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Assessing sustainable manufacturing related problems for marble facilities: an application

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Abstract

Negative impacts on people and environment should be minimized by considering all measures in marble sector where water and energy consumptions, also waste generation are very high. There is a need of systematical approaches for reducing the amount of waste material and increasing the production efficiency. Therefore, this study proposes a systematic methodology to assess marble facilities in terms of human factors, environment, and economical aspects. First, Theory of Inventive Problem Solving (Teoriya Resheniya Izobreatatelskikh Zadatch, TRIZ) method is used to solve the human factors related problems. In addition, electric energy and water consumption that are used during marble processing and marble wastes resulting from operations are also assessed in terms of economy and environment.

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Keywords: Sustainable manufacturing; marble manufacturing; energy efficiency; environment; ergonomics analysis; TRIZ

1. Introduction

The U.S. Department of Commerce defines sustainable manufacturing as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound" [1]. However, achieving sustainability in manufacturing requires a holistic view spanning not just the product, and the manufacturing processes involved in its fabrication, but also the entire supply chain, including the manufacturing systems across multiple product life-cycles

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[2]. Sustainable manufacturing is based on efficiency and seeks permanent solutions for environmental related problems. This study focuses on marble and natural stones since they are considered as non-renewable natural sources. The constraints in natural stones and sustainable manufacturing [3], sustainable development of stone and marble sector [4] and production of brick ceramic by use of powder marble [5] are a number studies in the literature considering sustainable manufacturing in marble industry. On the other hand, it is known that marble is one of the most important export products. Based on 2012 data, Turkey has a share of 40 % block marble and 29 % cut marble market. Turkey is listed as the third country in export product with a share of 16 % [6]. There are currently 1100 mining facilities, 1500 factory and 7500 workshops in the country that enables employment for 200000 people. However, most of the mining and machining processes take place in small or medium sized facilities where new and efficient technologies are not used extensively. Therefore, there is a potential to make improvements for marble industry considering sustainable manufacturing to improve efficiency and reduce manufacturing costs.

This study proposes a systematic methodology to assess marble facilities in terms of human factors, environment, and economical aspects. It is known that the variables in TRIZ are very much tied up with engineering problems. Since many of the human factors problems encountered in a manufacturing facility are found at the intersection between people, technology (equipment, machinery, computers) and work (tasks and activities that necessitate the interaction of people with technology), applying the inventive principles of TRIZ [7]. TRIZ method is proposed to deal with human factor problems and then suggestions for energy consumption of machines in use and waste materials and water. Second section of the paper introduces the steps of the methodology and third section provides the application of the methodology steps of in a marble facility. Final section summarizes the results and provides directions for future studies.

2. Methodology to assess manufacturing facilities in terms of sustainable manufacturing

The increase of population and technological development has led to speed up the manufacturing and use of limited resources. Also, as the manufacturing increases, more consumption results with environmental problems. Therefore, social, economic and environmental problems should be considered together and a systematical approach is needed to make assessment.

TRIZ is used to define and assess the problems in manufacturing environments related with human factors [8]. Likewise, this study also utilizes TRIZ to solve problems related with human factors in marble manufacturing facilities. The steps of the methodology considering human factors, environment, and economics is summarized in Figure 1. In the first step, production in the facility is determined. Then, working conditions of the workers are assessed based on human factors. When using TRIZ methodology, first, contradiction matrix and then innovative principles based on TRIZ contradiction matrix is defined. Innovative principles are applied and improvements are evaluated. In the third section, environmental effects of machines and equipment are assessed. Current system is evaluated and potential improvements for environment and economy in the fifth step. Outcomes are assessed in the final step.

2.1. Methodology to solve problems related with human factors: TRIZ

TRIZ is a methodology that is developed by Genrich Altshuller in 1946 [9]. TRIZ enables to avoid trial-error and speeds up the problem solving process [10]. Ideality is a measure of how close a system is to the best it can possibly be i.e. the ideal machine (or the ideal final result -IFR). The benefits are the useful functions provided by the system and harms are its unwanted outputs, waste products (also regarded as harmful functions) of the system. One of the objectives of TRIZ is to increase ideality (or move a system toward the IFR). The term contradiction matrix in TRIZ is a matrix of 39 technical parameters that are arranged on the vertical and horizontal axis to interact with one another. It is used to point out the 40 inventive principles, conceptual solutions to technical and physical contradictions that can be applied to solve technical contradiction [11].