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Mapping key performance indicators for sustainable hospital waste management

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Abstract: The increase in population has led to an increasingly important role for healthcare and, consequently, an increase in medical waste. Medical waste requires special care due to its capacity to transmit diseases. Therefore, evaluating the performance of a given hospital waste supply chain through certain performance indicators plays an especially important role in supply chain management. A literature review was therefore carried out about the hospital waste supply chain and its performance indicators. The main objective of this article is to analyze which performance indicators for hospital waste supply chains exist and what their impact is through the analysis of some case studies. A qualitative and quantitative analysis of existing publications on this subject was also carried out using the Scopus database with the keywords "key performance indicators" and "supply chain". From this study it can be seen that 2023 was the year with the highest number of publications, and the lowest number of publications was in 2011. Article is the typology with the highest number of publications, with more than 50% of the total.This study shows that performance indicators enable better decision-making in order to improve the efficiency of a hospital waste supply chain.

1 Introduction

The progress made in healthcare, the growth of the population and the expanding number of medical facilities have led to an increasing production of medical waste, which has also led to an increase in the importance of analyzing healthcare-related waste management [1]. The healthcare sector is a crucial component of the world economy, focusing on improving the experience of care, the health of the population, while reducing the costs associated with healthcare [2].

Health services contribute to the control, prevention and treatment of diseases, and are a sector that contains a substantial amount of financial and human resources, creating a large amount of material and waste, thus affecting environmental sustainability [3].

Healthcare-related waste is medical or biomedical waste resulting from all activities performed in healthcare establishments, research centers and laboratories associated with healthcare procedures [4,5]. One of the main objectives of a healthcare facility is to provide a secure and trustworthy healthcare waste management system. Hospital waste can affect people's health, as it can be infectious, toxic, lethal because of the potential to transmit disease [6]. In addition to providing healthcare to people, healthcare facilities generate infectious and non-infectious waste that affects the health of healthcare workers, patients and the population [7].

Supply chain management is critical to a company's ability to remain competitive in the global scale, with the challenge of identifying the most effective way to meet customer needs at the lowest cost [8]. The proper management of healthcare waste can potentially control the transmission of serious diseases that threaten human health and the environment, as well as avoid wasting energy and reducing costs [9]. Hospital supply chains face economic, environmental and social challenges [10].

Performance measurement plays a vital role in hospital management and there have been an increasing number of studies to evaluate healthcare performance [11]. A adequate performance measurement provides the information needed for a better decision-making [12].

The article looks at performance indicators related to the health sector and assesses their impact by analyzing case studies related to the central theme. The article provides a range of contributions to the health sector, including the following:

- An increase in both theoretical and practical knowledge of the key performance indicators of hospital waste supply chains.

- Improving decision-making and the appropriate selection of key performance indicators.

This article is divided into 5 sections. Section 1 presents an introduction to the central themes. Section 2 discusses the hospital waste supply chain and some concepts and also presents the performance indicators in hospital waste supply chains and their impact on them with some case studies relating hospital supply chains and hospital waste. Section 3 presents the methodology carried out throughout this study. Section 4 presents a quantitative and qualitative study using the Scopus database in order to analyze the publications already published in the area. Section 5 presents some conclusions drawn from the study.

2 Literature review

2.1 Hospital/healthcare waste supply chain

The healthcare supply chain has been evaluated in a different way to the standard supply chain due to its high level of complexity [8]. The healthcare sector is a major factor in environmental pollution, generating large amounts of waste, consuming a large amount of energy and emitting greenhouse gases [13].

Healthcare-related waste includes all the materials generated in healthcare centers, research centers, medical laboratories, but also healthcare-related waste generated at home [14]. Among all the waste generated, the waste considered hazardous for health professionals and patients is between 10 and 25% of the total medical waste [5]. A contaminated needle used incorrectly has a risk of 1 in 3 of developing hepatitis B infection, 1 in 30 of hepatitis C infection and 1 in 300 of HIV infection [15].

