Simulation-Based Approaches to Enhance Operational Decision-Support in Healthcare 5.0: A Systematic Literature Review

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Abstract. The objective of this study is to systematically evaluate peer-reviewed literature and analyze the current research on the thematic area "Simulation-Based Approaches to Enhance Operational Decision-Support in Healthcare 5.0" using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. This systematic review was conducted in compliance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement and implemented with the aid of the StArt software. Appropriate keywords were used in a search of the Science Direct, SCOPUS, and Web of Science databases. A total of 357 papers were retrieved from the databases and evaluated automatically. Eventually, 79 papers were analyzed according to their title, keywords and abstract. After the full-text analysis, 33 papers successfully met the inclusion criteria in the study. The review showed that healthcare providers and decision-makers can be guided by applying the Key Performance Indicators (KPIs) obtained from the simulation-based platforms to ensure quality and resilient health system.

Keywords: Decision-Support · Healthcare 5.0 · Simulation

1 Introduction

Over the years, healthcare systems have experienced evolutionary changes in line with the industrial evolution from healthcare 1.0 to healthcare 5.0. This translates to the evolution of healthcare system from traditional healthcare system to smart healthcare system. Healthcare 5.0 is described as the introduction of the Artificial Intelligence (AI) principles in the healthcare system, coupled with the use of smart intelligent technologies and the integration of high-speed (5G) data transfer networking protocols [1].

The evolutionary smart healthcare system which have paved way for remote healthcare services have brought about a decrease in the number of patients that would naturally be present physically in the hospital. However, improving quality healthcare while minimizing costs still remains a universal challenge. As a result, it is paramount that decisions are made to review and boost the performance of various healthcare processes and services at all the strategic and functional levels. Healthcare providers need suitable tools,

such as simulation, to successfully investigate different scenarios in order to forecast the influence of these decisions on the overall system performance of health facilities in healthcare 5.0 [2, 3].

Simulation is a decision support tool that enables key players in an industry to carry out investigations with models that imitates or duplicate large parts of the actual situation or real-life's systems under study. Simulation modelling in the scope of healthcare covers the area of Healthcare management [4–6]. Simulation in healthcare creates a safe learning environment in which researchers and practitioners can test new operational processes and enhance their decision support system for a resilient healthcare system [7–9].

2 Methods

2.1 Protocol

The objective of this study is to systematically review and analyze the current trend in the thematic area: "Simulation-based Approach to Enhance Operational Decision-Support in Healthcare 5.0" The systematic review technique followed the guidelines stated in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol) to trace the appropriate literature in the research area and tries to answer the following research questions:

- What are the possible set of KPIs that will aid decision support for a resilient healthcare system?
- How can hybrid simulation approach be used to improve the quality of lives of the patient and healthcare providers?

2.2 Literature Search

For the review, online research engines such as Science Direct, Web of Science (WOS), and SCOPUS, were explored using the keywords; Simulation, Healthcare 5.0 and Decision-support. Search criteria were developed to consider the demographic and outcomes of interest in order to generate an exhaustive list of all original literature pertinent to the research questions. The following terms were part of the search algorithm used: "Simulation" AND "Modelling" AND "Decision-Support" AND "Healthcare". The stated algorithm was applied in the search engine of all 3 databases used for this study. The search for articles was restricted to those published between January 2017 to June 2022 with the assumption that healthcare 5.0 which is an evolutionary concept will be tackled within that range.

2.3 Eligibility Criteria

The systematic review was conducted in accordance with the inclusion and exclusion criteria as shown in Table 1.

Table 1. Inclusion and exclusion criteria for eligibility

Criteria	Inclusion	Exclusion
Language	English	Languages other than English
Access	Open access	Access blocked
Literature type	Articles, Conference paper, Review	Books, Abstract only, Thesis, Websites, Duplicate articles
Publication Year	January 2017–June 2022	Articles earlier than or later than the stipulated range
Search String	Articles that contains at least a keyword in the search combination	Articles that do not contain in its keywords any of the component of the search string

2.4 Data Extraction

The search results from the database searches were collected and recorded in the Microsoft Excel Professional format with the following data columns: title, authors, publication, year of publication and status selection. Next, the studies were scrutinized for inclusion or exclusion at the selection stage by evaluating the title, keywords and abstract. Furthermore, for the final extraction, the papers were critically evaluated to ascertain their level of relevance for inclusion in the present review, focusing on the following components: objectives of the article, healthcare 5.0, methods and KPIs for decision making.

3 Results

3.1 Study Selection

In the study, predetermined eligibility criteria were used to evaluate the title, keywords and abstract of publications discovered through electronic databases to determine their eligibility for selection and extraction (Table 1). In the event that the publication's title, keywords and abstract lacked sufficient information to determine selection eligibility, they were exempted. Full-text publications that met the extraction criteria were collected and the complete article was screened. Full-text articles were retrieved and evaluated for bias risk if the abstract or article met our eligibility requirements. Tools and methods for data extraction were designed and validated. It was implemented with the aid of the StArt software.

On 22 June 2022, a search was conducted on Scopus and Science Direct databases using the combinations of key words, while Web of Science database was accessed on 24 June 2022. A total number of 357 papers were sourced in the following order: Scopus 177 papers, Science Direct 80 papers and Web of Science 100 papers. Following the initial screening from the search databases, and limiting the search to open access articles and articles published within the last 5 years in English, a total of 79, were extracted in a RIS format and saved on the software for the systematic review.

