International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Developing a Strategic Model to Improve the Reuse of Construction Material by Integrating CBM and BIM

Vishnu vardan .M, Raj prasad J

Abstract - Circular Business Models (CBMs) are an evolving concept in the construction industry. These models help organizations in reducing the wastage of materials, increasing the judicious usage of raw materials, maintaining material productivity over the lifecycle and enhancing overall sustainable productivity in construction projects. The aim of the present work is studying the current status of implementation of BIM tools in building demolition projects in construction industries in the Chennai Region, Tamil Nadu. The present work assessed the employees' awareness of BIM and LCA, their attitude towards and support for BIM adoption, perceived performance improvement because of BIM and barriers in the implementation of BIM across the selected construction demolition projects. In addition, the study proposes a framework for integrating tools like BIM and LCA in construction demolition projects. The results show that the level of awareness and extent of implementation of BIM has been mediocre. The proposed framework that integrates BIM and LCA using CBM approach could drastically reduce wastages and enhances productivity in construction projects.

Keywords: Barriers in BIM, Awareness in BIM, Life cycle assessment

I. INTRODUCTION

In developing countries like India construction demolition waste is becoming a form of pollution which threatens earth by the emission of Carbon Dioxide. Construction materials are largely consumed but are not properly used till its end of life. Many large and small demolition companies aren't aware about reusing or recycling building materials that is demolished. There is no legalized waste management technique for demolished materials in India. Due to this landfill space increases and carbon is emitted which threatens the earth.

The integration of CBM and BIM helps in reusing demolition waste which produces lesser co_2 emission. As far as seen the implementation of BIM is used only in the planning and execution phase only 10% where the BIM is used by construction companies in demolition sector because its costly and due to lack of its awareness. It is a need to give attention to the end of life of building in terms of waste generation because research shows that deconstruction work account for over 40% of the total Construction and Demolition Waste output of the construction industry.

Deconstruction design is not just about the recovery of building components at the deconstruction phase but to make building materials easily reusable. Despite efforts in avoiding demolition waste through deconstruction, there has not been a progressive increase in the level of DD. Evidence shows that DD is still far from reaching its waste minimization potentials since less than 1% of existing buildings are fully demountable. In CBM, a principle called Produce, use, reuse is implemented where a product is used till its end of life period. In CBM the product is designed to be used till its end of life and not to think how to reuse it after the demolition is done. CBM can't be just implemented into the construction industry as it involves lot of departments and interest to change a product from design stage that can be reused. CBM is a sustainable development strategy that aims at improving the efficiency of materials and energy usage. This is because reuse of materials requires minimum energy usage as compared to that of material recycling. Based on this building deconstruction is becoming more preferred over demolition because of its economic and environmental benefits. Therefore, to achieve full efficiency, the Life Cycle Assessment (LCA) of the building materials is done which keeps record of the materials consumed and their carbon emission. The individual performance profile of building components will provide an idea about the overall performance of the building over a given time. This approach will therefore be useful at the design stage to identify the type sand volume of recoverable materials that are reusable and recyclable.

II. METHODOLOGY

Life Cycle Assessment is done based on Cradle to Gate concept which helps in assessment of building materials from its Production to end of life usage. The literature study was done for getting an understanding about the Circular Business Model. The data of materials was gathered by carrying out site visits. The data of materials used is integrated with the Circular Business Model (CBM). The data of the materials used will be integrated with Revit, a Building Information Modeling (BIM) software. The results are gathered and presented.

Revised Manuscript Received on 30 May 2019.
***** Correspondence Author
Vishnu vardan.M*, Department of civil engineering, SRM Institute of Science and Technology, Chennai, India.
Raj prasad J, Department of civil engineering, SRM Institute of Science and Technology, Chennai, India.