Sustainable Supply Chain Management (SSCM) in the medical sector involves the management of the flow of materials, services and information from suppliers to healthcare suppliers [13].

Table 1 presents the different types of solid medical waste and gives some examples.

Table 1 Types of solid HCW [16]

Solid Healthcare waste	
Cytotoxic	Drugs used in cancer therapy
Pharmaceutical	Expired and unused drugs
Sharps	Syringes with needles; blades; scalpels
Infectious	Blood and other body fluids; laboratory cultures
Chemical	Laboratory reagents; disinfectants; batteries
Radioactive	Sealed sources; absorbent paper; swabs
Pathological	Human tissues; organs or fluids; body parts

Due to mishandling and inadequate treatment, the management of healthcare waste in developing countries is a public health and environmental problem [17]. In addition, the use of disposable devices in developed countries is increasing due to the use of advanced technological practices and safety concerns, leading to an increase in waste generation in these countries compared to developing countries [18].

The storage of hospital waste in health centers and the transport of these materials to treatment centers are two risky tasks, involving risks for health professionals and people in the community [19]. Proper management of medical waste, avoids being a danger to health professionals and the general population, but also to the environment [5].

Figure 1 illustrates an example of a medical waste supply chain.

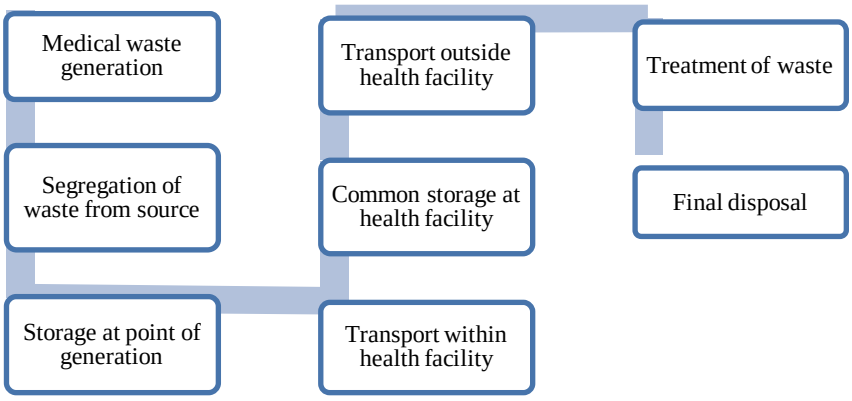

Figure 1 Example of Hospital medical waste chain [20]

The separation of hospital waste is an important step in the correct management of healthcare waste and the analysis of the composition of the waste makes it possible to determine the most appropriate methods for the disposal and treatment of healthcare-related waste [21].

Good waste management practices are best achieved by preparing and implementing a Health Services Waste Management Plan, describing all the steps and strategies according to each type of waste and containing actions to prevent possible impacts on public health and the

environment [22]. The sustainable disposal of hospital waste is a field that requires further study due to its significant importance [23].

Faced with the negative effects that inadequate treatment of medical waste has on people, including environmental, economic and social issues, cities with higher population density need to find and develop a reliable medical waste management system [23].

2.2 Key performance indicators in healthcare

The instability of the environment and the dynamic changes taking place in world economies lead to the necessity of implementing and using new tools, such as the identification and implementation of indicators (KPIs) in the evaluation system, which make it possible to develop and improve organizations [24].

KPIs correspond to a quantitative index that shows the main success factors of a certain organization, and is adjusted to the context and objectives of each organization [25]. KPIs are considered to be management tools that allow management decisions to be planned, supported and controlled, making it possible to ensure the desired performance [26].

Performance indicators are used by hospitals to monitor and evaluate performance in relation to the values of other similar organizations or reference values, making it possible to ascertain whether performance is at the right level and to identify where improvements can be implemented [27,28].

An efficient and rational healthcare performance measurement system makes it possible to improve the quality of medical services, reduce costs, optimize service processes and obtain the best allocation of resources [11]. Evaluation of the healthcare sector is complex, since unsatisfactory performance can result from long waiting times, inefficiencies, patient dissatisfaction and burnout among healthcare professionals [29].

