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Healthcare 4.0: Trends, Challenges and Benefits

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Full Paper

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Abstract

The Fourth Industry Revolution, known as Industry 4.0, refers to the forces that are transforming industry, including the healthcare industry, where it has been termed Healthcare 4.0. Though lagging other industries in the adoption of new innovative technologies, the healthcare industry is embracing the potential benefits that arise from new innovative technologies. New trends revealed both in the academic literature and by industry practice show that researchers and practitioners are becoming more aware of the benefits technology can bring to an industry as complex as the healthcare industry. The object of the study is to identify the challenges, trends and gaps in the existing body of research with regard to Healthcare 4.0. In this study, a systematic literature review on Healthcare 4.0 research papers was conducted to identify trends, challenges and the perceived benefits that may arise from it. This paper found that there is a need to conduct more empirical studies in this area. It, further, identified the need to implement practical procedures in the industry to get feedback from patients and healthcare participants in order to promote the adoption of new Healthcare 4.0 technologies.

Keywords: Health 4.0, Industry 4.0, healthcare

1 INTRODUCTION

Industry 4.0 is changing all segments of the industry (Pang et al. 2018). Starting mainly with a focus on the manufacturing sector, it is now affecting other industries, such as healthcare, where it has been called Healthcare 4.0 (Chung and Kim 2016). The research was conducted using a systematic literature review of healthcare research articles to identify the trends, challenges, and perceived benefits in Healthcare 4.0.

The healthcare industry has already experienced several waves of technological change, starting with Healthcare 1.0, where doctors kept patient records manually (Hathaliya et al. 2019). Healthcare 2.0 followed, where paper-based manual records were replaced by electronic record (Hathaliya et al. 2019). Healthcare 3.0 advanced to the point where wearable devices were introduced (Hathaliya et al. 2019). The key technological characteristic that individuates Healthcare 4.0 from its predecessors is that a large number of devices of varying types communicate with each other (a) to monitor a patient's health and (b) to conduct other health-related activities driven by Internet of Things (IoT) , Cyber-physical Systems (CPS) and Internet of Services (Chung and Kim 2016). Pang et al. (2018) defines Healthcare 4.0 as a combined application of IOT, artificial intelligence, robotic, and intelligent sensing in healthcare in order to transform its value chain. It aims at digitising healthcare enterprise and services. Therefore, in this paper we aim to highlight the implication of this technology for the practice and delivery of healthcare services.

2 METHODOLOGY

This paper follows the six step approach of Mathiassen et al. (2004) for conducting a systematic literature review. Firstly, four academic databases, Scopus, Science Direct, PubMed and Web of Science were selected, and then two search categories were used to search them. One focusing on Health and related terms, such as 'Healthcare OR Clinics OR Hospitals OR Pharmacy; and the other focusing on Industry 4.0 concepts, such as Industry 4.0 OR Healthcare 4.0 OR Care 4.0. Then, after having scanned each article's title and abstract, the researchers chose a data set of relevant for a full text review. Then, other relevant articles selected from the reference list of chosen articles in pervious step.

The search covered papers published in English to July 2019, which were then filtered according to steps: (1) duplicates were removed; (2) books, book chapters, and conference papers were either removed or filtered based on their abstract and title; and (3) all the remaining papers were read in detail to identify those papers which focused on Health 4.0. The research process flow is shown in Figure 1.

