A Practical Model to Assess and Improve Sustainability in Stone and Marble Industry in the Palestinian Territories

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Assessing the sustainability level is now an essential procedure for improving sustainability practices in a certain industry. The stone and marble industry is one of the most important industries in Palestine, its contribution to the overall industrial revenue is 25%, and it employs directly about 25,000 workers. This paper presents a customized model to assess and improve sustainability level in stone and marble facilities. It uses an assessment tool (performance criteria) in the form of a checklist with impeded weighted scoring scale. The tool covers six main themes: energy, water, waste, transportation, site management and landscape, and human health and safety. Based on the assessment level, the model suggests a specific "To-do list" targeting the areas of improvement with the greatest potential to help the facility to improve to the next better level.

Keywords: Sustainability, Stone and marble industry, Sustainability assessment model, Sustainability indicators

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1. Introduction

The global society is increasingly facing scarce water, material, and energy resources. This raised concerns with regard to future generations and their ability to survive in the future world. The western industrial revolution increased the environmental effects since the manufacturing industry grew very rapidly, and therefore more natural resources were depleted and caused a larger amount of emissions and pollution. Moreover, the recent new wave of the Chinese industrial "revolution" drew the attention of the global community and the necessity to act as soon as possible in order to protect our planet and alleviate harm [1]. On a global scale, roughly ten billion tons of engineering materials are consumed per year. In addition, about nine billion tons of hydrocarbon fuels are consumed yearly [2]. Such huge consumption rates are expected to produce emissions of CO2 as well as other poisonous materials that mix with air, soil and water.

As a result, new initiatives and concepts have been proposed to face the aforementioned challenges. Sustainability has been one of the main concepts driving a global trend with its promising economic, environmental and social objectives [3]. The concept of sustainable development appeared initially in the early 1980s [4], and it has then popularized in the publication of the World Commission on the Environment and Development report on sustainability, which was entitled "Our Common Future". Sustainability was defined in this report as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" [5]. With this definition, all eco-friendly approaches, methodologies and researches to preserve environmental conditions and resources could be categorized under sustainability [6]. A special interest was given to the sustainability of dimensional stone industries by the Natural Stone Council (NSC) in the USA. It has issued the natural stone sustainability standards ANSI/NSC-373 in 2014 [7].

One important philosophy within sustainability is green manufacturing; it deals with maintaining sustainability's
environmental, economic and social objectives in the manufacturing domain [8]. This new concept considers redesigning manufacturing to employ various green strategies and techniques to become more eco-efficient and sustainable [9]. Such strategies include creating systems and products that consume less material and energy and are able to reduce waste and convert outputs to inputs again [10].

In Palestine, the same challenges exist in addition to the lack of awareness and absence of green practices. For instance, the wastewater network is the main method of disposing of wastewater for 67.9% of the establishments, and 95.9% of establishments do not treat the produced wastewater in their sites [11]. More than 92.6% of the establishments do not separate solid waste [11]. About 59.7% of the establishments dispose its solid waste more than 4 times a week, and the common solid waste transportation method is the traditional one [11]. Palestine suffers from a serious shortage of water and electricity and many other challenges due to the restrictions imposed by Israel, which is the source of energy to Palestine and at very high prices compared to neighboring countries [12]. In 2018, 58% of the total imported energy to the Palestinian territories was fuel and gas, and 29% was electrical energy. Although utilizing alternative energy is necessary in Palestine case, less than 13% of the total estimated amount of produced energy in the Palestinian territories was using solar energy [13].

Although these challenges place additional pressure on the Palestinian industry, sometimes constraints can be good for innovation, and it can also be a motivation to embrace sustainability [14]. Process innovation, which is defined as "...the implementation of a new or significantly improved production or delivery method" and it includes significant changes in techniques and equipment according to the Oslo manual [15], can be utilized to develop continuously cleaner production processes within the firms and across the supply chain. Nidumolu et al. [16] showed that sustainability-driven firms managed to lower costs by reducing the inputs they use and generated additional revenues from better products.

The marble and stone industry in Palestine is very important to the national economy, and it has a lot of challenges ahead. Internal and external pressures to become greener, although difficult, but it is imperative. The industry faces many environmental challenges and needs to be revamped in the long term through implementing strict sustainability measures. This will also help firms working in the industry to advance their operations and hence improve their productivity. In the marble and stone industry, the product lifecycle analysis and the specific interventions associated with each stage was a useful case to convince the industry as presented in [17]. However, a standard and practical assessment tool is needed not just to evaluate the current practice such as [18], but to advise on ready-to-use remedy practices such as the ones we have developed in the form of a To-do list in this paper.

After the introduction section, the second section presents a brief literature review about sustainable manufacturing and international best practices and the marble and stone industry in Palestine. The third section provides the research methodology, while the fourth and fifth sections present the model development and case study demonstration, respectively. Finally, the sixth section offers the conclusions.

