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Multi-Criteria Decision-Making Model to Achieve Sustainable Developmental Goals in Industry 4.0 for Smart City Infrastructure

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Abstract

Due to a shortage of funding and other market challenges, Small and Medium-sized Enterprises (SMEs) face difficulties in adopting new technologies. Numerous technological obstacles negatively impact the long-term commercial achievement of SMEs. The deployment of Industry 4.0hopes to resolve these technological challenges. A sustainable city is a complex structure where economic, societal, and ecological components interact and compete. There is a scarcity of l methodologies for measuring interactions in this complex structure. Industry 4.0 aims to obtain higher performance effectiveness, profitability, and automation. The main goal is to develop a reliable method of evaluating small and medium-sized enterprises (SMEs) adopting Industry 4.0 technologies, particularly concerning smart city applications. This paper aims to determine the influence of Industry 4.0 in fostering economic efficiency and sustainability amongst these SMEs. The study introduces a multi-criteria decision-making (SC-MCDM) system designed to test an SME's achievement of their targeted sustainable developmental goals. A technique for computing the interaction between various standards, i.e., (static interactions and dynamical pattern resemblance), as well as the weightage of variables of every indicator generated by the connection, is included within SC-MCDM. Furthermore, applying the suggested technique is validated by assessing the sustainable development goals of twelve Chinese cities within the Triple Bottom Line (TBL) paradigm. From a geographic-temporal viewpoint, spatial variations in city sustainability reveal regional sustainable inequalities. Indicator scores suggest that the most significant factors for most communities are the lack of research spending, falling financing in stationary assets, shortage of financial development, and inadequate shared transit. Furthermore, the growth of tertiary industries, improvement of energy performance, expansion of green areas, and reduction of pollution emissions are key driving forces for enhancing sustainability. Compared to other methodologies, Multi-Criteria Decision Making (MCDM) considers the interplay between conditions. This is why it is an excellent approach to assess the sustainability of any city. Our experimental findings highlight the impact of MCDM and sustainability towards achieving a city's sustainable development goals. Compared to other methods, the SC-MCDM system is more successful rate of 89.7%, a more sustainable rate of 92.1%, a more precise ratio 93%), more accurate (95%), and a less mean absolute error, and mean squared error rate of 8.3% while trying to achieve sustainable city development goals.

Keywords: Sustainable Developmental Goal; Sustainable City; Industry 4.0; Multi-Criteria Decision Making.

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1. Introduction

Industry 4.0 has revolutionized several industries by integrating modern technologies like the Internet of Things (IoT), Cyber-Physical Systems (CPS), and big data analytics. The advancement of smart cities is one area that benefits greatly from this change, as it has great potential to improve urban infrastructure, increase sustainability, and stimulate economic growth via new technologies. However, Assessing SMEs' endurance and effectiveness in such an environment is challenging. Sustainable cities play a critical role in strategic sustainable development; thus, they have assumed a prominent role in implementing this concept. This is represented clearly in the Sustainable Development Goal 11 of the 2030 Plan of the United Nations, which seeks to make cities more sustainable, adaptable, accessible, and safe [1]. The concept of a sustainable city has been discussed for over three decades. Many stakeholders are keen on identifying scientific and practical solutions for deploying a sustainable city [2]. Sustainable urbanization remains a difficult problem due to inputs often required from legislators and political decision-makers, particularly in formulating and implementing regulatory processes and effective governance towards stimulating innovation and supervising progress made amongst sustainable communities [3].

The fourth industrial revolution, known as Industry 4.0, includes smart factories as a key element to improve efficiency in part production. New technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), web crawling and robotics, are being incorporated into traditional manufacturing processes as part of Industry 4.0. AI, IoT, and robotics represent only some of the cutting-edge technology used in a "smart factory," a highly automated manufacturing facility in Industry 4.0. Smart factories implement digital technologies to boost productivity and efficiency. IoT, AI, web crawling and robotics are just a few of the cutting-edge technologies used in today's "smart factories," which are additionally highly automated and connected to improve the effectiveness of production. To facilitate continuous monitoring, analysis, and decision-making, machines and equipment in an Industry 4.0 "smart factory" are interconnected and communicate with one another and a central control system [4].

Decision-making analyses can be carried out using multi-criteria and metaheuristic methodologies, which have been developed as part of this SC-MCDM. These analysis techniques enable the resolution of multi-criteria problems, both symmetric and asymmetric. As a result, the search time is decreased, and the symmetry reshapes the decision space. Consequently, this research aims to categorize the uses of multi-criteria and metaheuristic approaches.

However, a systematic and exhaustive evaluation of performance measures is still lacking in the literature [5]. This research aims to fill this gap by highlighting the implications of the Industry 4.0 revolution on SMEs [6]. It describes how Industry 4.0 can assist SMEs overcome a variety of technical obstacles and boost their long-term success.

From a larger viewpoint, evaluating a sustainable city may be considered an MCDM issue [7]. The construction of an evaluation system, selection of a weighting technique, and determination of the aggregating operators are three primary phases in the MCDM procedure that are required for assessing the sustainability of a city. An index system incorporating economic, societal, and ecological factors (Triple Bottom Line (TBL)) is often used to determine sustainable developmental activities. A weighted approach is computed by applying five measures, i.e., Analytical Hierarchy Procedure (AHP) [8], Entropy Methodology [9], DEMATEL Methodology [10], TOPSIS [11], and Coefficient-Variation Mechanism (CVM) [12].

MCDM ultimately produces an aggregated value. Numerous operators are available to accumulate criteria and weights, including Ordered Weighted Aggregating (OWA) [13], Induction Ordering Weighted Aggregating (IOWA) [14], Dense Weighted Aggregating (DWA) [15], and Intuitionistic Fuzzy Weighted Geometrical Aggregating (IFWGA) [16]. In this regard, any MCDM can combine all indicators with various units in an acceptable manner. Furthermore, many studies overstate the MCDM issue by assuming that markers are independent of one another and ignore their interdependencies. The assessment findings can be greatly skewed if the interdependencies are significant.

This paper introduces three significant inputs to enhance work in this area further. Firstly, it gives actual evidence of the assessment of city sustainability for a particular instance, focusing on the interplay between criteria. Secondly, it adds to the theoretical approach without verified techniques for measuring the interaction between criteria, particularly dynamic trend similarities. Thirdly, it offers policymakers academic consequences about using assessment to enhance environmental sustainability. This is why this research includes the relationship between criteria in the technique to determine the sustainability of a city.

- The paper discusses the issues that plague small and medium-sized businesses (SMEs), such as a lack of capital and technological hurdles. It emphasizes Industry 4.0's potential as a response to these problems. Recognizing the relevance of technical progress to the long-term success of SMEs, this article introduces Industry 4.0 principles and technologies intending to improve their economic efficiency and sustainability.
- This paper details creating a Multi-Criteria Decision Making (MCDM) system that can evaluate the progress toward SDGs made by small and medium-sized enterprises (SMEs). Both static interactions and dynamical pattern

similarities are incorporated into this MCDM system, among other criteria and indications. It not only provides a thorough framework for assessing and measuring sustainability in SMEs, but it also gives these indicators weight.

- Within the Line (TBL) paradigm framework, this framework findings shed insight into regional differences in urban sustainability and highlight important elements shaping urban sustainability. This paper highlights the potential of multi-criteria decision-making (MCDM) to assist cities in meeting their sustainability objectives.
- SC-MCDM incorporates a method for calculating the interaction between different standards (static interactions and dynamical pattern similarities) and the weightage of variables of each indication produced by the connection. The Triple Bottom Line (TBL) paradigm is used to evaluate the sustainable development objectives of twelve Chinese cities, providing more evidence for the viability of the proposed method. Spatial differences in city sustainability indicate regional sustainable inequities from a spatial-temporal perspective.

The remaining parts of the article are laid out in the following fashion: In part 2, we will discuss the historical context of a sustainable city and its long-term objectives. Within this part, the Sustainable City uses Multi-Criteria Decision Making (SC-MCDM) that is presented, constructed, and theoretically proven. In the fourth section, the findings of the experiments and the system's effects are shown graphically. The discussion of the results and the conclusion are explained in Section 5. Table 1 states the Nomenclatures and abbreviations.

