Intelligent mobility management system (IMMS): Scoping review

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Abstract

Smart mobility is one of the essential aspects of smart cities, and the proper management of intelligent mobility can create an optimized and sustainable smart city. For these reasons, the field of intelligent transport remains a sector that attracts research attention, and hence there is a need for a scoping review on this topic. This paper presents a scoping review of intelligent mobility management systems (IMMSs) with the aim of clarifying and summarizing the status of relevant articles dealing with this topic.

In this paper, we describe and apply the process of a scoping review as proposed by Peterson to the topic of IMMSs, based on a research method previously applied in the field of medicine. A total of 266 relevant articles were selected, and a classification framework was applied to extract the information needed to carry out an in-depth analysis of IMMSs. This analysis gave us a clear vision of the subject and produced a new state of the art. The novel contributions of our work are as follows:

1. We introduce a general framework for classifying information from studies in this area;
2. We present a summary of current research on the subject;
3. We discuss our results and their implications for future research.

This scoping review provided us with a general overview of the topic of IMMSs and helped us identify gaps and trends in this field. One of the conclusions that can be drawn from this scoping review is that this is an active research area that is attracting attention from researchers, with many open issues still to be addressed.

Keywords
IMMS, Mobility management, IoT, Systematic mapping study, Smart city.

1. Introduction
Following recent technological developments and rapid urbanization, a new paradigm has been developed that aims to meet the requirements of these new cities. This paradigm is known as the 'smart city'. A city is considered smart if it has adopted the following characteristics: a smart economy, smart people, smart governance, smart living, a smart environment and smart mobility (Giffinger et al. 2007). The aim of smart mobility is to meet the transportation requirements of city dwellers and to offer a quality transportation service by exploiting information and communication technology (ICT) (Fernández-Ares et al. 2017; Ma et al. 2017; Zhong et al. 2015). Hence, the use of mobility management solutions (conventional or smart) will contribute to smart city management and optimize the use of resources (fuel, modes of transportation, etc.).
In order to propose a reliable and relevant IMMS, it is necessary to have a general overview of the subject, and to identify the gaps and trends in this area, the equipment and technologies employed, etc. The best approach to understanding IMMSs is a scoping review, which will allow us to identify, analyze and classify documents that deal with the topic of IMMSs. To carry out a scoping review (also known as a systematic mapping study), we followed the methodology defined in the guidelines for conducting scoping reviews in the field of software engineering (Petersen et al. 2008; Petersen et al. 2015). The primary studies to be used in this scoping review were drawn from two databases, Scopus and IEEE Xplore. The total number of these studies reached 30,580 in the initial selection phase, which was reduced to 266 after applying a set of inclusion and exclusion criteria.
The main contributions of this paper are as follows: (i) a classification of research in the field of IMMSs; (ii) a summary of the materials and technologies used in IMMSs; (iii) a review of the trends in terms of document types, application areas, and research types; and (iv) a review of publication trends based on country and year.
The remainder of this document is organized as follows: Section 2 introduces the research method used in this study, Section 3 provides the results of the study, Section 4 discusses the results, and Section 5 presents the conclusion to this scoping review.

2. Methodology

2.1 Research questions and research objective
The main objective of this paper was to understand the subject of IMMSs as a whole by answering the following question:

What methods have been used by researchers for the development of smart mobility systems, and how have these methods been applied?

This question was divided into six research sub-questions as presented below, following the guidelines proposed by Peterson et al. (2008; 2015; Kitchenham and Charters 2007).

- RQ1: What methods and techniques are used in IMMSs?
- RQ2: What are the annual trends in the produced papers?
- RQ3: How are papers distributed across countries?
- RQ4: In which areas are IMMSs most often applied?
- RQ5: Which publication channels are the main target for research on IMMSs?
- RQ6: What types of studies are being conducted on IMMSs?

2.2 Research process and data sources
2.2.1 Search string
In order to select the primary studies, we chose two scientific databases, Scopus and IEEE Xplore, as shown in Table 1. These databases are recognized for their scientific reputations and the quality of the studies included, which makes them reliable channels for carrying out systematic literature reviews in the field of software engineering (Petersen et al. 2008; Petersen et al. 2015).

Table 1: Database sites

	Database name	Link
1	SCOPUS	https://www.scopus.com/
2	IEEE Xplore	http://ieeexplore.ieee.org/

PICOC is a framework that allows the user to formulate an efficient search string that can find adequate numbers of primary studies (Kaiwartya et al. 2016).