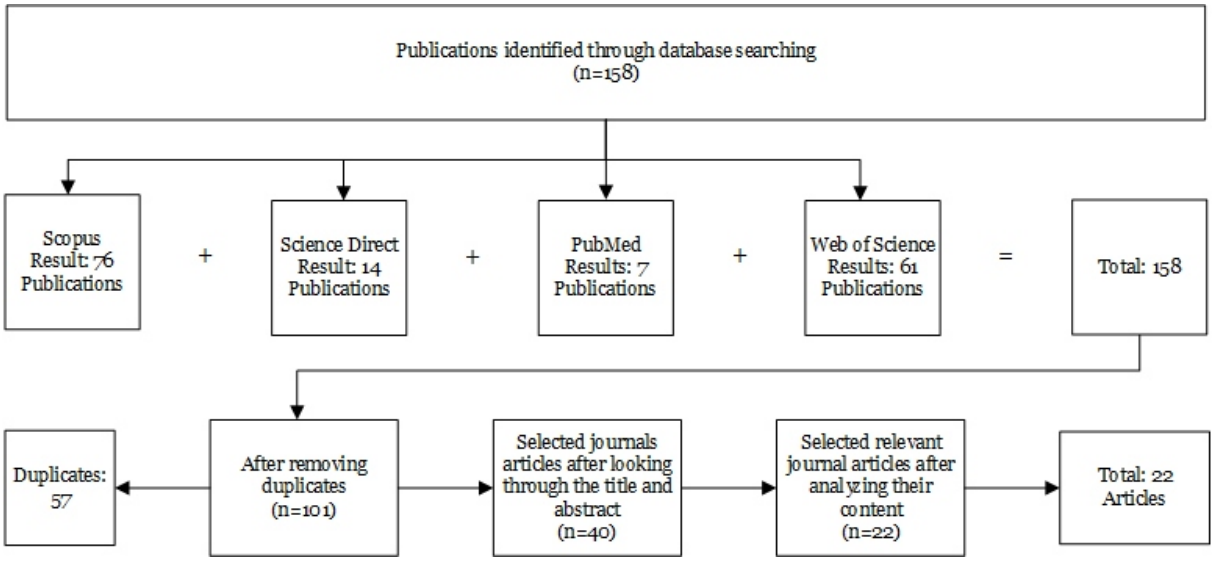

Figure 1. Workflow of the systematic literature review

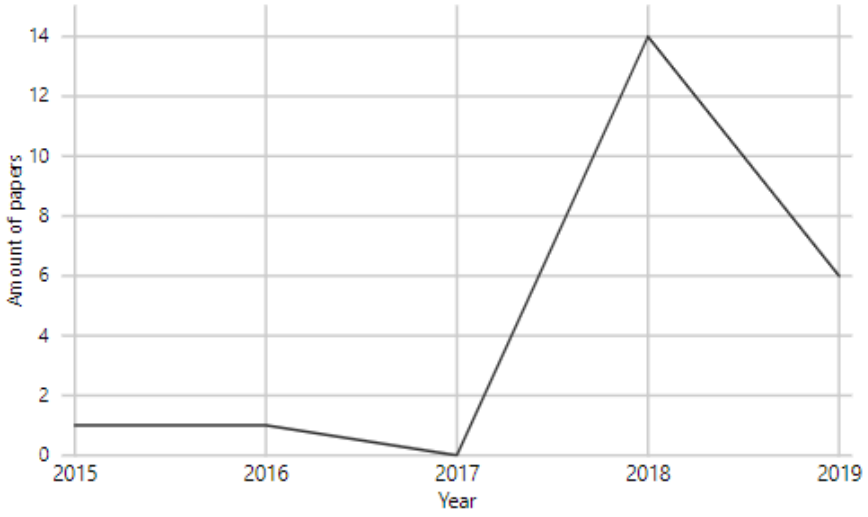

Figure 2. The number of selected articles published per year

Figure 2 shows that the selected papers were published either in 2018 or, to a lesser extent, in 2019. The clear implications to be drawn are that this area of research area is relatively new in that most of the work has been conducted in recent years, and that there is room for future research in the area.

