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LIFE CYCLE ASSESSMENT OF SUSTAINABLE URBAN DESIGN: EVALUATING THE ENVIRONMENTAL IMPACT OF STREET AND BUILDING EXTERIOR SURFACE MATERIALS

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ABSTRACT

In this study, the environmental impacts of building exterior surface and street surface materials using the life-cycle assessment (LCA) method will be discussed. A complete understanding of these materials' ecological implications will arise from an exploration from raw extraction to the discarding phase. The materials used in this research are asphalt, ceramics, aluminum, alucobond, artificial stone, glass, and steel which have been evaluated against various factors such as electricity consumption, greenhouse gas emissions, depletion of resources, and waste production by using OpenLCA software. From a global warming perspective, glass ceramic and artificial stone contribute less compared to scenarios where steel and aluminum are used, but for the case of depletion of resources, ceramics alone hold more than a third lesser amount than all other alloys combined. This paper proposes guidelines for designers, stakeholders, and decision-makers to take appropriate actions towards sustainable urban design.

KEYWORDS

Environmental impact; Exterior surface; Street surface materials; Life Cycle Assessment; Sustainable.

1. INTRODUCTION

Life Cycle Assessment (LCA) comprises one out of several tools that are used for management purposes of environmental issues evaluation (Khasreen et al., 2009). The effects of construction materials and products on the environment are increasingly being researched using scientifically based life cycle assessment (LCA) (Means and Guggemos, 2015). The façade is an essential architectural component that minimizes energy consumption and enhances the ecological impact of a building (Balali and Valipour, 2020). When assessing the environmental effects of a structure "from cradle to grave", life cycle assessment should be applied to inform decision making (Androsevic et al., 2019). The building sector is a significant energy user, and external walls are especially exposed to the elements and human activity (Wang et al., 2005). Concrete is the most commonly used material in construction projects in Iraq, and as infrastructure development becomes more and more consumed, so will the demand for this material. Portland cement, aggregates, and water are the ingredients of concrete, which is prized for its durability and adaptability. However, a major contributor to environmental pollution is the large amounts of carbon dioxide released into the atmosphere during cement manufacture, a necessary component of concrete. Because of its detrimental effects on the environment, this conventional reliance on concrete raises questions for life and safety in addition to affecting energy use in buildings (Mohammed et al., 2018). By utilizing LCA on buildings, complete environmental impact analyses can be provided which will also promote sustainability initiatives (Talpur et al., 2023). Promoting design guidelines for circular building elements has become a key strategy in developing sustainable constructions (Stijn et al., 2020). To counteract increased greenhouse gas emissions levels and energy use in the construction sector, key structural elements such as floors, walls, roofs, and foundations have gained eco-friendliness over time. Life Cycle Assessment (LCA) was originally designed for products used by airlines and other commercial goods. When applied to construction processes, it offers significant potential for enhancing sustainability and reducing greenhouse gas emissions (Farooq et al., 2021).

LCA is increasingly being used in measuring the environmental impacts of building materials and construction techniques by many researchers. However, Means et al. emphasize that contemporary LCA methods are limited as they tend to deal with isolated life cycle stages or separate materials, hence the need for inclusive, standardized, and simple LCA tools in architecture, engineering, and construction best practices (Means and Guggemos, 2015).

1.1. literature reviews

The concept of life cycle assessment is a means to evaluate the effects that products and services have on the environment throughout their entire lifespan, starting from the extraction of raw materials to the disposal of waste (Widheden et al., 2007). According to Balali et al. (2020), buildings' smart materials are studied using Sustainable Development Goals (SDGs) as a framework for (their) suitability holistic study in Shiraz, Iran (Balali and Valipour, 2020), this aligns with the broader integration of frameworks like the SDGs and the New Urban Agenda (NUA), which are increasingly becoming embedded in the fabric of global society, influencing both formal and informal structures across various sectors (Oloto and Adebayo, 2023). Based on the above study by Balali et al. (2020), data analysis through the Analytical Hierarchy Process (AHP), and Friedman test, thermal and photovoltaic materials are found to be the best options for sustainable facades. (Balali and Valipour, 2020). Androsevic et al. (2019), on the other hand, focus on life cycle assessment (LCA) that helps in designing construction solutions that minimize waste during its life cycle. They state that the use of circular construction techniques makes prefabricated timber walls more recyclable and durable, as shown by their case study on external walls (Androsevic et al, 2019). Talpur et al. (2023) examine how LCA can be used by South Asian construction firms to create circular buildings, saying that their building practices do not adhere to principles of circularity. They point out flaws in local LCA databases and issues about required certifications (Talpur et al., 2023). Indian academic buildings were assessed by Hussain et al. (2019) using the Ecological Footprint Index and Life Cycle Assessment to examine environmental impacts. Their study offers a thorough analysis of various characteristics including resource consumption and waste generation along different life cycle stages of a building (Husain and Prakash, 2019). Pamu et al. (2022) discussed the environmental implications of using building materials in residential structures across India. They analyzed the two categories of materials using Open LCA software and concluded that sustainable materials reduce environmental pollution (Pamu, et al., 2022). Life cycle assessment (LCA) is considered a critical element in choosing and designing materials for urban sustainability. Therefore, comprehensive and localized LCA approaches are necessary. The question this study seeks to address is: what are the environmental effects of the materials employed in outdoor building construction and road surface, and what measures can be adopted to lessen these effects for the purpose of encouraging sustainable urban design? The underlying idea here indicates that divergent kinds of materials have different relations with their life cycle and environment to adopt low-energy-intensity building products will significantly help enhance cities' ecological sustainability.

