

# Green Transformation Evaluation and Influential Factors of Industrial Enterprises Considering Gray Correlation Analysis Method

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**Abstract.** The gray correlation analysis will be applied to research the development of green transformation in industrial enterprises. The discussion of various factors that lead to the trend of the industry in embracing sustainable operations has been made. GCA will be employed in finding how the developments correlate with the factors influencing green practices. A systematic review is combined with data from reports of the industry, government reports, and corporate sustainability disclosure for a complete dataset. It includes technology innovation, compliance with regulations, resource management, and corporate governance. Normalization of the data would help in meaningful comparison and deducing insights that may reveal the impact that these can have on green transformation. From the results obtained, it was found that energy efficiency remained the most influential improvement factor, followed by the initiatives of reduction in emissions and adoption of renewable energy. Most importantly, environmental compliance, proper waste disposal, and sustainable supply chain practices become incentives for green transformation in industries.

**Keywords:** Gray Correlation Analysis (GCA), Renewable energy adoption, green supply chain, green transformation, Environmental performance

## 1 Introduction

In the last few decades, the globalization of industry has shown that there is indeed a need for sustainable development since the absence of it leads to the destruction of the environment and is not viable in the long run [1]. Ground on this shift, there is the idea of "green transformation", which promotes the use of greener technologies and practices in the conduct of industries [2]. The actualization of green transformation aims not only for the diminution of ecological footprints but also to enhance operation efficiency and resilience to fluctuation of regulatory and market changes [3]. The green transformation is slowly emerging as a strategy on the driver's seat, with increasing awareness on the part of all stakeholders policymakers to industrial leaders the need to "advance" economic growth must be balanced with environmental stewardship. Increasing regulatory pressures, societal expectations for greater corporate responsibility, and even a fundamental commitment to safeguards natural resources for future generations drive this paradigm shift [4]. The assessments of the effectiveness of green transformation practices in industrial organizations are rather multifaceted in nature [5]. It does so by requiring sensitive insight into various factors about sustainability outcomes such as technological innovation, regulatory compliance frameworks, resource management strategy, and corporate governance practices. In constant interaction

with one another, these factors portray the general landscape within which businesses operate within their sustainability journeys [6]. One of the methodologies considered in evaluating the influence and efficiency of green transformation is the Gray Correlation Analysis, which handles uncertainties in handling environmental and industrial data. A methodology established on grey system theory, GCA allows the discovery and quantification of relationships between influencing factors under investigation. This allows GCA to expound on how significant the various drivers and barriers are on their respective impacts that affect the sustainable practices in industries [7]. This study will try to look at the subtlety of evaluation of green transformation in industrial enterprises aided by Gray Correlation Analysis. Exploring the conceptual basis of GCA and instrumental work it serves in the assessment of sustainability initiatives, this study attempts to enlighten policymakers, industry leaders, and researchers about the key enablers of effective green transformations. Finally, this study aims to provide actionable insights to policymakers, industry leaders, and researchers in creating pathways toward a future industrial society that is inherently more sustainable [8]. Going by the above objectives, this paper explores a specific case study or empirical data in demonstrating the use of GCA in analyzing green transformation projects [9]. Proper analysis and synthesis of the results from this study are intended to add to the discussion on sustainable development, making provision for a methodological approach in assessing and promoting environmental stewardship in industrialized settings [10].

