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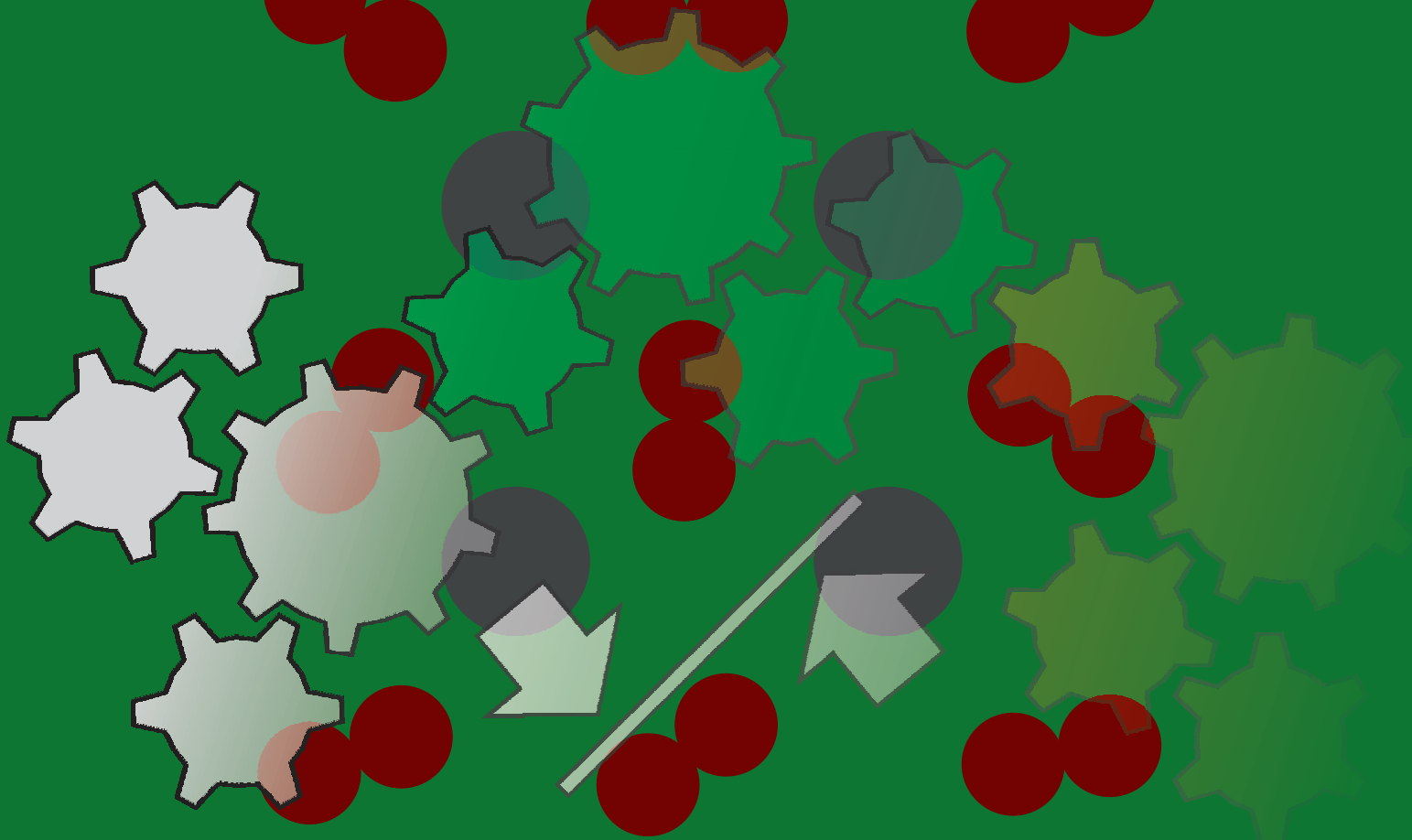

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Evaluating the climatic factors affecting road accidents - a case study in Poland
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Evaluating the climatic factors affecting road accidents - a case study in Poland

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Keywords: factors affecting road accidents, road accident, weather conditions.
Abstract: Globally, the number of traffic accidents is declining year. The epidemic has been the primary factor influencing its score in recent years. This figure is still quite high, though. Because of this, every attempt should be taken to lower the quantity of traffic incidents. The article's goal is to examine the likelihood that certain variables, which are dependent on weather, will have an impact on the quantity of traffic accidents. Ten measuring sites in Poland were chosen at random for this purpose, and the number of accidents at each location was examined. Based on the study, it can be stated that overcast and rainy days, together with favourable weather conditions, have the greatest impact on the number of traffic accidents. Furthermore, the likelihood of a traffic collision rises by 29% and 20%, respectively, in overcast and rainy skies. For this reason, special care should be taken to minimize road accidents.

1 Introduction

Every nation has a serious societal issue with road accidents. A number of variables, including speed, alcohol usage, weather, and other factors, can contribute to traffic accidents. The World Health Organization [1] reports that road accidents claim the lives of over 1.35 million people year, millions more of whom are seriously injured and have long-term health repercussions. Economic losses are also a result of accidents. Globally, the number of traffic accidents is declining year. The epidemic has been the main factor affecting this score in recent years. This number is still quite high, though (Figure 1). Every day, there are about 62 traffic incidents with an average of 62 fatalities and 72 injuries.

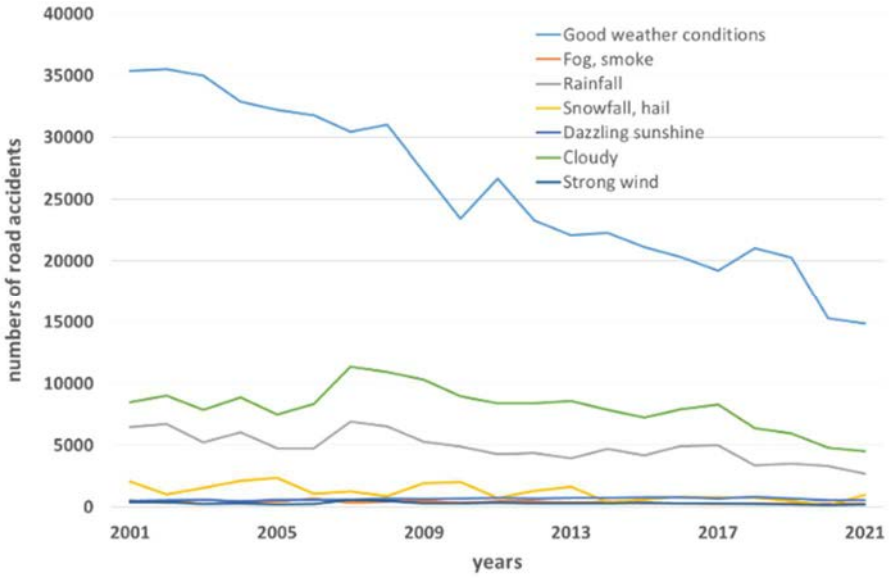

Figure 1 Number of road accidents in Poland according to weather conditions from 2001 to 2021 [2]

The aforementioned occurrences are linked to higher medical expenses, the requirement for car and road infrastructure maintenance, and detrimental environmental effects including oil spills. Because of this, every effort should be made to prevent traffic accidents in order to lower their frequency. Finding the variables influencing the quantity of traffic accidents is one way to do this [2,3].

According to studies by Zhai et al. and Holland et al., pedestrians are less protected than passengers in cars, which puts them at the highest risk of being involved in a traffic collision. They also sustain severe injuries among all those involved in traffic. Another of their investigations revealed that the severity of pedestrian injuries is influenced by variables such alcohol use, driver age or gender, illumination, road conditions, pedestrian conduct, accident site, vehicle, speed, and adverse weather [4-7]. More serious accidents on the roadways are frequently caused by bad weather and poor illumination, particularly at pedestrian crossings [7-9]. But this varies according on the field of study. For instance, it was demonstrated in the paper [10] that meteorological conditions typically have minimal impact on traffic accidents. This study subject can also be found in the works of Masello et al. [11] and Becker et al. [12], where the authors presented a model of the likelihood of traffic accidents based on the time of day and the meteorological conditions. The relationship between weather conditions and road accidents was also analysed in the work of the [13-25].

Apart from decreasing the frequency of traffic accidents, the current weather also influences traffic volume and driver behavior, including how quickly they respond to traffic circumstances [16,26-27].

In his research, Eisenberg [18] examined the connection between precipitation and road accidents in the United States and demonstrated that inclement weather is associated with a higher number of traffic accidents.

Brodsky and Hakkert [28] examined a related subject and discovered that accident rates rose by 100% in the presence of rain, whereas in Denmark the rise was only about 10%. Fridstrøm et al. [16], on the other hand, discovered that rainfall had no influence on the change in the number of traffic accidents in Sweden and Norway. Conversely, in Poland, the majority of road accidents happen when the weather is nice. Moreover, the frequency of traffic accidents rises with rising temperatures and favorable weather [2,27,29].

For the purpose of this work, it was assumed [30]:

- good atmospheric conditions are:
  - air temperature > 3ºC,
  - no precipitation,
  - wind < 5.5 m/s,
  - visibility > 10 km,
  - pressure difference over the day < 8 hPa.
- Bad weather conditions (if one of the following factors is met) are:
  - slippery pavement (temperature < 3ºC and occurrence of precipitation),
  - heavy rain (temperature > 0ºC, precipitation > 3 mm),
  - snowstorm (temperature < 0ºC, precipitation > 3 mm),
  - strong wind (wind > 10 ms/s),
  - dense fog (visibility < 300 m).

In their study, Masello et al. offered an alternative method of examining traffic incidents. They investigated how driver assistance technologies may raise traffic safety. The investigation was carried out in a variety of weather and traffic scenarios.

The relationship between the three elements of traffic (the so-called safety triangle) is also influenced by atmospheric conditions. These elements are the vehicle (its technical state, traffic speed, load), the environment (road infrastructure), and the human being (and his psycho-motor state, fatigue, stress, and concentration) (Figure 2).

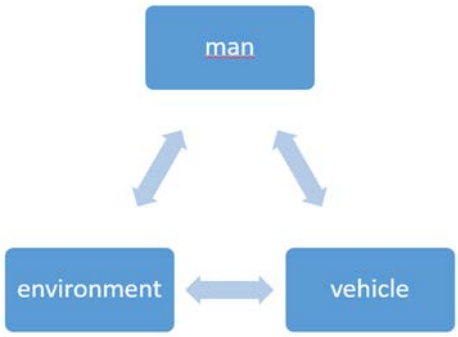

Figure 2 Safety triangle

It is possible to draw a variety of inferences from the literature research on the likelihood of a traffic accident given the current weather conditions. A few researches evaluate their detrimental effect on the quantity of traffic accidents. However, a lot of academics assert that this impact does not exist. It has been acknowledged that there is a need to evaluate the variables influencing the quantity of traffic accidents. Because of this, the article's goal is to evaluate the significance of the influence of particular atmospheric conditions on the likelihood of a traffic collision. Because of this, it is possible to ask: What impact do meteorological conditions have on the quantity of traffic accidents? To do this, ten measuring sites in Poland were chosen at random, and the following data were examined for each location: the quantity of accidents in relation to the weather at the time of the incident.

2 Equations

This paper's objective is to evaluate the impact of specific climatic variables (such as fog, high wind, cloud cover, sunshine, snow, and rain) on the likelihood that a traffic accident will occur at the examined measurement point. The following algorithm was used to calculate the likelihood of a traffic collision for this purpose:

- 10 measurement points on different types of national and provincial roads in Poland were randomly selected.
- The following parameters were determined for the selected points:
    - Location of the measuring point.
    - Type of road on which the measurement point is located (national road, voivodeship road).
    - Geographical coordinates.
    - Traffic speed at the point under analysis.

The study employed the CART approach. The CART approach is built on two key components: regression trees, which are used to forecast the value of the target variable and are defined by a continuous type target variable, and classification trees, which are used to classify classes and are characterized by a categorical target variable. The fundamental idea behind the CART algorithm is that data is divided at the nodes based on a single decision variable, and that data splitting stops when an answer to one question has no bearing on the answer to another. The CART technique is typified by recursive binary splitting, which consistently splits a parent node into two daughter nodes. Because the classification error of each layer is determined after the divides are made, there will be some variability in the final category [31].

The investigation also made use of Minitab software. Statistical software called Minitab is used globally to evaluate data and enhance goods and services. Among the many options the application offers for efficient analysis is an interactive assistant that may aid at any point during the process.

2.1 Selection and location of sites

Ten randomly chosen places in Poland were examined to ascertain the effect of specific meteorological conditions on the likelihood of a traffic collision (Table 1).

Table 1 Coordinates of measurement points [32]

	Measurement Point	Road signage	Longitude of the point	Latitude of the point
point1	Piła - Wojska Polskiego	DW 179	16.732301	53.151436
point2	Piła - Poznańska	DK 11	16.752994	53.126343
point3	Piła - Al. Piastów	DK 11	16.737967	53.150107
point4	Piła - Niepodległości	DK 11	16.737933	53.163308
point5	Manowo	DK 11	16.287356	54.132729
point6	Mścice	DK 11	16.080240	54.219427
point7	Sianów	DK 6	16.302716	54.230299
point8	Strzekęcino	DW 167	16.165485	54.099837
point9	Sucha Koszalińska	DW 203	16.266325	54.260465
point10	Szczeglino	DW 206	16.384696	54.180654

We examined the following information for these points: number of accidents varying according to the weather at the time of the incident (Figure 3, Figure 4). Both national (DK 6 and DK11) and provincial (DW167, DW179, DW 203, and DW206) highways were used to choose the spots. The maximum allowed speed for vehicular traffic at all presumptive measuring stations was 50 km/h.

Figure 3 Measurement points within the city of Pila [33]

Figure 4 Measurement points in Koszalin County [33]

3 Results and analysis

The current study has used data from ten locations in different sections of Poland. A table (Table 2) that displays the frequency of accidents in a certain type of environment and atmospheric conditions across all locations has been created based on the accident data.

The data makes it abundantly evident that the two main causes of traffic accidents in the majority of the locations are high levels of cloud cover and precipitation. As a result, additional information has been gathered, as shown in Table 3, which provides the total proportion of different climatic conditions that cause traffic crashes regardless of location. As is evident, comparable information is also shared by the general statistics, namely that rain and overcast skies are the factors that contribute to an increased frequency of accidents. The total proportion may not equal 100% since numerous incidents occur in locations with different climates.

Table 2 Percentage of accidents in different locations under different environmental conditions

Locations	Climatic condition	Average rate of accidents (%)
1	Fog	0
	Strong Wind	0
	Cloudy Sky	32.26
	Sunshine	1.08
	Snowfall	1.08
	Rainfall/Precipitation	19.35
2	Fog	0
	Strong Wind	1.28
	Cloudy Sky	29.49
	Sunshine	3.85
	Snowfall	1.28
	Rainfall/Precipitation	15.38
3	Fog	0
	Strong Wind	2.17
	Cloudy Sky	19.57
	Sunshine	6.52
	Snowfall	6.52
	Rainfall/Precipitation	21.74
4	Fog	0
	Strong Wind	3.85
	Cloudy Sky	23.08
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	26.92
5	Fog	0
	Strong Wind	0
	Cloudy Sky	28.57
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	14.29
6	Fog	0
	Strong Wind	0
	Cloudy Sky	35.29
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	0
7	Fog	0
	Strong Wind	0
	Cloudy Sky	47.83
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	4.35
8	Fog	0
	Strong Wind	0
	Cloudy Sky	0
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	100
9	Fog	0
	Strong Wind	0
	Cloudy Sky	25
	Sunshine	25
	Snowfall	25
	Rainfall/Precipitation	0
10	Fog	0
	Strong Wind	0
	Cloudy Sky	50
	Sunshine	0
	Snowfall	0
	Rainfall/Precipitation	0

Table 3 Proportion of road accidents based on climatic conditions

Climatic condition	Overall average rate of accidents (%)
Fog	0
Strong Wind	0.73
Cloudy Sky	29.109
Sunshine	3.645
Snowfall	3.388
Rainfall/Precipitation	20.203

In this study, we've tried to create a model that can tell us how likely it is that traffic accidents would occur given certain weather conditions. This may be combined with information on driver behavior, road layout, and other factors to provide a more comprehensive picture of the precise likelihood of a traffic crash. Two mathematical techniques, namely logistic regression and classification/decision trees, can be employed to simulate the likelihood of traffic accidents according to weather conditions. The likelihood of this road collision event was determined using the CART, or Classification and Regression Tree, approach since probability is a continuous event that can lie anywhere between 0 and 1. The greater accuracy and predictability of the CART model over the logistic model is another important factor. The CART analysis was carried out using Minitab software. The regression tree study took into account every possible climate circumstance. Even if early research has shown that some weather conditions do not function as triggers for car collisions, it is nevertheless vital to include these aspects when forecasting the occurrence of crashes. Undoubtedly, it can be stated that these elements will decrease the accuracy of the model; nonetheless, they will not impair the predictability of the road collision incidents in general. According to the preliminary analysis's findings, six trees is the ideal amount for the highest R-square. Additionally, with six trees, the Mean Absolute Percentage Error (MAPE) is at its lowest—that is, just 0.7%. The selection criteria for the six trees are displayed in Figure 5, and the tree itself is shown in Figure 6. Figure 6 illustrates how the first two branches of the tree show that a cloudy sky and rainfall have an entirely different crash forecast, with a mean of 25%, compared to 1.9% for all other conditions combined. Once more, the tree tries to branch off the variables that affect collisions on the roads. For instance, among the two severe variables, rain and overcast skies together account for 20–21% of collisions and almost 29–30% of crashes. Comparable figures are also observed for other irrelevant parameters.

Results and analysis
Piotr Gorzelanczyk, Martin Jurkovic, Tomas Kalina, Malaya Mohanty

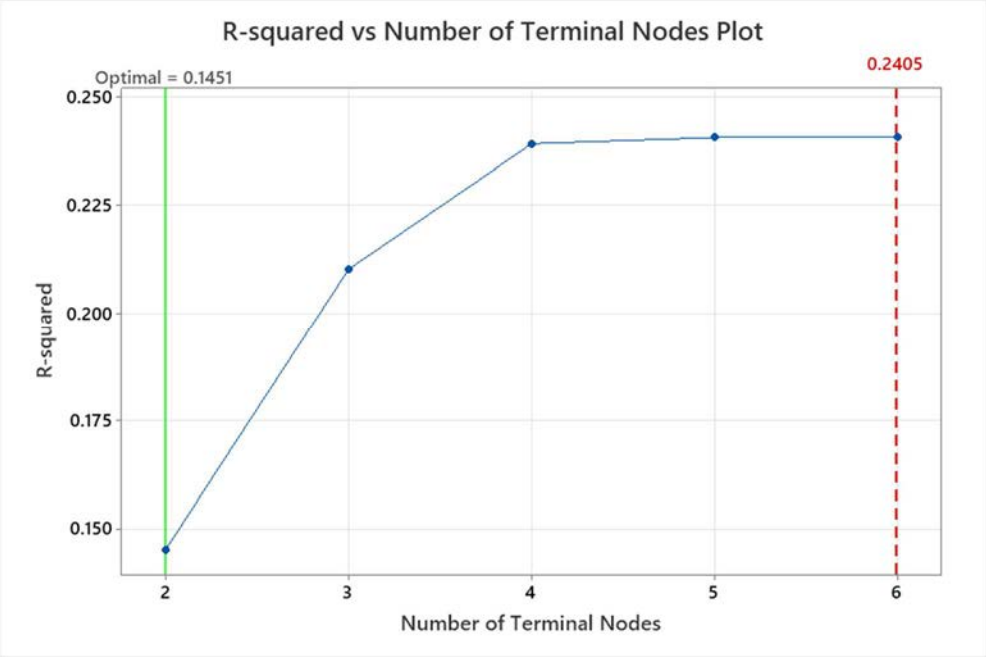

Figure 5 Number of trees required for highest R-squared value.

