Journal of Materials and Environmental Science
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2020, Volume 11, Issue 10, Page 1642-1657

http://www.jmaterenvironsci.com

Environmental impacts Analysis of High-Rise Construction in Tehran

Taniya Jafary Nasab[1], Seyed Masoud Monavari[2*], Seyed Ali Jozi[3], Hamid Majedi[4]

[1,2] Department of Environmental Science, Faculty of Natural Resources and Environment, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[3] Department of Environment, Islamic Azad University, North Tehran Branch, Tehran, Iran.
[4] Department of Civil Engineering and Architecture and Art, Science and Research Branch, Islamic Azad University, Tehran, Iran.

Received 15 Jun 2020,
Revised 10 Sept 2020,
Accepted 12 Sept 2020

Keywords
- ✓ Life Cycle Assessment,
- ✓ High-rise buildings,
- ✓ Environmental impacts,
- ✓ ReCiPe,

m.monavari836@gmail.com
Phone: +2144865154;
Fax: +2144865179

Abstract
This study deals with Life Cycle Assessment (LCA) of high-rise construction, which was conducted on a case study of a residential tower in Tehran Metropolitan City, Iran. According to the ISO 14040 and ISO 14044 guidelines, the LCA was implemented in SimaPro v8.5 software using ReCiPe method. The results showed that among the four processes mentioned, the supply of consumable materials has the highest environmental impact. The analysis of the results at the midpoint showed that the largest shares of the impacts respectively belongs to global warming (38%), human carcinogenic toxicity (12%), mineral resource scarcity (10%), fossil resource scarcity (10%), land use (10%), water consumption (8%), human non-carcinogenic toxicity (7%). Other impacts account for 5% of the total midpoint impacts. At the end-point, the largest shares are related to global warming (54%) and fine particulate matter formation (16%) and fossil resource scarcity (12%) and mineral resource scarcity (10%) and water consumption (2%) and human non-carcinogenic toxicity (2%). Other impacts account for 4% of the total endpoint impacts. Among the building materials, metal mold, PVC window frame, rebar, and concrete account for the largest shares, respectively.

1. Introduction
Growing population growth, along with land constraints in cities, has increased exponentially the demand for housing in urban areas. In addition, the progressive trend of prices of capable lands for urban development has necessitated high-rise construction, especially in metropolitan cities. Construction industry is one of the most important parts of economic development in any country and has a significant impact on the environment. According to the statistics provided by United Nations Environment Program (UNEP), the construction sector is a key component of sustainable development. From a global perspective, this sector usually accounts for 5-10% of employment at the national level and between 5% and 15% of the country's gross domestic product. The construction sector has the largest share in the use of natural land and resources, as well as extraction of materials. In Europe, buildings account for 40% to 45% of annual energy consumption and close to 30% of greenhouse gas emissions. Similarly, it provides important opportunities for saving energy and reducing greenhouse gas emissions. It can also play an important role in achieving the goals of Kyoto Protocol [1]. Lower energy reserves in recent decades, on one hand, and the importance of environment and sustainable development, as well as the essential role of building materials in this regard, on the other hand, necessitate more attention on

sustainable construction and optimization of energy consumption in construction industry. In recent years, the production of building materials, construction of buildings, and production of constructional wastes have led to high rates of energy consumption and different kinds of environmental pollution. Dust emissions, due to construction activities, spread of chemical pollutants, due to production of building materials, airborne contaminants, due to transportation of building materials to the desired sites, and generation of construction wastes are major causes of environmental pollution released during the construction of buildings. Accordingly, Life Cycle Assessment (LCA) of construction projects would of utmost importance [2]. Buildings and its affiliated industries are among the most consuming and polluting industries in the world. They are also the world's largest industry after agriculture. Accordingly, any building with any functions, whether during construction or after it, or during the operation or at the time of demolition, always releases pollutants into the environment. Therefore, new strategies in building construction are required to mitigate its environmental consequences. As such, Sim et al. wrote an article on atmospheric environmental impacts of life cycle of traditional buildings in Korea using carbon footprint analysis. Their findings showed that among the building materials, concrete accounts for the main source of CO_2 emissions, while transportation is responsible for the majority of CH_4 and NO_2 emissions [3]. AL-Nassar et al presented a framework for sustainability assessment of low rise commercial buildings in Alberta (Canada) using a Life Cycle impact index. They investigated three scenarios of environmental-centric, economic-centric, and neutral by Multi Criteria Decision Making analysis (MCDM) . According to their findings, concrete-steel structures were recognized as the most sustainable alternative in neutral and economy-centric scenarios and steel–wood buildings were found to be the most sustainable alternative under the eco-centric scenario [4]. Ali et al. studied the environmental impacts of the life cycle of residential buildings in Egypt. The results revealed that the greatest environmental impact of energy use, 7.9%, is related to the operational stage [5].Jafary Nasab et al. (2019) assessed the carbon footprint for high-rise a building and showed the importance of life cycle assessment for reducing environmental impact [6]. Cuéllar-Franc et al. studied the environmental impacts of life cycle of the residential sector in UK. They investigated three most common types of residential buildings in the UK, including detached, semi-detached, and terraced structures. Their results showed that the highest environmental impacts of these buildings could be global warming potential during the use phase. According to their estimates, about 90% of the global warming potential is related to the global warming the use phase, 9% to thee construction phase and the remaining 1% to the-end-of-life waste management [7]. Llantoy et al compared life cycle assessment (LCA) of different insulation materials for buildings. Life cycle assessment a good alternative to reduce environmental impacts in the analyzed scenario [8]. Gulck et al considered Environmental and cost assessment for façade renovations. This study shows using by life cycle assessment can choose the best materials based impact environmentally [9]. Hossain et al. studied the environmental impacts of the life cycle of the building based on an analytical review. This study proposed the framework can help support a sample shift to extensive research for increasing the accuracy of sustainability performance to the building industry [10]. Ghose et al. studied the environmental impacts of the life cycle of the office buildings sector in New Zealand. The impacts of the building were computed for non- refurbishing buildings;refurbishing buildings; refurbishing buildings with accepting resource and waste management and; refurbishing buildings with installing with solar panels. The results show that the Use of solar panels substantially increases the resource demand for refurbished buildings [11]. Life Cycle Assessment (LCA) is applied to execute a comprehensive environmental assessment of a building. The studies including LCA for buildings [12, 13,14]. Dong et al. was assessed Life Cycle Assessment of the life of Energy Performance of Reinforced Concrete and Timber buildings in China. Their results showed that the energy-saving potential afforded by timber stadiums is lower than of Reinforced Concrete Buildings [15]. Alshamrani et al. developed an integrated LCA-LEED model to assess sustainability of structure and envelope systems of school buildings in Canada. They investigated different types of envelope and structures, such as concrete and steel. Their results indicated that concrete and masonry structures have the highest energy consumption. They also concluded that these types of structures have the highest global warming potential during particular stages of their life cycle, including production, construction, and demolition. They gave the highest total LEED score of 19 to the concrete structures with minimum insulation and the second highest score of 17 to the masonry structures, while they allocated the lowest score of 14 to steel and steel-masonry buildings[16]. Heinonen et al. assessed the environmental impacts of the life cycle of multi-story residential buildings in Finland during the pre-use phase. They intended to investigate whether or not greenhouse gas emissions could be used as a general environmental indicator. The focus of this paper is mainly on comparing the accumulation of different environmental effects compared to the greenhouse gas emissions. Their results showed that eight types of impacts, including ozone, acidification degradation, eutrophication, photochemical oxide formation, suspended particles, ionization, fuel consumption, consumption of water resources have a strong correlation with greenhouse gas emissions [17]. Hong Dong et al. developed a model for assessing the environmental impacts of life cycle of building construction in Hong Kong. Their findings revealed that the carbon emission from a public rental housing project was 637 kg eCO_2m^2 of gross floor area [18]. Mithraratn et al. developed a life cycle analysis model, based on a simple method, to quantify the environmental impacts of life cycle of residential buildings in New Zealand. The model, based on energy data, materials, and equipment, and using the three main components of knowledge, search engine, and graphical interface with user, provides a possibility for analyzing the life cycle of energy in buildings [19]. Peixoto Rosado et al. studied the environmental performance of residential buildings in Brazil using LCA. They found that most of the impacts were due to the recycling of materials, particularly steel, glass, and plastic, which leads to global warming and respiratory in-organics [20]. Many LCA studies have been conducted in building sector, various studies mainly focused on active phase(use and maintenance) residential buildings. However, the study of building construction phase is low because access to data is difficult. This paper aims to evaluate the environmental performance of Hig- rise building in construction phase through the complete life cycle assessment (LCA) from ‘cradle to site’.

