Recent Trends in Civil Engineering and Built Environment Vol. 3 No. 1 (2022) 1222-1230

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

The Application of GIS in Environmental Engineering: Opportunities and Limitations

Nur Farah Aina Mohd Zuki[1], Nazirah Mohamad Abdullah[2]*

[1,2]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Parit Raja, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2022.03.01.139
Received 4 July 2021; Accepted 13 December 2021; Available online 15 July 2022

Abstract: Modern computer technology such as geographic information systems (GIS), assign cost-effective tools that can evaluate environmental outcomes to explore more comprehensively opportunities to apply GIS. Unfortunately, costs are presently the main obstruction to the use of GIS where software is comparatively extravagant concerning the other methodology. Thus, this research intends to conduct a systematic literature review on the major benefits, limitations and explores significant issues related to the application of GIS in environmental engineering. Through eligibility testing, a total of 38 publish review papers starting from 2015 to 2020 have been interpreting by using major platforms such as Scopus and the Web of Science to identify the key issues associated with the application of GIS in environmental engineering. Information acquired from main platforms and other platforms are also analyzed where 28% of them reviewed on GIS in environmental engineering, 25% reviewed on types of environmental engineering, another 22% on benefits and 25% for limitations of GIS. Within these concepts, GIS encloses a fundamental as an applicable set of value-added tools which combine capabilities spatial referencing with relational database management capabilities and efficiently presenting large volumes of data. Therefore, GIS technology will come out with a systematic literature review that can proceed to play an essential role, offer significant added value to the system environment as well as gain a better understanding of GIS applications in the future.

Keywords: GIS, Environmental Engineering, Benefits, Limitations

1. Introduction

Geographic Information Systems (GIS) is a computer system that competent in analyzing, capturing, storing and also displaying referenced information in terms of location such as longitude and latitude [1]. Environmental engineering challenges demand new innovative techniques and tools for the management and analysis of spatial and nonspatial data. Costs are presently the main obstruction to the use of GIS where software is comparatively extravagant concerning the other methodology [2]. GIS

*Corresponding author: nazirah@uthm.edu.my

gives advantages in promotes the linking of environment outcome data with social data sources and publicly available demographics to expand the utility, analytical scope, cost-effectiveness of explanations and feasibility. Lately, spatial representation and the use of GIS in various environmental issues make professionals arrive at conclusions in a better way in the field for both decision-making and environmental databases spatially referenced either explicitly or implicitly. The capability to form more complex algorithms together that associate various map algebras statements is the one of powerful features of GIS [3]. Data integration that been approach by GIS propose analytical tools for referencing data collected and defined at dissimilar geographic levels to demonstrate statistical graphics to expose relationships, underlying patterns and errors in the data.

The use of GIS disrupts by two factors such as potential users is not always acknowledged or appreciated the technical design of GIS who might be preoccupied with other pressing aspects of their applications and the value of GIS in many supplication areas has been confusing for new users about the potentiality of the technology as well as deficiently documented such that newcomer. An appearing issue in environmental research scrutinizes the development of integrated cost-efficient tools for management and framework, dispose of information needed in the monitoring, analysis and display of information needed in planning, monitoring and assessment [4]. Nevertheless, this can be catered by conducting a systematic literature review about the application of GIS in environmental engineering. It is more than an uncomplicated digital evolution from cartography to geographic data predominantly based on digital mapping and IT that offers limitless benefits to resource allocation engineering, research and also project management [5].

2. GIS in Environmental Engineering

GIS reinforces activities in environmental monitoring, mitigation, assessment and as well as can be used to effectuate Environmental models. GIS can be utilized the most impressively for environmental data arrangement and analysis [6]. GIS is a particularly key appliance in the environmental data framework for digital data transfer standards, data retrieval, data validation and also for analysis. 1 shows the GIS component Software, Hardware, Data, Procedures and Methods used by people for decision-making and analysis regarding the location are the main components of GIS.

