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REVIEW ARTICLE - ENGINEERING (MISCELLANEOUS)

A Review of Sustaining Sanitation Services Approach

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Abstract

The service sector, including the sanitation service, currently occupies a prominent part of the economic and social development plans. The scale of development in this sector has become a criterion for measuring progress and development in various countries of the world. Infrastructure services management has been introduced in many countries of the world including some of the leading experts in this field to ensure the sustainable development of the sanitation sector. The aim of this study is to systematically review the literature on sanitation to provide an overview of how researchers approach problem-solving to achieve sustainability in sanitation services. It was also found that recent studies tend to use geographic information systems (GIS) to analyze sanitation services. Studies using GIS technology have provided maps that can be used as a decision support tool for governmental and non-governmental organizations to prioritize sanitation in underserved areas.

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1. Introduction

The term "infrastructure" is used to include all community services, whether the network located below or above the surface, including water and sanitation services, which are very important for modern societies [1]. Water and sanitation services remain unequal, unreliable, and insecure for a large proportion of the world's population, particularly in low- and middle-income countries [2-4]. Understanding the technical, economic, and social characteristics of the community is essential to community rehabilitation [5]. Several technical approaches to providing sustainable sanitation services have been studied in many countries [6-9]. These approaches offer a variety of sanitation options, including on-site sanitation systems with water-saving toilets, septic tanks, and Resource-Oriented Sewage Systems (ROS) [10-12]. Some studies also compare different sewage systems based on economic opinions [13, 14]. Social approaches to sustainable sanitation have also been considered in several studies [8][15-21]. Unfortunately, there are no studies that dealt with reviewing studies related to the use of modern technologies such as geographic information systems to evaluate sanitation services. Accordingly, this study was conducted with the aim of reviewing different techniques used in selected previous studies to assess sanitation services on a small scale by traditional methods as well as on a large-scale using satellite imagery and GIS. Table 1, showing many studies related to health services for different countries around the world, and the importance of using geographic information systems (GIS) using statistical tools and analysis, are listed.

2. The Importance of Basic Sanitation and its Relationship to GIS Technique Application

2.1. Basic sanitation

There are clear problems in basic sanitation services and their instability, and despite the diversity of measures taken to improve services to preserve the environment, the efforts made by stakeholders and the community are still insufficient to secure a safe life for residents in large parts of urban centers. There is progress in the physical institutions that support living conditions at the global level. Data show that 76% of the population used drinking water in 1990, and this percentage rose to 89% in 2012 (WHO 2014). Despite the improvement in the living conditions of billions of people around the world, geographic, social, cultural and economic disparities still exist and are increasing in some

Nomenclature & Symbols			
GIS	Geographic Information System	GPS	Global Positioning System
ROS	Resource-Oriented Sewage	Q GIS	Questions Geographic Information System
GPS	Global Positioning System	WaSH	Water-Sanitation-Hygiene
WHO	World Health Organization	AHP	Analytic Hierarchy Process
GNSS	Global Navigation Satellite System	LISA	Local Indicators of Spatial Association
LU\LC	Land Uses and Land Cover	FMECA	Failure Modes, Effects, and Criticality Analysis
WWTP	Wastewater Treatment Plants	DEA	Data Envelopment Analysis

cases (WHO 2014). Restriction of basic sanitation infrastructure harms economic development, as well as the natural environment and the quality of life of the population in many countries of the world, where there are people who are in direct contact with drinking water and do not have access to it. This problem presents great risks of disease and increases the demand for public hospital services and reduces the ability to work in the economy. Water supply, sewage and solid waste represent basic health variables that directly affect the quality of life of the population and are therefore of interest to society, politics and administration.