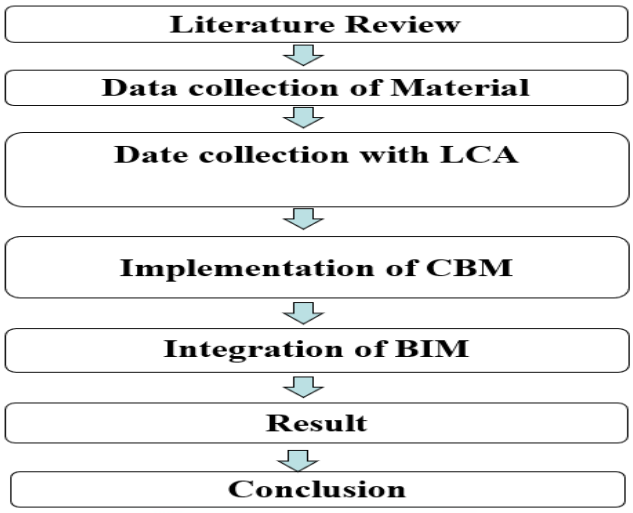


Fig 1: Methodology

III. LCA ON BUILDING MATERIALS

LCA is done to analyze the carbon emission from the building materials. The construction materials are the main part of many infrastructure projects which tends to have large environmental impact. The environmental impact done by the building materials is accounted to 60-75% of the total volume of CO2 produced. The building Life span is also considered for the LCA process in which the end of the life part is clearly analyzed.

The life cycle assessment consists of three main steps, first step is to define the scope of the work, second step is about the material analysis and operational factor, third factor is about the environmental impact factor analysis based on the different materials and their characteristics. The impact factor assessment is done based on the cradle to grave method which in analyzing the materials from is start to end of its life span.

For the purpose of LCA site selection is based on the demolition point view. The LCA was conducted in Chennai region with six demolition sites respectively.

- **Valasaravakkam site**
- **Chrompet site**
- **Madipakkam site**
- **L and T construction**
- **Nandhambakkam site**
- **Mountroad site**

From this site the material details where collected and based upon that LCA is done with following calculations.

Fig .2: Building demolition

A. Carbon emission calculation:

For calculation of carbon emission through the building materials quantity of each material required in construction process is calculated. After calculating quantity of material, the weight of that material in Kg is multiplied by its density. Thus, total embodied carbon emission is obtained by using carbon emission formulae.

a. Carbon Emission factors for Selected materials:

Carbon emission factor for concrete = 0.16Kg.
Carbon emission factor for wood =0.46Kg
Carbon emission factor for glass =0.85Kg
Carbon emission factor for bricks is = 0.22Kg
Carbon emission factor for steel is = 1.77Kg

b. Density for Selected materials:

Density of concrete is 2400 Kg/m3
Density of wood is 103 kg/m3
Density of glass is 2531 kg/m3
Density of bricks is 2000 kg/m3

Table .1: LCA on Building Materials

Material	Co2 emission (Kg)
Concrete	31488
Steel	1478060.165
Bricks	73.029
Glass	98.6
Timber	98.07

The graph indicates that the concrete and steel emit more amount of carbon into the environment. Where the bricks, glass and timber emit less carbon in environment.

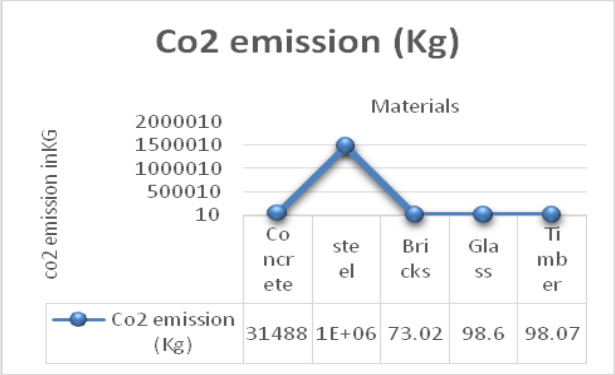


Fig. 3: Co2 emission of building materials

IV.CBM IN BUILDING MATERIALS

In recent years the linear economy's value is reduced due to the increase in landfill which creates lots of environmental impact. The linear economy approach for Produce-use-dispose can no longer be sustainable so the consumers and stakeholders are shifting to new business models. So, the Circular business model has been taken into consideration and has gained lot of attention. The circular economy approach for the produce-use-reuse and recycle. Which helps in less environmental impact and less carbon emission. The circular economy gives more feasibility to the retail business and the stakeholders.