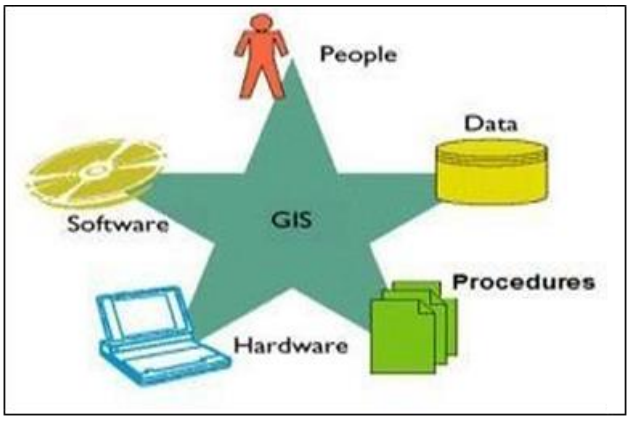

Figure 1: Components of GIS [4]

The usefulness of GIS especially in environmental decision-making and problem-solving intensify as the entanglement and scale of the environmental problem escalate [7]. For high-risk environments, GIS can play an essential role in formulating and analyzing the mitigation plans more swiftly and expeditiously. New spatial interrelation can produce overlay that includes demographics, a heterogeneity of socioeconomic and environmental information to environmental outcomes data. GIS capabilities concerning analyzing spatial data and presenting information procured from such data as thematic maps and other scientific works can be considered as the stated potential of GIS technology [8]. This can succor as the definitive communication of environmental information towards the

policymakers and also the public as this is the basis for a multimedia point of view in environmental decision-making. Hence, it acknowledges a better understanding and view of physical features in addition to the interpretation of the relationship that influences the critical environmental condition.

3. Methodology

This research is focusing on a systematic literature review on the assessment of GIS application in environmental engineering. Figure 2 shows the research methodology is divided into a preliminary study, formulating research questions and literature review.

