rectangular-250 x 150mm Ledge
ST-BEAM-CIP- L Shape-600 x 1500mm x HCS 320
ST-BEAM-CIP- Inverted Tee-600 x 825mm x HCS T1 320 x HCS T2 320
ST-BEAM-CIP- L Shape-600 x 625mm x HCS 320
ST-BEAM-CIP-Rectangular-400 x 750mm
ST-BEAM-CIP-Rectangular-400 x 750mm
ST-COL- CIP-Rectangular-600 x 600mm
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
Carbon Produced (Tonne)
Total Carbon Produced (Tonne)

EC PRODUCED FROM THE MANUFACTURING OF MATERIALS SUMMARY REPORT

Element Id(Revit)	Family Name(Revit)	Type (Revit)	Cross Category	Cross Material	Mass(ton)	Unit Weight Of CO2 Produced Per Tonne	Total Carbon Produced (KG)
623256	ST-COL- CIP-Rectangular	600 x 800mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	13.25	110.54	1464.655
623290	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	6.04	110.54	667.6616
623629	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	13	110.54	1437.02
623753	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	9.97	110.54	1102.0838
623761	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	13.32	110.54	1472.3928
623826	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	13.32	110.54	1472.3928
623895	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	9.95	110.54	1099.873
1400160	ST-COL- CIP-Rectangular	1500 x 400mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	16.02	110.54	1770.8508
1801897	ST-COL- CIP-Rectangular	300 x 1500mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	11.44	110.54	1264.5776
1801904	ST-COL- CIP-Rectangular	300 x 1500mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	11.02	110.54	1218.1508
640054	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.86	110.54	647.7644
640114	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.46	110.54	603.5484
640135	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	2.37	110.54	261.9798
1759161	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	0.33	110.54	36.4782
640085	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.74	110.54	523.9596
642263	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.7	110.54	519.538
640780	ST-BEAM-CIP-Rectangular	300 x 1600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	6.81	110.54	752.7774
1347502	ST-BEAM-CIP-Rectangular	400 x 1600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	9.25	110.54	1022.495
1347502	ST-BEAM-CIP-Rectangular	400 x 1600mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	9.25	110.54	1022.495
640801	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.39	110.54	595.8106
640874	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.95	110.54	547.173
640891	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.95	110.54	547.173
640910	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	1.37	110.54	151.4398
641780	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.53	110.54	500.7462
640812	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.39	110.54	595.8106
641719	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.35	110.54	591.389
641032	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.02	110.54	554.9108
641701	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.44	110.54	601.3376
641815	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.28	110.54	583.6512
647231	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	14.09	110.54	1557.5086
647233	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	14.09	110.54	1557.5086
647235	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 265 x HCS T2 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	12.58	110.54	1390.5932
648263	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	11.72	110.54	1295.5288
648267	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	7.9	110.54	873.266
648313	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	14.02	110.54	1549.7708
648315	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	14.09	110.54	1557.5086
648317	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	12.44	110.54	1375.1176
1245305	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.23	110.54	467.5842
1245305	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	4.23	110.54	467.5842
1326172	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	11.6	110.54	1282.264
1327368	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	9.67	110.54	1068.9218
1327781	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	12.46	110.54	1377.3284
1327956	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	13.62	110.54	1505.5548
1410673	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	8.25	110.54	911.955
1467300	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	12.51	110.54	1382.8554
1554679	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.14	110.54	568.1756
1838079	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	12.23	110.54	1351.9042
648261	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	5.98	110.54	661.0292
1249262	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	11.02	110.54	1218.1508
1249478	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	7.37	110.54	814.6798
1249622	ST-BEAM-CIP- L Shape	400 x750mm x HCS 265	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	2.09	110.54	231.0286
1315015	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	7.32	110.54	809.1528
1315017	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	7.58	110.54	837.8932
1315017	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20MPa (flyash 35%)_Liquid Concrete	7.58	110.54	837.8932

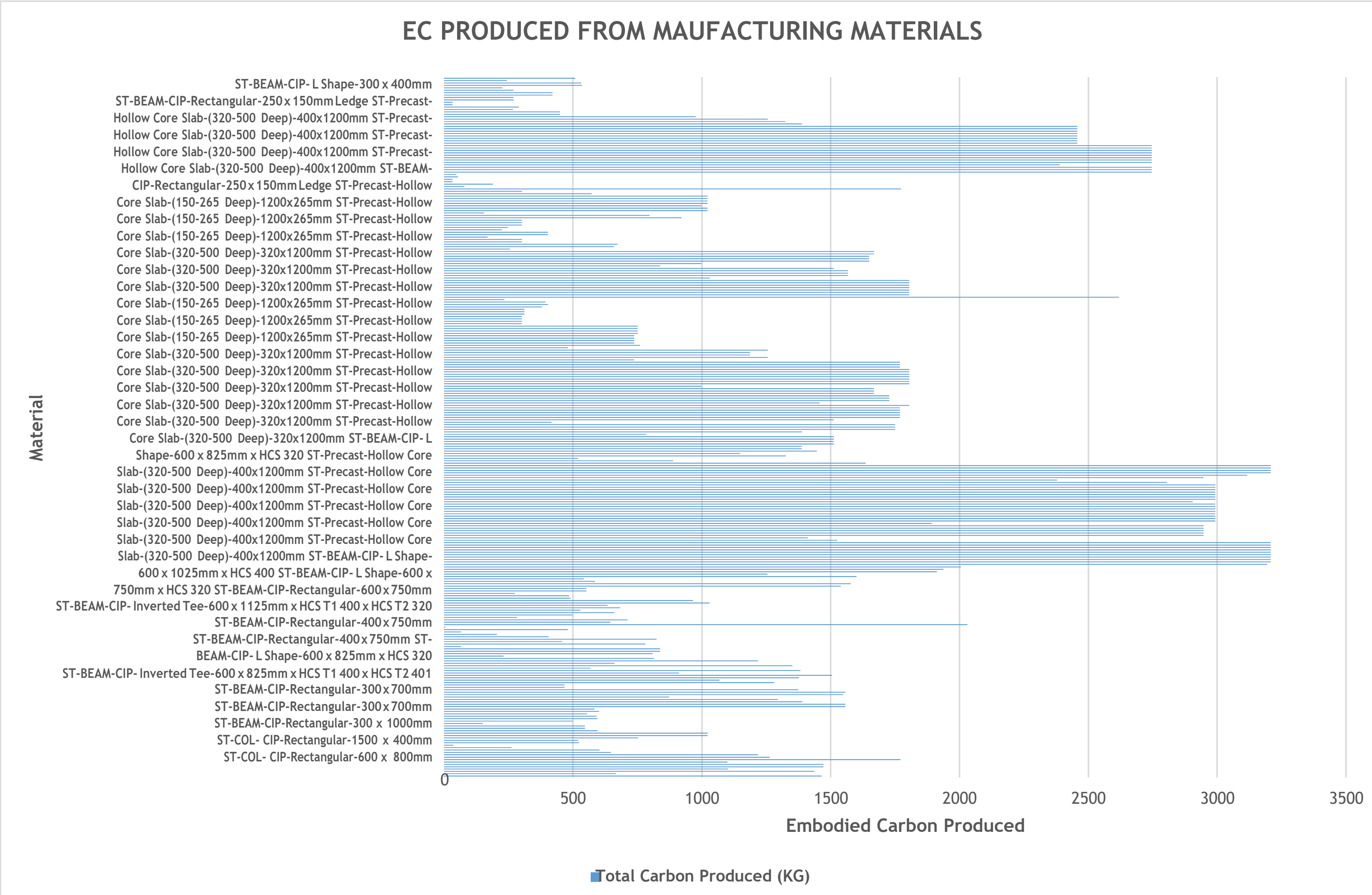
1329746	ST-BEAM-CIP-Rectangular	315 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.6	110.54	66.324
1448677	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	7.07	110.54	781.5178
1448679	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.14	110.54	457.6356
1450862	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	7.46	110.54	824.6284
1809319	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	3.67	110.54	405.6818
1809321	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1.86	110.54	205.6044
2025510	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.6	110.54	66.324
2025556	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.35	110.54	480.849
2025648	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.05	110.54	5.527
648363	ST-BEAM-CIP- Inverted Tee	600 x 1125mm x HCS T1 400 x HCS T2 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	18.37	110.54	2030.6198
658520	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5.84	110.54	645.5536
658913	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	6.44	110.54	711.8776
658915	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.56	110.54	282.9824
1479150	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.51	110.54	498.5354
1479193	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5.98	110.54	661.0292
1542699	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.79	110.54	529.4866
1543124	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	6.18	110.54	683.1372
1543220	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5.74	110.54	634.4996
1795288	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	9.32	110.54	1030.2328
1797047	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	8.74	110.54	966.1196
1821809	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.44	110.54	490.7976
1821972	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.39	110.54	485.2706
1822026	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.49	110.54	275.2446
1836174	ST-BEAM-CIP- L Shape	600 x 750mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5	110.54	552.7
1836174	ST-BEAM-CIP- L Shape	600 x 750mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5	110.54	552.7
658522	ST-BEAM-CIP-Rectangular	600 x1200mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	13.93	110.54	1539.8222
658690	ST-BEAM-CIP-Rectangular	600 x 1200mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	14.28	110.54	1578.5112
658917	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	5.3	110.54	585.862
1295796	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.91	110.54	542.7514
659019	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	14.48	110.54	1600.6192
1257327	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	11.35	110.54	1254.629
1257424	ST-BEAM-CIP- Inverted Tee	600 x 1025mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	17.3	110.54	1912.342
1257576	ST-BEAM-CIP- Inverted Tee	600 x 1025mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	17.53	110.54	1937.7662
1786288	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	18.14	110.54	2005.1956
804138	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.97	458.27	3194.1419
804141	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804144	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804147	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804150	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804153	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804156	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804159	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804162	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804165	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
804168	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	3.33	458.27	1526.0391
1419029	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	3.08	458.27	1411.4716
1419032	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1419035	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1419038	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1419041	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1419044	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1419047	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	4.13	458.27	1892.6551
1419050	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419053	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419056	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419059	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419062	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419065	ST-Precast-Hollow Core Slab	400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031

1419068	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419071	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419074	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.34	458.27	2905.4318
1419077	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419080	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419083	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419086	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419089	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419092	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1419095	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.53	458.27	2992.5031
1486470	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.12	458.27	2804.6124
1486495	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.19	458.27	2378.4213
1486898	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.43	458.27	2946.6761
1744179	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	6.8	458.27	3116.236
1744387	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
1744390	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
1744393	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
1744396	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	7	458.27	3207.89
2056401	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	3.57	458.27	1636.0239
1257635	ST-BEAM-CIP- Inverted Tee 600 x 825mm x HCS T1 320 x HCS T2 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	8.04	110.54	888.7416
1260445	ST-BEAM-CIP- L Shape 600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.7	110.54	519.538
1260592	ST-BEAM-CIP- L Shape 600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	12	110.54	1326.48
1260750	ST-BEAM-CIP- L Shape 600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	10.39	110.54	1148.5106
1261363	ST-BEAM-CIP- L Shape 600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	13.09	110.54	1446.9686
1479157	ST-BEAM-CIP- L Shape 600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	12.56	110.54	1388.3824
1479157	ST-BEAM-CIP- L Shape 600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	12.56	110.54	1388.3824
1267980	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1267982	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1267984	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1267986	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1267988	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.71	458.27	783.6417
1268049	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.03	458.27	1388.5581
1268051	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.82	458.27	1750.5914
1268053	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.82	458.27	1750.5914
1268055	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.82	458.27	1750.5914
1268065	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	0.91	458.27	417.0257
1268202	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1268204	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1268206	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1268208	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1268210	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1278278	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1463769	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479357	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.18	458.27	1457.2986
1479360	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.77	458.27	1727.6779
1479363	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.77	458.27	1727.6779
1479366	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.77	458.27	1727.6779
1479369	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.64	458.27	1668.1028
1479372	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.64	458.27	1668.1028
1479375	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.64	458.27	1668.1028
1479390	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.18	458.27	999.0286
1479393	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479396	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479399	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479402	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479405	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479408	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1479411	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838

1760678	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1760680	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1760682	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.86	458.27	1768.9222
1760684	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.61	458.27	737.8147
1796563	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.74	458.27	1255.6598
1796565	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.59	458.27	1186.9193
1796567	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.59	458.27	1186.9193
1835645	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.74	458.27	1255.6598
1835833	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.05	458.27	481.1835
2011534	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.66	458.27	760.7282
1268057	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.61	458.27	737.8147
1268059	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.61	458.27	737.8147
1268061	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.61	458.27	737.8147
1268063	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.61	458.27	737.8147
1295832	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.64	458.27	751.5628
1295834	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.64	458.27	751.5628
1295836	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.64	458.27	751.5628
1295838	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.64	458.27	751.5628
1479378	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1479381	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1479384	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1479387	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1480257	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.68	458.27	311.6236
1480260	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.68	458.27	311.6236
1480263	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.68	458.27	311.6236
1480266	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.83	458.27	380.3641
1480269	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.88	458.27	403.2776
1480272	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.86	458.27	394.1122
1840103	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.51	458.27	233.7177
1283288	ST-BEAM-CIP- L Shape 600 x 1500mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	23.69	110.54	2618.6926
1326588	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326590	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326592	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326594	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326596	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326598	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1326600	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.94	458.27	1805.5838
1327001	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.25	458.27	1031.1075
1327003	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.42	458.27	1567.2834
1327005	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.42	458.27	1567.2834
1327007	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.42	458.27	1567.2834
1327009	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.3	458.27	1512.291
1488389	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.83	458.27	838.6341
2402554	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	2.18	458.27	999.0286
2403930	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.6	458.27	1649.772
2403933	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.6	458.27	1649.772
2403936	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.6	458.27	1649.772
2403939	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.64	458.27	1668.1028
2403942	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	3.64	458.27	1668.1028
2403945	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	0.56	458.27	256.6312
2404258	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.44	458.27	659.9088
2406261	ST-Precast-Hollow Core Slab 320x1200mm	Concrete	Precast Concrete _Concrete	1.47	458.27	673.6569
1331354	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1331356	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1331358	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.37	458.27	169.5599
1331360	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.88	458.27	403.2776
1331362	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.88	458.27	403.2776
1331364	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.49	458.27	224.5523

1410340	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.54	458.27	247.4658
1410342	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1410344	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1410346	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1450089	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.01	458.27	921.1227
1450091	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.74	458.27	797.3898
1486584	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.34	458.27	155.8118
1745400	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745403	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745406	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.18	458.27	999.0286
1745409	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745412	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745415	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745418	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	2.23	458.27	1021.9421
1745754	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	1.25	458.27	572.8375
2405432	ST-Precast-Hollow Core Slab 1200x265mm	Concrete	Precast Concrete _Concrete	0.66	458.27	302.4582
1331391	ST-BEAM-CIP- L Shape 600 x 950mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	16.04	110.54	1773.0616
1426889	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.72	110.54	79.5888
1473634	ST-BEAM-CIP-Rectangular 300 x 1250mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	1.72	110.54	190.1288
1784252	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.3	110.54	33.162
1784357	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.3	110.54	33.162
1784470	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.49	110.54	54.1646
1788281	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.44	110.54	48.6376
1796355	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1796357	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1796359	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1796361	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.21	458.27	2387.5867
1834651	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834653	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834655	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834657	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834758	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834760	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834762	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1834764	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.99	458.27	2745.0373
1835072	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835074	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835076	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835078	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835083	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835085	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835087	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835089	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	5.36	458.27	2456.3272
1835338	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	3.03	458.27	1388.5581
1835452	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	2.89	458.27	1324.4003
2011606	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	2.74	458.27	1255.6598
2012018	ST-Precast-Hollow Core Slab 400x1200mm	Concrete	Precast Concrete _Concrete	2.13	458.27	976.1151
1802657	ST-BEAM-CIP-Rectangular 300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.07	110.54	449.8978
1802659	ST-BEAM-CIP-Rectangular 300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.07	110.54	449.8978
1802661	ST-BEAM-CIP-Rectangular 300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.42	110.54	267.5068
1809323	ST-BEAM-CIP-Rectangular 300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.63	110.54	290.7202
1851624	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.3	110.54	33.162
1851702	ST-BEAM-CIP-Rectangular 250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	0.3	110.54	33.162
1853665	ST-BEAM-CIP-Rectangular 300 x 2500mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.44	110.54	269.7176
1853951	ST-BEAM-CIP-Rectangular 300 x 2500mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.44	110.54	269.7176
1854139	ST-BEAM-CIP-Rectangular 300 x 3900mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	3.81	110.54	421.1574
1854278	ST-BEAM-CIP-Rectangular 300 x 3900mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	3.81	110.54	421.1574
2139556	ST-BEAM-CIP-Rectangular 300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.44	110.54	269.7176

2430608	ST-BEAM-CIP-Rectangular	200 x 400mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.05	110.54	226.607
2431966	ST-BEAM-CIP- L Shape	300 x 400mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.84	110.54	535.0136
2432849	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.81	110.54	531.6974
2433574	ST-BEAM-CIP- L Shape	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	2.21	110.54	244.2934
2434549	ST-BEAM-CIP- L Shape	300 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete	4.6	110.54	508.484



EC PRODUCED FROM MAUFACTURING MATERIALS
Material
ST-BEAM-CIP- L Shape-300 x 400mm
ST-BEAM-CIP-Rectangular-250 x 150mm Ledge ST-Precast-
Hollow Core Slab-(320-500 Deep)-400x1200mm ST-Precast-
Hollow Core Slab-(320-500 Deep)-400x1200mm ST-Precast-
Hollow Core Slab-(320-500 Deep)-400x1200mm ST-Precast-
Hollow Core Slab-(320-500 Deep)-400x1200mm ST-BEAM-
CIP-Rectangular-250 x 150mm Ledge ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(150-265 Deep)-1200x265mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-Precast-Hollow
Core Slab-(320-500 Deep)-320x1200mm ST-BEAM-CIP- L
Shape-600 x 825mm x HCS 320 ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-Precast-Hollow Core
Slab-(320-500 Deep)-400x1200mm ST-BEAM-CIP- L Shape-
600 x 1025mm x HCS 400 ST-BEAM-CIP- L Shape-600 x
750mm x HCS 320 ST-BEAM-CIP-Rectangular-600 x 750mm
ST-BEAM-CIP- Inverted Tee-600 x 1125mm x HCS T1 400 x HCS T2 320
ST-BEAM-CIP-Rectangular-400 x 750mm
ST-BEAM-CIP-Rectangular-400 x 750mm ST-
BEAM-CIP- L Shape-600 x 825mm x HCS 320
ST-BEAM-CIP- Inverted Tee-600 x 825mm x HCS T1 400 x HCS T2 401
ST-BEAM-CIP-Rectangular-300 x 700mm
ST-BEAM-CIP-Rectangular-300 x 700mm
ST-BEAM-CIP-Rectangular-300 x 1000mm
ST-COL- CIP-Rectangular-1500 x 400mm
ST-COL- CIP-Rectangular-600 x 800mm
0
500
1000
1500
2000
2500
3000
3500
Embodied Carbon Produced
Total Carbon Produced (KG)