Based upon the LCA the implementation of the Circular business can be done by three ways
1. Repair point
2. Online market
3. Recycling plant

V. BIM IN BUILDING DEMOLITION

BIM in building demolition is a emerging concept that is adopted in large demolition works. As far as Indian construction demolition work is concerned the building demolishers are not quite aware of these new adoptions of BIM. A case study was conducted in Tamil Nadu, Chennai region on the BIM in building demolition considering five important factors. Each factor consists of different set of questionnaires and data analysis is done based on these factors.
The factors are as follows:
a. Awareness on BIM process
b. Attitude towards BIM in Construction Demolition Projects
c. BIM Adoption and Support in Construction Demolition Projects
d. Performance Improvement
e. Barriers in the implementation of BIM?

VI. DATA ANALYSIS FOR BIM

The analysis of results of the data collected from the selected (150) employees of the construction industry in Chennai region, Tamil Nadu. The data is organized into four sections, the first section provides the frequency and percentage analysis of the demographic variables of the study which includes gender, age, qualification and profession. The second section discuss about the descriptive statistical analyses in which statistical methods like minimum statistic, maximum statistic, mean, standard deviation, skewness and kurtosis were used to analyze the data from the respondents of the study. Reliability analysis is also included in the second section. The third section focus on the inferential statistics which includes hypothesis testing using statistical techniques like Independent Sample t-test, one-way ANOVA and Correlation analysis is presented. The final section describes the confirmatory factor analysis using structural equation model (SEM). Statistical Package for Social Sciences (SPSS) Software Version 21.0 was used for data analysis. The SEM modelling was carried out using AMOS 21.0 software.

A. Descriptive statistics

The descriptive statistics for the data collected from the employees of the study is shown. The descriptive statistics considered in the study are Minimum Statistic, Maximum Statistic, Mean, Std. Deviation, Skewness and Kurtosis.
It is very clear that, Attitude towards BIM was the top -rated variable with mean value of 4.34, followed by Awareness on BIM with mean value of 4.33BIM Adoption and Support was the third rated factor with mean rating of 4.04. The Performance Improvement received a mean rating of 3.93.Skewness and Kurtosis for all the variables are within prescribed limits of between (+2 to -2) indicating that the data is normal and appropriate for further statistical analysis.

Table 2: Descriptive Statistics

Factors	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Performance Improvement	3	5	3.93	0.498	0.755	0.583
BIM Adoption and Support	3.2	5	4.04	0.368	0.852	1.67
Attitude towards BIM	3.8	5	4.34	0.392	0.587	-0.932
Awareness	3.4	5	4.33	0.448	0.198	-0.796
Barrier to the Implementation of BIM	3	5	3.88	0.606	0.959	-0.409

B. Reliability statistics

The reliability of the survey instrument was measured using coefficient of reliability namely "Cronbach's Alpha'. The value of Cronbach's Alpha ranges from zero to one. The greater the value of Cronbach's alpha, the better will be the reliability of the survey instrument (Nunnally 1975). In general, value of Cronbach Alpha above 0.7 suggests that the reliability of the questionnaire is good. It is evident that all the items used for measuring the variables have higher Cronbach's alpha value exceeding the threshold limit of 0.7. Hence, can be confirmed that the survey instrument used in the present study is reliable and can be applied among the sample of respondents of the study for data collection.

Table 3: Reality statistics

Factors	No. of Items	Cronbach's Alpha
Performance Improvement	5	.862
BIM Adoption and Support	5	.719
Attitude towards BIM	5	.716
Awareness	5	.733
Barriers for Implementation of BIM	13	.844

A. Confirmatory Factor Analysis (CFA) MODEL

The Structural Equation Modelling (SEM) was used to develop confirmatory factor analysis (CFA) model with BIM factors like Performance Improvement, BIM Adoption and Support, Attitude towards BIM and Awareness.
Regression Weights of the SEM Model is presented