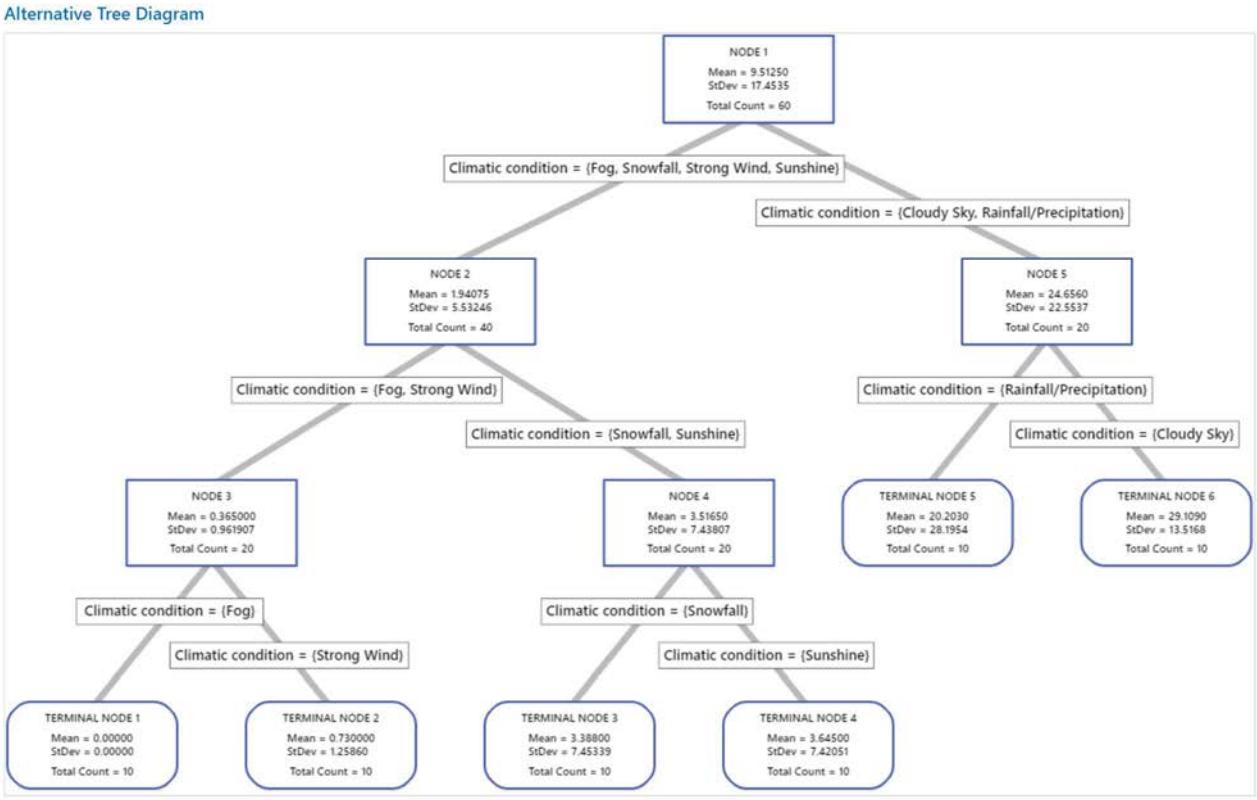

Figure 6 Regression tree for predicting road crashes under different climatic conditions

The predict option in Minitab software's CART analysis allows it to forecast the occurrence of dependent variables depending on the data that is supplied. In this study, we've tried to forecast the likelihood of traffic accidents occurring in a given weather scenario. Figure 7 shows pictures illustrating how to determine the likelihood of a traffic accident occurring in a given set of meteorological circumstances.

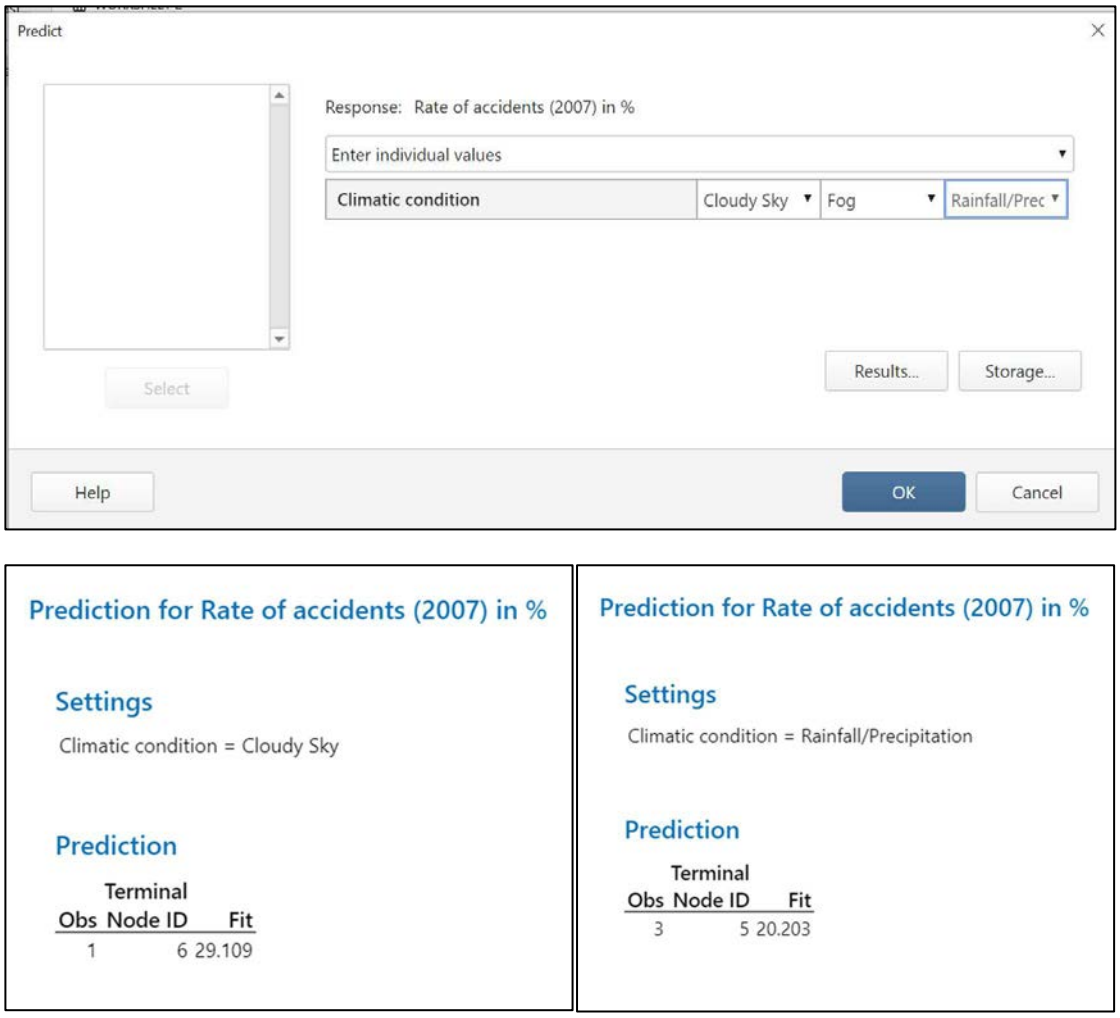

Figure 7 Screenshots from Minitab software for predicting road crashes

According to historical data for the area, Figure 7 shows that the likelihood of a traffic collision rises by 20% in the event of rain and by 29% in the case of cloudy sky. When applied at a specific site based on historical data, these probabilities will be highly helpful in recommending tactical actions to lower the number of traffic accidents.

4 Conclusion

The factors influencing the quantity of road accidents are examined in the article. This is a historical issue that impacts road safety, as is widely recognized. throughout order to do this, ten measuring sites throughout Poland were chosen at random, and the number of accidents at each location was examined. The study data reveal a higher frequency of road accidents on gloomy and rainy days. Minitab software and CART analysis were used in the investigation. The research indicates that the most significant influences on the frequency of traffic accidents are overcast and rainy days and favorable weather conditions. Furthermore, the likelihood of a car collision rises by 29% and 20%, respectively, with cloud cover and rain. The authors' subsequent thoughts will focus on a more thorough examination of other variables that may have an impact on the quantity of traffic accidents.

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The role of information in the development of new technologies

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Keywords: information, development, new technologies and data processing, evolution, artificial intelligence.
Abstract: When developing a new technology, a large amount of information is needed both at the beginning and during the development and at the end of the development of a new technology, there is a large amount of data everywhere, information that creates a combination of highly necessary data with data that creates noise. The evolution of a new technology starts from one initial original idea, or with the help of partial or partial solutions it approaches the conclusion of what needs to be achieved through research. Experiments and information collection reach results not only after the information part, but also after the technical-technological part. Another important source of information is quantitative data obtained from books, magazines, old planning documentation, the Internet, various repositories, as well as using artificial intelligence tools. The article is devoted to the principled attitude of obtaining information and resources that are available and that are important for the development of a new technology from the initial data at the beginning to the data that is collected during the development process.

1 Introduction

Information and communication technologies (ICT) play a significant role in all aspects of modern society. ICT have changed the way in which we communicate with each other, how we find needed information, work, conduct business, interact with government agencies, and how we manage our social lives. As ICT affect everyday lives, they also impact the macroeconomic growth, which in turn further affects society by enabling infrastructure and standard of living improvements [1].

The question is why successful companies often fail to adapt to new technologies and what lessons can be drawn from this for the development of new technologies [2].

Tech ethics is not only instrumental for governing technoscientific projects in the present but is equally instrumental for the construction of socio-technical imaginaries and the essentialization of technological futures [3].

The contrasting term, continuous innovations, refers to the normal upgrading of products that does not require us to change behaviour. The groups are distinguished from each other by their characteristic response to a discontinuous innovation based on a new technology. Each group represents a unique psychographic profile-a combination of psychology and demographics that makes its marketing responses different from those of the other groups. Understanding each profile and its relationship to its neighbours is a critical component of high-tech marketing lore [4].

Our quick doubling calculation helps us understand why progress with digital technologies feels so much faster these days and why we´ve seen so many recent examples of science fiction becoming business reality [5].

The successive shifts of key factors from mechanics to energy to information have often been taken as indicative of a trend toward decreasing emphasis on material goods. This may be wishful thinking, however, given the continued importance of mechanics and energy as the necessary substrate for information and communication [6].

The education level of the household head, the average education level of the household and the proportion of trained labour force have a significant negative impact on the improvement of grain production technology innovation. Promoting technological innovation in grain production is conducive to the rational allocation of resources and provides guarantees for food security [7].

The simultaneous tracking of program participants and a matched comparison group can enhance the evaluation of technology innovation programs by helping to isolate the effects of the government program from the host of other factors that influence the commercialization of inventions [8].

Although the technology remains unpredictable and sometimes baffling, individuals from all across the world and from all walks of life are finding it useful, supportive, and comforting, too [9].

By introducing Industry 4.0 technology into business practice, new processes are expected to be created. These processes will involve more technology and be smarter, but they will remain processes. Processes will continue to require analysis, the definition of capabilities, control to be effective and efficient, but they will also require information and the definition of new parameters that will affect them [10].

In any industry, the future belongs to products that grow with their users, adapt to new contexts, and create sustainable value over time [11].

When developing a new technology, a large amount of information is needed, both at the beginning of the research and during its course, and the output itself is a large amount of data, information that forms a certain guide, the process

of creating a new technology. The value of information during the development of a new technology, from the beginning to the end, increases. The result of the development is a set of information, the value of which increases several times and, in some cases, can be very high. When developing a new technology, from an information point of view, the procedure shown in the following figure must be followed (Figure 1).

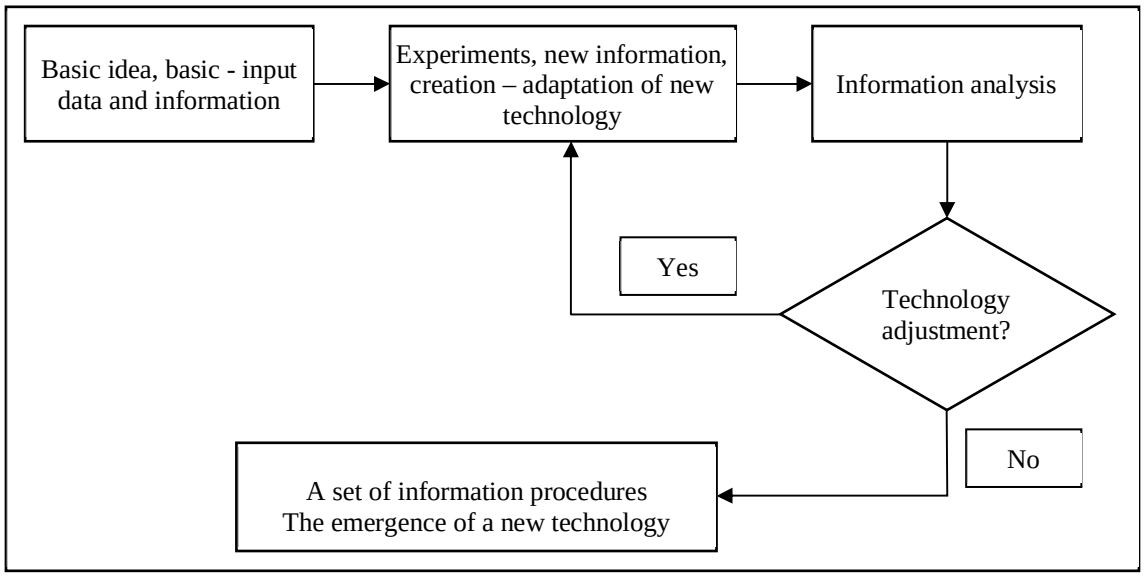

Figure 1 New technology development information system

Nowadays, technologies are developing at a rapid pace, which has a significant impact on our daily existence and affects various areas of life. Information sites on the development of new technologies play a key role in the dissemination of knowledge and news, allowing entrepreneurs, researchers and the general public to be aware of the latest trends and innovations. The aim of this information site is to provide an overview of current technologies, their development and potential applications, as well as the challenges we face in their implementation. We will focus on various aspects, such as not only technical and scientific, but also ethical and societal issues that arise in connection with the development of new technologies. We believe that this site will contribute to a better understanding and discussion of the technologies that shape our future.

2 Methodology - basic idea, input data and information

When developing a new technology, we start from the initial original idea, or with the help of partial solutions we get closer to what we want to achieve through research. Through experiments and collecting information, we will get to the result not only from the information side, but also from the technical and technological side.

Before proceeding to the experiments themselves, it is necessary to collect a large amount of data and information that enters the development process. The term information will be understood as knowledge that satisfies a specific subjective information need of its recipient. The carriers of information can be numbers, text, sound, image, information from perceptions and senses. Then we can understand information as data to which the recipient attributes meaning based on the knowledge they have. Data is information that is on carriers where we can process it automatically.

The information that enters the process can be divided into two types:

- information that directly relates to the problem being solved,
- information that solves the problems of the development of the new technology itself.

Information directly related to the development of new technology can be obtained from various sources. Where possible, primary information is obtained from the knowledge and experience of operators. Another important source of information is the amount of data obtained from books, magazines, project documentation, with the help of sensors and transducers, from the Internet, data repositories, with the help of artificial intelligence and others (Figure 2). During the development of a new technology, not only the technological side of the technology, but also the information side of the technology undergoes development.

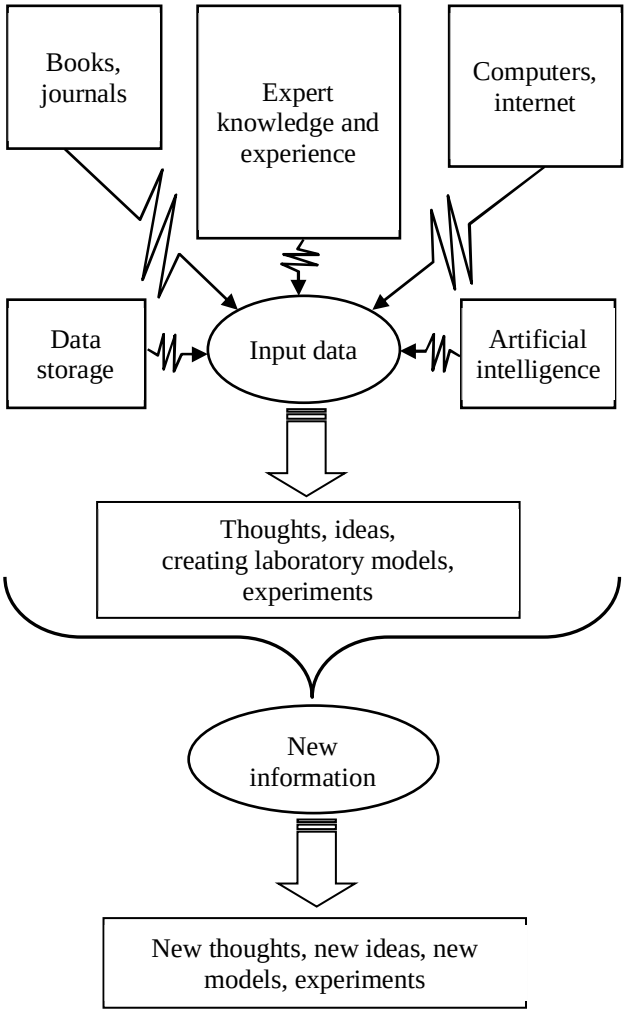

Figure 2 The information base for the emergence of new ideas

Information that solves the problems of the development of a new technology itself does not concern the solution of technological problems, but rather solves problems such as: how to secure financing for development, who will supply the necessary materials, under what conditions can a new technology be patented, what standards must a new technology meet, what standards must be observed during its development, the preparation and implementation of contracts and permits related to the development of a new technology. This information is as important for the emergence of a new technology as the information that directly concerns it. Without this information and clear answers, the research itself would be practically impossible.

2.1 Overview of technologies, developments, applications and challenges

Current technological advances offer fascinating opportunities to improve quality of life and efficiency in various areas. However, in implementing these technologies, we face many challenges that require careful consideration and collaboration between experts, governments, and society.

1. Artificial Intelligence (AI)

Development: Artificial intelligence has evolved from simple algorithms to complex machine learning and deep learning systems. Neural networks, generative adversarial networks (GANs), and image recognition have become key components.

Potential applications: Process automation, personalized recommendations, healthcare (diagnostics), customer support (chatbots), and autonomous vehicles.

Challenges: Ethical issues, privacy, algorithmic bias, and regulatory frameworks.

2. Internet of Things (IoT)

Development: IoT is expanding with the increasing number of connected devices and advances in sensors and connectivity (e.g., 5G).

Potential applications: Smart home technologies, health monitoring, efficient energy management, and smart cities.

Challenges: Security risks, device interoperability, and challenges in managing large amounts of data.

3. Blockchain

Development: Originally created for cryptocurrencies, blockchain technologies are expanding into various industries such as transaction security and transparency.

Potential applications: Financial services, supply chains, digital identities, and voting systems.

Challenges: Scalability, energy consumption, and regulatory issues.

