Assessment of Sustainability in Marble Quarry of Khyber Pakhtunkhwa Province Pakistan

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Abstract—Marble industry of Pakistan is under developed facing so many problems from initial stages of extraction at quarry to the finish product due to traditional methods and techniques used in a process. Pre-manufacturing phase of marble has an influencing effect on the quality of marble product, with the most significant factor is the technique used for extraction. Generally two techniques are used for extraction of marble industry in quarry i.e. mechanized and non-mechanized. This paper gives an analysis of extraction phase of marble to compare both techniques by Analytical Hierarchical Process (AHP) with respect to of economic, environment and societal indicators of sustainability. A framework was developed on basis significant parameters under economic, environmental and societal indicators marked by experts and researchers to find sustainability of marble industries in Khyber Pakhtunkhwa province.

Index Term—Analytical Hierarchical Process (AHP), Mechanized and Non-Mechanized Techniques, Societal Indicators, Sustainability

I. INTRODUCTION
Pakistan is blessed with different type of natural resources and minerals such as marble, gypsum, silica, iron ore, rock salt, silver, gems, copper, coal, graphite and fire clay. Marbles industry contributed significant to Pakistan GDP and its process starts with the selection of raw material on deposits with respect to the requirement of final product’s physical properties in terms of color, texture, hardness etc., then it is extracted in form of block or boulders by technique either by mechanized or non-mechanized, then transported to process industry for cutting and sizing those blocks of raw material into finish product with specific dimension (Prentice 1990, Trade 2010). Most of marble reserves in Pakistan are located at Khyber Pakhtunkhwa (KPK), mostly at Swabi, Nowshera, Bunir, Mardan and Mansera city. According to S. Mahmood (2011), the province is producing one of finest and purest grades of marble product, but due to lack of technology and mechanism in quarry phase, the industry is unable to produce as much as required by national and international market. It is estimated that there is more than 85 percent of waste produced in extraction phase of marble which is more than 45 percent as per international standard. Mining industry is searching for cheaper and rapid methods for extraction of minerals due to increased profit and pressure from the international markets (Cloe 1996, Javurek 1999).

Generally the total life of marble product can be divided into four main stages i.e. Pre-manufacturing (Quarry), Manufacturing (production), Use and Post use phase (Jaafar 2007). Quarry reflects the pre-manufacturing phase of marble product. One of the major factors which affect the quality of marble product is technique used for extraction in quarry. Extraction techniques can be divided into mechanize and non-mechanize. The former included advance technologies like diamond wire cutting, chain cutting, spiral cutting, water jet cutting, slot drilling technique and flame jet cutting, while the latter involve blasting (Singh and Rajoria 1987). Block is a regular shaped, cubical form produced by mechanized method where as non-mechanized technique of blasting producing irregular and potato shape material called boulder (Qadhi 2008). The quarries as a result of extraction process using both techniques are shown in Figure 1. Mechanized techniques are able to cut blocks at quarry with fever waste as shown in Figure 1a, whereas non-mechanized cause accumulation of debris and waste at quarry which cannot be further processed as shown in Figure 1b. There is growing need to provide quarry a sustainable environment by introducing sustainable manufacturing.

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Sustainability was defined by Brundtland (1987) in Report ‘Our Common Future’ as “the process which fulfills the needs of present without compromising the ability of future generation in order to meet their own needs”. For the three decades, it has become necessary and an important aspect for industrial sector to enhanced their research and development towards sustainable manufacturing (Hart 1995). United State department of commerce define sustainable manufacturing as “the creation of manufactured products that use processes which minimizes negative impacts on environment, conserve energy and natural resources, safe for employees, communities, and consumer and are economically sound” (Jayal, Badurdeen et al. 2010). The life cycle sustainability analysis of product can be formally find by the sum of assessment of three Performance Measurement Indicators (PMI) i.e. economic, environment and societal (Finbeiner May 2008).

