Sustainable development of stone and marble sector in Palestine

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ABSTRACT

This paper focuses on the environmental, economic, and social impact of stone and marble industry in the Middle East and North Africa region taking Palestine as a case study. It presents the lifecycle of stone and marble, with adequate indicators, and proposes strategy for proper and efficient use of resources including natural stone, water and energy during production processes. 3Rs (Reclaim, Reuse and Recycle) principles are used to minimize the waste at each stage of stone and marble lifecycle and hence improve its material efficiency. Stone and marble sector is modeled using doughnut-modeling technique taking into account most of the factors influencing this sector. The value contribution of this sector is discussed showing the rational relation between consumption and production.

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1. Introduction

Stone and marble industry is considered one of the main economic resources in most of the Middle Eastern and Mediterranean countries especially in Palestine. This sector contributes widely to the local production, exports and employment capacity. Moreover, it is considered one of the main materials employed in building and construction sector. Stones have been used since a long time ago. The ancient Egyptians used stones as a permanent structure for their civilization in building pyramids and other long life buildings that still exist till now. Greek and Roman empires, as well, used stones in the construction of columns and theaters that are still considered main touristic places in most of the Mediterranean countries. Nowadays, these countries use stones and marble for external building and internal decorations for their public and private buildings. This reflects the belief that stones are the most sustainable and long living material for construction works.

Sustainable indicators of stone industry are discussed by Zografidis et al. (2007). The paper depicts the influence of sustainability and sustainable indicators on environment, economic and social situation in European countries. Two different solutions are suggested in the research: low input/low output and high input/high output solutions. The authors take the Greek situation as a case study. Sibley (2006) discusses some lessons of sustainability and future development for the historic public Baths called Hammam in Damascus (Syria) and Fez (Morocco). A special concentration is given to their urban location and water distribution systems besides to the main furnace (source of energy for water heating). An Egyptian sustainability case study is shown by Mohamed and Abdelkadir (2009). The authors take the inhabitants of El-Maghara region in Sinai (Egypt) as a case study for the necessity of sustainability and equity. Mining and quarrying activities are discussed here amongst other aspects of life like water shortage, governance, employment, environment and health degradation. Different scenarios are given by authors to increase sustainability and improve life of people. Angel et al. (2010) introduced a study for the characteristics of different types of stones in terms of thermal conductivity. The study aims at showing the importance of using natural stone as a main construction material to save energy in Spain. Their study contributes in the improvement of energy efficiency in buildings and constructions. Gutowski et al. (2013) introduce a strategy to reduce demand by providing material services with less material (called ‘material efficiency’). Wang and Seliger (2012) show that it is very difficult to address water footprint, because of its diversity and since production chains are complex and differs between nations and companies. Weinert et al. (2011) emphasize that planning and operating energy-efficient production systems require detailed knowledge on the energy consumption behavior of their components. Energy Consumption Prediction is used. The methodology is based on the representation...
of production operations as segments of specific energy consumption for each operating state of the production equipment. Modeling any process chain is possible by arranging the segments according to the production program.

Pepe et al. (2004) show an Italian study for using titanium dioxide in a matrix of cement or marble material for surface finish of stones without influencing the characteristics of material. The ideal usage of sustainable materials in interior design in Jordan is demonstrated by Hussein (2011). The author introduces a nice study for the construction demolition waste management. Hunger and Brouwers (2008) from Netherlands depict a new technique for implementing the fine stone powder produced by cutting processes in the design of cement for a special type of concrete. The paper contains a good study for the properties of powders of stone and marble and show the best way to use in the concrete mixture. The prepared concrete is then tested and characterized. Aukour and Al-Qinna (2008) show a case study in Jordan for the impact of stone cutting process on environment and society. The foregoing literature review shows a wide study for the previous researches and studies conducted in the Middle Eastern, Mediterranean and European regions about stone and marble sector and their sustainability and lifecycle. This following section will talk about the challenges and problems met by the local in the field of stone and marble in terms of environment and society. Jaradat (2007) depicts the influence of the stone and marble sector and economy in Palestine while ARJ (2006) shows the Israeli challenges and restriction on mobility and their drawback on the general economy. The next section discusses the lifecycle of stone and marble suggesting a new model for sustainability in flow chart form and doughnut-modeling techniques. At the end of the paper, a specific case study of stone cutting factories in Palestine is discussed. The value contribution is calculated in this case study and results are discussed to show the importance of sustainability in this industry referring to information discussed by USMI (2011). One of the most important issues to mention here is that partnership between private sector in stone and marble field and the academic universities is required for initiating and implementing research projects to improve and develop this sector. This paper aims at narrowing the knowledge gap between industry and university and increasing awareness to the necessity of having a sustainable sector. AbdElall et al. (2012) discuss the general situation of economy and life of people living in MENA region. This study gives a statistical overview that helps in understanding the requirements and impacts on economy in MENA region.