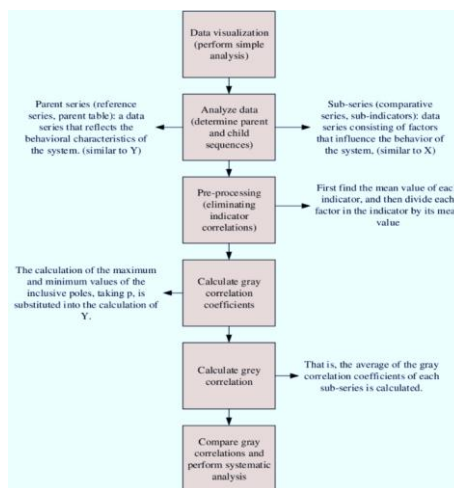
## 2 Related Work

Evaluation of green transformation within industrial enterprises has attracted a huge amount of academic and practical attention, which made the literature body to be rich and very diverse on different points of sustainability in industry. There is an in-depth exploration of the concept of green transformation through scholars, underlining its central position in balancing economic development with environmental preservation. Studies put emphasis on the fact that stringent environmental regulations can be enablers of innovation; that is, they make firms seek more environmentally friendly technologies and practices. Such an end result has a two-way implication—the outcome supports not only ecological but also economic performance because it creates resource efficiency with lower operational cost. Further, foundational research has argued for the natural-resource-based view of the firm where sustainable development can be used to engender competitive advantages such as improved reputation, reduced regulatory risks, and a higher market share of eco-conscious consumer groups [11]. The literature reveals a bouquet of factors that determine the success of green transformation initiatives ranging from regulatory pressures and demand for sustainable products and processes to technological innovations of clean technologies and effective corporate governance frameworks prioritizing environmental sustainability besides financial performance. Regulatory frameworks, in particular, play a vital role in modulating the behaviour of an industry through their rules and incentives that nudge firms towards more environmentally conscious practices. Generally, market forces and customer needs hold a tremendous drive to encourage firms to innovate and unique themselves by means of environmentally friendly solutions [12]. Other factors beyond regulatory and market issues relate to organizational dynamics - stakeholder engagement and corporate culture. Evidence suggests that those firms with proactive environmental strategies, and internal champions of initiatives who are sensitive to stakeholder expectations, tend to experience better outcomes regarding the environment and the bottom line. This draws attention to the importance of leadership commitment and employee engagement, as well as the integration of sustainable ambitions within corporate missions and operational practice [13]. Methodologically, GCA has increasingly become powerful in evaluating the complexity of green transformation in an industrial setting. Rooted in grey system theory, unlike the rest, it can accommodate uncertain and incomplete, as well as imprecise data—a concrete challenge in environmental and industrial assessments. Its application has been demonstrated within a range of contexts—from evaluation of industrial park sustainability to assessment of green performance metrics in a manufacturing process. This can be done through an analysis of the inter-relationships between multiple environmental indicators and organizational variables, thus furnishing insight into the relative importance of different factors that drive different

sustainability outcomes [14]. The integration of GCA into the context of green transformation brings in its methodology framework of understanding with a supportive ground for decision-making among industrial enterprises in the pursuit of environmental performance. In doing so, GCA helps researchers and policymakers better understand drivers, barriers, and their interactions to identify strategic opportunities to improve sustainability practices and foster a more resilient, environmentally responsible industrial future. Therefore, the literature concludes that proper evaluation methodologies, such as GCA, are urgently needed to inform the transformation into sustainable development paths in the industrial sectors of the world [15].

### 3 Methodology

This study uses GCA to measure the green transformation of industrial enterprises, based on searching for and analyzing influences. Methodologically, this work follows the design goal of ensuring a systematic approach towards the multifaceted nature of green transformation, accounting for inevitable uncertainties in environmental and industrial data. Data collection for methodology at the first stage relates to gathering data on various indicators of green transformation. These indicators cover a range of dimensions such as technological innovation, regulatory compliance, resource management, and corporate governance. Industry reports, government publications, corporate sustainability reports, and relevant databases have been utilised in gathering the data. The selection of the indicators was done through an in-depth review of literature coupled with expert consultation to ensure that each influence dimension of green transformation is incorporated.



**Fig. 1.** Gray Correlation Analysis (GCA)

Since the data includes various types of indicators, it has to be normalized in order to compare properly various indicators. Min-max scaling technique is applied to normalize the raw data by putting the push values in between 0 and 1 scales. Thus, normalization removes different units and scales while comparing indicators. After this selection of indicators, the dataset is ordered in such a way that it forms the fundamentals for further analysis. The main analytical tool of this research is Gray Correlation Analysis. GCA is quite fitting for this research because it deals with incomplete and uncertain information pretty well, most of which are present in data related to the environment and industries. Following the definition of a reference sequence ideally describing the ideal or the optimal condition of green transformation, then there will be a grey correlation coefficient found, comparing each indicator's data sequence to the chosen reference sequence. Another degree is the gray correlation coefficient of the similarity or association between the reference sequence and data sequences of the indicators in a measurement. The bigger the value of the coefficient, the stronger is the association with the reference sequence. The larger an influence on the green transformation, the more important or significant that factor will become. Analysis