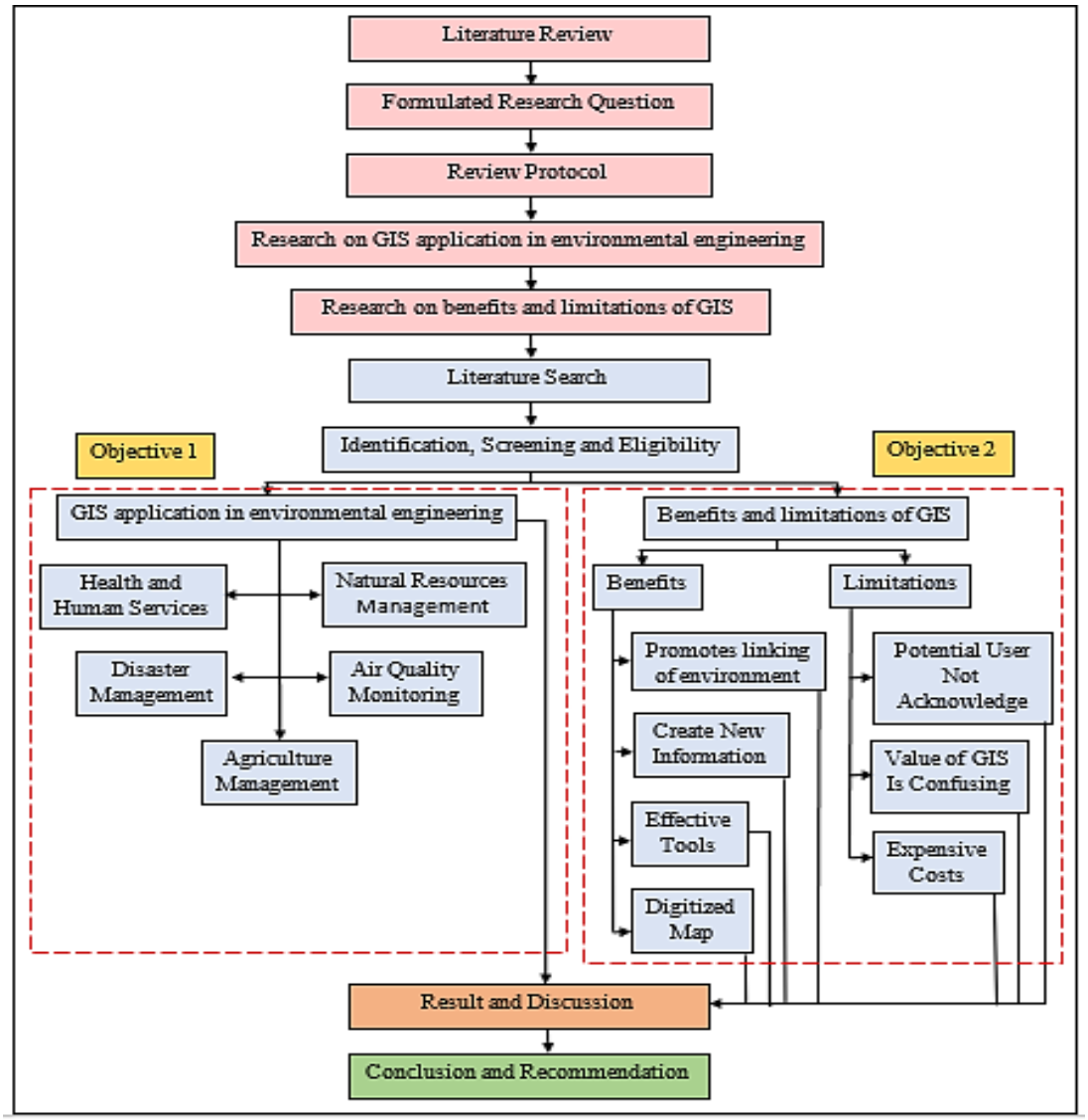

Figure 2: Research framework

3.1 Literature Review

A literature review is usually used to gather information related to the field of research to increase the understanding of researchers in their research. Literature reviews not only benefit from the building of knowledge but also provide researchers with numerous ideas to enable them to continue their research more efficiently. After a lot of reviews, reviewing also helps to narrow the research area that needs to be studied and to avoid any duplication with other studies.

3.2 Research Questions

The first step in a systematic review is to formulate Research Questions. Well- formulated research questions will guide the review process such as narrowing the focus, determining the eligible criteria, searching articles, collecting data and also presenting the findings. In this step, there is also important to identify the inclusion and exclusion criteria. Inclusion criteria are decided criteria that will be taken to be reviewed while unnecessary elements will be excluded. This determination is crucial before starting any reviewed research to avoid bias.

3.3 Published Guideline

A published guideline is necessary to enhance the validity of the research process and minimize the risk of bias and for the use of basic reporting. It is good to register the review protocol but it is optional. It is worth using as a guide or report to carry out a systematic review. Since there is no published review protocol or standard for the field of Geomatics Engineering, PRISMA id preferred reporting items for systematic reviews is used as a guide in this research.

3.4 Literature Search

To carry out the data collection, the systematic searching strategies consist of 3 sections which are Identification, Screening and Eligibility. PRISMA provides a flow diagram to use as a guide for the determination of included articles. Before the collection, Scopus and Science Direct are selected as the leading databases used to search the related articles in this research. Both of these two databases provide more than 4000 publishers that are related to GIS application in environmental engineering. The selected supporting databases include Google Scholar, Science Direct, SpringerLink and IEEE Xplore Digital Library.

3.5 Identification

To search the articles more efficiently, keywords are used rather than the whole title. More keywords allow more related articles to be searched. Suitable keywords can be identified from the synonym, related terms and the variation from the main keywords. From the main keywords and enriched keywords, a method called advanced searching is used to search the articles. Hence, keywords provided by previous studies or keywords suggested by the databases can be taken into consideration.

3.6 Screening

There are 2 stages in the Screening section which are removing and duplication and screening based on research limit. The research limit can be selected in the databases and filter the articles automatically based on the selection. The specific criteria will be listed in Table 1.