2. Challenges and efforts

2.1. Environmental challenges

Stone industry has a severe impact on the environment in both sites; quarries and cutting workshops. In quarries, the rock extraction process is accompanied by dust polluting air besides to the wide excavations that leave severe effect on landscape and soil. In cutting workshops, the problem of dust is partially treated by adding water to the cutting process which reduces air pollution but on the other hand, it causes water pollution and forms big basins of mud that need to be solved. Keeping in mind that water in Palestine and most of the Mediterranean countries is a scarce commodity and should be used efficiently. The powder extracted out of this mud can be used in construction materials especially concrete mixtures and paper production. Cutting process is noisy and therefore cutting workshops must be located away from the local community clusters, and noise safety measures should be taken by the workers. Dust is considered as one of the main health problems due to its influence on lungs and respiratory systems. On the other hand, large amount of energy is required for the quarrying machinery and later for the stone cutting processes. Energy constitutes 6% of operational costs in quarries and stone cutting factories. Electrically driven motors are used for the cutting tools, and electricity prices are relatively high, for example, in Palestine it reaches 0.20 $/kWh in some locations as shown in ECB (2002). Environmental impact of stone and marble industry can be summarized by the following actions:

The items impacting environment mentioned before can be solved by the following techniques and practices:

<table>
<thead>
<tr>
<th>Process</th>
<th>Environmental impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarring</td>
<td>Waste stone and dust</td>
</tr>
<tr>
<td>Stone cutting</td>
<td>Powder and noise</td>
</tr>
<tr>
<td>Hole drilling</td>
<td>Liquid sludge, vibrations and noise</td>
</tr>
<tr>
<td>Vehicle operation</td>
<td>Fuel emissions and dust</td>
</tr>
</tbody>
</table>

the most water consumers where they consume about 500,000 m³/year. This water is used in these factories for cooling saws and for polishing processes. Most of the factories employ several processes for reusing and recycling the consumed water. More modern processes and technologies are required to reduce the wastewater because Palestine is considered one of the countries suffering sharp shortage in water resources.

2.2. Social challenges

Stone and marble industry similar to other small business in most of Mediterranean producing countries is categorized as a family owned business which suffers from and restricts the possibilities of development and employment. Many accidents occurred either in quarries or in cutting workshops or in building sites due to the lack of awareness of safety rules and their enforcement. Most of these accidents occurred due to discarding the importance of using safety shoes, gloves, and helmets. Workers are subject to respiratory and lung disease as they breathe the particulate polluted air. Using hand held tools (motorized or manual) leads to the problem of white finger disease and blood vessels blockage. These hand arm vibration syndrome diseases have very big influence on the worker health on the long term. PFI (2009) showed that most of the workers in stone and marble sector are considered non-skilled labor and their salaries are relatively low. This fact increases poverty and creates a wide poor cluster. This poverty can be avoided by increasing skills of these workers thus increasing their productivity and consequently increasing their salaries and improving their standard of living. The Palestinian marble and stone industry employs around 15,000 workers. The industry’s demand for workers has increased due to the expansion of local construction activities. The industry’s workers can be classified into three categories (administrative, skilled and unskilled workers).

Annual wage average approximately $6000 per year for unskilled workers, the highest wage paid to unskilled laborers in any major industry in Palestine. Average annual product sales per
employee are approximately $17,000 accounting for 9% of the total Palestinian production labor market. It is estimated that the Palestinian marble and stone industry has a very low annual injury rate if it is compared to their counterparts in other countries. Typically, it does not exceed 0.05% of the total industry workforce.