1.2. Research Objectives

The main objectives of this research are: A- To evaluate how certain materials, such as asphalt, glass, artificial stone, alucobond, aluminum, steel and ceramic perform when employed in urban architecture and provide a comprehensive understanding of their impact on the environment. B- Identify the main causes of the negative effect of selected materials on the environment, according to the usage of electricity and fuel, generation of waste, depletion of resources, and emissions of greenhouse. C- Providing proposals that reduce the environmental negative effects of selected materials in urban design procedures. The sub objectives of this research are: A- Integrating life cycle assessment (LCA) into the material evaluation to increase knowledge in the field of sustainable urban design. B- Educate designers, decision-makers, and stakeholders regarding optimal methods for selecting materials that will improve the sustainability of urban areas. C- Encouraging the establishment of urban design rules to facilitate the selection and use of sustainable materials and reduce the environmental effect act of urban development.

2. LIFE CYCLE ASSESSMENT STAGES

Programming, design, construction, usage and maintenance, conversion, reuse, and deconstruction/demolition are some of the stages that make up the construction building process of buildings (Androsevic et al, 2019). Using a quantitative method, a life cycle assessment (LCA) assesses a system's overall impact on the environment while avoiding subjective beliefs such as (fossil fuels are bad) or (organic is better). It also assesses how the ecosystem is affected by the system's extraction, processing, manufacturing, distribution, transport, use, reuse, maintenance, recycling, and ultimate disposal, although LCA may be "cradle-to-gate" or "gate-to-gate", it takes into account "cradle-to-grave" implications (Harding, 2011). Life cycle assessment (LCA) is an effective tool, to assess and compare the environmental performance associated with goods or processes (Chen et al., 2024). The term demolition is defined in the dismantling stage as dismantling or dismantling with the aim, if possible, of returning all parts to the construction phase, An LCA can help in this process (Androsevic et al, 2019). Life cycle stages are: A- Production stage: extraction and supply of raw materials, transportation to the manufacturing site, and manufacturing procedures are all considered in the production stage. B- Construction stage: the products must be transported to the construction site and installed. C- Use stage: application, maintenance, repair, replacement, renovation, operational power consumption, and water usage are all included in the use stage. D- End of life: the demolition, trash transportation, recycling, and disposal phases comprise the end-of-life stage (Seyedabadi and Eicker, 2023), Fig. 1.

3. RESEARCH METHODOLOGY

The first step in this research, carry out and, analysis of the different stages of the life cycle for each finishing façade material besides street finishing surface material, the tool which was used in this research OpenLCA software. OpenLCA is an open source program for life cycle assessments and sustainability, extremely thorough explanations of the computation and analysis results; highlighting key factors at each stage of the process, by flow or impact category; displaying the results, and putting them on a chart (OpenLCA). Fig. 2 explains the methodology of the research, first of all, make a project to compare LCA for each material by: A- Import the database from OpenLCA nexus. B- Create processes for each life cycle stage for each material such as production, construction, use phase and end of life stage. C- Set the location of our project. D- Insert input and output data (which obtained them from (Ecoinvent), for each stage for each material with their unit and choose the flow for each data then connect the process together by using ecoinvent 2.2 LCIA method which imported from OpenLCA (Nexus) site to generate product system for each material, which add them to our project to compare between them. E- Analysis of the results for each LCA for each material. F- Export the data to Microsoft Excel to reach the result of the study.

In this study, we will use ReCipe and TRACI methods from eccoinvent LCIA method, which both of which are suitable for covering Acidification, climate change, and depletion of resources, beside ReCipe could cover resources, fossil and ozone depletion, and also climate change, energy use, and land use (OpenLCA manual). The life cycle evaluation is influenced by various environmental factors such as energy consumption, emissions, waste generation, and others at each stage.

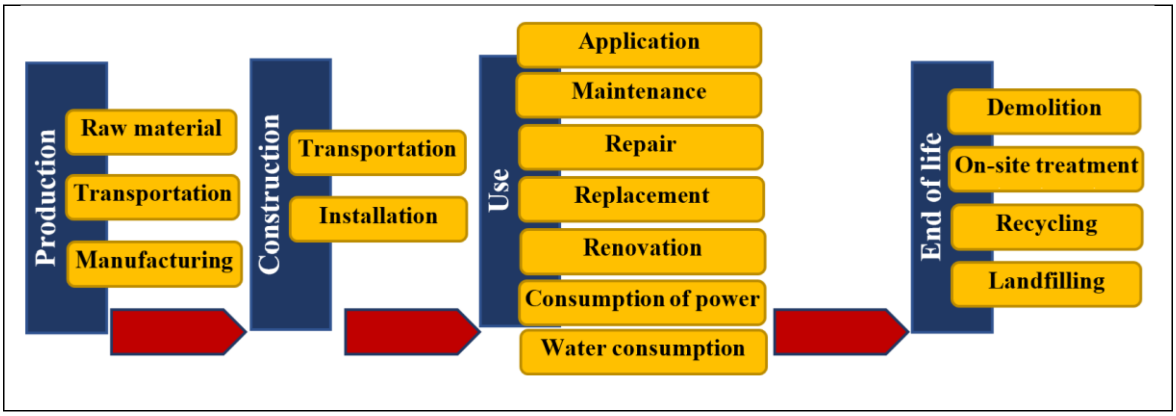

Fig. 1. Life Cycle Assessment stages. (Researchers).

