Applications of Geographic Information Systems (GIS) in Supply Chain Management: Systematic Literature Review

Anastasia Tsakiridi

Amazon UK, Orion Blvd, Great Sankey, Burtonwood, Warrington WA5 3XA, United Kingdom

[1]tsakiria@amazon.com

***Abstract*—To date, the knowledge regarding the potential uses of Geographic Information Systems (GIS) in Supply Chain Management (SCM) and how the GIS applications can deliver business benefits is limited. To explore the current uses of GIS in SCM, a systematic literature review (SLR) was conducted. Three databases (Web of Science, ProQuest and Business Source Premier) were explored, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. A total of 79 papers were included in the literature review. The combined findings showed that the GIS applications in SCM were a) network/ transportation analysis/ routing algorithms (53 papers), b) Location-Allocation Site Search/ Selection (using multiple-criteria decision analysis [MCDA]) (45 papers), c) spatial analysis (people or land) (34 papers), d) connection with optimisation tools (32 papers) and e) visualisation/ monitoring or Building Information Modelling (BIM) (8 papers). The industries and related Supply Chain (SC) domains that used GIS were a) Biomass Biofuel/Wood (33), b) Logistics (22), c) Humanitarian/ Emergency/ Healthcare (10), d) Food/ Agro-Industry (5), e) Petroleum/ Coal/ Shale Gas (3), f) Faecal Sludge (2), g) Recycle & product footprint (2) and h) Construction (2). The research case studies took place in 26 countries, and the most prominent GIS software provider was Esri's ArcGIS. The findings of the first literature review of the GIS applications in SCM showed that many business industries have not utilised the GIS capabilities, such as visualisation, spatial analysis, optimisation, and site research. However, GIS can significantly contribute to SCM decision making by providing answers to cost minimisation, supplier selection, facility location, SC network configuration and asset management.**

***Keywords*—** Supply Chain Management, Logistics, Systematic Literature Review, GIS

1. Introduction

GIS is the '*organised activity by which people measure and represent geographic phenomena, then transform these representations into other forms while interacting with social structures*'[1]. The GIS is widely used to help business analysts obtain, store, study and present geographically referenced information through integrated hardware and software.

It is also used to help manage assets and services, visualise land-related information, track service delivery, model transportation systems, provide market share estimation, optimise network planning, analyse competitors and identify retail growth areas [2]. Another [application of GIS is business location decision making (Location science), as it can provide insights into where is the best location to construct one or more activities or facilities [3]. Incorporating GIS applications in SCM activities could enhance the strategic planning process, facilitate supply chain redesign, clarify channel dynamics, enable monitoring of supply chain strategy and provide a basis for supply chain analysis [4]. For example, modern logistics systems rely on high-tech information technology (IT) to ensure their regular operations. Therefore, the combination of logistics and GIS can help control and coordinate the supply chain, reduce logistics costs, and enhance its efficacy and profitability, as it can formulate reasonable distribution and inventory strategy [5]. Moreover, it can support the creation and better design of road networks for public buses and senior drivers. Significant improvements can derive from that development [6], [7].

However, despite the many potential benefits, GIS has not been adequately applied in business and remains unknown to many corporations [8]. A primary reason for the adequate application of GIS in SCM is that academic research on this topic is scarce. Therefore, in the lack of a complete overview of all the GIS techniques and methodologies in the literature, the need for a systematic review on the topic was justified. The aim of this study was to systematically review the literature and investigate the different GIS applications in SCM.

2. Methodology

Three databases (Web of Science, ProQuest and Business Source Premier) were explored, identifying the peer-reviewed literature published in the last five years (2015–2020), using the PRISMA methodology. Table 1 presents the protocol that was followed according to the SLR methodology [9]:

Table 1: Research Protocol Methodology

SLR Criteria	Boolean operators	Justification
Key Words		
Geographic Terms	("GIS" **OR** "Geographic Information System*")	GIS systematically appear in the bibliography as a Geographic Information System/s.
Supply Chain Terms	**AND** ("Supply Chain" **OR** "Supplier*" **OR** "Logistics") **NOT** ("logistic regression" **OR** "Statistic*")	The supply chain terms will guarantee a precise SLR. However, systematically the term Logistic* creates much noise to our first SLR search results (up to 200.000), because the databases include mathematical/spatial epidemiological results like Logistic Regression or Logistic Distribution. Therefore, false results will be a problem to exclude them as Abstract reading will be an enormous work. Thus, some common mathematical terms were excluded.
Boolean Research	("GIS" **OR** "Geographic Information System*") AND ("Supply Chain" OR "Supplier*" **OR** "Logistics") NOT ("logistic regression" OR "Statistic*")	
Databases	Web of Science, ProQuest, Business Source Premier	The Databases were carefully selected to include general academic results, but also business-related as the topic is scientifically interdisciplinary.
Limitations		
Language	English	The research results are constrained to the English language due to multilingual limitations.
Date	2015 - 2020	As the topic is technologically related, any publication that was conducted before 2010 is considered as obsolete.
Document Type	Article (Scholarly Journals)	As the topic is very generic and not field/industry excluded all the scientific publications were included. Any business marketing material or company's report/review that may be relevant but does not fulfil the academic standards were excluded.
Quality Assessment	Peer-Reviewed (Refereed Journal)	Only peer-reviewed journals were included as they would guarantee high academic quality standards.
Part of the researched text	**TI** = Title (Web of Science) OR **AB** = Abstract or Author-Supplied Abstract (Pro-Quest, Business Source Premier)	In order to include as many related results as possible, the search of relevant keywords was conducted in the publication's abstract. However, this option was not available to the "Web of Science" Database. Thus, for this database, the search for relevant keywords was conducted in the "Title".

Figure 1 depicts the flow diagram according to the PRISMA Statement four-phase flow diagram [10].

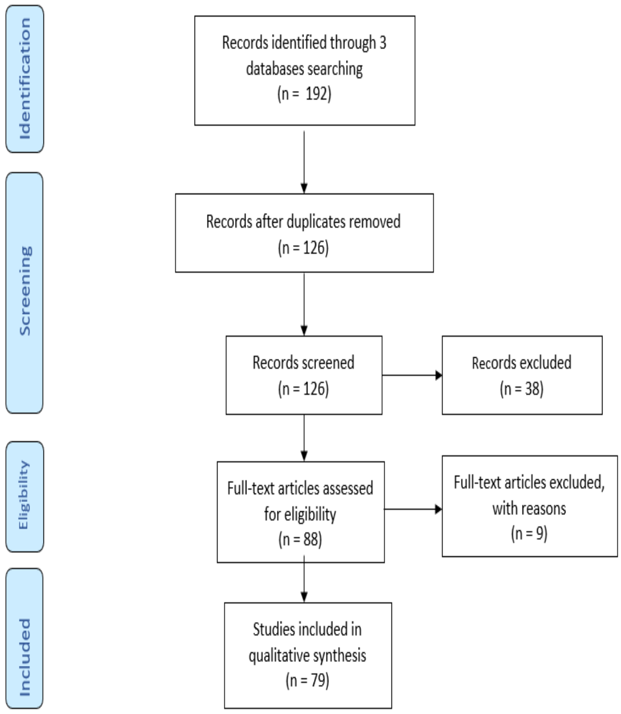

Figure 1: Flow of information through the different phases of a systematic review

Table 2 shows the initial research findings. After investigation and rejection of duplicated findings, a two-stage process was followed with a) the screening of abstracts and b) selection of the relevant papers for full text screening (Table: 3). Thus, the papers that did not answer the research question and were irrelevant to the research were excluded.

Table 2: Research Findings

Date 2015-2020	ProQuest	Web of Science	Business Source Premier
Initial findings	147	18	27
After removing duplicates	111	9	6
After reading abstracts	77	9	2
After reading the whole text	69	8	2

3. Results

Table 3 shows the 79 papers were considered eligible and included in the synthesis. The results of the literature review highlighted several business industries that used GIS in their Supply Chain Management.

3.1. Categorisation of business sectors that use GIS

Figure 2 depicts the identified industries divided into eight categories with distinct characteristics to observe, analyse and critically evaluate the potential various benefits/ uses of GIS, presented in detail below.