Table 1. A previous literature review of sanitation

Authors	Study area Country	Technique used	Results
Marcelo Carlos et al. (2022) [22]	(Brazil)	• GIS • Analytic Hierarchy Process (AHP).	After collecting and analyzing the data, it was seen that, according to the water shortage risk map, seven neighborhoods had a "Very high" risk, in which the criteria with the greatest weight were the Distance from distribution reservoirs, the main supply network and altimetry. The map of the degree of sanitary sewage insufficiency showed that four neighborhoods have a "Very high" degree; these neighborhoods are far from the main sewage network and from sewage treatment stations and have the lowest rates of households served by the system. Such characteristics need to be highlighted in the planning and implementation of water and sewage services. Thus, it is concluded that the use of high-resolution spatial databases for the planning of urban services, as carried out in the present work, provides a greater level of confidence for solutions that can be implemented in the expansion of service networks to the population.
Ankita, et al. (2022) [23]	(India)	• Water, Sanitation and Hygiene (WaSH) index, • SVMR models, • GIS	Conducted a study of spatial pattern synthesis of water, sanitation, and hygiene water sanitation and hygiene (WaSH) in rural India using an integrated interpretation of WASH practices. Multiple techniques were used in this study for the water and sanitation index, SVMR Models, and GIS. The findings show that the WaSH index may be used as a tracking device by nearby policymakers to reduce the WaSH gaps.
Ouma, et al. (2022) [24]	(Uganda)	• GIS • Multi-Criteria Evaluation • Suitability, Sensitivity Analysis, • Analytical Hierarchy Process (AHP)	Used GIS to position appropriate locations for water, sanitation, and hygiene facilities, in a case study of Busia Municipality in Busia District, Uganda. In this study, a geographic information system was used to demonstrate the appropriateness of the multi-criteria assessment, in particular the Analytical Hierarchy Process (AHP) in the study of sanitation services. The results showed that more than 60% of the city's population resided in these settlements, which had inadequate urban services and poor sanitation.
Nezar et al., (2022) [25]	(Jordan)	• (GIS). • Analytic, Hierarchy Process (AHP).	Mapped vulnerability hotspots to enhance sanitation service delivery in Jordan using the Analytical Hierarchy Process (AHP), which is one of the most important methods of multi-criteria decision-making (MCDM) based on GIS. The results showed that the areas most exposed to risks are those located in the northern governorates, which are classified as the most vulnerable areas, while the southern areas indicate a low need for sanitation services. This is even due to the small population of these areas or the availability of sanitation services.
Chaudhuri et al., (2020) [26]	(India)	• GIS • Spatial algorithms (Moran's I and LISA).	In this study, Evaluated water, sanitation, and hygiene infrastructure using a composite index, spatial algorithms, and suicide correlation in rural India. With the help of application of geographical information systems technique to spatial algorithms (Moran I and LISA) using more than one geospatial algorithm and statistical analysis the study tested the spatially correlated nature of WaSH. This study emphasized that coverage options should collectively address parameters.