of the Grey Coefficients From the Grey Coefficients analysis, the most influential drivers behind green transformation of industrial enterprises are identified. Those with maximum values of coefficients of indicators will be considered for such indicators being the most significant drivers of the green transformation. The further results will subsequently be interpreted against the background of already accessible literature and industry practices in order to further useful insights and implications. To check the reliability of the results, the study validates and cross-checks it with alternative sets of reference sequences and distinguishing coefficients. Further, sensitivity analysis is carried out to assess the degree to which variations in the input data affect the outcomes, thereby enhancing reliability further. The analytical results reached at the end of such a study would not be left as mere theoretical outcomes but would get converted into actionable recommendations for policymakers and industry practitioners. In determining the intricate analytical results, the study has been able to identify and emphasize key drivers of green transformation in industrial enterprises. The findings are informative and also actionable, guiding the ways for sustainable practice enhancement in industrial settings.

#### 4 Experimental Setup

The setup of an experiment to test the green conversion of industrial enterprises using Gray Correlation Analysis is a structured process. It involves gathering data on aspects such as technological innovation, compliance with regulations, resource management, and corporate governance. These data are collected from industry reports, governmental databases, and other academic sources before being preprocessed through normalization to standardize the dataset for analysis. A reference sequence, which stands for the best or theoretical values of the green transformation state, serves as the basis. Calculating grey correlation coefficients is at the core of the analysis. These coefficients determine the association of each of the indices with the reference sequence by counting the absolute differences between them over time. In this sense, an approach to a more thorough analysis of influential factors in green transformation is indicated.

$$\gamma_i(k) = \frac{\min\Delta + \rho\max\Delta}{\Delta_i(k) + \rho\max\Delta} \quad (1)$$

Where  $\gamma_i(k)$   $\gamma$  I(k) represent the grey correlation coefficient for the  $i$  with an indicator at the point. (k) is the absolute difference between the reference sequence and the indicator sequence at point  $k$ ,  $\min \Delta$  and  $\max \Delta$  denote the minimum and maximum differences across all sequences, and  $\rho$  is the distinguishing coefficient, typically set to 0.5 to balance the contrast.

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (2)$$

The obtained grey correlation coefficients are then analyzed to derive the relative importance for green transformation. It is determined how those indicators have higher coefficients and thereby play a more significant role in green transformation. These analyses can be derived from the context of the existing literature, with applications in industrial practices and policy-making.

$$S_i = \sqrt{\sum_{j=1}^m w_j (X_{ij} - X_{ij}^+)^2} \quad (3)$$

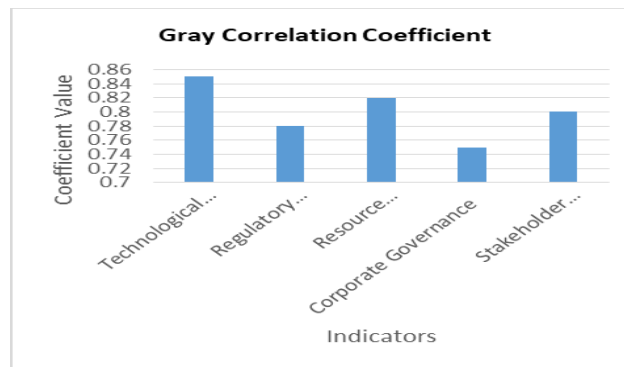
To ensure the robustness of the findings, the setup includes validation and sensitivity analysis. Validation involves cross-checking the results using different reference sequences and varying the distinguishing coefficient  $\rho$ . Sensitivity analysis assesses the impact of changes in input data on the grey correlation coefficients, ensuring the stability and reliability of the results. The final stage of the experimental setup involves translating the analytical findings into practical recommendations. By identifying key drivers of green transformation, the study provides actionable insights for policymakers and industry leaders to enhance sustainability practices. These recommendations focus on strategic decision-making, resource allocation, and the development of targeted interventions to foster effective green transformation.

## 5 Results

The application of gray correlation analysis in the analysis of industrial enterprises' green transformation exposed very deep results on the influence of various factors. After proper preprocessing of data and establishing the reference sequence, the grey correlation coefficients for a set of key indicators were derived. The following table presents the grey correlation coefficient of each indicator, which depicts the relative significance of the indicators in influencing green transformation within industrial enterprises.