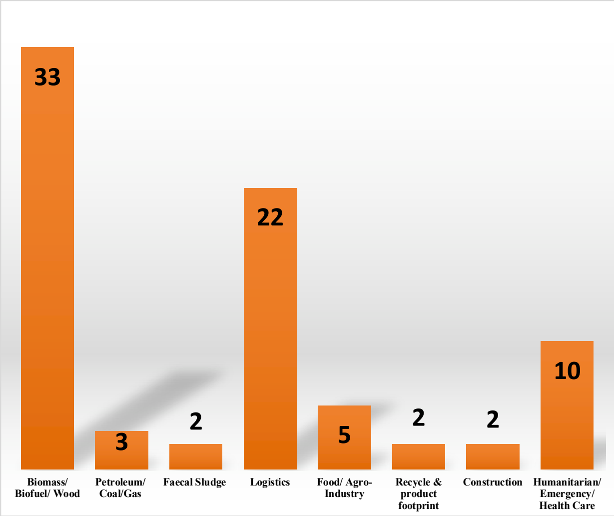

Figure 2: Number of studies that used GIS applications in different industries

3.1.1 GIS in biomass/ biofuel/ wood industry

The papers included in this category had the most complex methodology of applied GIS in SC activities. In many cases, they exhausted all the application categories of **Error! Not a valid bookmark self-reference.** 3, including all possible combinations. The reason behind this extensive GIS use in this industry (33 papers, the most significant category) is the motivation of the researchers to provide a solution to a complex financial dilemma. They aim to provide attractive biomass products and crops to both customers and investors to obtain the maximum profits possible in regards to using fossil fuels or farming a different crop [11]. With this consideration, most of the papers presented below are focusing on minimising the logistics costs, such as transportation and warehousing, to optimise the SC and satisfy both stakeholders (producers and customers).

In order to minimise the transportation costs from the field to the appropriate treating facilities or warehouses, many researchers used the GIS application of network analysis [12]–[14] and location-allocation analysis [15], [16] combined with optimisation tools, such as the OPTIMASS [17] or mathematical programming [18]–[22]. They aimed to find the most suitable locations for the facilities to minimise distances that the products will need to be transported. Other researchers used the more complex but similar methodology of minimising the total transportation cost according to different modes, which will not necessarily be the minimum distance [23].

In parallel, extensive research has been conducted to investigate appropriate locations for warehouse and facility siting to minimise transportation costs and greenhouse gas (GHG) emissions and to satisfy demand through the use of GIS and MCDA techniques, such as Analytical Hierarchy Process (AHP) [24] or Fuzzy Analytical Hierarchy Process (FAHP) [25], combined with location-allocation analysis [26] and mathematical programming [27]–[29]. A robust addition to this research area has been made by Ref. [68], as the authors provided a novel technique of stakeholder satisfaction to the MCDA site selection process.

Another use of GIS in biomass SC was the investigation of available croplands (feedstock supply) [30] and biofuel demand [31]. In some studies, the integration of complex mathematical models [32] and optimisation tools, such as the OPTIMASS, were implemented to maximise the net energy output and the financial performance [33], [34].

In more complete and advanced studies, almost all examined GIS applications were included. The researchers expanded the investigation of feedstock supply, providing a network analysis [11], [35], [36], an MCDA [37] combined with location-allocation plant siting analysis [38], [39], and SC optimisation and simulation tools [40], [41] to minimise the transportation costs (field to plant to customer). Finally, the authors in Ref. [42], proposed a new application, the CyberGIS-BioScope, which adds to all the above research questions and also provides map-based visualisation of the interactive results.

3.1.2. GIS in petroleum/ coal/ gas industry

To date, only a few studies have focused on the role of GIS in the petroleum industry. In Ref. [43] the authors applied GIS to investigate the ground, waterway networks, rail and pipeline networks based on an impedance factor (distance) and shortest path algorithms to consider accurate and realistic decisions on the transportation planning level. Therefore, GIS was used as a first step towards selecting potential distribution centre locations.Then, using a multi-echelon Mixed-integer linear programming (MILP) optimisation model, they assigned transfer volumes to the transportation networks and identified the optimal facility locations.