4. Augmented and Virtual Reality (AR/VR)

Development: AR and VR technologies have improved in terms of graphics and user experience, leading to wider use.

Potential applications: Education, entertainment (video games), simulations, and therapeutic applications.

Challenges: High technology costs, need for quality content, and potential for health issues (e.g., motion sickness).

5. 5G and telecommunications technologies

Development: 5G networks offer higher speeds and low latency, enabling faster and more reliable connections.

Potential applications: Development of IoT, autonomous vehicles, smart cities, and advanced mobile services.

Challenges: Infrastructure investment, health and safety concerns, and spectrum regulation.

6. Biotechnology and Genomics

Development: Advances in DNA sequencing and CRISPR technologies have enabled faster and more precise genetic editing.

Potential applications: Personalized medicine, biotech products, and sustainable agriculture.

Challenges: Ethical dilemmas, regulatory issues, and the risk of genetic alterations in ecosystems.

2.2 The technical and scientific aspects

The technical and scientific aspects are crucial for the successful development and implementation of new technologies. Their proper consideration can significantly contribute to innovation and efficiency of technologies in various fields. The technical and scientific aspects of developing a new technology are fundamental factors that influence the process of innovation and the implementation of new solutions. Below are the key aspects to consider:

1. Basic Research and Development (R&D)

Basic Research: The identification and investigation of fundamental principles and theories that can lead to innovation. This process is usually theoretical and long-term goal-oriented.

Applied Research: Focusing on the practical application of basic research to develop specific technologies or products.

2. Technological Engineering

Prototyping: The creation and testing of prototypes that allow the functionality and effectiveness of new technologies to be verified before they are mass-produced.

Optimization: The improvement of technical parameters such as performance, efficiency, cost, and reliability.

3. Software and Hardware Development

Software Engineering: The design and implementation of software solutions that are often the basis of modern technologies such as applications, systems, and platforms.

Hardware Engineering: The development of the physical components of technologies, such as the devices and systems that are required for the software to function.

4. Interdisciplinary approach

Bridging disciplines: Nowadays, technologies increasingly draw from multiple disciplines, such as computer science, biology, physics, and engineering, and this interdisciplinary approach leads to new innovations.

5. Testing and validation

Testing: Rigorous testing of new technologies to verify their performance in real-world conditions, which may include laboratory tests, field tests, and user tests.

Validation: Confirming that the technology meets the requirements and expectations of users and the market.

6. Regulations and standards

Compliance: The development of new technologies often requires procedures to comply with regulations and standards that ensure the safety and quality of products.

Ethical and legal aspects: Consideration of ethical and legal issues, such as privacy, intellectual property, and responsibility for distributing the technology.

7. Implementation and scaling

Technology deployment: Planning and executing the implementation of the new technology, including user training and change management.

Scaling: Extending technology to larger user groups or broader applications, often requiring changes to architecture and infrastructure.

8. Evaluation and Feedback

Evaluating effectiveness: Measuring the performance of a new technology and its impact on users and society.

Gathering feedback: Incorporating user opinions and experiences to further improve and develop the technology.

2.3 The ethical and social aspects

The ethical and social aspects of developing new technology play a key role in ensuring that technologies benefit society as a whole. It is important that all stakeholders – from developers to regulators – take these aspects into account and strive to create technological solutions that are responsible, equitable and sustainable.

The ethical and social aspects of developing new technology are key factors that influence how technologies are implemented and what impact they have on society. These aspects must be taken into account throughout the technology development process to ensure that technologies benefit society and do not have negative consequences. Here are some of the most important ethical and social aspects:

1. Privacy

Data collection and management: Many new technologies, particularly in the areas of artificial intelligence and the Internet of Things (IoT), collect vast amounts of personal data. It is important to ensure that this data is managed responsibly, and that individuals' privacy is protected.

Transparency: Users should be informed about what data is being collected and how it is being used and should be able to decide whether to consent.

2. Bias and discrimination

Algorithmic bias: Technologies such as machine learning algorithms may contain biases that lead to discrimination against certain groups of users. It is important to monitor and remove these biases in the design and development of technologies.

Access to technologies: Consideration needs to be given to how technologies are distributed and whether they are accessible to all groups of the population, in order to avoid exacerbating social and economic inequalities.

3. Responsibility and transparency

Developer responsibility: Technology developers must be responsible for the potential consequences of their products. This means that they should consider ethical dilemmas and potential risks when developing technology.

Transparency of decision-making processes: Organizations should be open about how technology works and what decision-making processes are behind it in order to increase user trust.

4. Impact on employment

Automation and unemployment: The rapid development of technology can lead to the automation of many jobs, which can have a negative impact on employment. It is important to consider how to help workers by transitioning to new jobs or eliminating redundant positions.

New job opportunities: On the other hand, new technologies can create new jobs and sectors, which can have a positive impact on the economy.

5. Ethical use of technology

Misuse of technology: There is a risk that new technologies can be misused for harmful purposes, such as surveillance, manipulation or the spread of disinformation. Regulations and control mechanisms need to be developed to prevent such abuse.

Social implications: Technologies can have a wide-ranging impact on social interactions and culture. It is necessary to consider how technology can influence societal norms, values and interpersonal relationships.

6. Ecological and sustainable aspects

Environmental impact: The development of new technologies should take into account their ecological impact, as well as the possibilities for recycling and sustainable development. Taking the environmental aspect into account is important for ensuring a sustainable future.

Resource and energy intensity: Technologies should be designed with resource and energy efficiency in mind in order to minimize their ecological footprint.

3 Results, discussion - experiments, creation, adaptation of new technology, new information, analysis of information

An information website about the development of a new technology has the potential to create a significant impact on innovation, education, collaboration, and responsible access to technology. Properly designed and managed, websites can serve as a valuable resource for both professionals and the general public, while promoting positive changes in society and the economy.

After collecting the input data and analysing them, we can proceed to the preparation of laboratory equipment and the laboratory experiments themselves. Without experiments and the information, we obtain from them, the development of a new technology is practically impossible. The results of the experiments are information that relates to individual experiments and, as a whole, provide an insight into the entire technology and the further direction in the development of the new technology. The information obtained must be analysed in the research team (Figure 3).

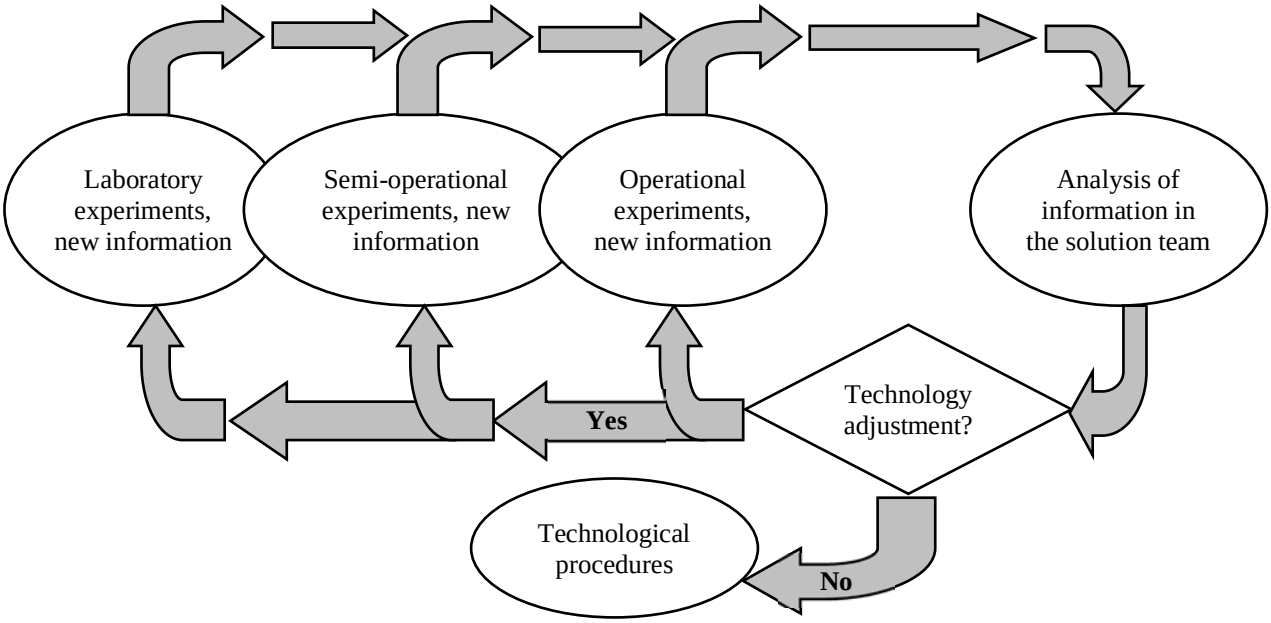

Figure 3 Information circulation during the development of new technology

After analysing the information obtained from laboratory experiments, decisions are made as to whether to make adjustments to the laboratory equipment and repeat the experiments, or whether the laboratory work and development process are completed. After the laboratory experiments are completed, we obtain output information, which is the input data for the creation of semi-operational or operational technology. Semi-operational experiments follow, from which it is possible to obtain a further amount of information that must be analysed, and the information circulation is repeated as in laboratory experiments. Output information from semi-operational experiments becomes input data for the creation of operational technology. All information obtained from experiments must be analysed in a solution team or with experts, e.g. in the form of brainstorming. The results of consultations and discussions are information that should lead to the solution of problems that arose during the experiments.

Laboratory experiments are closely linked to the development of new technology by activities that transform the phenomena obtained in experiments into informational, and therefore theoretical, form. Measuring and monitoring devices and instruments are used to obtain information from laboratory experiments or technological practice. These measuring instruments are different for different areas of research, but they all have one thing in common, namely that they provide information in numerical, textual, graphic or audio form.

The result of development activities can be some tangible element, a set of information of a certain quality and value, free from noise, know-how. If activities during the development of a technology were not recorded, it could happen that we do not know or are not able to achieve repeatedly suitable solution results and therefore that we do not know how to use or build the technology.

The path of the emergence and development of a new technology is intertwined with a lot of information that we obtain from various sources. In the process of developing a new technology, information is also developed that becomes its information content. Information content ensures the achievement of the right results anywhere and enables the further dissemination of the technology.

The results of an information site focused on the development of a new technology can take many forms and benefits. These sites serve to share information, support research and development, and provide a forum for interaction between experts and the general public. Here are some of the key results that can result from such sites:

1. Increased awareness

Current technology overview: Information sites provide users with an overview of the latest trends and innovations, helping professionals and laypeople stay informed about important issues.

Education and enlightenment: These sites can offer educational content, articles, videos, and webinars that increase knowledge about technologies and their applications.

2. Supporting innovation

Sharing research and results: Experts and researchers can share their findings and innovative ideas, encouraging collaboration and mutual inspiration.

Discussions and collaborations: Information sites can serve as a platform for discussion and exchange of ideas, which can lead to the development of new projects and partnerships.

3. Gathering feedback

Gathering user opinions: Sites can allow users to provide feedback on technologies and their applications, which can help developers improve their products.

Surveys and polls: Conducting surveys and polls provides valuable data on user preferences and needs.

4. Networking opportunities

Connecting experts: Information sites can provide a space for technology experts, researchers, entrepreneurs, and investors to connect.

Organizing events: Conferences, seminars, and webinars can be organized where experts from different fields meet and share their experiences.

5. Catalyst for regulation and ethics

Discussion on ethical aspects: Information sites can stimulate discussion on ethical issues related to new technologies, helping to shape policy and regulations.

Encouraging responsible development: Sites can reinforce the importance of an ethical and responsible approach to technology, which is important for responsible progress.

6. Supporting the community

Creating a community: An information site can unite people with common interests who focus on the same technologies or research areas.

Sharing success stories: Good practices and success stories can be shared to inspire others.

7. Economic impacts

Promoting entrepreneurship and investment: Increased awareness and knowledge sharing can support entrepreneurship, innovation and attract investment in new technologies.

4 Conclusion

In conclusion, we can conclude that information sites on the development of new technologies are an indispensable tool in the dynamically changing world of technology. They provide users with valuable information that allows them to better understand innovations, their potential benefits and the challenges we face. With constant advances in technology, it is important to keep up with the latest trends and developments, not only from a technical perspective, but also from an ethical and social perspective.

By sharing information and stimulating discussion about new technologies, we can contribute to creating a more sustainable and responsible future. Ultimately, each individual contribution to this site represents a step towards a better understanding and acceptance of technologies that have the potential to change our lives. Let this information site be a place where passion for technology is combined with hope for positive progress in our society. After collecting the input data and analyzing them, we can pro

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Supply chain management in diary industries – future scope and its importance

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Keywords: supply chain management, time, cost, distance, demand and dairy industry.
Abstract: Supply networks are a major component of contemporary industrial systems. In its most basic form, supply chain management involves controlling the movement of materials and products from producers to consumers via an appropriate transportation network. The primary function of supply chain management is thought to be profitability. It aims to optimize the difference between what consumers pay and the cost of producing and delivering the product. Another goal is to strike the best possible balance between quality and manufacturing costs. From the source of raw materials to the final product reaching the client without delays, price increases, or subpar customer service, an efficient system is created through supply chain integration. This study aims to review the supply chain management of the dairy industry on a national and international scale by gathering fundamental data from credible publications worldwide. Time, cost, distance, and demand are the main key importance factors that are taken into consideration in this work for the dairy supply chain system.

1 Introduction

Managing the flow of milk from dairy farms, processing it when needed, and delivering it to final consumers is known as dairy supply chain management. A dairyman, dairymaid, dairy cattle, or dairy goat are examples of the animals and workers that support the manufacture of milk-based products, derivatives, and processes. A dairy factory transforms the milk from a dairy farm into a variety of dairy products. We are committed to working with farmers and suppliers to address the two primary challenges in dairy supply chains: greenhouse gas (GHG) emissions and animal welfare.

The globe is impacted by the trash produced by industrial processes and the excessive use of natural resources. The dairy business plays a significant role in the food and agriculture sectors and contributes significantly to the global economy. The industry produces, processes, and distributes a variety of dairy products, including milk, cheese, butter, and yogurt. India, the United States, China, Brazil, and Russia are the world's leading producers of dairy products (FAO, 2018).

India is the world's largest producer of buffalo milk, whereas the United States is the world's largest producer of cow milk. With about 30% of global dairy exports, New Zealand is a significant player in the dairy export market. From 522 million tons in 1986 to 798 million tonnes in 2016, milk production has grown by 53% worldwide over the past three decades (FAO, 2021). Since milk production makes up the majority of agricultural activity in India, the dairy industry is a significant economic sector. The industry employs millions of people and makes a substantial economic contribution to the nation.

India's dairy market is expected to reach INR 30,840 billion by 2027, from its 2018 valuation of INR 13,174 billion (Khanna et al., 2022). By 2023, 266.5 million metric tons of milk would be produced in India, according to the National Dairy Development Board (NDDB).

The states with the highest milk production are predicted to be Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan, and Uttar Pradesh. A number of National Dairy Projects have also been put in place by the Indian government to meet the growing demands of Indian customers while increasing milk production, animal productivity, and ultimately farmer lives. Many factors, such as the use of non-scientific methods, poor cattle breeding, a disregard for quality standards, a lack of transparency, and—above all—a lack of adequate technological support, have contributed to the Indian dairy industry's slower-than-expected growth. These factors ultimately cause information asymmetry in the multilayer supply chain, endangering sustainability.

To achieve better social, economic, and environmental performance, sustainability-oriented food supply chains combine forward (buying, producing, and distributing materials) and reverse (collecting and returning used products) operations (Paul et al., 2020). In addition, they emphasize the importance of using green energy instead of conventional energy for production and delivery.

"Green supply chain management" (GSCM) is the process of integrating environmentally friendly practices into all stages of the supply chain, from consumer product design to disposal at the end of its useful life. Supply Chain Management's goal is to minimize the supply chain's impact on the environment while maintaining or improving its financial performance. It addresses sustainable sourcing, energy-efficient transportation, product design, waste reduction, and environmental performance monitoring. GSCM strategies can assist companies by reducing costs, enhancing brand awareness, and complying with legal requirements. It can also help firms stay competitive by meeting the increasing demand for sustainable products and services. Sustainable supply chain practices are actions and activities that address the social, economic, and environmental aspects of manufacturing organizations (Kumar et al., 2022). Organizational performance has increased thanks to sustainable supply chain and logistics strategies (Sinha, 2022).

The dairy supply chain network framework model that has been proposed:

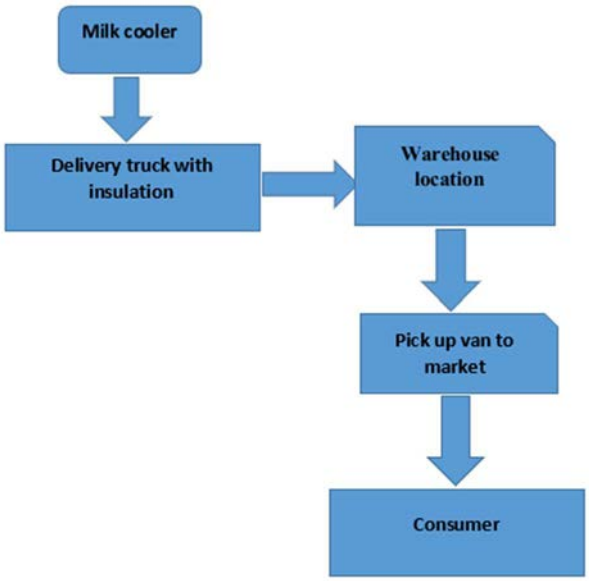

Figure 1 Model suggestion for the dairy supply chain network

The Figure 1 describes the model framework of diary supply chain operation which was shown in the graphical illustration.

In the present model the raw materials milk is taken from milk cooler or chiller plant from there it is taken to delivery truck with insulation. with the help of the insulation truck the raw materials is stored in warehouses. From warehouse the raw materials were taken to various market collection point with the help of pick up van. Finally, the product was sold to consumer at right time in right place. Hence in this work the following main important factors taken into considerations such as time, cost, distance and demand for the commodities. attempt has been to solve mathematical model for dairy supply chain network using linear programming model.

2 Literature review

Mohammad Shamsuddoha et al. [2023] The dairy industry makes a substantial contribution to the global food chain by providing essential nutrients for human consumption and creating jobs in rural areas. A family in Bangladesh can maintain their way of life with just a tiny dairy. Nonetheless, it is also connected to other environmental and social impacts, which makes it crucial for achieving sustainability. Simulation modeling and the system dynamics technique were used to build dairy supply chain networks and evaluate the data to find the best way to use the dairy waste produced on the farm. Therefore, the simulation model incorporates viewpoints on waste management and value addition to discover improved resource utilization and achieve sustainable results. In order to obtain further economic, social, and environmental benefits for the enterprise and the community, this study ends with a review of the simulation results and possible extensions [1].

R.R. Pant et al. [2015] In order to manage dairy supply chain networks, this article offers a framework for information flow, transparency, and traceability. Three different kinds of dairy supply chains that are typical in India are the subject of this case study-style research. Customers want assurances for food qualities and are growing more conscious of safety issues, new risks, and difficulties in the context of food products as a result of the increased emphasis on the food processing industries and the fact that processed food is now required rather than optional [2].

Farnaz Zarei-Kordshouli et al. [2023] In today's cutthroat marketplace, resilience tactics and sustainable growth are unquestionably important, particularly in light of the coronavirus outbreak. Therefore, this study creates a multi-phase framework for decision-making in order to examine the supply chain network design challenge while taking resilience and sustainability into account. Therefore, the potential suppliers' scores based on the sustainability and resilience components were calculated using the MADM technique. The proposed mathematical model's second step then used these scores as inputs to determine which provider should be selected [3].