- **Population:** Published scientific literature dealing with IMMSs.
- **Intervention:** Studies involving the use of IMMS.
- **Comparator:** N/A.
- **Output:** Classification methods found from the selected studies.
- **Context:** Adoption of an IMMS.

Based on the PICOC structure and using the logical operators (AND) and (OR) to link the elements of the PICOC structure, a search string was generated as follows:

(Intelligent OR Smart) AND (Mobility OR Transportation) AND Management AND (System OR Software OR Application)

2.2.2 Paper filtering process

The inclusion and exclusion criteria were applied to all of the primary studies to extract only the relevant ones in order to answer the RQs. Table 2 summarizes the inclusion and exclusion criteria that were applied.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	
IC1	Documents in the form of a scientific journal paper, book or book chapter
IC2	Documents consisting of full papers
IC3	Documents published within the last five years
IC4	Documents dealing with IMMSs
Exclusion criteria	
EC1	Documents in languages other than English
EC2	Duplicate works
EC3	Papers published outside the time frame [2017-2021]
EC4	Documents that were not open access papers

Figure 1 illustrates the stages applied to filter documents and the evolution of the number of papers.

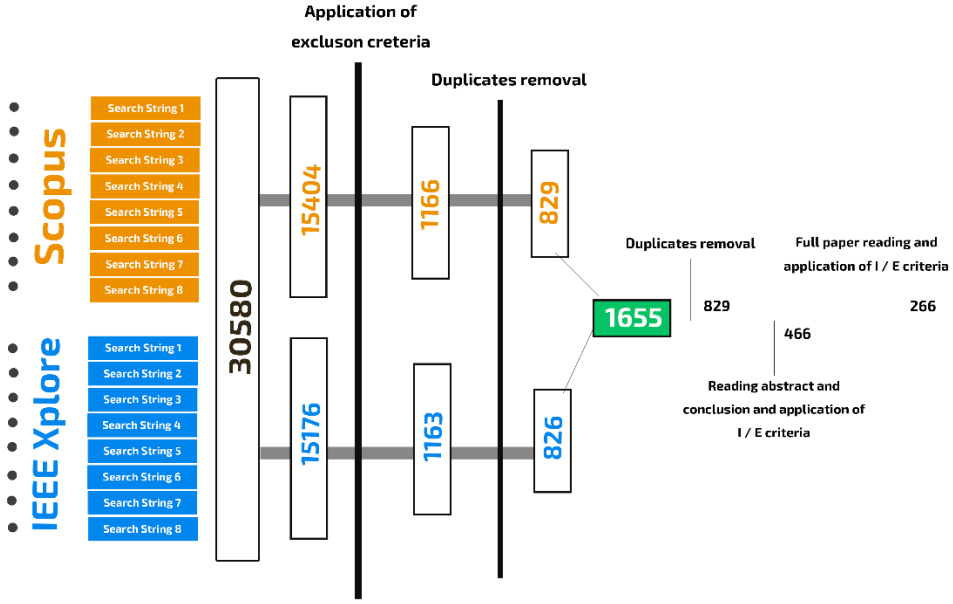

Figure 1: Steps used to filter papers

3. Results

The aim of this work is to analyze and review the collected data related to IMMSs. The results of these studies are described below.

RQ1: What methods and techniques are used for IMMSs?
In this section, 'methods and techniques' refers to the use of materials and technologies. According to the collected data, many materials and technologies have been applied in IMMSs. Artificial intelligence (AI) was the most widely used (102/217, i.e., 47%), followed by GPS (17/217, i.e., 7.83%), and then IoT technologies (16/217 i.e., 7.37%). The dominance of AI depends on the intelligence skills offered to the different solutions. GPS and IoT were among the most requested solutions due to the number of connected objects.

RQ 2: What are the annual trends in the produced papers?
For this article, we studied papers published between 2017 and 2021. The range of data was reduced so that we could consider only recent papers that reflect technological progress.
As shown in Figure 2, 2019 and 2020 showed a great increase in interest in IMMSs (2019 produced 82/266 papers, while in 2020, this rose to 105/266 papers). In 2021, the frequency of publications associated with IMMSs was reduced (46/266 papers) compared to the previous two years. It should be noted that our scoping review started at the beginning of December 2021.