Table 1. Nomenclature and abbreviations

MCDM	Multi-Criteria Decision Making
SMEs	Small and Medium-sized Enterprises
TBL	Triple Bottom Line
RMSE	Root Mean Square Error
MSE	Mean Square Error
CVM	Coefficient-Variation Mechanism
IoT	Internet of Things
AI	Artificial Intelligence
IOWA	Induction Ordering Weighted Aggregating
DWA	Dense Weighted Aggregating
AHP	Analytical Hierarchy Procedure
PCA	Principal Component Analysis
PLR	Packet Loss Ratios
NSSP	National Strategy Smart Project
SC	Smart City
SWARA	Step-wise Weight Assessment Ratio Analysis
CoCoSo	Combined Compromise Solution
BWM	Best-Worst Method
BD	Big Data
SF	Smart Factories
IT	Information Technology
PSO	Particle Swarm Optimization
SDGs	Sustainable Development Goals
PLR	Packet Loss Ratios

2. Background of a Sustainable City and Its Long-Term Objectives

Sustainability in whatever form may assist in developing ideal circumstances for addressing corporate and environmental concerns of the 21st century, among many others. Regarding its administration, planning, construction, evolution, and administration within the sustainability framework, sustainable cities face various problems, conflicts, and obstacles.

This paper examines each ingredient required for a sustainable and functioning city [17]. The system follows a straightforward strategy by elucidating each sustainability concept, emphasizing its underlying principles, and elaborating on why it is an essential choice for city planning. The system evaluates the present sustainable cities by providing justifications for their advantages and descriptions of their weaknesses.

This report assesses 28 European capital cities [18]. The research synthesized 32 parameters into 4 elements using the clustering technique and Principal Component Analysis (PCA) and then generated ranking ratings. Depending on this ranking value, the European capital cities were ranked. These data assist cities in understanding their position relative to other cities, allowing politicians to discover places for improvements while capitalizing on areas of strength.

A systematic technique for assessing urban sustainability in developing nations is available [19]. Using Iraq as a test case, a stakeholder-driven structural technique discovers and evaluates context-relevant signals and sets weights for collecting indication values using an Analytic Hierarchical Process (AHP). The system is anticipated to play an important role in promoting the durability of the constructed landscape.

This research comprehensively examines the benefits associated with trees [20]. Trees contribute to the improvement of health and social well-being through several means, such as the reduction of air pollution, the alleviation of stress, the promotion of physical exercise, and the facilitation of social relationships and communities. As urban weather conditions continue to escalate, the presence of trees has the potential to alleviate urban warming. Animals are provided with both shelter and sustenance. Trees have a crucial role in both stormwater management and green architecture.

The proposed sustainability assessment methodology incorporates building information and energy simulation modelling [21]. The comprehensive sustainability assessment relies on a well-defined mathematical technique and a focus on user accessibility. The study's results indicate that the utilization of the multiple-level weight structure in this approach has the potential to reveal regional variations.

A revolutionary smart city platform design has been widely discussed and researched [22]. Testable theories regarding efficiency metrics are first gathered and examined regarding the queue length, including power consumption, battery lifespan, latency, variance, and Packet Loss Ratios (PLR).

Another article investigates green building evaluation tools from a social standpoint [23]. Consequently, this study aimed to construct a system of social criteria backed by classifications and metrics for evaluating sustainable growth in structures. The suggested framework was combined with the current green construction analysis tool to enhance the appraisal of sustainable buildings to achieve growth in the constructed landscape.

This paper provides a dependable smart city resource delivery system at the platform's edge [24]. To improve the accessibility, stability, and protection of smart city systems, the solution employs a collaborative method, including dispersed network edges and private mediation nodes with the assistance of intrusion detection technology.

This paper evaluates sustainable city facilities created by the Korean National Strategy Smart Project (NSSP) against those provided in 15 towns in Australia and London [25]. The use of 5G telecommunications technology and the development of its information format define NSSP services. Smart city plans have recently included steps to make cities sustainable and actions to create promising industrial regions, which need collaboration between publicly available and construction technologies.

We examine how to construct citizen and resource-centric stronger cities by relying on current Smart City (SC) growth activities that include proven use cases, future SC planning processes, and SC application development services [26]. SC's primary characteristics are presented in the context of current technological progress, specific municipal needs, and dynamics. This approach is intended to be implemented into real-world SC developmental initiatives.

After introducing the Step-wise Weight Assessment Ratio Analysis (SWARA) and the Combined Compromise Solution (CoCoSo) and evaluating them with Z-numbers, Hosseini Dehshiri et al. [27] presented a hybrid decision-making approach. The findings of this research highlight the significance of laying a solid technological foundation for the successful application of blockchain in agricultural SCs, integration at all SC levels, and the adoption of sustainable practices. The findings further emphasize the relevance of encouraging collaboration and partnership among various SC stakeholders by establishing conducive regulations and enabling pooled investments in infrastructure development to create sustainability and competitive advantage.

The criteria for incorporating blockchain technology into the supply chain (SC) were evaluated using a decision-making technique based on the best-worst method (BWM) that was proposed by Hosseini Dehshiri et al. [28]. This method first compiles the thoughts of DMs in nine independent processes and then uses separate BWM models to assign weights to each criterion. The research also develops two decision-making procedures that may be used in individual and group settings: nonlinear goal programming-based BWM II (NGPBWM II) and linear goal programming-based BWM II (LGPBWM II). This research offers a novel BWM-based group decision-making strategy for assessing blockchain technology evaluation criteria in SCs. The study's findings validate the NGPBWM II approach through numerical examples and highlight its utility for evaluating blockchain technology in the context of the automotive supply chain. Sousa et al. [29] conducted a literature review on MCDM approaches to guide decisions concerning the regional, national, and local implementation of the 2030 Agenda for Sustainable Development and attaining the UN Sustainable Development Goals. The decision problem related to the SDGs, the MCDM methodological approach (such as the use (or lack thereof) of fuzzy set theory, sensitivity analysis, and multistakeholder approaches), the MCDM application context, and the MCDM classification (whether utility-based, compromise, multi-objective, outranking, or other MCDM methods) were all considered. The extensive use of MCDM techniques in intricate settings proves they can aid decision-makers in resolving multi-faceted challenges related to major concepts within the 2030 Agenda.

The impact of I4.0 technologies [30] on the completion of the SDGs has not been thoroughly or methodically studied. Researchers may assist policymakers in updating and harmonizing policies and strategies in many sectors (e.g., education, industry, and government) with the SDGs if they have a firm handle on the connection between I4.0 technologies and the SDGs. This study aims to fill this void by examining how I4.0 technologies might help achieve sustainability goals.

When formulating hypothetical outcomes and methods to attain them, sustainable cities look farther ahead. Environment, Information and Communication Technology (ICT), and urbanization are three major macro-shifts rapidly reshaping society and driving the push toward a long-term perspective. Realizing a connection between these developments, sustainable cities worldwide have established far-reaching objectives and devised various strategies to attain them.

- This research investigates how SMEs might utilize Industry 4.0 to overcome technological challenges. This breakthrough indicates a way for SMEs to use cutting-edge technologies to boost their bottom lines in the long run.
- One significant advancement is the development of SC-MCDM or Sustainable City Multi-Criteria Decision Making. This method provides a thorough framework for evaluating the extent to which SMEs meet sustainable development goals, considering various indicators and their interplay.
- Twelve Chinese municipalities' sustainable development plans are evaluated, proving the paper's point on the efficacy of the SC-MCDM system proposed. This exemplifies its broad applicability and draws attention to disparities in regional sustainability and important elements impacting city sustainability beyond only SMEs.
- The current research demonstrates the superiority of the SC-MCDM system over alternative methods for precision, accuracy, and sustainability assessment. It contributes to the study of urban sustainability by providing a method that is more likely to succeed in the long run, to be exact and accurate, and to achieve the desired results in sustainable city development.

2.1. Gap Analysis and Contribution of the Paper

2.1.1. Gap Analysis

The present study exposes an imbalance in current urban planning methods by highlighting that several sectors require sustainable urban expansion, such as energy, transportation, and waste management, which are rarely coordinated. The research additionally emphasizes the importance of making judgments in urban development based on objective criteria instead of subjective beliefs.

2.1.2. Contribution of the Paper

This paper presents a framework to achieve sustainable urban development by integrating Industry 4.0 technologies with MCDM techniques. Secondly, it aids in making decisions that align with the SDGs, where the suggested framework considers numerous criteria, including environmental effect, economic feasibility, and social equality. Lastly, the framework fills a void in present urban development methods, where there is frequently a lack of integration between the many sectors involved in sustainable urban development, by permitting a more data-driven and integrated approach to such development.