Rajeev Kumar [2014] This study investigates the relationship between dairy supply chain management (DSCM) strategies and operational performance. The many DSCM practices that are investigated through a comprehensive literature review in order to ascertain their relationship to operational performance include

information and communication technology practices, supplier relationship practices, supply chain manufacturing practices, warehousing management systems, transportation management systems, and customer relationship management. Two illustrations Using multiple regression analysis, the relationship between dependent and independent variables was investigated, and the t-test was used to compare the degree of agreement and acceptance of various DSCM techniques. The difference between agreement level and adoption level was less pronounced for information and communication technology practices, transportation management systems, and customer relationship management practices, but it was significantly greater for supplier relationship practices, supply chain manufacturing practices, and warehousing management systems [4].

Kartik Mahajan et al. [2024] Through an analysis of several DSCM practices, such as supplier relationship management, supply chain manufacturing, warehousing management systems, transportation management systems, customer relationship management, and information and communication technology practices, the research paper aims to ascertain whether there is a correlation between different DSCM practices and operational performance. Examining supply chain management challenges and issues in the Indian dairy industry is the main objective of the study. Based on the findings, the ultimate goal is to make recommendations to companies who are just starting to implement dairy supply chain management in order to strengthen their ties with suppliers and consumers [5].

Gyanesh Kumar Sinha et al. [2023] The dairy industry in India, one of the fastest-growing industries globally and a contributor to over 5% of the country's GDP, directly employs millions of farmers. Implementing sustainable supply chain practices is becoming more and more important as the industry expands in order to maintain viability and lessen negative impacts on the environment and society. The current study's objective is to look into the supply chain management plans of the two leading dairy firms, Amul and Danone. This study primarily uses reports, trustworthy websites, and peer-reviewed papers as secondary sources. A case study approach has been used primarily to compare two leading dairy companies in terms of supply chain sustainability. Comparatively, significant elements such as the scale of dairy production, pricing, technology utilization, traditional supply chain management, artificial intelligence in sustainable supply chains, and logistics management in a few dairy enterprises have all been carefully studied [6].

Yash P Sale et al. [2021] Supply chain management is used to plan and regulate the movement of information between customers, warehouses, suppliers, and facilities. The main objective of supply chain management is to expand the clientele while making an effort to maintain expenses as low as possible. Supply chain management includes obtaining materials from suppliers, transporting materials from suppliers to facilities, manufacturing at facilities, transferring items from facilities to cold storage, and transferring milk products from cold storage to retailers. The four core and crucial components of supply chain management are retailer zones (RZs), distribution centers (DCs), milk processing facilities, and milk suppliers (farmers). Operational management is necessary for the acquisition of raw materials, their processing and conversion into finished products, and the ultimate delivery of milk products to merchants [7].

Rahul S Mor [2018] Particularly in terms of women's empowerment, the dairy industry significantly improves the socioeconomic status of rural India. Most of the time, the literature talks about the dairy supply chain's structure or its subcomponents, but it doesn't explain why, what, or how. The number of systematic literature reviews (SLRs) on dairy supply chain management (DSCM) practices is few. This paper offers a thorough analysis of the literature on publications pertaining to DSCM methods. Furthermore, the paper assesses the extent to which the SLR technique may be applied to DSCM in order to create a consistent knowledge pool by creating a context-sensitive research. They highlight the primary points brought up in the articles under examination. The authors selected papers from peer-reviewed journals and categorized them into three groups: decision-making methods (DMS), risk management (RM), and distribution management (DM). The research was conducted within the last eleven years [8].

ZiaUllah Muhammad et al. [2014] The particular aims of this article are to illustrate the importance of dairy supply chain management and offer instances of current industry practices in Pakistan. specifically utilizing information from the FAO and the Pakistan Economic Survey to provide light on the production and consumption trends in emerging nations. There were 730 million tonnes of milk produced worldwide in 2011, and this number is expected to increase. Notably, 98% of Pakistan's milk supply chain is controlled by informal dealers, who manage 80% of milk consumption in developing countries. Supply chain disruption has become a major issue due to informal channel bargaining leverage and knowledge barriers. Currently, Pakistan, India, and China are the top four milk-producing nations in the world. However, both milk farmers and consumers have been suffering from the financial, social, and health effects of the unauthorized dairy supply chain actors [9].

Byomkesh Talukder et al. [2021] Convergent innovation (CI), which creates a thorough integrated framework of indicators currently utilized in lean, agile, sustainable, and resilient supply chain paradigms, is used to consider the management of a dairy company's supply chain, including the procurement, processing, and customer distribution of its products. CI is a meta-framework that focuses business and actor decisions across society on the convergence of economic, social, and environmental outcomes to create supply and demand for profitable outcomes, thereby opening up new opportunities

for supply chains, market systems, and commercial innovation [10].

Teja Naganboyina et al. [2022] Among the most successful in the Indian market, the dairy sector has been the world leader in milk production since 1997. About 48% of India's milk production is believed to be consumed by the producers themselves, with the remaining 52% being marketed in cities. Of this, the organized sector (private dairies and dairy cooperatives) handles just 40%, while the unorganized dairy sector handles the remaining 60%. To boost the percentage of organized flow in the dairy business, the government has launched a number of initiatives. The size and expansion of the dairy market in India during the past ten years, together with its statistics, were reviewed in this paper. I conducted in-person interviews with several dairy chain participants in order to develop the process flow chart that depicts the procurement and delivery of milk to the end user in both the organized and unorganized sectors. I pay special attention to the cold chain [11].

Devi Prasad Kotni et al. [2022] India has become the largest producer and consumer of dairy products in the world since 1998 due to a steady increase in the supply of milk and milk derivatives. Dairy farming is a major source of revenue and employment in rural India. Milk collection in the Prakasam District began in 1975 with the opening of the Ongole Milk Chilling Center. The majority of the milk producers in the district are members of marginal, small farmer, and landless agricultural labor groups who are also socially and economically disadvantaged. In addition to examining Prakasam Milk Producer Company Limited's supply chain from farmers to consumers, the study aims to identify various milk supply chain operations at each supply chain member, including farmers, milk collecting agents, the company, distributors, agents, retailers, and customers [12].

Ritul Tripathi et al. [2021] Supply chain management seeks to minimize expenses for the business while facilitating the effective movement of appropriate products to the appropriate locations at the appropriate times, creating value for the consumers. Dairy products mean shorter turnaround times between manufacture and delivery. Products leave the producer's table and arrive at retailers more quickly. However, quick product life cycles, shorter lead times for retail inventories, and quick product distribution are some of the issues that dairy product retail network companies like Amul Dairy, Parag Diary, and others frequently confront. The main topic of this research paper is how supply chain management has helped two well-known dairy product brands—Amul Dairy and Parag Dairy in particular—overcome significant obstacles. Amul Dairy and Parag Diary's supply chain management is evidence of their status as a significant and prosperous retail behemoth on a worldwide scale. According to Gartner, Parag Diary is ranked third in the supply chain. A comparative study of their inventory management strategies is also included [13].

Janvi Mungekar et al. [2023] This study investigates how block chain technology can revolutionize the dairy supply chain, with a focus on increasing transparency and traceability. We carefully investigate the smooth integration of block chain across various supply chain stages using a thorough case study methodology. The results highlight the effectiveness of smart contract automation, the strength of real-time data sharing, and the underlying characteristics of block chain that strengthen trust. By addressing issues such as early setup expenses, we offer workable solutions [14].

Albert Tan et al. [2020] Dairy product end-to-end food traceability systems have been overlooked, despite the fact that they are essential for everyone because of their extensive global consumption. Vietnamese consumers who purchase local dairy products have limited access to reliable traceability solutions that allow them to independently confirm their purchases. "How can technology such as Block chain help address the food safety issues in the Vietnamese domestic dairy sector?" is the question that motivates the writers to seek answers. with the intention of both furthering uncharted research and offering practical applications [15].

Yingrong Zheng et al. [2022] Developing recommendations to improve the efficiency of dairy supply chain management in large cities was the goal of this research. The study's goal was achieved through a complex multi-stage research effort that involved online interviews with three key categories of dairy supply chain participants: farmers, intermediaries, and end consumers. In order to collect objective data from the producer to the end user, the three main groups were each questioned at the same time. Kazakhstan's Almaty and the Russian Federation's Yekaterinburg assessed the proposed approaches for their supply chains for dairy products [16].

Romana Heinzova et al. [2022] Food production is one of the most significant sectors of the food industry in the Czech Republic and the EU. Its close ties to the main agricultural sector, from which it purchases supplies to process and market, are another significant influence. The product's safety and quality are essential requirements for this process. Companies must use an efficient traceability system and traceability of these criteria to demonstrate the safety and quality of their food. Production and logistical elements are greatly impacted by these circumstances. The dairy sector is the main topic of this study. The entire agri-food cycle depends on this industry. Operations in these kinds of businesses are governed by a number of regulations that impact logistics and production. Both products and raw materials are perishable. Conversely, the consumer anticipates a high-quality, secure product at the appropriate moment. The primary goal of the article was to identify the risks associated with each stage of the logistical procedures used by the dairy industry. Special attention was paid to the areas of production, purchasing, and transportation. Increasing the theoretical understanding of dairy management was the secondary

goal. There is a lack of scientific literature and expert studies in this field [17].

Abhirup Khanna et al. [2022] Traditional food supply chains have problems with data loss, product anomalies, quality compromises, and a single point of failure. Also, they are centralized. An enhanced decentralized supply chain paradigm is desperately needed, as seen by the daily influx of reports of food fraud, contamination, and adulteration from all throughout India. A country like India, which gains a lot from its demographic dividend, cannot afford to let a large portion of its youngsters go hungry by eating contaminated and adulterated dairy products. Given the severity of the situation, we propose a supply chain platform for the dairy industry that is enabled by block chain technology [18].

Ish Kumar et al. [2024] The research aims to boost productivity and reduce expenses in the dairy business by improving urban distribution, particularly at Bhopal Sanchi dairy. In addition to identifying inefficiencies, it assesses current routes and suggests novel distribution tactics. These adjustments result in notable enhancements, lowering dead kilometers and overall distribution costs while increasing vehicle capacity utilization. According to the report, addressing urban distribution issues is crucial to effectively meeting the growing demand for milk. By maximizing profits and reducing losses, it helps create sustainable dairy distribution systems. To analyze fleet and route optimization, ArcGIS software is used. In general, the study tackles the urgent requirement for effective. urban dairy distribution, particularly in light of India's position as a major milk producer [19].

Annie Rose Nirmala et al. [2022] Fresh milk must be properly treated from milking to processing since it is perishable. If it is not, bacteria will infect it, reducing its quality and shelf life. Reduced farmer output upstream also results in less product availability downstream from a quantity perspective. The supply chain may be somewhat at danger due to this circumstance. Tirunelveli Aavin Nellai Milk Plant samples must be used to map the risk along the supply chain. In addition to examining the supply chain pattern and its risk, this study aimed to provide techniques for risk treatment and mitigation [20].

Asma Ben Mahmoud et al. [2008] As companies realize the importance of building integrated relationships with their suppliers and consumers, supply chain management, or SCM, is a significant issue in many industries. By providing the correct product at the proper time, location, and cost, supply chain management (SCM) aims to meet the needs of the final customer. Interest in SCM in agribusiness grew in the 1990s in both the USA and Europe. The idea and its implementation have been a primary area of research and development in agriculture for the last ten years. The potential and implications of supply chain management (SCM) in developing nations have garnered more attention in recent years [21].

Vandana & Kunal Sinha et al. [2019] Being the largest producer and user of milk in the world, India's dairy industry is gaining prominence. With 127.8 thousand tonnes of milk produced annually, Gujarat ranks fourth among Indian states. This study looks into how supply chain management works in the dairy industry. The planning and management of the flow of goods and information between farmers, cooperative societies, dairy cooperatives, distributors, retailers, and, finally, final consumers is known as supply chain management, or SCM. The foundation for Gujarat's dairy supply chain is presented in this article, with particular attention to the functions of the many players involved. The secondary literature on supply chain management for dairy products provided the information [22].

Azarruddin Shamshuddin Mulani et al. [2021] Similar to many other agribusinesses, the supply chain for the diary is intricate. From a technical standpoint, the diary chain starts with the manufacturing of raw milk and ends when different businesses, organizations, and consumers use the goods created along the value chain. The supply chain must immediately adapt to satisfy the ever-evolving demands of consumers since their choices and behaviors are not constant. A major source of revenue is thought to be dairy, although agricultural depends on the monsoon season. It is widely accepted that Indian dairy is a tool for both social and economic advancement. Milk in the nation is supplied by millions of small farmers dispersed throughout rural regions. Expanding milk production to satisfy growing demand brought on by population expansion and income rises is a challenge for the dairy industry [23].

Rayka K. Vladova et al. [2023] Around the world, millions of people regularly eat milk and milk products. In order to increase industrial competitiveness and efficiency, a sustainable supply chain management strategy that covers every process from raw materials to end users is essential. Supply chain sustainability is impacted by changes in the market. In this paper, a fresh case study from Bulgaria is used to build a sustainable dairy supply chain under ambiguous product needs using a robust optimization approach. Three milk suppliers, two dairies, and three markets are all included in the study. The supply chain entails manufacturing dairy products in accordance with different recipes while adhering to economic and ecological requirements [24].

Joseph Kasten et al. [2019] Food safety and quality are highly valued by producers, processors, regulators, and consumers across the supply chain. Since the testing labs in the US dairy supply chain are often owned by or connected to the growers and processors, there may be a conflict of interest. Several foods are tested at the time of harvest and at various intermediate stages of processing. The study's suggested approach uses blockchain technology to make sure that test results from milk analysis cannot be altered or manipulated without the other parties' knowledge, especially the regulatory body [25].

N. K. Kale et al. [2017] The Patna Dairy project's raw milk purchase from rural areas throughout five districts in

Bihar through a single channel was examined in this study. In Bihar's five districts, liquid milk is sold through two channels in the town areas. Every farmer owns his own buffalo and livestock. In the race for buffaloes, native breeds prevail 72% of the time, but the Jersey breed has the most cows (52%) [26].

Shinde V. H. et al. [2019] An important participant in the dairy industry is India. Both the livestock population and milk output in the nation are the greatest in the globe. India's dairy sector is growing rapidly because it is nutrient-dense. A common beverage in most households is milk and milk products. The number of cities and semi-urban areas in India has increased significantly. Therefore, most city people are eager to buy premium milk and milk products. In today's competitive market, supply chain management makes it possible to deliver the right items on time. Cutting expenses and improving customer satisfaction can be achieved using the newest technology, supply chain management. Quality milk and milk products are critical to the dairy industry's survival [27].

Bilge Bilgen et al. [2015] Because of its structural features—such as lengthy sequence-dependent setup times, high changeover costs, a wide variety of flavored and colored product types with intricate changeover regulations, and a limited shelf life that restricts storage duration and delivery conditions for each perishable raw material, intermediate, and final product—the dairy industry's supply chain management has drawn a lot of attention recently. This study aims to provide a critical evaluation of quantitative supply chain models used in the dairy sector. Many problem variations are examined in terms of: 2) problem and model attributes; 3) decision levels; and 4) solution techniques [28].

Yigit Kazancoglu et al. [2022] The frequency of supply chain issues is decreased by Internet of Things-enabled technologies that facilitate data gathering and analysis, especially in supply chain operations. Technology offered by the Internet of Things is essential to support this process, especially in supply networks that are vulnerable to disruptions, like the dairy supply chain. Additionally, the most waste is produced by dairy supply chains; evaluating this waste is very beneficial to the circular economy. Therefore, using Internet of Things-enabled technologies and data monitoring in dairy supply chains help to minimize losses; it is essential to have Internet of Things-enabled circular dairy supply networks operating [29].

Jiaying Zhang et al. [2022] Dairy products are necessary foods for people to eat. Nonetheless, there are regular reports regarding the safety and quality of dairy products. This study suggests a cooperative block chain-based system for monitoring the safety and quality of dairy products. It establishes the traceability connection in the dairy supply chain and builds the barcode and basic foundation of the system. At the technology level, the system guarantees the accuracy and safety of traceability data and provides dairy traceability services to customers, enterprises, and the government [30].

From the above survey analysis on dairy supply chain operations it is observed that many several researchers have shared their opinion or Interests in improving the efficiency of DSCM Practices by considering the following parameters from the literature say time, cost, distance and demand of items. In the literature researchers approached various methods like doing survey type, Quantitative analysis like mathematical model.

3 Methodology

An effort has been made in this section to conduct survey using Google forms on Dairy supply chain operations from various professionals like Faculties, Industry experts etc. The Target responses were focused to be 25 responses only.

The survey form contains 6 questions as listed below:

Q1. Which of the following requires significant attention and advancement to increase productivity, based on the organization's existing growth process?

Q2. Do you know which supply chain department is having trouble managing the raw materials?

Q3: How would you rank the dairy industry's supply chain operations' performance?

Q4: What is the most important aspect of supply chain management in the dairy sector?

Q5. Do you believe technology is essential to the management of the dairy supply chain?

Q6: In your opinion, what are the essential elements of a successful supply chain?

Nearly 11 replies were received from individuals working in technical institutions/industries, etc. Individual respondents' perceptions on the desired aspects of dairy supply chain management practices were collected.

4 Discussions

In this section the various responses given by the professionals were discussed in detailed manner as follows:

- When it comes to the organization's growth potential in terms of supply chain operations, almost 45.5% of respondents prioritized operational activities. The effectiveness of supply chain management was mostly determined by the operational features of distributors, retailers, and, ultimately, customers.
- Next thing is handling of raw materials in Supply chain operations in those aspects nearly 36.4 % of the people gave more preferences for material storage in warehouse.
- Regarding the performance of the Dairy industry in Supply chin operations it is observed that nearly 72.2% of the people gave high priority by stating that performance was good.

- Nearly 54.5% of the people gave importance to timely delivery of goods in Supply chain operations that is one of the main primary key components. Cloud computing and the Internet of Things (IoT) together provide the capacity to track important dairy product parameters across the supply chain. Distributed ledger technology, like blockchain, can be utilized to effectively share and monitor quality standards for dairy products.
- Nearly 63.6% of the people gave importance to modern technology: the integration of Block chain, IOT and cyber security. Block chain technology, nearly 54.5% of individuals prioritized timely delivery, safe packaging of items, and product availability at a low cost as features of good supply chain systems.

5 Conclusion

In conclusion, managing the supply chain for milk is a complex undertaking that calls for meticulous preparation, cooperation, and legal compliance. To sum up, supply chain management has advanced significantly from the horse and cart to the Internet of Things. Technology and data analytics have revolutionized the supply chain sector, enabling more effective and efficient handling of commodities and products. An attempt has been made to carry out diversified survey on dairy supply chain management systems through questionnaire technique. Totally 11 responses were submitted by the individuals from various institutions. The most common thing noted here is Speedy delivery of items, Modernization of technology in supply chain operations and safe packing of items are some of the main characteristics noted in the survey questionnaire.

Suggestions:

From Organization point of view:

Today technology modernization has become more rapid development and considered to be quick responsive in all possible ways. Suggestions is Organization must develop the facilities by equipping modernized technology like IOT, Block Chain and Cyber security.

Using this features every organization must streamline their Operational activities in effective manner.