Sl No	Element Id (Revit)	Category (Revit)	Material Class (Revit)	Family(Revit)	Type(Revit)	CrossCategory	CrossMaterial
1	623256	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 800mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
2	623290	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
3	623629	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
4	623753	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
5	623761	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
6	623826	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
7	623895	Structural Columns	Concrete	ST-COL- CIP-Rectangular	600 x 600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
8	1400160	Structural Columns	Concrete	ST-COL- CIP-Rectangular	1500 x 400mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
9	1801897	Structural Columns	Concrete	ST-COL- CIP-Rectangular	300 x 1500mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
10	1801904	Structural Columns	Concrete	ST-COL- CIP-Rectangular	300 x 1500mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
11	640054	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
12	640114	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
13	640135	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
14	1759161	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
15	640085	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
16	642263	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1000mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
17	640780	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
18	1347502	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	400 x 1600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
19	1347502	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	400 x 1600mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
20	640801	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
21	640874	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
22	640891	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
23	640910	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
24	641780	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
25	640812	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
26	641719	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
27	641032	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
28	641701	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
29	641815	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
30	647231	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
31	647233	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
32	647235	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 265 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
33	648263	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
34	648267	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
35	648313	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
36	648315	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
37	648317	Structural Framing	Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 400 x HCS T2 401	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
38	1245305	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
39	1245305	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
40	1326172	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
41	1327368	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
42	1327781	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
43	1327956	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete

44	1410673	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
45	1467300	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
46	1554679	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
47	1838079	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
48	648261	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
49	1249262	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
50	1249478	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
51	1249622	Structural Framing Concrete	ST-BEAM-CIP- L Shape	400 x750mm x HCS 265	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
52	1315015	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
53	1315017	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
54	1315017	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
55	1329746	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	315 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
56	1448677	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
57	1448679	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
58	1450862	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
59	1809319	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
60	1809321	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
61	2025510	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
62	2025556	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
63	2025648	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
64	648363	Structural Framing Concrete	ST-BEAM-CIP- Inverted Tee	600 x 1125mm x HCS T1 400 x HCS T2 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
65	658520	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
66	658913	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
67	658915	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
68	1479150	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
69	1479193	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
70	1542699	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
71	1543124	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
72	1543220	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	400 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
73	1795288	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
74	1797047	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
75	1821809	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
76	1821972	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
77	1822026	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
78	1836174	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 750mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
79	1836174	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 750mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
80	658522	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x1200mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
81	658690	Structural Framing Concrete	ST-BEAM-CIP-Rectangular	600 x 1200mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
82	658917	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
83	1295796	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 625mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
84	659019	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
85	1257327	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
86	1257424	Structural Framing Concrete	ST-BEAM-CIP- Inverted Tee	600 x 1025mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
87	1257576	Structural Framing Concrete	ST-BEAM-CIP- Inverted Tee	600 x 1025mm x HCS T1 400 x HCS T2 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
88	1786288	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 1025mm x HCS 400	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
89	804138	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
90	804141	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete

91	804144	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
92	804147	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
93	804150	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
94	804153	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
95	804156	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
96	804159	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
97	804162	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
98	804165	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
99	804168	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
100	1419029	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
101	1419032	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
102	1419035	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
103	1419038	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
104	1419041	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
105	1419044	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
106	1419047	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
107	1419050	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
108	1419053	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
109	1419056	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
110	1419059	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
111	1419062	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
112	1419065	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
113	1419068	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
114	1419071	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
115	1419074	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
116	1419077	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
117	1419080	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
118	1419083	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
119	1419086	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
120	1419089	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
121	1419092	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
122	1419095	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
123	1486470	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
124	1486495	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
125	1486898	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
126	1744179	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
127	1744387	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
128	1744390	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
129	1744393	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
130	1744396	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
131	2056401	Structural Framing Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
132	1257635	Structural Framing Concrete	ST-BEAM-CIP- Inverted Tee	600 x 825mm x HCS T1 320 x HCS T2 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
133	1260445	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
134	1260592	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
135	1260750	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 825mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
136	1261363	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
137	1479157	Structural Framing Concrete	ST-BEAM-CIP- L Shape	600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete

138	1479157	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 1075mm x HCS 320 -680	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
139	1267980	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
140	1267982	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
141	1267984	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
142	1267986	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
143	1267988	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
144	1268049	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
145	1268051	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
146	1268053	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
147	1268055	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
148	1268065	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
149	1268202	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
150	1268204	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
151	1268206	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
152	1268208	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
153	1268210	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
154	1278278	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
155	1463769	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
156	1479357	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
157	1479360	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
158	1479363	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
159	1479366	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
160	1479369	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
161	1479372	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
162	1479375	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
163	1479390	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
164	1479393	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
165	1479396	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
166	1479399	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
167	1479402	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
168	1479405	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
169	1479408	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
170	1479411	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
171	1760678	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
172	1760680	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
173	1760682	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
174	1760684	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
175	1796563	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
176	1796565	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
177	1796567	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
178	1835645	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
179	1835833	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
180	2011534	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
181	1268057	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
182	1268059	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
183	1268061	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
184	1268063	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete

185	1295832	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
186	1295834	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
187	1295836	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
188	1295838	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
189	1479378	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
190	1479381	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
191	1479384	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
192	1479387	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
193	1480257	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
194	1480260	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
195	1480263	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
196	1480266	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
197	1480269	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
198	1480272	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
199	1840103	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
200	1283288	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 1500mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
201	1326588	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
202	1326590	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
203	1326592	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
204	1326594	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
205	1326596	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
206	1326598	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
207	1326600	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
208	1327001	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
209	1327003	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
210	1327005	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
211	1327007	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
212	1327009	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
213	1488389	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
214	2402554	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
215	2403930	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
216	2403933	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
217	2403936	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
218	2403939	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
219	2403942	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
220	2403945	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
221	2404258	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
222	2406261	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	Concrete	Precast Concrete _Concrete
223	1331354	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
224	1331356	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
225	1331358	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
226	1331360	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
227	1331362	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
228	1331364	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
229	1410340	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
230	1410342	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
231	1410344	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete

232	1410346	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
233	1450089	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
234	1450091	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
235	1486584	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
236	1745400	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
237	1745403	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
238	1745406	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
239	1745409	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
240	1745412	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
241	1745415	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
242	1745418	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
243	1745754	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
244	2405432	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Concrete	Precast Concrete _Concrete
245	1331391	Structural Framing	Concrete	ST-BEAM-CIP- L Shape	600 x 950mm x HCS 320	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
246	1426889	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
247	1473634	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 1250mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
248	1784252	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
249	1784357	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
250	1784470	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
251	1788281	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
252	1796355	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
253	1796357	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
254	1796359	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
255	1796361	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
256	1834651	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
257	1834653	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
258	1834655	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
259	1834657	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
260	1834758	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
261	1834760	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
262	1834762	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
263	1834764	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
264	1835072	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
265	1835074	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
266	1835076	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
267	1835078	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
268	1835083	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
269	1835085	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
270	1835087	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
271	1835089	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
272	1835338	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
273	1835452	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
274	2011606	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
275	2012018	Structural Framing	Unassigned	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Concrete	Precast Concrete _Concrete
276	1802657	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
277	1802659	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete
278	1802661	Structural Framing	Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete	Concrete 20 MPa (flyash 35%)_Liquid Concrete

279	1809323 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
280	1851624 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
281	1851702 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	250 x 150mm Ledge	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
282	1853665 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 2500mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
283	1853951 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 2500mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
284	1854139 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 3900mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
285	1854278 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 3900mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
286	2139556 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 700mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
287	2430608 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	200 x 400mm Ledge	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
288	2431966 Structural Framing Concrete	ST-BEAM-CIP- L Shape	300 x 400mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
289	2432849 Structural Framing Concrete	ST-BEAM-CIP-Rectangular	300 x 750mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete
290	2433574 Structural Framing Concrete	ST-BEAM-CIP- L Shape	300 x 750mm	Liquid Concrete Concrete 20 MPa (flyash 35%)_Liquid Concrete

EMBODIED ENERGY FOR MANUFACTURING MATERIALS SUMMARY REPORT

Sl No	Family(Revit)	Y	Z	Elevation (Revit)	Height (Revit)	Width (Revit)	Length (Revit)	Volume (m3) (Revit)	Density Tonne /(m3)	Mass Tonne	Embodied Energy (MJ/Tonne)	Total Embodied Energy (MJ)
1	ST-COL- CIP-Rectangular	-19.68	2.57	2.57	0.6	0.8	11.92	5.7	2.32	13.224	630.4	8336.4096
2	ST-COL- CIP-Rectangular	-19.68	0.22	0.22	0.6	0.6	7.23	2.6	2.33	6.058	630.4	3818.9632
3	ST-COL- CIP-Rectangular	14.02	0.57	0.57	0.6	0.6	15.92	5.59	2.33	13.0247	630.4	8210.77088
4	ST-COL- CIP-Rectangular	-19.68	2.57	2.57	0.6	0.6	11.92	4.29	2.33	9.9957	630.4	6301.28928
5	ST-COL- CIP-Rectangular	14.02	0.57	0.57	0.6	0.6	15.92	5.73	2.33	13.3509	630.4	8416.40736
6	ST-COL- CIP-Rectangular	14.02	0.57	0.57	0.6	0.6	15.92	5.73	2.33	13.3509	630.4	8416.40736
7	ST-COL- CIP-Rectangular	-8.08	2.58	2.58	0.6	0.6	11.9	4.28	2.33	9.9724	630.4	6286.60096
8	ST-COL- CIP-Rectangular	-12.65	2.57	2.57	0.4	1.5	11.92	6.89	2.33	16.0537	630.4	10120.25248
9	ST-COL- CIP-Rectangular	1	3.07	3.07	0.3	1.5	10.92	4.92	2.33	11.4636	630.4	7226.65344
10	ST-COL- CIP-Rectangular	-4.3	3.07	3.07	0.3	1.5	10.92	4.74	2.33	11.0442	630.4	6962.26368
11	ST-BEAM-CIP-Rectangular	-8.65	-2.9	-2.9	0.3	1	8.4	2.52	2.33	5.8716	630.4	3701.45664
12	ST-BEAM-CIP-Rectangular	-19.83	-2.9	-2.9	0.3	1	9.7	2.35	2.33	5.4755	630.4	3451.7552
13	ST-BEAM-CIP-Rectangular	-19.83	-2.9	-2.9	0.3	1	4.03	1.02	2.33	2.3766	630.4	1498.20864
14	ST-BEAM-CIP-Rectangular	-12.7	-2.9	-2.9	0.3	0.48	1	0.14	2.33	0.3262	630.4	205.63648
15	ST-BEAM-CIP-Rectangular	-19.83	-3.15	-3.15	0.3	1	7.25	2.04	2.33	4.7532	630.4	2996.41728
16	ST-BEAM-CIP-Rectangular	-16.28	-3.15	-3.15	0.3	1	7.4	2.02	2.33	4.7066	630.4	2967.04064
17	ST-BEAM-CIP-Rectangular	-11.18	-2.97	-2.97	0.3	1.6	6.4	2.93	2.33	6.8269	630.4	4303.67776
18	ST-BEAM-CIP-Rectangular	-7.98	-2.97	-2.97	0.4	1.6	6.24	3.98	2.33	9.2734	630.4	5845.95136
19	ST-BEAM-CIP-Rectangular	-7.98	-2.97	-2.97	0.4	1.6	6.24	3.98	2.33	9.2734	630.4	5845.95136
20	ST-BEAM-CIP-Rectangular	-13.85	-3.37	-3.37	0.3	0.7	11.05	2.32	2.33	5.4056	630.4	3407.69024
21	ST-BEAM-CIP-Rectangular	-8.18	-3.37	-3.37	0.3	0.7	10.15	2.13	2.33	4.9629	630.4	3128.61216
22	ST-BEAM-CIP-Rectangular	-8.18	-3.37	-3.37	0.3	0.7	10.15	2.13	2.33	4.9629	630.4	3128.61216
23	ST-BEAM-CIP-Rectangular	-8.08	-3.37	-3.37	0.3	0.7	2.86	0.59	2.33	1.3747	630.4	866.61088
24	ST-BEAM-CIP-Rectangular	-3.62	-3.37	-3.37	0.3	0.7	9.41	1.95	2.33	4.5435	630.4	2864.2224
25	ST-BEAM-CIP-Rectangular	-14.15	-2.75	-2.75	0.3	0.7	11.65	2.32	2.33	5.4056	630.4	3407.69024
26	ST-BEAM-CIP-Rectangular	-2.78	-2.75	-2.75	0.3	0.7	11.1	2.3	2.33	5.359	630.4	3378.3136
27	ST-BEAM-CIP-Rectangular	2.77	-3	-3	0.3	0.7	10.3	2.16	2.33	5.0328	630.4	3172.67712
28	ST-BEAM-CIP-Rectangular	8.32	-3	-3	0.3	0.7	11.4	2.34	2.33	5.4522	630.4	3437.06688
29	ST-BEAM-CIP-Rectangular	8.4	-3	-3	0.3	0.7	11.25	2.27	2.33	5.2891	630.4	3334.24864
30	ST-BEAM-CIP- Inverted Tee	-8.08	3.42	3.42	0.83	0.9	10.28	6.06	2.33	14.1198	630.4	8901.12192
31	ST-BEAM-CIP- Inverted Tee	-8.08	3.42	3.42	0.83	0.9	10.2	6.06	2.33	14.1198	630.4	8901.12192
32	ST-BEAM-CIP- Inverted Tee	-8.08	3.42	3.42	0.83	0.9	9.21	5.41	2.33	12.6053	630.4	7946.38112
33	ST-BEAM-CIP- L Shape	-19.6	3.42	3.42	0.75	0.82	10	5.04	2.33	11.7432	630.4	7402.91328
34	ST-BEAM-CIP- L Shape	-19.6	3.42	3.42	0.75	0.83	6.41	3.4	2.33	7.922	630.4	4994.0288
35	ST-BEAM-CIP- Inverted Tee	2.77	3.42	3.42	0.83	0.9	10.17	6.03	2.33	14.0499	630.4	8857.05696
36	ST-BEAM-CIP- Inverted Tee	2.77	3.42	3.42	0.83	0.9	10.2	6.06	2.33	14.1198	630.4	8901.12192
37	ST-BEAM-CIP- Inverted Tee	2.77	3.42	3.42	0.83	0.9	9.2	5.35	2.33	12.4655	630.4	7858.2512
38	ST-BEAM-CIP- L Shape	12.2	3.42	3.42	0.75	0.82	3.64	1.82	2.33	4.2406	630.4	2673.27424
39	ST-BEAM-CIP- L Shape	12.2	3.42	3.42	0.75	0.82	3.64	1.82	2.33	4.2406	630.4	2673.27424
40	ST-BEAM-CIP- L Shape	5.77	3.42	3.42	0.75	0.82	9.85	4.99	2.33	11.6267	630.4	7329.47168
41	ST-BEAM-CIP- L Shape	-8.33	3.42	3.42	0.75	0.83	8.35	4.16	2.33	9.6928	630.4	6110.34112
42	ST-BEAM-CIP- L Shape	-2.48	3.42	3.42	0.75	0.83	11.41	5.36	2.33	12.4888	630.4	7872.93952
43	ST-BEAM-CIP- L Shape	8.4	3.42	3.42	0.75	0.83	11.25	5.86	2.33	13.6538	630.4	8607.35552

