Life-Cycle Assessment

Individual Project Assignment #2

Life-Cycle Analysis and Multi-Criteria Decision Making

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Table of Context

1 Introduction

The building sector has substantial impact on environment. With the extensive use of construction materials, this industry plays a crucial role in resource consumption and environmental stress. According to Ahmed et all (2019) “The construction industry is responsible for several impacts on the site and the region where it installs a particular work. These impacts extend from the manufacture and transport of materials to the execution of a particular project, and they are of environmental, social, and even economic nature”.

2 Goal and Scope

The main goal of this work is to observe the energy use and carbon emissions of the construction of a subsystem of a concrete office building system. The substructure is chosen as column. The scope and the boundaries of the assessment are presented in the Figure 1.

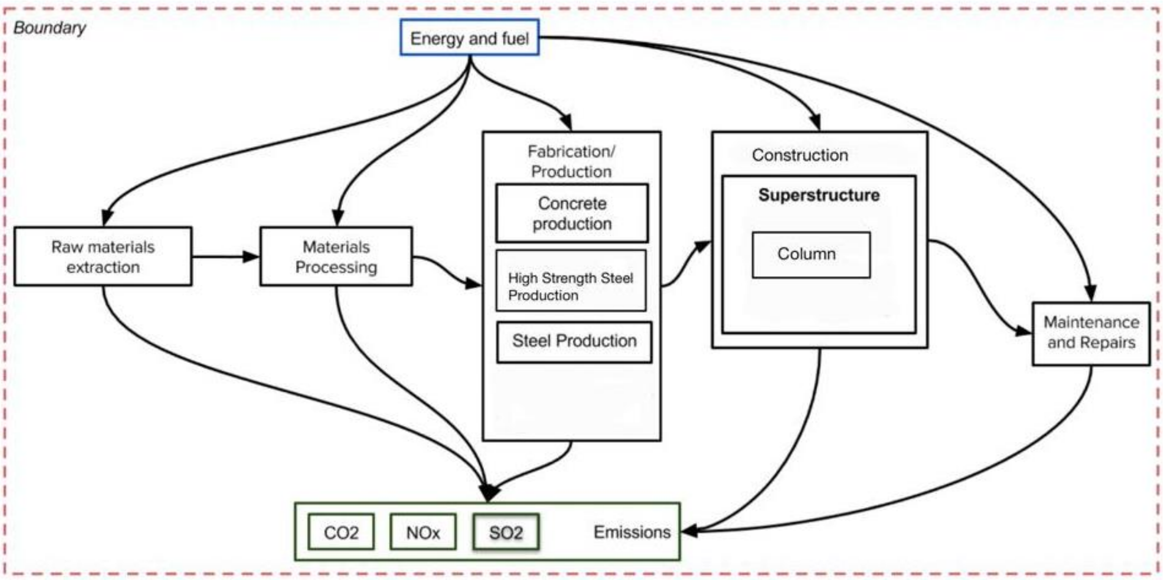

Figure 1: Scope and the boundaries of the assessment.

3 Design Alternatives

The design alternatives for a column are shown in Figure 2. Simple-supported column with a load bearing capacity of an axial force of 5000 kN and a bending moment of 100 kNm is considered for this study (Ahmed et all, 2019).

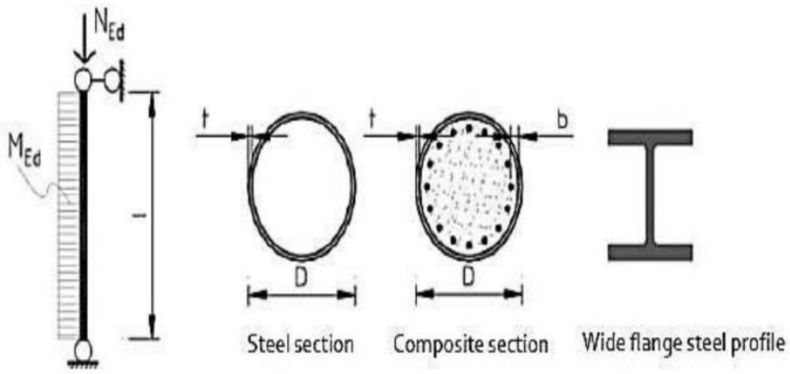

Figure 2: Design alternatives for a column.

Definitions of the design alternatives is presented in Table 1. The properties of these options also shown in the Table 2.