4. CASE STUDIES DESCRIPTION

The scope of the research is educational buildings at the University of Mosul in Iraq because there is a very large diversity in the building materials used in the building materials used in the different buildings on the university campus, because they were built in several stages from the founding of the university until now, the university of Mosul includes twenty-four colleges each college includes many departments, in this study the researcher chose some buildings from these colleges, Fig. 3, Fig. 4, because their facades have different finishing materials and they were built in different time periods to study their impact on the environment and thus in sustainable urban design, Table 1 explain materials used in finishing exterior facade.

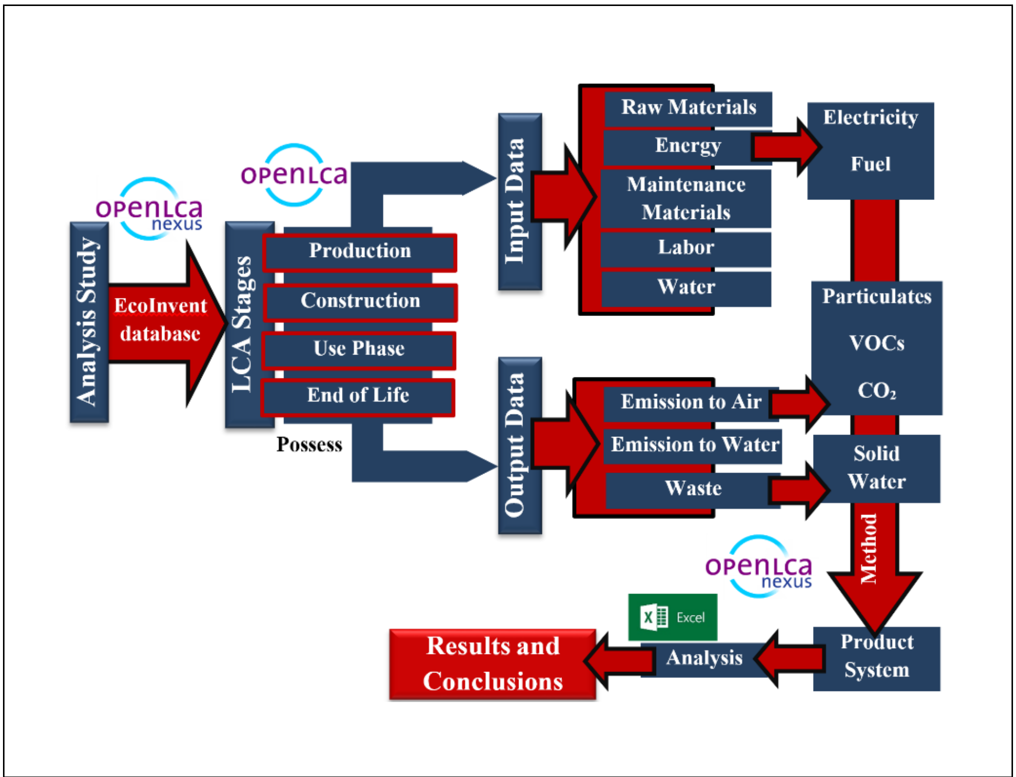

Fig. 2. Methodology of the research. (Researchers)

No.	Color	College Name
١		Pharmacy
٢		Dentistry
٣		Engineering
٤		Computer Science and Mathematics
٥		Education for Pure Science
٦		Environmental Science
٧		Islamic Science
٨		Administration and Economics
٩		Arts
١٠		Education for Girls

Map Key | University of Mosul Boundary

Fig. 3. Selected colleges and their location inside University of Mosul. (Researchers)


1


2


3


4


5


6


7


8


9


10

1- College of Pharmacy
2- College of Dentistry
3- College of Engineering
4- College of Computer Science and Mathematics
5- College of Education for Pure Science
6- College of Environmental Science
7- College of Islamic Science
8- College of Administration and Economics
9- College of Arts
10- College of Education for Girls

Fig. 4. Selected college buildings from the University of Mosul. (Researchers)

Table 1. Building Exterior Surface Materials. (Researchers)

No.	College Name	Material					
		Artificial Stone	Cladding-Alucobond	Ceramic	Aluminium	Steel	Glass
1	Pharmacy	■		■		■	■
2	Dentistry	■		■		■	
3	Engineering	■		■		■	■
4	Computer Science and Math.	■			■	■	■
5	Education for Pure Science	■			■		■
6	Environmental Science		■			■	■
7	Islamic Science	■		■	■	■	■
8	Administration and Eco.	■			■		■
9	Arts	■	■		■	■	■
10	Education for Girls	■	■		■	■	■

5. EXPERIMENTAL STUDY

The buildings sample selected for the study consist of two to four floors, and to study the life cycle of both the street finishing material and the exterior facade finishing material, it will be assumed that 1000 square meters of each material are used, and the building's expected lifespan is fifty years. Fig. 5-a, Fig. 5-b shows the different data for all stages of LCA for street surface which was asphalt and all surface exterior façade materials as collected from references Ecoinvent (Ecoinvent).