44 ST-BEAM-CIP- L Shape	-16.23	3.42	3.42	0.75	0.83	7.5	3.55	2.33	8.2715	630.4	5214.3536
45 ST-BEAM-CIP- L Shape	13.95	3.42	3.42	0.75	0.83	10.27	5.38	2.33	12.5354	630.4	7902.31616
46 ST-BEAM-CIP- L Shape	-19.6	3.42	3.42	0.75	0.83	4.48	2.21	2.33	5.1493	630.4	3246.11872
47 ST-BEAM-CIP- L Shape	13.95	3.42	3.42	0.75	0.82	10	5.26	2.33	12.2558	630.4	7726.05632
48 ST-BEAM-CIP-Rectangular	-19.78	3.45	3.45	0.4	0.75	9.27	2.57	2.33	5.9881	630.4	3774.89824
49 ST-BEAM-CIP-Rectangular	8.4	3.45	3.45	0.6	0.75	11.25	4.74	2.33	11.0442	630.4	6962.26368
50 ST-BEAM-CIP-Rectangular	8.4	3.45	3.45	0.4	0.75	11.25	3.17	2.33	7.3861	630.4	4656.19744
51 ST-BEAM-CIP- L Shape	8.73	3.45	3.45	0.55	0.75	3.4	0.9	2.33	2.097	630.4	1321.9488
52 ST-BEAM-CIP-Rectangular	-2.88	3.45	3.45	0.4	0.75	11.3	3.15	2.33	7.3395	630.4	4626.8208
53 ST-BEAM-CIP-Rectangular	-13.88	3.45	3.45	0.4	0.75	11.6	3.26	2.33	7.5958	630.4	4788.39232
54 ST-BEAM-CIP-Rectangular	-13.88	3.45	3.45	0.4	0.75	11.6	3.26	2.33	7.5958	630.4	4788.39232
55 ST-BEAM-CIP-Rectangular	-1.66	3.45	3.45	0.15	0.6	5.59	0.26	2.33	0.6058	630.4	381.89632
56 ST-BEAM-CIP-Rectangular	-2.7	3.45	3.45	0.4	0.75	10.95	3.04	2.33	7.0832	630.4	4465.24928
57 ST-BEAM-CIP-Rectangular	-11.35	3.45	3.45	0.4	0.75	6.35	1.78	2.33	4.1474	630.4	2614.52096
58 ST-BEAM-CIP-Rectangular	8.4	3.45	3.45	0.4	0.75	11.25	3.21	2.33	7.4793	630.4	4714.95072
59 ST-BEAM-CIP-Rectangular	1	3.45	3.45	0.3	0.75	7.16	1.58	2.33	3.6814	630.4	2320.75456
60 ST-BEAM-CIP-Rectangular	-4.3	3.45	3.45	0.3	0.75	7.16	0.8	2.33	1.864	630.4	1175.0656
61 ST-BEAM-CIP-Rectangular	-12.6	3.45	3.45	0.3	0.75	1.15	0.26	2.33	0.6058	630.4	381.89632
62 ST-BEAM-CIP-Rectangular	-8.45	3.45	3.45	0.3	0.75	8.6	1.87	2.33	4.3571	630.4	2746.71584
63 ST-BEAM-CIP-Rectangular	-4.3	3.45	3.45	0.3	0.55	0.75	0.02	2.33	0.0466	630.4	29.37664
64 ST-BEAM-CIP- Inverted Tee	14.02	3.27	3.27	0.9	1.13	9.31	7.9	2.33	18.407	630.4	11603.7728
65 ST-BEAM-CIP-Rectangular	2.77	8.48	8.48	0.4	1.4	10	2.51	2.33	5.8483	630.4	3686.76832
66 ST-BEAM-CIP-Rectangular	-19.78	8.48	8.48	0.4	1.4	9.52	2.77	2.33	6.4541	630.4	4068.66464
67 ST-BEAM-CIP-Rectangular	-19.78	8.48	8.48	0.4	1.4	4.63	1.1	2.33	2.563	630.4	1615.7152
68 ST-BEAM-CIP-Rectangular	14.02	8.48	8.48	0.6	1.4	9.33	1.94	2.33	4.5202	630.4	2849.53408
69 ST-BEAM-CIP-Rectangular	-12.65	8.48	8.48	0.4	1.4	8.98	2.57	2.33	5.9881	630.4	3774.89824
70 ST-BEAM-CIP-Rectangular	2.77	8.48	8.48	0.6	1.4	10.45	2.06	2.33	4.7998	630.4	3025.79392
71 ST-BEAM-CIP-Rectangular	-8.18	8.48	8.48	0.6	1.4	10.45	2.66	2.33	6.1978	630.4	3907.09312
72 ST-BEAM-CIP-Rectangular	-8.18	8.48	8.48	0.4	1.4	10	2.47	2.33	5.7551	630.4	3628.01504
73 ST-BEAM-CIP-Rectangular	14.02	8.48	8.48	0.6	1.4	10.45	4.01	2.33	9.3433	630.4	5890.01632
74 ST-BEAM-CIP-Rectangular	8.71	8.48	8.48	0.6	1.4	10	3.76	2.33	8.7608	630.4	5522.80832
75 ST-BEAM-CIP-Rectangular	1	8.48	8.48	0.3	1.4	8.66	1.91	2.33	4.4503	630.4	2805.46912
76 ST-BEAM-CIP-Rectangular	-4.3	8.48	8.48	0.3	1.4	8.66	1.89	2.33	4.4037	630.4	2776.09248
77 ST-BEAM-CIP-Rectangular	-1.88	8.48	8.48	0.3	1.4	6	1.07	2.33	2.4931	630.4	1571.65024
78 ST-BEAM-CIP- L Shape	11.37	8.48	8.48	0.75	1.4	5.32	2.15	2.33	5.0095	630.4	3157.9888
79 ST-BEAM-CIP- L Shape	11.37	8.48	8.48	0.75	1.4	5.32	2.15	2.33	5.0095	630.4	3157.9888
80 ST-BEAM-CIP-Rectangular	2.77	8.25	8.25	0.6	1.85	9.45	5.99	2.33	13.9567	630.4	8798.30368
81 ST-BEAM-CIP-Rectangular	-8.08	8.25	8.25	0.6	1.85	9.45	6.14	2.33	14.3062	630.4	9018.62848
82 ST-BEAM-CIP- L Shape	-19.6	8.54	8.54	0.75	1.28	6.52	2.28	2.33	5.3124	630.4	3348.93696
83 ST-BEAM-CIP- L Shape	-14.75	8.54	8.54	0.75	1.28	6.07	2.11	2.33	4.9163	630.4	3099.23552
84 ST-BEAM-CIP- L Shape	-2.68	8.34	8.34	0.75	1.68	11.3	6.23	2.33	14.5159	630.4	9150.82336
85 ST-BEAM-CIP- L Shape	8.4	8.34	8.34	0.75	1.67	11.25	4.88	2.33	11.3704	630.4	7167.90016
86 ST-BEAM-CIP- Inverted Tee	8.4	8.34	8.34	0.9	1.68	11.25	7.44	2.33	17.3352	630.4	10928.11008
87 ST-BEAM-CIP- Inverted Tee	-2.7	8.34	8.34	0.9	1.68	11.25	7.54	2.33	17.5682	630.4	11074.99328
88 ST-BEAM-CIP- L Shape	8.25	8.34	8.34	0.75	1.68	11.56	7.8	2.33	18.174	630.4	11456.8896
89 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.85	2.45	6.9825	1620.61	11315.90933
90 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427

91 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
92 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
93 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
94 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
95 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
96 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
97 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
98 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
99 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	1.36	2.45	3.332	1620.61	5399.87252
100 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	1.26	2.45	3.087	1620.61	5002.82307
101 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
102 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
103 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
104 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
105 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
106 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.7	3.59	3.59	0.48	1.2	10.31	1.69	2.45	4.1405	1620.61	6710.135705
107 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
108 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
109 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
110 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
111 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
112 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
113 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
114 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
115 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.7	3.59	3.59	0.48	1.2	10.31	2.59	2.45	6.3455	1620.61	10283.58076
116 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
117 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
118 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
119 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
120 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
121 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
122 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.67	2.45	6.5415	1620.61	10601.22032
123 ST-Precast-Hollow Core Slab-(320-500 Deep)	8.4	3.59	3.59	0.48	1.2	11.25	2.5	2.45	6.125	1620.61	9926.23625
124 ST-Precast-Hollow Core Slab-(320-500 Deep)	8.4	3.59	3.59	0.48	1.2	11.25	2.12	2.45	5.194	1620.61	8417.44834
125 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.81	3.59	3.59	0.48	1.2	10.53	2.63	2.45	6.4435	1620.61	10442.40054
126 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.78	2.45	6.811	1620.61	11037.97471
127 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
128 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
129 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
130 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	2.86	2.45	7.007	1620.61	11355.61427
131 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.88	3.59	3.59	0.48	1.2	11.6	1.46	2.45	3.577	1620.61	5796.92197
132 ST-BEAM-CIP- Inverted Tee	-11.23	8.44	8.44	0.9	1.48	6.9	3.46	2.33	8.0618	630.4	5082.15872
133 ST-BEAM-CIP- L Shape	12.2	8.44	8.44	0.75	1.48	3.64	2.02	2.33	4.7066	630.4	2967.04064
134 ST-BEAM-CIP- L Shape	5.62	8.44	8.44	0.75	1.48	9.55	5.16	2.33	12.0228	630.4	7579.17312
135 ST-BEAM-CIP- L Shape	-8.4	8.44	8.44	0.75	1.48	8.5	4.47	2.33	10.4151	630.4	6565.67904
136 ST-BEAM-CIP- L Shape	-2.7	8.32	8.32	0.75	1.72	11.55	5.63	2.33	13.1179	630.4	8269.52416
137 ST-BEAM-CIP- L Shape	8.25	8.32	8.32	0.75	1.72	11.55	5.4	2.33	12.582	630.4	7931.6928

138	ST-BEAM-CIP- L Shape	8.25	8.32	8.32	0.75	1.72	11.55	5.4	2.33	12.582	630.4	7931.6928
139	ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.58	8.66	8.66	1.05	1.2	8.38	1.35	2.45	3.3075	1620.61	5360.167575
140	ST-Precast-Hollow Core Slab-(320-500 Deep)	-10.78	8.66	8.66	1.05	1.2	8.38	1.35	2.45	3.3075	1620.61	5360.167575
141	ST-Precast-Hollow Core Slab-(320-500 Deep)	-11.98	8.66	8.66	1.05	1.2	8.38	1.35	2.45	3.3075	1620.61	5360.167575
142	ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.18	8.66	8.66	1.05	1.2	8.38	1.35	2.45	3.3075	1620.61	5360.167575
143	ST-Precast-Hollow Core Slab-(320-500 Deep)	-14.38	8.66	8.66	1.05	1.2	8.38	0.7	2.45	1.715	1620.61	2779.34615
144	ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.93	8.66	8.66	1.05	1.2	9.7	1.24	2.45	3.038	1620.61	4923.41318
145	ST-Precast-Hollow Core Slab-(320-500 Deep)	-11.13	8.66	8.66	1.05	1.2	9.7	1.56	2.45	3.822	1620.61	6193.97142
146	ST-Precast-Hollow Core Slab-(320-500 Deep)	-12.33	8.66	8.66	1.05	1.2	9.7	1.56	2.45	3.822	1620.61	6193.97142
147	ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.53	8.66	8.66	1.05	1.2	9.7	1.56	2.45	3.822	1620.61	6193.97142
148	ST-Precast-Hollow Core Slab-(320-500 Deep)	-19.53	8.66	8.66	1.05	1.2	4.18	0.37	2.45	0.9065	1620.61	1469.082965
149	ST-Precast-Hollow Core Slab-(320-500 Deep)	-19.18	8.66	8.66	1.05	1.2	9.83	1.35	2.45	3.3075	1620.61	5360.167575
150	ST-Precast-Hollow Core Slab-(320-500 Deep)	-17.98	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
151	ST-Precast-Hollow Core Slab-(320-500 Deep)	-16.78	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
152	ST-Precast-Hollow Core Slab-(320-500 Deep)	-15.58	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
153	ST-Precast-Hollow Core Slab-(320-500 Deep)	-14.38	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
154	ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.05	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
155	ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.58	8.66	8.66	1.05	1.2	9.96	1.61	2.45	3.9445	1620.61	6392.496145
156	ST-Precast-Hollow Core Slab-(320-500 Deep)	-12.08	8.66	8.66	1.05	1.2	9.55	1.3	2.45	3.185	1620.61	5161.64285
157	ST-Precast-Hollow Core Slab-(320-500 Deep)	-10.88	8.66	8.66	1.05	1.2	9.55	1.54	2.45	3.773	1620.61	6114.56153
158	ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.68	8.66	8.66	1.05	1.2	9.55	1.54	2.45	3.773	1620.61	6114.56153
159	ST-Precast-Hollow Core Slab-(320-500 Deep)	-8.48	8.66	8.66	1.05	1.2	9.54	1.54	2.45	3.773	1620.61	6114.56153
160	ST-Precast-Hollow Core Slab-(320-500 Deep)	-7.28	8.66	8.66	1.05	1.2	9.24	1.49	2.45	3.6505	1620.61	5916.036805
161	ST-Precast-Hollow Core Slab-(320-500 Deep)	-6.08	8.66	8.66	1.05	1.2	9.24	1.49	2.45	3.6505	1620.61	5916.036805
162	ST-Precast-Hollow Core Slab-(320-500 Deep)	-4.88	8.66	8.66	1.05	1.2	9.24	1.49	2.45	3.6505	1620.61	5916.036805
163	ST-Precast-Hollow Core Slab-(320-500 Deep)	1.12	8.66	8.66	1.05	1.2	9.98	0.89	2.45	2.1805	1620.61	3533.740105
164	ST-Precast-Hollow Core Slab-(320-500 Deep)	2.32	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
165	ST-Precast-Hollow Core Slab-(320-500 Deep)	3.52	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
166	ST-Precast-Hollow Core Slab-(320-500 Deep)	4.72	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
167	ST-Precast-Hollow Core Slab-(320-500 Deep)	5.92	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
168	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.12	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
169	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.32	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
170	ST-Precast-Hollow Core Slab-(320-500 Deep)	9.52	8.66	8.66	1.05	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
171	ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.18	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
172	ST-Precast-Hollow Core Slab-(320-500 Deep)	-11.98	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
173	ST-Precast-Hollow Core Slab-(320-500 Deep)	-10.78	8.66	8.66	1.05	1.2	9.83	1.58	2.45	3.871	1620.61	6273.38131
174	ST-Precast-Hollow Core Slab-(320-500 Deep)	-8.38	8.66	8.66	1.05	1.2	9.83	0.66	2.45	1.617	1620.61	2620.52637
175	ST-Precast-Hollow Core Slab-(320-500 Deep)	12.52	8.66	8.66	1.05	1.2	10.08	1.12	2.45	2.744	1620.61	4446.95384
176	ST-Precast-Hollow Core Slab-(320-500 Deep)	11.32	8.66	8.66	1.05	1.2	10	1.06	2.45	2.597	1620.61	4208.72417
177	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.12	8.66	8.66	1.05	1.2	10	1.06	2.45	2.597	1620.61	4208.72417
178	ST-Precast-Hollow Core Slab-(320-500 Deep)	13.72	8.66	8.66	1.05	1.2	10.08	1.12	2.45	2.744	1620.61	4446.95384
179	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.92	8.66	8.66	1.05	1.2	10	0.43	2.45	1.0535	1620.61	1707.312635
180	ST-Precast-Hollow Core Slab-(320-500 Deep)	-8.38	8.66	8.66	1.05	1.2	8.38	0.68	2.45	1.666	1620.61	2699.93626
181	ST-Precast-Hollow Core Slab-(150-265 Deep)	-14.73	8.68	8.68	0.99	1.2	4.48	0.66	2.45	1.617	1620.61	2620.52637
182	ST-Precast-Hollow Core Slab-(150-265 Deep)	-15.93	8.68	8.68	0.99	1.2	4.48	0.66	2.45	1.617	1620.61	2620.52637
183	ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.13	8.68	8.68	0.99	1.2	4.48	0.66	2.45	1.617	1620.61	2620.52637
184	ST-Precast-Hollow Core Slab-(150-265 Deep)	-18.33	8.68	8.68	0.99	1.2	4.48	0.66	2.45	1.617	1620.61	2620.52637

185 ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.21	8.68	8.68	0.99	1.2	4.93	0.67	2.45	1.6415	1620.61	2660.231315
186 ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.21	8.68	8.68	0.99	1.2	4.93	0.67	2.45	1.6415	1620.61	2660.231315
187 ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.21	8.68	8.68	0.99	1.2	4.93	0.67	2.45	1.6415	1620.61	2660.231315
188 ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.21	8.68	8.68	0.99	1.2	4.93	0.67	2.45	1.6415	1620.61	2660.231315
189 ST-Precast-Hollow Core Slab-(150-265 Deep)	-3.68	8.68	8.68	0.99	1.2	1.79	0.27	2.45	0.6615	1620.61	1072.033515
190 ST-Precast-Hollow Core Slab-(150-265 Deep)	-2.48	8.68	8.68	0.99	1.2	1.79	0.27	2.45	0.6615	1620.61	1072.033515
191 ST-Precast-Hollow Core Slab-(150-265 Deep)	-1.28	8.68	8.68	0.99	1.2	1.79	0.27	2.45	0.6615	1620.61	1072.033515
192 ST-Precast-Hollow Core Slab-(150-265 Deep)	-0.08	8.68	8.68	0.99	1.2	1.79	0.27	2.45	0.6615	1620.61	1072.033515
193 ST-Precast-Hollow Core Slab-(150-265 Deep)	10.72	8.68	8.68	0.99	1.2	1.99	0.28	2.45	0.686	1620.61	1111.73846
194 ST-Precast-Hollow Core Slab-(150-265 Deep)	11.92	8.68	8.68	0.99	1.2	1.99	0.28	2.45	0.686	1620.61	1111.73846
195 ST-Precast-Hollow Core Slab-(150-265 Deep)	13.12	8.68	8.68	0.99	1.2	1.99	0.28	2.45	0.686	1620.61	1111.73846
196 ST-Precast-Hollow Core Slab-(150-265 Deep)	10.72	8.68	8.68	0.99	1.2	2.24	0.34	2.45	0.833	1620.61	1349.96813
197 ST-Precast-Hollow Core Slab-(150-265 Deep)	11.92	8.68	8.68	0.99	1.2	2.34	0.36	2.45	0.882	1620.61	1429.37802
198 ST-Precast-Hollow Core Slab-(150-265 Deep)	13.12	8.68	8.68	0.99	1.2	2.34	0.35	2.45	0.8575	1620.61	1389.673075
199 ST-Precast-Hollow Core Slab-(150-265 Deep)	-17.03	8.68	8.68	0.99	1.2	5.3	0.21	2.45	0.5145	1620.61	833.803845
200 ST-BEAM-CIP- L Shape	-14	8.03	8.03	0.75	1.85	11.38	10.19	2.33	23.7427	630.4	14967.39808
201 ST-Precast-Hollow Core Slab-(320-500 Deep)	2.3	3.63	3.63	0.4	1.2	10.6	1.61	2.45	3.9445	1620.61	6392.496145
202 ST-Precast-Hollow Core Slab-(320-500 Deep)	3.5	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
203 ST-Precast-Hollow Core Slab-(320-500 Deep)	4.7	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
204 ST-Precast-Hollow Core Slab-(320-500 Deep)	5.9	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
205 ST-Precast-Hollow Core Slab-(320-500 Deep)	7.1	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
206 ST-Precast-Hollow Core Slab-(320-500 Deep)	8.3	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
207 ST-Precast-Hollow Core Slab-(320-500 Deep)	9.5	3.63	3.63	0.4	1.2	9.98	1.61	2.45	3.9445	1620.61	6392.496145
208 ST-Precast-Hollow Core Slab-(320-500 Deep)	-19.32	3.63	3.63	0.4	1.2	8.45	0.92	2.45	2.254	1620.61	3652.85494
209 ST-Precast-Hollow Core Slab-(320-500 Deep)	-18.12	3.63	3.63	0.4	1.2	8.69	1.4	2.45	3.43	1620.61	5558.6923
210 ST-Precast-Hollow Core Slab-(320-500 Deep)	-16.92	3.63	3.63	0.4	1.2	8.69	1.4	2.45	3.43	1620.61	5558.6923
211 ST-Precast-Hollow Core Slab-(320-500 Deep)	-15.72	3.63	3.63	0.4	1.2	8.69	1.4	2.45	3.43	1620.61	5558.6923
212 ST-Precast-Hollow Core Slab-(320-500 Deep)	-14.52	3.63	3.63	0.4	1.2	8.69	1.35	2.45	3.3075	1620.61	5360.167575
213 ST-Precast-Hollow Core Slab-(320-500 Deep)	1.73	3.63	3.63	0.4	1.2	10.6	0.75	2.45	1.8375	1620.61	2977.870875
214 ST-Precast-Hollow Core Slab-(320-500 Deep)	-13.35	3.63	3.63	0.4	1.2	8.69	0.89	2.45	2.1805	1620.61	3533.740105
215 ST-Precast-Hollow Core Slab-(320-500 Deep)	-11.05	3.63	3.63	0.4	1.2	9.1	1.47	2.45	3.6015	1620.61	5836.626915
216 ST-Precast-Hollow Core Slab-(320-500 Deep)	-9.85	3.63	3.63	0.4	1.2	9.1	1.47	2.45	3.6015	1620.61	5836.626915
217 ST-Precast-Hollow Core Slab-(320-500 Deep)	-8.65	3.63	3.63	0.4	1.2	9.1	1.47	2.45	3.6015	1620.61	5836.626915
218 ST-Precast-Hollow Core Slab-(320-500 Deep)	-7.45	3.63	3.63	0.4	1.2	9.25	1.49	2.45	3.6505	1620.61	5916.036805
219 ST-Precast-Hollow Core Slab-(320-500 Deep)	-6.25	3.63	3.63	0.4	1.2	9.25	1.49	2.45	3.6505	1620.61	5916.036805
220 ST-Precast-Hollow Core Slab-(320-500 Deep)	-5.05	3.63	3.63	0.4	1.2	9.25	0.23	2.45	0.5635	1620.61	913.213735
221 ST-Precast-Hollow Core Slab-(320-500 Deep)	-12.25	3.63	3.63	0.4	1.2	9.1	0.59	2.45	1.4455	1620.61	2342.591755
222 ST-Precast-Hollow Core Slab-(320-500 Deep)	14.3	3.63	3.63	0.4	1.2	10.31	0.6	2.45	1.47	1620.61	2382.2967
223 ST-Precast-Hollow Core Slab-(150-265 Deep)	10.7	3.66	3.66	0.34	1.2	1.97	0.27	2.45	0.6615	1620.61	1072.033515
224 ST-Precast-Hollow Core Slab-(150-265 Deep)	11.9	3.66	3.66	0.34	1.2	1.97	0.27	2.45	0.6615	1620.61	1072.033515
225 ST-Precast-Hollow Core Slab-(150-265 Deep)	13.1	3.66	3.66	0.34	1.2	1.97	0.15	2.45	0.3675	1620.61	595.574175
226 ST-Precast-Hollow Core Slab-(150-265 Deep)	10.7	3.66	3.66	0.34	1.2	2.37	0.36	2.45	0.882	1620.61	1429.37802
227 ST-Precast-Hollow Core Slab-(150-265 Deep)	11.9	3.66	3.66	0.34	1.2	2.37	0.36	2.45	0.882	1620.61	1429.37802
228 ST-Precast-Hollow Core Slab-(150-265 Deep)	13.1	3.66	3.66	0.34	1.2	2.37	0.2	2.45	0.49	1620.61	794.0989
229 ST-Precast-Hollow Core Slab-(150-265 Deep)	-4	3.66	3.66	0.34	1.2	2.37	0.22	2.45	0.539	1620.61	873.50879
230 ST-Precast-Hollow Core Slab-(150-265 Deep)	-2.8	3.66	3.66	0.34	1.2	2.37	0.27	2.45	0.6615	1620.61	1072.033515
231 ST-Precast-Hollow Core Slab-(150-265 Deep)	-1.6	3.66	3.66	0.34	1.2	2.37	0.27	2.45	0.6615	1620.61	1072.033515