The principle objective of this study is to contribute towards a better understanding of the LCA impacts of High-rise buildings in Tehran (Iran) with 50 year's lifespans. In order to attain the main objective, the following sub objectives have to be fulfilled:

- assesses the environmental impacts of the main construction materials in the High-rise building's subsector.
- Select the best material's type, which contributes the least environmental impact throughout its life cycle.

This paper present first conducting in the Iran. These results are the used to estimate the life cycle environmental impacts of High-rise building sector with the aim of identify hot spots and improvement opportunities along the construction phase. The study chooses existing building, typical of High-rise construction in Tehran city. The next sections present and compare the life cycle impacts of building construction phase. This event is followed by a discussion of the environmental impacts of the high-rise sector in the Iran. We hope that the results of this work will be useful for a range of stakeholders, including house designers, developers, and owners as well as policy makers.

2. Material and Methods

2.1. Life cycle assessment

LCA is a document that describes the emissions and energy flows associated with a final product. With the aim of predicting environmental impacts in response to a decision, it assesses the critical environmental cycles LCA of buildings is a tool for evaluating performance and identifying different scenarios throughout the life cycle of buildings [21]. Based on the building LCA by the American Institute of Architecture (AIA), LCA helps decision makers select a project or process that has the slightest environmental impact. In addition, the data gathered during this process can be re-used to study other parameters such as the cost and data needed to select a product or a process. The ability to track the environmental impacts of a product or process enables managers and decision makers to identify all related environmental impacts and adopt proper policies against any of the consequences. Using LCA, the following achievements can be obtained   systematic assessment of the environmental consequences of a product or project, - Quantitative estimation of the emissions to the air, water, and soil in each primary cycle or process, and- Ecological and human impact Assessment the consumables on a local, regional and global scales [22].Although LCA is a great and complex task that deals with many variables, there is a general agreement on the formal structure of the LCA, which consists of four steps:

• Goals and scope definition
• Inventory analysis
• Impact assessment
• Interpretation

Figure 1 shows the structure of LCA according to ISO standards [23].

2.2. Definition of goal, system boundary, and functional unit

The purpose of this study was to evaluate the environmental performance of high-rise construction in a tower in Tehran Metropolitan City. It also investigated the indirect environmental impacts associated with the use of energy resources, transportation, and waste generation. To better understand the goals of LCI goals and perform the LCA more accurately, system boundaries should be identified, clearly.

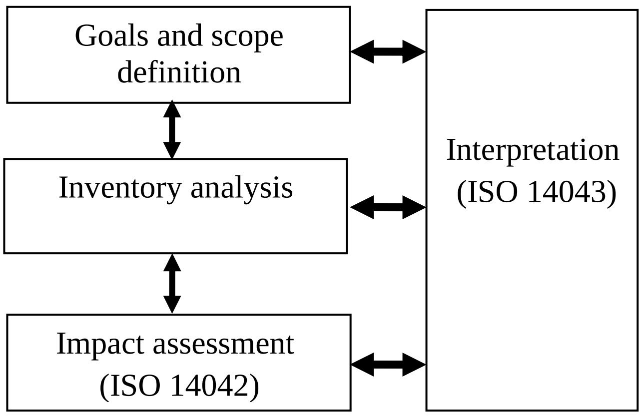


Figure 1:. LCA structure according to ISO 14040 [23]

Since it is very costly and time consuming to consider the life cycle of all processes involved with high-rise construction and in many sectors, it is practically impossible to do this due to lack of access to data, usually this assessment is limited to one or two main processes. The system boundary in the LCA of the high-rise building at construction phase is depicted in Figure 2. As the figure suggests, the boundary is limited to transportation of building materials from the factory (transportation process) and the construction site.

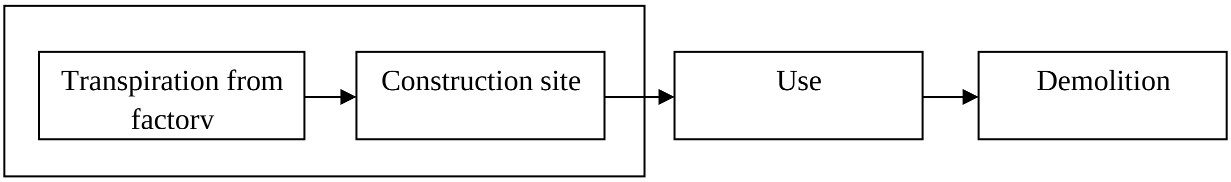


Figure 2: System boundary and the research scope

A functional unit is a quantitative description of the service system or the product of the process under study [24]. Therefore, according to the purpose of this research, the functional unit is 1 m^2 of Gross Floor Area (GFA).

3. Results and discussion

3.1. Study area and building system

The study site is located in District 1 of Tehran, in northern part of the city. The district has 10 sub-districts and 26 neighborhoods. The area of the district, without taking into account its privacy area 164 km^2, is 164 km^2. According to the 2017 census, the population of the district is estimated to be more than 487 thousand people. In recent years, due to the influx of investments in housing sector and the increasing demand for housing, the sustainability of urban development in the district has been threatened thoroughly. This has disrupted the relative balance between urban development and the environmental capabilities and capacities of the district. This is while a mass of ready-to-move-in or under construction building projects will bring the district's population in the near future to nearly 500,000 people. In this study, the input data on materials, transportation, and energy was gathered by field visits and answering questions. The project is a garden tower with a steel concrete structure, which is made up of 20 floors consisting of 60 units with a residential use. The area under each building is 1450 m^2 and the total floor area of the building is 30,000 m^2. The tower has been built on an area of 5000 m^2. The general specification of this building project is presented Table 1.