3. Proposed Sustainable City using Multi-Criteria Decision-Making System

This study focuses on the three primary components of Industry 4.0, namely Big Data (BD), Information Technology (IT), and Smart Factories (SF). All these characteristics have a substantial relationship with the manufacturing and operations of SMEs to boost their success. These components, coupled with an intelligent manufacturing unit, can enable SMEs to overcome technical obstacles and enhance their long-term commercial success.

The sustainable Industry 4.0 structure is shown in Figure 1. It demonstrates that five aspects of Industry 4.0 substantially influence manufacturing and operations. Production and activities have a substantial impact on the success of production services. This demonstrates that it improves the effectiveness of industrial operations. The literature demonstrates that it positively affects manufacturing and operations and improves efficiency. Smart City Multi-Criteria Decision-Making (SC-MCDM) uses efficiency, sustainability, and relevance to smart city goals to choose its criteria. Economic efficiency, social stability, technological innovation, environmental impact, and infrastructural resilience are usually key requirements. To justify investments and guarantee cost-effectiveness, economic efficiency is evaluated. The environmental effect assesses the sustainability of activities, which aligns with global aspirations. Enhancements to inhabitants' quality of life, guaranteeing inclusion and safety, are indicators of social well-being. The efficacy of cutting-edge technology is measured by technological innovation. To keep operations running amid interruptions, infrastructure resilience is essential. Weighed and standardized according to their significance, these criteria are derived from literature research, expert consultations, and stakeholder engagement. They are validated via pilot testing and feedback to ensure they are suitable and successful in reaching smart city objectives.

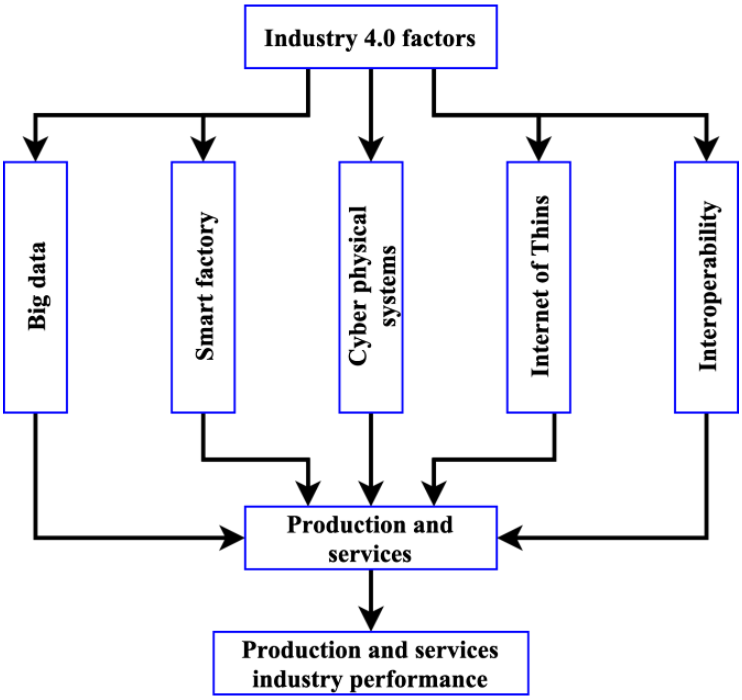

Figure 1. The sustainable industry 4.0 structure

This paper's Sustainable City Multi-Criteria Decision Making (SC-MCDM) framework provides a decision-making framework that considers sustainability criteria when implementing Industry 4.0 technologies in manufacturing and operations. Thus, it relates to the Sustainable Industry 4.0 structure in Figure 1.

Specifically, as shown in the Sustainability Assessment block of Figure 1, the SC-MCDM framework can assess and select Industry 4.0 technologies and solutions that align with sustainability goals. To aid in making decisions that align with the SDGs, the framework considers several variables, such as environmental effect, economic feasibility, and social equality. There is congruence between this and the Sustainability Goals section of Figure 1.

Big Data

Big Data's relationship to Industry 4.0 is that it requires gathering and analyzing massive volumes of data from various sources. Machines, sensors, and processes generate vast data essential to Industry 4.0.

Industry 4.0 uses Big Data to learn more about improving production, product quality, and customer satisfaction. Data analytics and machine learning all aid predictive maintenance, production optimization, and better decision-making.

Information Technologies

Cloud computing, the IoT, and artificial intelligence are just a few examples of the many IT technologies directly bearing on Industry 4.0. The goal of Industry 4.0 would not be possible without these innovations.

Technology (IT) components are used in "smart" factories to set up networks between various pieces of equipment. To gain insights and automate processes, data collected in real-time by Internet of Things sensors is stored and processed in the cloud, where AI algorithms evaluate the data. With the help of IT, all of the parts of the production process may talk to each other and work together.

Smart Factories

Smart factories are key to the notion of Industry 4.0. They are emblematic of the evolution of factories into automated, efficient, and networked workplaces.

Smart factories optimize production with the help of technologies like robotics, IoT sensors, and state-of-the-art control systems, all of which find use in the context of Industry 4.0. These plants are distinguished by their responsiveness to immediate changes in customer demand and their overall versatility. They allow for better resource management, less downtime, and higher-quality output. The collaborative utilization of the SC-MCDM framework by government agencies, private enterprises, and non-profit organizations holds the potential to facilitate the development of urban areas that exhibit enhanced sustainability and resilience. This aligns with the Collaboration section depicted in Figure 1, emphasizing the imperative of intergroup cooperation to achieve sustainability in the context of Industry 4.0.

The research proposes the SC-MCDM framework as a tool for implementing the Sustainable Industry 4.0 structure depicted in Figure 1. This framework incorporates sustainability goals and stakeholder participation, providing a decision-making framework for operationalizing the above structure.

3.1. Evaluation Process

The main aim of this study is to propose a methodology for quantifying the level of inactivity among criteria by integrating static interactions and dynamic trend similarities. Furthermore, this research approach assessed the sustainability endeavours undertaken by 1w municipalities in China over the past five years. This study's assessment approach encompasses data standardization, implementation of a weighting scheme, and utilization of an aggregate operation. Meanwhile, the determination of the weighting scheme is contingent upon the Orness judgments, which arise from the intricate interplay of several factors. Furthermore, the IOWA operation is the aggregating approach employed to elucidate the evaluation procedure, with the essential steps expounding in the subsequent sections. The MCDM framework uses the Induction Ordering Weighted Aggregating (IOWA) model to aggregate and prioritize the sustainability criteria. The complete assessment it provides by considering different weighing elements and its capacity to manage complicated decision-making situations with many criteria led to its selection. Combining ordered weights and aggregation functions, the IOWA method expands upon conventional aggregation approaches. The goal is a more organized set of decision criteria aggregated in a form that represents their relative significance. Simple and medium-sized enterprises (SMEs) may get useful insights about their sustainability performance from this technique, which applies to real-world scenarios. It provides a transparent and organized review process that aids in decision-making.

3.2. Selection Criteria

The absence of a clear definition, vagueness of certain aspects, and lack of standard indicators for developing city sustainability criterion systems were significant. However, TBL incorporates economic, societal, and ecological components and is commonly acknowledged for evaluating the sustainability of a city. To pick indicators for the construction of the criterion framework, variables utilized in this study must satisfy the conditions: (1) Measures have an immediate or indirect link with urban sustainability; (2) they may designate distinct economic, societal, and ecological properties; and (3) data are available and quantifiable. Due to data limitations, 21 variables were derived from statistical handbooks. These 21 indicators were chosen to balance the depth and breadth of this study and cover all the method's subject areas. Selecting these 21 indicators might be biased depending on the criteria used. The results could not represent the SMEs' actual performance if the indicators don't align with the study's primary goals. Many important aspects could influence the success and longevity of small and medium-sized enterprises (SMEs) in a smart city setting, but limiting the research to only 21 indicators runs the risk of missing some of them.