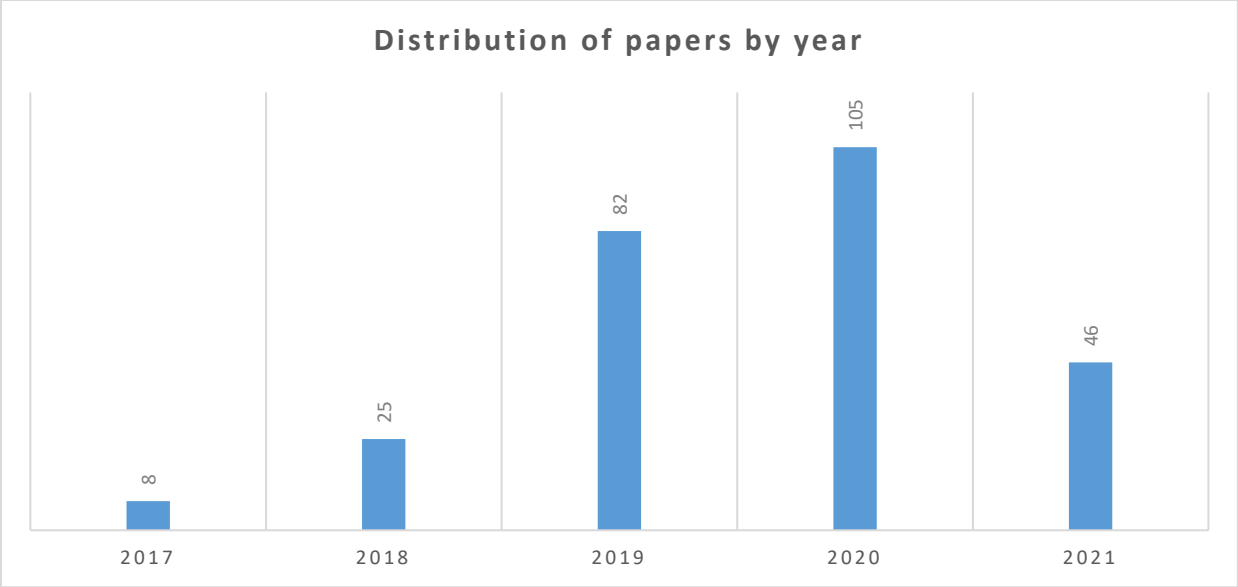

Figure 2: Annual trends in the production of papers

RQ 3: How are papers distributed across countries?
To identify the countries that have made the most contributions to the subject of IMMSs, we relied on information on the laboratory and the university to which the authors belonged. As shown in Figure 3, China and USA were the predominant countries in terms of scientific contributions to the subject of IMMSs (China with 175/266 papers and the USA with 39/266 papers), followed by South Korea (16/266 papers) and Pakistan (13/266 papers).

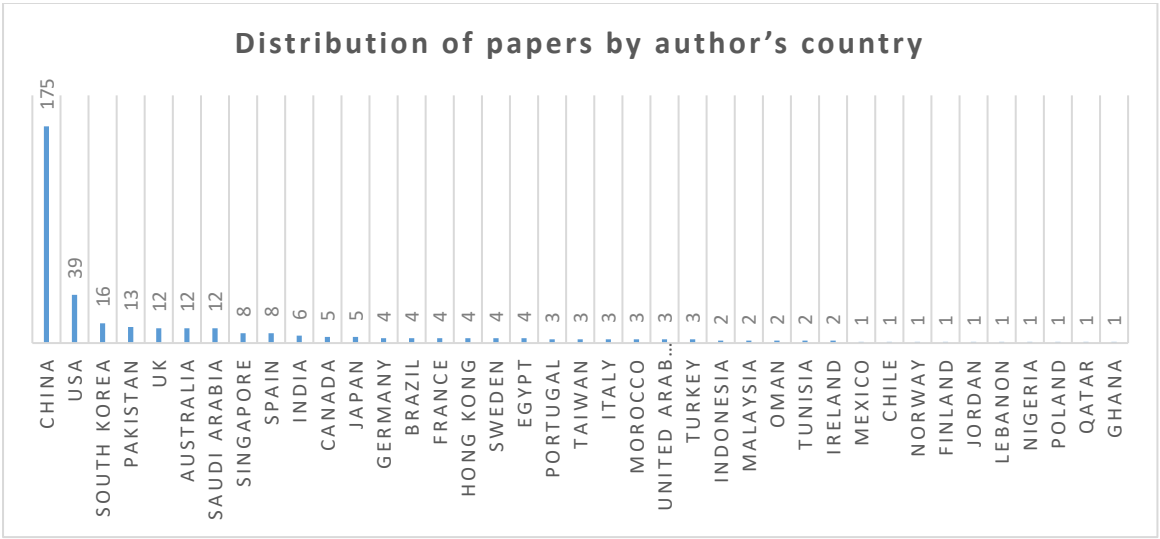

Figure 3: Distribution of papers by author's country

RQ 4: In which areas are IMMSs most often applied?
In general, the areas of application of IMMSs can be grouped into road, rail, maritime and air transportation. A fifth area was identified under the term 'mobility', since during our review of the papers, we found an intersection between

the above areas (e.g., between road and rail). According to the results, IMMSs have been applied most frequently to road transportation during the last three years (207/266), followed by rail transportation (32/266).