From Logistics point of View:

For products that are being transshipped from a manufacturer to a warehouse or market segment, safe handling and packaging are crucial. Utilizing tracking sensors in each last item to verify that it is securely packaged and in good condition will help us enhance the packing quality.

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Enhancing biomaterial performance: the advantages and applications of Collagen coating

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Keywords: Collagen coating, biomaterials, surface modification, tissue engineering, regenerative medicine.
Abstract: Collagen, the primary structural protein in the extracellular matrix, has gained significant attention as a surface modification agent for biomaterials due to its exceptional biocompatibility, bioactivity, and ability to promote cellular adhesion and proliferation. Collagen coatings enhance the integration of synthetic and natural biomaterials with biological tissues, making them highly relevant in biomedical engineering, regenerative medicine, and implantable medical devices. This review explores the mechanisms by which collagen coatings improve biomaterial properties, including their role in modulating surface chemistry, hydrophilicity, and cellular interactions. Furthermore, we discuss various coating techniques, such as adsorption, covalent binding, and electrospinning, and their implications for optimizing material performance in biomedical applications. The advantages of collagen coatings in orthopedic, dental, and cardiovascular implants, as well as wound healing and drug delivery systems, are also examined. By highlighting the potential of collagen-functionalized surfaces, this article provides insight into the future directions of biomaterial innovation aimed at improving patient outcomes and medical device efficacy.

1 Introduction

Biomaterials play a fundamental role in modern medicine, particularly in applications such as prosthetics, implants, and tissue engineering scaffolds [1,2]. However, many biomaterials, including metals (e.g., titanium and stainless steel), ceramics (e.g., hydroxyapatite), and polymers (e.g., polylactic acid and polyethylene glycol), lack the inherent bioactivity necessary for optimal integration with biological tissues [3]. A major challenge in biomaterial science is developing surfaces that support cell adhesion, proliferation, and tissue regeneration while preventing immune rejection or fibrotic encapsulation [4,5].

Collagen, as the most abundant structural protein in the ECM, provides a bioactive and biocompatible surface modification strategy that enhances cell-material interactions (Figure 1). The presence of integrin-binding sites (e.g., RGD sequences) within collagen allows for direct interaction with cell surface receptors, promoting cytoskeletal organization, cell migration, and differentiation. Furthermore, collagen coatings influence hydrophilicity, charge distribution, and protein adsorption, factors that collectively impact material performance in vivo [6,7].

The use of collagen coatings has been explored across multiple disciplines, including orthopedic and dental implantology, cardiovascular stents, wound healing, and controlled drug delivery (Table 1). Despite its numerous advantages, several challenges remain in terms of long-term stability, degradation kinetics, and large-scale manufacturing. This review provides a comprehensive analysis of collagen coating methodologies, their impact on biomaterial properties, and their biomedical applications [8]. Harnett et al. calculated the surface energy of various tissue culture substrates (polystyrene, silicon, silicon dioxide, and indium tin oxide) before and after coating with adhesion molecules (collagen, fibronectin, poly-l-ornithine, and poly-d-lysine) to assess their hydrophobicity. Wetting experiments with culture media and saline revealed that fibronectin consistently created the most hydrophobic surface, while the hydrophilicity of other coatings depended on the underlying substrate, providing insights relevant to cell manipulation and biomedical research [9].

Nagai et al. in their study examined the effect of collagen coating on titanium implants by evaluating the initial attachment of human gingival fibroblasts and their morphological changes using SEM. Results showed that collagen coating enhanced cell attachment and promoted the formation of lamellipodia and filopodia, suggesting its potential to improve peri-implant soft tissue integration [4].

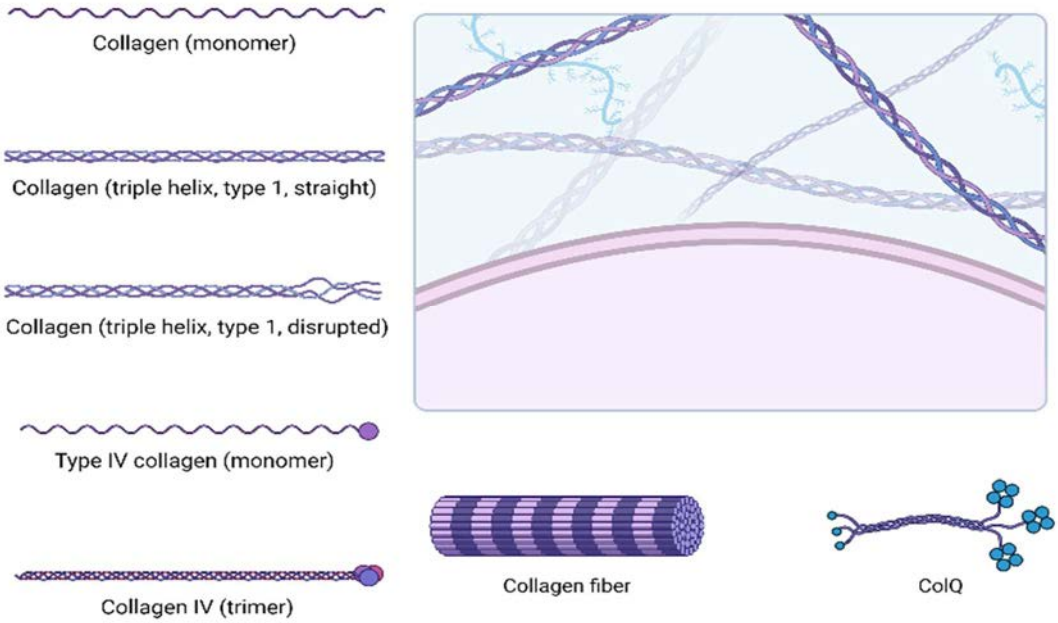

Figure 1 Different collagen structures, including monomers, triple helices, collagen IV trimers, and collagen fibers, highlighting their organization and role in the extracellular matrix (created with Biorender.com)

Table 1 Uses of collagen coating [5,10,11,12]

Application Area	Coated material	Function
Orthopedic Implants	Titanium	Improves osseointegration
Dental Materials	Hydroxyapatite	Enhances bone bonding
Cardiovascular Stents	Metal stents	Reduces thrombogenicity
Wound Dressings	Hydrogel dressings	Accelerates tissue regeneration

2 Methods of Collagen coating

The effectiveness of collagen coatings in biomedical applications depends significantly on the method used for their deposition onto biomaterial surfaces (Table 2). Various techniques have been developed to improve the adhesion, stability, and bioactivity of collagen layers, each tailored to specific applications. The selection of a coating method influences the long-term performance of the biomaterial, as it determines not only the mechanical and chemical stability of the collagen layer but also its ability to support cellular interactions [13,14].

Table 2 Methods of collagen coating [15-17]

Coating Method	Advantages	Limitations
Adsorption	Simple, cost-effective, preserves collagen structure	Weak adhesion, prone to desorption
Covalent Binding	Strong adhesion, long-term stability, bioactive sites remain functional	May alter collagen bioactivity, requires chemical modifications
Electrospinning	Mimics ECM, high porosity, supports cell growth	Complex fabrication, requires specialized equipment
Layer-by-Layer (LbL)	Tunable thickness, controlled release properties	Time-consuming, requires multiple processing steps

2.1 Adsorption method

The adsorption method is based on the spontaneous adhesion of collagen molecules onto the surface of biomaterials through non-covalent interactions, including:

- **Electrostatic forces** – Arise due to charge differences between collagen and the substrate surface.
- **Hydrophobic interactions** – Collagen adsorption is often influenced by the hydrophobicity of the biomaterial.
- **Hydrogen bonding** – Occurs between functional groups on the biomaterial and collagen molecules.
- **Van der Waals forces** – Weak interactions that contribute to molecular adhesion.

This method is widely used due to its simplicity, cost-effectiveness, and ability to preserve collagen's native structure. It is particularly effective for polymers and metallic biomaterials, where collagen can adhere passively without requiring chemical modification [17,18].

The primary advantage of adsorption is its **ease of application and preservation of collagen's native structure,** as the process does not involve harsh chemical modifications that could alter its bioactivity. This method is highly suitable for **metallic, polymeric, and ceramic biomaterials** used in orthopedic and dental implants. Additionally, it allows for **rapid processing and cost-effective production,** making it an attractive option for large-scale applications. Jacquermat et al. study investigated the supramolecular organization of collagen adsorbed on polystyrene under varying adsorption durations and drying conditions using AFM, XPS, radioassays, and wetting measurements. Results showed that collagen adsorption plateaued after 5 hours, forming a dense felt-like layer, with slow drying causing reorganization due to dewetting, while fast drying led to a more stable structure [14].

Despite its simplicity, adsorption suffers from **poor long-term stability**, as collagen layers are prone to desorption when exposed to bodily fluids and competitive protein interactions. This instability is particularly problematic in dynamic environments, such as **vascular implants**, where fluid shear forces can rapidly remove the adsorbed collagen layer. To improve adhesion, surface pre-treatment methods such as **plasma treatment, oxidation, or polyelectrolyte layering** are often employed to increase the affinity of collagen for the biomaterial [19].

2.2 Covalent binding

Covalent binding methods offer a more stable alternative to adsorption by chemically attaching collagen molecules to the biomaterial surface. This process involves the formation of permanent chemical bonds between collagen's functional groups (such as amine or carboxyl groups) and reactive sites on the biomaterial. Covalent immobilization is widely employed in applications requiring long-term bioactivity and resistance to enzymatic degradation, such as load-bearing implants and cardiovascular grafts [20,21].

Yang et al. modified poly(L-lactic acid) (PLLA) by covalently grafting collagen via gamma irradiation with poly(acrylic acid) as a coupling agent, achieving a dose-dependent grafting yield exceeding 7% at 21 kGy. Characterization by XPS, swelling experiments, and immunostaining confirmed successful collagen attachment, crosslinking, and retention of biologically active binding sites, demonstrating the potential of this method for enhancing scaffold biocompatibility in tissue engineering [22].

2.2.1 Crosslinking strategies for Covalent binding

Several chemical crosslinking strategies have been developed to achieve covalent binding of collagen to biomaterials:

- **Glutaraldehyde Crosslinking:** This approach involves the reaction between aldehyde groups and primary amines on collagen and biomaterial surfaces, forming Schiff base linkages. While highly effective, residual glutaraldehyde can be cytotoxic, necessitating additional washing or neutralization steps.
- **Carbodiimide Chemistry (EDC/NHS):** This method activates carboxyl groups on collagen, allowing their reaction with amine-containing biomaterials to form stable amide bonds. This technique is more biocompatible than glutaraldehyde crosslinking and retains collagen's bioactivity.
- **Diisocyanate Crosslinking:** This strategy forms urethane linkages between hydroxyl or amine groups of collagen and biomaterials, commonly used for polymeric scaffolds [23].

Covalent immobilization significantly improves coating stability, durability, and mechanical resilience, making it ideal for implants and scaffolds that must maintain bioactivity over long periods. However, excessive crosslinking can reduce the natural flexibility and bioactivity of collagen, potentially altering its ability to interact with cells. To mitigate this, dual crosslinking strategies that combine synthetic and enzymatic crosslinkers (e.g., genipin) are being explored [24].

Myles et al. study developed a method to covalently couple adhesion peptides containing the arginine-glycine-aspartic acid (RGD) sequence to type I collagen monomers before fibrillogenesis, using a heterobifunctional coupling agent to form stable bonds. The modified collagen retained similar microstructure and gelation properties as unmodified collagen, while enhancing cell adhesion in a dose-dependent manner, demonstrating its potential for controlled cell localization in tissue engineering applications [16].

2.3 Electrospinning

Electrospinning is a versatile technique that allows for the deposition of collagen nanofibers onto biomaterial surfaces, creating a highly structured, biomimetic coating that closely resembles the extracellular matrix (ECM). This process involves applying a high-voltage electric field to a collagen solution, which causes the formation of ultrafine fibers that are collected onto a substrate. The resulting coatings exhibit high porosity, controlled fiber orientation, and tunable mechanical properties, making electrospinning particularly useful for tissue engineering, wound healing, and scaffold fabrication [25].

Dupont-Gillian's study developed a strategy to create nanoscale polymer surface architectures by adsorbing

collagen onto PMMA, drying it at different rates, and then spin-coating PMMA solutions over it. The resulting surfaces, analyzed by AFM and XPS, showed that collagen layers influenced PMMA dissolution and redeposition, enabling the formation of controlled surface topographies with pits or cavities depending on drying conditions and PMMA concentration [15].

3 Discussion

The findings presented in this review highlight the critical role of collagen coatings in enhancing biomaterial performance across various biomedical applications. By modifying surface chemistry, hydrophilicity, and bioactivity, collagen coatings improve cellular interactions, thereby promoting adhesion, proliferation, and integration with biological tissues. These effects are particularly beneficial in implantology, tissue engineering, and regenerative medicine, where successful biomaterial integration is paramount [26,27].

One of the most significant advantages of collagen coatings is their ability to enhance cell adhesion through integrin-mediated interactions. Studies demonstrate that the presence of collagen coatings on metallic and polymeric substrates leads to increased cellular attachment and spreading, as observed in titanium implants for dental and orthopedic applications. The formation of lamellipodia and filopodia on collagen-coated surfaces further indicates improved cytoskeletal organization and migration potential, factors that are crucial for tissue regeneration [7,21].

Additionally, collagen coatings influence biomaterial hydrophilicity, which plays a vital role in protein adsorption and cellular response. Hydrophilic surfaces are generally more favorable for cell attachment, and collagen's ability to modulate this property provides a strategic advantage in designing biomaterials tailored for specific applications. However, variations in collagen layer stability across different coating techniques present a challenge. Adsorbed collagen layers, while simple and cost-effective, often lack long-term stability due to weak non-covalent interactions, which may lead to desorption under physiological conditions. Conversely, covalent immobilization offers greater durability but may require additional processing steps to preserve collagen's bioactivity and structural integrity [28,29].

Despite the numerous advantages, some challenges remain. The long-term stability, degradation kinetics, and cost-effectiveness of collagen coatings require further investigation to optimize their clinical translation. Additionally, batch-to-batch variability in collagen sources and differences in coating methodologies can impact reproducibility, necessitating standardized protocols for biomedical applications [13,30].

4 Conclusion

Collagen coatings have emerged as a powerful strategy for enhancing the bioactivity and biocompatibility of biomaterials across various biomedical applications. By promoting cell adhesion, proliferation, and integration with biological tissues, collagen-functionalized surfaces play a critical role in improving the performance of orthopedic implants, dental materials, cardiovascular devices, wound dressings, and drug delivery systems. The selection of an appropriate coating technique—whether adsorption, covalent binding, or electrospinning—significantly influences the stability, functionality, and long-term efficacy of collagen coatings [5].

Despite their numerous advantages, challenges such as coating degradation, variability in collagen sources, and large-scale manufacturing constraints must be addressed to optimize clinical translation. Future research should focus on refining coating methodologies, developing crosslinking strategies that balance stability with bioactivity, and exploring novel biomaterial-collagen composites for advanced regenerative medicine applications. By continuing to innovate in this field, collagen coatings hold immense potential to improve patient outcomes, enhance medical device performance, and contribute to the next generation of biomaterial development [7,17].

While collagen is a widely used biopolymer for surface modification, other polymers such as chitosan, alginate, polyethylene glycol (PEG), and polylactic acid (PLA) have also been explored for their bioactive properties. These polymers offer unique advantages, including antibacterial effects, controlled degradation rates, and tunable mechanical properties, making them suitable alternatives or complementary materials to collagen in biomedical applications [31,32].

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Marine trader's method of payment and level of satisfaction towards infrastructural facilities of dry ports in India – an empirical study

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Keywords: sea and dry ports, marine trade, CONCOR and BOP, shipping industry, world trade and ministry of commerce and Industry.
Abstract: All commodities and services moved by sea require at least two seaports; the importance of seaports to the smooth operation of an economy cannot be overstated. Maritime transport is used for most of the domestic and international trade (import/export). Due to a shortage of contemporary equipment and human resources throughout India, the shipping industry is experiencing delays in the transportation process for both imports and exports. Further shipping industry personalities are facing financial challenges related to the overseas transaction between two or more countries due to the huge payment formalities in India. India's shipping industry one of the backbones of Indian economy. In near future, the ministry of commerce and industry must take considerable steps for improving the effective method of payments as well as marine traders level satisfaction towards developing infrastructural facilities in dry port for utilize the great opportunities of shipping industry earnings to strengthen the India's BOP position as well as economic position and export-import volume in the world trade market.

1 Introduction

Seaports are essential for the waterborne transportation of all goods and services, their significance for the efficient functioning of an economy cannot be emphasized. Most local and international trade, including import/export, occurs via maritime transit. Despite this, there are still several challenges facing the Indian shipping sector in relation to domestic marine transportation as well as import and export. Seaborne trade is totally dependent on seaports for their operations, since they act as an interface conduit between inland and maritime container depots (dry port).

Therefore, in order to have a viable and effective maritime transport system, seaport productivity needs to be guaranteed. The present study is focusing towards determine the level of satisfaction regarding the dry port's infrastructures in the study location and to understand the payment methods performed by the maritime traders.

2 Literature review

A seaport's primary function is to ensure that goods and services are transported via its facilities quickly and safely, hence lowering average costs for shippers. "Seaports are interfaces between several modes of transport, and thus they are centres for combined transport," is how UNCTAD defines the relevance of seaports. Moreover, these are multipurpose marketplaces and industrial zones where products are not only transported but also processed, produced, and delivered. Maritime ports are multifaceted systems that, in order to adequately perform their roles, need to be integrated into logistical chains. Indian dry ports, or inland hubs for distribution and cargo consolidation, are anticipated to be essential in linking the country's numerous seaports to the global market. However, in this process, dry ports contribute considerable role towards connecting the goods production place to port of loading place as well as port of importing place to goods consumption place in India.

India's dry ports are accessed by road or rail, with minimal value-added operations taking place. The Government of India began building a satellite port in Bombay in 1987 after realizing the value of both dry and maritime ports. The port opened for business in 1988, later the particular seaport is called as NNP port. The first dry port was subsequently built by CONCOR in Tughlakabad, New Delhi. Various marine traders at dry ports require different skills and experiences. In addition, the foreign traders must fulfil the legal obligations and business procedures that must be adhered to scrupulously. An exporter might need, for instance, a capable freight broker to bargain for the cheapest prices for a shipping voyage, a highly trained professional is involving with handling the appropriate stuffing process, another EXIM documentation professionals are following the foreign trade guidelines. For dry port users, these facilities will be great to receive all services from a single organization. However, since specialists can provide better value for money, the potential professional's marine trade activities have led to the emergence of experts in every field. As a result, the dry port operator has to make it less difficult for its customers to receive these experts' services from one location [1].

As per last count, India's 7,517 km coast includes 187 minor ports in addition to the 13 major ports. Approximately seventy-five percent of India's total trade in terms of value and 95% of its trade in volume are handled by these ports. Major ports have been overloaded and operating exceeding their intended capacity. Expansion in worldwide production and trade are the primary drivers of

maritime transport activities. Therefore, the quantity of seaborne cargo that ports handle is primarily influenced by the levels and fluctuations of both domestic and worldwide industry. From April to February of 2022–2023, the volume of cargo handled at India's 12 major ports climbed by 9.4% to 711.55 million tonnes, up from 650.14 million tonnes in 2021–2022. All over India, the dry ports are acting as intermediary between the industries to seaports. The flow of EXIM information between shipping lines/carriers and shippers/consignees has been considerably quicker through these dry ports. In this paper, the researcher provides a perspective on existing marine traders level of satisfaction towards sea and dry ports as well as their method of payments to observe the present position of marine trade [2].

