Investigation of Factors Driving Manufacturing Companies to Green Manufacturing Using Direct Rating Technique

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ARTICLE INFO	ABSTRACT
	Environmental practices have been incorporated into business models and procedures in today's competitive climate, and they are now significant challenges that require attention. Businesses have undergone several changes as a result of these practices, including concerns about preserving a habitable environment for future generations and guaranteeing energy efficiency with sustainable production. To the extent that green manufacturing practices have been included into business strategies and used to inform future planning. In this context, green production practices have emerged as a crucial factor that requires careful attention from businesses. Nowadays, green production is a crucial tool for manufacturing businesses. The study investigated what motivates manufacturing companies to engage in green production practices. The goal was to weight the characteristics that were identified as driving businesses to engage in green manufacturing operations. To do this, the identified criteria were weighted using one of the multi-criteria decision analysis techniques, direct rating. The results of the application showed that "support from top management," "increasing demand for green products," and "increasing public pressure" were the main drivers of manufacturing companies' transition to green production practices.

1. Introduction

The lack of natural resources, global warming, and waste management concerns make it difficult for manufacturing enterprises to adhere to stringent environmental requirements today. Green manufacturing strategies are being adopted by firms worldwide due to growing environmental concerns and awareness [1]. Due to commerce and globalization, sustainable environmental practices have grown in significance across all industries in recent years. Environmental approaches are now crucial sustainable projects in public institutions and commercial businesses, as a result of

economic, social, and legal demands on environmental protection, energy conservation, reprocessing, production, and recycling [2].

According to Orji and Wei [3], green manufacturing is a notion that has been described as an effective approach that should be included in the production and design processes required for the development of new product strategies and production system activities that aim to reduce the negative environmental impact. Green manufacturing, according to Shrivastava and Shrivastava [4], is a system that reduces and minimizes the impact on the environment by integrating product and process design issues that affect production planning and control to define, measure, evaluate, and manage environmental waste flow. According to a different definition, this concept is the ongoing implementation of an environmental strategy to the production phases by taking the environment into account during the production process and lowering the risks to both the environment and humans [5].

Green manufacturing is an approach to ensuring the long-term viability of environmental, economic, and social objectives in the production process. Green manufacturing operations include waste prevention, reduced gas emissions, and recycling. According to the literature, the relationship between green manufacturing and sustainability is as follows: "Green manufacturing is a sustainable approach to all engineering activities carried out in order to minimize environmental impact in R&D and / or system studies." [6,7]

Green manufacturing and sustainability are closely related concepts that aim to reduce negative environmental impacts while protecting natural resources. Green manufacturing is the use of sustainable resources, energy-efficient technological items and equipment, and waste-reduction measures to produce things with the least negative environmental impact. This approach includes taking into account a product's whole life cycle (from production to disposal/recycling) [8]. In this regard, an increasing number of businesses have begun to concentrate on green manufacturing implementation in response to growing worries about pollution, natural resource depletion, and global warming [9].

Thus, companies today prefer green manufacturing and green production processes for a variety of reasons. Numerous factors have been cited in relation to this matter, including public pressure and environmental movements, government pressure (including legal pressures), pressure from environmental volunteer groups, cost increases, the pursuit of sustainable development, a rise in social responsibility, life cycle analysis, and the creation of new opportunities through environmentally conscious design [10]. In other words, companies initially adopted green manufacturing because of compelling considerations such government regulations, and subsequently to obtain a competitive advantage [11].

Green manufacturing procedures also demonstrate the business's commitment to sustainability and environmental responsibility. This can enhance businesses' status and customer loyalty, as well as attract new customers who are environmentally conscious. Furthermore, several countries have enacted legislative regulations and policies to promote the adoption of sustainable industrial techniques. Businesses who implement green production have the option to become compatible with the legislation by adhering to these standards and avoiding penalties. Green manufacturing also encourages businesses to find new and inventive ways to optimize their production processes while reducing their environmental impact. This results in the development of new technologies and processes, helping organizations to explore their inventive potential [12,13]. In fact, green manufacturing is a means of reducing waste and pollution through product and process design. The primary goal of green production is sustainability [14].