Continue Table 1. A previous literature review of sanitation			
Mohamed et al, (2021) [27]	(Alger)	• The Failure Modes, Effects, and Criticality Analysis (FMECA). • The Analytical Hierarchy Process (AHP).	Use both failure-impact and criticality analysis (FMECA) methods and the analytical hierarchy process (AHP) to manage wastewater networks in Algeria. The results showed that the Oued Kniss community needs to rehabilitate the distribution of the required movements in line with the general structural performance of the studied community, in accordance with FMECA and AHP.
Larissa Guarany Ramalho Elias et al. (2021) [28]	(Brazil)	• GIS • Spatial algorithms (Moran's I and LISA).	The repetition of a pattern was noted, in which unfavorable rates were concentrated in the North and Jequitinhonha-Mucuri regions: water vulnerability, sewage system with collection and without treatment, total investment, average investment, per capita income and municipal human development index. Both also have low rates of sewage and water supply when compared to others. On the other hand, Zona da Mata and Triângulo regions have favorable rates for hydric vulnerability, sewage system with collection and without treatment and water supply. The Triângulo Mineiro region also presented favorable rates of total investment, average investment, per capita income, and municipal human development index. It is concluded that the inequality between the regions is, initially, of natural origin, and reinforced by the social context and inequality in sanitation investments in the different regions.
Edilberto & Mario (2020) [29]	(Brazil)	• GIS • Moran's, Global Index (Moran's I) • Local Indicators of Spatial Association (LISA) • Getis-Ord, GI*(d)	Studied the geographical distribution of basic sanitation services to households in Parana, Brazil by identifying temporal distributions, spatial patterns, and clusters using data from 2000, 2010, and 2016. Spatial variance in sanitation services for households receiving water supply, waste collection, and sewage treatments was measured using the Moran Global Index (Moran's I), while the Local Spatial Association Indicators (LISA) and Getis-Ord Gi*(d) were used to determine the presence of agglomerations and points hot potential in the percentage of households with sanitation. The results showed strong evidence that sanitation service rates were significantly lower than those of water supply and waste collection. The waste collection proved to have the highest service rate in the study area followed by the water supply service.
Seyed, et al. (2020) [30]	(Iran)	• Data Envelopment Analysis (DEA). • Geospatial Information System (GIS) and Analytic Hierarchy Process (AHP).	Assessed the failure risks of urban sewage pipelines in Iran using an integrated approach of geographical information system (GIS) Analytic hierarchy process (AHP), and digital elevation model (DEM). The results indicated that the sewer pipelines fit within the study space and among the 1605 sewage pipelines in the study area, only forty-eight (about 3%) required a rehabilitation program.
Nam, et al. (2019) [31]	(Korea)	• Geographic Information Systems (GIS). • Analytic Hierarchy Process (AHP).	Applied an Analytical Hierarchy Process (AHP) to evaluate sewage system assessment services in South Korea based on public opinions collected from experts in the field. The main criteria used in implementing this approach were management, operation, maintenance, service, environment, and finance. Using the expert survey built into the AHP method, the five criteria were prioritized, consisting of a total of 14 indicators and 34 checklists at three levels. Among the sets of criteria, operation and maintenance were found to be the most important indicator, making up 43% of all scores. The AHP results showed that the 34 checklists and 13 indicators were explained as candidates for key performance indicators (PIs), and these results were expected to be used by stakeholders involved in the provision of sewage services, such as undertaking companies, policy-making bodies, and financing agencies.
Shaharie, et al. (2019) [32]	(Bangladesh)	• GIS • Analytic Hierarchy Process (AHP). • SERVQUAL model.	This study presented a combined methodology for SERVQUAL and AHP to assess customer satisfaction in railway slums with respect to the sanitation service standard, which can be used as a powerful tool for impartial analysis within the urban area. The GIS results indicate that the sanitation service achieves an average level of satisfaction (58.5%) of the general expectations in the railway slums of Khulna city. This study introduced a combined methodology of SERVQUAL and AHP to live client satisfaction in railway slums regarding the standard of sanitation service which may be used as a robust tool for neutral analysis within the urban area. The results of GIS indicate that the sanitation service meets a moderate satisfaction level (58.5%) of public expectations in the railway slums of Khulna city. This combined methodology provides a crystal-clear plan of sanitation service quality during a less complicated method with no quantitative information demand which can be useful in applicable municipal service coming up with management.

