LITERATURE SURVEY

ABSTRACT

With urbanization, rising income and consumption, the production of waste increases. One of the most important directions in the field of sustainable development is the design and implementation of monitoring and management systems for waste collection and removal. Smart waste management (SWM) involves for example collection and analytics of data from sensors on smart garbage bins (SGBs), management of waste trucks and urban infrastructure; planning and optimization of waste truck routes; etc. The purpose of this paper is to provide a comprehensive overview of the existing research in the field of systems, applications, and approaches vis-à-vis the collection and processing of solid waste in SWM systems. To achieve this objective, we performed a systematic literature review. This study consists of 173 primary studies selected for analysis and data extraction from the 3,732 initially retrieved studies from 5 databases. We

1) identified the main approaches and services that are applied in the city and SGB-level SWM systems,

2) listed sensors and actuators and analysed their application in various types of SWM systems,

3) listed the direct and indirect stakeholders of the SWM systems,

4) identified the types of data shared between the SWM systems and stakeholders, and

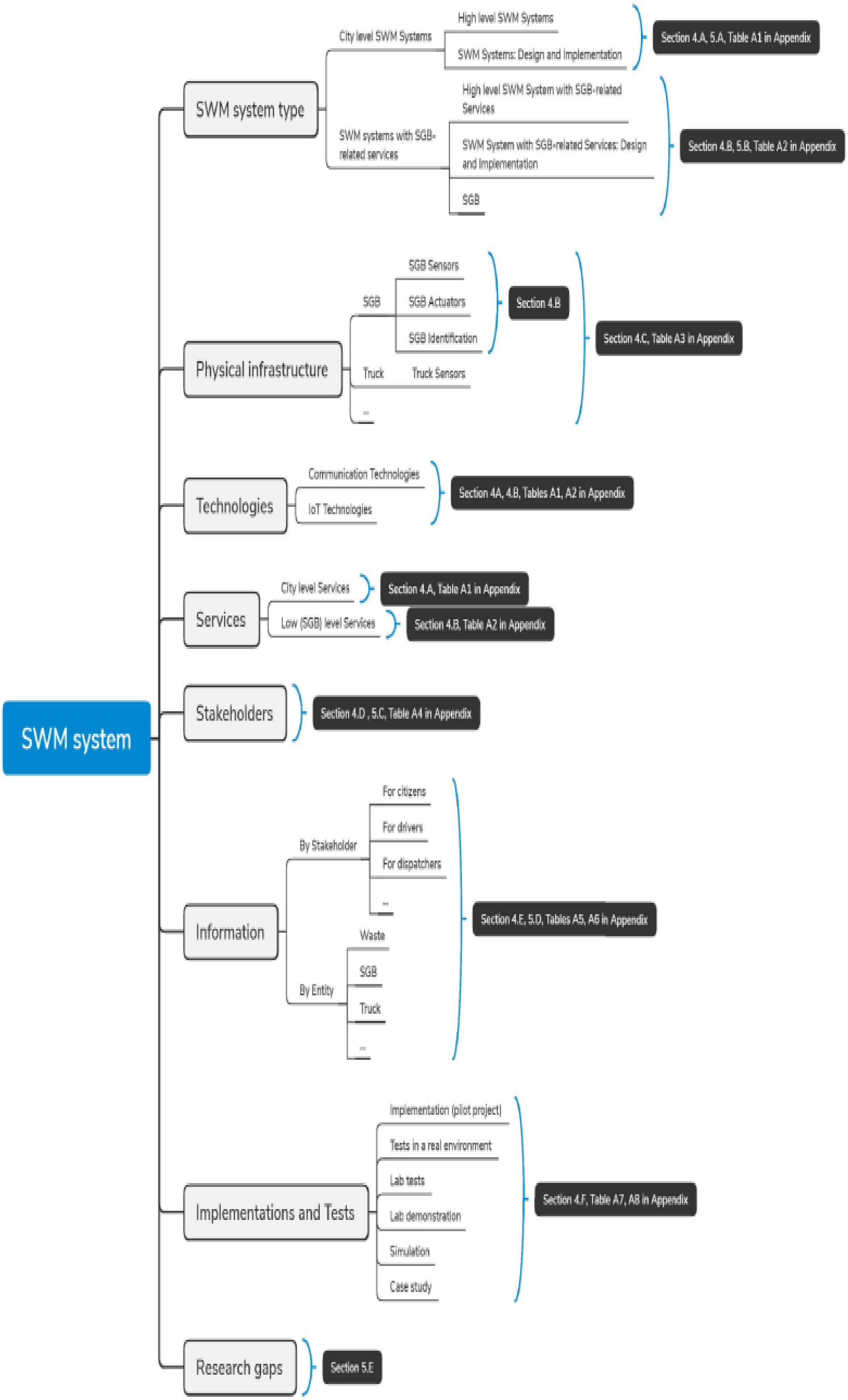
5) identified the main promising directions and research gaps in the field of SWM systems. Based on an analysis of the existing approaches, technologies, and services, we developed recommendations for the implementation of city-level and SGB-level SWM systems