Table 1: Research Limit

Item	Refine Result	Criteria
1	Access Type	Open access and others
2	Year	2015 – 2020
3	Subject Area	Engineering
4	Document Type	Research Article, Review Paper and Conference Paper
5	Publication Stage	Final
6	Keywords	All listed
7	Sources Type	Journal
8	Language	English

3.7 Eligibility

This is the last section for data collection. All articles that remained after the Screening section will be manually selected in this section. The title and abstract of the research will be reviewed and related articles are download prior. In full article assessment, all the contents in the article are advised to be

reviewed in order to ensure that the remaining articles fulfilling all the inclusion criteria. Hence this research is focusing on the empirical part, title, abstract and result or discussion are reviewed. In the Eligibility section, full-articles assessment is suggested to carry out. Therefore, a full-article assessment is carried out together with a group called as review partners and to ensure the quality of systematic review it been verified by the supervisor.

4. Results and Discussion

The data of this study were obtained from secondary sources. Although the data collected was fewer than 10 or 10 articles for each scope as stated in Chapter 3. As a result, from those articles, the data could also be verified. Figure 3 presents the number of articles that referred to GIS applications in the field of environmental engineering obtained from Scopus and the Web of science as leading databases and other websites.

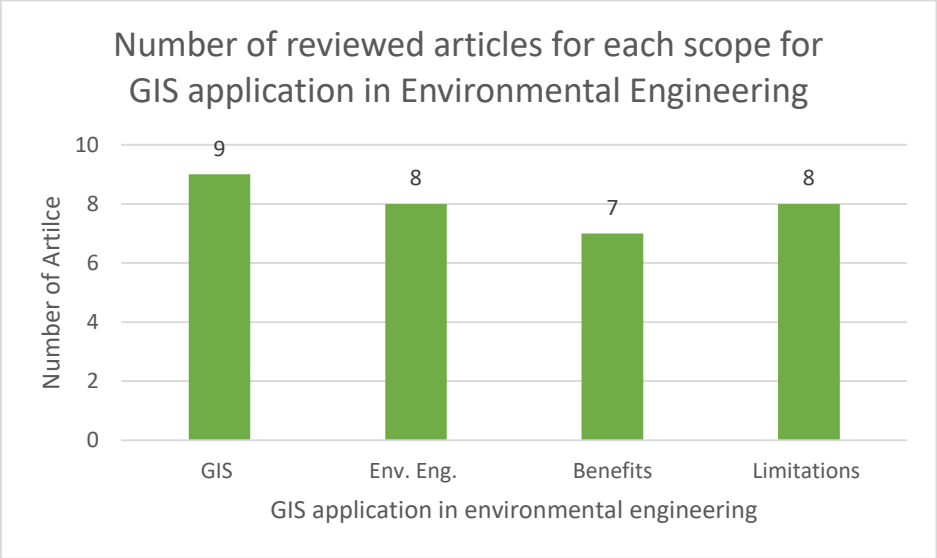

Figure 3: Number of reviewed articles for each scope

4.1 Data Acquisition and Analysis

For analysis purposes, the data are obtained from several papers that had been reviewed through Scopus, Web of Science and other databases. Consequently, Figure 4 to Figure 7 shows the GIS, environmental engineering, benefits and limitations of the GIS are the main scope that commonly used throughout these studies.