232 ST-Precast-Hollow Core Slab-(150-265 Deep)	-0.4	3.66	3.66	0.34	1.2	2.37	0.27	2.45	0.6615	1620.61	1072.033515
233 ST-Precast-Hollow Core Slab-(150-265 Deep)	5.92	3.66	3.66	0.34	1.2	5.35	0.82	2.45	2.009	1620.61	3255.80549
234 ST-Precast-Hollow Core Slab-(150-265 Deep)	5.92	3.66	3.66	0.34	1.2	5.35	0.71	2.45	1.7395	1620.61	2819.051095
235 ST-Precast-Hollow Core Slab-(150-265 Deep)	5.92	3.66	3.66	0.34	1.2	5.35	0.14	2.45	0.343	1620.61	555.86923
236 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
237 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
238 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.53	3.66	3.66	0.34	1.2	5.99	0.89	2.45	2.1805	1620.61	3533.740105
239 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
240 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
241 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
242 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.91	2.45	2.2295	1620.61	3613.149995
243 ST-Precast-Hollow Core Slab-(150-265 Deep)	-11.47	3.66	3.66	0.34	1.2	6.11	0.51	2.45	1.2495	1620.61	2024.952195
244 ST-Precast-Hollow Core Slab-(150-265 Deep)	0.8	3.66	3.66	0.34	1.2	2.37	0.27	2.45	0.6615	1620.61	1072.033515
245 ST-BEAM-CIP- L Shape	-13.97	3.35	3.35	0.75	0.95	11.61	6.9	2.33	16.077	630.4	10134.9408
246 ST-BEAM-CIP-Rectangular	-14.3	3.52	3.52	0.15	0.61	8.16	0.31	2.33	0.7223	630.4	455.33792
247 ST-BEAM-CIP-Rectangular	-19.83	-3.02	-3.02	0.3	1.25	2.57	0.74	2.33	1.7242	630.4	1086.93568
248 ST-BEAM-CIP-Rectangular	11.58	8.2	8.2	0.15	0.66	4.12	0.13	2.33	0.3029	630.4	190.94816
249 ST-BEAM-CIP-Rectangular	11.92	8.2	8.2	0.15	0.66	3.6	0.13	2.33	0.3029	630.4	190.94816
250 ST-BEAM-CIP-Rectangular	-1.86	8.2	8.2	0.15	0.66	6.02	0.21	2.33	0.4893	630.4	308.45472
251 ST-BEAM-CIP-Rectangular	-17.19	8.19	8.19	0.15	0.66	5.58	0.19	2.33	0.4427	630.4	279.07808
252 ST-Precast-Hollow Core Slab-(320-500 Deep)	7.22	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
253 ST-Precast-Hollow Core Slab-(320-500 Deep)	6.02	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
254 ST-Precast-Hollow Core Slab-(320-500 Deep)	4.82	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
255 ST-Precast-Hollow Core Slab-(320-500 Deep)	3.62	8.62	8.62	1.13	1.2	10	2.13	2.45	5.2185	1620.61	8457.153285
256 ST-Precast-Hollow Core Slab-(320-500 Deep)	1.27	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
257 ST-Precast-Hollow Core Slab-(320-500 Deep)	0.07	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
258 ST-Precast-Hollow Core Slab-(320-500 Deep)	-1.13	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
259 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.33	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
260 ST-Precast-Hollow Core Slab-(320-500 Deep)	-3.53	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
261 ST-Precast-Hollow Core Slab-(320-500 Deep)	-4.73	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
262 ST-Precast-Hollow Core Slab-(320-500 Deep)	-5.93	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
263 ST-Precast-Hollow Core Slab-(320-500 Deep)	-7.13	8.62	8.62	1.13	1.2	10	2.45	2.45	6.0025	1620.61	9727.711525
264 ST-Precast-Hollow Core Slab-(320-500 Deep)	1.27	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
265 ST-Precast-Hollow Core Slab-(320-500 Deep)	0.07	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
266 ST-Precast-Hollow Core Slab-(320-500 Deep)	-1.13	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
267 ST-Precast-Hollow Core Slab-(320-500 Deep)	-2.33	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
268 ST-Precast-Hollow Core Slab-(320-500 Deep)	-3.53	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
269 ST-Precast-Hollow Core Slab-(320-500 Deep)	-4.73	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
270 ST-Precast-Hollow Core Slab-(320-500 Deep)	-5.93	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
271 ST-Precast-Hollow Core Slab-(320-500 Deep)	-7.13	8.62	8.62	1.13	1.2	8.7	2.19	2.45	5.3655	1620.61	8695.382955
272 ST-Precast-Hollow Core Slab-(320-500 Deep)	2.47	8.62	8.62	1.13	1.2	10	1.24	2.45	3.038	1620.61	4923.41318
273 ST-Precast-Hollow Core Slab-(320-500 Deep)	8.42	8.62	8.62	1.13	1.2	10	1.18	2.45	2.891	1620.61	4685.18351
274 ST-Precast-Hollow Core Slab-(320-500 Deep)	2.47	8.62	8.62	1.13	1.2	8.7	1.12	2.45	2.744	1620.61	4446.95384
275 ST-Precast-Hollow Core Slab-(320-500 Deep)	2.92	8.62	8.62	1.13	1.2	9.3	0.87	2.45	2.1315	1620.61	3454.330215
276 ST-BEAM-CIP-Rectangular	1	-2.67	-2.67	0.3	0.7	8.66	1.75	2.33	4.0775	630.4	2570.456
277 ST-BEAM-CIP-Rectangular	-4.3	-2.67	-2.67	0.3	0.7	8.66	1.75	2.33	4.0775	630.4	2570.456
278 ST-BEAM-CIP-Rectangular	-1.73	-2.67	-2.67	0.3	0.7	5.15	1.04	2.33	2.4232	630.4	1527.58528

279 ST-BEAM-CIP-Rectangular	-1.73	3.53	3.53	0.3	0.75	5.15	1.13	2.33	2.6329	630.4	1659.78016
280 ST-BEAM-CIP-Rectangular	11.79	3.55	3.55	0.15	0.67	3.38	0.13	2.33	0.3029	630.4	190.94816
281 ST-BEAM-CIP-Rectangular	11.79	3.55	3.55	0.15	0.67	3.38	0.13	2.33	0.3029	630.4	190.94816
282 ST-BEAM-CIP-Rectangular	10.25	7.28	7.28	0.3	1.4	2.5	1.05	2.33	2.4465	630.4	1542.2736
283 ST-BEAM-CIP-Rectangular	10.25	7.28	7.28	0.3	1.4	2.5	1.05	2.33	2.4465	630.4	1542.2736
284 ST-BEAM-CIP-Rectangular	10.25	1.88	1.88	0.3	1.4	3.9	1.64	2.33	3.8212	630.4	2408.88448
285 ST-BEAM-CIP-Rectangular	10.25	1.88	1.88	0.3	1.4	3.9	1.64	2.33	3.8212	630.4	2408.88448
286 ST-BEAM-CIP-Rectangular	-1.73	-0.54	-0.54	0.3	0.7	5.15	1.05	2.33	2.4465	630.4	1542.2736
287 ST-BEAM-CIP-Rectangular	-13.85	7.38	7.38	0.4	0.55	11.05	0.88	2.33	2.0504	630.4	1292.57216
288 ST-BEAM-CIP- L Shape	-2.97	7.48	7.48	0.7	0.75	10.71	2.08	2.33	4.8464	630.4	3055.17056
289 ST-BEAM-CIP-Rectangular	-19.83	1.75	1.75	0.3	0.75	9.52	2.07	2.33	4.8231	630.4	3040.48224
290 ST-BEAM-CIP- L Shape	-19.85	1.8	1.8	0.35	0.75	4.33	0.95	2.33	2.2135	630.4	1395.3904

CraneName	Family Name	Type	Distance From Crane To Material Positon(m)	Distance From Crane To storage(m)	Distance From Material Positon To storage(m)	Swing Distance From Storage To Material Position(m)	Hoist Travel Distance From Storage To Material Elevation(m)
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.09241	10	33.663733	40.46	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.661637	10	33.938163	40.01	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.260043	10	34.252458	39.6	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.886282	10	34.605533	39.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.53903	10	34.996213	38.86	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.216998	10	35.423254	38.53	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.918931	10	35.885358	38.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	41.643618	10	36.381189	37.93	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	42.389891	10	36.909388	37.66	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.156632	10	37.468586	37.41	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.942768	10	38.057416	37.18	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	48.759706	10	40.068802	22.63	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	47.689715	10	39.068004	22.67	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.626054	10	38.07872	22.72	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.569166	10	37.101872	22.77	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.519534	10	36.138468	22.82	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.477683	10	35.189614	22.87	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	42.387715	10	34.186524	22.8	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	41.419668	10	33.340499	22.99	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.404813	10	32.44301	23.06	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.400367	10	31.565628	23.14	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.407146	10	30.710078	23.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.426046	10	29.878235	23.31	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.458043	10	29.072133	23.4	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.50421	10	28.293973	23.51	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.565719	10	27.546123	23.63	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.572584	10	26.741698	23.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	32.74002	10	26.151652	23.9	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	31.855751	10	25.510564	24.05	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	30.992723	10	24.910819	24.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	30.152759	10	24.35547	24.41	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	29.337841	10	23.847618	24.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	28.550112	10	23.390359	24.85	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	27.791886	10	22.986711	25.11	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.205685	10	28.734551	10.76	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.096105	10	24.790006	10.8	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	49.27005	10	40.547969	22.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.31598	10	38.341963	37.08	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	55.100363	10	47.455769	35.26	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	54.142497	10	46.598391	35.36	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	53.194455	10	45.75642	35.47	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	52.25677	10	44.930724	35.59	3.59

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	51.330011	10	44.122217	35.71	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	49.588508	10	41.818896	30.48	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	50.290159	10	42.648565	31.9	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	51.010392	10	43.495518	33.32	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	51.748431	10	44.358766	34.75	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	52.503525	10	45.237375	36.2	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	42.306323	10	35.676673	31.88	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.136354	10	36.657128	33.38	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.983463	10	37.650299	34.9	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	44.846683	10	38.655207	36.42	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	47.875825	10	42.711762	44.81	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.63517	10	39.777231	46.53	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	42.588591	10	38.626262	44.83	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	41.550308	10	37.478368	43.15	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	40.520959	10	36.333842	41.47	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	39.501242	10	35.193012	39.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	41.664721	10	34.930631	30.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	35.57081	10	30.69662	33.22	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	33.123557	10	31.131495	40.39	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.999531	10	29.932758	38.61	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	30.881224	10	28.734126	36.83	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	29.77311	10	27.536124	35.06	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	28.609048	10	26.330165	33.37	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	27.509955	10	25.131606	31.61	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	26.419644	10	23.93319	29.87	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.952377	10	17.922112	21.46	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	19.936953	10	16.723699	19.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	18.943128	10	15.525531	18.15	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.974485	10	14.327669	16.54	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.035319	10	13.130198	14.94	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	16.130781	10	11.933235	13.38	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	15.267027	10	10.73695	11.86	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	14.45137	10	9.541598	10.37	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	38.491923	10	34.056249	38.14	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	37.493841	10	32.923975	36.5	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	36.507918	10	31.796668	34.86	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	34.576699	10	29.55923	31.63	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.634974	10	21.94474	6.55	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.941979	10	22.367163	7.78	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.252287	10	22.808113	9.02	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.410374	10	21.619704	5.33	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.603834	10	23.302575	10.27	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	48.906238	10	41.007561	29.08	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.006364	10	38.363526	38.46	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.933285	10	39.423345	40.04	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	45.872869	10	40.490988	41.64	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	46.824354	10	41.565853	43.24	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	57.073837	10	49.753622	39.25	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	56.151784	10	48.938971	39.38	8.68

PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	55.24041	10	48.14045	39.51	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	54.340251	10	47.358874	39.66	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	27.19725	10	23.239845	26.86	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	26.204015	10	22.069218	25.22	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	25.228761	10	20.901923	23.59	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	24.273657	10	19.738551	21.98	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	17.038322	10	9.628312	8.67	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.487098	10	8.615358	7.34	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.007011	10	7.656657	6.04	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.935465	10	8.785465	9.42	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.019726	10	7.680814	7.89	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	9.208415	10	6.587481	6.4	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	53.330034	10	46.455274	39.59	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.113448	10	16.761587	19.74	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	18.948016	10	15.544366	18.19	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.978301	10	14.346404	16.57	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.037937	10	13.148814	14.97	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	16.132058	10	11.951707	13.41	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	15.266804	10	10.755245	11.88	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	14.449474	10	9.55967	10.39	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	40.027561	10	38.369332	51.21	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	38.879681	10	37.170278	49.4	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	37.735045	10	35.971289	47.59	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	36.593956	10	34.772368	45.78	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	35.456757	10	33.573525	43.98	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.589718	10	17.330219	20.52	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	34.352102	10	32.404736	42.23	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.081105	10	30.093144	38.97	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	30.959155	10	28.894105	37.19	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	29.843279	10	27.695149	35.42	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	28.765405	10	26.499972	33.62	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	27.66515	10	25.301393	31.86	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	26.57353	10	24.102956	30.11	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	33.208512	10	31.292256	40.76	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	11.997471	10	4.831076	4.85	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	17.039346	10	9.640503	8.69	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.486701	10	8.626198	7.36	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.005102	10	7.665722	6.06	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.911737	10	8.824171	9.46	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.026864	10	7.703116	7.92	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	9.213577	10	6.609841	6.43	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	27.635204	10	23.620002	27.21	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	26.643883	10	22.452093	25.57	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	25.670382	10	21.287755	23.94	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	24.716806	10	20.127605	22.34	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	36.539049	10	27.439062	13.4	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	37.661733	10	28.49923	13.38	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	35.905082	10	26.843526	13.41	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	49.252233	10	41.859079	32.88	3.66

PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	48.315531	10	41.0462	33	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	47.429325	10	40.29815	33.19	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	46.478452	10	39.479697	33.26	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	45.57954	10	38.728471	33.4	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.69477	10	38.000296	33.55	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	43.824999	10	37.296521	33.72	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	43.346236	10	36.914715	33.82	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	23.785552	10	18.972414	20.76	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.169866	10	24.088171	12.06	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.615473	10	24.698178	13.35	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.097507	10	25.350345	14.65	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.614448	10	26.041505	15.96	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.722017	10	27.496591	18.58	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.333215	10	28.286083	19.94	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.973267	10	29.103651	21.31	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.640703	10	29.946995	22.7	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.334091	10	30.813998	24.11	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.052049	10	31.702721	25.53	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.793247	10	32.611386	26.97	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.556411	10	33.538374	28.42	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.081572	10	35.159423	18.27	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.578302	10	35.780232	19.57	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.101497	10	36.430001	20.89	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.650246	10	37.10721	22.22	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.223641	10	37.810382	23.56	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.820775	10	38.538098	24.91	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	47.440753	10	39.288993	26.27	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	48.082689	10	40.061765	27.65	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.14118	10	26.737661	17.23	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	32.762173	10	23.523605	10.79	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.612212	10	34.569134	16.98	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.72222	10	34.621272	16.49	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.09241	10	33.663733	40.46	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.661637	10	33.938163	40.01	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.260043	10	34.252458	39.6	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.886282	10	34.605533	39.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.53903	10	34.996213	38.86	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.216998	10	35.423254	38.53	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.918931	10	35.885358	38.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	41.643618	10	36.381189	37.93	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	42.389891	10	36.909388	37.66	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.156632	10	37.468586	37.41	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.942768	10	38.057416	37.18	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	48.759706	10	40.068802	22.63	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	47.689715	10	39.068004	22.67	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.626054	10	38.07872	22.72	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.569166	10	37.101872	22.77	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.519534	10	36.138468	22.82	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.477683	10	35.189614	22.87	3.59

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	42.387715	10	34.186524	22.8	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	41.419668	10	33.340499	22.99	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.404813	10	32.44301	23.06	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.400367	10	31.565628	23.14	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.407146	10	30.710078	23.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.426046	10	29.878235	23.31	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.458043	10	29.072133	23.4	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.50421	10	28.293973	23.51	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.565719	10	27.546123	23.63	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.572584	10	26.741698	23.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	32.74002	10	26.151652	23.9	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	31.855751	10	25.510564	24.05	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	30.992723	10	24.910819	24.22	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	30.152759	10	24.35547	24.41	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	29.337841	10	23.847618	24.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	28.550112	10	23.390359	24.85	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	27.791886	10	22.986711	25.11	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.205685	10	28.734551	10.76	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.096105	10	24.790006	10.8	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	49.27005	10	40.547969	22.62	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.31598	10	38.341963	37.08	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	55.100363	10	47.455769	35.26	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	54.142497	10	46.598391	35.36	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	53.194455	10	45.75642	35.47	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	52.25677	10	44.930724	35.59	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	51.330011	10	44.122217	35.71	3.59
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	49.588508	10	41.818896	30.48	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	50.290159	10	42.648565	31.9	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	51.010392	10	43.495518	33.32	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	51.748431	10	44.358766	34.75	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	52.503525	10	45.237375	36.2	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	42.306323	10	35.676673	31.88	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.136354	10	36.657128	33.38	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.983463	10	37.650299	34.9	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	44.846683	10	38.655207	36.42	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	47.875825	10	42.711762	44.81	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	43.63517	10	39.777231	46.53	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	42.588591	10	38.626262	44.83	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	41.550308	10	37.478368	43.15	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	40.520959	10	36.333842	41.47	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	39.501242	10	35.193012	39.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	41.664721	10	34.930631	30.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	35.57081	10	30.69662	33.22	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	33.123557	10	31.131495	40.39	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.999531	10	29.932758	38.61	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	30.881224	10	28.734126	36.83	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	29.77311	10	27.536124	35.06	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	28.609048	10	26.330165	33.37	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	27.509955	10	25.131606	31.61	8.66

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	26.419644	10	23.93319	29.87	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.952377	10	17.922112	21.46	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	19.936953	10	16.723699	19.8	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	18.943128	10	15.525531	18.15	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.974485	10	14.327669	16.54	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.035319	10	13.130198	14.94	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	16.130781	10	11.933235	13.38	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	15.267027	10	10.73695	11.86	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	14.45137	10	9.541598	10.37	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	38.491923	10	34.056249	38.14	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	37.493841	10	32.923975	36.5	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	36.507918	10	31.796668	34.86	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	34.576699	10	29.55923	31.63	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.634974	10	21.94474	6.55	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.941979	10	22.367163	7.78	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.252287	10	22.808113	9.02	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	31.410374	10	21.619704	5.33	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.603834	10	23.302575	10.27	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	48.906238	10	41.007561	29.08	8.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.006364	10	38.363526	38.46	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.933285	10	39.423345	40.04	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	45.872869	10	40.490988	41.64	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	46.824354	10	41.565853	43.24	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	57.073837	10	49.753622	39.25	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	56.151784	10	48.938971	39.38	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	55.24041	10	48.14045	39.51	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	54.340251	10	47.358874	39.66	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	27.19725	10	23.239845	26.86	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	26.204015	10	22.069218	25.22	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	25.228761	10	20.901923	23.59	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	24.273657	10	19.738551	21.98	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	17.038322	10	9.628312	8.67	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.487098	10	8.615358	7.34	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.007011	10	7.656657	6.04	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.935465	10	8.785465	9.42	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.019726	10	7.680814	7.89	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	9.208415	10	6.587481	6.4	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	53.330034	10	46.455274	39.59	8.68
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.113448	10	16.761587	19.74	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	18.948016	10	15.544366	18.19	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.978301	10	14.346404	16.57	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	17.037937	10	13.148814	14.97	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	16.132058	10	11.951707	13.41	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	15.266804	10	10.755245	11.88	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	14.449474	10	9.55967	10.39	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	40.027561	10	38.369332	51.21	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	38.879681	10	37.170278	49.4	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	37.735045	10	35.971289	47.59	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	36.593956	10	34.772368	45.78	3.63

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	35.456757	10	33.573525	43.98	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	20.589718	10	17.330219	20.52	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	34.352102	10	32.404736	42.23	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	32.081105	10	30.093144	38.97	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	30.959155	10	28.894105	37.19	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	29.843279	10	27.695149	35.42	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	28.765405	10	26.499972	33.62	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	27.66515	10	25.301393	31.86	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	26.57353	10	24.102956	30.11	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	33.208512	10	31.292256	40.76	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	320x1200mm	11.997471	10	4.831076	4.85	3.63
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	17.039346	10	9.640503	8.69	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.486701	10	8.626198	7.36	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	16.005102	10	7.665722	6.06	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.911737	10	8.824171	9.46	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	10.026864	10	7.703116	7.92	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	9.213577	10	6.609841	6.43	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	27.635204	10	23.620002	27.21	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	26.643883	10	22.452093	25.57	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	25.670382	10	21.287755	23.94	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	24.716806	10	20.127605	22.34	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	36.539049	10	27.439062	13.4	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	37.661733	10	28.49923	13.38	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	35.905082	10	26.843526	13.41	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	49.252233	10	41.859079	32.88	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	48.315531	10	41.0462	33	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	47.429325	10	40.29815	33.19	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	46.478452	10	39.479697	33.26	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	45.57954	10	38.728471	33.4	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	44.69477	10	38.000296	33.55	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	43.824999	10	37.296521	33.72	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	43.346236	10	36.914715	33.82	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	23.785552	10	18.972414	20.76	3.66
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.169866	10	24.088171	12.06	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	33.615473	10	24.698178	13.35	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.097507	10	25.350345	14.65	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	34.614448	10	26.041505	15.96	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.722017	10	27.496591	18.58	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.333215	10	28.286083	19.94	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	36.973267	10	29.103651	21.31	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	37.640703	10	29.946995	22.7	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	38.334091	10	30.813998	24.11	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.052049	10	31.702721	25.53	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	39.793247	10	32.611386	26.97	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	40.556411	10	33.538374	28.42	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.081572	10	35.159423	18.27	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	44.578302	10	35.780232	19.57	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.101497	10	36.430001	20.89	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	45.650246	10	37.10721	22.22	8.62

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.223641	10	37.810382	23.56	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	46.820775	10	38.538098	24.91	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	47.440753	10	39.288993	26.27	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	48.082689	10	40.061765	27.65	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	35.14118	10	26.737661	17.23	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	32.762173	10	23.523605	10.79	8.62
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	43.612212	10	34.569134	16.98	8.62

CraneName	Family Name	Torolley Movement Distance From Storage To Material Position(m)	Time For Hoist Movement(Hr)	Swing Angle From Storge To Material Position	Time For Trolley Movement (min)	Time For Swing Movement (Hr 10^9)	Hoist Power Consumption (KWH)	Trolley Power Consumption (KWH)	Swing Movement Power Consumption (KWH)	Total Power Consumption (KWH)	Embodied Energy (MJ)
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.09241	0.398889	1.090751	5.644252	0.046282	0.811074	1.03478	0.020827	1.866681	6.719772
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.661637	0.398889	1.062486	5.762841	0.045767	0.811074	1.056521	0.020595	1.88819	6.797201
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.260043	0.398889	1.035084	5.887509	0.045298	0.811074	1.079377	0.020384	1.910835	6.878719
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.886282	0.398889	1.008544	6.017975	0.044863	0.811074	1.103295	0.020188	1.934557	6.964115
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.53903	0.398889	0.982864	6.153965	0.044451	0.811074	1.128227	0.020003	1.959304	7.053201
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.216998	0.398889	0.958033	6.295208	0.044074	0.811074	1.154121	0.019833	1.985028	7.145803
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.918931	0.398889	0.934041	6.441444	0.043719	0.811074	1.180931	0.019674	2.011679	7.241743
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.643618	0.398889	0.91087	6.59242	0.043388	0.811074	1.20861	0.019525	2.039209	7.340847
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.389891	0.398889	0.888502	6.747894	0.043079	0.811074	1.237114	0.019386	2.067574	7.442956
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.156632	0.398889	0.866921	6.907632	0.042793	0.811074	1.266399	0.019257	2.09673	7.547913
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.942768	0.398889	0.8461	7.07141	0.04253	0.811074	1.296425	0.019138	2.126637	7.655574
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.759706	0.398889	0.464198	8.074939	0.025886	0.811074	1.480405	0.011649	2.303128	8.290915
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.689715	0.398889	0.475463	7.852024	0.025932	0.811074	1.439538	0.011669	2.262281	8.143872
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.626054	0.398889	0.487245	7.630428	0.025989	0.811074	1.398912	0.011695	2.221681	7.997718
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.569166	0.398889	0.499573	7.410243	0.026046	0.811074	1.358545	0.011721	2.18134	7.852497
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.519534	0.398889	0.512486	7.19157	0.026103	0.811074	1.318454	0.011746	2.141274	7.708265
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.477683	0.398889	0.526022	6.974517	0.026161	0.811074	1.278661	0.011772	2.101507	7.56511
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.387715	0.398889	0.537993	6.747441	0.026081	0.811074	1.237031	0.011736	2.059841	7.415119
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.419668	0.398889	0.555118	6.545764	0.026298	0.811074	1.200057	0.011834	2.022965	7.282371
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.404813	0.398889	0.570772	6.334336	0.026378	0.811074	1.161295	0.01187	1.984239	7.142963
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.400367	0.398889	0.587227	6.125076	0.026469	0.811074	1.122931	0.011911	1.945916	7.005006
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.407146	0.398889	0.604539	5.918155	0.026561	0.811074	1.084995	0.011952	1.908021	6.868589
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.426046	0.398889	0.622765	5.71376	0.026664	0.811074	1.047523	0.011999	1.870596	6.733865
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.458043	0.398889	0.641965	5.512092	0.026767	0.811074	1.01055	0.012045	1.833669	6.600933
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.50421	0.398889	0.662204	5.313377	0.026893	0.811074	0.974119	0.012102	1.797295	6.469992
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.565719	0.398889	0.683551	5.117858	0.02703	0.811074	0.938274	0.012164	1.761512	6.341179
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.572584	0.398889	0.703586	4.910955	0.027019	0.811074	0.900342	0.012159	1.723575	6.204611
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.74002	0.398889	0.729864	4.737504	0.027339	0.811074	0.868542	0.012303	1.691919	6.090655
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.855751	0.398889	0.754983	4.553281	0.02751	0.811074	0.834768	0.01238	1.658222	5.96935
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.992723	0.398889	0.78152	4.373484	0.027705	0.811074	0.801805	0.012467	1.625346	5.851002
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.152759	0.398889	0.809555	4.198491	0.027922	0.811074	0.769723	0.012565	1.593362	5.735864
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.337841	0.398889	0.839172	4.028717	0.028162	0.811074	0.738598	0.012673	1.562345	5.624208
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.550112	0.398889	0.870452	3.864607	0.028426	0.811074	0.708511	0.012792	1.532377	5.516327
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.791886	0.398889	0.903473	3.706643	0.028723	0.811074	0.679551	0.012925	1.50355	5.412554
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.205685	0.398889	0.281679	5.876184	0.012308	0.811074	1.0773	0.005539	1.893913	6.817803
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.096105	0.398889	0.316743	5.020022	0.012354	0.811074	0.920337	0.005559	1.73697	6.252831
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	39.27005	0.398889	0.459018	8.18126	0.025875	0.811074	1.499898	0.011644	2.322616	8.361069
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.31598	0.398889	0.83664	7.149162	0.042415	0.811074	1.31068	0.019087	2.140841	7.706706
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	45.100363	0.398889	0.639871	9.395909	0.040333	0.811074	1.722583	0.01815	2.551807	9.186122
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	44.142497	0.398889	0.653106	9.196354	0.040448	0.811074	1.685998	0.018202	2.515274	9.054609
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	43.194455	0.398889	0.666814	8.998845	0.040574	0.811074	1.649788	0.018258	2.47912	8.92446
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	42.25677	0.398889	0.681017	8.803494	0.040711	0.811074	1.613974	0.01832	2.443368	8.795758

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.330011	0.398889	0.695736	8.610419	0.040848	0.811074	1.578577	0.018382	2.408033	8.668558
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	39.588508	0.962222	0.614741	8.247606	0.034866	1.956518	1.512061	0.01569	3.484269	12.542846
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	40.290159	0.962222	0.634235	8.393783	0.03649	1.956518	1.53886	0.016421	3.511799	12.64195
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.010392	0.962222	0.653185	8.543832	0.038114	1.956518	1.566369	0.017151	3.540038	12.743606
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.748431	0.962222	0.671602	8.69759	0.03975	1.956518	1.594558	0.017888	3.568964	12.847735
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	42.503525	0.962222	0.689496	8.854901	0.041409	1.956518	1.623399	0.018634	3.598551	12.954244
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.306323	0.962222	0.753637	6.730484	0.036467	1.956518	1.233922	0.01641	3.20685	11.544179
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.136354	0.962222	0.773923	6.903407	0.038183	1.956518	1.265625	0.017182	3.239325	11.661084
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.983463	0.962222	0.793437	7.079888	0.039922	1.956518	1.297979	0.017965	3.272462	11.780372
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.846683	0.962222	0.812206	7.259726	0.04166	1.956518	1.33095	0.018747	3.306215	11.901878
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.875825	0.962222	0.936027	7.890797	0.051257	1.956518	1.446646	0.023066	3.42623	12.333914
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.63517	0.962222	1.066346	7.007327	0.053225	1.956518	1.284677	0.023951	3.265146	11.754036
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.588591	0.962222	1.052728	6.78929	0.05128	1.956518	1.244703	0.023076	3.224297	11.606986
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.550308	0.962222	1.038426	6.572981	0.049359	1.956518	1.205047	0.022212	3.183777	11.46112
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.520959	0.962222	1.023394	6.358533	0.047437	1.956518	1.165731	0.021347	3.143596	11.316474
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.501242	0.962222	1.007582	6.146092	0.045527	1.956518	1.126784	0.020487	3.103789	11.173175
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.664721	0.962222	0.739219	6.596817	0.035232	1.956518	1.209416	0.015854	3.181788	11.45396
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.57081	0.962222	0.934042	5.327252	0.038	1.956518	0.976663	0.0171	2.950281	10.620569
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.123557	0.962222	1.219446	4.817408	0.046201	1.956518	0.883191	0.02079	2.860499	10.297367
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.999531	0.962222	1.206539	4.583236	0.044165	1.956518	0.84026	0.019874	2.816652	10.139525
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.881224	0.962222	1.192696	4.350255	0.042129	1.956518	0.797547	0.018958	2.773023	9.982467
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.77311	0.962222	1.177503	4.119398	0.040105	1.956518	0.755223	0.018047	2.729788	9.826827
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.609048	0.962222	1.166271	3.876885	0.038171	1.956518	0.710762	0.017177	2.684457	9.663643
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.509955	0.962222	1.149103	3.647907	0.036158	1.956518	0.668783	0.016271	2.641572	9.509263
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	16.419644	0.962222	1.130511	3.420759	0.034168	1.956518	0.627139	0.015376	2.599033	9.356129
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.952377	0.962222	1.024238	2.281745	0.024548	1.956518	0.41832	0.011047	2.385885	8.588828
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	9.936953	0.962222	0.992949	2.070199	0.022649	1.956518	0.379536	0.010192	2.346246	8.446134
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.943128	0.962222	0.95834	1.863152	0.020761	1.956518	0.341578	0.009342	2.307438	8.306431
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.974485	0.962222	0.919951	1.661351	0.01892	1.956518	0.304581	0.008514	2.269613	8.170266
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.035319	0.962222	0.877261	1.465691	0.01709	1.956518	0.26871	0.00769	2.232918	8.03817
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	6.130781	0.962222	0.829687	1.277246	0.015305	1.956518	0.234162	0.006887	2.197567	7.910912
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	5.267027	0.962222	0.776598	1.097297	0.013566	1.956518	0.201171	0.006105	2.163794	7.789334
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	4.45137	0.962222	0.717332	0.927369	0.011862	1.956518	0.170018	0.005338	2.131874	7.674427
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.491923	0.962222	0.990936	5.935817	0.043628	1.956518	1.088233	0.019633	3.064384	11.031323
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.493841	0.962222	0.9734	5.727884	0.041752	1.956518	1.050112	0.018788	3.025418	10.891051
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.507918	0.962222	0.954909	5.522483	0.039876	1.956518	1.012455	0.017944	2.986917	10.752453
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.576699	0.962222	0.914801	5.120146	0.036181	1.956518	0.938693	0.016281	2.911492	10.480934
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.634974	0.962222	0.206941	4.507286	0.007492	1.956518	0.826336	0.003371	2.786225	10.029992
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.941979	0.962222	0.243459	4.571246	0.008899	1.956518	0.838062	0.004005	2.798585	10.074486
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.252287	0.962222	0.279578	4.635893	0.010318	1.956518	0.849914	0.004643	2.811075	10.119448
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.410374	0.962222	0.169543	4.460495	0.006097	1.956518	0.817757	0.002744	2.777019	9.996852
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.603834	0.962222	0.314962	4.709132	0.011748	1.956518	0.863341	0.005287	2.825146	10.170102
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.906238	0.962222	0.594694	8.105466	0.033264	1.956518	1.486002	0.014969	3.457489	12.446442
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.006364	0.964444	0.874051	7.084659	0.043994	1.961036	1.298854	0.019797	3.279687	11.806381
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.933285	0.964444	0.89119	7.277768	0.045801	1.961036	1.334257	0.02061	3.315903	11.936753
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	35.872869	0.964444	0.907631	7.473514	0.047631	1.961036	1.370144	0.021434	3.352614	12.068908
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	36.824354	0.964444	0.923408	7.67174	0.049462	1.961036	1.406486	0.022258	3.38978	12.2027
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	47.073837	0.964444	0.687739	9.807049	0.044897	1.961036	1.797959	0.020204	3.779199	13.60455
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	46.151784	0.964444	0.701305	9.614955	0.045046	1.961036	1.762742	0.020271	3.744049	13.478015

PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	45.24041	0.964444	0.715322	9.425085	0.045195	1.961036	1.727932	0.020338	3.709306	13.352945
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	44.340251	0.964444	0.729806	9.237552	0.045366	1.961036	1.693551	0.020415	3.675002	13.229456
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	17.19725	0.964444	0.987485	3.58276	0.030725	1.961036	0.656839	0.013826	2.631701	9.473729
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	16.204015	0.964444	0.962259	3.375836	0.028849	1.961036	0.618903	0.012982	2.592921	9.334127
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	15.228761	0.964444	0.935064	3.172659	0.026984	1.961036	0.581654	0.012143	2.554833	9.197016
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	14.273657	0.964444	0.905706	2.973679	0.025143	1.961036	0.545174	0.011314	2.517524	9.062709
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	7.038322	0.964444	0.508808	1.466317	0.009917	1.961036	0.268825	0.004463	2.234324	8.043231
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.487098	0.964444	0.445201	1.351479	0.008396	1.961036	0.247771	0.003778	2.212585	7.964974
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.007011	0.964444	0.377489	1.251461	0.006909	1.961036	0.229435	0.003109	2.19358	7.896559
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.935465	0.964444	0.861773	0.194889	0.010775	1.961036	0.03573	0.004849	2.001615	7.205514
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.019726	0.964444	0.787516	0.00411	0.009025	1.961036	0.000754	0.004061	1.965851	7.076769
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.791585	0.964444	0.695434	0.164914	0.007321	1.961036	0.030234	0.003294	1.994564	7.180131
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	43.330034	0.964444	0.742292	9.02709	0.045286	1.961036	1.654966	0.020379	3.636381	13.090426
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.113448	0.403333	0.981415	2.106968	0.02258	0.82011	0.386277	0.010161	1.216548	4.37939
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.948016	0.403333	0.959811	1.86417	0.020807	0.82011	0.341764	0.009363	1.171237	4.216278
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.978301	0.403333	0.92151	1.662146	0.018954	0.82011	0.304727	0.008529	1.133366	4.079948
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.037937	0.403333	0.878914	1.466237	0.017124	0.82011	0.26881	0.007706	1.096626	3.947689
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	6.132058	0.403333	0.831438	1.277512	0.015339	0.82011	0.234211	0.006903	1.061224	3.820247
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	5.266804	0.403333	0.778451	1.097251	0.013589	0.82011	0.201163	0.006115	1.027388	3.698443
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	4.449474	0.403333	0.719285	0.926974	0.011885	0.82011	0.169945	0.005348	0.995403	3.583301
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.027561	0.403333	1.279387	6.255742	0.058578	0.82011	1.146886	0.02636	1.993356	7.175783
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.879681	0.403333	1.27052	6.0166	0.056508	0.82011	1.103043	0.025429	1.948582	7.014603
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.735045	0.403333	1.261114	5.778134	0.054437	0.82011	1.059325	0.024497	1.903932	6.85387
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.593956	0.403333	1.251119	5.540408	0.052367	0.82011	1.015741	0.023565	1.859416	6.693619
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.456757	0.403333	1.240483	5.303491	0.050308	0.82011	0.972307	0.022639	1.815056	6.533929
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.589718	0.403333	0.996804	2.206191	0.023472	0.82011	0.404468	0.010562	1.23514	4.446319
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.352102	0.403333	1.229437	5.073355	0.048306	0.82011	0.930115	0.021738	1.771963	6.378801
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.081105	0.403333	1.214835	4.60023	0.044577	0.82011	0.843376	0.02006	1.683546	6.060513
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.959155	0.403333	1.201327	4.366491	0.042541	0.82011	0.800523	0.019143	1.639776	5.902948
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.843279	0.403333	1.186805	4.134016	0.040516	0.82011	0.757903	0.018232	1.596245	5.746243
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.765405	0.403333	1.168598	3.909459	0.038457	0.82011	0.716734	0.017306	1.55415	5.594707
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.66515	0.403333	1.151618	3.68024	0.036444	0.82011	0.674711	0.0164	1.511221	5.440169
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	16.57353	0.403333	1.133237	3.452819	0.034442	0.82011	0.633017	0.015499	1.468626	5.286833
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.208512	0.403333	1.227428	4.835107	0.046625	0.82011	0.886436	0.020981	1.727527	6.218838
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	1.997471	0.403333	0.404346	0.41614	0.005548	0.82011	0.076292	0.002497	0.898899	3.235902
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	7.039346	0.406667	0.51012	1.46653	0.00994	0.82689	0.268864	0.004473	1.100227	3.960652
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.486701	0.406667	0.446558	1.351396	0.008419	0.82689	0.247756	0.003789	1.078435	3.882204
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.005102	0.406667	0.378881	1.251063	0.006932	0.82689	0.229362	0.003119	1.059371	3.813577
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.911737	0.406667	0.86714	0.189945	0.010821	0.82689	0.034823	0.004869	0.866582	3.119565
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.026864	0.406667	0.789629	0.005597	0.00906	0.82689	0.001026	0.004077	0.831993	2.99505
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.786423	0.406667	0.697795	0.163838	0.007355	0.82689	0.030037	0.00331	0.860237	3.096724
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	17.635204	0.406667	0.9845	3.674001	0.031125	0.82689	0.673567	0.014006	1.514463	5.45184
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	16.643883	0.406667	0.959579	3.467476	0.029249	0.82689	0.635704	0.013162	1.475756	5.3125
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	15.670382	0.406667	0.932749	3.264663	0.027385	0.82689	0.598522	0.012323	1.437735	5.17563
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	14.716806	0.406667	0.903828	3.066001	0.025554	0.82689	0.5621	0.011499	1.400489	5.04155
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	26.539049	0.406667	0.366682	5.528969	0.015328	0.82689	1.013644	0.006898	1.847432	6.650478
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	27.661733	0.406667	0.35526	5.762861	0.015305	0.82689	1.056525	0.006887	1.890302	6.804804
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	25.905082	0.406667	0.373473	5.396892	0.015339	0.82689	0.98943	0.006903	1.823223	6.563329
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	39.252233	0.406667	0.667543	8.177549	0.037611	0.82689	1.499217	0.016925	2.343032	8.434564

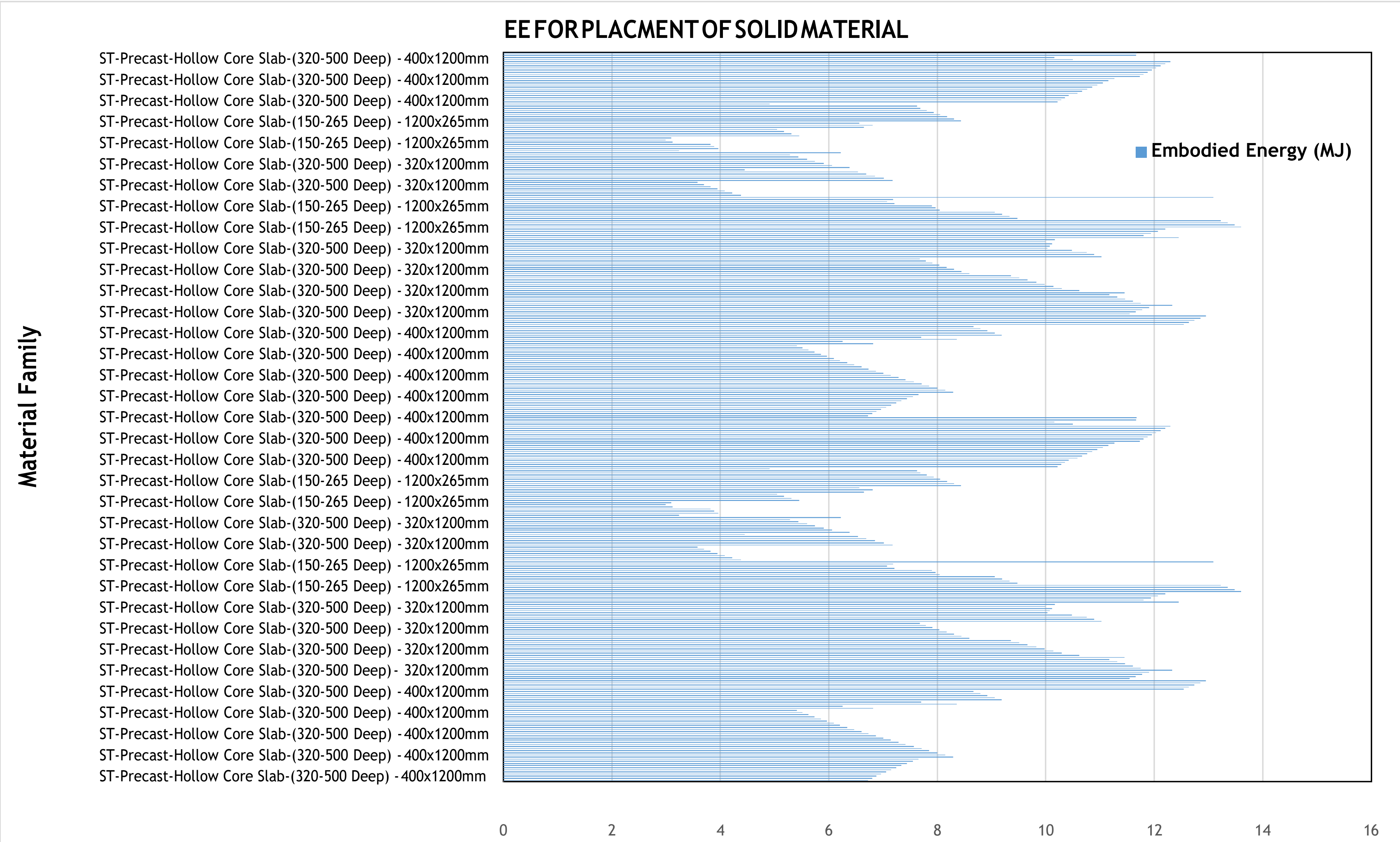
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	38.315531	0.406667	0.682919	7.982402	0.037748	0.82689	1.46344	0.016987	2.307317	8.305995
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	37.429325	0.406667	0.699867	7.797776	0.037966	0.82689	1.429592	0.017085	2.273567	8.1845
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	36.478452	0.406667	0.715511	7.599678	0.038046	0.82689	1.393274	0.017121	2.237285	8.05389
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	35.57954	0.406667	0.732782	7.412404	0.038206	0.82689	1.358941	0.017193	2.203024	7.930556
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.69477	0.406667	0.750743	7.228077	0.038377	0.82689	1.325147	0.01727	2.169307	7.80918
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	33.824999	0.406667	0.769423	7.046875	0.038572	0.82689	1.291927	0.017357	2.136174	7.689906
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	33.346236	0.406667	0.780178	6.947132	0.038686	0.82689	1.273641	0.017409	2.11794	7.624266
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	13.785552	0.406667	0.872613	2.87199	0.023747	0.82689	0.526532	0.010686	1.364108	4.910584
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.169866	0.957778	0.363711	4.827055	0.013795	1.947482	0.88496	0.006208	2.83865	10.218714
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.615473	0.957778	0.39708	4.91989	0.015271	1.947482	0.90198	0.006872	2.856334	10.282374
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.097507	0.957778	0.429541	5.020314	0.016758	1.947482	0.920391	0.007541	2.875414	10.351059
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.614448	0.957778	0.461063	5.12801	0.018256	1.947482	0.940135	0.008215	2.895832	10.424561
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.722017	0.957778	0.520014	5.358754	0.021253	1.947482	0.982438	0.009564	2.939484	10.581701
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.333215	0.957778	0.548679	5.486086	0.022809	1.947482	1.005782	0.010264	2.963528	10.668256
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.973267	0.957778	0.576375	5.619431	0.024376	1.947482	1.030229	0.010969	2.98868	10.7588
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.640703	0.957778	0.603108	5.75848	0.025966	1.947482	1.055721	0.011685	3.014888	10.853145
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.334091	0.957778	0.628892	5.902936	0.027579	1.947482	1.082205	0.012411	3.042098	10.951096
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.052049	0.957778	0.653745	6.05251	0.029203	1.947482	1.109627	0.013141	3.07025	11.052439
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.793247	0.957778	0.677684	6.206926	0.030851	1.947482	1.137936	0.013883	3.099301	11.157019
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.556411	0.957778	0.700737	6.365919	0.032509	1.947482	1.167085	0.014629	3.129196	11.264636
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.081572	0.957778	0.414425	7.100328	0.020899	1.947482	1.301727	0.009405	3.258614	11.730522
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.578302	0.957778	0.439066	7.203813	0.022386	1.947482	1.320699	0.010074	3.278255	11.801226
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.101497	0.957778	0.463151	7.312812	0.023896	1.947482	1.340682	0.010753	3.298917	11.875606
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.650246	0.957778	0.486672	7.427135	0.025417	1.947482	1.361641	0.011438	3.320561	11.953522
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.223641	0.957778	0.50962	7.546592	0.02695	1.947482	1.383542	0.012128	3.343152	12.034846
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.820775	0.957778	0.531995	7.670995	0.028494	1.947482	1.406349	0.012822	3.366653	12.119446
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.440753	0.957778	0.553795	7.800157	0.03005	1.947482	1.430029	0.013522	3.391033	12.20721
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.082689	0.957778	0.575024	7.933894	0.031628	1.947482	1.454547	0.014233	3.416262	12.298031
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.14118	0.957778	0.490376	5.237746	0.019709	1.947482	0.960253	0.008869	2.916604	10.499337
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.762173	0.957778	0.329473	4.742119	0.012343	1.947482	0.869388	0.005554	2.822424	10.160303
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.612212	0.957778	0.389234	7.002544	0.019423	1.947482	1.2838	0.00874	3.240022	11.663593
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.72222	0.957778	0.377109	7.025462	0.018863	1.947482	1.288001	0.008488	3.243971	11.677809
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.09241	0.398889	1.090751	5.644252	0.046282	0.811074	1.03478	0.020827	1.866681	6.719772
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.661637	0.398889	1.062486	5.762841	0.045767	0.811074	1.056521	0.020595	1.88819	6.797201
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.260043	0.398889	1.035084	5.887509	0.045298	0.811074	1.079377	0.020384	1.910835	6.878719
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.886282	0.398889	1.008544	6.017975	0.044863	0.811074	1.103295	0.020188	1.934557	6.964115
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.53903	0.398889	0.982864	6.153965	0.044451	0.811074	1.128227	0.020003	1.959304	7.053201
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.216998	0.398889	0.958033	6.295208	0.044074	0.811074	1.154121	0.019833	1.985028	7.145803
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.918931	0.398889	0.934041	6.441444	0.043719	0.811074	1.180931	0.019674	2.011679	7.241743
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.643618	0.398889	0.91087	6.59242	0.043388	0.811074	1.20861	0.019525	2.039209	7.340847
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.389891	0.398889	0.888502	6.747894	0.043079	0.811074	1.237114	0.019386	2.067574	7.442956
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.156632	0.398889	0.866921	6.907632	0.042793	0.811074	1.266399	0.019257	2.09673	7.547913
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.942768	0.398889	0.8461	7.07141	0.04253	0.811074	1.296425	0.019138	2.126637	7.655574
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.759706	0.398889	0.464198	8.074939	0.025886	0.811074	1.480405	0.011649	2.303128	8.290915
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.689715	0.398889	0.475463	7.852024	0.025932	0.811074	1.439538	0.011669	2.262281	8.143872
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.626054	0.398889	0.487245	7.630428	0.025989	0.811074	1.398912	0.011695	2.221681	7.997718
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.569166	0.398889	0.499573	7.410243	0.026046	0.811074	1.358545	0.011721	2.18134	7.852497
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.519534	0.398889	0.512486	7.19157	0.026103	0.811074	1.318454	0.011746	2.141274	7.708265
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.477683	0.398889	0.526022	6.974517	0.026161	0.811074	1.278661	0.011772	2.101507	7.56511