2. Background

2.1. Sustainable Manufacturing

Responsible consumers are not just driving sustainability from the consumer side but also encouraging business organizations, industrial firms, in particular, to adopt more sustainable production [19]. Competitive sustainable manufacturing has been considered as one of the main enablers towards sustainable economic growth [20]. Although sustainable manufacturing can be pushed by tighter regulations, it can also be utilized to provide a competitive edge to the industrial firms in the specific industry [21]. Sustainable manufacturing will continue to be a key driver along with the shift towards Industry 4.0 where the resources of energy, water and materials can be managed more efficiently utilizing the intelligent systems embedded across the value chain in Industry 4.0 systems [22]. The emerging technologies can enable Industry 4.0 to have positive impacts on all the sustainability dimensions in an integrated way, such as sustainable business models, circular production systems, green supply chains, sustainable product design [23]. For instance, blockchain could help in addressing potential barriers to achieving sustainability in manufacturing systems, as discussed in [24].

There have been various initiatives to support enterprises to embark on sustainability assessment as an initial stage towards improving their sustainability level. ISO 14031 is an important standard that focuses on measuring the environmental performance of firms [25], World Business Council for Sustainable Development proposed the corporate eco-efficiency tool to enable managers to assess, measure and improve eco-efficiency performance and improve decision-making [26], and most recently UN Economic and Social Commission for Asia and the Pacific has expanded the scope of eco-efficiency indicators measurement beyond the production side and the business sector to the economy-wide level [27]. Although these standards
are useful for organizations to report sustainability, such as Global Reporting Initiative, there is room for improvement and perhaps adaptation when they are applied in real scenarios and specific industries [28]. Also, practical and well-established methodologies can be utilized as continuous improvement methodologies such as lean six sigma, as discussed in [29]; by including sustainability metrics to help firms make their manufacturing operations more sustainable. These metrics can be specific and employed as part of rigour experiments such as those presented in [30]; where Embodied Energy Eco-Cost Carbon Emission was deployed to measure the environmental impact on Waste Recycled Composite Materials.

One specific standard that promotes sustainability in natural stone industries is ANSI/NSC-373, which focuses on the sustainability assessment of quarry and natural dimensional stone processing industries [7]. Hence, different approaches are proposed to analyze and assess sustainability in industries in general [31] or in specific industry contexts [32, 33]. Product and process metrics for sustainable manufacturing are mainly considered [34]; however, the focus is usually on the process aspect of production. Therefore, concepts such as life cycle analyses [35, 36], value stream mapping [37] and materials planning [38] are utilized and usually demonstrated in a specific industry. Practical and easy to use toolkit can be useful for SMEs such as [39], where the sustainability awareness and technical expertise are low as the current case in Palestine [1].

The marble and stone industry is essential for the construction sector all around the world. But the activities of this industry have a harmful impact on the environment and the human; to alleviate this impact internationally and make it more sustainable, concerned institutions, companies and researchers have introduced and developed eco-friendly approaches that help in the preservation of the environment, natural resources and human health [7, 40–45]. The adoption of such approaches makes the marble and stone industry more sustainable. In particular, the Natural Stone Council has published a guide for best practices of the natural stone industry [46]; the guide mainly presents best practices on transportation, waste management, quarry site, and water consumption, treatment and reuse. Transportation best practices are centered on four interconnected principles: efficiency, relationships, evaluation, and sustainability. Waste best practices are built on three hierarchical principles: Produce less waste by improving production methods, exploit the value of waste by implementing strategies to reuse, recycle, compost, sell, and create new products, and manage waste properly by following lawful disposal of waste that can’t be given a second life. Quarry site best practices consider: minimizing dust, noise and Vibrations, site cleanliness and organization. As for Water Consumption best practices, each processing facility must have a strategy that includes four aspects: water use minimization, wastewater collection and treatment, water reuse, and sludge management. Implementing such practices will minimize water pollution to the most. Best practices in these categories are presented in detail in the NSC guide. Best practices in other categories, such as energy consumption, are presented in [47]. It is worth mentioning that best practices in this industry will have a positive impact not only on the environment and human health but on the economy and community as well.