In along with infrastructure, superstructure, and equipment, a functioning seaport requires appropriate links to other forms of transportation, motivated management, and a workforce having the appropriate skills. The ninety percentage of Indians economy is based on the shipping industry only, India has 1071 ships with 722 coastal areas with 349 overseas mother vessels. Naturally India's geographically located 7517 km coastline. 70 percentages of India's maritime transport are moving through sea route only. Therefore, GOI joined with ministry of commerce and shipping for improving the Indian foreign trade through offering various incentives schemes to marine traders, enterprises, port operators, ship builders as well as logistics players. For observe the operational efficiency of Indian Mari time industry and its mediator's level of satisfaction and challenges faced by them are necessary to obtain the real time data and study for improving the Indian economy as well as BOP position. That is the reason why, this present study is attempted by the researcher for observing actual situation and recommend to the maritime authorities and others involving with shipping industry to rectify the challenges [3].

Under the Companies Act, CONCOR was founded in 1988 and started operating in 1989, using the seven ICDs that the Indian Railways currently had across the country. The establishment of CONCOR was to provide multimodal logistical assistance for India's domestic and international trade and freight. As per the GOI, Ministry of Shipping report stated at present 2020, there are 247 Dry Ports and CFS involving with shipping transportation in Indian coastal area to other destination in 170 are functional condition and rest under implementation conditions [1-4].

A quality logistics service depends on good infrastructural facilities offered by sea and dry ports in any country. The transfer of commodities across international borders is greatly aided by logistics services; ineffective logistics services hinder trade by adding to the cost of both time and money. The need for effective logistics services is growing as industrialized countries move away from traditional manufacturing and agriculture and towards international vertical specialization. By decreasing the cost of products transportation, excellent logistics services help governments who suffer by being distant from major markets becoming stronger competitors in the international market for exports. If the administrator of dry port knows the actual requirements of dry port users, it will be useful to develop the existing facilities of dry port. Therefore, this study will investigate the level of satisfaction perceived by marine traders and method of payment followed by them in the study area [5].

3 Data and methodology

The researcher has applied the stratified random sampling method for collecting the primary data and secondary published data related to marine traders in Indian perspectives. The researcher has selected the Coimbatore as an area of the study for conducting this present study. The sample for the study area was selected by the researcher employing a stratified random selection technique. Only relevant details were included in this study, which assisted in properly achieve the objective of the present study. The obtained data was not simply accepted; it additionally contained extraneous information and excessively data are minimized.

The primary data collected by the researcher through questionnaire method. The researcher has collected the questionnaire from marine traders that are exporter concern employee, importer concern employee, mediator's organization employees in Coimbatore dry port. The published data has collected from journals, articles, magazine, EXIM times, chamber of commerce Coimbatore, port of economics website, CONCOR website and ministry of commerce, ministry of shipping. The present study period is carried out by the researcher during the period June 2024 to February 2025.

Experts in field of marine trade are given the questionnaire to evaluate critically. Twenty respondents were given the questionnaire to complete in each of the four Tamilnadu locations in order to undertake pre-testing and pilot research. The purpose of the pretesting was to confirm the questionnaire's validity and reliability. It was done to ensure that the quality of questionnaire and its clarity level. The questionnaire was modified as needed with the help of pilot study, taking into account the feedback from the chosen sample of respondent's opinion. The respondents included in the pilot study are not included in the final study (data analysis). Apart from the pilot study 20 respondents, the researcher has collected 217 respondents in the study area [5-8].

The researcher has applied simple percentage method for find out the method of payments followed by marine traders and factors analysis for observe the level of satisfaction of marine traders in the study area.

There are certain limitations in the study that the researcher has identified, as it was conducted using both primary and desk research data. The accuracy of the information provided by all respondents may not always be known because some have a tendency to provide their own experience information. This present study is entitled as method of payment (Table 1) followed by marine traders and level of satisfaction of infrastructural facilities in dry

port in Indian perspectives, even after a careful investigation is inseparable from the limitations. This study is not included the exporter, importer, ICD officials, CFS officials, seaport authorities, documentation developers, service providers, public in this study due to time constraint [9-14].

Table 1 Method of payment followed by marine traders in dry port in Coimbatore

S. No.	Purpose of payment	Method	Always		Frequently		Some times		Rarely		Not at all	
			No.	%	No.	%	No.	%	No.	%	No.	%
1.	Receipt of Export payment by the exporters	DD	26	12	74	34.1	58	26.7	32	14.7	27	12.4
		Account	16	7.4	28	12.9	92	42.4	48	22.1	33	15.2
		NEFT	-	-	58	26.7	85	39.2	49	22.6	25	11.5
		LC	13	6.0	12	5.5	69	31.8	97	44.7	26	12
2.	Import payment by the Importer	DD	26	12	20	9.2	84	38.7	57	26.3	30	13.8
		Account	30	13.8	67	30.9	55	25.3	41	18.9	24	11.1
		NEFT	37	17.1	41	18.9	72	33.2	42	19.4	25	11.5
		LC	25	11.5	55	25.3	80	36.9	41	18.9	16	7.4
3.	Warehouse Cargo Examination Charges	Cash	23	10.6	60	27.6	77	35.5	44	20.3	23	10.6
		DD	19	8.8	62	28.6	69	31.8	52	24.0	15	6.9
		Account	24	11.1	21	9.7	93	42.9	52	24.0	27	12.4
		NEFT	31	14.3	73	33.6	40	18.4	33	15.2	40	18.4
4.	Public and Private Bonded warehouse charges	Cash	41	18.9	48	22.1	27	12.4	75	34.6	26	12
		DD	14	6.5	71	32.7	81	37.3	26	12.0	25	11.5
		Account	12	55	.58	26.7	80	36.9	55	25.3	12	5.5
		NEFT	9	4.1	27	12.4	97	44.7	56	25.8	28	12.9
5.	Terminal Charges	Cash	22	10.1	59	27.2	45	20.7	44	20.3	47	21.7
		DD	29	13.4	58	26.7	36	16.6	57	26.3	37	17.1
		Account	14	6.5	62	28.6	75	34.6	42	19.4	24	11.1
		NEFT	-	-	72	33.2	55	25.3	68	31.3	22	10.1
6.	Equipment (Trailer, Fork- lift, Crane) Charges	Cash	39	18	29	13.4	52	24	71	32.7	26	12
		DD	22	10.1	66	30.4	81	37.3	17	7.8	31	14.3
		Account	3	1.4	50	23.0	73	33.6	60	27.6	31	14.3
		NEFT	3	1.4	19	8.8	146	67.3	21	9.7	28	12.9
7.	Cargo handling(Stuffing and de-stuffing charges)	Cash	25	11.5	64	29.5	71	32.7	24	11.1	33	15.2
		DD	14	6.5	49	22.6	61	28.1	63	29.0	30	13.8
		Account	26	12	47	21.7	67	30.9	65	30.0	12	5.5
		NEFT	14	6.5	71	32.7	40	18.4	58	26.7	34	15.7
8.	Consolidation charges	Cash	34	15.7	74	34.1	61	28.1	29	13.4	19	8.8
		DD	33	15.2	85	39.2	48	22.1	37	17.1	14	6.5
		Account	24	11.1	41	18.9	137	63.1	12	5.5	3	1.4
		NEFT	3	1.4	38	17.5	120	55.3	43	19.8	13	6.0
9.	Customs documentation Charges	Cash	17	7.8	44	20.3	66	30.4	63	29.0	27	12.4
		DD	21	9.7	18	8.3	95	43.8	57	26.3	26	12
		Account	16	7.4	71	32.7	34	15.7	96	44.2	0	0
		NEFT	30	13.8	39	18	44	20.3	74	34.1	30	13.8
10.	Customs Duty and fee	Cash	25	11.5	51	23.5	66	30.4	48	22.1	27	12.4
		DD	13	6.0	80	36.9	45	20.7	60	27.6	19	8.8
		Account	50	23	46	21.2	92	42.4	17	7.8	12	5.5
		NEFT	14	6.5	50	23.0	92	42.4	39	18	22	10.1
11.	Mediator(CHA, FF, NVOC, Liners) Charges	Cash	29	13.4	53	24.4	37	17.1	64	29.5	34	15.7
		DD	14	6.5	39	18	76	35	51	23.5	37	17.1
		Account	32	14.74	70	32.25	33	15.21	64	29.49	18	8.29
		NEFT	-	-	94	43.3	58	26.7	33	15.2	32	14.7
12.	GSP Certificate, Fumigation & demurrage Charges	Cash	11	5.1	59	27.2	103	47.5	20	9.2	24	11.1
		DD	12	5.5	69	31.8	52	24	71	32.7	13	6.0
		Account	13	6.0	34	15.7	113	52.1	51	23.5	6	2.8
		NEFT	3	1.4	31	14.3	72	33.2	99	45.6	12	5.5

4 Results and discussion

In this present study, a sample of 217 respondents was analysed. Factor analysis, the most effective multivariate technique for identifying groups of determinants, was performed on the collected data after it had been categorized, tabulated, and processed. This method connects seemingly unrelated variables, revealing the underlying structure of the data by identifying common dimensions among observable variables. The objective of this study is to condense most of the original data into the fewest possible variables for predictive purposes. To achieve this, Principal Component Analysis (PCA) was employed. PCA is a factor model in which the factors are determined based on total variance. Another important concept in factor analysis is the rotation of factors. One widely used technique for simplifying the factor structure by maximizing the variance of a pattern matrix column is the varimax rotation. Additionally, the latent root criterion is applied; the column sum of squares for a factor is known as an Eigen value, which indicates the degree of data variance. Once the common factors have been identified, factor scores are calculated for each factor. The observed variables are expressed as linear combinations of these common elements.

Table 2 Level of satisfaction perceived by marine traders in the study area

LEVEL OF SATISFACTION PERCEIVED BY MARINE TRADERS	Initial	Extraction
Total areas of the dry port	1.000	.940
Annual capacity in terms of TEU	1.000	.843
Plot areas in terms of Sq.Mtrs	1.000	.940
Open container yard area	1.000	.894
Warehouse capacity	1.000	.980
Reefer point facilities with available engineers	1.000	.958
Under one roof: surveyors, employees, and customs	1.000	.786
EDI and IT system connectivity	1.000	.794
Road and Rail connectivity	1.000	.919
Order fulfillment are	1.000	.940
Pick and Pack are	1.000	.809
Special cargo handling are	1.000	.830
Barcode scanning are	1.000	.989
Inventory visibility are	1.000	.893
Temporage controlled storage are	1.000	.950
Bonded warehouse are	1.000	.930
Non-bonded warehouse are	1.000	.915
DWELL TIME STUDY- Cargo arrival time in warehouse are	1.000	.906
Traffic time are	1.000	.978
Stuffing and de-stuffing time are	1.000	.864
Documentation processing time between entry to stuffing or De-stuffing are	1.000	.956
Cargo inspection time are	1.000	.937
Weighbridge facilities are	1.000	.933
Trailers facilities are	1.000	.926
Forklifts facilities are	1.000	.950
Reach stackers facilities are	1.000	.901
Top lifters are	1.000	.863
Cranes facilities are	1.000	.928
Gantry and container crane facilities are	1.000	.843
Customs filing and documentation process for export	1.000	.933
Customs filing and documentation process for import	1.000	.923
Pre-shipment documentation processes in EDI	1.000	.960
Post-Shipment documentation processes in EDI	1.000	.904
Level of cooperation of customs officials and inspectors are	1.000	.840
Dry and sea port Labour support for loading and unloading the cargo are	1.000	.944
EDI department employee advice and cooperation are	1.000	.961
Skilled professionals and trained manpower are	1.000	.874
Pilferage-Free ICD/sea port	1.000	.907
Round the clock CCTV surveillance	1.000	.904
Controlled access for visitors to the dry and marine port's gate, warehouse, and other locations	1.000	.906
Fire Fight Equipment	1.000	.954
Regular mock drill for health and safety	1.000	.862
High mast light for day light feel	1.000	.910
Underground drainage system	1.000	.962
Order management	1.000	.979
Vendor managed inventory	1.000	.889
Kitting	1.000	.941
Cargo insurance	1.000	.914
Assembly	1.000	.887
Re-packing and co-packing	1.000	.881
Reverse logistics	1.000	.878
Quarantine and disposal management	1.000	.807
Distribution of cargo	1.000	.936
Capacity to provide 3PL service	1.000	.934
Capacity to launch new trailer	1.000	.956
Capacity to handle different types of cargo	1.000	.938
Ability to adapt altering schedule	1.000	.983
Speed of action to take decisions	1.000	.902

A straightforward link between the variables and the factors is known as factor loading. Both the factors and the factor loading are contained in the factor matrix. Using a five-point rating system ranging from 5 to 1, the researcher used factor analysis to determine the degree of satisfaction of marine traders with the state of the available

infrastructural facilities in the Coimbatore dry port. The SPSS software was used to conduct the factor analysis for the 58 factors. The analysis was carried out in phases, including the extraction method Principal Component Analysis. PCA is the extraction method (Table 2).

Table 3 Explained by total variance

Combination	Values			Squared loadings		
	Overall	Proportion of variation	Combined percentage	Total	Proportion of variation	Combined Percentage
1	8.189	14.119	14.119	8.189	14.119	14.119
2	5.526	9.527	23.646	5.526	9.527	23.646
3	5.065	8.732	32.378	5.065	8.732	32.378
4	4.489	7.739	40.117	4.489	7.739	40.117
5	3.769	6.498	46.615	3.769	6.498	46.615
6	3.599	6.205	52.820	3.599	6.205	52.820
7	3.220	5.551	58.371	3.220	5.551	58.371
8	2.914	5.024	63.395	2.914	5.024	63.395
9	2.699	4.653	68.049	2.699	4.653	68.049
10	2.482	4.279	72.328	2.482	4.279	72.328
11	2.073	3.574	75.902	2.073	3.574	75.902
12	1.899	3.273	79.175	1.899	3.273	79.175
13	1.800	3.103	82.278	1.800	3.103	82.278
14	1.540	2.656	84.934	1.540	2.656	84.934
15	1.389	2.395	87.329	1.389	2.395	87.329
16	1.185	2.043	89.372	1.185	2.043	89.372
17	1.027	1.771	91.143	1.027	1.771	91.143
18	.884	1.524	92.666			
19	.798	1.375	94.041			
20	.758	1.307	95.349			
21	.722	1.245	96.594			
22	.569	.981	97.575			
23	.437	.753	98.328			
24	.381	.657	98.986			
25	.218	.376	99.362			
26	.171	.294	99.656			
27	.092	.158	99.815			
28	.088	.152	99.967			
29	.019	.033	100.000			
30	.000	.000	100.000			
31	.000	.000	100.000			
32	.000	.000	100.000			
33	.000	.000	100.000			
34	.000	.000	100.000			
35	.000	.000	100.000			
36	.000	.000	100.000			
37	.000	.000	100.000			
38	.000	.000	100.000			
39	.000	.000	100.000			
40	.000	.000	100.000			
41	.000	.000	100.000			
42	.000	.000	100.000			
43	.000	.000	100.000			
44	.000	.000	100.000			
45	.000	.000	100.000			
46	.000	.000	100.000			
47	.000	.000	100.000			

48	.000	.000	100.000			
49	.000	.000	100.000			
50	.000	.000	100.000			
51	.000	.000	100.000			
52	.000	.000	100.000			
53	.000	.000	100.000			
54	.000	.000	100.000			
55	.000	.000	100.000			
56	.000	.000	100.000			
57	.000	.000	100.000			
58	.000	.000	100.000			

The EIGEN values are presented in the table labelled "Initial Eigen Values." Each EIGEN Value indicates the "Total Variance" (Table 3) attributed to a specific factor. According to the extraction sum of squared loadings, the I factor accounted for a variance of 8.189, or 14.119%. The II factor explained a variance of 5.526, or 9.527%; the III factor explained 5.065, or 8.732%; the IV factor accounted for 4.489, or 7.739%; and the V factor explained 3.769, or 6.498%. The VI factor accounted for a variance of 3.599, or 6.205%; the VII factor explained 3.220, or 5.551%; the VIII factor explained 2.914, or 5.024%; the IX factor accounted for 2.699, or 4.653%; the X factor explained 2.482, or 4.279%; and the XI factor accounted for 2.073, or 3.574%. Additionally, the XIII factor explained a variance of 1.800, or 3.103%; the XIV factor accounted for 1.899, or 3.273%; and the XV factor explained 1.540, or 2.656%. The XVI factor accounted for a variance of 1.389, or 2.395%; the XVII factor explained 1.185, or 2.043%; and the variance attributed to the XVIII factor is noted. This process illustrates factor determination using Eigen Values.

Table 4 Inducing variables into factors and clustering

Factor	GENERATING VARIBALES	Factor loading with rotation
I	Dry and sea port Labour support for loading and unloading the cargo are	.735
	Order management	.719
	Assembly	.688
II	Documentation processing time between entry to stuffing or De-stuffing are	.679
III	Warehouse capacity	.673
	Cargo insurance	.665
	Vendor managed Inventory	.619
	Plot areas in terms of Square Meters.	.618
	Top lifters are	.615
IV	Temporage controlled storage are	.610
	Level of cooperation of customs officials and inspectors are	.600
	Road and Rail connectivity	.593
	Ability to adapt altering schedule	.590
V	Inventory visibility are	.579
	Fire Fight Equipment	.576
	Controlled access for visitors to the dry and marine port's gate, warehouse, and other locations	.574
VI	Pre-shipment documentation processes in EDI	.570
	Capacity to handle different types of cargo	.568
	Skilled professionals and trained manpower are	.567
VII	Underground drainage system	.562
	Capacity to launch new trailer	.562
	Pilferage-Free ICD/sea port	.560
VIII	Speed of action to take decisions	.550
	Under one roof: surveyors, employees, and customs	.548
	Customs filing and documentation process for import	.546
IX	Reach stackers facilities are	.538
	Quarantine and disposal management	.535

	Weighbridge facilities are	.535
	Trailers facilities are	.532
	DWELL TIME STUDY- Cargo arrival time in warehouse are	.532
X	reverse logistics	.529
	cranes facilities	.526
	Kitting	.523
	Open container yard area	.523
	Customs filing and documentation process for export	.518

Seventeen factors were found to account for the maximum percentage of variance in the Table 4. Factor I is the variable Dry and Sea Port Labour Support for loading and unloading the cargo; it contributes 0.735 percent to the variance in the total. With a score of 0.518, the variable Customs filing and documentation process for export is the last factor to be secured.

As per the present study results reveals that, marine traders are receiving their export payments from importer through bank accounting transaction between two countries. At the same time, import payments are followed through bank demand draft. Marine traders are remitting their warehouse cargo examination charges through accounting transaction, public and private bonded warehouse charges, terminal charges, and equipment charges, cargo handling charges, consolidation charges, customs duty and fee are remitted through NEFT transaction in Indian sea and dry port operations area.

The ministry of commerce and shipping ministry join together for simplifies the marine traders and its facilitators like shipping mediators' way of remitting the payments in two way process both export and import payments connected with shipper payments as well as Government duties and charges for improve the operational efficiency of international traders in connected with shipping industry. As per the ministry of commerce and industry Indians exports volume in March 2021 were USD 34.45 Billion and Imports in March 2021 were USD 48.38 Billion (Rs.3,52,191.21Crore) rupees, this volume shows that India have huge export –import transaction even the pandemic period. So, the GOI, ministry of commerce & industry, ministry of shipping, port trust authorities, chamber of commerce and shipping industry inter mediatory organization must convince the meeting for improve the effective export import and its allied payments methods in India. The present method of payments are little complicated one since foreign traders are dealing with demand draft, Account transaction, NEFT transaction and letter of credit transaction for their shipping payment process, instead of the various method, if GOI is establish and propose the common e-payment method for completing the export and import payments in shipping industry it will be more useful to improve the India's BOP position, efficiency of Indian foreign traders as well as intermediaries of shipping industry in India.