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.387715	0.398889	0.537993	6.747441	0.026081	0.811074	1.237031	0.011736	2.059841	7.415119
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.419668	0.398889	0.555118	6.545764	0.026298	0.811074	1.200057	0.011834	2.022965	7.282371
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.404813	0.398889	0.570772	6.334336	0.026378	0.811074	1.161295	0.01187	1.984239	7.142963
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.400367	0.398889	0.587227	6.125076	0.026469	0.811074	1.122931	0.011911	1.945916	7.005006
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.407146	0.398889	0.604539	5.918155	0.026561	0.811074	1.084995	0.011952	1.908021	6.868589
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.426046	0.398889	0.622765	5.71376	0.026664	0.811074	1.047523	0.011999	1.870596	6.733865
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.458043	0.398889	0.641965	5.512092	0.026767	0.811074	1.01055	0.012045	1.833669	6.600933
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.50421	0.398889	0.662204	5.313377	0.026893	0.811074	0.974119	0.012102	1.797295	6.469992
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.565719	0.398889	0.683551	5.117858	0.02703	0.811074	0.938274	0.012164	1.761512	6.341179
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.572584	0.398889	0.703586	4.910955	0.027019	0.811074	0.900342	0.012159	1.723575	6.204611
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.74002	0.398889	0.729864	4.737504	0.027339	0.811074	0.868542	0.012303	1.691919	6.090655
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.855751	0.398889	0.754983	4.553281	0.02751	0.811074	0.834768	0.01238	1.658222	5.96935
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.992723	0.398889	0.78152	4.373484	0.027705	0.811074	0.801805	0.012467	1.625346	5.851002
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.152759	0.398889	0.809555	4.198491	0.027922	0.811074	0.769723	0.012565	1.593362	5.735864
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.337841	0.398889	0.839172	4.028717	0.028162	0.811074	0.738598	0.012673	1.562345	5.624208
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.550112	0.398889	0.870452	3.864607	0.028426	0.811074	0.708511	0.012792	1.532377	5.516327
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.791886	0.398889	0.903473	3.706643	0.028723	0.811074	0.679551	0.012925	1.50355	5.412554
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.205685	0.398889	0.281679	5.876184	0.012308	0.811074	1.0773	0.005539	1.893913	6.817803
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.096105	0.398889	0.316743	5.020022	0.012354	0.811074	0.920337	0.005559	1.73697	6.252831
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	39.27005	0.398889	0.459018	8.18126	0.025875	0.811074	1.499898	0.011644	2.322616	8.361069
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.31598	0.398889	0.83664	7.149162	0.042415	0.811074	1.31068	0.019087	2.140841	7.706706
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	45.100363	0.398889	0.639871	9.395909	0.040333	0.811074	1.722583	0.01815	2.551807	9.186122
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	44.142497	0.398889	0.653106	9.196354	0.040448	0.811074	1.685998	0.018202	2.515274	9.054609
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	43.194455	0.398889	0.666814	8.998845	0.040574	0.811074	1.649788	0.018258	2.47912	8.92446
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	42.25677	0.398889	0.681017	8.803494	0.040711	0.811074	1.613974	0.01832	2.443368	8.795758
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.330011	0.398889	0.695736	8.610419	0.040848	0.811074	1.578577	0.018382	2.408033	8.668558
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	39.588508	0.962222	0.614741	8.247606	0.034866	1.956518	1.512061	0.01569	3.484269	12.542846
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	40.290159	0.962222	0.634235	8.393783	0.03649	1.956518	1.53886	0.016421	3.511799	12.64195
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.010392	0.962222	0.653185	8.543832	0.038114	1.956518	1.566369	0.017151	3.540038	12.743606
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	41.748431	0.962222	0.671602	8.69759	0.03975	1.956518	1.594558	0.017888	3.568964	12.847735
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	42.503525	0.962222	0.689496	8.854901	0.041409	1.956518	1.623399	0.018634	3.598551	12.954244
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.306323	0.962222	0.753637	6.730484	0.036467	1.956518	1.233922	0.01641	3.20685	11.544179
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.136354	0.962222	0.773923	6.903407	0.038183	1.956518	1.265625	0.017182	3.239325	11.661084
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.983463	0.962222	0.793437	7.079888	0.039922	1.956518	1.297979	0.017965	3.272462	11.780372
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.846683	0.962222	0.812206	7.259726	0.04166	1.956518	1.33095	0.018747	3.306215	11.901878
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.875825	0.962222	0.936027	7.890797	0.051257	1.956518	1.446646	0.023066	3.42623	12.333914
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.63517	0.962222	1.066346	7.007327	0.053225	1.956518	1.284677	0.023951	3.265146	11.754036
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	32.588591	0.962222	1.052728	6.78929	0.05128	1.956518	1.244703	0.023076	3.224297	11.606986
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.550308	0.962222	1.038426	6.572981	0.049359	1.956518	1.205047	0.022212	3.183777	11.46112
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.520959	0.962222	1.023394	6.358533	0.047437	1.956518	1.165731	0.021347	3.143596	11.316474
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.501242	0.962222	1.007582	6.146092	0.045527	1.956518	1.126784	0.020487	3.103789	11.173175
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	31.664721	0.962222	0.739219	6.596817	0.035232	1.956518	1.209416	0.015854	3.181788	11.45396
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.57081	0.962222	0.934042	5.327252	0.038	1.956518	0.976663	0.0171	2.950281	10.620569
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.123557	0.962222	1.219446	4.817408	0.046201	1.956518	0.883191	0.02079	2.860499	10.297367
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.999531	0.962222	1.206539	4.583236	0.044165	1.956518	0.84026	0.019874	2.816652	10.139525
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.881224	0.962222	1.192696	4.350255	0.042129	1.956518	0.797547	0.018958	2.773023	9.982467
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.77311	0.962222	1.177503	4.119398	0.040105	1.956518	0.755223	0.018047	2.729788	9.826827
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.609048	0.962222	1.166271	3.876885	0.038171	1.956518	0.710762	0.017177	2.684457	9.663643
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.509955	0.962222	1.149103	3.647907	0.036158	1.956518	0.668783	0.016271	2.641572	9.509263

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	16.419644	0.962222	1.130511	3.420759	0.034168	1.956518	0.627139	0.015376	2.599033	9.356129
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.952377	0.962222	1.024238	2.281745	0.024548	1.956518	0.41832	0.011047	2.385885	8.588828
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	9.936953	0.962222	0.992949	2.070199	0.022649	1.956518	0.379536	0.010192	2.346246	8.446134
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.943128	0.962222	0.95834	1.863152	0.020761	1.956518	0.341578	0.009342	2.307438	8.306431
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.974485	0.962222	0.919951	1.661351	0.01892	1.956518	0.304581	0.008514	2.269613	8.170266
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.035319	0.962222	0.877261	1.465691	0.01709	1.956518	0.26871	0.00769	2.232918	8.03817
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	6.130781	0.962222	0.829687	1.277246	0.015305	1.956518	0.234162	0.006887	2.197567	7.910912
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	5.267027	0.962222	0.776598	1.097297	0.013566	1.956518	0.201171	0.006105	2.163794	7.789334
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	4.45137	0.962222	0.717332	0.927369	0.011862	1.956518	0.170018	0.005338	2.131874	7.674427
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.491923	0.962222	0.990936	5.935817	0.043628	1.956518	1.088233	0.019633	3.064384	11.031323
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.493841	0.962222	0.9734	5.727884	0.041752	1.956518	1.050112	0.018788	3.025418	10.891051
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.507918	0.962222	0.954909	5.522483	0.039876	1.956518	1.012455	0.017944	2.986917	10.752453
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.576699	0.962222	0.914801	5.120146	0.036181	1.956518	0.938693	0.016281	2.911492	10.480934
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.634974	0.962222	0.206941	4.507286	0.007492	1.956518	0.826336	0.003371	2.786225	10.029992
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.941979	0.962222	0.243459	4.571246	0.008899	1.956518	0.838062	0.004005	2.798585	10.074486
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.252287	0.962222	0.279578	4.635893	0.010318	1.956518	0.849914	0.004643	2.811075	10.119448
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	21.410374	0.962222	0.169543	4.460495	0.006097	1.956518	0.817757	0.002744	2.777019	9.996852
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.603834	0.962222	0.314962	4.709132	0.011748	1.956518	0.863341	0.005287	2.825146	10.170102
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.906238	0.962222	0.594694	8.105466	0.033264	1.956518	1.486002	0.014969	3.457489	12.446442
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.006364	0.964444	0.874051	7.084659	0.043994	1.961036	1.298854	0.019797	3.279687	11.806381
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.933285	0.964444	0.89119	7.277768	0.045801	1.961036	1.334257	0.02061	3.315903	11.936753
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	35.872869	0.964444	0.907631	7.473514	0.047631	1.961036	1.370144	0.021434	3.352614	12.068908
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	36.824354	0.964444	0.923408	7.67174	0.049462	1.961036	1.406486	0.022258	3.38978	12.2027
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	47.073837	0.964444	0.687739	9.807049	0.044897	1.961036	1.797959	0.020204	3.779199	13.60455
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	46.151784	0.964444	0.701305	9.614955	0.045046	1.961036	1.762742	0.020271	3.744049	13.478015
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	45.24041	0.964444	0.715322	9.425085	0.045195	1.961036	1.727932	0.020338	3.709306	13.352945
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	44.340251	0.964444	0.729806	9.237552	0.045366	1.961036	1.693551	0.020415	3.675002	13.229456
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	17.19725	0.964444	0.987485	3.58276	0.030725	1.961036	0.656839	0.013826	2.631701	9.473729
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	16.204015	0.964444	0.962259	3.375836	0.028849	1.961036	0.618903	0.012982	2.592921	9.334127
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	15.228761	0.964444	0.935064	3.172659	0.026984	1.961036	0.581654	0.012143	2.554833	9.197016
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	14.273657	0.964444	0.905706	2.973679	0.025143	1.961036	0.545174	0.011314	2.517524	9.062709
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	7.038322	0.964444	0.508808	1.466317	0.009917	1.961036	0.268825	0.004463	2.234324	8.043231
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.487098	0.964444	0.445201	1.351479	0.008396	1.961036	0.247771	0.003778	2.212585	7.964974
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.007011	0.964444	0.377489	1.251461	0.006909	1.961036	0.229435	0.003109	2.19358	7.896559
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.935465	0.964444	0.861773	0.194889	0.010775	1.961036	0.03573	0.004849	2.001615	7.205514
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.019726	0.964444	0.787516	0.00411	0.009025	1.961036	0.000754	0.004061	1.965851	7.076769
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.791585	0.964444	0.695434	0.164914	0.007321	1.961036	0.030234	0.003294	1.994564	7.180131
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	43.330034	0.964444	0.742292	9.02709	0.045286	1.961036	1.654966	0.020379	3.636381	13.090426
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.113448	0.403333	0.981415	2.106968	0.02258	0.82011	0.386277	0.010161	1.216548	4.37939
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	8.948016	0.403333	0.959811	1.86417	0.020807	0.82011	0.341764	0.009363	1.171237	4.216278
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.978301	0.403333	0.92151	1.662146	0.018954	0.82011	0.304727	0.008529	1.133366	4.079948
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	7.037937	0.403333	0.878914	1.466237	0.017124	0.82011	0.26881	0.007706	1.096626	3.947689
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	6.132058	0.403333	0.831438	1.277512	0.015339	0.82011	0.234211	0.006903	1.061224	3.820247
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	5.266804	0.403333	0.778451	1.097251	0.013589	0.82011	0.201163	0.006115	1.027388	3.698443
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	4.449474	0.403333	0.719285	0.926974	0.011885	0.82011	0.169945	0.005348	0.995403	3.583301
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.027561	0.403333	1.279387	6.255742	0.058578	0.82011	1.146886	0.02636	1.993356	7.175783
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.879681	0.403333	1.27052	6.0166	0.056508	0.82011	1.103043	0.025429	1.948582	7.014603
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.735045	0.403333	1.261114	5.778134	0.054437	0.82011	1.059325	0.024497	1.903932	6.85387
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.593956	0.403333	1.251119	5.540408	0.052367	0.82011	1.015741	0.023565	1.859416	6.693619

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.456757	0.403333	1.240483	5.303491	0.050308	0.82011	0.972307	0.022639	1.815056	6.533929
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	10.589718	0.403333	0.996804	2.206191	0.023472	0.82011	0.404468	0.010562	1.23514	4.446319
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.352102	0.403333	1.229437	5.073355	0.048306	0.82011	0.930115	0.021738	1.771963	6.378801
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.081105	0.403333	1.214835	4.60023	0.044577	0.82011	0.843376	0.02006	1.683546	6.060513
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	20.959155	0.403333	1.201327	4.366491	0.042541	0.82011	0.800523	0.019143	1.639776	5.902948
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	19.843279	0.403333	1.186805	4.134016	0.040516	0.82011	0.757903	0.018232	1.596245	5.746243
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	18.765405	0.403333	1.168598	3.909459	0.038457	0.82011	0.716734	0.017306	1.55415	5.594707
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	17.66515	0.403333	1.151618	3.68024	0.036444	0.82011	0.674711	0.0164	1.511221	5.440169
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	16.57353	0.403333	1.133237	3.452819	0.034442	0.82011	0.633017	0.015499	1.468626	5.286833
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.208512	0.403333	1.227428	4.835107	0.046625	0.82011	0.886436	0.020981	1.727527	6.218838
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	1.997471	0.403333	0.404346	0.41614	0.005548	0.82011	0.076292	0.002497	0.898899	3.235902
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	7.039346	0.406667	0.51012	1.46653	0.00994	0.82689	0.268864	0.004473	1.100227	3.960652
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.486701	0.406667	0.446558	1.351396	0.008419	0.82689	0.247756	0.003789	1.078435	3.882204
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	6.005102	0.406667	0.378881	1.251063	0.006932	0.82689	0.229362	0.003119	1.059371	3.813577
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.911737	0.406667	0.86714	0.189945	0.010821	0.82689	0.034823	0.004869	0.866582	3.119565
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.026864	0.406667	0.789629	0.005597	0.00906	0.82689	0.001026	0.004077	0.831993	2.99505
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	0.786423	0.406667	0.697795	0.163838	0.007355	0.82689	0.030037	0.00331	0.860237	3.096724
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	17.635204	0.406667	0.9845	3.674001	0.031125	0.82689	0.673567	0.014006	1.514463	5.45184
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	16.643883	0.406667	0.959579	3.467476	0.029249	0.82689	0.635704	0.013162	1.475756	5.3125
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	15.670382	0.406667	0.932749	3.264663	0.027385	0.82689	0.598522	0.012323	1.437735	5.17563
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	14.716806	0.406667	0.903828	3.066001	0.025554	0.82689	0.5621	0.011499	1.400489	5.04155
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	26.539049	0.406667	0.366682	5.528969	0.015328	0.82689	1.013644	0.006898	1.847432	6.650478
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	27.661733	0.406667	0.35526	5.762861	0.015305	0.82689	1.056525	0.006887	1.890302	6.804804
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	25.905082	0.406667	0.373473	5.396892	0.015339	0.82689	0.98943	0.006903	1.823223	6.563329
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	39.252233	0.406667	0.667543	8.177549	0.037611	0.82689	1.499217	0.016925	2.343032	8.434564
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	38.315531	0.406667	0.682919	7.982402	0.037748	0.82689	1.46344	0.016987	2.307317	8.305995
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	37.429325	0.406667	0.699867	7.797776	0.037966	0.82689	1.429592	0.017085	2.273567	8.1845
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	36.478452	0.406667	0.715511	7.599678	0.038046	0.82689	1.393274	0.017121	2.237285	8.05389
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	35.57954	0.406667	0.732782	7.412404	0.038206	0.82689	1.358941	0.017193	2.203024	7.930556
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	34.69477	0.406667	0.750743	7.228077	0.038377	0.82689	1.325147	0.01727	2.169307	7.80918
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	33.824999	0.406667	0.769423	7.046875	0.038572	0.82689	1.291927	0.017357	2.136174	7.689906
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	33.346236	0.406667	0.780178	6.947132	0.038686	0.82689	1.273641	0.017409	2.11794	7.624266
PeccoSK 560	ST-Precast-Hollow Core Slab-(150-265 Deep)	13.785552	0.406667	0.872613	2.87199	0.023747	0.82689	0.526532	0.010686	1.364108	4.910584
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.169866	0.957778	0.363711	4.827055	0.013795	1.947482	0.88496	0.006208	2.83865	10.218714
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	23.615473	0.957778	0.39708	4.91989	0.015271	1.947482	0.90198	0.006872	2.856334	10.282374
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.097507	0.957778	0.429541	5.020314	0.016758	1.947482	0.920391	0.007541	2.875414	10.351059
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	24.614448	0.957778	0.461063	5.12801	0.018256	1.947482	0.940135	0.008215	2.895832	10.424561
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.722017	0.957778	0.520014	5.358754	0.021253	1.947482	0.982438	0.009564	2.939484	10.581701
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.333215	0.957778	0.548679	5.486086	0.022809	1.947482	1.005782	0.010264	2.963528	10.668256
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	26.973267	0.957778	0.576375	5.619431	0.024376	1.947482	1.030229	0.010969	2.98868	10.7588
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	27.640703	0.957778	0.603108	5.75848	0.025966	1.947482	1.055721	0.011685	3.014888	10.853145
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	28.334091	0.957778	0.628892	5.902936	0.027579	1.947482	1.082205	0.012411	3.042098	10.951096
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.052049	0.957778	0.653745	6.05251	0.029203	1.947482	1.109627	0.013141	3.07025	11.052439
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	29.793247	0.957778	0.677684	6.206926	0.030851	1.947482	1.137936	0.013883	3.099301	11.157019
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	30.556411	0.957778	0.700737	6.365919	0.032509	1.947482	1.167085	0.014629	3.129196	11.264636
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.081572	0.957778	0.414425	7.100328	0.020899	1.947482	1.301727	0.009405	3.258614	11.730522
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	34.578302	0.957778	0.439066	7.203813	0.022386	1.947482	1.320699	0.010074	3.278255	11.801226
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.101497	0.957778	0.463151	7.312812	0.023896	1.947482	1.340682	0.010753	3.298917	11.875606
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	35.650246	0.957778	0.486672	7.427135	0.025417	1.947482	1.361641	0.011438	3.320561	11.953522

PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.223641	0.957778	0.50962	7.546592	0.02695	1.947482	1.383542	0.012128	3.343152	12.034846
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	36.820775	0.957778	0.531995	7.670995	0.028494	1.947482	1.406349	0.012822	3.366653	12.119446
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	37.440753	0.957778	0.553795	7.800157	0.03005	1.947482	1.430029	0.013522	3.391033	12.20721
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	38.082689	0.957778	0.575024	7.933894	0.031628	1.947482	1.454547	0.014233	3.416262	12.298031
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	25.14118	0.957778	0.490376	5.237746	0.019709	1.947482	0.960253	0.008869	2.916604	10.499337
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	22.762173	0.957778	0.329473	4.742119	0.012343	1.947482	0.869388	0.005554	2.822424	10.160303
PeccoSK 560	ST-Precast-Hollow Core Slab-(320-500 Deep)	33.612212	0.957778	0.389234	7.002544	0.019423	1.947482	1.2838	0.00874	3.240022	11.663593