2.2. Marble and Stone Industry in Palestine

Palestine, mainly the West Bank, is recognized globally for its high-quality marble and stones, which is basically limestone characterized by its attractive colors ranging from creamy to white, yellowish-white or reddish-brown. It has high water resistance, which keeps its natural colors for many years. This property makes it highly demanded in local and international markets. This industry is still considered a labor-intensive industry although automated in certain functional areas. The stone and marble industry is considered one of the most significant and most active industrial sectors in Palestine, as this sector contributes to approximately 25% of Palestinian overall industrial revenue, 4.5% of the total Palestinian GNB [48] and accounts for 20-25% of the Palestinian exports [49]. The total number of stone and marble processing facilities in the West Bank is about 1200 facility; these vary between quarries (∼ 22%), crushers (∼ 4%) and stone and marble processing facilities (∼ 74%); about 50% of these facilities are located in the southern West Bank [49]. Stone and marble processing facilities are classified according to size into 4 categories: micro facility (59%), which has 1-4 employees, small facility (25%) has 5-9 employees, medium facility (11%) has 10-19 employees, and large facility (5%) has more than 20 employees, 88% of the facilities are classified as sole proprietorship establishment [50].

The stone and marble industry in Palestine still faces many challenges including the following:

1. Large quantities of waste: it is estimated that the solid and liquid (slurry/sludge) waste generated yearly is not less than 1.24 million ton; however, insignificant quantities are recycled [49].

2. Limited resources: most of the natural rock reserves are located in area C (about 62% of the West Bank) in which both the civil administration and the security
are controlled by the Israelis, whereas the Palestinian National Authority has limited self-governance of areas A and B (about 38% of the West Bank), the stone and marble industry may face problems in the near future as the accessible rock reserves in areas A and B are being depleted, and licensing new quarries for Palestinians in area C is almost impossible [49]. Moreover, water and electricity sources are both under the Israeli authorities; the Israelis, as the sole providers of water and electricity, control the quantities to be sold to the Palestinian Authority.

3. High level of hazards to the soil, water, air and green cover: the waste resulting from cutting the limestone is mainly CaCO3. It accumulates on the soil surface and in cavities forming a hard lime-cemented layer that obstructs rainwater infiltration and plants’ roots penetration into the soil layers. The liquid waste usually streams in nearby open areas causing an increase in soil’s acidity and salinity and decrease soil’s permeability; of course all this harms the green cover. Moreover, as time passes, some of the liquid waste may infiltrate and reach the groundwater aquifer system and pollute its water content [51]. On the other hand, because of wind, the dry fine-powder is blown around and covers the soil and the surrounding green lands; this also makes the dust particles mix with the air, causing air contamination. As an example, measures of particulate matter with 10 µm or less in diameter (PM10) were taken in Jammain area in the northern West Bank where several stone cutting facilities exist, the results showed that the content is 325.0–1079.7 µg/m3, which indicates high level of air pollution when compared to World Health Organization “WHO” standard value (25–50 µg/m3). Such results lead to real public health problems, including the health of the workers on sites [52].

4. Poor safety measures: the work environment in the stone cutting facilities is hazardous; several facilities lack essential safety standards and regulations, including devices and equipment. For instance, Hussain in [33] showed that 66.8% of the facilities don’t have emergency exits, 87.4% don’t have safety-instruction flyers, 19.5% don’t have safety-guards to isolate the liquid-waste pits, only 7.7% of workers regularly wear safety helmets, 7.1% of the workers regularly use goggles, 5.5% of workers regularly use earmuffs, and 13.2% of the workers regularly wear air-purifying mask.

5. Unreliable electricity supply: the electricity supply is inadequate in some areas of the West Bank due to insufficient network capacity and/or amounts of electricity sold by the Israelis to the Palestinian Authority; this, in some cases, necessitates the use of private diesel generators to generate electricity but at a higher unit cost [48]. As stated earlier, the cost of electricity in the West Bank is high compared to neighboring countries; the 2018 electricity tariff for stone factories is $ 0.18 per kilowatt/hour, which is the highest in comparison to other local industrial sectors [54].

6. Inadequate machinery: stone cutting factories and workshops are using low-level technology, especially in northern areas of the West Bank; equipment is relatively old and needs frequent maintenance. Equipment downtime is common, which increases the production cost. In 2009, 66% of the stone and marble firms indicated that purchasing new equipment and technology represents their essential investment need [48].

7. Inefficient use of water: the water distribution system is inappropriate for the needs of the stone and marble industry; available water quantities are insufficient, especially in the southern areas of the West Bank, the Palestinian Authority is forbidden to drill new wells without prior permission from the Israelis; such permissions are very rare. In some cases, the water is delivered to firms by tankers at a higher price. Firms don’t practice efficient water management; most of the stone cutting establishments don’t have wastewater recycling systems [48], they just collect the liquid waste in special pits then transfer it by tankers and dispose it in open areas; this practice is adopted by 52% of the establishments, whereas 37% dispose their liquid waste directly to the public sewage system or the nearby valleys [55]; which means large quantities of recyclable water is wasted daily.

8. Weak awareness of sustainable production practices: the awareness of sustainable production in the Palestinian industry (including stone cutting) varies between firms; some firms already apply selective sustainable practices that would result in significant cost reduction and reflect positive financial results, while other firms seemed incurious; this indicates weak awareness and lack of governmental regulations that force firms to be sustainable [1].