5 Conclusion

Seaports are essential for linking domestic supply chains to the international market in the era of globalization. Many nations now prioritize improving port operations. In match with the growth of world GNP, the development of international business has become more noticeable. The need for shipping services is increased since a larger portion of exports are now shipped by sea through dry ports. The previous few years have seen a rise in global trade in goods, instrumental for achieving the growth of global trade is dry ports. The entire marine trade business sector activities are getting progressive growth in recent years and there are no changes in the positive growth area in shipping industry (IAME 2007). The shipping industry are facing delay shipment process in two ways exports as well as imports, due to the lack of infrastructural facilities like marine trade experts and modern equipment's in India. Further shipping industry personalities are facing financial challenges related to the overseas transaction between two or more countries due to the huge payment formalities in India. India's shipping industry one of the backbones of Indian economy. It is acting as a major role between India versus other countries in terms of transfer the surplus goods to world market and imports the deficit goods to Indian markets through sea routes. Right now, during the pandemic period 2020-21 Indian shipping industry are acting as major safeguard elements to supply the basic medicines and its related goods from world market to India. As per the WTO prediction, the world trade volume will fall down nearly 32% due to the impact of Covid-19. The entire marine trade is affected from shipyards to seaports. It shows that, India's marine trade operation bottlenecks in terms infrastructural facilities and lack of smart technologies like port digitization, artificial intelligence, RFID technologies and internet of things. In near future, the ministry of commerce and industry must take considerable steps for improving the effective method of payments as well as marine traders level satisfaction towards developing infrastructural facilities in dry port for utilize the great opportunities of shipping industry earnings to strengthen the India's BOP position as well as economic position and export-import volume in the world trade market.

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Shaping sustainable agribusiness through ESG: a bibliometric study

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Abstract: The integration of Environmental, Social, and Governance (ESG) principles has become increasingly important in the agribusiness sector, which faces significant challenges related to sustainability, resource management, and social responsibility. This study explores the motivations and implications of adopting ESG practices within agribusiness, highlighting how these practices can support both environmental stewardship and corporate resilience. This study provides a comprehensive bibliometric analysis of research publications concerning ESG from 2000 to 2023. The analysis aims to evaluate the current state of knowledge, identify prevailing trends, and uncover existing research gaps. Utilising a dataset comprising 3874 research publications retrieved from the Web of Science database, the findings indicate a substantial growth in ESG-related research, underscoring an increased global awareness of critical challenges. Through a review of relevant literature, the research analyses the role of ESG across three key pillars: the environmental impact of agricultural activities, social considerations such as fair labour practices and community engagement, and governance aspects related to transparency and accountability. The findings suggest that companies that prioritize ESG principles are better equipped to meet the growing expectations of stakeholders, including investors, consumers, and regulatory bodies, while also enhancing their competitive position in the market. Additionally, the study emphasizes the importance of climate-smart agriculture and effective governance in addressing the sector's complex challenges. Ultimately, the research underscores the critical role of ESG integration in promoting sustainable development and long-term viability for agribusinesses.

1 Introduction

In recent years, the integration of Environmental, Social, and Governance (ESG) principles into the business practices of various industries has gained significant attention, with the agribusiness sector standing out as one of the most critically impacted. The agribusiness industry plays a vital role in global food security and economic development, but it also exerts significant pressure on natural resources, ecosystems, and local communities. Consequently, the adoption of ESG practices in this sector has become increasingly important for ensuring sustainability and long-term corporate viability. This document provides an overview of the relationship between ESG principles and agribusiness, focusing on the motivations behind this integration and the implications for companies operating in this sector. The environmental, social, and governance pillars of ESG each present unique challenges and opportunities for agribusinesses, and this article explores the relevant literature to understand how companies are responding to these pressures.

Agribusinesses, due to their reliance on natural resources, are at the forefront of sustainability challenges, particularly as global demand for food increases in the face of climate change and resource depletion. Companies that operate within the sector are increasingly required to address their environmental impact, labour practices, and governance structures to meet the growing expectations of investors, consumers, and regulators [1,2]. Moreover, the rise of socially responsible investing (SRI) and the prioritization of ESG criteria by institutional investors have further driven agribusinesses to integrate these principles into their operations to remain competitive and resilient [3]. This article reviews the current state of ESG in the agribusiness sector by analysing the environmental, social, and governance pillars, presenting findings from various studies, and discussing the theoretical implications of ESG integration for this critical industry.

2 Literature review

The environmental pillar of ESG is critically important in agribusiness, as agricultural activities significantly impact ecosystems and natural resources. The agribusiness sector is a major contributor to environmental degradation, including deforestation, water pollution, and biodiversity loss [4]. These impacts are often driven by unsustainable agricultural practices, such as the excessive use of pesticides, fertilizers, and water. According to Zeng and Jiang [3], environmental performance directly affects the outcomes of companies in the agricultural and forestry sectors, underscoring the need for sustainable practices.

Consequently, companies in this sector face increasing pressure to adopt more sustainable agricultural practices that minimize their environmental footprint. One such approach is organic farming, which reduces reliance on

synthetic chemicals and promotes soil health and biodiversity conservation. Companies that adopt these practices not only reduce their ecological impact but also gain a competitive advantage by appealing to environmentally conscious consumers and investors [5]. Alsayegh et al. [6] further emphasize that ESG disclosure can transform a company's sustainability performance, highlighting the importance of transparency in environmental initiatives.

The importance of climate-smart agriculture (CSA) as a framework for addressing environmental challenges in agribusiness is well recognized [7]. CSA aims to enhance agricultural productivity while reducing greenhouse gas emissions and increasing resilience to climate change. However, the adoption of CSA practices remains relatively low due to various barriers, including financial constraints, lack of technical knowledge, and insufficient policy support. Gemtou et al. [8] provide a systematic review identifying the decision-making factors that influence farmers' adoption of CSA, stressing the need for supportive policies and education.

Governments and industry stakeholders must collaborate to create incentives, such as subsidies and training programs, to promote the widespread adoption of CSA practices. This is supported by Wang and Sun [9], who found that the intensity of environmental regulation and ESG performance can influence firms' green innovation. Beyond these policy measures, technological innovation, such as precision agriculture and the integration of renewable energy, is crucial for enhancing the environmental sustainability of agribusiness. Fazrakhmanov et al. [10] discuss the integration of ESG principles in agribusiness management technologies, emphasizing technological advancements as a key factor.

Moreover, Velten et al. [4] discuss the broader implications of sustainable agriculture for global food systems, emphasizing the need for a systemic approach that considers both environmental and social factors. Sustainable agricultural practices, such as crop rotation, agroforestry, and the use of renewable energy sources, can help mitigate the sector's environmental impact while ensuring long-term food security. These practices not only contribute to environmental sustainability but also provide economic benefits by reducing input costs and improving crop yields.

The social pillar of ESG is equally critical in the context of agribusiness, as it encompasses labor practices, community engagement, and the overall social impact of agricultural operations. Fair labor practices and community development initiatives significantly contribute to the social sustainability of agribusinesses [11]. Research indicates that companies that prioritize worker welfare, ensure fair wages, and engage with local communities tend to experience improved productivity and stronger stakeholder relationships. This, in turn, enhances the company's reputation and reduces the risk of labor disputes, which can be costly both financially and in terms of public image. Amaral et al. [12] specifically analyse the impact of the social pillar of ESG on sustainability, emphasizing its importance in corporate performance.

The role of gender diversity on corporate boards is another important social consideration. Although this aspect is not directly covered in the provided sources, Alsayegh et al. [6] and Aguilera et al. [11] touch upon social aspects that include diversity and inclusion as part of ESG performance. Companies with greater diversity on their boards are more likely to excel in ESG metrics, particularly in the social and governance dimensions. Diverse boards are better equipped to address a broader range of social issues, such as gender equality, workplace safety, and community development. This diversity of perspectives leads to more comprehensive ESG strategies and improves decision-making processes, ultimately benefiting the company's long-term sustainability.

Socially responsible investment (SRI) increasingly focuses on companies that demonstrate strong labour practices, as these companies are perceived as lower-risk investments with potential for long-term growth [13]. In the agribusiness sector, where labour conditions can vary significantly depending on geographic location and local labour laws, ensuring fair and equitable treatment of workers is essential for maintaining social sustainability.

The governance pillar of ESG is foundational for ensuring that agribusinesses operate with transparency, accountability, and integrity. Governance structures determine how companies manage risks, comply with regulations, and engage with stakeholders. Strong governance is particularly important in agribusiness, where companies often face complex challenges related to supply chain management, environmental compliance, and social responsibility [14]. Effective governance practices, such as board diversity, ethical leadership, and robust internal controls, enable companies to navigate these challenges and maintain their social license to operate.

The growing importance of ESG reporting in the agribusiness sector has been highlighted in recent studies [15]. Transparent ESG reporting practices not only improve a company's accountability but also attract investors who prioritize sustainability. Au et al. [16] map the landscape of ESG strategies and recommend that future research focus on improving ESG reporting standards. Companies that regularly disclose their ESG performance are better positioned to build trust with stakeholders and demonstrate their commitment to sustainable business practices. ESG reporting is also a key tool for identifying areas for improvement, as it allows companies to benchmark their performance against industry standards and set measurable goals for future progress.

The strategic implications of governance in the agri-food industry are crucial for effectively managing ESG risks [17]. Strong governance structures not only support environmental and social initiatives but also enhance the overall resilience of agribusinesses to external shocks, such as regulatory changes and supply chain disruptions.

The relationship between ESG practices and financial performance is further examined by Tancke et al. [18], focusing on car manufacturers. Their findings demonstrate that strong ESG practices enhance financial performance, suggesting that ESG is not only a compliance requirement but also a strategic asset that can lead to improved profitability. Liu et al. [19] similarly emphasize the positive impact of ESG on financial performance in specific regions, highlighting the broader financial benefits of strong ESG adherence.

Government policies also play a significant role in shaping ESG performance in businesses. Yan et al. [20] provide evidence from natural resource accountability audits in China, showing how government environmental regulation influences corporate ESG performance. This is further supported by Wang and Sun [9], who discuss the substitution effect of environmental regulation intensity and ESG performance on firms' green innovation.

In the context of agribusiness, integrating ESG principles into management technologies is essential. Fazrakhmanov et al. [10] discuss how ESG principles can be applied in agribusiness management technologies, emphasizing the need for technological advancements that support sustainability goals.

Finally, geographical factors impacting agribusiness are considered by Yue et al. [21], who study the effect of geographic distance on domestic trade in the U.S. green industry. Their findings suggest that governance strategies should consider geographic considerations to optimize supply chain management and sustainability outcomes.

3 Methodology and data

Although a literature review and theoretical background are essential for understanding the context and foundational principles of a research topic, they often lack the systematic and quantitative rigor needed for a comprehensive assessment of the state of research within a field [22]. Bibliometric analysis complements these approaches by providing a structured, data-driven evaluation of the research landscape. Unlike literature reviews, which identify gaps through qualitative synthesis, bibliometric analysis highlights underexplored areas and research opportunities by mapping the intellectual structure of a field, such as co-citation networks or keyword trends [23]. Moreover, bibliometric tools enable the visualization of connections between authors, institutions, and journals, offering a holistic view of the collaborative and geographical dynamics that shape the research domain.

The method of textual analysis, introduced by Callon et al. [24], has become a crucial tool for researchers across various disciplines. This approach facilitates the analysis and visualization of the bibliometric structure of numerous topics. It has gained traction not only among researchers but also among librarians, as it aids in the exploration of large datasets of scientific publications, revealing hidden patterns and trends.

One of the prominent tools used in this analysis is the VOSviewer software, which, according to van Eck and Waltman [25], allows users to generate and visualize bibliometric maps of scientific literature. The software simplifies navigation through the intricate realm of academic publications, offering a clear perspective on contemporary trends and patterns in a specific research area. It enables the creation of maps that illustrate the relationships between academic fields, authors, institutions, and other components of the scientific community.

Table 1 Filter settings on the Web of Science platform

	Description	**No. of documents**
Keywords	agriculture, ESG index, ESG ratings, ESG score, Environmental Social and Governance score, ESG, Corporate Social Responsibility, Environmental Social and Governance index, Environmental Social and Governance performance, corporate social responsibility, financial performance, sustainable development, biodiversity, technology and innovations, carbon footprint, climate change, resource management, regenerative agriculture, ecological footprint, carbon neutrality, soil health, circular economy, food safety and quality, and water management	152 301
1st filter	Management, Business, Business Finance, Economics, Operational Research Management Science, Public Administration, Mathematics, Multidisciplinary Sciences, Mathematics Interdisciplinary Applications, Mathematics Applied, and Public Environmental Occupational Health.	14 764
2nd filter	Year 2000 - 2023	14 643
3rd filter	English language	14 384
4th filter	Article	13 058
5th filter	Open access	3 874
Final sample	The total number of the documents	3 874

VOSviewer employs various analytical and visualization techniques, such as co-occurrence word algorithms, bibliographic coupling, and co-authorship algorithms, as explained by van Eck and Waltman [26]. These techniques allow for the creation of highly detailed maps, which can be adjusted to emphasize particular features or relationships within the scientific domain.

It is essential to recognize that the outcomes of bibliometric analysis using VOSviewer do not represent an endpoint but rather a component of a broader analytical process. A comprehensive analysis of patterns and trends shown in the maps enables researchers to draw conclusions about the research environment, identify key thematic clusters, important academic fields, prominent scientific institutions, or leading authorities in a given area of research.

After conducting an extensive review of the relevant literature, twenty-three key terms were identified, with which we filtered out a total of 152 301 publications, to which we subsequently applied a series of several filters (the data filtering process is presented in Table 1). This process resulted in a final data set containing 3 874 publications.

These keywords were selected for bibliometric analysis as they comprehensively cover the key areas of ESG within the context of agriculture and sustainability. They include fundamental ESG concepts (indices, ratings, performance), the relationship between ESG and financial performance, specific environmental challenges (biodiversity, carbon footprint, climate change), and crucial technologies and innovations necessary for enhancing sustainability. The selection also reflects the interdisciplinary nature of ESG, integrating environmental, social, and economic dimensions, which facilitates the identification of trends and research gaps in this domain.

4 Web of Science research results

The analysis of scientific publications from 2000 to 2023 reveals a distinct upward trend in the volume of research within the studied scientific field. The academic interest in ESG has shown a steady increase, transitioning into exponential growth, as illustrated in Figure 1.

In 2000, no articles on this subject were published, but by 2010, this number had increased to 31, reaching a peak of 693 articles in 2022. This growth in publication activity may have been driven by several factors, such as shifts in funding and research support policies, technological advancements, and the progressive development of sustainability criteria.

Although the observed trend presents a promising outlook for the growth and expansion of scientific knowledge, it is essential to recognize that this trend remains subject to potential fluctuations due to a range of external and internal factors. Economic recessions, political shifts, or natural disasters may impact research funding and priorities, potentially leading to a deceleration in publication rates. Conversely, technological advancements, such as the emergence of new data analysis methods or progress in artificial intelligence, could substantially accelerate research activities and improve the efficiency of publishing.

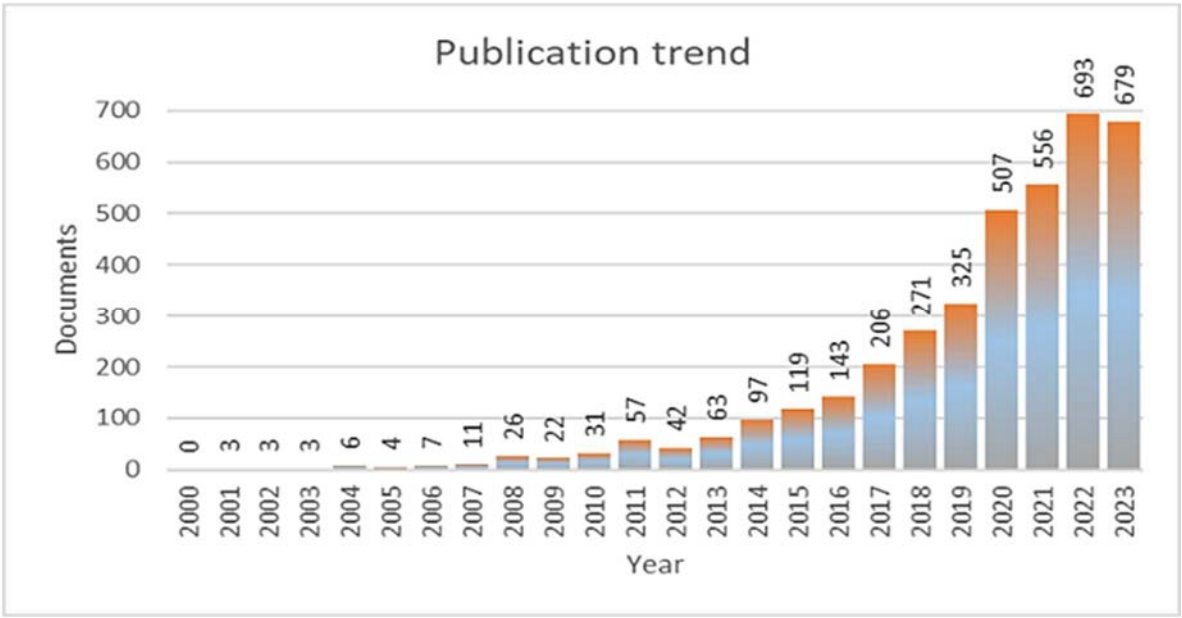

Figure 1 Publication trend

While the current data suggest a positive trajectory, they do not provide a conclusive basis for predicting the sustained increase in publications. Ongoing monitoring of publication trends and adapting to evolving conditions will be critical for maintaining progress and ensuring that research remains relevant within the academic sphere.

Table 2 The number and share of individual countries in publication activity focused on ESG

	Country	No. of documents	% of a publication
1	United Kingdom	881	22.74%
2	USA	579	14.95%
3	Spain	332	8.57%
4	China	327	8.44%
5	Italy	258	6.66%
6	Australia	243	6.27%
7	Germany	222	5.73%
8	France	216	5.58%
9	Netherland	180	4.65%
10	Malaysia	164	4.23%
38	Slovakia	45	1.16%

Based on data from the Web of Science platform, the United Kingdom has the highest share of published scientific articles, representing 22.74% of all works. The United States follows, contributing 14.95% and ranking second. Other countries also exhibit a relatively balanced presence in scientific output, including Spain with 8.57%, China with 8.44%, and Italy, which accounts for 6.66% of the total publications. Australia, Germany, and France also hold notable positions in the global scientific landscape, contributing 6.27%, 5.73%, and 5.58%, respectively. Netherlands and Malaysia complete the list of the top ten countries with contributions of 4.65% and 4.23%.

Slovakia, while not a global leader, contributed approximately 1.16% of all scientific articles, positioning it 38th overall. This ranking reflects Slovakia's active engagement in the international scientific community. However, there is a significant difference in scientific output between leaders such as England and the USA, and other countries, highlighting geographical and possibly financial inequalities in access to scientific resources and publishing (Table 2).