Table1: General information about the project studied

Total area of the building site	5000 m^2
Total floor area	30000 m^2
Floor area	1450 m^2
Number of floors	20
Number of units	60

The structure of this building is a dual system with a bending frame, special for steel and concrete structures. The roof of the structure is inside the core of the shear wall and the rest is concrete slab. The walls are of light block type. The plan of the floors is provided in Figure 3. This study examines the life cycle of eleven types of the most important commonly used building materials. The amount of materials used in the building is given in Table 2. The amount of energy used in this project is given in Table 3. The used energy for transportation of building materials was estimated based on road transportation by 16-32-ton trucks. The distance of transportation of materials from the factory to the landfill site, and transportation of generated wastes from the project site to the landfill is given in Table 4.

3.2. Environmental impacts Assessment of the construction project

So far, several LCA methods have been developed to assess impacts of life cycles, such as, "CML 2001" [25], "Eco-indicator 99" [26], "EDIP 2003" [27], "IMPACT 2002+" [28], "ReCiPe 2008" [29], "TRACI

2" [30] etc. The LCA, in this research, was performed by ReCiPe method in SimParoV8.5 software. This approach was developed by RIVM in 2008, based on the concepts of "CML 2001" [24] and the Eco-indicator 99 [25]. In "ReCiPe" there are 18 categories of impacts that are attributed to three categories of damage. Normalization is based on European and global scales, while weighting is available for the end-point version. In fact, one of ReCiPe's outstanding features is that it contains the midpoint and endpoint versions [28].

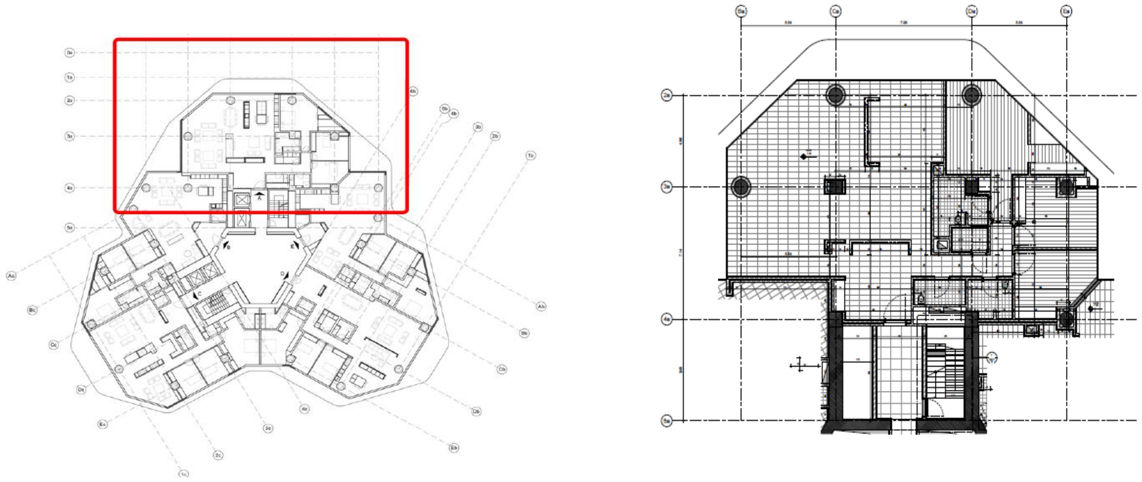


Figure 3: Plan of the floors in the residential tower

Table 2: Materials used in the construction project under study

Building material	Unit	Quantity
Concrete	M^3	11105
Steel frame	Kg	1142900
Rebar	Kg	442000
Mortar	Kg	330498
Iron door	M^2	11.68
Cellular lightweight concrete	Kg	1827000
Glass	M^2	6400
Gypsum plaster	Kg	289000
PVC window frame	Kg	6244
Stone façade	Kg	704000
Ceramic and tiles	Kg	165000

Table3: Energy used in the construction project under study

Energy consumption rate by type	Quantity	Unit
Electricity	241.2	kWh
Diesel	113833	l
Water	1837998.25	l
Petrol consumption	30000 L	l

Table4: Transportation distance of the building materials used in project under study Building materials

building material	Distance from Factory (km)	Distance to landfill (km)
Concrete	17	31
Steel frame	75	75
Rebar	471	60
Mortar	300	31
Iron door	40	31
cellular lightweight concrete	50	60
Glass	52	31
Gypsum plaster	312	31
PVC window frame	40	60
Stone façade	522	31
Ceramic tile	622	31

3.3. Interpretation of the project life cycle impacts

The interpretation of the life cycle is a step in which the results of the analysis are evaluated and the overall conclusions are made. The data of the Tables 2-4 were entered into the Simapro software. Table 5 gives results of the midpoint characterization of 18 impact categories. The results of the characterization units vary among the different categories. Because the ReCiPe method lacks weighting at the midpoint, it cannot be used directly to compare the impacts at the midpoint. Therefore, the final comparison was done by classifying the end-point impacts.

Table 5: Midpoint characterization

Midpoint impact category	Unit	Per GFA(M^2)
Global warming	kg CO2 eq.	761
Stratospheric ozone depletion	kg CFC11 eq.	2.5
Ionizing radiation	kBq Co-60 eq.	39
Ozone formation, Human health	kg NOx eq.	4.2
Fine particulate matter formation	kg PM2.5 eq.	1.19
Ozone formation, Terrestrial ecosystems	kg NOx eq.	9.1
Terrestrial acidification	kg SO2 eq.	3.3
Freshwater eutrophication	kg P eq.	3.7
Marine eutrophication	kg N eq.	1.8
Terrestrial ecotoxicity	kg 1,4-DCB	3.9
Freshwater ecotoxicity	kg 1,4-DCB	4.5
Marine ecotoxicity	kg 1,4-DCB	64
Human carcinogenic toxicity	kg 1,4-DCB	239
Human non-carcinogenic toxicity	kg 1,4-DCB	136
Land use	m2a crop eq.	207
Mineral resource scarcity	kg Cu eq.	196
Fossil resource scarcity	kg oil eq.	202
Water consumption	m^3	155

Figure 4 provides a comparison on the environmental impacts of each of the project's consumables. As the figure shows, among the mid-impacts of the project, the share of global warming is 38%, human carcinogenic toxicity12%, mineral resource scarcity and fossil resource scarcity and land use 10%, water consumption 8%, human non-carcinogenic toxicity 7%. Other impacts account for 5% of the total midpoint impacts. The contribution of each process in global warming is illustrated in Figure 5.