		Ceramic		Artificial stone		Glass	
Production Stage	Input	Clay	1500 kg	Cement	4000 kg	Silica Sand	25000 kg
		Additives	300 kg	Aggregates	18000 kg	Soda ash	5000 kg
				Additives	100 kg	Limestone	1000 kg
				Pigments	200 kg	Dolomite	500 kg
		Truck transport	100 km			Other additives	300 kg
		Electricity	2000 kWh	Electricity	5000 kWh	Electricity	3000 kWh
		Water	3000 liters	Water	2000 liters	Water	3000 liters
		Natural Gas	5000 m³	Natural Gas	5000 m³	Natural gas	675 m³
	Output	Ceramic Tiles	1000 m²	Artificial Stone	1000 m²	Glass product	1000 m²
		CO_2	5000 kg	CO_2	10000 kg	CO_2	9000 kg
		NO_x	10 kg	NO_x	20 kg	NO_x	4.5 kg
		SO_2	5 kg	SO_2	20 kg	SO_2	3 kg
				Particulate Matter	10 kg	Particulate Matter	1000 kg
		Waste	200 kg	Waste	500 kg	Waste	550 kg
						Suspended solids	50 kg
						Heavy metals	5 kg
Construction Stage	Input	Ceramic Tiles	1000 m²	Mortar	2000 kg	Adhesives	100 kg
		Fuel (Diesel)	100 liters	Fuel (Diesel)	2000 liters	Fuel (Diesel)	600 liters
		Electricity	50 kWh	Electricity	1000 kWh	Electricity	5000 kWh
		Grout	50 kg	Water	500 liters	Sealants	200 kg
		Labor	100 hours	Artificial stone	1000 m²		
		Adhesives	100 kg	Adhesives	500 kg		
	Output	Installed Tiles	1000 m²	Installed Stone	1000 m²		
		CO_2	250 kg	CO_2	1000 kg	CO_2	1926 kg
				NOx	100 kg	NOx	7.2 kg
				SOx	100 kg		
				VOCs Volatile organic compounds	2 kg	Installed glass	1000 m²
		Waste	10 kg	Waste	300 kg	Waste	2000 kg
				Packaging materials	200 kg	SOx	1.4 kg
				Excess mortar and adhesives	100 kg	Offcuts	50 kg
Use Phase Stage	Input	Cleaning agents	2500 liters	cleaning agents, sealants	5000 liters	Cleaning agents	2500 liters
		Electricity	500 kWh	Electricity	500 kWh	Electricity	100000 kWh
		Water	5000	Water	1000 liters	Water	500000 liters
	Out-put	CO_2	50 kg			CO_2	100 kg
		Waste	250 kg	Waste	2500	Used cleaning materials	500 kg
						Repair debris	250 kg
End of Life Stage	Input	Fuel (Diesel)	200 liters			Transportation of waste	50 km
		Electricity	100 kWh	Electricity	2000 kWh	Electricity	5000
				Fuel (Diesel)	2000 liters	Fuel (Diesel)	500 liters
				Recycled materials	2000 kg	Recycled Glass	800 m²
	Output	CO_2	250 kg	CO_2	1000 kg	CO_2	1926 kg
		Waste	1000 kg	Broken stone and mortar	8000 kg	Waste to Landfill	200 m²
				Dust	50 kg	NOx	7.2 kg
				NOx	50 kg	SOx	1.4 kg
				SOx	50 kg		

Fig. 5-a. Data for LCA stages of 1000 m² for Ceramic, Artificial stone, and Glass used for finishing building façades (Researchers).