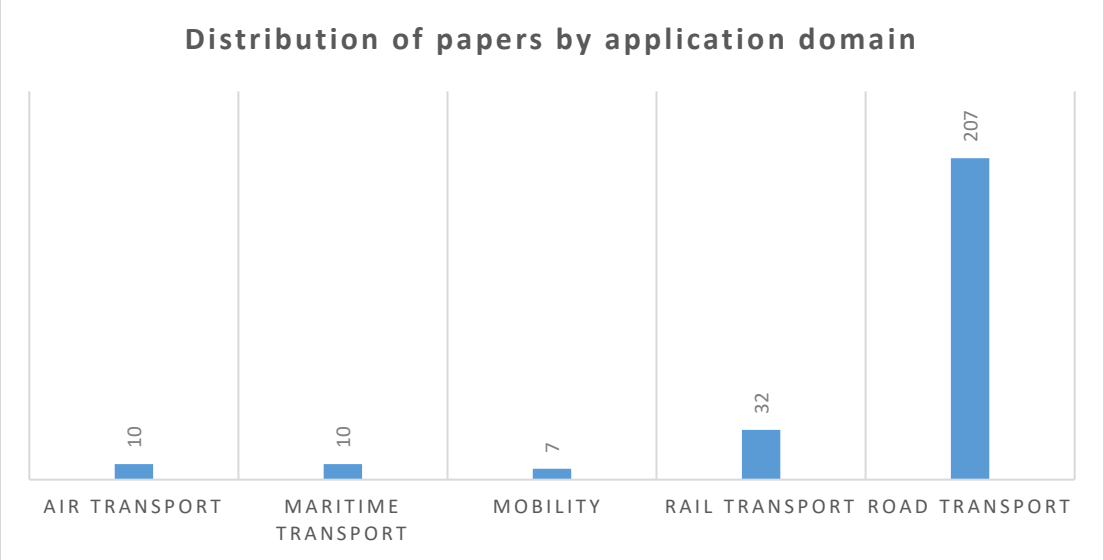

Figure 4: Domains of application

RQ 5: Which publication channels are the main target of research on IMMSs?
As illustrated in Figure 5, the most dominant type of document was journal papers.

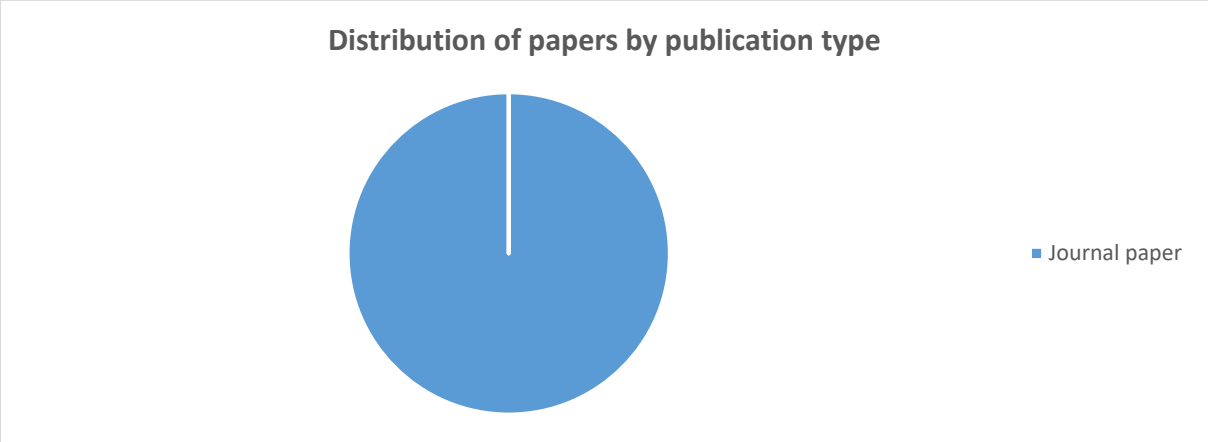

Figure 5: Types of publication

RQ 6: What types of studies are being conducted on IMMSs?
Numerous scientific papers have discussed IMMSs. The classification taxonomy proposed by Wieringa et al. (2006) was used to classify the selected papers, and the results showed that solution proposals were the most dominant type of publication (249/266 papers), followed by evaluation research (7/266 papers), synthesis papers (5/266 papers), experience papers (3/266 papers) and finally philosophical papers (2/266 papers). These results indicate that the topic of IMMSs is an active one that is attracting attention from researchers and that there are still problems to solve in this field.