Table 2 contains examples of performance indicators related to hospital waste supply chains, divided into 4 types.

Table 2 Performance indicators and definition [30,31]

Typology	Indicator
Operational	Hospital Waste per Bed: Quantity of Hospital Waste produced per month/total number of existing beds
	Hospital Waste Production per Surgery: Quantity of Hospital Waste produced per month/total number of surgeries occurring in the operating room per month
	Production of Hospital Waste per External consult: Quantity of hospital waste produced per month/total number of outpatient visits per month
	Water Consumption per Sterilized Material: Consumption of H20 in the sterilization center per month/quantity of sterilized surgical instruments per month
	Water Consumption per Packaging Material: Consumption of H20 in the sterilization center per month/quantity of packaging material used in the sterilization center per month
	Electricity Consumption per Hospital Waste produced per month: Consumption of electricity per month/amount of hospital waste generated per month
Management	Containers collected per Employee: Number of containers collected/area where containers collected by each employee assigned to the waste collection per month/total building area
	Container collected per area: Number of containers collected by each employee assigned to the waste collection per month/total building area
Economic	Cost of Hospital Waste per bed management: Cost of hospital waste management collected and sent by external entity for final treatment per month/total number of existing beds
	Cost of Hospital Waste/Employee management personnel: Cost of personnel assigned to waste management per year/number of employees
Environmental	Total common healthcare waste (kg)/Total healthcare waste (kg)
	Cost of healthcare waste removal (bed)/Cost of healthcare waste removal (liters)
	Recyclable healthcare waste (kg)/Common healthcare waste (kg)

2.3 Key performance indicators for hospital waste supply chain – case studies

This section analyzes some case studies that show the use of performance indicators for hospital waste supply chains.

The case study carried out by Burlea-Schiopoiu & Ferhati [32] focuses on identifying a range of key performance indicators (KPIs) to enable managers and employees to assess, monitor and control the crucial factors influencing the performance of the healthcare sector in Algeria. The results show that the proper implementation of KPIs allows managers to make better decisions and are also used as tools for the developing of sustainable health systems both in Algeria and in developing countries.

In the case study presented by Ferronato et al. [33], the purpose is to present a proposal for a tool for integrated management as a first method of assessment to detect the predominant problems in a healthcare waste management system in Bolivia. The results prove the usefulness of applying indicators to analyze the priorities that should be considered in order to improve the healthcare waste management system.

Another case study carried out by Amos et al. [1], the objective is to define key performance indicators to increase the performance of waste management services in public hospitals in Ghana. Thus, data was collected and analyzed through interviews in hospitals and a general questionnaire survey, and then structural equations were modeled by partial least squares to model the relationships between the performance variables. A balanced scorecard was also used to categorize the performance variables. The results show a significant influence of the strategic quality and internal business indicators on waste management performance.

A case study proposed by Tudor et al. [34], this paper shows the results of two organizations - Cardiff and Vale NHS Trust and Cornwall NHS Trust - in relation to the systems they have implemented to minimize waste. A number of systems implemented by the two institutions aimed at the sustainable management of waste streams were analyzed. The results demonstrate the need to develop and implement systems to develop best practice.

3 Methodology

Research methodology is the science that allows the analysis of how research is carried out from a scientific point of view, with the main objective of describing and analyzing the methods, clarifying and highlighting the limitations and resources [35].

The aim of this study is to investigate performance indicators for improving supply chains related to healthcare and its waste. A literature review was conducted to contextualize the central concepts of the study, such as hospital waste supply chains, as well as the importance and examples of performance indicators.

Figure 2 illustrates the methodology used throughout this study.