Various approaches and researches for sustainable manufacturing have been adopted in different industries considering different indicators. Indicators in a group when analyzed all together provide a view of sustainability as compared to individual indicators (Joung, Carrell et al. 2012). Indicators are a set of performance measurement variables, on the basis of which decision makers categorize the actual performance and compare it to the benchmark. Global Report Initiative (GRI) is a sustainability reporting indicator set, comprising 70 indicators which are based on the main three aspects of sustainability that is environment, society and economic. (GRI 2006, Staniskis and Arbaciauskas 2009). In order to compare mechanized and non-mechanized technique in pre-manufacturing phase of marble industry on basis of PMI, an intelligent decision making tool is required for the analysis. Such tool (AHP) is a set of concepts used to give an easy way to understand and analyze the data and helps decision makers to find the best alternative on basis of criteria as a performance indicators (International Hellenic University, Côté, Salmela et al. 1993). Sustainable products are defined as “the process of making products in a more sustainable way throughout their entire lifecycle, from conception to end-of-life” (Maxwell D. 2003). In order to develop a base for sustainable manufacturing at product level, it is necessary for an industry to move forward from 3R (Reuse, Reduce, Recycle) concept to 6R concept with the introduction of redesign, recover and remanufacture (Joshi 2006, Kuik, Nagalingam et al. 2011). Introducing and initiating such frameworks requires organization to enhance the technology and process planning to minimize resources, energy consumptions, waste etc. and other resource consumption (Jawahir 2007).

This paper analyzes the processes involved in the pre-manufacturing phase of marble industry of KPK to collect the data on basis of PMI. And by application of AHP, identify the significant indicators of quarry phase, and to find the best technique used for extraction among mechanized and non-mechanized techniques.

II. RESEARCH METHODOLOGY

First hand data related to sustainability regarding marble industry in Pakistan is not available. Therefore a comprehensive questionnaire is developed to obtain the data from pre-manufacturing phase of marble industry. The questionnaire is based on the sustainability indicators grounded by Gupta A (2010) in his study related to sustainability manufacturing. The questionnaire was then distributed with 100 well known engineers and manager’s related to marble industry. A total of 70 questionnaires were received, the number of respondents from mechanized and non-mechanized industries are shown in Figure 2.

Fig. 2. Responses received from marble industries
The collected questionnaires were then statistically analyzed by measures of central tendency. The mean was selected to be used for the development of pairwise matrix. The data was subjected to a decision making tool, AHP for evaluating whether mechanized quarry is good or non-mechanized.

Figure 3 shows the preliminary flow chart used for solving this problem via AHP. In this chart, the AHP is divided into four levels, represented by zero level (L0), first level (L1), second level (L2), and third level (L3). The L0 is related to the objective which is to evaluate sustainability at pre-manufacturing phase of a marble industry. The L1 focuses on the different aspects of sustainability which is Economic, Environmental and Social. The L2 considers the different indicators such as Labor cost, Material environmental impact and Worker health associated with the sustainability aspects in L1. The fourth level on the basis of indicators gives a certain decision value related to significance of either mechanized or non-mechanized technique. The hierarchical structure for selection of technique used for marble extraction is given in Figure 3.

In order to find the best alternative in terms of technique used for extraction of raw material as in structure in Figure 4 first of all it is necessary to find the more significant criteria in form of Material Extraction (ME), Design for Environment (DFE) and Material Processing (MP). Initial matrix is related to the data obtained from questionnaire subjected to measure of central tendency (mean) is shown in Table I.

The evaluated mean was used to generate the pairwise matrix as shown in Table I. The normalized matrix is obtained by dividing each element of a column of pair wise comparison matrix by its sum as given in Table II and the priority matrix is generated by summing all elements of row in normalized matrix and finds its average given in Table III.
Consistency ratio (CR) of given pair wise comparison matrix is to make sure that the weight given to the indicators were consistent or not. For a given comparison matrix, CR=0 < 0.1, so given input data is consistent. Now in order to find the best technique (mechanized and non-mechanized) for extraction with respect to criteria i.e. material extraction, design for environment, and material processing, the input matrices and priority matrices are given in Table III, IV and V respectively.

Table III illustrates that the mechanized technique is more suitable on basis of material extraction criterion i.e. 0.62 while non-mechanized technique is 0.38 significant.

Table IV illustrates that the mechanized technique is more favorable having 0.81 score as compared to non-mechanized technique with 0.19.

Similarly, Table V considered the material processing criterion, it is resulted that mechanized technique is more significant having 0.61 positive impact. The matrix obtained from the pairwise comparison matrices of mechanized and non-mechanized technique in Table III, IV and V, when multiplied with the priority matrix of ME, DFE and MP in Table II, will be the overall priority matrix for techniques as shown in Table VI (Dr. Rainer Haas 2014).

The matrix obtained in Table VI shows that mechanized technique is 69% good for environment in quarry of marble on the other hand, it is clear that there is only 31% positive impact of non-mechanized technique on environment.