Jaabari (2011) emphasizes that bridging the gap between this sector and academic universities can be considered as a high requirement. Academic institutions can contribute in developing stone and marble industry by optimizing the use of resources including stone, energy, water and human resources, as well as improving the processes and increasing its efficiency. In addition, Assasat (2009) shows that they can contribute also in improving the safety measures during the production and transport of products.

The level of education of the Palestinian population is the highest in the whole region, with the exception of Israel. In the UNDP Education Index, based on literacy and gross enrollment in primary, secondary and tertiary education, the Palestinian Territories scores 88% compared to an average level of 61% for Arab States, 84% for Middle Income Countries, and 77% for the world. The illiteracy rate among the Palestinian adult population is declining to reach 7.7% in 2004, compared to 10.8% in 2000 and 15.7% in 1995. The Palestinian labor force in particular is distinguished by a high level of education. Statistics show that 26.6% of the labor force had completed more than 13 years of education, 30.7% had finished 10–12 years, and 25.2% had completed 7–9 years of schooling at the end of 2005. Such figures indicate that the Palestinian labor force has sufficient skills to explore new, knowledge-intensive industries that depend on modern technology.

2.3. Political and economic challenges

It is evident that the stone and marble sector is the biggest in some of MENA countries especially in the Palestinian industry, but it faces many political and economic problems starting from the limited resources to difficulties of product transportation. Although Palestine landscape contains a plenty of rocky mountains, but keep in mind that such resources are not renewable and being depleted continuously. Moreover, USMI (2011) shows that there are many difficulties in transporting products between cities and areas because of political restrictions. Most of the instruments and machines used in the stone industry are imported from outside which complicates the production processes when repair and maintenance problem arises. Although this sector forms about 30% of the Palestinian exports but it could be further increased if more flexibility has been given to it by providing more than one border point for export of Product.

The Palestinian stone production is the 12th largest in the world and the annual production of finished stone and marble is 16 million square meters, equal to 1.8 million tons. Industry experts estimate annual sales at around $400 million, but according to the Palestinian Union of Stone and Marble Industry — USMI (2011) the turnover maybe as high as $600 million. This sector contributes approximately 25% to Palestine’s overall industrial revenues, making up 4.5% of the Gross National Product (GNP) and 5.5% of the Gross Domestic Product (GDP). The Israeli-imposed closures and curfews, the Apartheid Wall and the instability of the political situation since the start of the Al-Aqsa Intifada have negatively affected the stone and marble industry by decreasing production and sales by half.

3. Analysis framework for stone and marble industry

3.1. Stone and marble lifecycle

In order to find out the possibilities and opportunities for development of the stone and marble industry, it is very important to carry out lifecycle analysis of stones as a construction material. Fig. 1 shows a flow chart for the complete life cycle of the stones starting from the extraction process of the stones from rocks to using shaped stones in the building and possibility of recycling stones after buildings are demolished. This flow chart is designed to provide a scientific easy way for the understanding of this process.

Stone lifecycle begins in the Quarry, in which rocks are extracted from rocky mountains. The extracted rocks are divided into two categories. The first category is huge massive blocks transported to cutting factories and workshops to be sliced and turned into building stones. The second category is the small pieces of stones and rocks that cannot be easily formed into building stones, these pieces are transported to stone crushers where they are crushed into aggregate in different sizes to be used directly as a raw material in the ready-mixed concrete plants or in the building sites. The percentage of these two categories depend on the landscape and type of extracted stones where in some places first category reaches to 80% while in others it is much less quantities.

Rock blocks transported to cutting workshops are unloaded and handled using special cranes and human labor. After being cut and shaped in different sizes and forms, stones are sorted and packaged according to their shape, size and use. Cranes and fork lifts are used to load these packages to be shipped to the building sites. More than 90% of these stones are used in building and the cracked stones are returned back to crushers. Besides to useful stones, the outputs of the cutting process include little broken stone pieces and stone powder.

The broken stones are recycled back to the crushers to be crushed into aggregate used for concrete mixture, while the stone powder is processed to be used in the construction materials and like cement for concrete mixture. This powder does not exceed 5% of the product but there is a need to recycle it and mitigate its pollution effect. Formed stones are shipped in packages to the building sites where they are built in suitable places and some of them are shaped to the proper size and shape using manual abrasive cutters. Small stone pieces broken from the shaping process can be recycled back to crushers to be turned into aggregate. The whole waste from building sites can be reduced and returned back to quarries to fill the excavation sites in order to reclaim the land and improve the landscape of the site. After demolishing the built houses for different reasons, stones can be reused by returning back to the cutting and forming process before being rebuilt again. The previously discussed lifecycle for stone and marble has been completely designed and formed in the shape of a flow chart. This type of representation aims at facilitating ideas and leads to better understanding of this product as it is considered sustainable material and goes through several cycles back and forth.