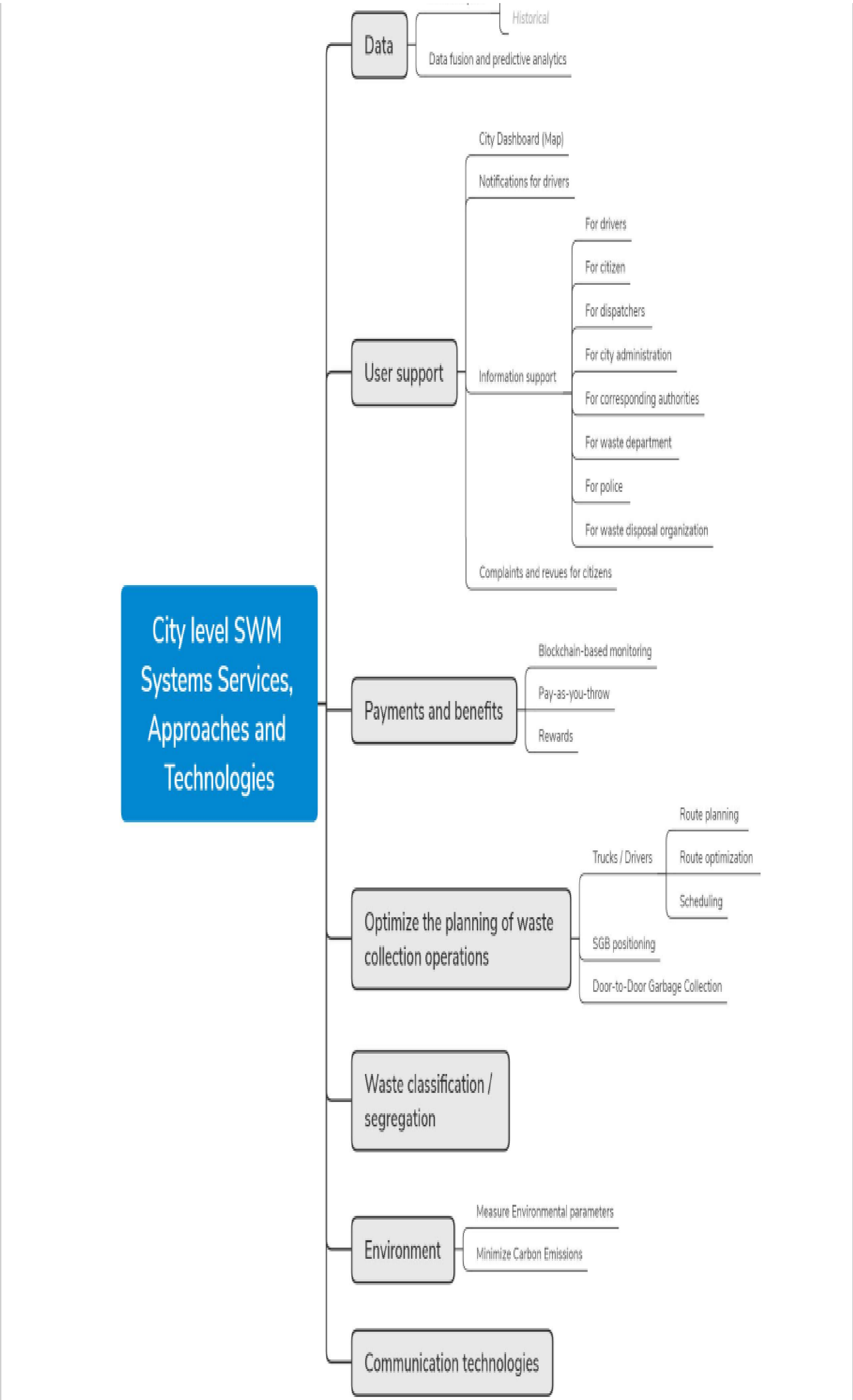
INTRODUCTION

According to one estimate,1 the world population is projected to reach 9.9 billion by 2050, an increase of more than 25% from the current 2020 population of 7.8 billion. With the growth of the world's population and the gradual relocation of a large number of people to cities, the concept of smart cities is becoming ever more relevant. A smart city is a concept that entails integrating a range of information and communication technologies, such as the Internet of Things (IoT), to manage public space and city services in a sustainable manner. Climate change and ensuing events, such as rising sea levels, flooding from changing river flows, and increased risk. One of the most important directions in the field of sustainable development is the design and implementation of monitoring and management systems for waste collection and removal. With urbanization, rising income and consumption, the pro duction of waste increases. According to estimates [2], [3], the amount of waste is expected to increase to 2.2 billion tons by 2025 worldwide. The effective organization of waste collection and processing is a necessary service and a challenging task for any large city. Therefore, smart waste management (SWM) can be seen as an essential part of a smart city, and it requires a com plex multi-criteria approach [4]. SWM involves collection and analytics of data from sensors on smart garbage bins (SGBs), garbage trucks and urban infrastructure; routes planning and optimization; information and decision support for users (drivers, dispatchers, citizens); waste classification and segregation; payments and benefits for citizens; monitoring of the ecological situation. The objective of this paper is to carry out a systematic analysis of the published research in the field of systems, applications, and approaches vis-à-vis the collection and processing of solid waste in SWM systems.

RELATED WORK