4. Discussion

In this section, we present an analysis of our results and the main conclusions of this scoping review.

4.1 Methods and techniques

According to our results, AI was the most widely used technology (102/217), followed by GPS (17/217) and IoT (16/217). The use of AI, GPS, and IoT in IMMSs can be explained by the desire to improve the transport sector and to make it intelligent (via AI) and to achieve autonomy and high communication (provided by IoT and GPS), and hence to achieve the transformation of traditional cities into smart cities.

4.2 Annual trends in publications

For this paper, we studied articles published between 2017 and 2021. The two years of 2019 and 2020 produced large numbers of publications (82/266 and 105/266) compared to the others, while in 2021, 46/266 publications were produced. The number of publications appearing between 2019 and 2020 was due to the emergence of COVID-19, which prompted researchers to publish more articles on IMMSs to improve and facilitate transportation. Regarding the number of contributions for the year 2021, we note that we began this study in 2021.

4.3 Trends in authors' countries

In order to determine which countries made more contributions to the field of IMMSs, we based our information on the institutions to which the authors belonged. As Figure 5 shows, China and USA made more contributions (175/266 papers for China and 39/266 for the USA). These rankings may be due to the economic power of these countries and the rate of investment in R&D. The USA is the world's highest investor in R&D, followed by China (Khan et al. 2020; Sargent and John 2021).

4.4. Application domain

Figure 4 shows that the field of road transportation had more contributions (207/266 papers) than rail transportation and other domains. This can be explained by the difficulties and transportation problems that disrupted the world during the COVID-19 pandemic; these encouraged researchers to focus more closely on road transport, since it was the only form that remained operational, albeit with certain precautions to avoid the spread of the epidemic.

4.5. Publication channels

Reaching a trade-off between "existing research coverage on a topic" and "a manageable range of studies to examine" represents the key to the success of any systematic study (Haibi et al. 2022). To achieve this objective, we limited our search to open access documents; this decision was made due to the very high number of studies found during the first screening, and also the accessibility to data offered by this type of research document. In addition, there has been a shift from hard copies to electronic copies, which has greatly increased the accessibility of published studies, and especially open access publications (Drissi et al. 2020). The results for this research question indicate that the dominant publication channel was journal papers. A set of ethics and rules frame the process of publication in a rigorous scientific journal, resulting in the production of high-quality research content (Drissi et al. 2020). This may justify the high numbers of this type of document.

4.6. Types of studies

We obtained the following results: solution proposal (249/266 papers), followed by evaluation research (7/266), experience papers (3/266), and synthesis papers (2/266). The explanation for the number of solution proposal publications being greater than the other types of publication may be that the field of IMMSs is not yet a mature domain. Our scoping review shows that most authors have proposed methods and solutions that have not yet been empirically validated, suggesting that future work should focus on validating these methods.

5. Conclusion

This paper has presented a scoping review of IMMSs, and has provided a general overview of the topic with its trends and gaps. The number of evaluated papers was 266, all of which were published between 2017 and 2021 in recognized databases (IEEE Xplore and Scopus). We obtained the following results, which may clarify the outlook of researchers wanting to work on IMMSs. The methods most commonly applied to this topic were AI, IoT, and GPS. The use of these techniques may be explained by the very high numbers of connected devices and the aim of creating an intelligent world. The year 2020 saw a large number of scientific contributions to the subject of IMMSs. In the period between 2017 and 2021, China and USA were the countries with the highest interest in this topic. This result is likely to be due to the R&D investment rates of these countries. Although there are several application areas associated with IMMSs, road transportation was predominant during the period studied, and the main contribution was mobility management.

For the publication channels and types of studies, we obtained the following results: 100% of the documents were journal papers, and solution proposals made up 249 of the 266 papers, representing 93.6% of the studies.

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Biographies

Sohaib Chengaou received his bachelor's degree in Net Businesses from the Polydisciplinary Faculty of Tetouan - Abdelmalek Essaâdi University, Morocco in 2015 and subsequently he obtained his Master's degree in Computer Networks and Embedded Systems from the Faculty of Sciences of Meknes in 2017, Moulay Ismail University, Morocco. He is currently a PhD student in Computer Science at Moulay Ismail University (UMI). His main research interests are transport intelligence, Real-time systems, medication domain (with an application in hospital field) and the Internet of Things.

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