The cost analysis of the sector’s value chain gives 41% to the raw material while there is an investment of 3% only in research and development (R&D). The maintenance and utilities take 16% of the cost while the direct and indirect labor is 21%. The packaging and marketing cost reaches around 6% and the rest is for tax and other expenses.

It can be seen from Fig. 2 that most of the quarries, factories and small workshops in the field of stone extraction and cutting exist mostly in the southern part of Palestine, namely, Hebron and Bethlehem. Ramallah, Nablus and Jenin have a medium contribution in this sector while the other regions are extremely weak. The biggest automated factories in these cities produce and export a significant amount of their products where they participate in about 40% of the total Palestinian exports. It is worth mentioning that 13.9% of the Palestinian employees work in this sector most of them are from Hebron, Bethlehem and Ramallah.

3.2. Sustainability model

The lifecycle of stones and marble can be modeled for sustainability using doughnut-modeling technique. Doughnut model has...
been used by Wegner (2004) to represent knowledge management strategies in a safe and sustainable environment. Others used the doughnut techniques to represent sustainable green design of systems. This modeling technique implies the fact that the internal ring of the model is the social foundation under which people can live safely away from the environmental risks. The outer ring of the model represents the environmental ceiling above which human being will be exposed to environmental hazards due to chemical pollution, climate and land changes besides to other impacts that influence human and nature. This fact ensures working under sustainable conditions in parallel with keeping an acceptable margin of profit which increases the value of contribution of the modeled process.

The doughnut model implies the fact that as far as the size of any process or item is in the measured range then work is sustainable. Moving inward, away from the specified range toward the center of the doughnut, means reducing production and increasing safety while moving outwards away from the center of the model means...
increasing risks and environmental drawbacks with increasing productivity and production. This leads to the fact that the doughnut model is a compromise between production and consumption which can be considered an indication for sustainability. The value contribution of these systems is estimated as the ratio between the production and the consumption.

\[
\text{Value Contribution} = \frac{\text{Production}}{\text{Consumption}}
\]

Fig. 3 depicts a doughnut model for the different tasks and requirements that take place in quarry site work and processes.

In this model related to quarry, quarrying, crushing and loading processes need to be enlarged and accelerated to improve the productivity of the quarry but this enlargement and acceleration require smart and hard work or experience and need more stone, energy and other resources consumption. This is also accompanied with other risks related to health of workers and possibilities of being exposed to work accidents. It leads also to risk of environmental pollution and landscape changes. In other words, quarry processes include four production items.

- **Quarrying**: it is required to enlarge this process in order to increase the production rate which in turn increases the income and improves economy.
- **Crushing**: increasing crushing processes increases the produced aggregate, reduces the lost waste and develops the building sector.
- **Loading**: this process is a result of augmentation in production.
- **Sorting**: well sorting and packaging reduces working efforts.

And four consumption items:

- **Health and accident risks**: this can be measured by estimating the number of accidents and amount of money paid on health issues.
- **Environmental impact**: the measurement indicator here lies in the percentage of dust measured in the ambience surrounding these quarries.
- **Energy consumption**: the indicator here is the amount of electricity bill and oil bill paid for each quarry.
- **Smart and hard work (experience)**: the indicator to measure this value is the amount of salaries paid for skilled labor employed in this field.

A sustainable model for quarry means the necessity to increase the production items and decrease the consumption ones.

In stone cutting workshops, the diversity of production processes makes the doughnut model, shown in Fig. 4, different from that of the quarry. In this model, the production processes and items can be summarized as follows.

- **Unloading**: this is a measure for augmentation in production because it needs using forklifts and hand working.
- **Crane loading**: this is also a measure for increase in production and using facilities that save time and money.
- **Cutting and shaping**: the indicator here is that the more shaped stones, the bigger the building sector.
- **Scaling and packaging**: better scaling and packaging process improves and facilitates work and reduces required time.
- **Sorting and storage**: the same indicator as in scaling and packaging.
- **Shipping**: the bigger the shipped quantity, the larger the production and profit.