C(1,1) and C(1,2) were chosen to represent the economic expansion and advanced level of independent cities as one of the requirements for financial stability. C(1,3) accurately reflects the advancement of the service sector; C(1,4) reveals the town's level of financial openness; C(1,5) was chosen to reveal a city's financial system's capabilities of expanding procreation; C(1,6) demonstrates a city's level of innovation assistance; and C(1,7) reveals the state of employment and labour. Regarding social sustainability, C(2,1) symbolizes the rate of population expansion within a city; C (2,2) was chosen to represent the schooling support of an autonomous community. C (2,3) and C (2,4) depict the current state of healthcare centres and doctors in the city; C (2,5) and C (2,6) depict the degree of sociocultural connectivity; and C (2,7) show the present system of social health coverage. C(3,1) and C(3,2) were chosen for the ecological sustainability stage to represent the scenario of vegetation spaces within a city; C(3,3) must reflect the utilization productivity of manufacturing wastes; C(3,4), C(3,5), and C(3,6) accurately depict the discharge quality of wastewater, air demography, and dust emissions generated by commercial advancement; and C(3,7) reveals the power effectiveness of a city. Table 2 states the terms and meanings of all the terminologies. To provide a more all-encompassing depiction of the Industry 4.0 setting, it would be beneficial to include components like connectivity and CPS in the research. This more holistic view might capture more facets of smart city infrastructure and the performance of SMEs. Incorporating these elements permits a more thorough examination of the effects of CPS and linked systems on efficiency and sustainability. Potentially, it may show how various parts of the smart city ecosystem interact. The integration of connection and CPS brings new measurements and data points. By providing a more complete view of the elements impacting sustainability and performance, this extended data set has the potential to improve the accuracy and reliability of the conclusions. The research may mitigate the effects of bias caused by using an oversimplified collection of indicators if it uses a more comprehensive set of variables. The complex impact of Industry 4.0 technology may be better captured in this way.

Table 2. Terms and Meaning

Terms	Meaning
$p_{xy}(t)$	Beginning information of the substitute x
$p_{xy}(t)$	= {0,1}
V_y	Order-inducing component resulting from the combination of criteria for indication y
W_y	The weighted factor of the indication with the y^{th} longest ordering parameter V_y
$q_x(t)$	Reflect the alternative's assessment value in the period t
$p^s{}_{xy}(t)$	Represents the static interactions
$p_{xk}(t)$	Are determined using Grey Grid
S_{xu}, S_{xy}	Trend modification of criteria
$p^{"}{}_{xy}(t-1)$	Second-order differentiation
T	Total samples
n	Dimensions
$p^d{}_{xy}.$	Normalized indicator
w	Weight function

3.3. Weighting and Aggregation Methods

This condition must be considered since existing anomalies in the criterion often impact evaluation findings. Let p_xy (t) represent the beginning information of the substitute x for indication y in the year t, whenx∈(0,1,2,⋯,n), n is the number of sustainable towns assessed,y∈(0,1,2,⋯,m), m is the number of markers assessed, and t∈(0,1,2,⋯,T) is the number of years examined. The research used Equation (1) when the greater the criteria value, the greater the outcome (or indication of advantage). The paper discusses how the proposed scheme, the Particle Swarm Optimization (PSO) algorithm, differs from the more traditional Multi-Criteria Decision Making (SC-MCDM) approach. SC-MCDM and PSO are useful; however, they solve distinct problems and have different applications. PSO is an optimization technique, while SC-MCDM makes decisions in multi-criteria settings. No information is given in the text on the precise differences between the proposed SC-MCDM system and traditional PSO. Decision-making analyses can be carried out using multi-criteria and metaheuristic methodologies, which have been developed as part of this SC-MCDM. These analysis techniques enable the resolution of multi-criteria problems, both symmetric and asymmetric. As a result, the search time is decreased, and the symmetry reshapes the decision space. Consequently, this research aims to categorize the uses of multi-criteria and metaheuristic approaches.

$$p_{xy}(t) = \frac{p_{xy}(t) - \left(p_{xy}(t)\right)}{\left(p_{xy}(t)\right) - \left(p_{xy}(t)\right)} \tag{1}$$

The normalized indicator x data for substitute y in the given year t is represented by$p_{xy}(t)$. The highest and lowest values for marker x over all years t are $\left(p_{xy}(t)\right)$ and $\left(p_{xy}(t)\right)$, respectively, where $\left(p_{xy}(t)\right) = \{p_{1y}(t), p_{2y}(t), \cdots, p_{ny}(t)\}$, and $\left(p_{xy}(t)\right) = \{p_{1y}(t), p_{2y}(t), \cdots, p_{ny}(t)\}$. Take note that $p_{xy}(t) = \{0,1\}$. In circumstances where the smaller the criteria value, the higher the outcome (or cost indication), the system used Equation 2.

$$p^*{}_{xy}(t) = \frac{\left(p_{xy}(t)\right) - p_{xy}(t)}{\left(p_{xy}(t)\right) - \left(p_{xy}(t)\right)} \tag{2}$$

Considering that the IOWA operation might indicate a preference, it combined the standard information. Assume $q_x(t)$ reflect the alternative's assessment value in the period t. A translation $R^m \longrightarrow R$ that such $w_y \in \{0,1\}$ and $\sum_{y=0}^{m} w_y = 1$ is an IOWA operation of dimensions m with an accompanying weighted vector. The output function is shown in Equation 3.

$$q_x(t) = f\{(V_1, p_{x1}(t)), (V_2, p_{x2}(t)), \cdots, (V_n, p_{xn}(t))\} = \sum_{y=1}^{m} W_y p_{xy}(t) \tag{3}$$

where V_y is the order-inducing component resulting from the combination of criteria for indication y and W_y is the weighted factor of the indication with the yth longest ordering parameterV_y. The input data is denoted as $p_{xy}(t)$.

The IOWA process of the proposed system is shown in Figure 2. It has a weighting system and aggregation operator. The data from the source is computed using IOWA, and the results are evaluated and plotted. Calculating the interaction between the conditions of indication y and each other yields the order-inducing parameter V_y. This research distinguished between static connections and dynamical trend similarities in terms of interaction. The stationary interactions among criteria are the length between a criterion and a substitute in year t. The dynamical trend similarities are described as the resemblance of alternatives that change as a tendency over time. First, the research establishes important criteria for assessing the long-term viability of SMEs in the context of Industry 4.0. Economic results, environmental impact, technological advances, and societal effects are all possible indicators. There is a weight given to each criterion that represents its significance in the overall assessment. Expert consultation, stakeholder comment, and quantitative analysis are used to set weights. There is a correlation between the weights assigned to each decision-making criterion and their implied importance. The IOWA approach allows sorting the criteria by significance or performance score. The ordering has a crucial role in determining how the criteria are aggregated. The ranking follows the importance of the criteria and how they affected the outcome.

When faced with making a decision involving numerous criteria, considering the interconnections between them might be beneficial, as exemplified in the context of Stationary Link-Based Many Criteria Decision Making (SC-MCDM). The proposed methodology utilizes the inverse Hamming value between parameters to ascertain the static link.