Table 3: A systematic review of the literature

Reference	Business Industry								GIS application in SCM				
	Biomass Biofuel/ Wood	Petroleum / Coal/ Shale Gas	Faecal Sludge	Logistics	Food/ Agro-Industry	Recycle & product footprint	Construction	Humanitarian/ Emergency/ Health Care	Network/ transportation analysis/ Routing algorithms	Spatial analysis (People or land)	Location – Allocation Site Search/ Selection (MCDA)	Visualisation/ monitoring or BIM	Connection with optimisation tools/ algorithms
[17]	√								√		√	√	√
[24]	√								√	√	√		
[44]				√					√	√		√	
[42]	√								√			√	√
[43]		√							√		√		√
[45]					√				√	√			√
[46]								√	√				
[47]								√	√	√			
[41]	√								√	√	√		√
[31]	√									√			
[33]	√								√	√	√	√	√
[48]				√					√		√		√
[32]	√									√			
[49]					√				√				
[35]	√								√	√	√		
[18]	√								√				√
[11]	√									√	√		
[50]				√						√	√		
[51]					√					√	√		
[52]				√					√				√
[27]	√								√	√	√		√
[30]	√									√			
[53]				√						√			
[54]				√					√				
[55]								√	√	√	√		
[38]	√								√	√	√		√
[19]	√								√		√		√
[56]				√					√				√
[12]	√								√				
[57]					√				√	√			
[58]								√	√		√		
[25]	√										√		
[13]	√								√		√		
[59]								√			√		
[60]							√		√			√	
[20]	√								√	√	√		
[61]				√							√		
[14]	√												
[21]	√								√		√		
[34]	√								√				
[22]	√								√	√	√		
[40]	√								√		√		
[62]				√							√		
[39]	√								√	√	√		
[37]	√									√	√		
[63]					√					√	√		
[64]				√					√				
[65]				√					√				
[26]	√								√		√		

Reference	Business Industry								GIS application in SCM				
	Biomass Biofuel/ Wood	Petroleum / Coal/ Shale Gas	Faecal Sludge	Logistics	Food/ Agro-Industry	Recycle & product footprint	Construction	Humanitarian/ Emergency/ Health Care	Network/ transportation analysis/ Routing algorithms	Spatial analysis (People or land)	Location – Allocation Site Search/ Selection (MCDA)	Visualisation/ monitoring or BIM	Connection with optimisation tools/ algorithms
[66]								√			√		
[67]							√		√		√	√	
[68]				√					√				
[69]				√					√				
[23]	√								√		√		
[70]								√		√			
[36]	√								√	√	√		
[71]								√		√			
[15]	√								√	√	√		
[72]			√						√	√			
[73]	√										√		
[28]	√										√		
[74]								√	√	√			
[75]				√					√	√	√		
[76]		√									√		
[77]		√							√	√	√		
[78]						√					√	√	
[79]				√							√		
[80]				√					√				
[81]				√							√		
[82]						√				√			
[83]				√					√				
[29]	√								√	√	√		
[84]				√					√				
[16]	√								√		√		
[85]								√	√				
[86]			√						√	√	√		
[87]				√					√				
[88]				√								√	
[89]				√							√		

A similar methodology in GIS usage in the petroleum industry has been used in Ref. [77]. The authors' focus was to assess the current infrastructure for the supply chain of shale gas in Mexico and investigate the water stress of each shale gas basin's whole gas exploitation system. In their study, they also combined GIS with a MILP model. However, their method was different, as they implemented an integrated approach of both water management and gas supply chain. GIS was used primarily to investigate transportation costs, water availability, water consumption patterns and the environmental impact of water exploitation in the examined area.

Then, using a multi-echelon Mixed-integer linear programming (MILP) optimisation model, they assigned transfer volumes to the transportation networks and identified the optimal facility locations.

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The problem of distribution site selection was also investigated in Ref. [76]. However, the authors examined an environmentally friendly coal distribution sites selection process by combining GIS and an equilibrium strategy-based, multi-objective, bi-level model. They aimed to resolve the potential conflicts of interest between authority and the collieries. The GIS and big data tools were used to identify potential candidate distribution sites, incorporating several location criteria.