Continue Table 1. A previous literature review of sanitation

Kaveh et al. (2017) [33]	(Australia)	•GIS-based statistical models.	Applied landscape epidemiology to assess potential public health risks due to poor sanitation in Australia using GIS-based statistical models. The study outcomes are expected to contribute to making an associate in-depth understanding of the link between illness prevalence and associated landscape factors for the delineation of disease risk zones within the context of knowledge paucity. The results show that of the total 14 criteria, operation and maintenance were found to be the most important indicators for successful performance in sanitary sewage systems. Indicators in environment and finance categories were considered as more important than management for the sustainability of sewage services.
Ntozini, et al (2015) [34]	(Zimbabwe)	• QGIS • Stata/SE software version 13 • GPS Global Positioning System • CyberTracker version 3.0	Used geographic information systems and spatial analysis methods to assess household water access and sanitation coverage in the SHINE Trial, Zimbabwe. Multiple technologies used in this study include QGIS, Stata/SE software version 13, Global Positioning System (GPS), and CyberTracker version 3.0. The results show that the determined high variability in water and sanitation access between clusters confirms that the SHINE approach of considering these factors throughout cluster organization is necessary to reduce the risk of bias. Linking the water-point data with SHINE participants can help understand the lack of uniformity in WASH practices and children's health outcomes. The most important previous studies conducted on sanitation services using GIS technology are summarized. The review of these studies showed the importance of GIS in improving sanitation services.

2.2. The importance of GIS in improving sanitation services

A GIS is an effective tool for managing, processing, and analyzing spatial data supporting the preparation and control of urban and regional planning when combined with spatial statistics techniques. GIS associated with basic sanitation services has been used in several studies, such as [35-38]. Risk factors and geolocation of areas with a high frequency of diseases, many of which are associated with a lack of basic sanitation, can be identified by using GIS and statistical techniques simultaneously. GIS has become a standard tool for collecting, managing and manipulating spatial data sets with the advent of low-cost, high-performance computing platforms. A number of worldwide researchers have developed several GIS framework techniques related to sanitation improvement for the purpose of sanitation mapping [29][35][39]. In recent years, the application of these technological tools in management, environmental planning, and sustainable development planning has expanded due to advances in geographic information systems (GIS), satellite navigation systems (GNSS), remote sensing, and multispectral and spatial sensors. The integration of these technologies enables their use as decision support tools for management and planning activities, including urban planning and environmental management.

3. Factors Affecting Sanitation Services

There are a number of indicators affecting sanitation services that play a dominant role in the stability and sustainability of sanitation services. The main categories are Water Resources, Land surface, Demography and population, and Sanitation (Fig. 1).

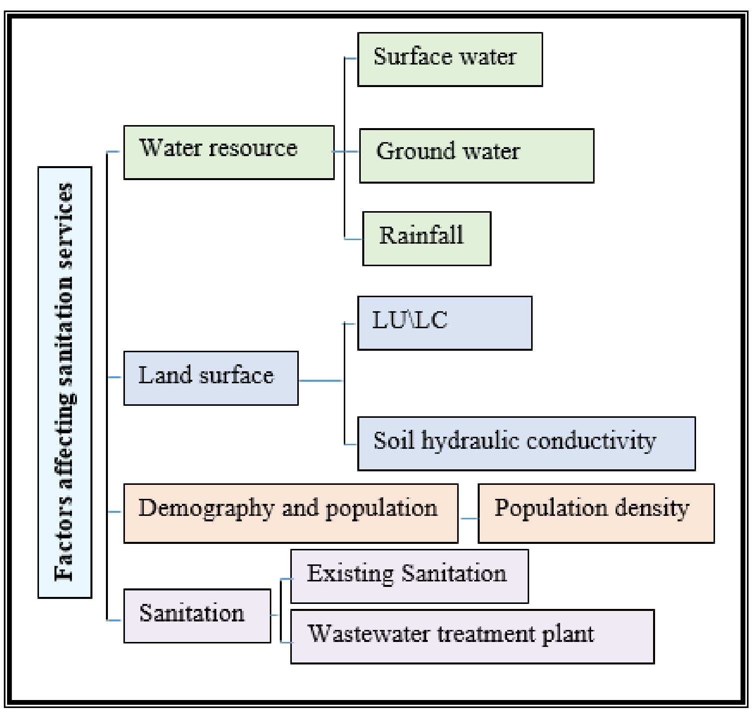

Fig. 1. Factors affecting sanitation services

3.1. Water resource

3.1.1. Surface water

It is one of the vital sources of drinking water in many areas that many people use without treatment, especially from tanks, which poses a threat to public health as it can be contaminated with domestic sewage water. Consequently, it must be taken into account in the study of sanitation.