According to the figure, the supply of materials accounts for 93%, transportation 5%, and waste and energy supply 1%. The contribution of the different types of the building materials used in global warming is illustrated in Figure 6. According to the figure, among the different types of the building materials used, steel accounts for 26 %, concrete 20%, PVC window frame 22%, and rebar 13% of the total global warming impacts. Based on Figure 7, in the midpoint impact of terrestrial eco-toxicity, the contribution of supply of building materials and transportation is 84%, and 16%, respectively. According to Figure 8, steel accounts for 43%, PVC window frame 30%, rebar 11%, and concrete 8% of the total terrestrial eco-toxicity impact.

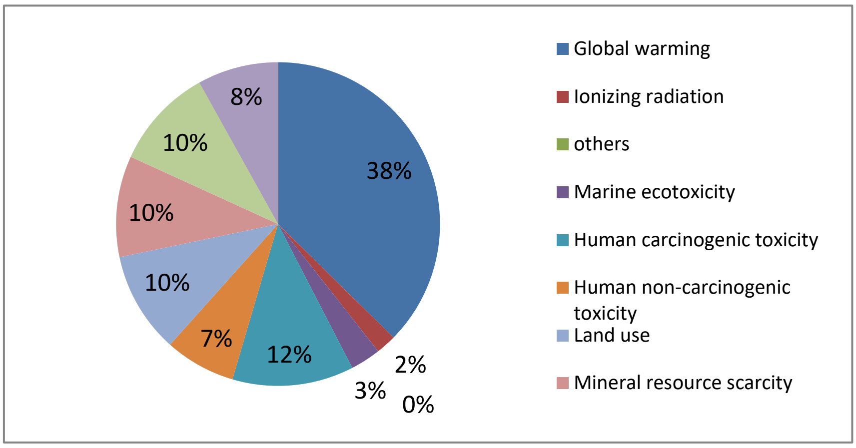


Figure 4: Contribution of the mid-point impact categories from the total life cycle impacts of the high-rise building project

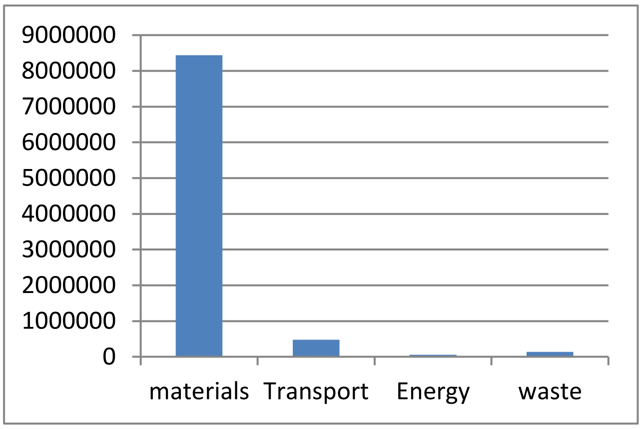


Figure 5: contribution of each process in global warming

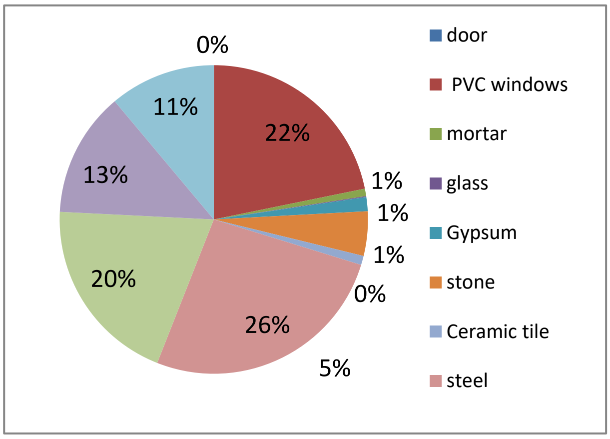


Figure 6: contribution of building materials in global warming

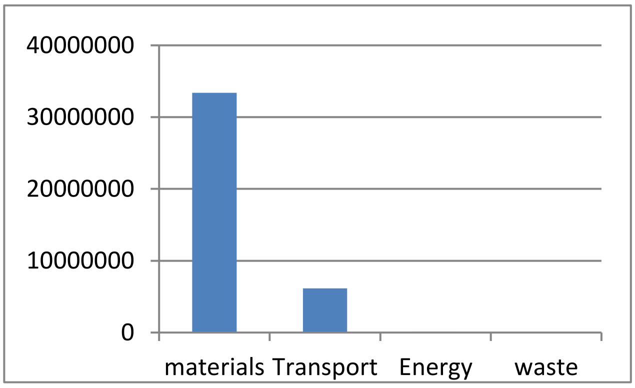


Figure 7: Contribution of each process (terrestrial eco-toxicity)

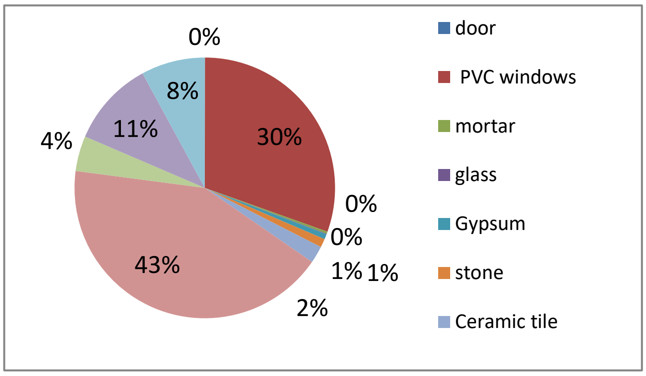
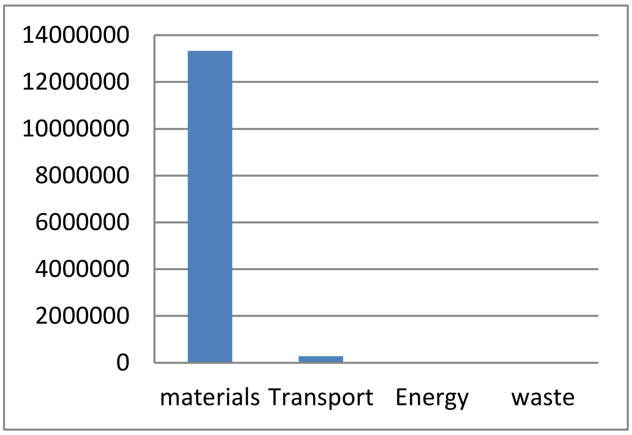


Figure 8:Contribution of different types of materials in (terrestrial Ecotoxicity)

Based on Figure 9, the share of supply of building materials and transportation process in human non-carcinogenic toxicity is 98% and 2%, respectively. As Fig 10 depicts, among different building materials, contribution of steel is 60%, PVC window frame 19%, rebar 11%, and concrete 4%. According to Figure 11, the supply of building materials account for 85% of the total midpoint impact of fossil resource scarcity. The shares of transportation and energy supply process are 8% and 7%, respectively. among the different types of the building materials, the largest shares respectively belong to PVC window frame (37%), steel (25%), rebar (12%), and cellular light weight concrete (9%) Figure 12.