Where the consumption items can be summarized as follows.

- **Accidents (safety)**: as mentioned before, this can be measured by the number of accidents and the cost of recovery.
- **Health risk**: the indicator here is cost spent on precaution step to avoid health drawbacks or workers’ injury.
- **Water and energy consumption**: the bills of water consumption and electricity are the best measures for this item.
- **Environment (air/water pollution)**: the indicator is not easy because it requires statistics and measurements of air and water pollution by dust and smoke.

Environmental impact can be added to the consumptions here although its influence is less than the quarry. Here again, sustainability can be improved by increasing the items related to productivity and decreasing those related to consumption.

Fig. 5 shows a similar doughnut model for building process. In this model it is clear that the production related items can be listed as follows.

- **Unloading**: this is a measure for augmentation in production because it needs using forklifts and hand working.
• **Sorting and distribution**: better sorting and distribution process improves and facilitates work and reduces required time.

• **Handling**: this process uses manual techniques in general. Increasing the possibilities of using automated handling techniques accelerated the building process.

• **Building**: this is the main task here and it can be improved by using modern techniques like pre-cast and templates.

• **Abrasive cutting**: abrasive cutting is used to shape stone in curves and intricate shapes. Although this process includes risks and requires more safety precautions but it is necessary for final architecture.

• **Lining**: lining means inserting cement between built stones to avoid rain water leakage through these lines. Pre-casting can accelerate this process and reduce its risks.

While the consumption items are listed as follows.

• **Health risk**: the indicator here is cost spent on precaution step to avoid health drawbacks or workers’ injury.

• **Accidents (safety)**: as mentioned before, this can be measured by the number of accidents and the cost of recovery.

• **Construction waste**: as far as there are building works there is a waste. This waste can be used for refilling and reclaiming.

The three doughnut models can be connected to each other in order to represent the complete lifecycle of stones from quarry to building through cutting processes. The complete model is shown in Fig. 6. The quarry doughnut is related to the cutting workshop doughnut through the transportation of the extracted rock blocks from quarry to workshop. On the other hand, quarry is related to building sites through the transportation of crushed aggregate to be used in the concrete mixture. Cutting workshops are related to building sites by the transportation of formed stones and marble to be used in the different building processes. Other connectors between the three doughnuts models are the 3Rs (Recycle, Reuse and Reclaim). Recycling processes is applied when broken stone pieces are returned back from cutting workshop to stone crushers to be crushed into aggregate. Reusing process is applied when stones extracted out from demolished houses are returned back to the cutting workshops to be reformed and reused again in a new building. Reclaim process is applied when the construction waste from the building sites is transported to fill out the excavated places of old quarries to improve the landscape and to reclaim the land for other agricultural uses.

In this overall model that relates the three phases of stone lifecycle, the production items that will be carried out by the sector’s employees are as follows.

• **Transportation of rock blocks**: increased transportation means increased production and augmented added value.

• **Transportation of aggregate**: the same as above.

• **Transportation of stone and marble**: the same as above.

On the other hand, the consumption items that are carried out by nature or by other sectors are as follows.

• **Recycling of stone pieces**: cracked stone pieces can be recycled by re-crushing them into aggregate to be used in concrete.

• **Reusing of old stones**: old stones extracted from demolished houses can be reused in building new houses.

• **Reclaiming the quarries using stone waste**: this process needs high costs and good landscape designs.

• **Environment (air and water pollution)**: the indicator is not easy because it requires statistics and measurements of air and water pollution by dust and smoke.

• **Energy and water consumption**: the bills of water consumption and electricity are the best measures for this item.

• **Workers’ safety and health risks**: this can be measured by estimating the number of accidents and amount of money paid on health issues.

In this model, sustainability can be improved by increasing the production items and decreasing the consumption items. The best compromise between production and consumption can be achieved by taking into consideration the supplies, demands and requirements of the region or country.