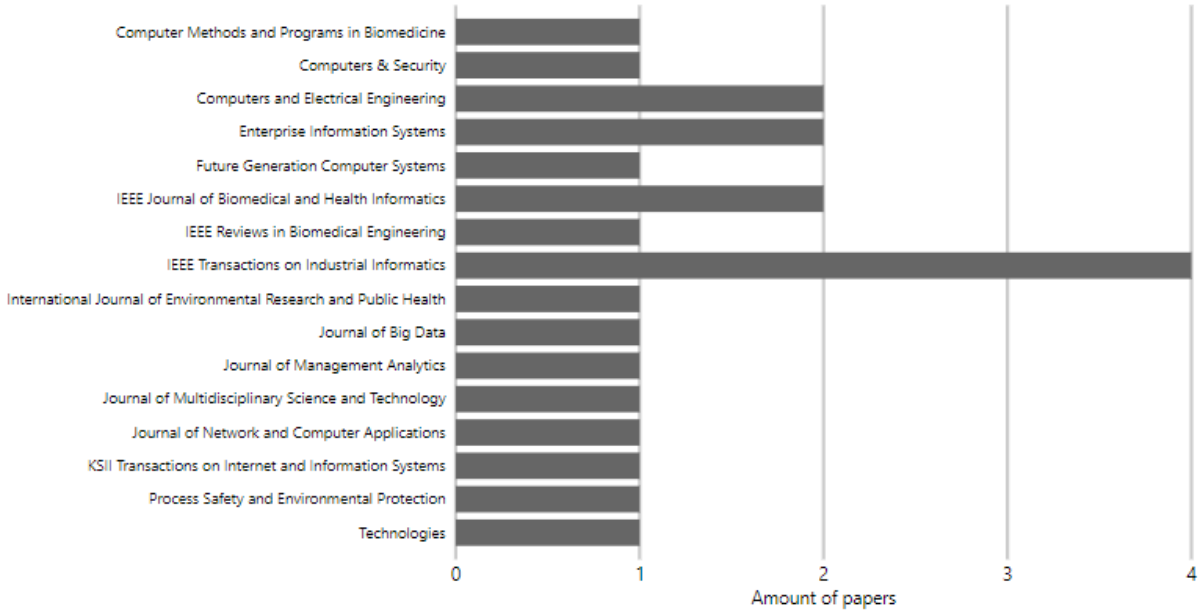

Figure 3. Journals with most of the selected publications from in the literature review

The Figure 3 shows the journals from which most of the papers were selected. IEEE Transactions of Industrial Informatics published the most article, four in total, followed by Computers and Electrical Engineering, IEEE Journal of Biomedical and Health Informatics and Enterprise Information Systems, each with two 2 papers. Measured by publications in other journals, some other fields of study may be less well represented, which may indicate that more work needs to be done in the areas for which those journals are known to specialise.

3 RESULTS

This section reports on the findings from a systematic literature review outlining the barriers, trends and perceived benefits of Healthcare 4.0.

After examination of the literature, fifteen barriers and challenges were identified for Healthcare 4.0 which are set out in Table 1, along with the articles relevant to them.

A total of six paper found that main barrier was security and privacy, with three finding that this barrier was one of the critical challenges in healthcare, namely (Hathaliya et al. 2019; Kumari et al. 2018; Pace et al. 2019). A significant contributing factor for this finding may be the high volume of data produced by IoT devices in healthcare (Kumari et al. 2018). Also, of relevance was that healthcare systems require collaboration between various stakeholders who operate within them, which necessitates for more and tighter security and privacy measures (Pang et al. 2018). Not surprisingly, a number of studies proposed ways to redress these issues, some of which are noted later in the section.

Another significant barrier/challenge identified was interoperability, which arose in four papers. Interoperability was described as important for ensuring that the devices in use by the stakeholders can be inter-connected without the issue of their compatibility arising (Branger and Pang 2015). The lack of interoperability in particular was singled out as a challenge for system designers, given the increased complexity of healthcare systems in their totality (Cui et al. 2018).

All the barriers/challenges noted need to be properly addressed to promote the adoption of Health 4.0 systems and technologies.