		Asphalt		Steel		Aluminum		Cladding- Alucobond	
Production Stage	Input	Bitumen	50000 kg	Steel	8000 kg	Aluminum Ingot	5400 kg	Aluminum sheets	12000 kg
		Aggregates	950000 kg	Lubricants, refractory materials	160 kg	Alloying elements	500 kg	Polyethylene core	4000 kg
						Coatings hypothetical	500 kg	Adhesives and coatings	1000 kg
		Electricity	15000 kWh	Electricity	20000 kWh	Electricity	60000 kWh	Electricity	25000 kWh
		Water	10000 liters	Water	40000 liters	Water	20000 liters	Water	20000 liters
		Fuel (Diesel)	10000 liters	Natural Gas	2400 m^3			Natural gas	3000 m^3
	Output			Scrap metal	400 kg	Aluminum Frames	5400 kg	Alucobond Panels	1000 m^2
		CO_2	65000 kg	CO_2	17600 kg	CO_2	27000 kg	CO_2	100000 kg
		NO_x	500 kg	NO_x	160 kg	NO_x	200 kg	NOx	15 kg
		SO_2	100 kg	SO_2	120 kg	SOx	100 kg	SOx	30 kg
				Wastewater	40000 liters	Waste	200 kg	Waste	600 kg
								Aluminum waste	2000 kg
		Particulate Matter	200 kg	Slag	800 kg	Particulate Matter	50 kg	Particulate Matter	50 kg
Construction Stage	Input	Asphalt mix	250000 kg	Steel frames	8000 kg	Fuel (Diesel)	500 liters	Fuel (Diesel)	500 liters
		Fuel (Diesel)	25000 liters	Fuel (Diesel)	800 liters	Electricity	3000 kWh	Electricity	2000 kWh
				Electricity	4000 kWh			Sealants	200 kg
				Fasteners	120 kg	Labor	400 hours	Labor Man-hours	500 hours
				Sealants	80 kg	Installed Window Frames	5400 kg	Installed Alucobond Panels	1000 m^2
	Out-put	Particulate Matter	250 kg	Construction debris	120 kg	CO_2	1500 kg	CO_2	1270 kg
		CO_2	80000 kg	CO_2	2400 kg	NOx	15 kg	NOx	7 kg
		NOx	600 kg	Particulates	80 kg	SOx	8 kg	SOx	0.4 kg
		SO_2	150 kg	Cleaning agents	50 kg	Waste	100 kg	Waste	500 kg
Use Phase Stage	In-Put	Maintenance materials	50000 liters	Maintenance paint	500 liters	Maintenance Materials	500 liters	Maintenance Materials	5500 liters
								Cleaning agents	25000 liters
								Water	1000000 liters
		Fuel (Diesel)	100000 liters	Electricity	100000 kWh	Electricity	50000 kWh	Electricity	Minimal
	Out-put	CO_2	100000 kg	VOCs	10 kg	CO_2	5000 kg	CO_2	25000 kg
		NOx	1000 kg	Used maintenance materials	150 kg	Waste	Minimal	Waste	25000 kg
		SOx	250 kg						
End of Life Stage	In-put	Demolition waste	250000 kg	Electricity	4000 kWh	Dismantling Energy	1500 kWh	Electricity	2000 kWh
				Fuel (Diesel)	1000 liters	Fuel (Diesel)	250 liters	Fuel (Diesel)	1000 liters
	Output	Recyclable materials	200000 kg	Scrap metal for recycling	7600 kg	Recycled Aluminum	4860 kg	Recycled Aluminum	11400 kg
				Nonrecyclable materials	400 kg			Polyethylene core disposal or recycling	2000 kg
		CO_2	60000 kg	CO_2	3000 kg	CO_2	1250 kg	CO_2	1270 kg
		Particulate Matter	200 kg	Particulates	80 kg	SOx	4 kg	Particulate Matter	10 kg
		NOx	500 kg			NOx	8 kg	NOx	5 kg
								SOx	0.2 kg
		SOx	100 kg			Waste	540 kg	Waste	1500 kg

Fig. 5-b. Data for LCA stages of 1000 m^2 for Asphalt used for finishing street surfaces, Steel, Aluminum, and Alucobond used for finishing building façades (Researchers).

After collecting the data from Ecoinvent, we make the steps which are mentioned in the methodology section to reach to LCA for each material Fig. 6-a, Fig. 6-b, then, make a project to compare the LCA for different materials by using ReCipe and TRACI methods.

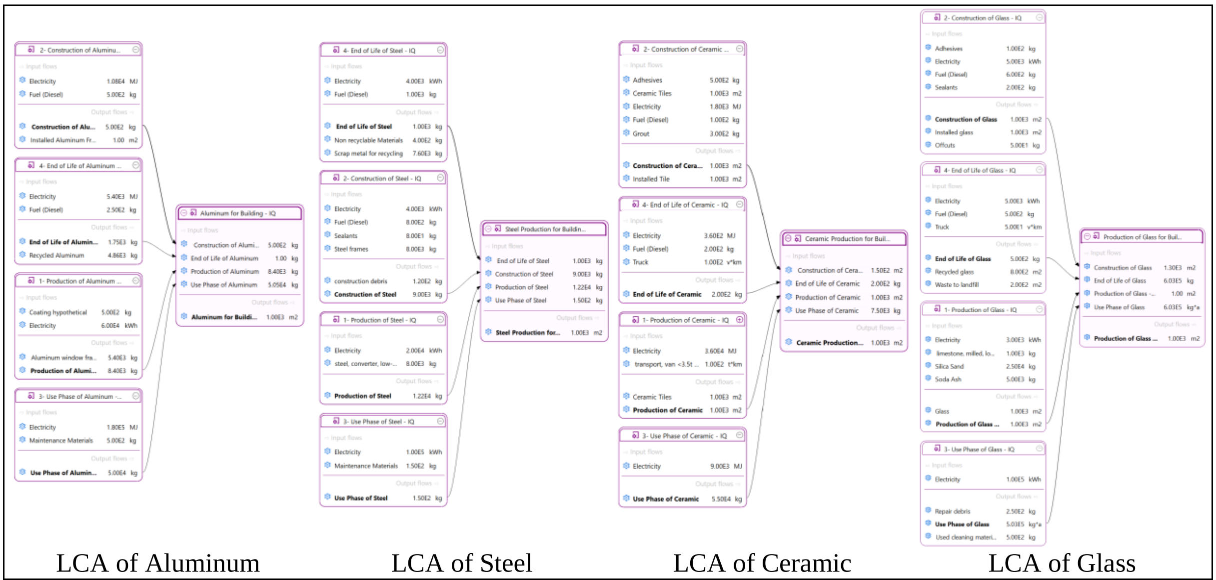

Fig. 6-a. LCA Model Graph of Aluminum, Steel, Ceramic and Glass which created in OpenLCA software.