The ideal way for a company to implement green manufacturing is to regulate four essential elements: the rate of resource utilization, the scope of green energy, the rate of hazardous environmental waste, and the recycling capability of these wastes [15].   Furthermore, the green production approach provides a viable and sustainable approach to eliminate or reduce pollutants such as sulfur dioxide and carbon dioxide.   It has been described as critical in tackling global environmental challenges such as acid precipitation, urban air pollution, and climate change (Noor, 2006). Process efficiency rises due to this strategy.   Enhancing a business's process efficiency will boost profitability and have a big effect on important cost categories like energy, raw materials, and natural resources.   Quality production and substantial financial gains can be achieved in the business because it has been stated that all technological applications, production processes, machines, raw materials, auxiliary chemicals used, water and energy consumption, all types of waste production, occupational and worker health, and the negative impact on the environment can be examined and optimized [16].

The purpose of green manufacturing is diverse, including environmental sustainability, economic benefits, and customer behavior.   Green manufacturing attempts to meet sustainable development goals by lowering pollution, avoiding resource waste, and protecting the environment [17,18]. According to Khare [19], the objective of green manufacturing is also to assess the influence of green characteristics on product categories and consumer perceptions.   Green environmental elements can influence purchasing intentions by helping consumers perceive environmental benefits.   The convergence of green characteristics in multifunctional technical products/services influences consumer decision-making processes and inclinations to buy convergent products with green features. Furthermore, these applications reduce the costs of the industrialist's products, treatments, health care, and environmental cleanup; they enhance the quality of the products and process efficiency, which boosts competition.   Along with the social and economic advantages, it has also been found to enhance the company's reputation in the community [20].

The application of sustainable supply chain management strategies in the manufacturing industry has been proven to have a significant positive impact on research on sustainable service supply chains [21].   By employing green production practices, businesses can reduce direct and indirect material expenses such as fuel and raw materials; increase production efficiency; lower waste disposal costs; and increase a company's competitiveness by producing green products and green processes. Local companies thus gain a competitive edge in international marketplaces.   In addition, green product design helps to create more useable items and reduces the environmental impact of products across their whole life cycle [22,23].

By using green production to reduce industrial waste, it helps to lessen the negative effects of industrial activities on the environment.   Moreover, the recycling method lowers costs, and the company's environmentally conscious approach improves working conditions.   By altering the working environment, accidents are avoided, and workers are shielded from toxins that can lead to occupational illnesses. Green manufacturing aids in compliance with environmental regulations and boosts staff engagement.   It makes it easier to adhere to the legal requirements [24,25].

According to the relevant issues, the incentives that motivate companies to employ green manufacturing approaches are substantial.   The concept is one that should be carefully considered because it addresses critical topics such as energy efficiency and sustainability.   The study investigated what inspires Giresun province's manufacturing businesses to engage in green manufacturing approaches.   The Direct rating technique was used to determine the factors that drive green manufacturing activities. The following sections of the study focused on the literature review on the notion of green manufacturing, as well as explanations of the direct rating technique, and its

application to Giresun province. In the last section of the study, the conclusion and directions related to future studies were presented.

2. Literature review

The extensive literature review includes numerous national and international studies on green manufacturing and its applications. Some significant studies are listed below.

- Neto and Jabbour [26] presented many guidelines to improve the adoption of green manufacturing in their study on Brazilian companies.
- Yılmaz and Bozkurt [27] evaluated the environmentally friendly practices of Turkey's ISO 500 listed firms, taking into account the EU harmonization process, as well as the relationship between these practices and the companies' competitiveness and other business functions.
- Green Jr. et al. [28] showed that green manufacturing has a favorable and significant impact on environmental and economic performance in a survey of 159 manufacturing companies.
- Kamande and Lokina [29] indicated in their Tanzanian study that boosting the company's eco-efficiency will increase its profitability.
- Yazgan et al. [30] investigated the impact of clean production techniques on the performance of medium and large-scale industrial firms in Düzce province.
- Yu and Ramanathan [31] discovered that green product and process design has a favorable and significant impact on environmental performance in their study of manufacturing companies in England.
- Sáez-Martínez et al. [32] conducted a study in Spain to showcase best practices in sustainable management, green production, and renewable energy.
- Rehman Khan and Qianli [33] discovered that green manufacturing has a positive and significant impact on company performance.
- According to Karakuş and Erdirençelebi [34], businesses that include green practices and production principles into their manufacturing, consumption, and recycling processes improve their performance in all areas.
- Özcan and Özgül [35] studied the factors influencing green marketing and consumer preferences for green products.
- Ekşi and Ömürgönülşen [36] analyzed the factors influencing the adoption of ISO 14001 Environmental Management System in Antalya firms, as well as the projected improvements from the use.
- Riskos et al. [37] investigated how green product information influences consumers' green purchasing intentions.
- Sarıcı and Erikli [38] analyzed previous studies on green products, manufacturing, the economy, and sustainability.
- Ordu and Der [13] made a thermoplastic material selection based on environmental impact for green manufacture.
- D'Angelo et al. [39] evaluated the impact of green production approaches on firm economic performance, which were divided into three categories: green activities, green investments, and product type.
- Bui et al. [40] identified the traits required for improving green production performance in the textile industry and investigated the topic of performance improvement under uncertainty.