Similar concerns in the region regarding this industry have been highlighted through sustainability assessment
studies with a focus on the environmental aspect. For instance, in Jordan Aukour and Al-Qinna [56] evaluated the environmental impacts of ornamental stone production and showed that noise and unsuitable solid and liquid waste disposal strategies need to be addressed urgently. Therefore, sustainability indicators and recommendations are discussed to alleviate such industry externalities [57].

Fig. 1 shows the life cycle of the stone and marble industry in Palestine, and it highlights the key sustainability themes. The process, in brief, starts with quarrying large rocks that are formed into large cubes of stones. These are transported by trucks to the cutting and shaping factories which are the key stage in this process. A lot of energy and water are used in almost all the different processes utilized to make different forms of dimension stones, which are then shipped to the construction market for internal and external uses. The aforementioned processes generate a significant volume of residues. This “waste” is usually transformed into useful products (crushed pieces) that are used in the construction market as raw building materials.

The marble and stone industry in Palestine uses approximately 0.5 million m³ of water yearly. The water is used basically in cooling the cutting saws, which is mixed with the dust and forms the slurry; its quantity is estimated to be 600 million kg annually [49]. Some of the water and the slurry are recycled but are currently limited to large factories where they have the local best practices. A considerable percentage (59%) of marble and stone processing facilities are small factories (workshops) where modern recycling technologies may not be feasible. The other main waste is the residues resulting from quarries and stone processing, which mainly goes to crushing; residues have other reuse in Palestine as in retaining walls, flooring, and sidewalks.

Despite the various challenges facing the marble and stone industry, there are still several opportunities that can be used to make this industry more sustainable and feasible, such as raising awareness and adopting best practices; this leads to cost reduction, better safety conditions, resource efficiency, and easier accessibility to global markets.

In this research, the stone and marble processing industry have been utilized as a case study to develop a customized Assessment and Improvement Model based on the green manufacturing model introduced by Deif [8] and the ANSI/NSC-373 standards [7]. This customized model uses an assessment tool in the form of a checklist with impeded weighted scoring scale. This practical tool can easily highlight the required remedial actions to improve the level of sustainability practices in the local stone and marble facilities.

The customized model developed in this study is also intended to enhance the awareness of the local marble and stone processing community about sustainability and possible remedy best practices that preserve the environment and results in cost reduction as well.

3. Research Methodology

A qualitative approach is often preferred in order to build understanding grounded in a detailed description of the phenomenon that is new and dynamic [58]. In this study, there was a need for an in-depth understanding of sustainability measures of a specific industry in a unique case. The objective of this study was to develop a tool to assess and improve sustainability level in stone and marble processing facilities. In order to address this objective, a straightforward research methodology was designed, relying mainly on the qualitative research method [59].

The development of the sustainability measurement and improvement model for the Palestinian marble and stones industry was an iterative process, which included the conceptual model development, validation, and customization. The selected industry is critical since it faces the challenge of how to adopt more sustainable practices.

The literature review associated with sustainability challenges of the marble and stone industry was used to identify sustainability measures [60, 61]. Mainly, the ANSI/NSC-373 standards [7] was very useful to develop a range of relevant sustainability indicators that suit the Palestinian case, including water, transportation, energy, waste, health and safety, and landscape and site management. Once consensus over the items had been reached, a first version of the sustainability model was developed and then it was circulated to a panel of 12 industry experts, key government stakeholders, and academic researchers to ensure content validity. The feedback from the aforementioned subject-matter experts was captured using a face-to-face semi-structured interviews.

The model was then tested in the field utilizing a pilot study which included a sample of 15 marble and stone processing facilities; a comprehensive sample was selected in accordance with the classification and distribution of stone and marble facilities stated earlier in section 2.2; the characteristics of the selected sample are as follows:

1. According to legal status; 12 facilities (80% of the sample) are sole proprietorship establishments, while 3 (20%) shareholding limited partnership company,

2. According to geographical location; 8 facilities (about 50%) located in the southern of the West Bank, the re-
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3. According to facility size; 5 facilities (33% of the sample) are micro facilities, 3 (20%) are small size, 3 medium size and 4 facilities are large size. The generated feedback from the pilot study helped in customizing the model further and in establishing the thresholds of the scoring scale in light of the recorded local best practices, which finally made the model sound to be implemented to other local stone and marble factories.

4. Development of customized sustainability assessment and improvement model

To develop a customized sustainability assessment and improvement model, the authors have utilized the previous literature, including Deif’s [8] important work and the result of the empirical part of this study. The general concept of the “System model for green manufacturing”, introduced by Deif [8], was relevant in developing an operational and practical model with a checklist and specific to-do list customized to the industry and the context of the study.