Several overviews of SWM systems and technologies have been provided by the researchers. Many studies are focused on city-level SWM systems services, approaches, and technologies. For example, [4] provides a structured overview and analysis city-level ser vices in SWM systems including concerns of architecture, DSS, GIS, dynamic scheduling, dynamic routing, social con text and experimental data. When analysing the systems considered in the article, the following characteristics are taken into account: physical infrastructure (SGB type and location, pneumatic pipes, fleet of trucks, depots, dumps, recycling, and processing), and software analytics (architecture, DSS, geographic information system (GIS), dynamic scheduling, dynamic routing, and social context). The focus of this review is on the energy-efficiency of IoT. It aims to present a wide range of models related to effective waste management. Special attention is given to garbage disposal. The authors see the need to define an efficient garbage collection model using IoT, which will relate to the inclusion of large-capacity garbage trucks as mobile warehouses, as well as to develop a model that allows to optimize the location of garbage bins for the maximum comfort of citizens. [6] reviews systems engineering approaches in the development of integrated solid-waste management for a smart city. Three systems engineering approaches—namely GIS, multi-criteria decision-making, and life-cycle analysis—to solid-waste management systems were reviewed. Based on the analysis authors concluded that systems should include a holistic, comprehensive, and interdisciplinary framework that combines technical, economic, and social components, stakeholders, and time frames. The use of ICT in solid-waste management increases the communication between different elements of the system and provides data for decision support and managerial activities. The authors in [7] provide a systematic review of ICTs and methods of operations research adopted in SWM, the processes of solid-waste management for which they were adopted, and which countries are investigating solutions for the management of solid waste in the 2010–2013 period. Devi provides a review of solid-waste management models in [8]. Nine waste management models are reviewed with the aim of finding out which existing model could be applied exclusively to Indonesia's transitioning villages through the lenses of sustainable urban planning by reviewing 10 existing models.