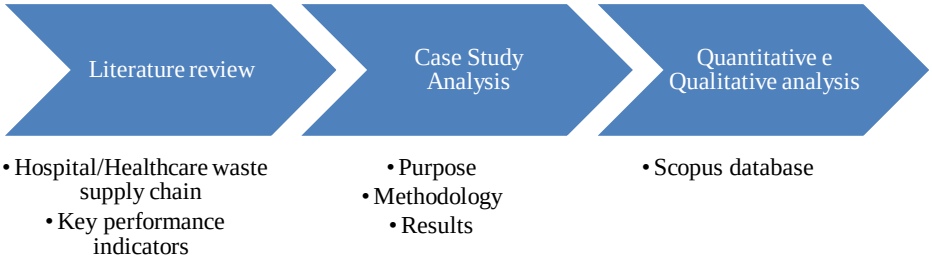

Figure 2 Research methodology

The case studies analyze the main objective of the work, the methodology used and the main results to be extracted from each case study. Through the analysis of various case studies, it is possible to investigate the different impacts and results that key performance indicators can have on supply chains.

Next, in the discussion section, the existence of publications related to the central theme of the study is analyzed in a qualitative and quantitative method with the support of the Scopus database, which investigates the concepts of “key performance indicators” and “supply chain”.

Finally, the conclusion section contains some of the conclusions drawn throughout the study and analyzes the importance of having performance indicators in hospital supply chains and hospital waste.

4 Result and discussion

Performance indicators allow organizations' performance to be monitored more carefully and make it possible to ascertain whether the results achieved make it possible to achieve the objectives set by the organizations. From the indicators, which are measured quantitatively, it is possible to analyze which areas need the most improvement.

Therefore, this section carries out a qualitative and quantitative analysis using the Scopus database in order to investigate the existence of publications relating performance indicators and supply chains with the criteria:

(“key performance indicators” and “supply chain”).

The following selection criteria were used to analyze documents related to the central theme of the study:

Research date: 27th May 2024
Research fields: "Article title, Abstract, Keywords"
Time period: Between 2010 and 2023
Language: English

Document Type: Article, Conference Paper, Book Chapter, Review, Conference review and Book

Figure 3 provides the number of results for each stage of the selection criteria.