The main purpose of our model is to assess and improve the level of adopting sustainability practices in local stone/marble processing facilities. Fig. 2 shows the assessment and improvement model for the Palestinian stone and marble industry. The structure of the model consists of four components: (1) Scoring sustainability level of facility based on customized performance criteria that adopt aggregation weighted scoring scale, (2) Identifying factors (indicators) with the greatest potential for level improvement; this is done by selecting a corresponding “To-do-list” based on scoring result, (3) Improving the sustainability level of the facility by implementing relevant actions to improve the status of the identified factors (indicators), and (4) Continuing improvement by regularly rescoring and tracking the status of indicators. The performance criteria in this model are casted in the form of an assessment tool (Checklist) with impeded weighted scoring scale; the checklist adopts to a large extent the structure given in the ANSI/NSC-373 standards [7]. The criteria cover six main themes: energy, water, waste, transportation, site management and landscape, and human health and safety.

4.1. Scoring sustainability level of facility (green level identification)

The objective of this component of the model is to identify the comparative sustainability level of a certain local stone and marble processing facility, which shows the “greenness” of the facility based on the aforementioned themes. For each theme, a set of sustainable production indicators was identified; the indicators and their targets were identified based on published sustainability assessment metrics [7, 57], national and international best practices [41], national environmental regulations, and recommendations of local experts and officials. In the process of identifying the customized indicators and their targets, a field survey (the pilot study) was initially conducted and covered a sample of 15 stone and marble facilities of different sizes in the West Bank. The objective of the survey was to share con-
tent, document local best practices, track life cycle of typical products, and collect data on actually achieved targets of potential indicators. Moreover, identified indicators were classified into compulsory (required) and optional indicators, themes and optional indicators were given weights. The values of the weights were developed by soliciting opinions of subject-matter experts considering the environmental impact and the relative importance of the themes and indicators in satisfying the economic and social objectives of sustainability. This structure of themes and indicators constructed the aggregation weighted scoring scale of the model. The scoring scale may rank a certain stone and marble facility into one of five possible levels (greenness level). Each level is described by a color based on the range of the aggregate score and ordered from least to most in terms of the extent to which a facility is adopting sustainability practices. The possible levels (colors) are Black (score in the range (0.00 – 1.40)), Gray (score in the range (1.41 – 3.40)), Brown (score in the range (3.41 – 4.00)), and Green (score in the range (4.01 – 5.69)). These ranges were developed based on the results from empirical data that was generated from implementing this tool on the selected sample of small, medium and large marble and stones processing facilities in West Bank.

As indicated above, each theme has one or more compulsory indicators (requirements) that are defined as the limits of minimum performance; otherwise, the facility is ranked “Dark Black” and has to satisfy all compulsory requirements at first, in addition to the satisfaction of compulsory requirements; the level of performance (color) depends on the value of the aggregated weighted score of all themes. An Excel sheet was developed to calculate the aggregated weighted scores.

4.2. Identifying potential factors (indicators) for level improvement

The objective of the second component of the model is to help stone and marble facilities to improve to the next level by identifying potential indicators for possible improvement in the different themes; identification of potential indicators is based on scoring result (facility color); for each facility color (level) there exists a corresponding ‘To-do list’ which targets the most potential indicators for improving the sustainability level to the next, the ‘To-do lists’ can be thought of improvement plans. We have developed the “To-do lists” utilizing best practices measures specific to the marble and stones industry [7, 41, 42, 44, 47] and benefited from the interviews with local experts in the industry. As a result, the list consists of relevant, effective and reasonable measures that can be implemented in the context of the marble and stones industry in Palestine. The list is sequenced so that facilities can start with improving simple indicators that need the implementation of easy less-cost sustainable practices, and then moves toward more complex indicators that need more money and effort. The structure of the ‘To-do list’ helps local stone and marble facilities to gradually graduate from one sustainability level to the next. The flowchart shown in Fig. 3 summarizes the procedure of
assigning ‘To-do list’ for each level.

4.3. Improving sustainability level of facility

The objective of the third component of the model is to implement the identified ‘To-do-list; this requires proper actions to be taken to achieve the defined target levels of the qualitative and quantitative indicators of the identified ‘To-do-list’. The actions cover the different themes and are implemented at the operational, process and system levels, and the actions must be scheduled and carried out without reducing the productivity of the facility. The actions may include recycling, reuse, compliance with secondary regulations, adopting new techniques, and others. The importance of this stage is achieving gradual improvement of the sustainability of the facility; in other words, moving the facility from adopting low-level indicators to implementing all identified levels of indicators of sustainable production.

4.4. Continuing improvement

The objective of the fourth component of the model is to ensure that the improvements done before at a certain level are continually implemented; this is done by regularly reassessing the sustainability level of the green facility. This regular assessment is a dynamic process expected to yield new To-do actions to improve the levels of indicators in the different themes to achieve a greener facility.