Barrier/Challenges	**Literature Sources**
Time constraints or delay	(Dautov et al. 2019; Elhoseny et al. 2018)
An increased (Big Data) workload	(Bhatti et al. 2019; Dautov et al. 2019)
Higher renting cost of cloud services	(Dautov et al. 2019)
Unnecessary computational and network workload	(Dautov et al. 2019; Elhoseny et al. 2018)
Increasing number of heterogeneous data sources	(Cui et al. 2018; Dautov et al. 2019)
Lack of quality data	(Mavrogiorgou et al. 2019)
Network limitation	(Dautov et al. 2019)
Security and privacy	(Beltran 2018; Branger and Pang 2015; Hathaliya et al. 2019; Kumari et al. 2018; Pace et al. 2019; Pang et al. 2018)
Feasibility	(Pace et al. 2019)
Scalability	(Cui et al. 2018; Kumari et al. 2018)
Interoperability	(Branger and Pang 2015; Chute and French 2019; Cui et al. 2018; Kumari et al. 2018)
Legal	(Pang et al. 2018)
Managerial issue	(Pang et al. 2018)
Standardisation	(Beltran 2018; Branger and Pang 2015)
Rapidly changing demands	(Wan et al. 2019)

Table 1. Barriers and Challenges identified in the literature

The central themes identified in Healthcare 4.0 are set out in tabular form in Table 2. Many papers took a technical approach and presented suggested architectures to address the needs of Healthcare 4.0, insofar as they from other industries (Dautov et al. 2019; Kumari et al. 2018; Pace et al. 2019). Edge computing and Fog computing were architectures proposed to address several key issues, including security (Pace et al. 2019). Approaching the problem from a different tack, some papers suggested that security issues could be addressed by developing new mechanisms (Beltran 2018; Hathaliya et al. 2019; Roy et al. 2019). Some papers suggested systems or tools to improve diagnosis, patient care and experience (Camgoz-Akdag et al. 2018; Donati et al. 2019). There was evidence that progress was being made in the area of Telemedicine to cater the elderly, as the population itself ages (Chen et al. 2018) .

Journal	Theme	Contribution	Advantages/ Perceived Benefits
(Dautov et al. 2019)	Developed a distributed data fusion architecture using edge computing	Architecture	Greater latency, faster decision time, flexible
(Pace et al. 2019)	Developed an architecture to cater to multiple devices and radios in healthcare domain	Architecture	Reduced communication delay, scalable and responsive, improved privacy, reduction in network load
(Roy et al. 2019)	Developed a scheme to secure Fine-Grained Data Access Control over multiple cloud servers in the healthcare environment in a mobile cloud computing application	Scheme	More secure, first to use fine-grained data access control over multiple cloud servers in a mobile cloud computing environment.
(Kumari et al. 2018)	Developed a patient driven architecture specific to healthcare 4.0 environment	Architecture	Low latency, real-time response, increase in efficiency of bandwidth
(Elhoseny et al. 2018)	New model for Cloud-IoT healthcare applications	Architecture	Higher efficiency
(Hathaliya et al. 2019)	Proposes a secure biometric-based scheme keeping in mind healthcare 4.0	Scheme	Less computation cost and communication cost
(Beltran 2018)	Proposes a federated and token based IAM mechanism	Mechanism	Interoperable, efficient, secure, flexible
(Donati et al. 2019)	Proposes a telemedicine system to cater to chronic patients	Architecture	Improves quality of life of the patient, reduces hospitalisation rate
(Camgoz-Akdag et al. 2018)	The study used value steam mapping to improve processes in the radiology department. The solution took help from industry 4.0 technologies	Tool	Reduces queue time, efficient, timely service
(Bhatti et al. 2019)	The study proposes a tool to identify disease patterns and help identify in deciding medication and treatment based on data	Algorithm, Tool	Aids in decision-making regarding medication and treatment, identifies disease trends, monitors medicine, stock availability
(Wan et al. 2019)	The study proposes a new architecture to ensure the pharmaceutical process meets the needs of healthcare industry	Architecture	Flexible, agile, robust
(Mavrogiorgou et al. 2019)	The study proposes a mechanism to access the quality of data from various heterogeneous sources.	Mechanism	Identifies data source, access quality of data
(Caggianese et al. 2019)	The study proposes a system to provide an entertaining rehabilitation treatment experience based on serious games and in-cloud analytics	System	Modular, service oriented, decentralized, real-time capability
(Cui et al. 2018)	The study proposes a development process of smart nursing homes in industry 4.0 environment.	Model, Tool	Addresses the issues faced while the development of smart nursing homes
(Xie et al. 2018)	The study proposes a model to address the issue of scalpers in mobile healthcare domain	Model	Achieved 72% precision and 77% recall for scalper detection on the test dataset
(Chen et al. 2018)	The study proposes a method to detect activity in elderly healthcare in the Industry 4.0 era	Method	Robust to obstructions and non-target object interference
(Chute and French 2019)	The study proposes a new paradigm know as Care 4.0 on the basis laid by industry 4.0 but Care 4.0 is more people centric and care oriented	Paradigms	New Care 4.0 paradigm