4.2 Geographical Information System (GIS)

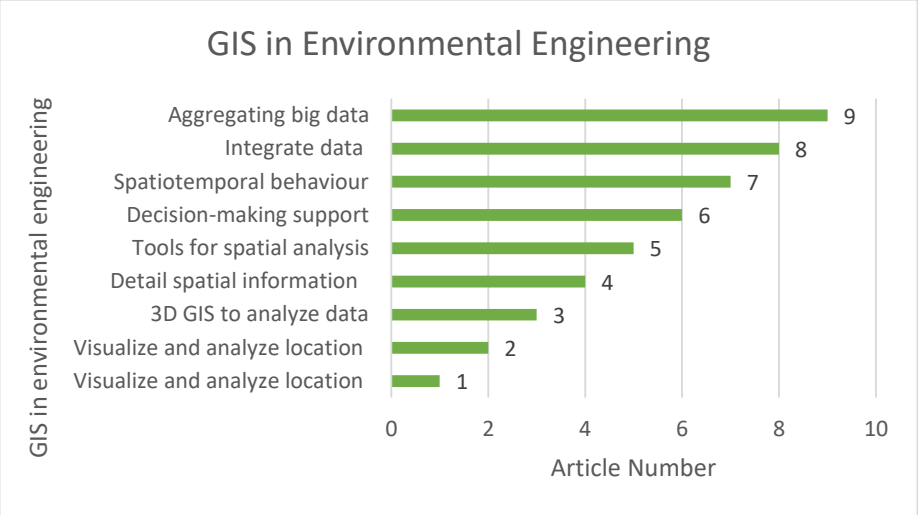

Figure 4: GIS in environmental engineering obtained from various articles

From the comparison between the papers that have been reviewed, the GIS system is utilized to interpret the objects that already exist around us, not restricted to data storage systems only and concentrate on information correlated to spatial configuration. Numerous applications have continued proposed mainly in the field of geoscience to manage natural phenomena using GIS as well as extensively implemented in every development. Hence, outlining, operation and also environmental management are the three varieties of GIS-based studies that produce a more comprehensive picture of the role of GIS as a support tool in decision making.This paves the way for data or spatial features to be deposited as geometry as well as referenced using maps and coordinates. Semantic and geometric data must be arranged in an adequate and good manner as a requirement in performing 3D GIS data management. Thus, smart maps explained by GIS can propose real-world simulations essentially to users and encompass ideas about how we apply our cognition to interpret spatial perceptions and configurations. Managing large data from a diversity of sources immediately is an extensive function of GIS in demonstrating the support for strong spatial information. Thus, GIS can be a precious tool in social mobilization, decision-making and community acknowledgment.

4.3 Environmental Engineering

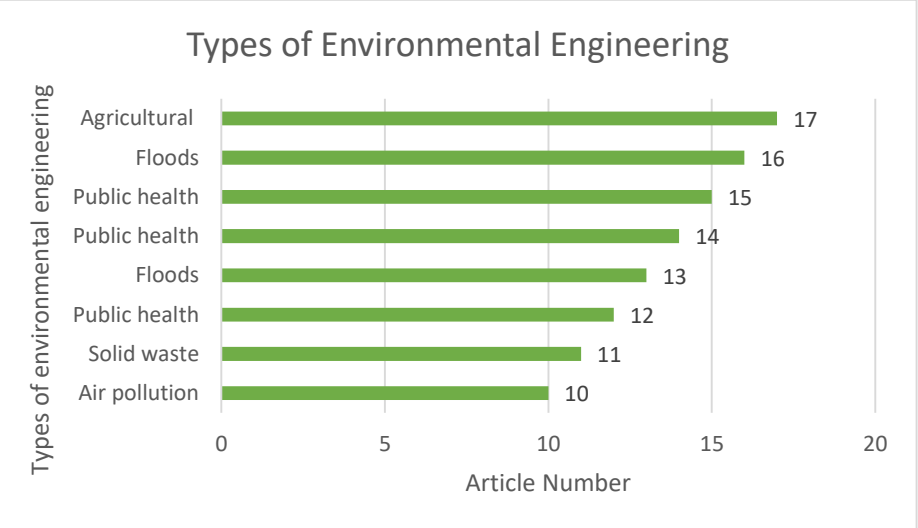

Figure 5: Types of environmental engineering obtained from various articles

From the comparison between the papers that have been reviewed, numerous problems related to the environment appear due to economic development, industry and also accelerated population growth. GIS has elevated approachability and reliability through an environment that can unite the mapping process and environmental data. However, pollution of the living environment seems to be inevitable if precautions are not prepared to eradicate this problem. one of the several concentrated issues in the environment is air pollution that hits nearly every edge of the world due to human actions and activities. Thus, GIS can prognosticate pollution concentrations to gain valuable data on the pattern of air pollution spread at unmonitored stations. Low and medium-cost initiatives are recommendations that may help the broader use of this technology when it is needed. Disease surveillance is involved with the tracking and compilation of data on the pervasiveness of incidence, and the expanse of disease. As a result, modelling and mapping can connect data on diseases by controlling environmental features by implementing GIS technology.