EE FOR PLACMENT OF SOLID MATERIAL
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
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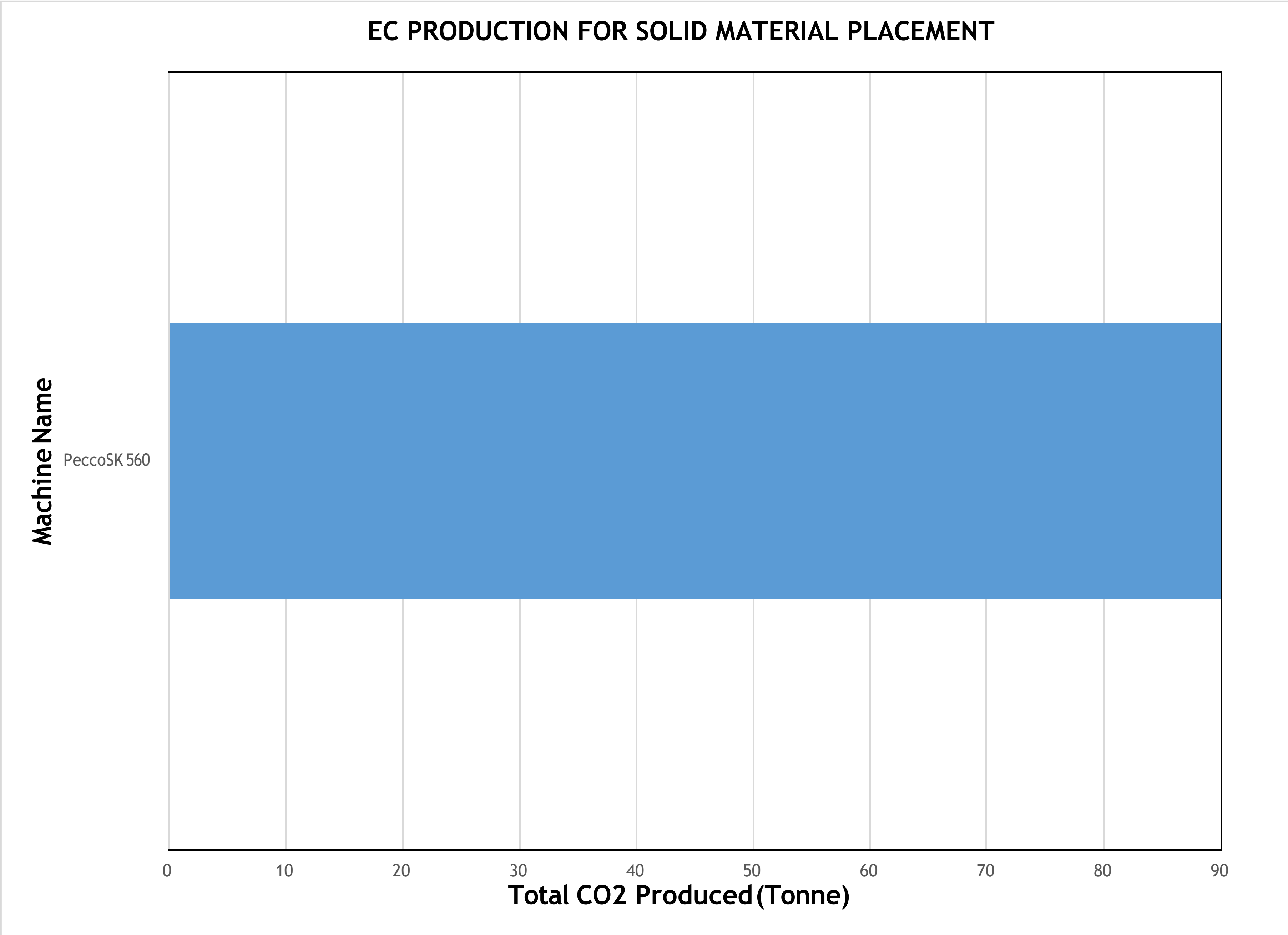
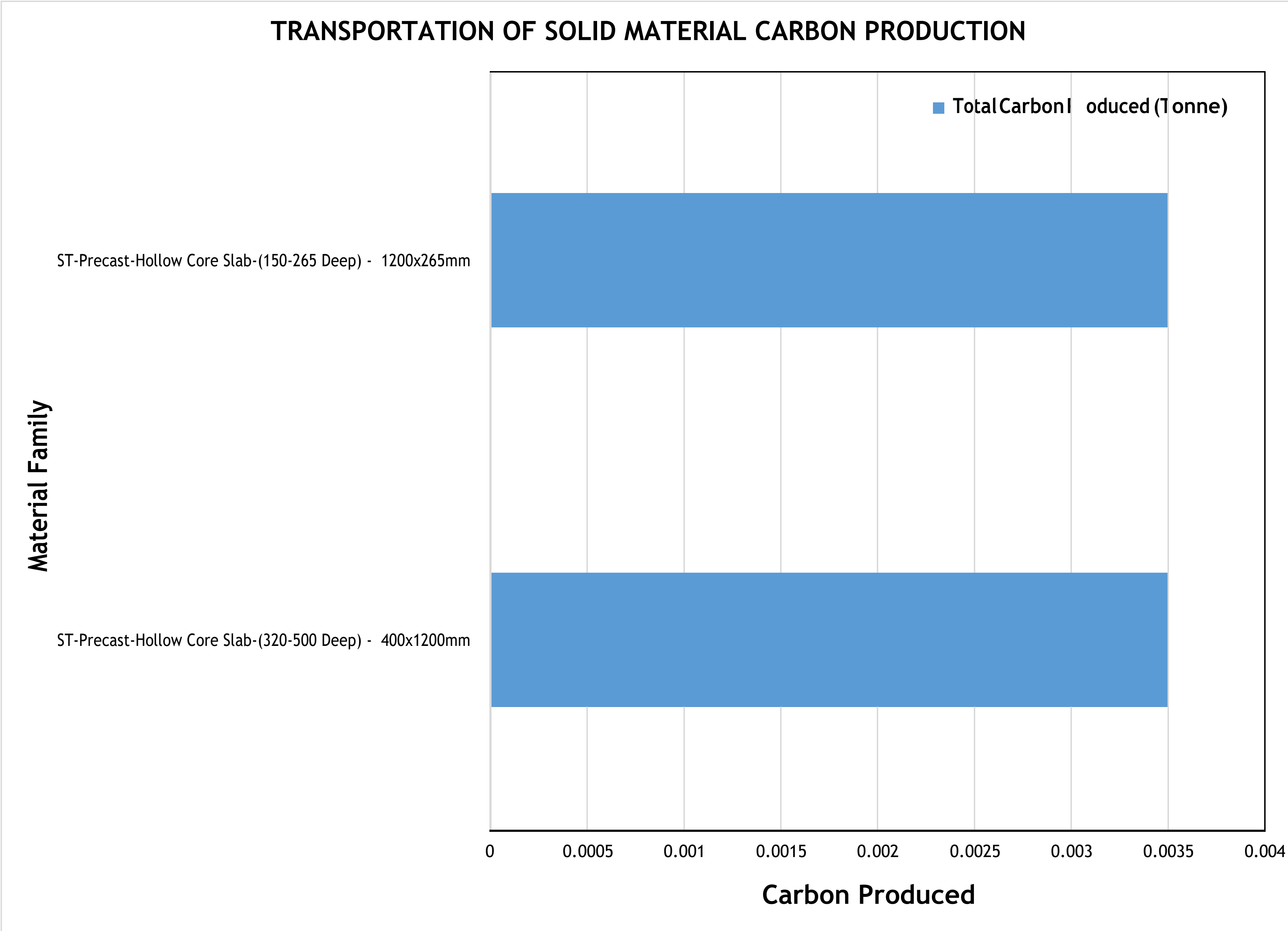
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 320x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
Embodied Energy (MJ)
Material Family
0
2
4
6
8
10
12
14
16
Embodied Energy (MJ)

EC FOR THE PLACEMENT OF SOLID MATERIALS SUMMARY REPORT

Machine Name	Amount Of Fuel Used (L)	Amount Electricity Used (KWH)	CO2 Producted By Fuel (Tonne)	CO2 Producted By Electricity (Tonne)	Total CO2 Produced (Tonne)
PeccoSK 560	0	812.989	0	81.5769	81.5769

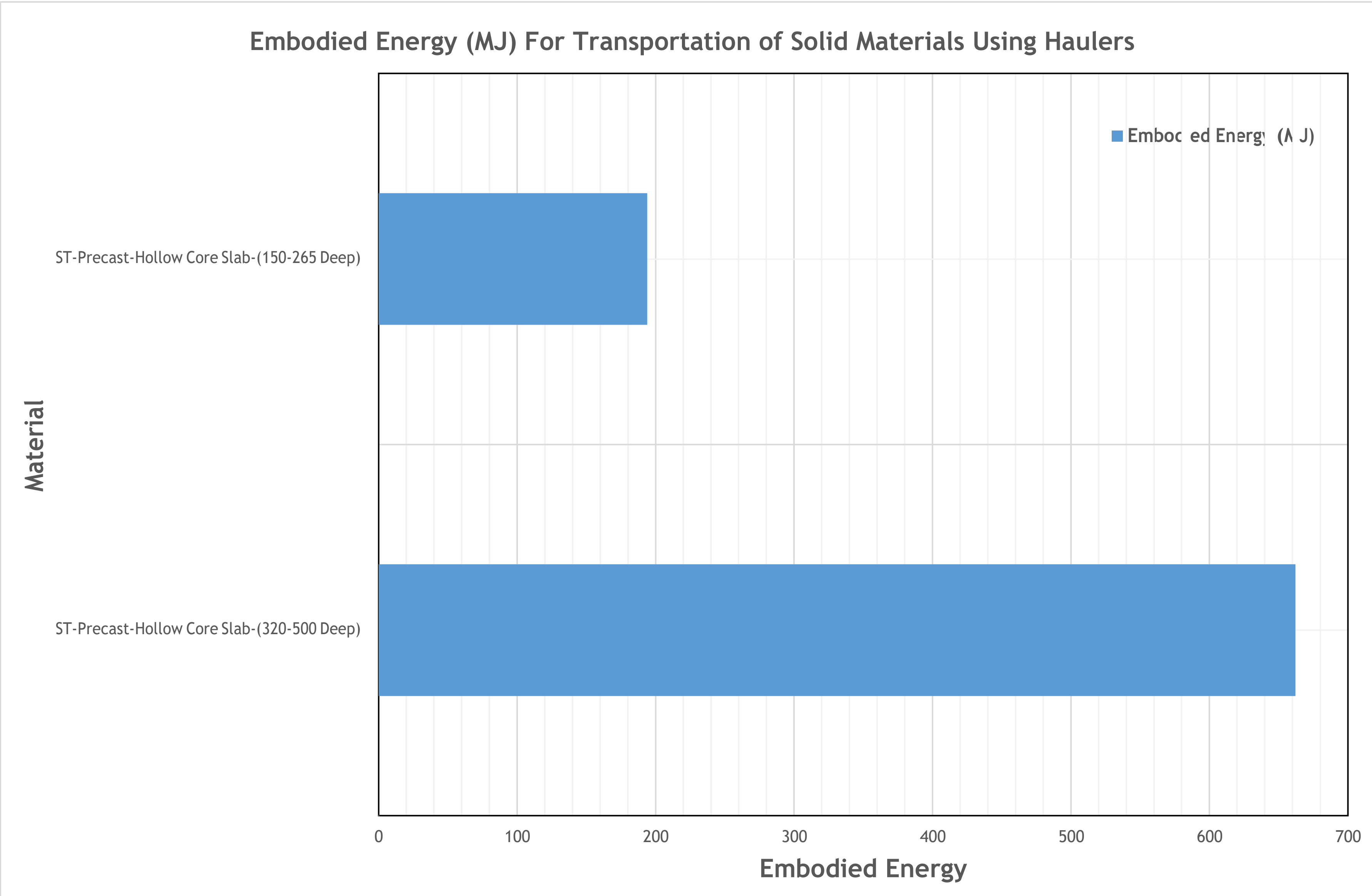

EC PRODUCTION FOR SOLID MATERIAL PLACEMENT
Machine Name
PeccoSK 560
0
10
20
30
40
50
60
70
80
90
Total CO2 Produced (Tonne)

SlNo	Family Name	Type	Cross Material	Transportation Medium	Vehicle Name	(Tonne)
1	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	Precast Concrete _Concrete	Hauler	TRACTOR-VOLVO-FH-4XX_A1	0.003463
2	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	Precast Concrete _Concrete	Hauler	TRACTOR-MERC-BENZ-ACTROS-38XX_F4	0.003463


TRANSPORTATION OF SOLID MATERIAL CARBON PRODUCTION
Total Carbon I oduced (T onne)
ST-Precast-Hollow Core Slab-(150-265 Deep) - 1200x265mm
ST-Precast-Hollow Core Slab-(320-500 Deep) - 400x1200mm
Material Family
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
Carbon Produced

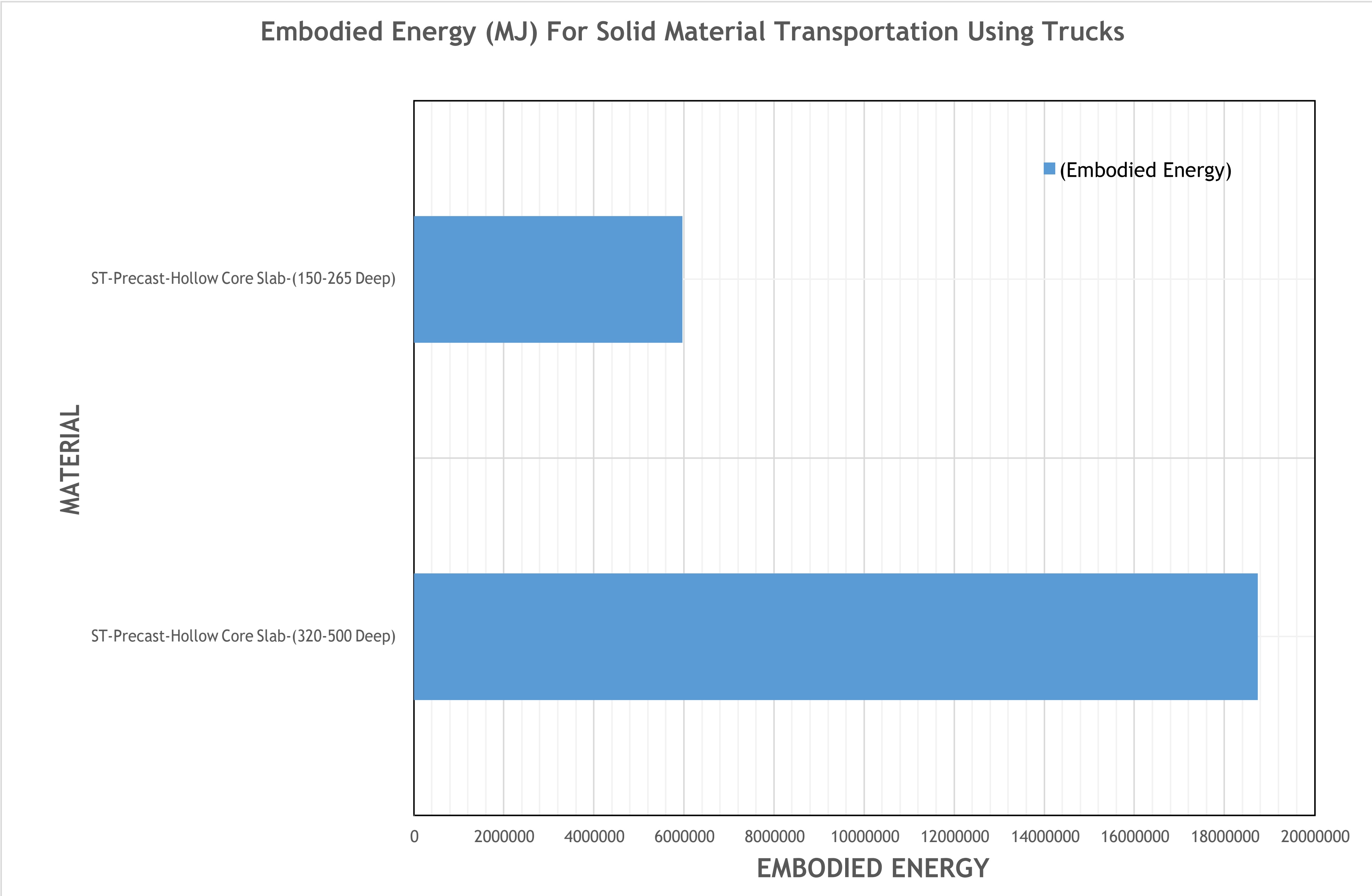
SOLID MATERIAL TRANSPORTATION THROUGH HAULER EE SUMMARY REPORT

Sl No	Family Name	Type	No of Materials	Total Volume (m3)	Distance (Km)	Truck Name	PayLoad (kg)	No of Trips	Total Fuel Consumption (KM/L)	Embodied Energy (MJ)
1	ST-Precast-HollowCoreSlab-(320-500Deep)	400x1200mm	131	247.49	17.5	TRACTOR-VOLVO-FH-4XX_A1	65999.9	1	172.88	661.97
2	ST-Precast-HollowCoreSlab-(150-265Deep)	1200x265mm	41	19.94	17.5	TRACTOR-MERC-BENZ-ACTROS-38XX_F4	26999.61	1	50.63	193.86


Embodied Energy (MJ) For Transportation of Solid Materials Using Haulers
Material
ST-Precast-Hollow Core Slab-(150-265 Deep)
ST-Precast-Hollow Core Slab-(320-500 Deep)
0
100
200
300
400
500
600
700
Embodied Energy

EE FOR SOLID MATERIAL TRANSPORTATION THROUGH TRUCKS SUMMARY REPORT

Sl No	Family Name	Type	Total Volume (m3)	Distance (Km)	Truck Name	Bed Length (m)	Bed Width (m)	Bed Height (m)	PayLoad (Kg)	No of Trips	Total Fuel Consumption (Km/L)	Embodied Energy (MJ)
1	ST-Precast-Hollow Core Slab-(320-500 Deep)	400x1200mm	247.49	17.5	NISSAN -TITAN_A1	1.98	1.27	4.64	5069	132	4895489.359	18744997.16
2	ST-Precast-Hollow Core Slab-(150-265 Deep)	1200x265mm	19.94	17.5	NISSAN -TITAN_A1	1.98	1.27	4.64	5069	42	1557655.7	5964317.26


Embodied Energy (MJ) For Solid Material Transportation Using Trucks
(Embodied Energy)
MATERIAL
ST-Precast-Hollow Core Slab-(150-265 Deep)
ST-Precast-Hollow Core Slab-(320-500 Deep)
0
2000000
4000000
6000000
8000000
10000000
12000000
14000000
16000000
18000000
20000000
EMBODIED ENERGY