### 3.3. Simplified sustainability model

Stone and marble sector can be modeled using an object-simplified model for better understanding of the relation between the different clusters and factors influencing the sector. This model is depicted in Fig. 7 using three main interfered circles. The first circle represents the quarrying field of work, the second circle represents the stone cutting cluster and the third circle represents the building cluster.
The main task of the quarry is to load and transport rock blocks to the cutting factories where hard and smart work is required in all activities operated by the two clusters. The cutting factories are responsible for cutting, shaping and transporting shaped stones to the construction sites to be used in building processes. Stone shaping is operated also in the building site which makes this task common between building and cutting. At the same time the quarry has another task summarized by crushing small stones into aggregate and transporting to the building site. Both, quarry and building process produce waste that needs to be solved by one of the recycling operations.

In order to keep sustainability in the whole process, stone waste from cutting factories is recycled and returned back to the quarry to be crushed to different sizes and transported to building sites or to ready-mixed concrete factories. On the other hand, when an old house is completely or partially demolished, stones of this building are transported back to the cutting factory to be reshaped and reused again in a new building. The rest of waste materials remain from house demolishing can be reclaimed to abandoned quarries to fill them for the purpose of reshaping the landscape.

All operations done in the three clusters include one or all of the four main sustainability items: water, energy, environment and safety. As water is an extreme demand in Palestine, it is important for any process to take into account recycling and reusing water especially in stone cutting factories where water consumption is very high. Energy conservation is also required here. Renewable energy resources like solar energy can be used to cover part of the energy consumption through hybrid installations. Another common issue between the three clusters is environment. This is represented by air and water pollution and fuel emissions of vehicles. Air pollution is reduced by adding water to the cutting process but this also leads to consume and pollute more water. Some modern factories use water jet cutting machines for cleaner production. Fuel emissions are reduced by using modern vehicles that obey the high standard rules of environment friendly engines besides to the necessity to plant more trees around cutting factories. The last item that should be taken into account for sustainable process is the safety of work and workers. Safety precautions include injury avoidance, this implies that workers should wear special shoes, gloves, goggles and aprons during cutting and handling processes. Proper transporting instruments should be used to transport large and heavy blocks and stones. Noise of machines is also harmful for workers; this implies providing workers with ear protectors specially those who work directly close to cutting saws.

Taking all the previous items into account during operations leads to sustainable stone and marble sector. It is possible sometimes to find contradiction between an item and the other. This means that there is a need for a compromise between them and sometimes an optimization process is required.

4. Conclusions

This work emphasizes the importance of stone and marble sector in MENA region and particularly in Palestine. This sector has a major contribution in the Palestinian economy but it requires further steps of improvement to be developed and turned into sustainable sector.

This paper focused on a discussion of sustainability of stone and marble sector in Palestine. This sector represents the major economical income in most of the Middle Eastern and Mediterranean stone producing countries. In Palestine, for example, it represents 34% of the national income. Nevertheless, this sector suffers from many problems and drawbacks that need to be dealt with in order to increase productivity and sustainability. The natural stone resource is limited and non-renewable. This leads to the fact that it should be used in the most efficient way. Moreover, the other resources such as water which is also very scarce and hardly accessible by most of the up-mentioned countries should be used also efficiently. This efficient use includes possibilities of reuse, recycle and treatment of the used water. In addition, the energy employed in this industry for transportation, and running the cutting and shaping machinery and tools is very expensive and if not used efficiently will lead to much higher cost that reduces the competitiveness of this industry. Renewable energy resources could be a viable option in this case, particularly solar energy which is a very rich source of energy in this region. Although solar energy is not feasible yet to feed such systems with high power but it could be used in a hybrid installation with other sources of energy. Social aspect of sustainability could be improved by health and safety measures for workers in the sector, in addition to providing awareness and training to improve productivity and increase their income.

The complete process of stone production has been divided into three clusters; Quarry, Cutting and Building. The various processes and linkages between the three main clusters have been shown in lifecycle flow chart and doughnut models. Different suggestions for the improvement of productivity and sustainability have been depicted by using Recycle, Reclaim and Reuse between the three doughnuts. These clusters still need more work on the specific items of each cluster alone to improve it. This study aims at starting work on this sector for the purpose of increasing its sustainability and improving its resource efficiency.

Two techniques of modeling have been conducted in this paper. The first technique depends on using doughnut models for each cluster showing the best practices and their influence in sustainability. The three sub-models are connected to each other in a comprehensive model. The second technique is a simplified one depending on oject modeling. This technique emphasizes the common factors in the three clusters that have high impact on sustainability.

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