Table 1: Design Options

Design Options	Description
Option1	Steel
Option2	Concrete, Steel
Option3	High Strength Steel

Table 2: Properties of The Options

Element	Cross Section Area (m^2)	Material
Option1: Circular hallow section (Φ350) (CHS – 85.2 kg/m)	0.01857	Steel (S355)
Option2: Steel Profile (HD – 83.2 kg/m)	0.01184	HSS (S690)
Option3: Composite circular section (Φ350) (CHS + Rebars + Concrete 273.8 kg/m)	0.028	Steel (S355), Concrete

4 Life Cycle Inventory

Table 3 presents the composition of different materials used. Data is gathered by Ahmed et all, for each material, encompassing details on energy consumption during fabrication and processing (measured in MJ/t), as well as emissions of CO2, NOx, and SO2 (expressed in kg/m3).

The scope column displays the association with various design options. It uses different numbers to represent quantities, each carrying a distinct meaning such as CR = Circular, HSS = High Strength Steel, COM = Composite.

Table 3: Materials

Material	Scope	Quantities	RE	NRE	CO2	NOX	SO2
Steel for Rebars	COM	1	2.222	16.488	1163	1.736	1.439
Steel for Tubes	CR	1	2.577	22.005	1590	2.08	3.10
High Strength Steel	HSS	1	2.483	21.264	1454	2.437	2.642
Crashed Aggregates	COM	0.5	0.010	0.001	1.425	0.012	0.001
Cement	COM	0.17	0.183	3.875	807.500	2.003	1.003
Concrete	COM	1	7.860	0.669	63.500	0.154	0.112

4.1 Life Cycle Timeline

Initiating the life cycle analysis requires establishing the lifespan of the selected system. It is equally crucial to delineate events occurring throughout its lifetime, encompassing maintenance activities such as repairs or rebuilding. In this context, a service life of 75 years has been assumed for both the building and the column. The generated timeline for the Options are shown below in the Figures 3, 4 and 5.

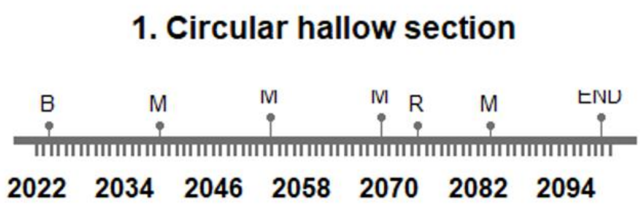

Figure 3: Timeline for Option1.

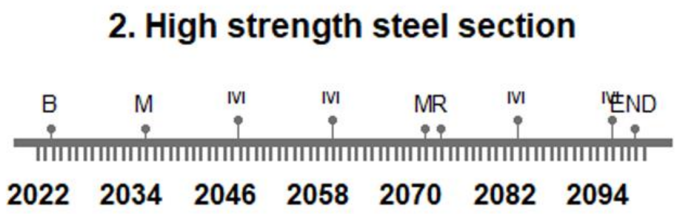

Figure 4: Timeline for Option2.

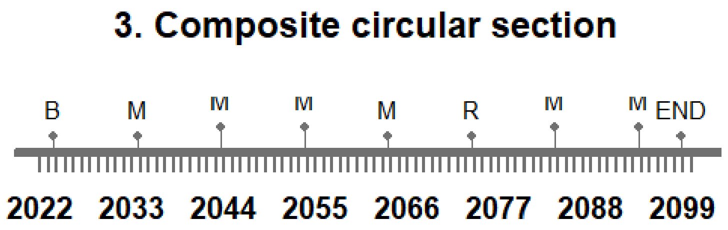

Figure 5: Timeline for Option3.

5 Life Cycle Inventory Analysis

The Life Cycle Inventory Analysis for the three options has been completed, and the corresponding results have been obtained and illustrated in the figures below.

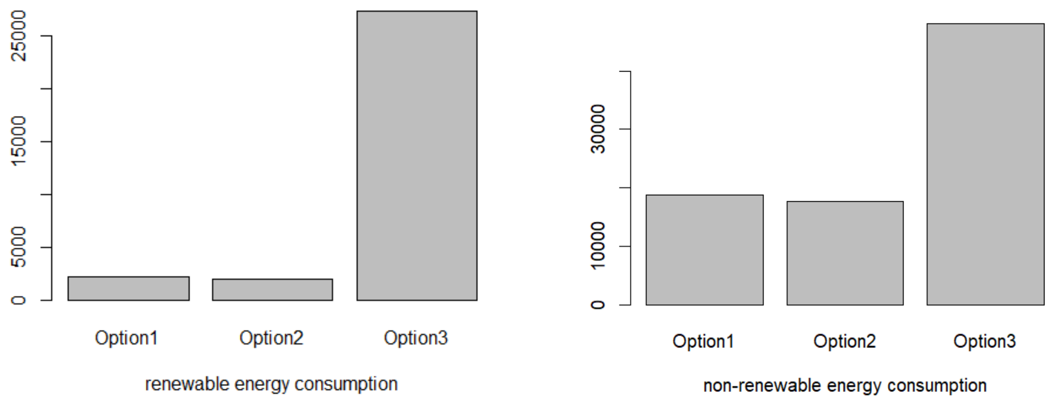

Figure 6: Energy consumption.