Table 4: Confirmatory Factor Analysis Model

Observed Variable		Latent Variable	Standardized Estimate	Unstandardized Estimate	S.E.	C.R.	P
Awareness	<---	BIM Factors	0.475	1			
Attitude towards BIM	<---	BIM Factors	0.84	1.547	0.299	5.173	***
BIM Adoption and Support	<---	BIM Factors	0.547	0.932	0.207	4.506	***
Performance Improvement	<---	BIM Factors	0.749	1.734	0.335	5.177	***

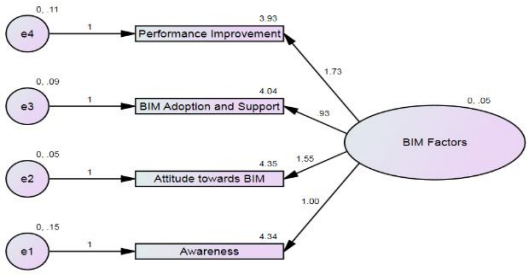


Fig. 4. Unstandardized Regression Coefficient

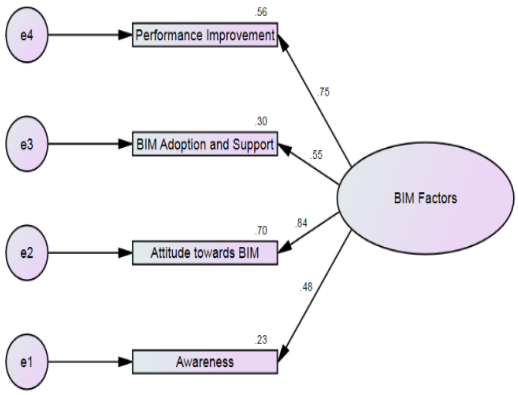


Fig. 5: Standardized Regression Coefficient

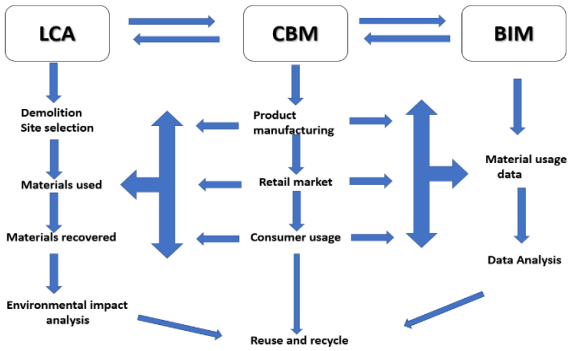
A. Model Fit Summary

The goodness of fit of the model indicates how well the models fits the set of observations. The data shows that the values obtained for the variables are conforming to the recommended values. Hence, the model can be treated as a good fit model. The values obtained for the indices are greater than the recommended value of 0.9 which shows that the model is perfectly fit.

Table 7: Goodness of FIT – AMOS Model

Variable	Recommended Value	Obtained Value
Chi-square value	-	1.619
P value	p>0.05	.445
RMSEA	< 0.09	.000
RMR	<0.08	.003
GFI	> 0.90	.995
AGFI	> 0.90	.974
CFI	> 0.90	1.000
TLI	> 0.90	1.008
RFI	> 0.90	.967
NFI	> 0.90	.989
Chisq/df	< 5.0	.810

VII.CONCLUSION



- The total embodied carbon emission due to construction material for residential building is about 1509817 kg.
- It has been seen that the major material responsible for embodied carbon emission are concrete, Steel.
- The results shows opportunities for use of sustainable material instead of conventional building material so as reduce the carbon emission.
- Attaining the circular economy is done by three different ways i.e..(Repair point, second hand shop, Online market) which helps in the reuse of material very easily.
- The data analysis was done in BIM and based upon the results a strategic model has been formed for the reuse of material.

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I. AUTHORS PROFILE

Vishnu vardan. M completed my B. Tech in Bharath university and pursuing my M. Tech in SRM Institute of Science and technology.

J. Raj prasad Completed D.C.E in Swamy Abedananda Polytechnic, 2001, B.E in civil engineering in Vellore Institute of Technology, University of Madras, 2004 and M.Tech in SRM Institute of Science and Technology ,2006.