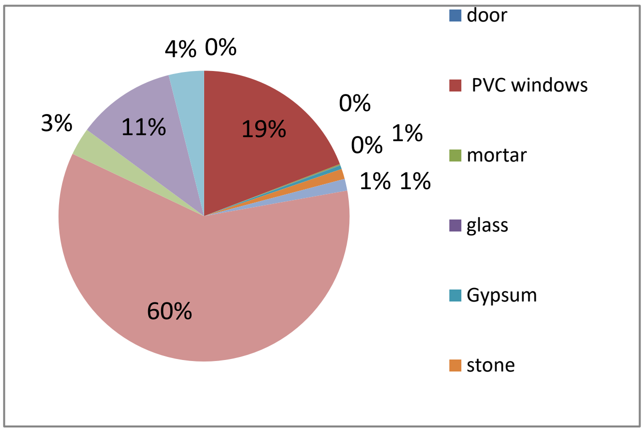
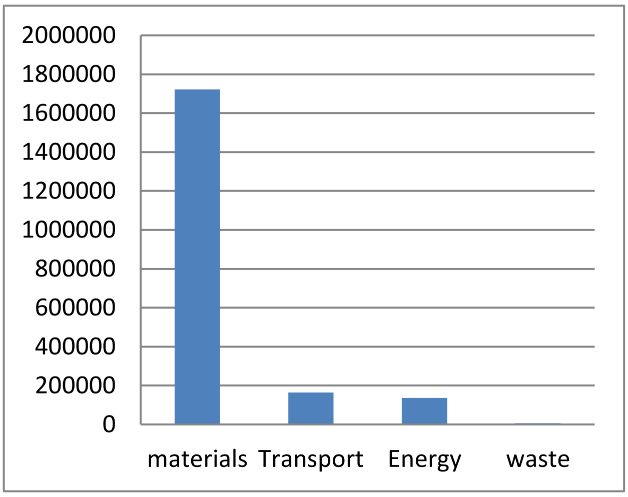


Figure 9: Contribution of each process in human non-carcinogenic

Figure 10: Contribution of different types of building Materials in human non-carcinogenic midpoint impact



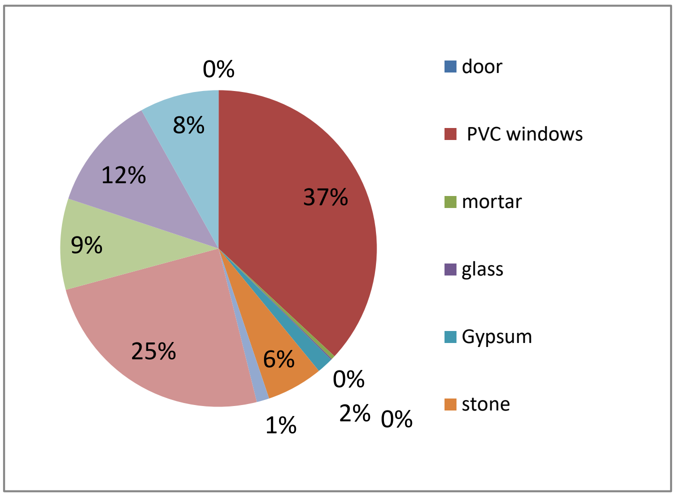


Figure 11: Contribution of each process in fossil resource scarcity

Figure 12: Contribution of building materials in fossil resource scarcity

The results of the endpoint impacts are provided in Table 6. According to the results, the damage to human health is mainly due to climate change, particulate matter, and human toxicity. Ecosystem damage is primarily related to climate change, land use, and damage to resources, which, in turn, are associated with mineral and fossil resources scarcity. In this project, 100% of the damage is related to human health. According to Figure 13, supply of building materials accounts for 93% of the endpoint impact of human health damage due to global warming. The shares of transportation and energy supply processes are 5% and 1%, respectively. Among the materials, the largest shares belong to steel (62%), PVC window frame (22%), concrete (20%), and rebar (13%) Figure 14.

Table 6: Endpoint characterization result

Damage category	Impact Category	Unit	Per GFA(M2)
Human health	Global warming, Human health	DAILY	247.89
	Stratospheric ozone depletion	DAILY	0.01
	Ionizing radiation	DAILY	0.003
	Ozone formation, Human health	DAILY	0.038
	Fine particulate matter formation	DAILY	75
	Human carcinogenic toxicity	DAILY	7.9
	Human non-carcinogenic toxicity	DAILY	3.1
	Water consumption, Human health	DAILY	0.3
Ecosystem	Global warming, Terrestrial ecosystems	Species/Year	0.7
	Global warming, Freshwater ecosystems	Species/Year	2.04
	Ozone formation, Terrestrial ecosystems	Species/Year	0.01
	Terrestrial acidification	Species/Year	0.007
	Freshwater eutrophication	Species/Year	0.002
	Marine eutrophication	Species/Year	3.2
	Terrestrial ecotoxicity	Species/Year	0.0004
	Freshwater ecotoxicity	Species/Year	0.0003
	Marine ecotoxicity	Species/Year	6.7
	Land use	Species/Year	0.01
	Water consumption, Terrestrial ecosystem	Species/Year	0.02
	Water consumption, Aquatic ecosystems	Species/Year	9.3
Resource	Mineral resource scarcity	USD2013	45
	Fossil resource scarcity	USD2013	57

