

Modeling the Contributing Factors to Carbon Emissions during Building Construction Using a Path Analysis Approach

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Abstract

Environmental consequences are a hindrance to achieving sustainability and evaluating the success of building projects. It is critical to identify numerous activities and materials that have direct and indirect carbon emissions in order to decrease these environmental impacts during building construction. Emissions from building construction begin with material manufacture, construction activities, usage phase and maintenance, destruction, and recycling and reuse. The correlation and relevance of elements contributing to carbon emissions during the pre-use stage of building construction are determined in this study utilising Linear Structural Relationship (LISREL).

Keywords: *Linear Structural Relationship (LISREL), Building Construction, Environmental impacts, Emissions, Sustainability*

INTRODUCTION

The climate system is being seriously harmed by greenhouse gas (GHG) emissions, the most major of which is carbon dioxide (CO₂). Construction-related activities require a lot of energy; hence they contribute a lot to the rise in carbon emissions. The rate of rise in carbon emissions can be controlled by

recognising and mitigating the numerous elements that contribute to carbon emissions. The stages, which include material manufacturing, transportation of materials, equipment, and trash, and construction activities, account for the vast bulk of total carbon emissions over the life cycle of a structure. Because of uncertainty in energy-efficient buildings, real

emissions during the usage phase may vary substantially over time. Cradle to service is a boundary condition connected with the carbon footprint of all activities beginning with the embodied carbon of materials, transportation of materials, and construction activities until the facility is ready for use.

METHODOLOGY

Previous research identified carbon emission sources up to the operational stage, which were then converted into a questionnaire to collect data from diverse sites. All materials and energy used for each action along the process are listed. Thus, carbon emissions from material and energy usage may be quantified. The analysis includes indirect emissions from materials, gasoline utilised to transport building materials and equipment to the construction site and to transport construction trash, and direct emissions from different construction on-site

operations. The data obtained is then transformed into carbon emissions, which are given in tonnes-CO₂eq. Carbon emissions during building construction were determined using equations by substituting the value of the relevant emission factor in the research. The data is analysed with Linear Structural Relation (LISREL) to create a route relation diagram demonstrating the link between variables in the research.

PATH RELATION NETWORK ANALYSIS

The emissions owing to embodied carbon in construction materials, transportation of building materials, transportation of equipment and machinery, waste disposal, and emissions related to sites activities are the independent or exogenous factors. Total cradle to service carbon emissions from building construction are the dependent or endogenous variable.

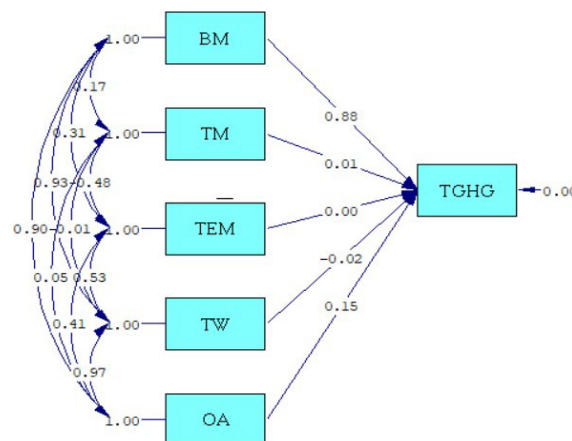


Fig.1:-Linear structural model showing analysis result

Figure 1 indicates that the transportation of construction trash has a negative association with construction carbon emissions, whereas the other has a positive relationship.

Figure 2 depicts the t-value, which is used to assess if there is a significant difference between the means of two groups. The larger the size of the t-value, the stronger the evidence against the null hypothesis.