- Queiroz et al. [41] investigated the integration of lean and green production activities in the automobile sector via the lens of operations
- Chen et al. [42] conducted a study on "resource - talent - competitive advantage" within the framework of the natural resource-based view, examining manufacturing companies' "greening" problems and gaining green competitive advantage through internal motivation and identity perspectives.
- Lu et al. [43] investigated the integrated optimization of multi-pass cutting parameters and tool route using hierarchical reinforcement learning for green production.

In the extensive literature analysis, there are few research on the factors that drive businesses to adopt green manufacturing. In this regard, it is expected that the study will contribute to the literature by considering both the approach and the region and city in which it is utilized.

3. Direct rating technique

In this section of the study, the technique to be used in weighting the criteria will be discussed. In this context, explanations about the Direct Rating technique are presented in the following parts. Weighting in multi-criteria decision problems involves assigning values to criteria based on their importance level. This can be done directly by the decision maker (e.g., an expert or analyst) or through techniques developed for this purpose. The literature divides weighting procedures into three categories: subjective, objective, and hybrid forms. Subjective weighting approaches use the decision maker's or expert's judgment to weight criteria, whereas objective weighting techniques use the data structure. Mixed weighting approaches combine subjective and objective processes [44]. However, most decision makers and experts are unfamiliar with the multi-criteria decision analysis methodologies utilized to solve decision problems. This condition makes the evaluation procedures for some approaches appear complex to evaluators, reducing the validity of the evaluations. In such circumstances, effective results may be achieved by simple and understandable techniques.

One technique that might be utilized in this context is Direct Rating Weighting [45–48]. A scale of 1 to 100 will be utilized in the Direct Rating technique in this study. The following procedures will be performed during the use of the Direct Rating technique [46].

Step 1: The criteria and experts are defined.

Step 2: Experts assign importance ratings to the criterion, with 1 indicating the lowest and 100 representing the highest value. Accordingly, v_{kj} represents the rate of j-th criterion determined by k-th experts, where $j = 1, …, n$ and $k = 1, …, r$.

Step 3: The expert ratings are combined with the geometric mean as shown in Eq. (1), where r is the number of experts.

$$v_j = \sqrt[r]{\prod_{k=1}^{r} v_{kj}} \tag{1}$$

Step 4: The integrated importance values are converted to criteria weight values with normalization based on total sum of values as shown in Eq. (2).

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \tag{2}$$

The criterion weight coefficients obtained via Eq. (2) will take values between 0 and 1.

4. Findings

The factors that drive manufacturing companies to adopt green manufacturing practices were evaluated in the study. An MCDA model was created to assess the factors that drive businesses toward green manufacturing. Expert suggestions and previous studies in the literature were used to identify the factors that drive businesses toward green manufacturing. Weighting the criteria was required because the determined criteria did not have the same degree of importance. In this case, factors that drive businesses to use green manufacturing were identified using the experts' opinions and literature reviews. Then they were ranked in order of significance using the Direct Rating technique. Three experts, including managers of manufacturing companies, provided their opinions to determine the criteria.

The criteria were determined using expert opinions and studies from Cengiz et al. [49], Sözüer [10], Turhan et al. [50], Sangwan and Choudhary [11], and Cao et al. [51]. Table 2 lists the criteria and expert judgments of the criteria's importance levels.