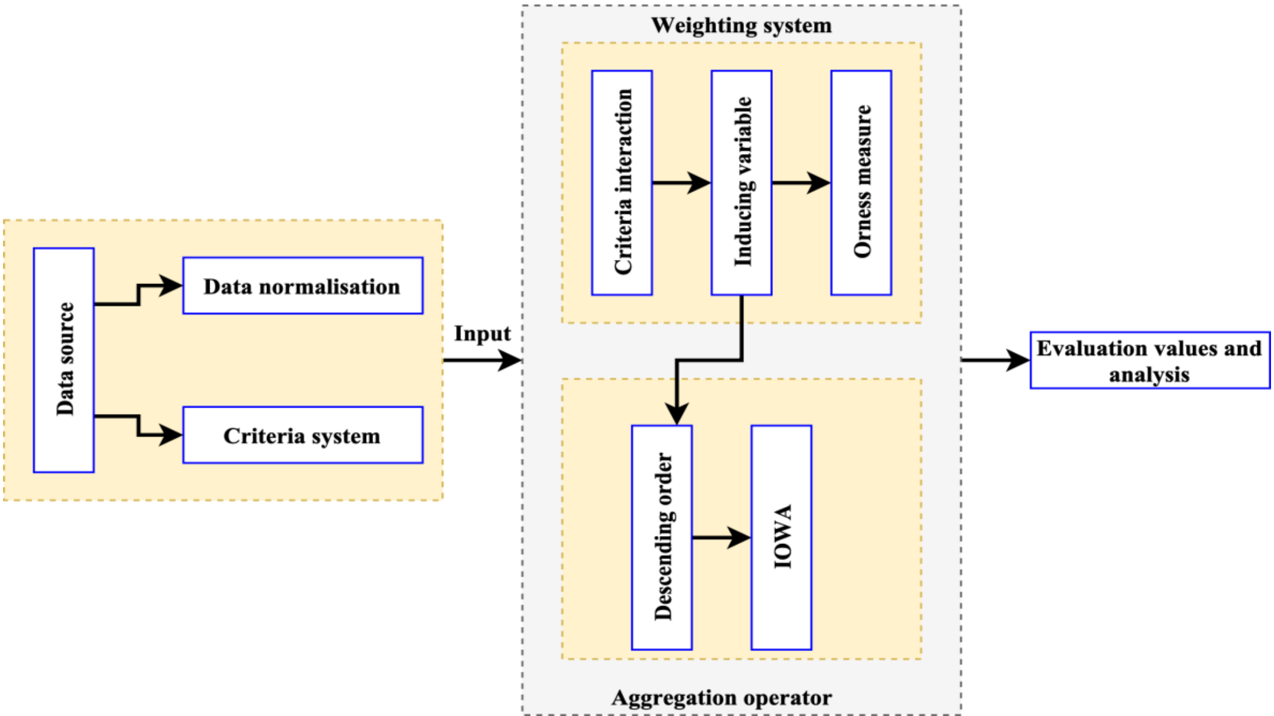

Figure 2. The IOWA process of the suggested system

Figure 2 depicts the IOWA method, which uses a weighting system and an aggregation operator to compute the source data. We can use this information to determine the order-inducing parameter V_y, which represents the relationship between the y-indicator conditions.

In SC-MCDM, the distance between a criterion and its substitute in year t describes the static links between the criteria. This means that the distance between criteria is employed to establish the relative weight of each factor. The inverse Hamming value between each parameter, a measure of the distance or dissimilarity between the criteria, is then used to determine the static connection.

Because of this shared emphasis on computing the interaction and importance of criteria in decision-making, the IOWA method and SC-MCDM are closely related. SC-MCDM employs the distance between criteria and their substitutes in year t, whereas the IOWA process uses the order-inducing parameter V_y. Both strategies intend to offer a methodical and impartial approach to decision-making considering various factors. All the variables and their meanings are shown below in Table 3.

Table 3. Variables and meaning

Terms	Meaning
$p_{xy}(t)$	Normalized indicator x data for substitute y in the given year t
$p^*_{xy}(t)$	Smaller criteria and higher outcome indicators
V_y	Rank
W_y	Weight
p^s_{xy}	Statistic indicator
p^d_{xy}	Dynamic indicator
S_{xu}, S_{xy}	Trend modification of criteria
$C_1, C_2, \cdots, C_n$	Criteria
$x_{y_1}, x_{y_2}, \cdots, x_{y_n}$	Best criteria
$x_{w_1}, x_{w_2}, \cdots, x_{w_n}$	Worst criteria
O	Orness
m	Decision maker
y	Magnitude
$\frac{1}{Tn-n}$	Ordering factor

The static connection is then computed using the inverse of the Hamming value between each parameter. This circumstance is expressed in Equation 4.

$$p^s_{xy}(t) = \frac{m-1}{\sum_{k=1}^{m}|p_{xy}(t)-p_{xk}(t)|} \tag{4}$$

where $p^s_{xy}(t)$ represents the static interactions of the substitute x for criteria y in the year t and $p^s_{xy}(t)$ is greater than zero, the static interactions (m) are superior. The dynamical trend similarity is denoted as $p_{xk}(t)$ are determined using Grey Grid Interaction Modeling (GGIM). The normalized indicator is denoted $p_{xy}(t)$. The dynamical condition is determined by Equations 5 and 6.

$$S_{xy}(t) = p'_{xy}(t) - p''_{xy}(t-1) \tag{5}$$

$$p^d_{xy} = \frac{1}{Tn-n}\sum_{t=0}^{T-1}\sum_{x=1}^{n} sgn(S_{xu}, S_{xy})\frac{1+|S_{ux}|+|S_{xy}|}{1+|S_{ux}|+|S_{xy}|+\left||S_{xu}|-|S_{xy}|\right|} \tag{6}$$

S_{xu}, S_{xy} reflect the trend modification of criteria u for alternative x, and criteria y for alternative x, while $sgn(S_{xu}, S_{xy})$ indicates the sign function, i.e., if $S_{ux}, S_{xy} > 0$, the $sgn(S_{xu}, S_{xy}) = 1$,; $sgn(S_{xu}, S_{xy}) = -1$. The dynamical trend similarities between option x and criteria y are denoted by p^d_{xy}. Clearly, as p^d_{xy} approaches $\{-1,1\}$, the pattern of condition x similarity among all standards increases over the period. The total samples are denoted T, and the dimension is denoted n. The first-order differentiation is denoted $p'_{xy}(t)$, and the second-order differentiation is denoted $p''_{xy}(t-1)$. The ordering factor is $\frac{1}{Tn-n}$, essentially the interactions between numerous criteria, is then calculated by Equation 7.

$$V_y = \frac{1}{(T-1)(2n)}\left\{\sum_{t=1}^{T-1}\sum_{x=1}^{n}\left(\frac{p^d_{xy}-(p^d_{xy})}{(p^d_{xy})-(p^d_{xy})} + \frac{p^s_{xy}-(p^s_{xy})}{(p^s_{xy})-(p^s_{xy})}\right)\right\} \tag{7}$$

The static indicator is denoted p^s_{xy}. The total samples are denoted T, and the dimension is denoted n. The exponential constant is V_y. The dynamical trend similarity among option x and option y is denoted p^d_{xy}. If $w = \{w_1, w_2, \cdots, w_n\}$ is the weighted array in decreasing order inspired by their triggering parameters and is denoted as $\frac{1}{(T-1)(2n)}$, and $w_y > w_{y+1} (y = 1,2,\cdots, m-1)$. The weight function is denoted in Equation 8.

$$w_y = \frac{f(V_y)}{\sum_{y=1}^{m} f(V_y)} \tag{8}$$

The exponential constant is denoted V_y, and the decision-making function is denoted $f(V_y)$. f(.) > 0 if f(.) is an emotional character variable that reflects the decision maker's desire for interactivity among criteria. Specifically, the system defines it as the exponential constant (V_y), $f(V_y) = (V_y)^k$. Since the system prioritizes those with greater engagement, $k > -1$. Yager's Orness variable is determined as y and is used to show the preferences for interacting among variables such as Orness. The Orness variable is shown in Equation 9.

$$O = \frac{1}{m-1}\sum_{y=1}^{m}\frac{(m-y)(V_y)^k}{\sum_{y=1}^{m}(V_y)^k} \tag{9}$$

The exponential factor is denoted V_v, and the total sample size is denoted m. The decision-making function is denoted $(V_v)^k$. The bigger values of O(w) indicate that the MCDM provides a weighted factor to the larger connection criteria (V_v). Smaller values of O(w) imply collected scenarios in which the decision maker (m) prioritizes the interactions as determined as k with the smallest magnitude (y). All the variables and their meanings are shown below:

3.4. Multi-Criteria Decision-Making Analysis

Using the SC-MCDM approach, the previous section's framework was then analyzed. By the SC-MCDM technique, professionals were entrusted with evaluating the facilitation of the big group and that of the subgroups. It was possible that the professionals would be unable to eliminate ambiguity and cope with uncertainty during the pairwise comparisons phase.

Instead of providing a specific number for a comparison between the two capabilities, a range was supplied. The method for performing the SC-MCDM is described here.

Step 1: This procedure included completing the circumstances to be addressed for problem-solving. In this case, a set of criteria (C_1,C_2,⋯,C_n) was used to choose available alternatives.

Step 2: Assignment of the best and worst criteria: This phase included assigning the Best and Worst parameters to the Primary Group and all its Subgroups. The primary groups are shown in Equations 10a and 10b.

$$X_Y = \{x_{y_1}, x_{y_2}, \cdots, x_{y_n}\} \tag{10a}$$

$$X_W = \{x_{w_1}, x_{w_2}, \cdots, x_{w_n}\} \tag{10b}$$

The best and worst criteria are shown as x_{y_1} *and* x_{w_1}.

Step 3: A range rather than a specific number was supplied in establishing the paired assessments. For instance, the relationship between enablers Y and W was provided as a range between 2.4 and 3.6. Consequently, an optimal value within this region was determined rather than a fixed number.