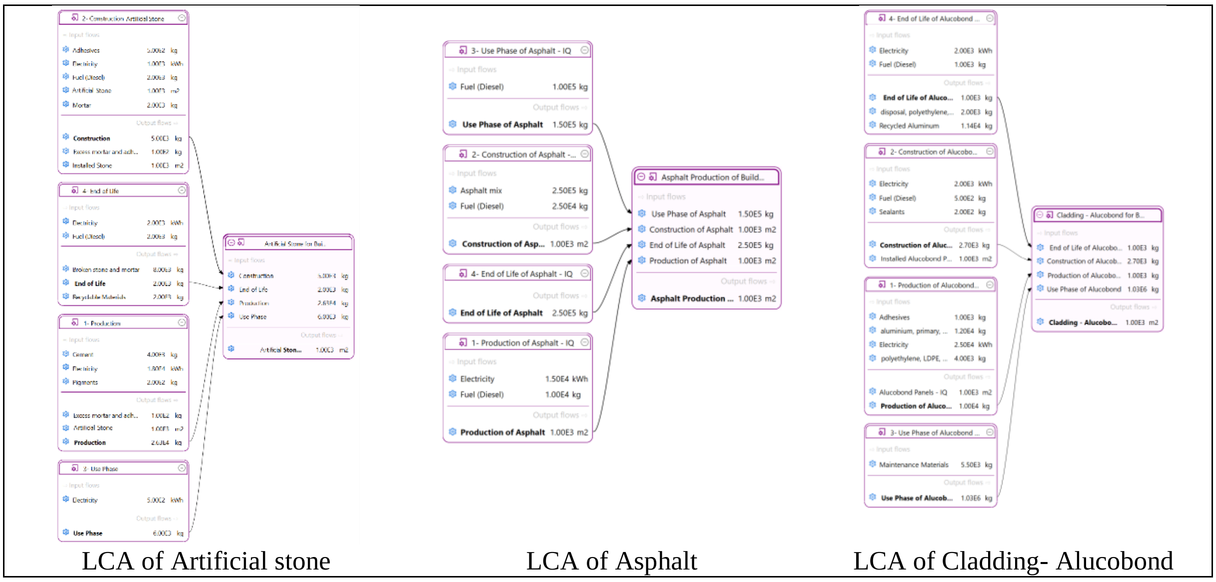

Fig. 6-b. LCA Model Graph of Artificial Stone, Asphalt, and Cladding Alucobond which created in OpenLCA software.

6. RESULTS AND DISCUSSIONS

There are many environmental impacts from using street surface material and, building façade surface external material - without taking into account the influence of neighboring buildings and the orientation of the building - such as global warming, eco toxicity, which obtain their results by using TRACI tool as a LCA method, and there are ecosystem quality impacts such as climate change, ecosystem and total ecosystem quality of street surface materials and building exterior surface materials such as Ozone depletion, which obtain their results according to ReCipe tool as LCA method.

The results show that:

A- The effect of LCA for materials on global warming are 100000, 120000, 150000, 180000, 200000, 500000, and 700000 kg for artificial stone, ceramic, glass, alucobond, asphalt, steel, and aluminum respectively which means the minimum impact when using artificial stone and the maximum impact when using aluminum Fig. 7.

B- The effect of LCA materials on ecotoxicity are 1000, 2500, 20000, 40000, 50000, 75000, and 600000 kg for asphalt, glass, ceramic, alucobond, steel, aluminum, and artificial stone respectively which mean the minimum impact when using asphalt and the maximum impact when using artificial stone, Fig. 7.

C- The metal depletion through LCA for materials are 500, 20000, 40000, 50000, 200000, 200000, and 300000 kg, for asphalt, ceramic, artificial stone, glass, alucobond, aluminum and, steel respectively which means the minimum metal depletion when using asphalt and the maximum metal depletion when using steel, Fig. 8.

D- The fossil depletion through LCA materials are 800, 3000, 4000, 5000, 6000, 9000, and 12000 kg for asphalt, glass, ceramic, artificial stone, steel, alucobond, and aluminum respectively that means the minimum fossil depletion when using asphalt and the maximum fossil depletion when using aluminum, Fig. 8.

E- The ozone depletion through LCA materials are 30, 70, 100, 100, 100, 200, and 400 kg for glass, ceramic, asphalt, aluminum, artificial stone, alucobond, and steel respectively which mean the minimum ozone depletion when using glass and the maximum ozone depletion when using steel, Fig. 8.

F- The effect of LCA for materials on climate change are 200000, 200000, 250000, 350000, 50000, 65000, and 75000 kg respectively which mean the minimum impact when using ceramic and glass and the maximum impact when using aluminum, Fig. 8.

G- Fig. 9 and Fig. 10, explain the main causes of street surface and, surface external materials' negative effects on the environment, including electricity usage, depletion of resources, greenhouse gas emissions, and waste production.

H- The electricity usage through LCA for materials with a life expectancy of 50 years are, 2650, 8500, 15000, 29000, 113000, 113000, and 128000 kWh for ceramic, artificial stone, asphalt, alucobond, glass, aluminum, and steel respectively that mean the minimum electricity usage when using ceramic and the maximum electricity usage when using steel, Fig. 9.