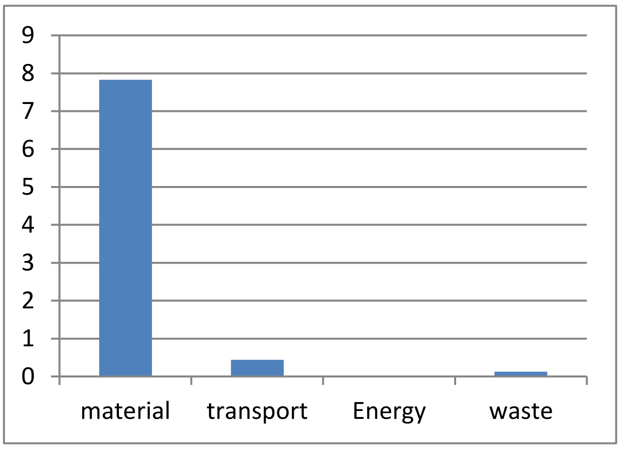


Figure 13: Contribution of each process in global warming at endpoint

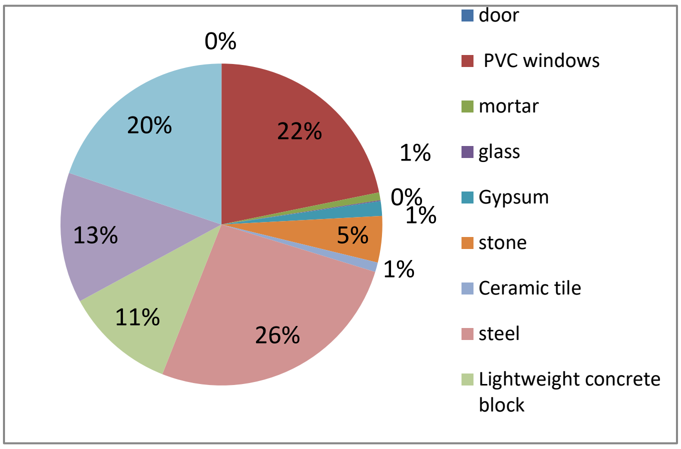


Figure 14: Contribution of building materials in Global warming at endpoint

3.4. Comparison with other studies

As mentioned in the introduction, no other LCA studies exist for the building sector in Iran, so that a full comparison of the results is impossible. Instead, we compare the results of the current work with an LCA study with other countries. Hong Dong et al. evaluated environmental impact of building construction for public rental housing for 13300 flats in Hong Kong [15]. Figure 14 shows a comparison with the Hong Kong building with the current study. The GWP reported by Dong et al. is 637 kg CO_2 eq./m^2 while in this study the GWP is estimated at 761 kg CO_2 eq./m^2. The buildings used precast concrete and Ready mixed concrete in Hong Kong but in the current study have been used cast-in-situ concrete. The concrete manufacturing and transport produce more than 50% of emissions, while precast concrete production and transport a little less than half that amount. Transportation of residential building materials contributes significantly to CO_2eq emissions. The results indicate that the using precast concrete can significantly improve the environmental performance of the project. Another difference relates to the mineral resource impacts in the construction stage. This event is due to the used wood, bricks in Hong Kong buildings while this research only uses Cellular lightweight concrete.

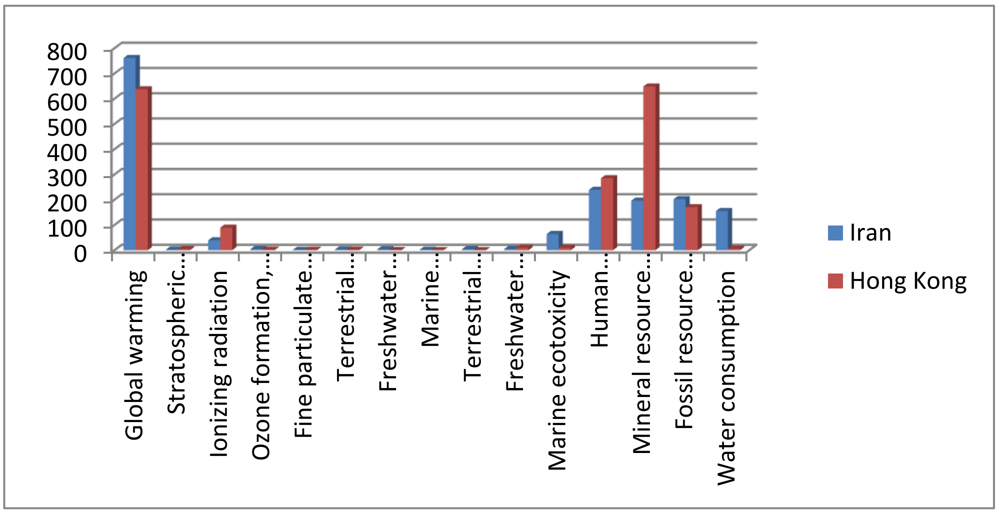


Figure 14: Comparison of environmental impacts between Iran and Hong Kong.

Emami et al. assessed Life Cycle of Two Residential Buildings in Finland. The primary building is a typical concrete base low-energy apartment building (named Pyry), has 28 apartments and 3085 m^2 of gross floor area [31]. The other building detached wooden house is called KÄPYLÄ. It has two floors and a gross floor area of 149 m^2. Figure 15 shows a comparison with the Finland house with this study. This difference is due to the consumption material used, and the type of structure in the Iran house compared to the Finland. However, the difference for global warming between the three studies is much larger, with this impact being 31 percent higher now study. It relates to high concrete consumption in this study.

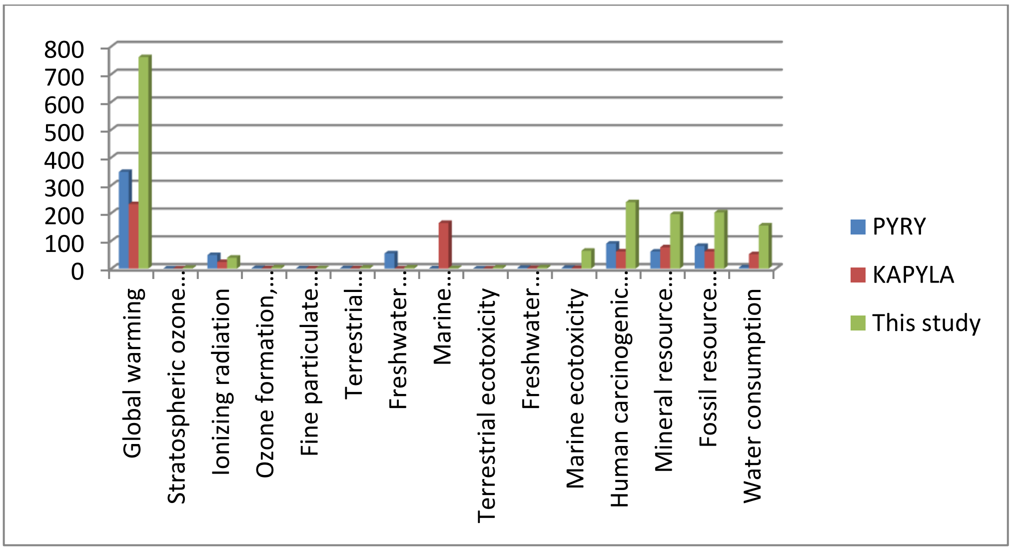


Figure 15: Comparison of environmental impacts between this and other studies.

Kumar et al. have been evaluated Life Cycle for residential buildings in Canada. Four different alternatives of residential buildings have been compared, including High Rise Apartment, Low Rise Apartment, Single family Attached House, and Single family Detached House [32]. It Was assumed that HRA has a single floor for family. HRA consists of concrete columns and beams for structures. In this study, TRACI 2.1 method is selected for Life cycle impact assessment. The results related to High Rise Apartment the best life cycle performance in environmental impacts. Even, the columns and beams, and floors of HRA have high influence on environmental impacts. This event is mainly because the columns, beams, and floors are comprised of environmental impacts than many other building materials when used in large quantities.

The results are compared both non-renewable energy and fossil fuel consumption has the highest environmental impacts with 45%, followed by global warming with the remaining 10% for High rise buildings but in this study the endpoint method, the largest shares are related to global warming (77%) and fine particulate matter formation (23%). There are many other reasons that may lead the considerable differences between the results. One of the fundamental reasons relates to deciding on from methodological and the usage of the right database with the reference country, in particular, the energy mix for electricity generation and shortage of transparency and accuracy in the definition of the goal and scope, and the absence of essential sensitivity and uncertainty analysis. One of the main a lack of relates to expertise LCA. In this study are important uncertainties which ought to be kept in thoughts whilst interpreting the findings. Only one case study was investigated, , this means that that the generalizability is low, but in line with the case look at technique philosophy, even one case is sufficient to identify potential problems and hypothesizing theories [33].