Step 4: Identifying the optimal option: The approach was used to discover the optimal solution for the given situation.

This method guaranteed the preservation of ambiguity and assisted decision-makers and operators in predicting sustainable adoption facilitators' most favourable impact values.

The flowchart below in Figure 3 describes that Multiple-criteria decision-making (MCDM) involves weighing potential courses of action using several standards. There are a few steps involved, some of which may be:

- The process of determining the issue at hand or the choice that must be made;
- Specifying the standards or benchmarks against which the review will be conducted;
- Placing a weight on each of the criteria to show how important they are in comparison to the others;
- Consider each potential option and assign a rating or score based on each criterion;
- Compiling all the marks or ratings into a single total to produce an overall rating for each option.

In this paper, the researchers use MCDM to evaluate the sustainability of twelve Chinese cities using the Triple Bottom Line (TBL) framework. The MCDM system was developed to determine how different criteria interact with one another and then construct weight variables for each indicator based on the results of those calculations. After determining the primary driving forces and limiting variables for sustainability, the researchers rated each city's sustainability using the MCDM approach.

The research concludes that MCDM has great promise as a method for evaluating urban sustainability and realizing sustainable development objectives. MCDM facilitates a more thorough and coordinated assessment of many criteria, which might reveal interactions between factors and rank measures for enhancing sustainability. Multiple-Criteria Decision Making (MCDM) is depicted here as a flowchart detailing steps like problem recognition, criterion definition, weighting, and rating. The Triple Bottom Line paradigm is used in this research to assess sustainability in twelve Chinese cities, and MCDM is used to help identify significant sustainability variables and rank the cities. This study demonstrates the value of MCDM in supporting sustainable development goals by illuminating the interdependencies between different assessment criteria.

4. Experimental Findings and Analysis

Experimental Setup and Environment:

- The research methodology employed in this study entailed an examination of the sustainability of a dozen urban centres by applying the Triple Bottom Line framework, which was evaluated based on a set of 21 distinct criteria [29].
- The analysis used a laptop computer with an octa-core processor, 16GB memory, and a solid-state driver.
- The experimental setup employed software tools such as MATLAB version 2021b and Python version 3.9.
- The database utilized for analysis encompassed a range of sustainability criteria metrics, including but not limited to energy consumption, releases of greenhouse gases, waste management measurements, social equity indexes and economic efficiency measurements.
- The data was obtained from credible sources, including official government reports and global databases, and underwent preprocessing to facilitate subsequent analysis.
- Reasons for Using MATLAB and Experimental Setup:
- MATLAB was chosen as the software based on its robust data analysis, modelling, and optimization functionality. This made it a suitable candidate for managing the intricate computations required for MCDM.
- Using MATLAB's inherent matrix functioning and optimizing functions enabled the proficient tampering and analysis of the extensive database.
- Python was employed for specific tasks, such as data preparation and representation, owing to its versatility, extensive libraries, and user-friendly nature.
- The laptop's configuration was deemed adequate for processing power and memory.
- Utilizing selected software tools and testing arrangements facilitated a thorough assessment of the environmental performance of the cities, considering various factors. This approach enabled well-informed decision-making and inter-city comparisons.

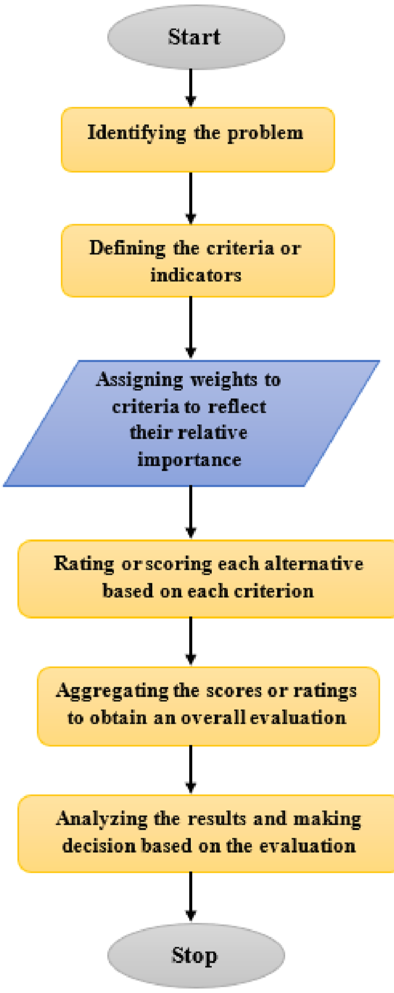

Figure 3. Flowchart Diagram

Table 4(a). Decision weight comparison of the SC-MCDM

Group	W_min	W_max	Best_min	Best_max
Organizational & Social	1.4	0.9	7.5	8.4
SC	2.4	3.7	2.3	3.4
Management & Economy	1.8	2.1	3.3	4.3
Environment	7.3	8.3	1.4	1.3
IT	3.7	4.2	1.7	2.6

It is possible to implement MCDM systems with a wide variety of software tools and programming languages; this choice is made in response to the project's particular requirements. MATLAB is a software package that is frequently utilized for MCDM. It is possible for the hardware requirements for MCDM systems to change depending on the size and complexity of the problem being studied; nonetheless, in most cases, MCDM systems require a computer with appropriate processing power and memory.

Since it offers various tools and capabilities for data analysis, modelling, and simulation, MATLAB has become one of the most widely used software packages for Multi-Criteria Decision Making (MCDM). Because of the intuitive design of the software's interface and the comprehensive nature of its accompanying documentation, it may be utilized by users with varied degrees of prior programming knowledge.

MATLAB's capacity to manage enormous data sets and intricate calculations is one of the primary reasons why MCDM practitioners choose to work with this software. Because it has built-in functions for matrix operations and optimization, the software is ideally suited for modelling and addressing multi-criteria decision-making (MCDM) problems involving several criteria and options.

The Triple Bottom Line (TBL) is a widely employed method of evaluating sustainability that considers all three aspects: social, ecological, and financial. Within the context of urban sustainability analysis, the TBL structure thoroughly assesses cities' efficacy concerning the economic, social, and environmental dimensions. To carry out the analysis, 21 distinct criteria were chosen to accurately reflect diverse facets of sustainability across all dimensions of the Triple Bottom Line. Possible indicators that could be considered as criteria are:

- The social dimension encompasses various factors such as access to medical care, education, fairness in society, and the incidence of crime.
- The environmental dimension encompasses various aspects such as air quality, water handling, waste handling, and using renewable energy sources.
- The economic dimension encompasses various indicators such as gross domestic product (GDP) per capita, job satisfaction, equality of earnings, and expenditure on sustainable facilities.
- The analysis sought to encompass a broad spectrum of variables that contribute to the general ecological viability of the cities under investigation by utilizing these 21 conditions.

A comprehensive examination, a multi-criteria investigation, and a comparable assessment are also performed in TBL. In addition, the weight factor of the signal was computed, including static interactions and dynamical pattern similarities, and the induction-ordered weighing mean was used to combine criteria. This research concludes that China's subpar urban sustainability and subsystems had weak growth velocities.

Determining decision weights for individual groups is commonly achieved through techniques such as pairwise comparison. Professionals or individuals with a vested interest allocate numerical values that signify the comparative significance of criteria within every category. Analyses are performed on the decision weights of several groups, such as Information Technology (IT), environment, management, and economy, Sustainable City (SC), and organizational and social groups, and Table 4(a) is used to depict those weights. The various decision-making weights, such as worst minimum (W_min), worst maximum (W_max), best minimum (Best_min), and best maximum (Best_max), are analyzed for different groups of the sustainable city, and the findings demonstrate variances in their choice making weightage. When reaching sustainable developmental objectives in Industry 4.0 by employing the MCDM capacity of various groups, the recommended SC-MCDM works very well.