SWM system
SWM system type
City level SWM Systems
High level SWM Systems
SWM Systems: Design and Implementation
Section 4.A, 5.A, Table A1 in Appendix
SWM systems with SGB-related services
High level SWM System with SGB-related Services
SWM System with SGB-related Services: Design and Implementation
SGB
Section 4.B, 5.B, Table A2 in Appendix
Physical infrastructure
SGB
SGB Sensors
SGB Actuators
SGB Identification
Section 4.B
Truck
Truck Sensors
...
Section 4.C, Table A3 in Appendix
Technologies
Communication Technologies
IoT Technologies
Section 4A, 4.B, Tables A1, A2 in Appendix
Services
City level Services
Section 4.A, Table A1 in Appendix
Low (SGB) level Services
Section 4.B, Table A2 in Appendix
Stakeholders
Section 4.D , 5.C, Table A4 in Appendix
Information
By Stakeholder
For citizens
For drivers
For dispatchers
...
By Entity
Waste
SGB
Truck
...
Section 4.E, 5.D, Tables A5, A6 in Appendix
Implementations and Tests
Implementation (pilot project)
Tests in a real environment
Lab tests
Lab demonstration
Simulation
Case study
Section 4.F, Table A7, A8 in Appendix
Research gaps
Section 5.E



Historical
Data
Data fusion and predictive analytics
City Dashboard (Map)
Notifications for drivers
For drivers
For citizen
For dispatchers
For city administration
User support
Information support
For corresponding authorities
For waste department
For police
For waste disposal organization
Complaints and revues for citizens
City level SWM Systems Services, Approaches and Technologies
Blockchain-based monitoring
Pay-as-you-throw
Payments and benefits
Rewards
Route planning
Trucks / Drivers
Route optimization
Scheduling
Optimize the planning of waste collection operations
SGB positioning
Door-to-Door Garbage Collection
Waste classification / segregation
Measure Environmental parameters
Environment
Minimize Carbon Emissions
Communication technologies

CONCLUSION

In this paper, we conducted a systematic analysis of the published research in the field of systems, applications, and approaches vis-à-vis SWM systems. This study resulted in 173 primary studies selected for analysis and data extraction from the 3,732 articles that were initially retrieved. The following research directions were considered during the research:

1) city-level SWM systems,

2) SGBs and SWM systems with SGB-related services,

3) stakeholders in SWM systems, and

4) information shared between SWM systems and stakeholders. Additionally, we studied the

REFERENCES

[1] A. Arroub, B. Zahi, E. Sabir, and M. Sadik, ''A literature review on smart cities: Paradigms, opportunities and open problems,'' in Proc. Int. Conf. Wireless Netw. Mobile Commun. (WINCOM), Oct. 2016, pp. 180–186, doi: 10.1109/WINCOM.2016.7777211. hysical infrastructure of SWM systems and SWM system implementations.

[2] J. W. Levis, M. A. Barlaz, J. F. DeCarolis, and S. R. Ranjithan, ''A generalized multistage optimization modeling framework for life cycle assessment-based integrated solid waste management,'' Environ. Model. Softw., vol. 50, pp. 51–65, Dec. 2013, doi: 10.1016/j.envsoft.2013.08.007.

[3] S. E. Vergara and G. Tchobanoglous, ''Municipal solid waste and the environment: A global perspective,'' Annu. Rev. Environ. Resour., vol. 37, no. 1, pp. 277–309, Nov. 2012, doi: 10.1146/annurev-environ-050511-122532.

[4] T. Anagnostopoulos, A. Zaslavsky, K. Kolomvatsos, A. Medvedev, P. Amirian, J. Morley, and S. Hadjieftymiades, ''Challenges and opportu nities of waste management in IoT-enabled smart cities: A survey,'' IEEE Trans. Sustain. Comput., vol. 2, no. 3, pp. 275–289, Jul. 2017.

[5] T. Anagnostopoulos, A. Zaslavsky, I. Sosunova, P. Fedchenkov, A. Medvedev, K. Ntalianis, C. Skourlas, A. Rybin, and S. Khoruznikov, ''A stochastic multi-agent system for Internet of Things-enabled waste management in smart cities,'' Waste Manage. Res., J. Sustain. Cir cular Economy, vol. 36, no. 11, pp. 1113–1121, Nov. 2018, doi: 10.1177/0734242X1878384