Table 2. Classification of some of the studies in aspect to Health 4.0 environment

Figure 4 shows in the form of a pie chart the geographical distribution of studies, with the notable finding that most studies, i.e., 22.73 per cent or five out of a total of twenty-two, were conducted in China.

Second was Italy with 18.18 per cent or four, then India with 13.64 per cent or three. Sweden and UK each had 9.09 per cent or two. The rest, including Egypt, Greece, Russia, South Korea, Spain and Turkey, each had 4.55 per cent or one study. As there were no studies for either Oceanian or America, more research for those regions may be indicated.

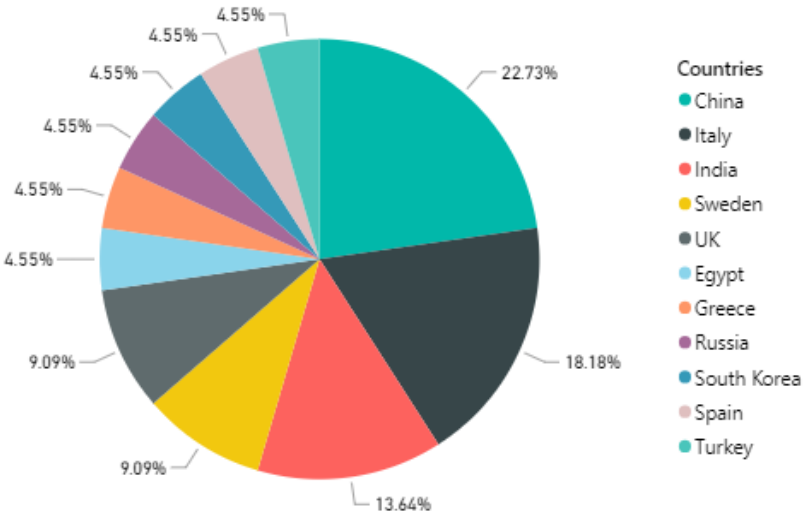

Figure 4. Geographical distribution of studies

Figure 5 shows the distribution of studies by fields of study. Most studies are from Science and Engineering journals with 45.45 per cent or ten out of twenty-two, followed by Informatics journals with 27.27 per cent or six. The remaining study are were Information Systems, Environment and Health, and Management with 13.64 per cent or three, 9.09 per cent or two and 4.55 per cent or one of the total, respectively. Clearly, more research needs to be conducted from the last three areas of study. Furthermore, as technology matures a shift from Science and Engineering to Informatics and the other related fields might assist in the implementation of those technologies.

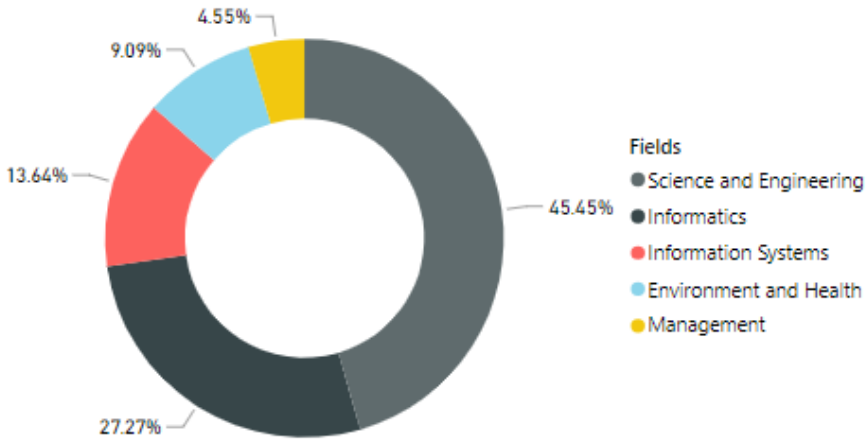

Figure 5. Distribution of studies by field of study

4 DISCUSSION

Figure 6 shows the network diagram based on analysis of the abstracts of the 22 studies. The content of the abstracts was cleaned to ensure that there were no issues to compromise the analysis.