3.7 Benefits of GIS

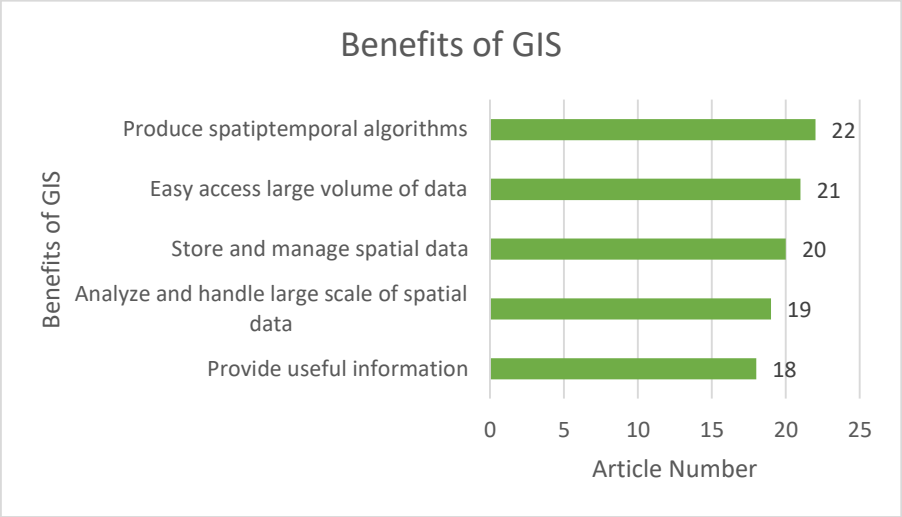

Figure 6: Benefits of GIS obtained from various articles

From the comparison between the papers that have been reviewed, there are diverse contributions where GIS can be applied to identify satisfaction of accessibility, measure severity, lessen travel expenses, vulnerabilities, map uncertainties and support optimization. Since GIS has more reliable results in general and having more genuine geographical management as well as communication. Thus, GIS has the precise characteristics of intuitive, definite, measurable, contrast, displayed in the mapping, and inexpensive because it does not reveal the basic characteristics of the regional environment. GIS has a broad scope of applications that can make an impression in crisis management and necessitate collaboration as well as communication more swiftly with each other. GIS has been invented in the appropriate way as it can give straightforward and instantaneous access to this vast amount of geographic data. GIS grants commercial and open-source combinations with worthy software alternatives where achievement evaluation status improved at the time. As a result, it can assist in producing spatiotemporal algorithms to discover contagious disease outbreaks as quickly as possible.