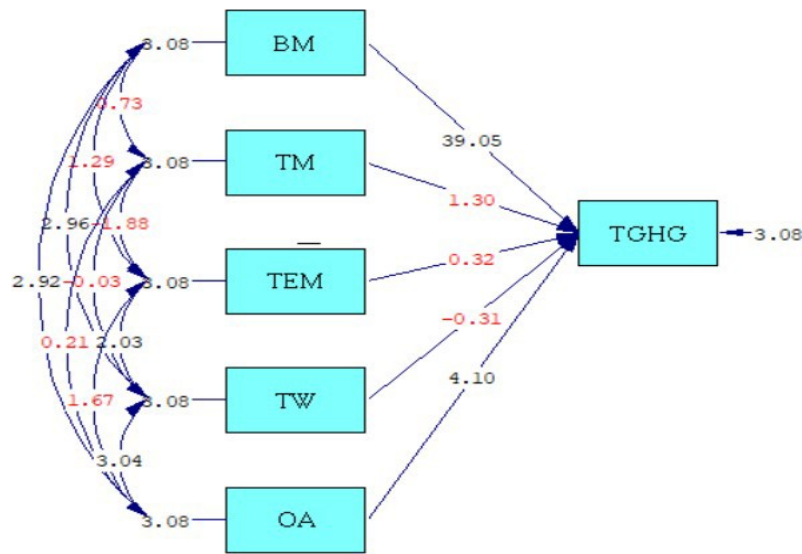


Fig.2:-Analysis of critical ratio (CR) between variables

Table 1:-Correlation between variables contributing carbon emissions

Sl. No.	Relationship between variables			SE	CR	β
1	Carbon emission	$\leftrightarrow$	Building materials	0.033	39.05	0.88
2	Carbon emission	$\leftrightarrow$	Transportation of materials	2.454	1.30	0.01
3	Carbon emission	$\leftrightarrow$	Transportation of equipment and machineries	1.289	0.32	0.001
4	Carbon emission	$\leftrightarrow$	Transportation of waste	3.490	-0.31	-0.02
5	Carbon emission	$\leftrightarrow$	Onsite activities	1.146	4.10	0.15

Table 1 shows S.E (standard error) and CR (critical ratio). The lower the value of SE the stronger the ability of exogenous variable to predict the endogenous variable. Building materials shows the lowest S.E value ($=0.033$) which means it has the strongest ability to predict carbon emission related to building construction. The transportation of waste has the highest value of SE ($=3.490$) which has the weakest ability to predict the carbon emission.

It is shown that the C.R. value between carbon emission and five exogenous variables are out of ± 1.96 range. When the critical ratio (CR) is greater than 1.96 for a regression weight, that the estimated path parameter is said to be significant. Therefore, two variables building material production (embodied carbon) and onsite

activities are significant variable to carbon emissions during to building construction.

Apart from that, the table shows the different correlation between five exogenous variables to endogenous variable, carbon emission. It is found that four exogenous variables pose a positive correlation with carbon emission which is building materials ($\beta = 0.88$), transportation of building materials ($\beta = 0.01$), transportation of equipment and machineries ($\beta = 0.001$), and onsite activities ($\beta = 0.15$). Among them, building material production has the highest correlation and is the most significant contributor to carbon emission. However, transportation of waste shows a negative correlation with carbon emission, where $\beta = -0.02$.

Table 2:-Correlation between five independent variables

Relationship between exogenous variables			CR	β
Building materials	↔	Transportation of materials	0.73	0.17
Building materials	↔	Transportation of equipment and machineries	1.29	0.31
Building materials	↔	Transportation of waste	2.96	0.93
Building materials	↔	Onsite activities	2.92	0.9
Transportation of materials	↔	Transportation of equipment and machineries	- 1.88	- 0.48
Transportation of materials	↔	Transportation of waste	- 0.03	- 0.01
Transportation of materials	↔	Onsite activities	0.21	0.05
Transportation of equipment and machineries	↔	Transportation of waste	2.03	0.53
Transportation of equipment and machineries	↔	Onsite activities	1.67	0.41
Transportation of waste	↔	Onsite activities	3.04	0.97

Table 2 shows the relationship between the exogenous variables in the study. C.R values which are out of ± 1.96 range (building material production – transportation of waste: CR=2.96; building materials – onsite activities: CR = 2.92; transportation of equipment and machineries – transportation of waste: CR=2.03; transportation of waste- onsite Activities: CR= 3.04) shows significant correlations between the variables. It means these variables are affecting each other.

RESULTS AND DISCUSSION

To discover the causes driving carbon emissions during building construction, a thorough investigation of the various stages from cradle to service was conducted utilising a process-based approach. According to the LISREL study results, the suggested regression model is acceptable for predicting carbon emissions from building construction. This is owing to the fact that all exogenous factors, such as emissions from construction material manufacturing, waste transportation, worksite operations, transportation of equipment and machinery, and trash transportation, significantly contribute to CO₂e emissions. And while reviewing various stages of building life cycle it was found that the material production stage

(embodied carbon in materials) is the major contributor of carbon emissions having lowest standard error (SE) value(=0.033). The transportation of waste has the highest value of SE, 3.490 which has the weakest ability to predict the carbon emission. Also the path relation network analysis shows that the building material production has the highest correlation and is the most significant contributor to carbon emission ($\beta = 0.88$).

CONCLUSION

From the literature reviews, various factors causing carbon emissions during a building construction were identified. The method used for the carbon equivalent is specified to the boundary condition of cradle to service. The result has highlighted the fact that carbon emission related to building construction is determined by evaluating building material production, transportation of waste, onsite activities, transportation of equipment and machineries and, transportation of waste using process based approach.

Path diagram analyses on variables contributing carbon emission during building construction were performed. The analysis shows that, the most significant contributor towards the carbon emission is embodied emission by building materials,

it greatly influence the total carbon emission from building construction ($S.E = 0.88$). It can act as a reference to decision maker for reducing the carbon emission. It also implies that the running of construction machines is a significant source of carbon emissions from on-site activities. During the construction phase of a building, materials and construction activities are two significant sources of carbon emissions.

Steel, cement, and bricks are used in significant quantities during building, which has a negative influence on the environment. Proper planning, management, and usage of machinery and equipment may minimise energy consumption, and hence carbon emissions, during building construction.

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