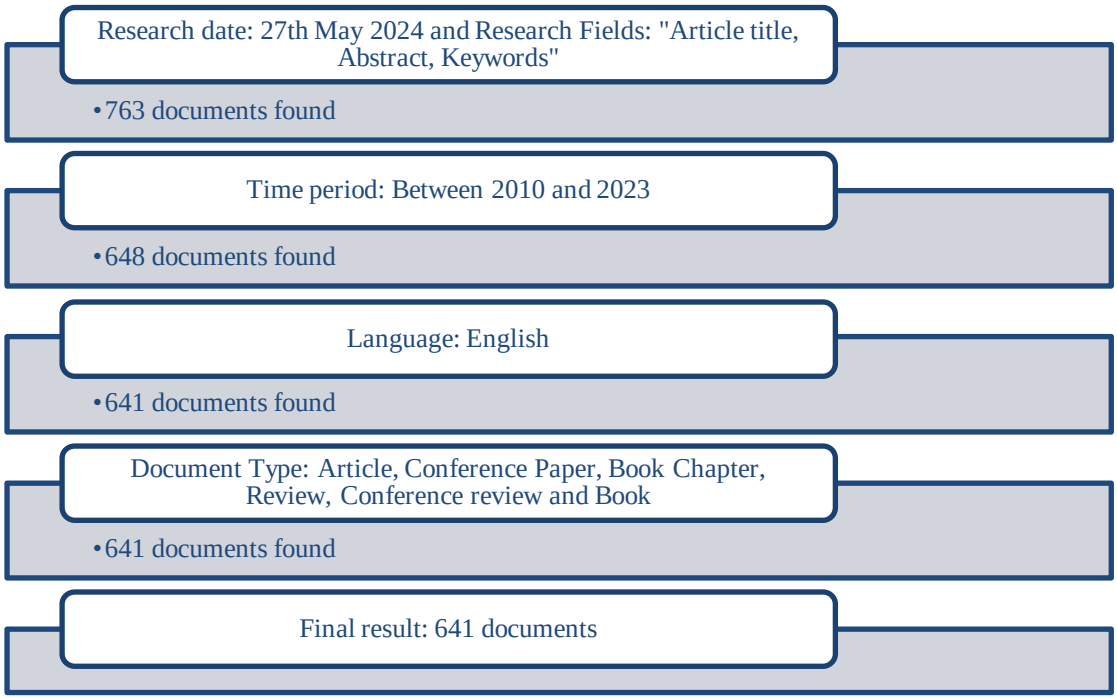

Figure 3 Number of documents found in each stage

Figure 3 shows that 763 documents were found in the first stage. When the search period was limited, the number was reduced to 648 documents. Seven documents whose language was not English were eliminated. Then, when the type of document was selected, the value did not change. Thus, the final result of the search was 641 documents.

Number of documents by year

Figure 4 presents the number of documents in each year.

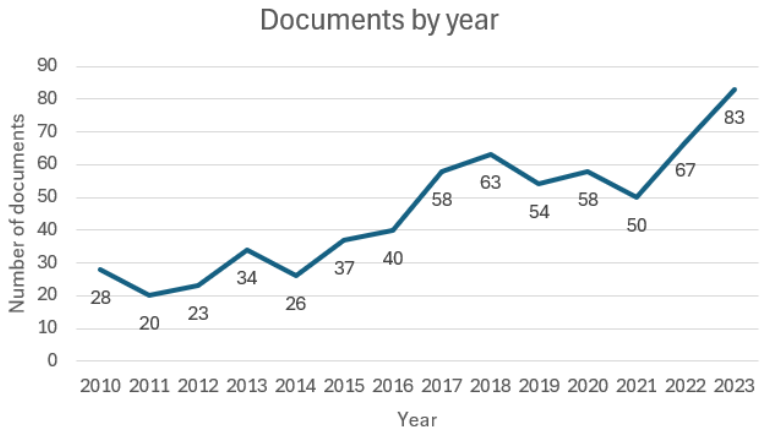

Figure 4 Number of documents in each year

Figure 4 shows an evolution in the number of publications using the concepts "key performance indicators" and "supply chain", with the minimum number being 20 in 2011 and the maximum number being 83 publications in 2023.

Number of documents by country

Figure 5 shows a map of the number of publications in each country. It should be noted that the higher the color density, the higher the number of publications in that country.

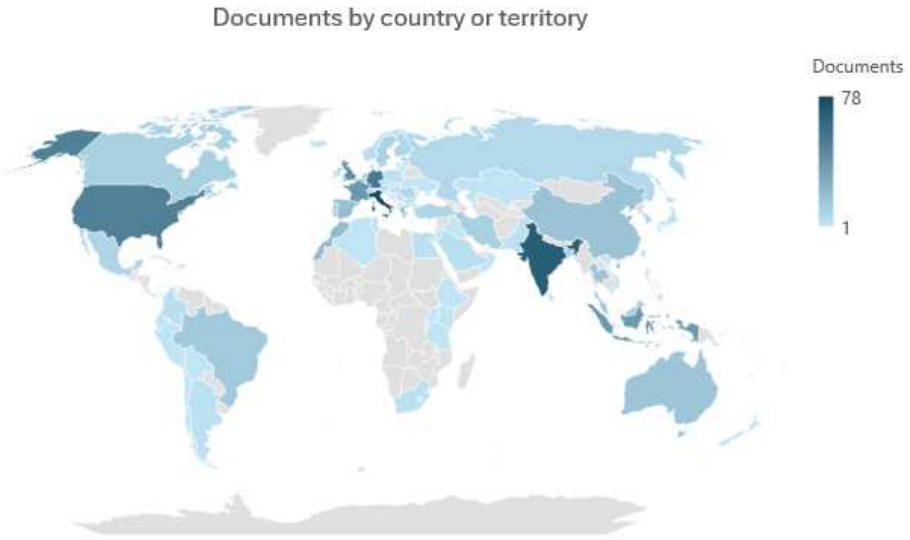

Figure 5 Number of documents by country/territory

Figure 5 illustrates that countries such as Italy, India, Germany and the United States have the highest number of publications on supply chain and performance indicators. There are also fewer publications on the African continent than in the rest of the world. Practically all European countries have published in this area.