Conclusion

The purpose of this paper was to analyze the environmental impacts of life cycle of a high-rise building in Tehran. The study was characterized by the practical application of an LCA methodology in a case study, through the analysis of quantities of materials consumed and basic considerations of the most critical inputs in the construction of high-rise buildings in Iran. Then, according to regulatory requirements and using SimaPro software and LCA methodology, obtaining the results for an interpretation and analysis perspective. The research findings revealed the construction phase of buildings has many environmental impacts. The analysis results at the midpoint showed that the highest share belongs to global warming impact (38%). Human carcinogenic toxicity accounts for 12% of the impacts. The share of belongs to mineral resource scarcity (10%) and fossil resource (10%) and land use (10%) and water consumption (8%). The contribution of other impacts is only 5% of the entire impacts of the building construction. The largest shares at the endpoint are related to the global warming (54%) and fine particulate matter formation (16%) and fossil resource scarcity (12%) and mineral resource scarcity (10%) and water consumption (2%) and human non-carcinogenic toxicity (2%). Other impacts account for 4% of the endpoint impacts. Among the consumables, the most significant environmental impacts are associated with metal mold, PVC window frame, rebar, and concrete. According to the findings of this study, the government should adopt more eco-friendly policies to establish and support green building industry, which leads to a reduction in the environmental impacts of high-rise construction [34]. This study showed that the use of recycled building materials can mitigate the environmental impacts of construction. In addition, recycling of building materials can lead to savings in natural resources and energy required for extra-quality production. Therefore, it is suggested that the high-rise building in Tehran metropolitan City is amended so that, in the framework of an integrated environmental approach, the environmental performance of the construction works is taken into account and include all stages of the life-cycle of buildings from design stage to use and demolition, it is not limited to the operation stage. Therefore, it is suggested that the high-rise building in Tehran's metropolitan be amended so that, in the framework of an integrated environmental approach, the environmental performance of the construction works is taken into account, and includes all stages of the life-cycle of buildings, from design to use and demolition, and is not limited to only the operation phase. Sustainable construction is considered as a way to keep the construction industry in line with environmental protection. Eco-building is seeking to establish a balance among social, economic, and environmental performance in construction projects. In the belief of this principle, the link between sustainable development and construction will be clear. Construction, despite the high importance, has many environmental and social impacts. In order to mitigate the harmful of construction on the environment and achieve sustainability in this industry, the fulfillment of three principles, including “savings in exploitation of resources”, “savings in costs”, and “taking into account the lifecycle of all construction stages” is necessary.

In Iran, similar to many other developing countries, there are many limitations and problems in the establishment of sustainable buildings. Here are provided some practical and executive suggestions to achieve the goals of sustainable construction.

- Provide a comprehensive conceptual and analytical framework for monitoring the performance of the housing sector. Observe energy standards in buildings as a tool for the design of energy efficient buildings. [Energy standards specify the minimum requirements for energy savings in buildings. It also provides methods for controlling energy losses in the building and presents tools for encouraging the efficient and conscious use of energy in buildings. Also, energy standards allow the use of innovative approaches and techniques for achieving effective energy efficiency in construction [35].
- Concrete, as the most commonly-used building material, plays a major role in development of countries. Considering the serious impacts of concrete on environment, it is necessary to improve the quality of concrete.
- The most effective way to reduce the environmental impacts of construction wastes is to prevent the production of this kind of wastes and reduce them as much as possible. The reduction of the construction waste will result in economical savings and environmental protection. Large amounts of construction and demolition waste reflects a larger withdrawal of raw materials. Since concrete is mainly made up of rocky materials and aggregates, which are directly harvested from natural resources, such as river banks and mines, there, its recycling will be economically viable and helps preservation of natural resources. It will also reduce decline in river and mineral deposits and mitigate the greenhouse gas emissions from production and transportation processes [36]. Therefore, by recycling concrete waste, effective and positive steps would be taken towards sustainable development.

Acknowledgement: This research was developed by the financial support of the Urban Research Planning center of Tehran Municipality [Project Number 137/719086].

Conflict of interest: The authors declare that they have no conflict of interest.

References

1. SBCI, UNEP. "Assessment of policy instruments for reducing greenhouse gas emissions from buildings." United Nations Environment Programme Sustainable Buildings and Construction Initiative, Paris, France (2007).
2. J. Monahan, JC. Powell, An embodied carbon and energy analysis of modern methods of construction in housing: a case study using a lifecycle assessment framework. *Energy Building*, 43 (2011) 179-188. DOI: 10.1016/j.enbuild.2010.09.005.
3. Jaehun Sim, Jehean Sim, The atmospheric environmental impact of a Korean traditional building's life cycle, along with carbon footprint analysis. Sustainable Cities and Society, 28 (2017) 172-186. https://doi.org/10.1016/j.scs.2016.09.008 .
4. F. AL-Nassar, R Ruparathna, G. Chhipi-Shrestha, H. Haider, K. Hewage, R Sadiq, Sustainability assessment framework for low rise commercial buildings : life cycle impact index-based approach, *Clean Technologies and Environmental Policy*, 18 (2016) 2579–2590. https://doi.org/10.1007/s10098-016-1168-1.
5. A. Ali, A Negm, M.Bady, M. Ibrahim , Environmental life cycle assessment of residential building in Egypt: A case study, *Procedia Technology*, 19 (2015) 349-356. https://doi.org/10.1016/j.protcy.2015.02.050.
6. T. Jafary Nasab, S.M. Monavari, S.A. Jozi, H. Majedi, Assessment of carbon footprint in the construction phase of high-rise constructions in Tehran, *Int. journal of Environmental Science Technol*, 17(2020)3153–3164. https://doi.org/10.1007/s13762-019-02557-3.
7. R. Cuéllar-Franc, A. Azapagic, Environmental impacts of the UK residential sector: Life cycle assessment of houses. *Building and Environment*, 54 (2012) 86-99. DOI:10.1016/j.buildenv.2012.02.005.
8. N. Llantoy, M. Chàfer, L. Cabeza, "A comparative Life Cycle Assessment (LCA) of different insulation materials for buildings in the continental Mediterranean climate.", *Energy and Buildings*, 225 (2020) 110323. https://doi.org/10.1016/j.enbuild.2020.110323.
9. L.Van Gulck, S. Van de putte, M. Delghust, N Van Den Bossche, M. Steeman,"Environmental and financial assessment of façade renovations designed for change: Developing optimal scenarios for apartment buildings in flanders." *Building and Environment*, 183 (2020) 107178. https://doi.org/10.1016/j.buildenv.2020.107178.
10. Md.u. Hossain, S. Thomas Ng. "Critical consideration of buildings' environmental impact assessment towards adoption of circular economy: An analytical review." *Journal of cleaner Production*, 205 (2018) 763-780. https://doi.org/10.1016/j.jclepro.2018.09.120.
11. A. Ghose, S. J. McLaren, David, Dowdell. "Upgrading New Zealand's existing office buildings–An assessment of life cycle impacts and its influence on 2050 climate change mitigation target. " *Sustainable Cities and Society*, 57 (2020) 102134. https://doi.org/10.1016/j.scs.2020.102134.
12. L. Cabeza, L.Rincón,V.Vilariño,G.Pérez,A.Castell , "Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review." *Renewable and sustainable energy reviews* ,29 (2014) 394-416. https://doi.org/10.1016/j.rser.2013.08.037.
13. A. Vilches, A. Garcia-Martinez, B. Sanchez-Montanes, "Life cycle assessment (LCA) of building refurbishment: A literature review. " *Energy and Buildings*, 135 (2017) 286-301. https://doi.org/10.1016/j.enbuild.2016.11.042.