3.7 Limitations of GIS

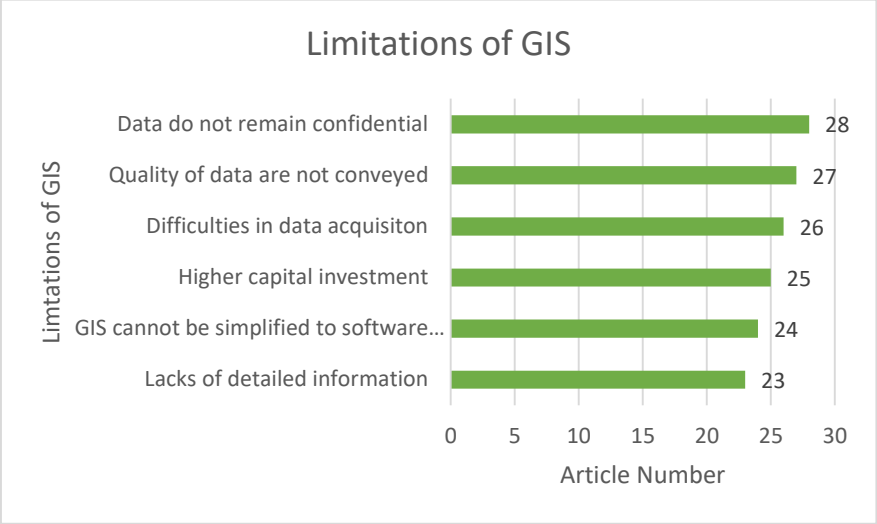

Figure 7: Limitations of GIS obtained from various articles

From the comparison between the papers that have been reviewed, GIS presents advantages as well as restrictions. Inequalities in research methodologies and varieties of GIS software applications, allow one GIS not to be alike as another user even in similar studies. It is very challenging to keep confidentiality as it is possible to distinguish the affected individual with the least additional information. Comprehensive technologies in GIS have expanded swiftly in map production, data preparation and platform construction. Difficulties are faced by GIS users in heterogeneous data consolidation and data acquisition. Therefore, inventing and implementing GIS standards to ensure lower variability is one of the aims of researchers in the future. GIS technology is linked with higher-end outcome versatility and more agile interpretation. Nevertheless, the more high-priced capital investment was initially related to GIS requirements as well as any unnecessary mapping trends. The evolution of the GIS environment can contribute information for land management design in enhancing its effectiveness as well as quality. As a result, the reliability of GIS research may be hampered if the data is not kept confidential.

5. Conclusion

In short, GIS technology will proceed to play an important role in the management of environmental systems. GIS can present enormous amounts of data on a map using the geographic coordinate system. GIS can integrate tools that allow the display of information in real-time and is also more proper for emergency operations. Valuable information can be communicated in the time required through GIS technology to take remedial measures in the most effective time possible. Through this study, there are several suggestions and recommendations for future jobs, for instance, developing a software system that contributes numerous GIS functions in a more user-friendly way to people [9]. A perfect GIS program should let the user concentrate on the content of the problem rather than on the tools. Developing the accessibility of the spatial data and discovering a way out for the problem of lacking skilled manpower in implementing GIS technology. Hence, improvements need to be made in the quality and quantity of data input for this system to assure that better geographical maps can be applied in the future so that definitive conclusions can be represented.

Acknowledgement

The authors would also like to thanks the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support as well as my supervisor, parents, siblings and friends.

References

[1] P. Folger, "Geospatial information and geographical information system (GIS): Current issues and future challenges," Congressional Research Science, vol 2, no. 1, pp. 1 – 30, June. 2009.

[2] E. C. N. Andersson, H. Nordh, R. J. Raanaas, and G. Aamodt, "GIS derived measures of the built environment determinants of mental health and activity participation in childhood and adolescence: A systematic review," Journal of Landscape and Urban Planning. vol. 177, pp. 19 – 37, 2018, doi:10.1016/j.landurbplan.2018.04.009.

[3] S. Saran, P. Singh, V. Kumar, and P. Chaulian, "Review of geospatial technology for infectious disease surveillance: Use case on Covid-19," Journal of the Indian Society of Remote Sensing. vol. 48, no. 8, pp. 1121 – 1138, 2020, doi:10.1007/s12524-020-01 140-5.

[4] M. Perumal, B. Velumani, A. Sahasivam, and K. Kamaswany, "Spatial data mining approaches for GIS – A brief review," Springer International Publishing Switzerland. vol. 338, no. 2, pp. 579 – 580, 2015, doi:10.1007/978-3-319-13731-5_63.

[5] E. C. Fradelos, L. V. Papathanasiou, D. Mitsi, K. Tsaras, C. F. Kleisiaris, and L. Kourkouta, "Health based geographical information systems (GIS) and their applications," Journal of Acta Inform Med. vol. 6, no. 1, pp. 402 – 405, 2014, doi:10.5455/aim.2014.22.402-405.

[6] K. Gharehbaghi and C. S. Young, GIS as a vital tool for environmental impact assessment and mitigation. Proc of International Conference on Renewable Energy and Environment, May 28, 2018, Melbourne. RMIT University, 2018.

[7] N. Clifford et al., Key methods in geography. 3rd ed. London: Sage Publications, 2016.

[8] N. T Shaw and S. K. Mcguire, "Understanding the use of geographical information systems (GISs) in health informatics research: A review," Journal of Innovation Health Informatics. vol. 24, no. 2, pp. 228 – 233, 2017, doi:10.14236/jhi. v24i2.940.

[9] P. V. Khandve and A. M. Mokadam, Application of GIS in Environmental Engineering. Proc of National Conference on Environment Pollution and Management, Jan 28-29, 2011, Aurangabad. College of Engineering, 2011.