Number of documents by type

Table 3 shows the number of each type of publication. Figure 6 shows the distribution of the type of publications with the respective percentages.

Table 3 Number of documents by type

Document Type	Number	Document Type	Number
Article	322	Conference Paper	246
Review	23	Book Chapter	40
Conference Review	8	Book	2

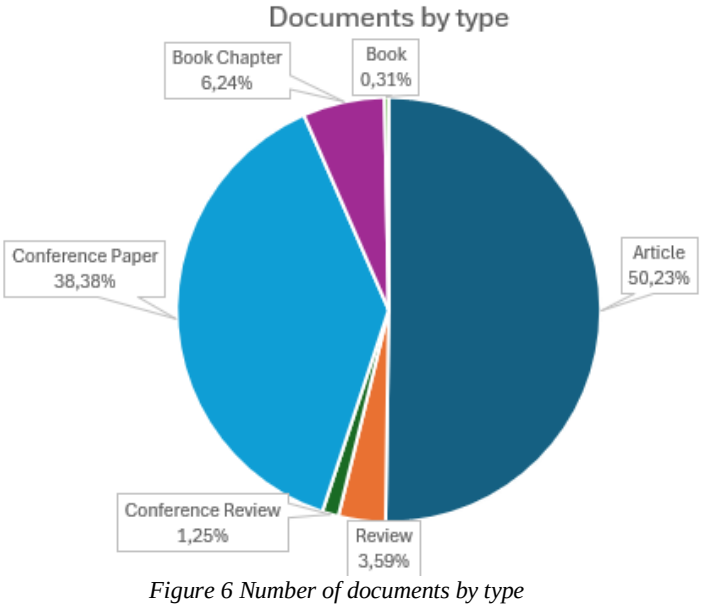

Figure 6 Number of documents by type

Table 3 and Figure 6 show that Articles and Conference Papers have the highest number of publications (together with 568 publications - 88.61% of all existing publications). Article is the typology that has more than half of the existing publications (around 50.23%).

Keyword Analysis

A study was also carried out looking at the keywords present in the publications in this study.

Figure 7 provides a visualization of the network which shows a graphic representation of the relationships between the keywords present in the set of documents under analysis. It should be noted that only keywords with at least 5 occurrences were used in this analysis.