14. R. Santos, A. AguiarCosta, J. D. Silvestre, T. Vandenbergh, L, Pyl, "BIM-based life cycle assessment and life cycle costing of an office building in Western Europe." *Building and Environment*, 169 (2020) 106568. https://doi.org/10.1016/j.buildenv.2019.106568.
15. Y. Dong, T. Qin, S. Zhou, L. Haung, R. Bo, H. Guo, X. Yin, "Comparative Whole Building Life Cycle Assessment of Energy Saving and Carbon Reduction Performance of Reinforced Concrete and Timber Stadiums—A Case Study in China." *Sustainability*, 12.4 (2020) 1566. https://doi.org/10.3390/su12041566.
16. O.S. Alshamrani, KH. Galal, S. Alkass, Integrated LCA-LEED sustainability assessment model for structure and envelope systems of school buildings. Building and Environment, 80 (2014) 61-70. DOI: 10.1016/j.buildenv.2014.05.021.
17. J. Heinonen, A. Saynajoki, J. Junnonen, A. Poyry, S. Junnila, Pre-use phase LCA of a multi-story residential building: Can greenhouse gas emissions be used as a more general environmental performance indicator, *Building and Environment*, 95 (2016) 116-125. https://doi.org/10.1016/j.buildenv.2015.09.006.
18. Y. Hong Dong, Ng T, A life cycle assessment model for evaluating the environmental impacts of building construction in Hong Kong. Building and Environment, 89 (2015) 183-191. Doi: 10.1016/j.buildenv.2015.02.020.
19. N. Mithraratne, B. Vale, Life cycle analysis model for New Zealand houses, *Building and Environment*, 39 (2004) 483-492. https://doi.org/10.1016/j.buildenv.2003.09.008.
20. L. Peixoto Rosado, P. Vitale, C. Penteado, U. Arena ,Life cycle assessment of construction and demolition waste management in a large area of São Paulo State Brazil. *Waste Management*, 85 (2018) 477-489. https://doi.org/10.1016/j.wasman.2019.01.011.
21. G. Finnveden, M. Hauschild, T. Ekvall, J. Guinee, R. Heijungs, S. Hellweg, A. Koehler, D. Penninton, S. Suh, Recent developments in life cycle assessment. *Environmental management*, 91(2009) 1-21. https://doi.org/10.1016/j.jenvman.2009.06.018.
22. Ch. Bayer, M. Gamble, R. Gentry, S. Joshi, AIA guide to building life cycle assessment in practice. The American Institute of Architects, Washington DC. (2010).
23. ISO 14040: Environmental Management — Life Cycle Assessment — Principles and Framework. International Organization for Standardization, Geneva, Switzerland (1997).
24. Guinée, J. (ed.): Handbook on Life Cycle Assessment. Operational Guide to the ISO standards. Kluwer Academic Publishers, Dordrecht, the Netherlands.ISBN:1402002289.(2002).
25. G. Rebitzer, T. Ekvall, R. Frischknecht, D. Hunkeler, G. Norris, T. Rydberg, W. Schmidt, S. Suh, B. Weidema, D.W. Pennington. Life cycle assessment Part1: Framework, go a land scope definition, inventory analysis, and applications. *Environment International*, 30 (2004) 701-720. DOI:10.1016/j.envint.2003.11.005.
26. M. Goedkoop, R. Spriensma, M. Volkshuisvesting, R. Enmilieubeheer, C. D. Communicatie, The Eco- indicator 99: A damage oriented method for life cycle impact assessment. The Netherlands: Ministerie van Volkshuisvesting, Ruimtleijke Ordeningen Milieubeheer. (1999).
27. J. Potting, M. Hauschild, Spatial Differentiation in Life Cycle Impact Assessment: A decade of method development to increase the environmental realism of LCIA. *The International Journal of Life Cycle Assessment*,11 (2006) 11-13.DOI: 10.1065/lca2006.04.005.
28. O. Jolliet, M. Margani, R. Charles, S. Humbert, J. Payet, G. Rebitzer, R. Rosenbaum, IMPACT 2002+: A new life cycle impact assessment methodology. *The International Journal of Life Cycle Assessment*, 8 (2003) 324-330. https://doi.org/10.1007/BF02978505.

29. M. Goedkoop, R. Heijungs, M. Huijbregts, A. De Schryver, J. Struijs, R.Van Zelm, "ReCiPe 2008." *A life cycle impact assessment method which comprises* harmonised *category indicators at the midpoint and the endpoint level*, 1st Edition June (2009) 1-126.
30. J.C. Bare, Traci. *Journal of Industrial Ecology*, 6 (2008) 49-78. https://doi.org/10.1162/108819802766269539.
31. N. Emammi, J. Heinonen, B. Marteinsson, A. Säynäjoki, J. Junnonen, J. Laine, S. Junnila, A Life Cycle Assessment of Two Residential Buildings Using Two Different LCA Database-Software Combinations: Recognizing Uniformities and Inconsistencies, Buildings, 9 (2019). https://doi.org/10.3390/buildings9010020.
32. V. Kumar, K. Hewage , R. Sadiq, Life Cycle Assessment of Residential Buildings: A Case Study in Canada, International Journal of Energy and Environmental Engineering ,9(2015) 30656 Doi.org/10.5281/zenodo.1107700.
33. K. Eisenhardt, M. Graebner, Theory Building from Cases: Opportunities and Challenges, *Journal of Academy of. Management*, 50 (2007) 25–32. https://doi.org/10.5465/amj.2007.24160888.
34. J.Cidell, Building Green: Conventions Theory and Industry Transformation Urbani izziv, Building Quality, 23b(2012) 186-94. DOI:10.5379/urbani-izziv-en.(2012).23-supplement-2-016
35. S. Maleki, M. Fahlimani, Advanced topics in high-performance sustainable buildings. Architecture and Sustainable Urban Spaces Conference Mashhad, Iran, December. (2013).
36. Resource Ventures Incorporated. "Construction Waste Management Guide for Architects, Designers, Developers, Facility Managers, Owners, Property Managers& Specification Writers." Resource Venture, Third edition, Seattle, OCLC Number: 70869176 (2005).

(2020) ; http://www.jmaterenvironsci.com