Table 4(b). MCDM weight analysis of the SC-MCDM

Group	Group weight	Rank
IT	0.18	3
Environment	0.24	2
Management & Economy	0.27	1
SC	0.15	5
Organizational & Social	0.16	4

The group weight, which depicts the relative significance of each group in the SC-MCDM evaluation, is used to calculate the ranking in Table 4(b). A weight analysis approach, pairwise comparison, is used to calculate the group weight to give values that represent the perceived significance of each category in the decision-making process. A higher rank signifies more relevance in the SC-MCDM evaluation, and the ranking shows how the categories are prioritized based on their relative weights. The MCDM expertise of the sustainable city is analyzed using 10 different cities in China, which are randomly selected based on the group weight and rankings of the entire China, and the results are tested with various groups of sustainable city residents, including IT, environmental, management, SC, organizational, and social group residents. Table 4(b) contains the calculated and tabulated results of the overall group weights and the groups' rankings. The most recent weights are used to produce the best possible outcomes using MCDM, which contributes to accomplishing the sustainable development objectives for the sustainable city and Industry 4.0. The IOWA approach further simplifies the process and makes it easier to locate results in a shorter amount of time.

The experimental results of the sustainable city are analyzed using many approaches, including Principal Component Analysis (PCA), Analytical Hierarchical Processing (AHP), the Contingent Valuation (CVM) method, entropy, and the suggested SC-MCDM system. These strategies' effectiveness in decision-making and long-term viability are tested using 10 distinct cities in China, and the aggregated results are presented in Table 5(a).

Table 5(a). Experimental findings of a smart city

Method	Decision-making efficiency (%)	Sustainability (%)
PCA	55.2	46.7
AHP	42.4	49.7
CVM	63.2	61.4
Entropy	59.7	57.8
SC-MCDM	89.7	92.1

Based on the smallest weight and smallest ranking, cities are randomly selected. It isn't easy to analyze the entire China, so 10 cities were randomly selected for the analysis, and the results were integrated into the entire China. The findings indicate that the recommended SC-MCDM approach would result in improved levels of MCDM efficiency as well as greater sustainability across all 10 cities. This is accomplished via IOWA and MCDM's abilities to adjust the weights of the various groupings. Figure 4 represents a Graphical Analysis of Experimental findings of the sustainable city. It shows the comparison of our proposed approach among Principal Component Analysis (PCA), Analytical Hierarchical Processing (AHP), the Contingent Valuation (CVM) method, and entropy.

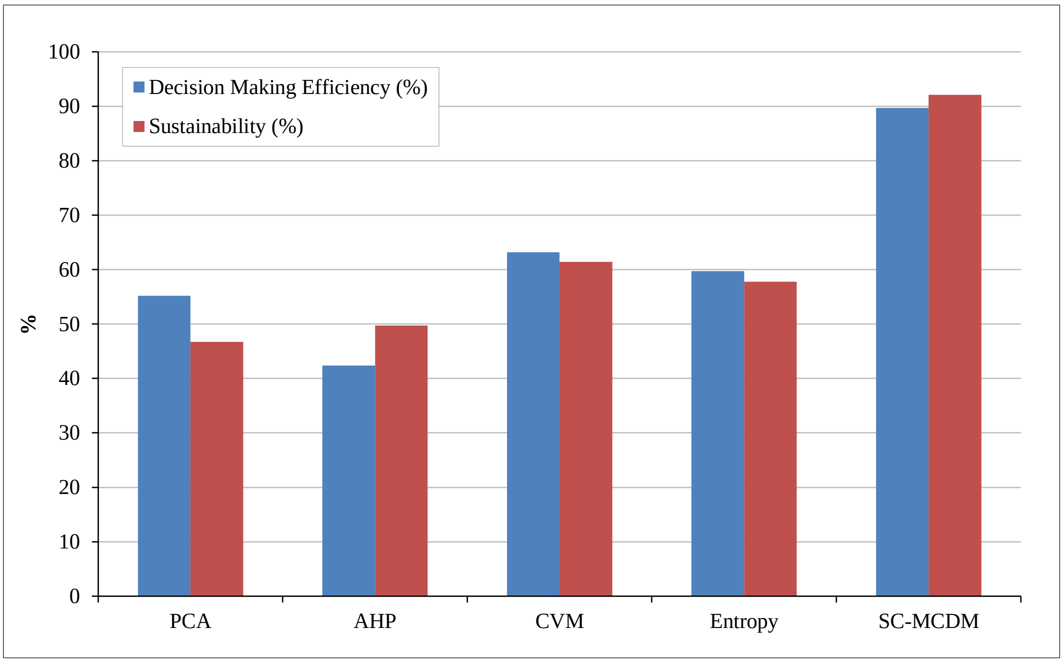

Figure 4. Graphical Analysis of Experimental findings of the sustainable city

Each criterion or category is often weighed based on its relative relevance to establishing the ranking in the SC-MCDM assessment. Group weight, established by subjective or objective weighing procedures, is the relevance given to each category. The proposed SC-MCDM system is put through its paces by employing 10 distinct towns in China as test subjects for its decision-making abilities. After determining the relative weights of each factor in the decision-making process and ranking them, the findings are shown in Table 5(b). With the assistance of MCDM and IOWA, the SC-MCDM system can reach greater sustainability. The best minimum, best maximum, worst minimum, and worst maximum weights are used to analyze the MCDM weights. These data are used to update the optimal weights, contributing to achieving the sustainable development objectives of Industry 4.0.

Table 5(b). Multi-criteria decision-making ability analysis of the suggested SC-MCDM system

City	Weight	Rank
1	0.74	1
2	0.31	10
3	0.58	5
4	0.51	6
5	0.48	7
6	0.63	3
7	0.59	4
8	0.73	2
9	0.36	9
10	0.42	8

The results of the simulation study of the SC-MCDM system in terms of precision, accuracy, Root Mean Squared Error (RMSE), and Mean Absolute Error (MAE) are calculated, and Table 6(a) and 6(b), respectively, indicate the findings of the analysis. The accuracy, precision, RMSE, and MAE are computed for the sustainable development of 10 cities in China's sustainability prediction value. The results of the SC-MCDM system are compared with the models that are already in existence, and the comparison demonstrates that the suggested system with the MCDM model is effective in Industry 4.0. The system functions more effectively and with fewer errors than before.

Table 6(a). Simulation analysis of the SC-MCDM system

Method	Precision (%)	Accuracy (%)
PCA	47	52
AHP	54	57
CVM	86	82
Entropy	75	79
SC-MCDM	93	95

Table 6(b). Error analysis of the SC-MCDM system

Method	RMSE (%)	MAE (%)
PCA	24.2	21.3
AHP	27.4	20.1
CVM	16.7	12.8
Entropy	21.8	19.8
SC-MCDM	8.3	8.9

The simulation study results about the SC-MCDM system have been calculated regarding precision, accuracy, root mean squared error (RMSE), and mean absolute error (MAE). The results of the analysis are depicted in Figures 5 and 6, respectively. The evaluation of the sustainable growth of ten cities in China's sustainability forecast value involves the computation of accuracy, precision, root mean square error (RMSE), and means absolute error (MAE) measures. The effectiveness of the SC-MCDM system is evaluated by a comparative analysis with established models, demonstrating its efficacy within the framework of Industry 4.0.