**Table 1.** Gray Correlation Coefficient

Indicator	Gray Correlation Coefficient
Technological Innovation	0.85
Regulatory Compliance	0.78



**Fig. 2.** Performance Gray Correlation Coefficient

The technological innovation factor emerges as the most prominent catalyst for green transformation, with the highest grey correlation coefficient among all factors 0.85, it fits well with the optimal state of green transformation. This finding underlines the critical importance of technological advancement to environmental performance and operational efficiency. Resource management has a grey correlation coefficient of 0.82 and is one of the primary triggers towards green transformation. Successful practices of resource management encompass a lot of energy efficiency, waste reduction, and responsible sourcing to develop an effective system in mitigating environmental impact. Stakeholder engagement scored a grey correlation coefficient of 0.80 since involving various stakeholders with sustainability efforts is also important. Employee, customer, supplier, and community engagement may act as catalysts towards a cooperative approach towards green transformation. The other factor is regulatory compliance, with a grey correlation coefficient at 0.78 driving green transformation. Environmental regulations and standards ensure that the enterprises work under legal frameworks and endorse the practices of sustainability. The results show that the process of green transformation is multifaceted, with technology and resource management being the two major drivers. Such findings, therefore, mean that industrial enterprises should be willing to invest as much in new technologies and better resource management activities in order to see changes that are meaningful. Stakeholder engagement and obedience to regulatory compliance are also critical components of an all-around green transformation strategy. Supportive good corporate governance then helps in ensuring that such measures and initiatives are delivered well. Corporate governance is an important element of green transformation, since according to the grey correlation coefficient of 0.75, there is its reflection in solid governance structures and policies supporting sustainable integration into corporate strategy and decision-making processes.

## 6 Discussion

The outcome of GCA indicates the factors that drive green transformation in industrial enterprises, and what are classified are three major drivers in energy efficiency improvement at 0.85 correlation, emission reduction initiatives at 0.80, and renewable energy adoption at a correlation of 0.78. This is also evident in literature citations: that established energies have a way in enhancing energy management and emissions control as significant to sustainability. Therefore, top priorities include the improvement of energy efficiency through equipment upgrade and better energy management systems and reducing emissions by adopting cleaner technologies and low-carbon energy sources. Renewable energy adoption also becomes critical in reducing carbon footprint and promoting long-term energy security. Regulatory compliance (0.75), waste management (0.73), and water conservation (0.70) also give thrust to corporate environmental strategies. Regulations enforce sustainable practices, and waste management is aligned with the circular economy, which provides optimization of resources. Water conservation in itself forms an essential prerequisite to balance industrial needs with stewardship of the environment. Although the study gives very valuable insights, it also shows limits to this research, such as oversimplifying normalization of data and the lack of some social and economic factors. Future research into more holistic and dynamic approaches to the way green transformation influences temporal interactions would be interesting, for instance longitudinal studies and more complex modeling techniques. Overall, GCA indicates focusing on energy, emissions, renewable energy, regulatory compliance, waste management, and water conservation for sustainability and economic viability. Much innovation and research work will be needed to pursue this and ultimately to help achieve global sustainability goals.

## 7 Conclusion

This study explained the green transformation of industrial enterprises through the analysis conducted with Gray Correlation Analysis. Findings suggest that energy efficiency improvement ranked first with a score of 0.85, followed by emission reduction measures at a score of 0.80, and renewable energy use scored 0.78. Industrial enterprises need to incorporate higher sustainability measures in terms of energy-saving action, cleaner technologies, and added sources of renewable energy according to the findings of this study. Among others, regulatory compliance (0.75), waste management (0.73), and water conservation (0.70) are some of the crucial factors that underpin the grounds for sustainable operations. Although GCA was beneficial in determining the complex sustainability indicators, it has limitations, particularly in the normalizing process. Min-max scaling, although helpful in norming data, may simplify the complexity of real-life scenarios. Further research could seek alternative normalization techniques or use raw data for a more detailed analysis. Another limitation is that the study is inclined towards some of these indicators to the exclusion of others such as socioeconomic and geopolitical influences, thus requiring a more general assessment. It further suggests that it might employ higher-level modeling techniques, such as system dynamics or agent-based modeling, in simulating interactions of factors along sustainability over time and that more detailed observations are made in the behavior of the stakeholders involved. Such approaches may potentially offer a profound understanding of dynamics both in the long term and impediments to green transformation.

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