Cowo software was used to identify the keywords and relations, most commonly used in the studies, to generate a map. Some adjustments were made to ensure the readability of the identified keywords. The VOS viewer was used to visualise the map.

The two words identified by the algorithm as being the most frequently used were Healthcare, with frequency of 72, and Industry 4.0, with a frequency of 26. All the other words had a frequency is the

single digits. The software only identified a single cluster, owing to the selection criteria used. However, it need be said that, as the studies focused on the healthcare and the Industry 4.0, it would not be unexpected to find that these were the most commonly used words on the map.

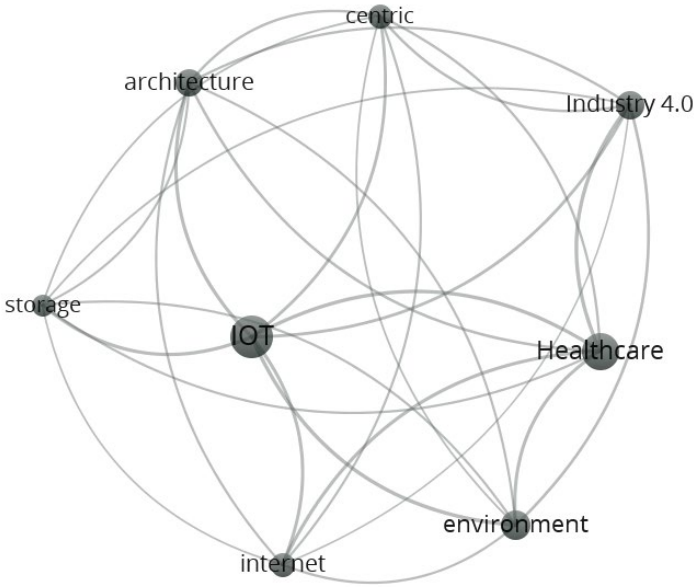

Figure 6. Network map of most frequent words used in selected studies

Most of the studies focused on bringing forward solutions which could help the adoption of Industry 4.0 technologies in the healthcare environment. The studies successfully recognised the importance of context of healthcare, and why healthcare is different from other industry sectors. Furthermore, they identified why there is need to adapt technology to the particular needs of healthcare.

Although the studies did provide a variety of solutions drawing upon various architectures and schemes, a lack of practical implementation of them was observed in the papers. This is demonstrated in Figure 7 which shows that in a significant proportion of the papers simulations/implementation were not used, with that proportion being 36.36 per cent or eight of the twenty-two papers. Simulation were used in five of the papers, or in 22.73 per cent of them. An equal number of papers used either a case study, dataset or an implementation for evaluation of their studies, i.e., 13.64 per cent or three of the twenty-two studies. All in all, this demonstrates a lack practical implementation in the majority of the studies, which, had they been applied might have shed light on practical barriers, as recorded by feedback from users and healthcare staff.