I- The Fuel (Diesel) usage through LCA for materials with a life expectancy of 50 years are 300, 750, 1100, 1500, 1800, 12170, and 35000 liters, for ceramic, aluminum, glass, alucobond, steel, asphalt, and artificial stone respectively that means the minimum diesel usage when using ceramic and the maximum diesel usage when using asphalt, Fig. 9.

J- The green gas emission through LCA for materials are, 5560, 12170, 12971, 23160, 34966, 127567, and 307600 kg for ceramic, artificial stone, glass, steel, aluminum, alucobond, and asphalt respectively which mean the minimum green gas emission when using ceramic and the maximum green gas emission when using asphalt, Fig. 10.

K- The total waste generation through LCA for materials are 840, 2700, 4550, 34750, 49870, and 225000 kg for aluminum, glass, alucobond, ceramic, steel, and asphalt respectively which means the minimum total waste generation when using aluminum and the maximum total waste generation when using asphalt, Fig. 10.

The results show that important of LCA in reaching to environmental impact of different buildings materials and that agree with the study of Husain and Prakash, (2019).

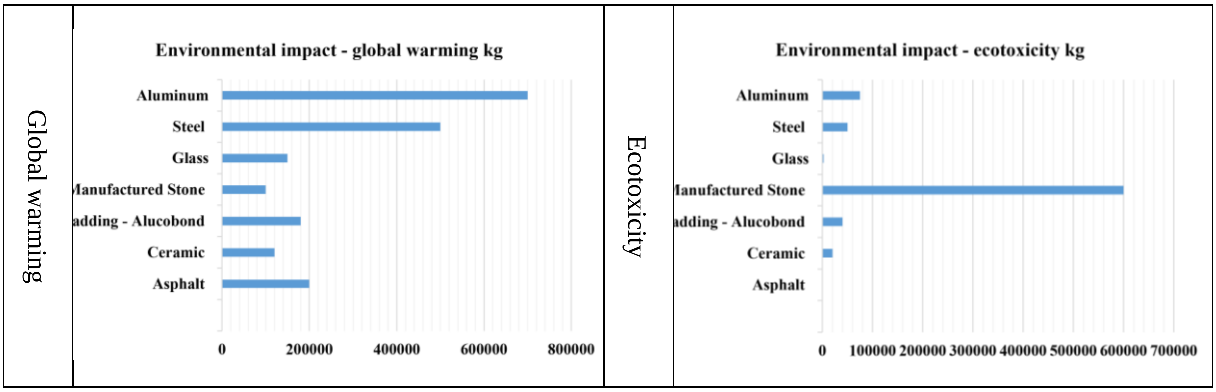

Fig. 7. Environmental impact of materials according to TRACI.

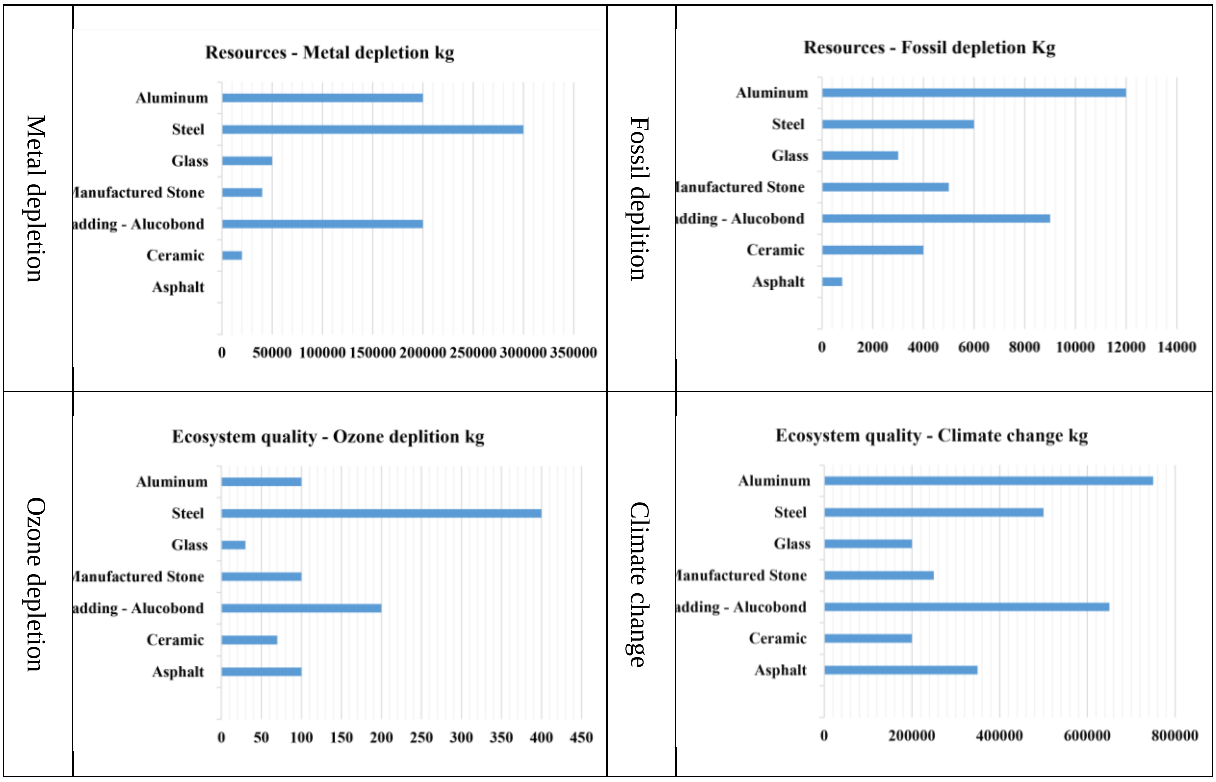

Fig. 8. Resources and ecosystem quality impact of exterior materials according to ReCipe.