3.1.3. GIS in faecal sludge sector

Over the last five years, only two studies researched the use of GIS in the management of the faecal sludge (FS) supply chain problem. Both used case studies that were implemented in African countries (Ghana and Uganda). Ref. [86], used a global positioning system (GPS) and GIS tools to optimise FS emptying, collection and transport logistics in the study area. Therefore, they implemented GIS software, a location-allocation analysis, and the shortest route analysis via the road network between the treatment plants and emptying events. Similarly, the authors in Ref. [72] research used GIS to rationalise the FS emptying and transport cost by minimising the travel distance and time. They also added an assessment of the population density and income levels of residents at neighbourhood level to their analysis.

3.1.4 GIS in the logistics industry

In logistics companies, the GIS has been implemented in various ways. A large and growing body of literature has investigated the optimisation of route/ transport networks. The authors in Ref. [52] investigated the optimal route while focusing on cost minimisation through tool costing integrated into Google Maps. Also, in Ref. [56] the authors aimed for route optimisation using a cooperative particle swarm optimisation in parallel with GIS. Ref. [44] includes research regarding transport routes wherein the authors investigated vulnerable seismic areas, and therefore the vulnerable logistics routes, that overran them by implementing advance spatial analysis, in order for the logistics companies to create alternative routes. Furthermore, in Ref. [64] the authors proposed a new digital traffic network route search tool aiming to address the problems of path search throughout the analysis of digital traffic.

Moreover, specific interest for the logistics route optimisation through GIS research has been given to port facilities investigation, especially for optimising transport routes for the Saint Petersburg (Russia) port aiming to improve terminal connectivity [80], [87]. In contrast, in Ref. [69] the authors compared three Spain ports according to their logistics performance. They used longitudinal data on port shipments from inland regions to investigate the changing spatial distribution of port hinterlands. They concluded that the use of rail is not the key driver behind the successful capture of distant markets.

During the past five years, much more information has become available on locating logistics facilities or companies through GIS and MCDA, multinomial logit (MNL) and mixed multinomial logit models (MMNL). For example, in Ref. [48] the authors used MNL and MMNL to identify the Flanders logistics companies' 'willingness to pay' for a specific characteristic (proximity to port or highway). Also, GIS and MCDA were used to weight the locating criteria with various methods, such as Jenks optimisation [50], calculating the Euclidean distance from delivery points [81], AHP and integer programming [89], AHP and TOPSIS (technique for order performance by similarity to ideal solution) [61], FAHP [62], fuzzy Stepwise Weight Assessment Ratio Analysis (SWARA) and CoCoSo (Combined Compromise Solution), compared with the results of other MCDA methods [79].

An inventive contribution to facility location research was made in Ref. [75]. The authors researched the accessibility of freight warehouses using GIS, focusing on Value of Time, spatial distributions of warehouses and intermodal freight facilities, and traffic characteristics. Additionally, pioneering research involving logistics company location and GIS was done in Ref. [53]. The authors used 16 spatially analysed criteria weighted by three MCDA methods (AHP, analytic network process and TOPSIS) to evaluate the logistics performance of Turkey's areas a work that can seem very useful for SCM. Their results may benefit SC managers that are considering business expansion and policymakers willing to improve the Logistics Performance Index (LPI) in one region [90]. Another work that included policy evaluation, GIS and MCDA was conducted in Ref. [84]. They investigated City Logistics strategies (routes) that support land use planning and organisation of logistics flow in the city centre of Salvador, Bahia, Brazil. Their limited case study must not undermine the importance of their proposed criteria, which can be examined in other historic cities with similar transportation problems. This piece of work came to complement the extensive research study of Ref. [54] in which the authors proposed a transport spatial decision support model to optimise the implementation of environmentally friendly vehicles in an existing road network using several parameters, such as environmental pollution, health, use of space and logistics operating costs.

In Ref. [65] the authors formalised the problem of optimal interaction locations on road networks when there are multiple moving objects. They used a context-based geoprocessing five heuristic methods framework. Also, a significant contribution has been made in Ref. [68] that aimed to identify the optimal meeting-up location of moving objects. Both papers used GIS and provide a significant innovative contribution, especially for SC managers that want to invest more in a new multimodal and complex logistics environment with many freight exchanges.

In Ref. [83] the authors also carried out innovative research that created an open coded warehouse operating software through a GIS environment that can help solve problems, such as the travelling salesman problem (TSP), in a warehouse. Their work can contribute to optimising robotic warehousing and other warehousing operating schemes.