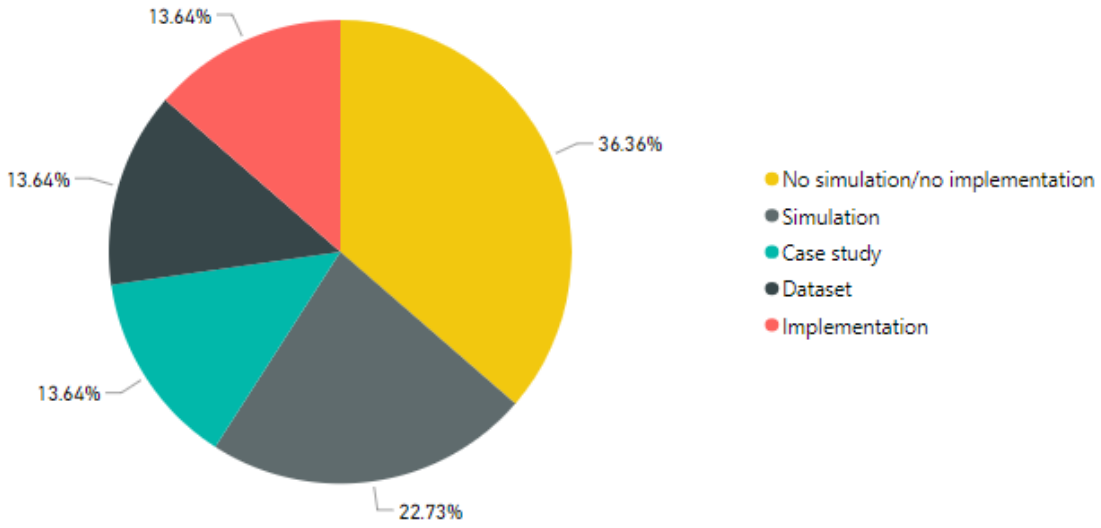

Figure 7. Evaluation method used by the literature

As can be seen from barriers identified in Table 1, the focus of the studies was directly more on technical barriers and issues, with the upshot that the issues the healthcare industry is currently facing were not being addressed, let alone how any solutions might be implemented to address them. Future studies need to be conducted in such a way to gain feedback from the perspectives of both medical staff and patients to understand the ground-level realities of the issues at hand.

Figure 8 shows that most of the studies were empirical studies, i.e., 68.18 per cent or fifteen of twenty-two. These were followed by analytical studies at 18.18 per cent or four studies, and literature reviews at 12.64 per cent or three of the twenty-two studies.

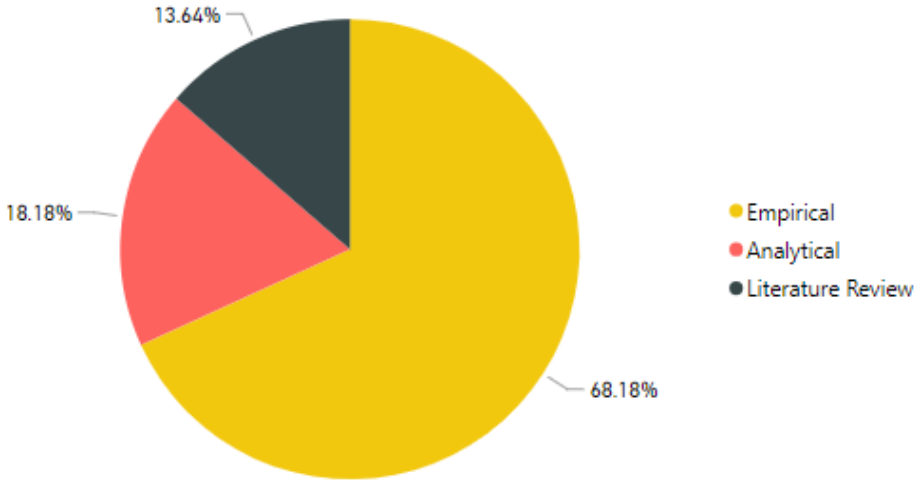

Figure 8. Research methods used in the selected literature

5 CONCLUSION

The study argues that there is a need to conduct more research in Healthcare 4.0. These studies should be evaluated by implementation to help address issues in healthcare in a realistic manner, and to ensure a higher rate of adoption of healthcare systems. The key barriers, as identified in the literature review, were summarised so that they might be better addressed in the implementation of Healthcare 4.0 technologies. Additionally, the study identified trends and gaps in the literature where more work needs to be done by future researchers. So were the regions and countries that might benefit from more research in healthcare. Lastly, more research in information systems, environment, health and management needs to be undertaken insofar as it relates to Healthcare 4.0.

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