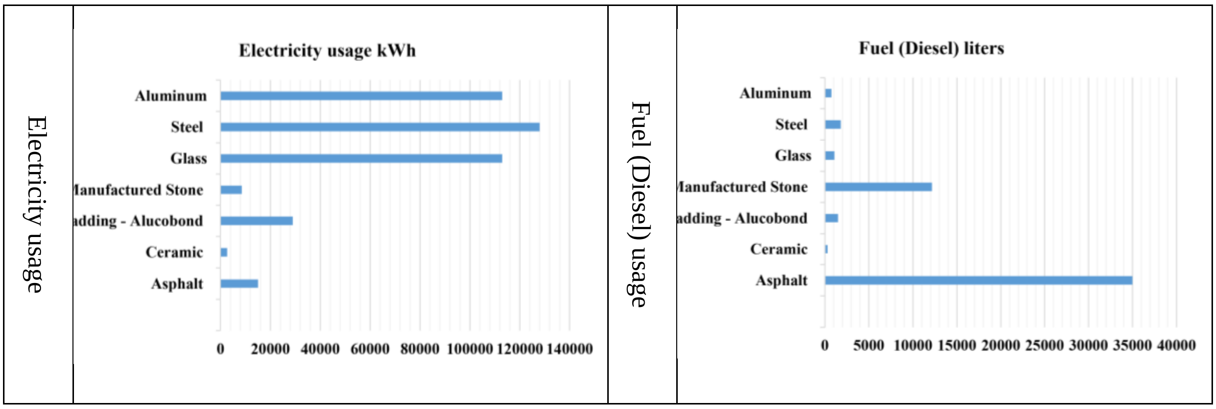

Fig. 9. Electricity usage and fuel usage.

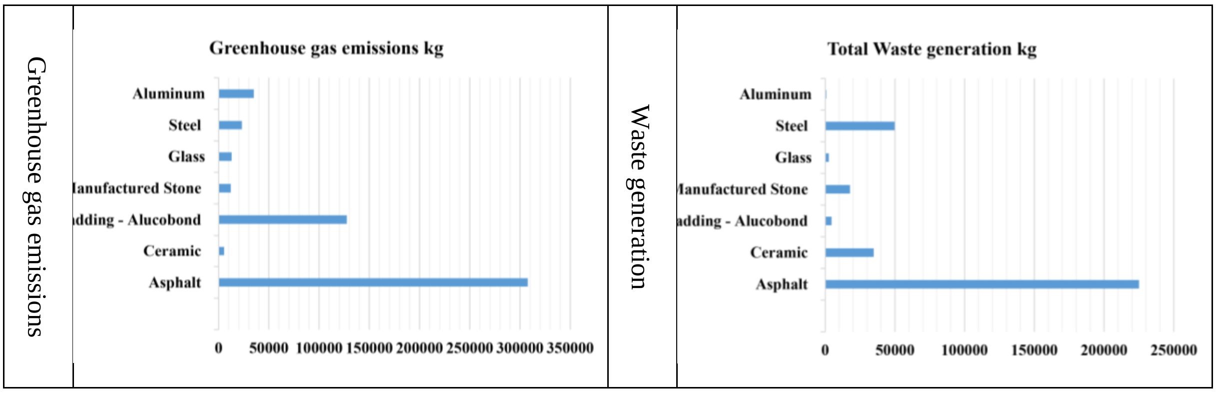

Fig. 10. Green gas emissions and total waste generation.

7. CONCLUSIONS

This research found that:

A- The environmental impact of materials according to global warming, using artificial stone, ceramic, and glass is less than half of the effect of steel and one-third of the effect of aluminum for the same quantity, thus making their use more suitable for the same quantity, while according to ecotoxicity, the glass, ceramic, steel and also the street surface material considered the least toxic materials.

B- Resources and ecosystem quality impact of exterior materials: regarding resource impact, ceramic and artificial stone consider less effect on metal and fossil depletions, and then glass, while glass has less effect on ozone depletion compared to other exterior surface and street surface materials, aluminum for windows frame comparing with steel consider the less effect on metal and ozone depletion while steel for windows frame consider the less effect on fossil depletion and climate change, ceramic and glass the less effect on ecosystem quality.

C- Electricity usage and fuel usage: ceramic, artificial stone and street surface materials consider the less usage of electricity compared with window frame material for the same quantity. Most of the exterior surface materials consider low consumption of diesel, the effects of using exterior surface materials consider very few compared with alucoboned and street surface materials.

D- Green gas emissions and total waste generation: green gas emissions from using exterior surface materials less than the emissions from street surface material. In terms of waste generation aluminum for windows frame, alucoboned, artificial stone, and glass consider the less effect compared with steel, ceramic and street surface materials.

Thus this study will provide multiple option in terms of the different impacts on the sustainable urban environment when choosing façade finishing material.

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