3.1.5. GIS in food/ agro-industry

The research conducted in Ref. [45] developed an integrated simulation tool that can calculate the spatial distribution and public health risk related to the spread of specific microbiological threat agents that result in contaminated food. The GIS was used to investigate the shortest path algorithm and was coupled with a simulation tool. Investigation of the shortest and fastest delivery routes for fresh products was also conducted through GIS in Ref. [49] in which the authors investigated the quickest routes, with the delivery time based on multiple time frames.

In contrast to the sole investigation of the shortest path analysis, in the study of Ref. [51] the authors provided an innovative method for selecting the agro-industry locations that combined a new and unique voting method with GIS. After the selection of criteria through a literature review, a GIS was used to determine the initial locations, and experts voted for the best among them.

3.1.6. GIS in recycle & product footprint sector

Plastic pollution has been drawing increasing awareness globally, as plastic is poorly disposed of, and it is a primary contributor to GHG emissions [91]. In Ref. [78] the authors aimed to address the plastic recycle problem by integrating modelling carbon price uncertainty with GIS, stochastic modelling and factors in the life cycle emissions of plastic. The limited use of GIS was applied in a visualised platform to observe the alteration of the SC configurations, the choices of facility locations, and the product flow within the SC across different plastic price scenarios.

Regarding the product footprint research, in Ref. [82] the authors discussed the water pollution caused by production and investigated a new method for obtaining an ecolabel. In the research, GIS was utilised to investigate the spatial and temporal dimensions of a product’s life cycle and water footprint by investigating the location of each product and the water and soil quality of the water basins in the area. However, a more comprehensive study would include specific animal species that may be impacted by the degradation of water quality in the examined region.

3.1.7. GIS in construction industry

In Ref. [60] the authors proposed a theoretical framework towards integrating BIM and GIS in construction SC to provide transparent construction material information, enhanced SC status visualisation and information for supplier selection. Thus, in their model, GIS was used to determine the relative distance/ time using network analysis between the available resources defined via BIM and the construction site itself, and to assist in a valid supplier selection. Besides, a more recent study the authors developed the above framework investigating not only the supplier selection by distance and material delivery activities but also the price of each transport unit and the allocation (price and location analysis) of consolidation centres via case studies [67].

3.1.8. GIS in humanitarian/ emergency/ healthcare sector

In Ref. [46] the authors proposed a way to react in a complex scenario with multi-traffic scenarios (risk alternatives), applying a new multi-attribute, impedance-based trip assignment model that utilised the shortest path algorithm embedded in a GIS Graphical User Interface tool. Similarly, in Ref. [85] the authors proposed a post-earthquake emergency logistics decision support GIS tool that compliments the previous research. They aimed to provide not only the shortest route but also a reference plan of emergency material allocation. However, they did not provide the same user-friendly environment. An extension to the route selection research was offered in Ref. [74]. The authors suggested a new framework for the shortest route based on GIS that considers the widths and structures of roads, tunnels and bridges, the strength of infrastructure according to its spatial characteristics and the legal speed limits in the pre- and post-earthquake disaster decision processes.

Another use of GIS in that industry was the network configuration and examination; however, GIS capabilities were limited. In the research of Ref. [47], GIS was used only to calculate distances and population attributes to design a mobile blood collection system. Also, limited use of GIS has been observed in Ref. [71] wherein they only calculated the population density distribution across a transport network area with several methodological limitations, failing to investigate – on a smaller scale – the specific affected population. However, their ground-breaking investigation offers a new perspective in a network configuration where they account for cost and the public health effect of the transport emissions exposure in populations living within five kilometres of the transportation routes.

In terms of the facility location, in Ref. [55] the authors used raster GIS to analyse potential flooding scenarios to investigate the number of emergency facilities and provided input to the optimisation of emergency facility location model. Their research aimed to optimise the network connectivity (network analysis) and emergency facility location siting (height above sea level and several other criteria) for flood scenarios in Mexico. Furthermore, a decision support framework for location identification in the domain of disaster relief SC using fuzzy analytical hierarchy process to weight and evaluate the location criteria and GIS to investigate the appropriate sites was proposed in Ref [59]. However, the study does not consider several previous pieces of research that propose different criteria. Therefore, the main weakness of the study is that it failed to acknowledge the fact that their framework cannot be considered from a global perspective. To complement that, in Ref. [66] the authors designed an urban emergency rescue facility location decision support tool with the use of GIS and emerging artificial intelligence technologies. They aimed to create a multi-objective optimisation algorithm with GIS for solving a geospatial multi-objective optimisation problem.