3.1.2. Ground water

Exposing the foundations to groundwater leads to concrete erosion, especially if it is mixed with sewage containing acid, which accelerates the erosion process, and thus threatens the integrity of the building as a whole and weakens it, especially basins and old buildings or structures that have not used the necessary waterproofing techniques and materials for protection. Moisture is one of the most significant factors that have a negative impact on the strength of the facility and poses a significant safety hazard. The arrival of water in the concrete leads to corrosion or rusting of the steel reinforcement, which can result in cracking or collapse of parts of it and can cause malfunctions in the sewage pipes.

3.1.3. Rainfall

Precipitation is of great importance for immediate sanitation services because it is the main source of natural groundwater recharge, and it is necessary to protect it from pollution in areas where rainfall increases. Accordingly, the amount of rain must be taken into account in the early stages of studying the sanitation services.

3.2. Land surface factor

3.2.1. Land uses and land cover (LU\LC)

Land cover is defined as the biological materials present on the earth's surface, which are the most important characteristics of the earth system and may be natural or man-made, as they reflect the biophysical state of the earth's surface and the different layers of the earth [40]. The land cover is either natural represented by natural vegetation, water bodies, forests, soil, and rocks or man-made, represented by all the structures on the surface of the earth [41]. The application of remote sensing data can study changes in land cover at a low cost, with better accuracy, and in less time [42]. Land use is an important factor in planning and drawing the structure of cities, closely related to urbanization which includes residential, commercial, industrial, areas [43]. It is necessary to know the uses of land because it has a direct impact on sewage services, consequently when the area of residential land increases, the need for sewage services and their development increases.

3.2.2. Hydraulic conductivity of the soil

Soil permeability affects the sewage network, as water intrusion increases when it is high, and thus negatively affects sewage and concrete pipes, as well as on foundations, infrastructure, and the establishment of various constructions and projects, whether residential or service.

3.3. Demography and population

3.3.1. Population density

An increase in population means an increase in the need for infrastructure services, especially basic services, such as energy, drinking water and sanitation services. The effect of an increase in population is largely determined by the number of families rather than by the number of family members, although this does not contradict the fact that consumption levels are determined according to the total size of the population. Societies with population maturity are characterized by a relative decrease in family size and a relative increase in the number of families, which leads to an increase in the number of families per unit of population. In general, there is no direct relationship between the demand for infrastructure services and the size of the population [44].

3.4. Sanitation

3.4.1. Exciting sanitation

This parameter describes the adequacy of sanitation services among the country's neighborhoods. If a region includes network services, this suggests a safer sanitation system is in place; if an area has cesspits or doesn't have any form of sanitation, this means less safe sanitation is in place.

3.4.2. Wastewater treatment plants (WWTP)

Accordingly, the shorter the distance, the better it is in terms of less excavation depth, avoiding the emergence of more groundwater, dispensing with some lifting stations for raising the network level, and reducing cost and time. As for the distant areas, it causes obstacles and problems in terms of tide, depth and cost.

4. Conclusion

Sanitation is one of the most crucial environmental and sustainable demanding situations for growing nations and societies. Many studies related to sustaining sanitation services in global regions were reviewed in this research, and a set of conclusions were reached.

- Most of the studies used modern survey methods such as geographic information systems (GIS) and remote sensing.
- Countries with limited water resources need more investments in managing water resources and sanitation services.
- Water supply, sanitary sewage and solid waste represent the basic sanitation variables that have a direct impact on the quality-of-life standards for residents, and therefore are of interest to society, politicians, and general managers
- Several indicators that play a dominant role in sanitation services can be classified into three main categories, and each category includes several indicators.
- The main categories are water resources, land surface, demography, population, and sanitation. Water resource factors include springs, groundwater wells, precipitation, and water reservoirs.

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