5. Case study

A selected sample of local facilities was used to test the model and demonstrate its usefulness in the context of Palestinian stone and marble manufacturers. Concurrent engineering approach was utilized to develop the model, where a simultaneous testing stage was useful in the design and redesign of the model itself. The Appendix demonstrates a full example of the assessment procedure for the six themes (energy, water, waste, transportation, site management and landscape, and human health and safety).

5.1. A- Scoring the sustainability level

Each theme was assessed based on the aggregation weighted scoring scale of the model described in the aforementioned sections. In the example, the facility was eventually ranked “Gray” with an aggregated score of 1.65 (see the Appendix) which fits the range of 1.41 – 3.40 as per the reference of Gray category. The facility demonstrated few positive areas, including the use of a mechanism to collect rainwater. The facility has a list of vendors, size of the truck consideration, a number of shipments and load per shipment is taken into consideration, energy consumption is taken into consideration when purchasing a new machine, existence of techniques that increase energy conservation, the facility characterizes the scrap according to its nature, achieved 10% to 25% reduction of solid waste inventory, the facility implements recycling strategies to decrease the amount of wastes, and employees wear safety equipment which of course helps in reducing the number of injuries. However, according to our criteria, this case is still a way to go, and great improvement opportunities are ahead.

5.2. B- Identifying potential factors (indicators) for level improvement

In the case presented, and according to the assessment result, which was gray, a specific “To-do lists” number 2 was recommended. This list includes the following action:

- The facility must raise the quantity of collected rainwater to at least 20% of its water inventory. Among good practices to raise quantity of harvested rainwater is to increase catchment surface area and tank size or add new tanks.
- The facility must raise the percentage of reused water to become 61% - 79% of the water accounted in the inventory for processing operations. Among available practices that can be properly selected to increase the amount of treated water for reuse are Filter presses, cyclone separators, sedimentation systems, retention basins, or combinations of these systems [41].
- The facility must adopt proper techniques/ways to enhance water conservation. Among available good practices: Regular maintenance of pipelines and tanks to prevent leakage, proper control of equipment flow rates, regular maintenance of cutting equipment to prevent overheating, proper collection of water used in the operations, and transferring water to treatment plants through pipes or closed channels.
- The facility must start taking into consideration (optimize) the distance and location of suppliers. A good practice is to re-evaluate: Re-evaluating locations of current suppliers is essential; contracting closer alternative suppliers can help in minimizing cost and relieving negative impacts on the environment [41].
- The facility must adopt certain measures to enhance energy conservation. Among good practices are: Install electrical meters, operate machinery according to specifications, avoid multiple halts and stops, regular inspection and maintenance [42, 47].
- The facility must make careful design and measure cuts to minimize scrap. Among good related practices
are: Repair blocks prior to cutting, optimizing cutting speed, use thinner cutting discs [42].

• The facility must start actions that support office waste reduction.

• The facility must take action to achieve 26% - 50% reduction in its solid waste inventory. Among good practices are: process modification, operational changes, equipment upgrading [41].

• The facility must use techniques/ways to reduce level of dust. Among good practices are: check dull cutting saws in order not to create excessive dust, select machinery that produces fewer fines, and sweep floors regularly.

• The facility must install a ventilation system.

• The facility must start having green areas.

Once the facility implements the actions stated in “To-do list” number 2 given above, it will graduate from Gray level to Brown. In fact, the facility is expected to prepare an action plan to implement the actions given in “To-do list” number 2; the plan has to include detailed best practices to be adopted by the facility to improve its sustainability level.

5.3. C- Improving sustainability level of facility

Translating the ‘To-do-list’ items to actionable plan and incorporate it as part of the general operational planning of the firm is essential to deliver the intended outcomes. Hence, an upgrade should be achieved by targeting a higher level of sustainability as per the model criteria. This step relies on the management of the firm to take the lead, and it is suggested that dedicated meetings are held to brainstorm and propose detailed appropriate improvement initiatives and practices deploying the necessary resources and manage each as a separate project with its own team and budget.

5.4. D- Continuing improvement

As mentioned in the model description, this step is about committing to a continuous improvement process where regular auditing is performed. This will help in maintaining the sustainability level of a green facility. The recommendation as part of the case emphasized the importance of developing implementation mechanisms and assigning new roles to an existing department or establishing a new unit within the organizational structure of the firm to manage and oversee the execution of the whole process.
6. Conclusions

Implementing green production processes can improve different dimensions of sustainability measures. This paper contributes to this by highlighting the key sustainability issues for the marble and stone industry. It has demonstrated the process of the development of a customized green model to assess and improve sustainability level in stone and marble facilities in Palestine. This model goes beyond evaluating the current practice regarding sustainability as described by national and international standards. It also provides practical interventions and corrective measures to a specific industry in a unique context such as Palestine, where access to high standards, technologies, and materials is limited.