In the health care sector, a distinguished research investigated by GIS a vehicle routing based location-allocation analysis [58]. The authors aimed to answer an essential question of whether locating one warehouse or a combination of a few warehouses is more effective (in terms of cost and delivery). They included the optimal location of one or more warehouses, delivery network coverage and efficiency of routes, as well as the accessibility of health centres and hospitals.

In terms of natural disasters, the authors in Ref. [70] investigated the quality improvement of environmental information systems through a service-oriented architecture. They aimed to provide a Web GIS-based environmental information, to estimate the risk of a natural disaster within the geographical region. Therefore, SC managers will be able to estimate the risk of a natural disaster to a specific area or route. However, only a small number of participants took part (38), so their limited sample bears limitations as the interviewees were only IT experts and not SC managers; therefore, the true users' satisfaction or interaction with the software was unclear.

3.2. Categorisation of applications

Throughout this paper, these applications are divided into five categories with different characteristics to observe, analyse and critically evaluate the potential benefits to SC activities. Figure 3 presents the category or categories of application that each paper contributed. Figure 4 depicts the countries where these studies were conducted.

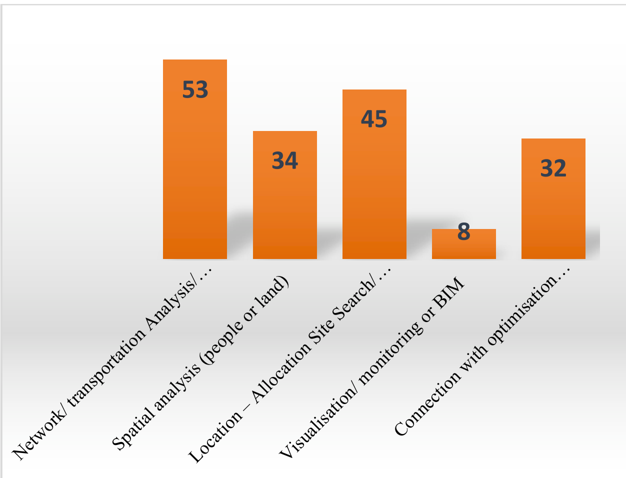

Figure 3: Number of studies that used different GIS applications

As depicted in Figure 4, in the last five years, 73 out of the 79 research papers about GIS for SC activities used case studies performed in 26 countries. Most case studies were conducted in the US (16) followed by China (7), Turkey (6) and Mexico (5). Surprisingly, many European countries (including the UK) did not have research studies on this topic.

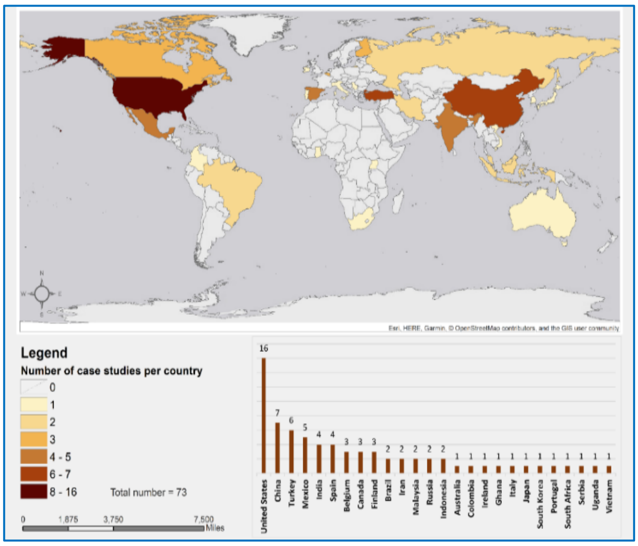

Figure 4: Map with the countries that had studies with a case examination of a GIS application. Created by the author.