Table 1

Criteria and expert judgments

Criteria	Expert 1	Expert 2	Expert 3
Increasing Public Pressure (C_1)	100	75	85
New Laws and Regulations on Green Practices (C_2)	100	65	85
Increasing Awareness of Environmental and Social Responsibility of Businesses (C_3)	50	75	55
Giving Emphasis to Approaches and Technologies Preventing Environmental Pollution (C_4)	50	55	55
Increasing Demand for Green Products (C_5)	100	75	90
More Efficient Use of Energy and Recycling (C_6)	50	90	55
Top Management Support (C_7)	100	80	90
Easy Disassembly and Separation (C_8)	50	65	55
Environmentally Sensitive Purchasing (C9)	50	55	60

The evaluations of the experts were integrated by applying the geometric mean. Then, the criteria weight values given in Table 2 were obtained.

Table 2

Weights of criteria

Criteria	The integrated importance value	Weight coefficient	Rank
C1	86.0650	0.1362	3
C2	82.0561	0.1299	4
C3	59.0833	0.0935	6
C4	53.2801	0.0843	9

C5	87.7205	0.1388	2
C6	62.7854	0.0994	5
C7	89.6281	0.1419	1
C8	56.3312	0.0892	7
C9	54.8481	0.0868	8

Table 2 shows that the most important criterion is the support from top management. Moreover, "Increasing demand for green products" is the second most crucial criterion.

4. Conclusions

Factors driving manufacturing businesses to green manufacturing are vital in solving critical issues such as sustainability, environmental protection, and energy efficiency, and are seen as components that must be carefully evaluated. These factors include crucial components for ensuring sustainable output. Green manufacturing, which is based on green thinking, is a concept that addresses green production and sustainability issues simultaneously. It has become a major topic because of pollution and environmental issues caused by rapid industrialization. The goal of green manufacturing is to provide people's needs while minimizing the environmental repercussions of production activities in all sectors, and to maintain this status.

According to the study's findings, "support from top management" is the most crucial driver for businesses to engage in green manufacturing operations. The findings are consistent with previous studies conducted by Ma et al. [52], Li et al. [53], and Gull et al. [54]. To be effective in green manufacturing, a company's senior management must have an in-depth awareness of environmental problems. Top management must ensure that employees at all levels of the organization are routinely informed about the environment, and that production, legal, and social activities in this regard are coordinated [55].

Another key driver for green manufacturing is the "increasing demand for green products." The findings are consistent with previous studies conducted by Peng et al. [56] and Román-Augusto et al. [57]. Businesses should use environmentally friendly recyclable raw materials, switch to renewable energy sources instead of depleting ones, adopt clean production principles, and incorporate green marketing strategies such as green product, green price, green distribution, and green promotion into all marketing endeavors in accordance with the sustainability principle. Businesses must do more than simply adopt green practices. The number of vendors with established green practices shall increase. When businesses select suppliers who have implemented green strategies, other suppliers will change their plans to match the green knowledge to maintain customers. Businesses must inform consumers about environmental issues as part of their social responsibilities in promotional activities, as well as support the development and implementation of projects aimed at providing education and development to create environmentally friendly consumer awareness within the context of a waste-free understanding of sustainability [58].

It also has an impact on businesses' increased understanding of environmental and social responsibility, their concentration on methods and technology that prevent pollution, and the development of green purchasing levels with more efficient energy consumption and recycling. At

the same time, it demonstrates the importance of businesses in the manufacturing sector prioritizing sustainable product development and cooperation in their products, reflecting this in their manufacturing processes, and explaining this process to consumers via the marketing department to ensure sustainability. Implementing green manufacturing processes is also critical for improving environmental performance and operational efficiencies. Manufacturing firms in Giresun province reduce waste through green production while also protecting resources. Manufacturing companies should prioritize investments in emissions-reducing technologies and procedures. Green manufacturing approaches can help businesses decrease environmental hazards while also improving long-term sustainability.

In this context, the study examined the factors that influence manufacturing companies' shift to green manufacturing. The findings can be used as a guide for all companies and stakeholders involved in topics such as green production/sustainability, the environment, and energy efficiency, not just manufacturing companies. The study's findings have substantial implications for theory and practice, emphasizing the need for firms to adopt holistic approaches to sustainability that include both production processes. Despite the study's limitations, the findings give significant recommendations for businesses seeking to implement sustainable practices and improve their supply chain operations for long-term success in an increasingly environmentally conscious society. The study can also be considered crucial in terms of developing a green industrial paradigm. This study can be assessed in the future using additional multi-criteria decision-making approaches, as well as parametric or non-parametric methodologies. It can also be improved by including fuzzy logic, and the results can be discussed through comparison.

Data Availability Statement
The data is provided in the study.

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