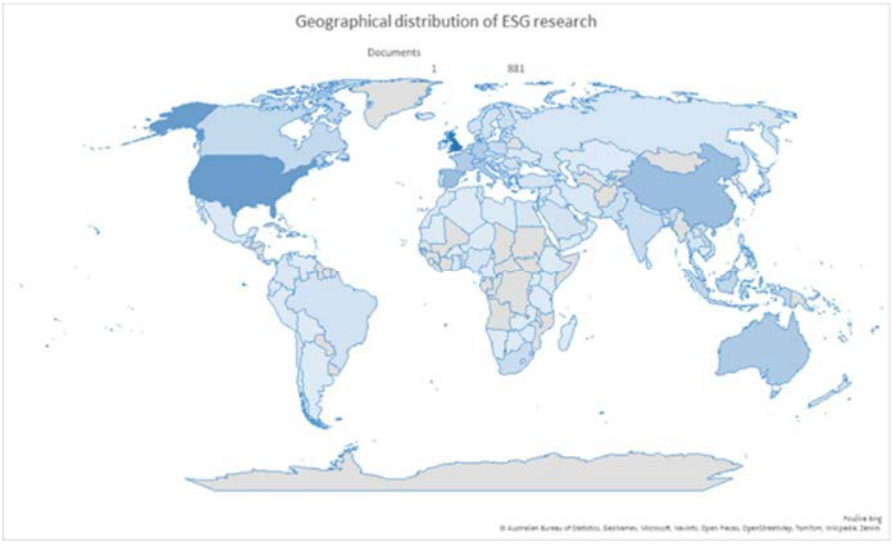

Figure 2 Geographical distribution of ESG research

The analysed dataset encompasses 123 countries (Figure 2), offering a comprehensive view of the global distribution of scientific publications. This broad scope provides valuable insights into how different countries contribute to the advancement of global knowledge. The data are essential for understanding the dynamics of the international scientific community and may serve as a foundation for further research into the influence of geographic and economic factors on scientific productivity.

The category of Business is the most prominent, encompassing 1 078 articles, which constitutes 27.82% of all publications. This indicates that a significant proportion of the research articles fall within the business studies domain, suggesting a strong focus on topics like corporate strategies, market analysis, and organizational behaviour.

Following closely is the Management category, which includes 1 072 articles, representing 27.66% of the total publications. This substantial share highlights the emphasis on management research, including studies on leadership, operations, and organizational dynamics. Together, Business and Management account for more than half of the total publications, showing their pivotal role in the research community's interests.

The third most significant category is Economics, with 841 articles, making up 21.70% of the dataset. This reflects a continued interest in economic theories, policy analysis, and economic impacts on various aspects of society. The substantial representation of this category indicates the critical role of economic perspectives in understanding broader societal trends.

Business Finance is also well-represented, comprising 783 articles or 20.21% of the publications. This category suggests a strong focus on financial aspects within business studies, such as corporate finance, investment analysis, and risk management.

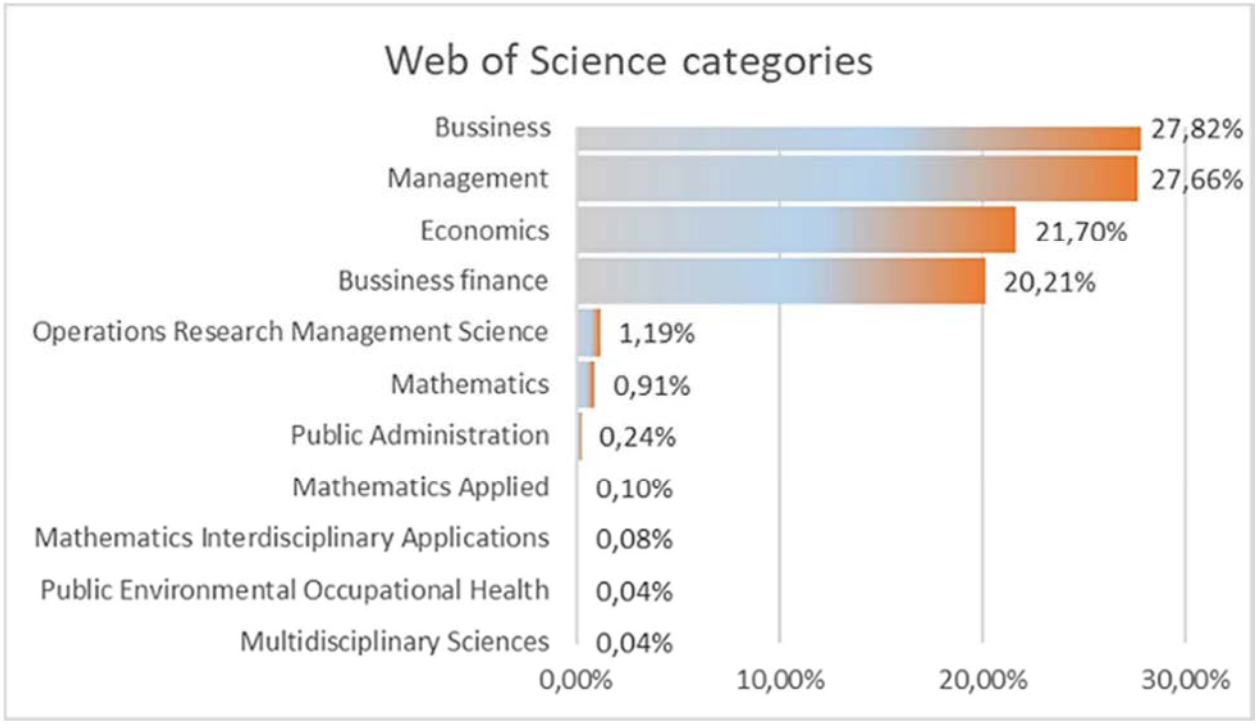

Figure 3 Web of Science research areas (final sample)

In contrast, fields like Operations Research and Management Science contribute 46 articles (1.19%), focusing on analytical models and optimization techniques aimed at improving organizational efficiency. Although this category represents a smaller portion of the dataset, it provides important insights into process improvements and decision-making methods within businesses.

Several other categories have a more limited representation. Mathematics includes 35 articles (0.91%), while Public Administration has 9 articles (0.24%). Even more specialized are Applied Mathematics and Mathematics Interdisciplinary Applications, with 4 articles (0.10%) and 3 articles (0.08%), respectively. Multidisciplinary Sciences and Public Environmental Occupational Health have the smallest shares, with just 2 articles each (0.04%). These categories, though limited in number, often provide highly focused or cross-disciplinary insights that can contribute to broader research areas.

This segmentation of categories from the Web of Science highlights that the majority of the research publications are concentrated in traditional fields like Business, Management, and Economics (Figure 3). These fields dominate the academic output, reflecting their broad appeal and the substantial research activity in these areas. Meanwhile, more niche fields like applied mathematics and public administration, although contributing fewer articles, play a vital role in providing specialized knowledge. This distribution offers a snapshot of the research priorities within the analysed dataset and how different disciplines contribute to the academic discourse.

5 Results of the keyword analysis

As stated earlier, the study comprises a total of 3,874 records. To analyse the relationships between key terms, VOSviewer software was employed, which specializes in visualizing and analysing such data. This analysis revealed 5,208 keywords, with 91 of them surpassing the threshold of 50 occurrences, indicating their presence in a substantial number of documents.

To facilitate better organization and analysis, the keywords were categorized into four primary groups. The first group consists of 28 items, the second has 27, the third includes 20, and the fourth, being the smallest, contains 16 items. This categorization enables a more in-depth understanding of the thematic structure and the relationships among the keywords. Table 3 presents the 30 most frequently occurring keywords, offering valuable insights into the predominant research trends and dynamics within the field.

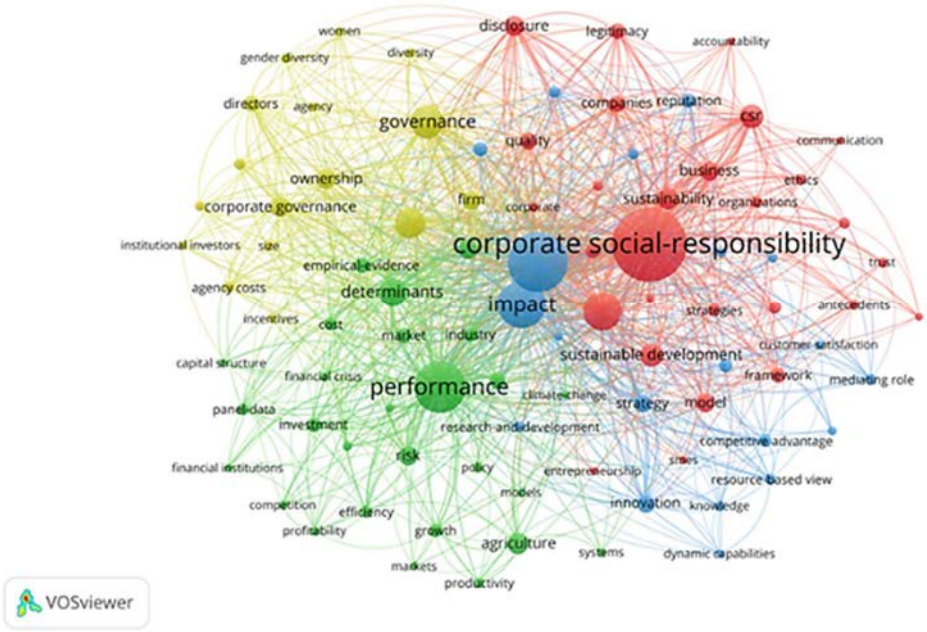

Figure 4 Keyword co-occurrence network for the final sample (2000-2023)

Table 3 Top 30 most frequently occurring keywords

Term	Frequency
corporate social-responsibility	1 868
financial performance	1 133
performance	903
impact	799
management	565
governance	445
firm performance	390
determinants	341
sustainable development	244
sustainability	226
agriculture	224
disclosure	202
ownership	202
corporate governance	200
business	195
risk	191
information	185
model	181
firm	176
innovation	166
strategy	162
quality	159
companies	147
firms	140
empirical-evidence	137
directors	135
legitimacy	133
framework	127
investment	126
market	126

5.1 Important authors

Tables 4 and 5 present the ten most productive authors in the area of environmental, social, and governance (ESG) practices related to agriculture, with Ruth V. Aguilera leading the list, having published three articles that have collectively received 2,061 citations. This distinction highlights her significant influence as a leading expert in the ESG field. The list serves as a valuable resource for those seeking to identify respected experts and key authorities in this area of study.

In total, the field has seen contributions from 9,880 authors. However, the analysis in Figure 4 focuses on those who have published a minimum of five papers and have garnered at least 100 citations. Only 35 authors met these criteria, emphasizing their considerable impact and recognition within the scientific community.

Table 4 Top 10 authors by number of citations

	Name	Documents	Citations
1	Ruth V. Aguilera	3	2 061
2	Jyoti Ganapathi	1	1 939
3	Deborah Rupp	1	1 939
4	Cynthia A. Williams	1	1 939
5	Sadok El Ghoul	2	1 588
6	Omrane Guedhami	2	1 588
7	Chuck Kwok	1	1 587
8	Dev Mishra	1	1 578
9	Collins Ntim	14	1 203
10	Rui Albuquerque	2	1 160

Table 5 Top 10 authors by number of documents

	Name	Documents	Citations
1	Khaled Hussainey	19	664
2	Collins Ntim	14	1 203
3	Andrea Pérez	12	299
4	Dalia Streimikiene	9	132
5	Albert Danso	8	294
6	Joseph Amankwah-Amoah	8	247
7	Ali Uyar	8	93
8	Alfredo De Massis	7	618
9	Ans Kolk	7	434
10	Habiba Al-Shaer	7	399

This information is not only relevant to academia but also serves as a critical guide for policymakers, practitioners, and organizations looking to adopt ESG practices. Authors with a high number of publications and citations are often viewed as leaders in their field, capable of offering valuable insights and direction in discussions on sustainable development.

The analysis of author (Figure 5) distribution based on the number of publications and citations reveals an essential aspect of scientific publishing: the quality and impact of the work are just as important as the volume of publications. This is reflected in the substantial differences among the top-ranking authors, where some works achieve notably higher citation counts, indicating their significant scientific impact and contribution to their disciplines.

This phenomenon highlights that the academic community values research not only for its quantity but, more importantly, for its quality and relevance. The high citation counts of certain works often reflect their innovativeness and importance for further research. This perspective is crucial for understanding the dissemination of scientific knowledge and how it is received and applied within the academic community.

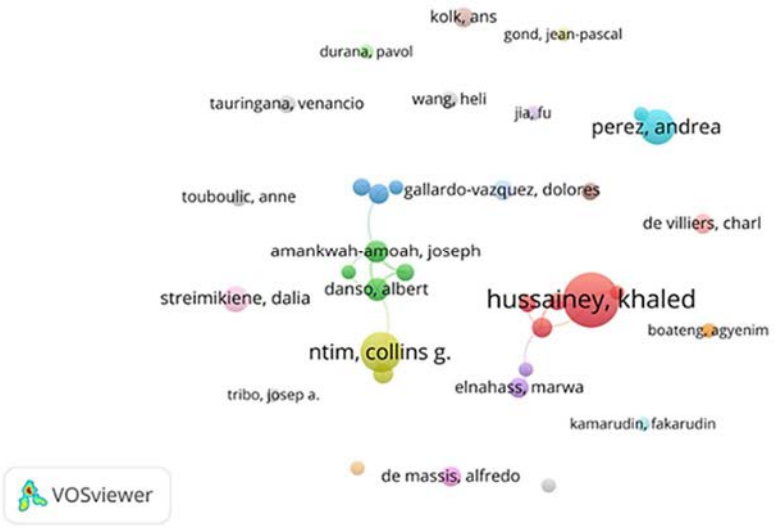

Figure 5 Visual display of individual authors

5.2 The most influential research organizations

Identifying the key institutions in ESG research is vital for understanding where in-novation and scientific progress are concentrated. These organizations often possess state-of-the-art technology and are instrumental in advancing both scientific knowledge and the formulation of global sustainability policies. Their initiatives encourage international cooperation, improving the depth and reach of research. Moreover, they play a crucial role in educating future specialists and driving economic development through the introduction of new technologies and solutions, significantly impacting societal progress.

Table 6 Top 10 organizations by number of documents and citations

	Name	Documents	Citations
1	Harvard University	18	3 922
2	University of Illinois Urbana-Champaign	12	2 462
3	Singapore Management University	21	2 455
4	University of Alberta	7	2 265
5	University of Leeds	51	2 176
6	The University of Sheffield	31	2 097
7	University of Kent	32	2 002
8	Massachusetts Institute of Technology	9	1 945
9	University of Southampton	50	1 849
10	Cardiff University	25	1 790

Table 6 provides a list of the top ten research institutions based on the number of published works, offering insights into the key players in ESG research. These institutions represent potential partners for future collaborations, particularly in exploring ESG's in-fluence on corporate performance. The analysis identified 3 425 universities and research institutions that have contributed studies related to ESG. Among these, Harvard Univer-sity stands out as a leading institution, with 3 922 citations, positioning it as one of the most prominent contributors to ESG research on a global scale. Harvard's work has made a significant impact on advancing scientific understanding in this field.

5.3 The most frequently cited documents

Table 7 presents a carefully selected list of the ten most frequently cited publications focusing on ESG factors. This compilation serves as a valuable reference for researchers and students looking to engage with and contribute to the ongoing scholarly discourse on ESG. The selection is primarily based on citation frequency, which serves as a strong measure of each publication's relevance, impact, and importance within the academic community studying ESG in connection with agriculture. These works are considered foundational, shaping the current understanding and conversations in the field, and providing essential insights and frameworks that are crucial for both emerging and continuing research in ESG studies.

The article receiving the most citations is titled "Putting the S back in corporate social responsibility: A multilevel theory of social change in organizations," authored by Ruth V. Aguilera, Deborah E. Rupp, Cynthia A. Williams and Jyoti Ganapathi, published in 2007 with a total of 1939 citations.

The article [11] provides a comprehensive theoretical model for understanding why businesses increasingly engage in corporate social responsibility (CSR) and their potential to promote positive social change. The authors propose a multilevel approach to analyse CSR, examining pressures from different stakeholders at individual, organizational, national, and transnational levels. They highlight that actors such as employees, management, institutional investors, and NGOs push organizations to adopt CSR initiatives, each driven by various motives including instrumental (self-interest), relational (social ties), and moral (ethical principles).

At the core of the model is the assertion that organizations do not operate in isolation; they are influenced by a complex array of internal and external pressures that shape their approach to CSR. The paper emphasizes that these pressures vary across different national and cultural contexts, affecting the nature and intensity of CSR initiatives. For example, corporations in countries with strong social partnership traditions may face different expectations regarding social responsibility compared to those in more market-driven economies [11].

The article [11] also explores the interaction between these different motives and how they contribute to the adoption of CSR practices. The authors suggest that understanding these dynamics is key to advancing CSR research beyond the debate of whether CSR is beneficial to exploring how and why businesses integrate social goals into their operations. They conclude with directions for future research and practical implications for managers looking to embed CSR into their strategic decision-making, advocating for a deeper consideration of the multifaceted nature of CSR pressures and their impact on organizational behaviour.

Table 7 Top 10 publications by number of citations

Title	Citations
Putting the S back in corporate social responsibility: A multilevel theory of social change in organizations	1939
Does corporate social responsibility affect the cost of capital?	1587
What Do We Learn from the Weather? The New Climate-Economy Literature	1008
Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications	793
The contribution of corporate social responsibility to organizational commitment	770
The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather	753
Corporate Social Responsibility and Firm Risk: Theory and Empirical Evidence	721
Firm performance: the interactions of corporate social performance with innovation and industry differentiation	663
Corporate governance and environmental performance: is there really a link?	652
Is doing good good for you? how corporate charitable contributions enhance revenue growth	577

6 Conclusions

The integration of Environmental, Social, and Governance principles within the agribusiness sector has emerged as a critical factor in aligning industry practices with sustainable development goals. As agribusinesses grapple with their significant environmental impacts, ranging from resource use to ecosystem disturbances, the adoption of ESG strategies becomes essential. This shift is driven not only by the inherent sustainability challenges of the sector but also by the increasing expectations of stakeholders such as investors, consumers, and regulators. Through embracing practices like climate-smart agriculture and improving governance structures, companies in this sector can enhance their long-term

resilience while contributing positively to global sustainability efforts.

The analysis of the ESG pillars reveals the interconnected nature of environmental stewardship, social responsibility, and governance within agribusiness. Environmentally, the sector's focus has expanded to include practices that reduce its ecological footprint, such as organic farming and precision agriculture. Socially, fair labour practices and community engagement have become crucial in fostering trust and productivity, while governance improvements ensure transparency and accountability, attracting investors who prioritize ethical practices. Together, these elements contribute to a more robust and sustainable business model that aligns with both market demands and global environ-mental goals.

Furthermore, the growing body of literature on ESG in agribusiness underscores the strategic benefits of integrating these principles. As socially responsible investment (SRI) gains momentum, companies that excel in ESG metrics are better positioned to attract capital and secure a competitive edge. The evolving regulatory landscape also encourages agribusinesses to incorporate ESG considerations into their core strategies, emphasizing the importance of adaptability in a rapidly changing global market. In conclusion, the successful integration of ESG principles in agribusiness not only supports environmental and social goals but also serves as a pathway for ensuring long-term corporate viability and resilience in a complex and dynamic industry.

Acknowledgement
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