Observing Figure 6, we can discern the energy consumption associated with each design option. Specifically, Option 2, high strength steel section, demands the least energy for both renewable and non-renewable energy. Composite column design requires the highest amount of energy.

Figure 7 presents the CO2 emissions for each design option. High strength steel section has least emission with circular steel section following it and composite section with the highest emission. The same comments can be made for the SO2 emissions that shown in Figure 8. Figure 8 presents the NOX emissions. Circular steel section has least emission with high strength steel section following it and composite section with the highest emission.

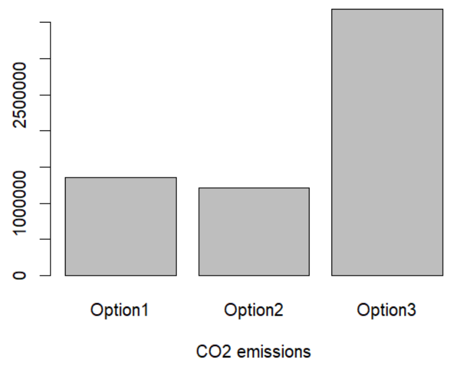

Figure 7: CO2 emissions for each design option.

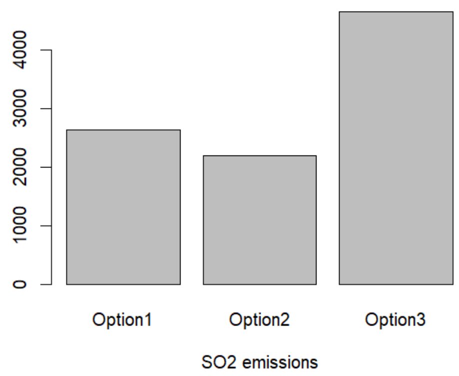

Figure 8: SO2 emissions for each design option.

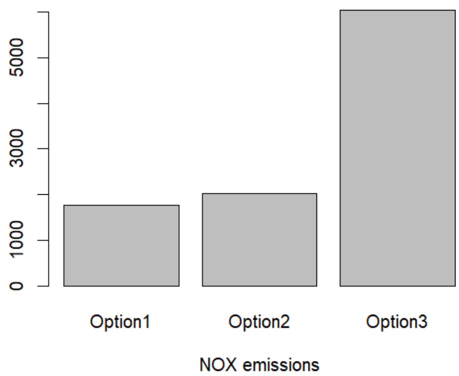

Figure 9: NOX emissions for each design option.