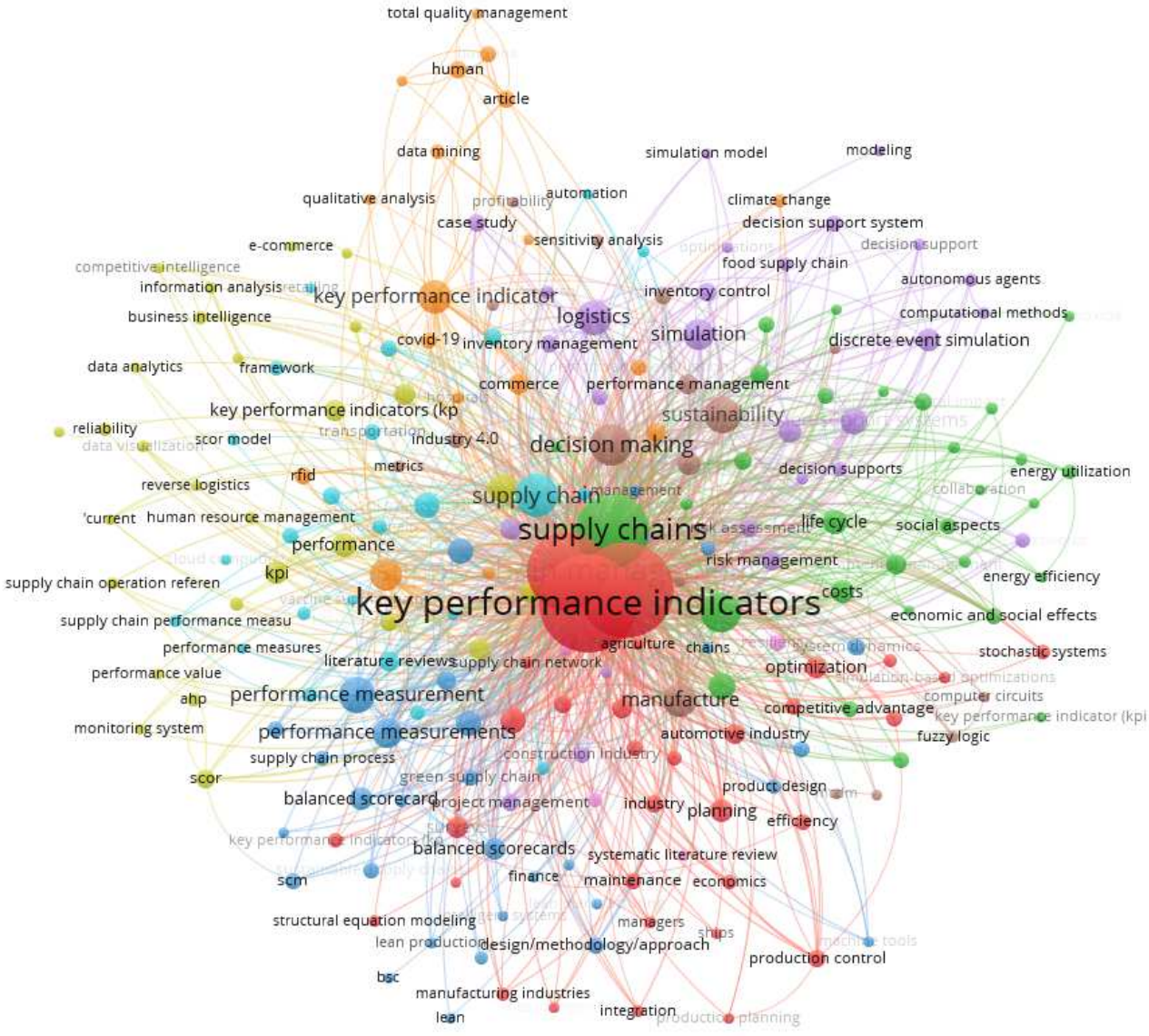

Figure 7 Network visualization

Figure 7 shows different colors representing different clusters. There are 9 clusters in this network with a total of 212 keywords. The most occurring keywords are “key performance indicators”, “benchmarking”, “supply chain management” and “supply chains”. It should be noted that the larger the size of the letter, the higher the number of occurrences. The high number of occurrences of these keywords in the different publications shows the importance of this topic for researchers.

5 Conclusions

The main purpose of this study was to analyze the importance of performance indicators in hospital waste supply chains. Thus, a contextualization of the main

concepts of this study was carried out and some case studies were analyzed, allowing for an analysis of the importance of performance indicators in hospital waste supply chains.

A quantitative and qualitative study was then carried out using the Scopus database, which showed an increase in the number of publications over the years and the existence of documents related to the subject on practically every continent (the smallest number on the African continent).

According to the results presented in the "Results and discussion" section, there has been an increase in the number of publications over the year, with 2023 being the peak year in terms of the number of publications. Countries such as Italy, India, Germany and the United States are the main ones responsible for the largest number of publications. The type of documents with the highest number of publications are articles, with 322, and conference papers with 246.

The increase in population has led to an exponential rise in medical waste generated by health institutions due to the need for more healthcare. If this waste is not treated correctly, it can have negative consequences for society. In this way, the implementation of performance indicators in hospital waste supply chains allows for better planning, monitoring and evaluation of the objectives proposed by organizations. Areas related to the health sector must be constantly analyzed, as it is one of the most important sectors for society.

As future work, it is necessary to carry out more case studies that show the importance of implementing performance indicators to improve the performance of hospital waste supply chains; to analyze the environmental, social and economic impact of hospital waste management.

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Review process
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