Moreover, the Biomass/ Biofuel/ Wood category reported significantly more application usage and outperformed all seven groups. Specifically, 59% of the papers that used GIS applications connected with optimisation tools, and 56% of the papers that used the location-allocation, site search/ selection (MCDA) GIS applications, were observed in the Biomass/ Biofuel/ Wood industry. In comparison, 26% of the included papers that used GIS Network/ Transportation Analysis/ Routing Algorithms and 25% of the included papers that used GIS Visualisation/ Monitoring or BIM tools were noted in the logistics industry.

Significant application use can be seen in the Humanitarian/ Emergency/ Health Care industry, where it was referred in the 11% among the papers that used GIS Network/ Transportation Analysis/ Routing Algorithms, in the 15% among those that used GIS Spatial analysis (people or land) and in the 6% among those that used GIS Location-Allocation Site Search/ Selection (MCDA).

4. Discussion

This study presents the first literature review of the different GIS applications in SCM. The main finding in this study is that many business industries have not utilised the GIS capabilities in their SCM yet. In the review, only eight industries have been identified that currently use GIS in their SCM, and the most prominent one was the Biomass/ Biofuel/ Wood industry (with 33 papers), followed by the logistics industry (22 papers).

Regarding the utilised GIS applications, the literature review results indicated several practices of GIS in relation to Supply Chain Management. The current data highlights the importance of GIS in SCM cost minimisation, and the findings suggest that, in general, a lot of businesses could benefit from GIS to minimise the SC costs; however, only a few are already using this application. Moreover, the findings indicate that the commercial application of ArcGIS was the most popular among the researchers.

What is also evident from the literature review is that only four studies included the development or the partial development of new GIS software to help SC activities [42], [66], [70], [83]. Most (51) of the included papers mentioned that they adopted the commercial software of ArcGIS 9.x/10.x and its analyst extensions (spatial analyst, network analyst and location-allocation). However, none of them used the same company's Business Analyst extension, and in only one research paper was the more advanced software of ArcGIS Pro 2.x employed [28]. This fact can guide future researchers that want to focus on this field or businesses that want to implement the same methodology to optimise their SC.

These findings should be interpreted considering several limitations. Due to the limited time and resources available, some strict methodological decisions needed to be made. For example, the timeframe of the studies included was set from 2015–2020. Therefore, a significant limitation of this study is that it includes only peer-reviewed publications and excludes grey literature and empirical GIS usage evidence. An additional uncontrolled factor is the possibility that significant research may have been written in a language other than English. Also, despite the effectiveness and practicality of commercial software providing most of the necessary tools, a researcher should be mindful that Esri does not provide all the algorithms that these tools are using, and this may have some research implications. For instance, Esri does not provide the in-house developed tabu search-based metaheuristic algorithm that aims to find the best sequence of visiting stops to solve the TSP Also, they do not provide the in-house developed, tabu search-based, metaheuristic algorithm that aims to solve the vehicle routing problem. However, Esri does share the routing solvers within the ArcGIS Network Analyst extension (Route, Closest Facility and origin-destination cost Matrix solvers), which are based on Dijkstra's algorithm for finding the shortest paths.

Further research should be undertaken to explore how the advanced methodologies of spatial analysis, combined with network analysis, mathematical programming, location-allocation and SC optimisation, and simulation tools, could be shared in industries other than biomass. Additionally, with regards to the biomass industry, further work should focus on determining the exact economic outcomes of GIS in their SCM. Thus, a meta-analysis on the subject would provide more information and would help us to establish a higher quality of evidence on this matter.

5. Conclusion

The findings of the first literature review of the GIS applications in SCM showed that many business industries have not utilised the GIS capabilities in their SCM yet. The GIS capabilities of visualisation, spatial analysis, optimisation, and site research can largely contribute to the SCM decision making process by providing strategically important answers to supplier selection, facility location, SC network configuration and asset management. Overall, this study strengthens the idea that GIS can be used to make leaner SC and logistics activities and provide guidance to SC strategic decisions.

The challenge that is being raised now by this study is to find ways to implement GIS applications in the SC of industries that are not currently used and to adopt successful practices. The investigation of how SC problems could be resolved utilising GIS applications from other industries could also be a fruitful area for further research in SCM, and it may lead to synergistic collaborations in the sector utilising the know-how from the relevant businesses and location-specific products.

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