Similarly when same process of AHP is applied on the societal indicators considered in pre-manufacturing phase i.e. Worker Safety (WS), Worker Health (WH) and Ergonomics (ERG) as criteria to find the best alternatives in form of mechanized technique (MT) and non-mechanized technique (NMT), the overall priority matrix obtained is given in Table VII.

Table VII presents the comparison in a way that the mechanized technique used for extraction of marble’s raw material has more positive impact i.e. 74% on society as compared to the non-mechanized technique with 26% in terms of WS, WH and ERG. At a same time, it is also an important aspect to find an economic impact in pre-manufacturing phase of marble industry. The indicators associated with criteria are Raw Material Cost (RMC) and Labor Cost (LC) with alternatives are MT and NMT, after application of AHP the overall priority matrix obtained on basis of economic aspect will be given in Table VIII.
Table VIII considered the economic aspect concluded that mechanized technique having eigen value of 0.59 is better than non-mechanized with an eigen value of 0.41.

III. RESULTS AND DISCUSSIONS
After analysis of economic, environment and societal impacts individually, the overall sustainability of mechanized and non-mechanized techniques can be calculated by Table IX. The given Table IX, column 2 lists eight indicators followed by the eigen values of MT and NMT in column 3 and column 4 respectively. The eigen values of all indicators comes from the priority matrix of each indicator as given in Table VI, VII and VIII respectively against MT and NMT for selection. When Table IX is analyzed, it is clear that the indicator ‘Worker Health’ a societal indicator having highest value of 0.82 while the technology is mechanized as compared to non-mechanized technique with 0.18, that is because there is maximum chance of injuries in case if extraction is done by blasting process (non-mechanized technique) instead of advance methods of diamond rope cutting process, which extract the material by cutting regular blocks from reserves. Furthermore ‘design for environment’ an environmental indicator also shows a big value of 0.81 in favor of mechanized technique against 0.19 for non-mechanized as because of negative impact on environment produced by non-mechanized technique in form of debris, air pollution, soil degradation and noise pollution. On the other hand few indicators are showing positive impact for non-mechanized technique i.e. ‘labor cost’ having maximum Eigen value 0.61 for non-mechanized technique and 0.39 significant for mechanized technique. It is because mechanized machines and equipment require worker to be trained and skilled, so extra cost incurred with the training and skill development and similar trend also followed by ‘raw material cost’ in terms of high energy, capital investment required by mechanized technique.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Indicators</th>
<th>Mechanized Technology</th>
<th>Non Mechanized Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material Extraction</td>
<td>0.62</td>
<td>0.38</td>
</tr>
<tr>
<td>2</td>
<td>Design for Environment</td>
<td>0.81</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>Material Processing</td>
<td>0.79</td>
<td>0.21</td>
</tr>
<tr>
<td>4</td>
<td>Worker Safety</td>
<td>0.66</td>
<td>0.34</td>
</tr>
<tr>
<td>5</td>
<td>Worker Health</td>
<td>0.82</td>
<td>0.18</td>
</tr>
<tr>
<td>6</td>
<td>Ergonomics</td>
<td>0.79</td>
<td>0.21</td>
</tr>
<tr>
<td>7</td>
<td>Raw Material Cost</td>
<td>0.43</td>
<td>0.57</td>
</tr>
<tr>
<td>8</td>
<td>Labor Cost</td>
<td>0.39</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>5.31</strong></td>
<td><strong>2.69</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td><strong>0.66</strong></td>
<td><strong>0.34</strong></td>
</tr>
</tbody>
</table>

It is clear that MT is showing positive impact for environment and societal PMI whereas NMT is good for economic PMI. From Table IX, Overall result shows that the MT is significant having sustainability value of 0.66 in quarry phase of marble industry as compared to NMT with 0.34 on basis of economic, societal and environmental PMIs.

IV. CONCLUSION
In this paper, AHP technique was successfully applied to the priority matrices on basis of criteria resulted that Mechanized techniques are sustainably best on basis of environment and social indicators but due to high labor cost in terms of skill development and training, it is not a good choice. On the other hand Non-Mechanized technique is a favorite on basis of economic indicator as it requires fewer raw materials and labor cost, and produces negative impact on environment by generating air, water and soil pollution, also it produces negative impact on safety and human factor of worker. Overall the Mechanized techniques are more suitable for quarries of marble in KPK on basis of economic, environment and societal PMIs.

REFERENCES