The structure of this customized model consists of four components: (1) Scoring the sustainability level of the facility, (2) Identifying factors (indicators) with the greatest potential for level improvement, (3) Improving the sustainability level of the facility, and (4) Continuing improvement. This customized model uses performance criteria in the form of a checklist with impeded weighted scoring scale. The criteria cover six main themes: energy, water, waste, transportation, and site management and landscape, and Human health and safety. The scoring scale may rank a certain facility into one of five possible levels; the levels are ordered from least to most in terms of the extent to which a facility is adopting sustainability practices; ranking thresholds were identified based on actual field data and opinions of experts. The model helps a certain facility to improve to the next level by providing it with “To-do lists”. These lists were constructed based on national best practices and green manufacturing measures.

The model was validated by implementing it to the selected sample of local facilities ranging from low to high ranks. It was found useful and easy to implement and can help Palestinian stone and marble manufacturers to improve the level of their sustainability practices.

Although this paper didn’t include a life cycle assessment to quantify and estimate savings and environmental impact. The proposed model is expected to make the aforementioned values to the industry. This would be ideal when “Stones Union of Palestine” adopts such a model with the right incentives to qualify firms according to the proposed sustainable levels in this paper. Future research studies can focus on this aspect by developing a procedure to quantify the economic, social and environmental impact associated with the interventions proposed in the to-do-lists for each level.

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### Appendices–Full Checklist

#### Theme No. 1: Water

<table>
<thead>
<tr>
<th>CHECK</th>
<th>Criteria No.</th>
<th>Required or Optional</th>
<th>Description Note: satisfying the requirements in this theme helps directly in reducing water pollution</th>
<th>Max Poss. Points</th>
<th>Weight = 0.25</th>
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<tbody>
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<td>Yes</td>
<td>X 1.1</td>
<td>Required</td>
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<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.2</td>
<td>Optional</td>
<td>Water source</td>
<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.21</td>
<td>Optional</td>
<td>The facility has a mechanism to collect rainwater</td>
<td>1 1</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.22</td>
<td>Optional</td>
<td>Total collected rainwater represents 20% of the water inventory</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.3</td>
<td>Optional</td>
<td>Water use Management (maximum 2 points)</td>
<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.3.1</td>
<td>Optional</td>
<td>A minimum of 60% of the water accounted in the inventory for processing operations is reused</td>
<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.3.2</td>
<td>Optional</td>
<td>61% - 79% of the water accounted in the inventory for processing operations is reused</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.3.3</td>
<td>Optional</td>
<td>80% or more of the water accounted for the inventory for processing operations is reused</td>
<td>2 0</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.4</td>
<td>Optional</td>
<td>Water conservation techniques and instructions</td>
<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.4.1</td>
<td>Optional</td>
<td>Existence of techniques/ways to Enhance water conservation</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 1.4.2</td>
<td>Optional</td>
<td>Existence of documented instructions to Enhance water conservation</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
</tbody>
</table>

Total points for Water: **1.50**

#### Theme No. 2: Transportation

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<th>Criteria No.</th>
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<th>Description</th>
<th>Max Poss. Points</th>
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<th>Weighted score</th>
</tr>
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<tbody>
<tr>
<td>Yes</td>
<td>X 2.1</td>
<td>Required</td>
<td>Activity tracking and management program in place for continuous improvement and data collection</td>
<td>R</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 2.2</td>
<td>Optional</td>
<td>List of vendors</td>
<td>1 1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 2.3</td>
<td>Optional</td>
<td>Size of the truck is taken into consideration</td>
<td>1 1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 2.4</td>
<td>Optional</td>
<td>Number of shipments and number of blocks per shipment is taken into consideration</td>
<td>1 1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 2.5</td>
<td>Optional</td>
<td>Distance and location of the supplier is taken into consideration</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 2.6</td>
<td>Optional</td>
<td>Usage of green materials for packaging</td>
<td>1 0</td>
<td>0 0</td>
<td></td>
</tr>
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</table>

Total points for Transportation: **0.50**
### Theme No. 3: Energy

<table>
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<tr>
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<th>Criteria No.</th>
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<th>Description</th>
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<th>Weight = 0.165</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>3.1</td>
<td>Required</td>
<td>Defined source of energy</td>
<td>R</td>
<td>0</td>
<td>0.165</td>
</tr>
<tr>
<td>X</td>
<td>3.2</td>
<td>Optional</td>
<td>Energy consumption is taken into consideration when purchasing a new machine</td>
<td>1</td>
<td>1</td>
<td>0.165</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>Optional</td>
<td>Energy conservation techniques and instructions</td>
<td>1</td>
<td>1</td>
<td>0.165</td>
</tr>
<tr>
<td>X</td>
<td>3.3.1</td>
<td>Optional</td>
<td>Existence of technique that lead to increase energy conservation</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>3.3.2</td>
<td>Optional</td>
<td>Certain measures have been taken to enhance energy conservation</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>Optional</td>
<td>The firm has renewable energy resource</td>
<td>1</td>
<td>0</td>
<td>0</td>
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</table>