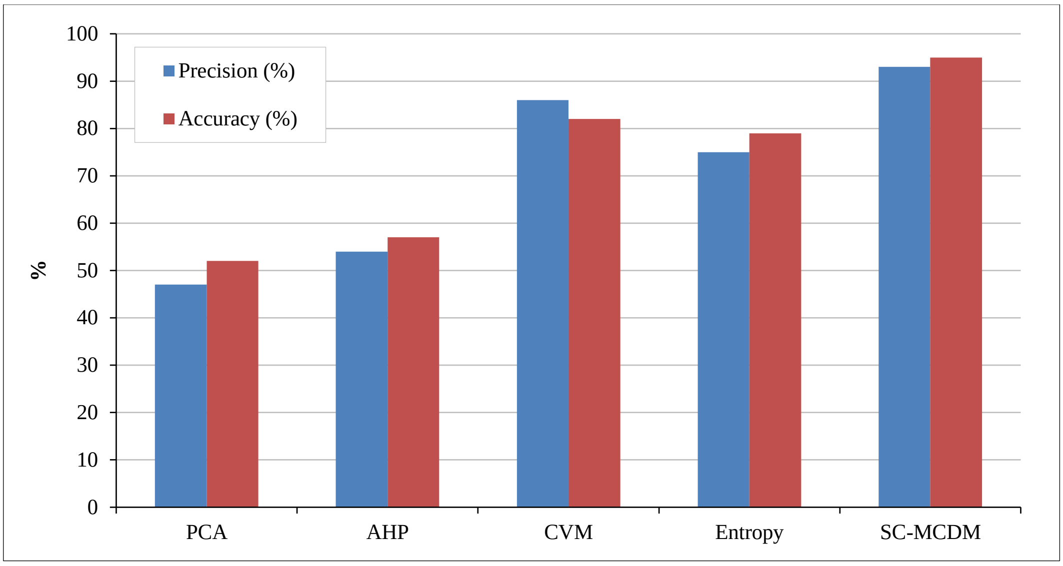

Figure 5. Graphical Analysis of Simulation Analysis of the SC-MCDM system

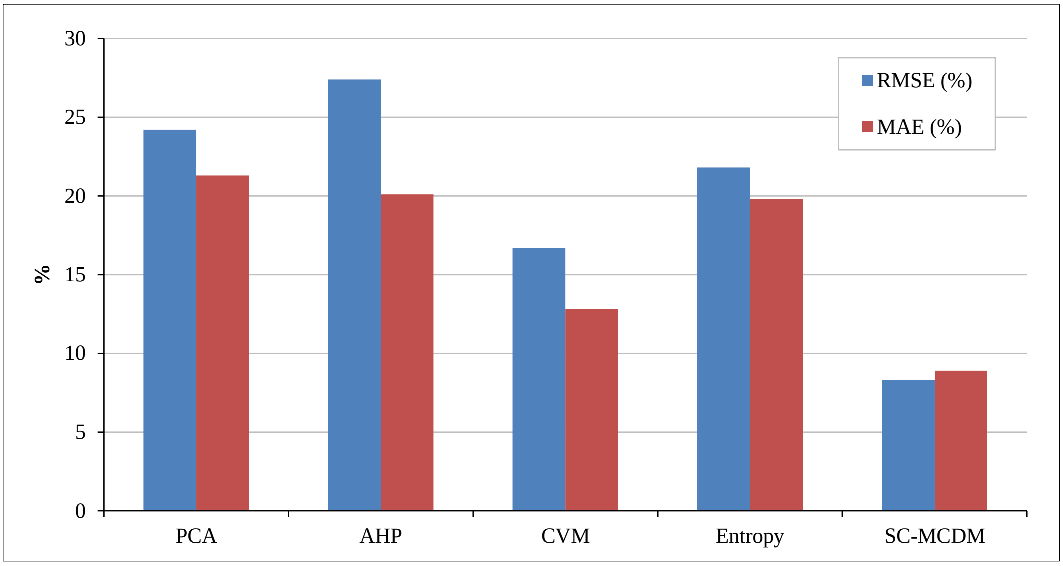

Figure 6. Graphical Analysis of Error Analysis of the SC-MCDM system

The results indicate that small and medium-sized enterprises (SMEs) may improve their sustainability results by concentrating on connecting more and implementing more modern CPS technology. In addition to enhancing operational efficiency, these features support smart city objectives, including lowering carbon emissions and raising equality for all. The SC-MCDM system integrates various Industry 4.0 components, allowing for a more nuanced assessment than older approaches. By taking a holistic view, we can better understand how SMEs are doing and where they might make changes. The findings lend credence to the idea that smart city initiatives should prioritize connection and work to promote the use of advanced technology. Policymakers may use these findings to create programs encouraging creativity and environmental responsibility in city environments.

4.1. Comparison Analysis Section

These numerical findings were obtained using simulations and experimental data that utilized various techniques, including PCA, AHP, CVM, Entropy, and the SC-MCDM method. The values provide quantitative measurements for assessing the proposed SC-MCDM system and indicate the efficiency and efficacy of each technique in terms of decision-making performance, sustainability prediction, precision, accuracy, and evaluation of errors. The SC-MCDM system outperforms other approaches in terms of decision-making effectiveness (89.7%), sustainability (92.1%), precision (93%), accuracy (95%), RMSE (8.3%), and MAE (8.9%), demonstrating its superiority over other approaches in accomplishing sustainable city development objectives. The paper compares existing approaches and the proposed SC-MCDM (Sustainable City Multi-Criteria Decision Making) method for assessing sustainability and decision-making performance. Results and significant findings: PCA, AHP, CVM, and Entropy are existing approaches. In sustainable city development and Industry 4.0, these methodologies were employed for decision-making, sustainability forecast, precision, accuracy, and error evaluation. The SC-MCDM technique evaluates sustainability and decision-making in Industry 4.0 and sustainable city development. It uses multiple criteria to decide, weigh, and assess sustainability. SC-MCDM's decision-making efficiency is 89.7%, confirming its superiority.

- Sustainability Assessment: Its 92.1% sustainability score shows its efficacy.
- Precision: The approach yields 93% precise outcomes.
- It predicts sustainability with 95% accuracy.
- The Root Mean Squared Error (RMSE) is 8.3%, and the Mean Absolute Error (MAE) is 8.9%, showing low error rates and great reliability.

The suggested SC-MCDM method surpasses existing methods in decision-making, sustainability assessment, precision, and accuracy. It makes sustainable city development in Industry 4.0 more efficient and accurate.

5. Conclusion

This research aims to determine the impact of Industry 4.0 on promoting sustainable business efficiency in SMEs, which face several technological difficulties. Through Industry 4.0, this research tried to resolve several technological difficulties. The report examines three key elements of Industry 4.0: BD, the IoT, and smart manufacturing industries.

To attain sustainable development objectives, a survey utilizes a cross-sectional study design. To accomplish this, the study developed a methodology for quantifying the interplay among many criteria, including static connections and dynamical trend similarities. Additionally, the study produced a method for determining the weight factors associated with each indicator based on their respective connections. Furthermore, the Induction Ordering Weighted Averaging (IOWA) operation combined criteria and their associated weighted factors, with the inclusion parameter determined by the interactions between these criteria.

While MCDM has proven to be an excellent tool for assessing the sustainability of a city, the study will require more research to pick more precise criteria. Due to information accessibility and measuring restrictions, only 21 indicators were extracted from statistics yearbooks, resulting in inadequate indicators. Utilizing more extensive and specific data to refine the indication method may become a focus of future development. Since small and medium-sized enterprises have scarce resources, the existing approach should be extended to high-tech SMEs. Future studies will include other features of Industry 4.0, including connectivity and Cyber-Physical Systems (CPS). To enhance the evaluation of sustainable development in the context of Industry 4.0, future research should concentrate on broadening criteria selection and improving the indication technique by utilizing more comprehensive and precise data. A worthwhile area for more research would be integrating connection and CPS inside small and medium-sized businesses. Compared to other methods, the SC-MCDM system is more successful rate of 89.7%, a more sustainable rate of 92.1%, a more precise ratio 93%), more accurate (95%), and a less mean absolute error, and mean squared error rate of 8.3% while trying to achieve sustainable city development goals.

Research Limitations: This investigation uses data collected from reputable sources; nonetheless, data inaccuracies or delays in collection could still affect the findings. Future research should look into ways to increase data quality and coverage. Additionally, the research is conducted primarily in twelve Chinese cities, which may limit its applicability to other regions. Widening the scope to include a larger number of cities could enhance the study's relevance. Furthermore, the study assumes that embracing Industry 4.0 will favor the long-term viability of small and medium-sized enterprises (SMEs). However, more research is needed to determine the realities of the adoption and the implementation barriers that SMEs encounter while attempting to implement Industry 4.0.

Suggestions for Further Research: Conduct a comparative investigation of the sustainability and acceptance of Industry 4.0 in different nations or regions to uncover contextual factors affecting the success of small and medium-sized enterprises (SMEs). Additionally, research the unique obstacles and solutions facing SMEs in light of financial and technological limitations when adopting Industry 4.0 technologies. Furthermore, it examines the effects of Industry 4.0 implementation on SMEs' long-term viability and economic efficiency by conducting longitudinal research that tracks their development over time.

6. Declarations

6.1. Author Contributions

Conceptualization, S.P. and D.A.; methodology, B.S. and S.J.; validation, S.P., S.M., and K.S.M.A.; formal analysis, S.J. and B.S.; investigation, S.M.; resources, D.A.; writing—original draft preparation, D.A., B.S., and S.P.; writing—review and editing, S.M. and K.S.M.A.; visualization, S.J.; funding acquisition, K.S.M.A. All authors have read and agreed to the published version of the manuscript

6.2. Data Availability Statement

The data presented in this study are available at https://www.kaggle.com/code/moustafateleb/analysis-on-sustainable-development-goals-sdgs (accessed on November 2024).

6.3. Funding

Part of the work was supported by Multimedia University.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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