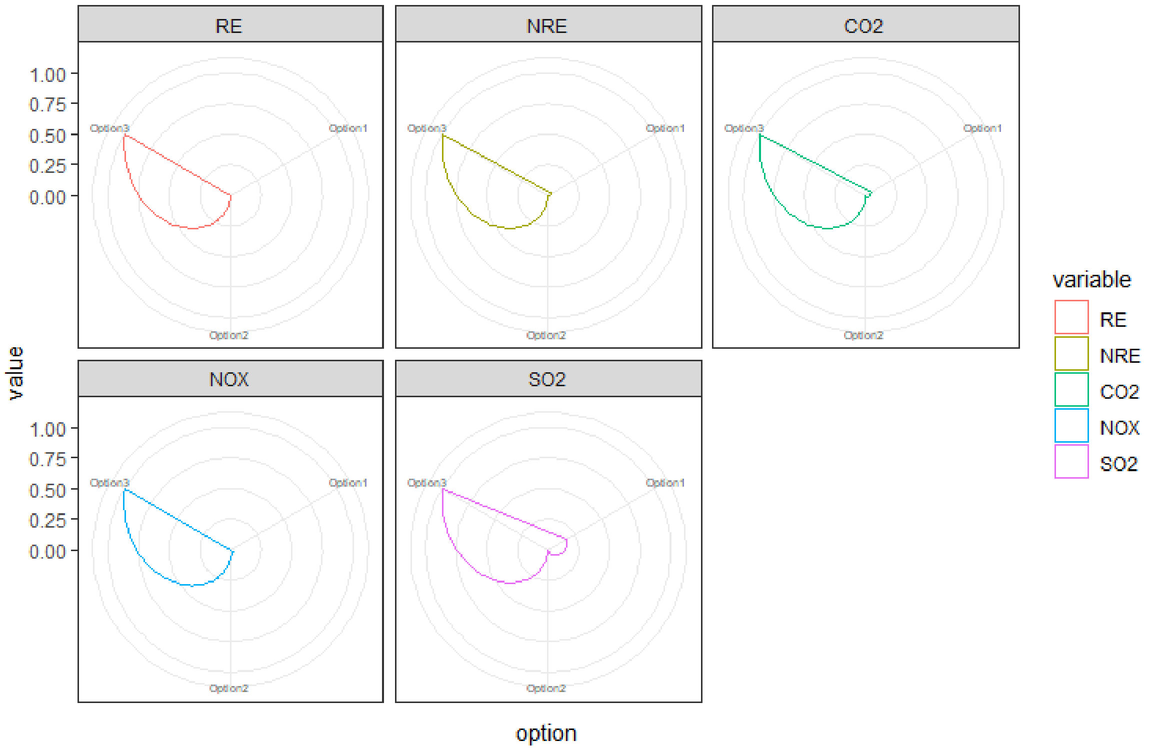

Figure 10: Radar plot for different indicators.

By looking at the figures and the radar plot (Figure 10), the Option 2 can be seen as best option.

6 MCDA

In this model, the TOPSIS method is used to analyse the system. It is a method of compensatory aggregation that compares a set of alternatives, normalising scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion (Wikipedia contributors, 2023). Defined weights for each indicator as follow:

- RE – 15%, NRE – 15%, CO2 – 35%, NOx – 15%, SO2 – 15%

For TOPSIS first method it is decided that the criteria to be minimum for all the indicators. In the second method of TOPSIS, the approach involves comparing alternatives to ideal solutions. The results of rankings are shown in Figure 11 and Figure 12.

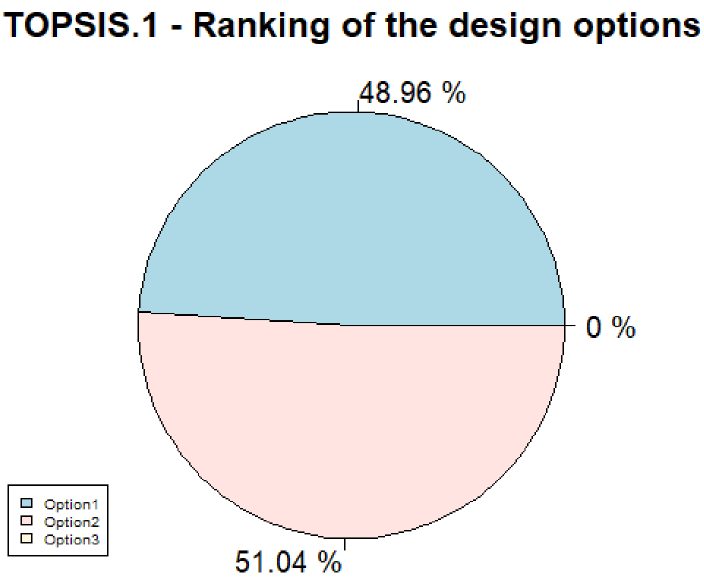

Figure 11: TOPSIS 1.

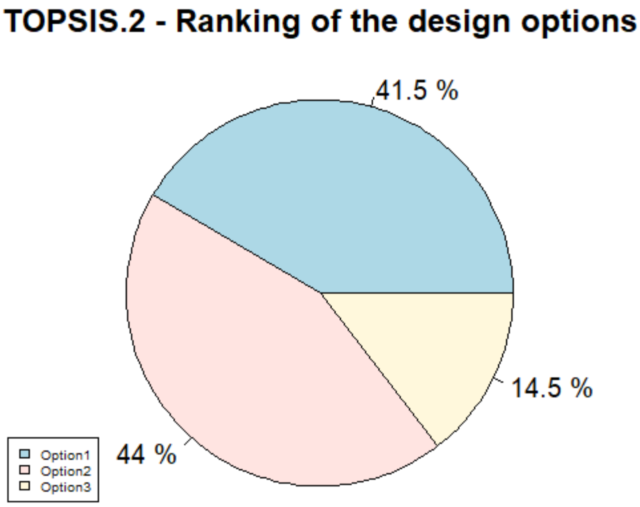

Figure 12: TOPSIS 2.

These results supporting Option 2 which is high strength steel section can be chosen as best option. Since there is no big difference between Option 1 and 2, Option 1 also can be considered but Option 3 can be seen as least desirable option.

7 REFERENCES

Ahmed, B., Rana, M. M., & Nguyen, H. T. (2019). Life cycle assessment of construction materials: Cradle-To-Gate and Cradle-To-Grave Approach. *Zenodo (CERN European Organization for Nuclear Research)*. https://doi.org/10.5281/zenodo.3379363

Wikipedia contributors. (2023, November 14). *TOPSIS*. Wikipedia. https://en.wikipedia.org/wiki/TOPSIS