Total points for Energy 0.66 0.33

### Theme No. 4: Waste

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<th>CHECK</th>
<th>Criteria No.</th>
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<th>Description</th>
<th>Max Poss. Points</th>
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<th>Weighted score</th>
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<tbody>
<tr>
<td>Yes</td>
<td>4.1</td>
<td>Required</td>
<td>Having documented waste management plan which leads to reduction in the generated scrap</td>
<td>R</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>4.2</td>
<td>Optional</td>
<td>Characterize the scrap according to its nature for potential reuse or converting to marketable new product (e.g. stone slabs, shrapnel .., etc)</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>X</td>
<td>4.3</td>
<td>Optional</td>
<td>Implement strategies to reuse, recycle, sell or create new products from the scraped material in order to decrease the amount of dumped wastes</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>X</td>
<td>4.4</td>
<td>Optional</td>
<td>Office waste reduction</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>4.5</td>
<td>Optional</td>
<td>Carefully design and measure cuts to minimize scrap</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>4.7</td>
<td>Optional</td>
<td>Follow regulations (environ. friendly way) when disposing yielded waste that cannot be given a second life</td>
<td>1</td>
<td>0</td>
<td>0</td>
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</table>

4.8 Demonstrated waste reduction (maximum 3 points)

<table>
<thead>
<tr>
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<th>Criteria No.</th>
<th>Required or Optional</th>
<th>Description</th>
<th>Max Poss. Points</th>
<th>Weight = 0.2</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>4.8.1</td>
<td>Optional</td>
<td>Achieved (10% -25%) reduction of solid waste inventory</td>
<td>1</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>X</td>
<td>4.8.2</td>
<td>Optional</td>
<td>Achieved (26% -50%) reduction of solid waste inventory</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X</td>
<td>4.8.3</td>
<td>Optional</td>
<td>Achieved (more than 50%) reduction of solid waste inventory</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

4.9 Sludge management

<table>
<thead>
<tr>
<th>CHECK</th>
<th>Criteria No.</th>
<th>Required or Optional</th>
<th>Description</th>
<th>Max Poss. Points</th>
<th>Weight = 0.2</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>4.9.1</td>
<td>Optional</td>
<td>Enhanced sludge management plan that exceeds national regulations: environment friendly reuse (like light-duty roads, re-vegetation, wall plastering)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Total points for Waste 1.80 0.6
**Theme No. 5: Human health and safety**

<table>
<thead>
<tr>
<th>CHECK</th>
<th>Criteria No.</th>
<th>Required or Optional</th>
<th>Description</th>
<th>Max Poss. Points</th>
<th>Weight = 0.165</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>X 5.1</td>
<td>Required</td>
<td>Every employee is included in the insurance plan</td>
<td>R 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.2</td>
<td>Required</td>
<td>Having a documented air emission management plan</td>
<td>R 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.3</td>
<td>Required</td>
<td>Adopting a procedure for tracking, classifying and reporting of work-related injuries and illness</td>
<td>R 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.4</td>
<td>Optional</td>
<td>Employees wear safety equipment</td>
<td>1 1 0.165</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.5</td>
<td>Optional</td>
<td>Existence of techniques to reduce Level of dust</td>
<td>1 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.6</td>
<td>Optional</td>
<td>Existence of Ventilation system</td>
<td>1 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.7</td>
<td>Optional</td>
<td>Existence of techniques to reduce Noise Level</td>
<td>1 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 5.8</td>
<td>Optional</td>
<td>Periodical examination of workers</td>
<td>2 0 0</td>
<td></td>
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</tr>
</tbody>
</table>

**Total points for Human Health and Safety** 0.99 0.165

---

**Theme No. 6: Landscape and Site management**

<table>
<thead>
<tr>
<th>CHECK</th>
<th>Criteria No.</th>
<th>Required or Optional</th>
<th>Description</th>
<th>Max Poss. Points</th>
<th>Weight = 0.12</th>
<th>Weighted score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>X 6.1</td>
<td>Required</td>
<td>The processing area (cutting ) is three way surrounded</td>
<td>R 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 6.2</td>
<td>Required</td>
<td>Facility area is pounded with walls</td>
<td>R 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 6.3</td>
<td>Optional</td>
<td>Facility includes some green areas (Trees)</td>
<td>1 0 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X 6.4</td>
<td>Optional</td>
<td>facility roads and external areas are paved</td>
<td>1 0 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total points for Landscape and Site management** 0.24 0