The 79 remaining articles were screened for eligibility criteria. The articles excluded from the reviewed were articles that did not meet the inclusion criteria. After the screening for eligibility, 38 articles were accepted and 41 excluded from the full-text evaluation. The search result is presented in the Fig. 1, which is a PRISMA 2020 flow diagram for systematic literature review.
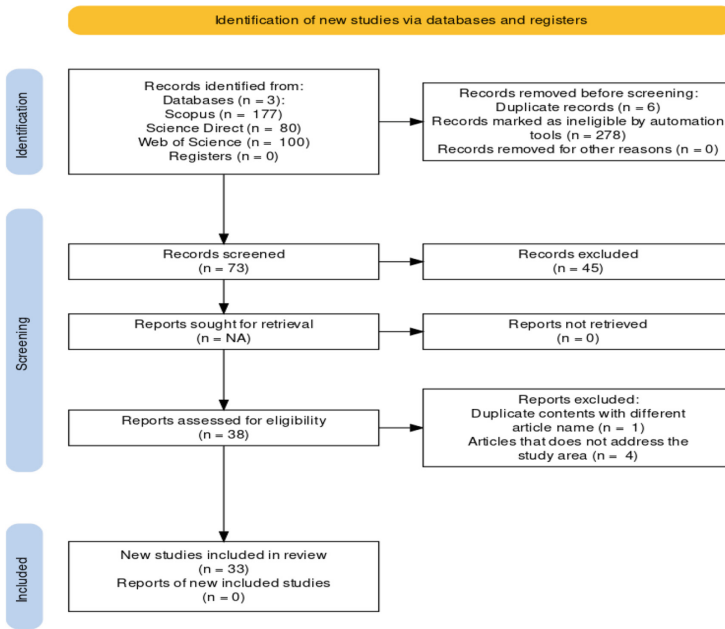
Fig. 1. PRISMA flowchart of the study selection for eligibility

3.2 Simulation Approaches

Simulation-based models provide a broad picture of the interactions between variables and the processes [10]. Discrete-event simulation is a valuable tool with regards to enhancing patient flow, and effective utilization of facility resources [11]. Discrete event simulation is a reliable decision support tool to improve healthcare quality [12, 13]. Most of the studies, approximately 50% of the studies reviewed, utilized the discrete event simulation approach in carrying out the simulation goals. Multi-agent programmable modeling environment and artificial intelligence methods is useful for the provision of recommendations about more effective policies from the standpoint of a decision support system [14]. The intricate situations that occur in hospitals, involving non-linear correlations and numerous interconnections, may be depicted using system dynamic modeling [15]. Hybrid simulation is a modeling strategy that incorporates two or more of the following techniques: agent-based simulation, discrete-event simulation, and System dynamics. The current and most effective technique is to merge ABS, SD and DES

models [16]. The greatest advantage of hybrid modeling is the ability to integrate different simulation approaches and empirical data from different sources [17–19].

3.3 KPIs

Key performance indicators (KPIs) are dimensions used to categorize and evaluate business performances. Key performance Indicators can be categorized and analyzed based on process, outcomes and structural indicators [20, 21]. KPIs that will make for a resilient healthcare can be classified based on quality, time related KPIs, Patient related KPIs and budget Related KPIs [22]. 70% of the studies reviewed presented patient related KPIs and time related KPIs. The quality and resilience of any healthcare system or service is largely dependent on the metrics chosen for evaluation and decision support. [23–25]. A study presented three main elements for developing healthcare simulation; medical activities, service times and arrival times [26]. As the stress on the health system increases, the standards of care decreases [17]. The deduction here is the determinant which is the level of healthy, satisfied and properly managed healthcare facilities, services and healthcare providers. It is a patient centric health system that degenerates to a population centric system when under stress (Heavy Demand). Operational quality KPIs such as staff, power outage, operating room and availability of patient record is considered for the achievement of a more resilient healthcare sector. The quality of care can be improved when the patients and healthcare providers are put into consideration when identifying key performance indicators [27]. This is in line with the holistic approach expected of the healthcare 5.0 concept.

4 Discussion

From the results, it is evident that most studies adopted the discrete event simulation approach when compared to the other simulation approaches. To address the dynamics of social-technical systems, insufficient research has been carried out on agent-based simulation, system dynamics, and hybrid modeling. The interplay between people and technology in the delivery of health care would shift in numerous ways as a result of digital transformation. The promise of future healthcare delivery that eliminates institutional borders and the methods used currently to test and demonstrate functionality are at odds with each other. A deeper comprehension is needed from the interrelated relationships between care providers in order to model individual level requirements, which will help close this gap.

The findings indicated that while there are only a limited body of empirical studies on determining the specific KPIs that will make for a resilient healthcare operation in the context of industry 5.0, this body of work can therefore be regarded as emerging, and does exist, however, a small body of empirical work that reports on the possible sets of KPIs. The body of literature accessed is not sufficient enough to tackle healthcare 5.0. This is as a result of lack of articles addressing the subject area because of its novelty. This can be deduced from the Fig. 2 which is a bibliometric analysis of articles available on the database via Vos viewer. Another key limitation of this study is that, only literatures obtained in line with the PRISMA guidelines were reviewed. As a result,

the search results were limited to Scopus, Science Direct and Web of Science databases. Though, they are the most frequently used in literature search [28, 29]. Hand searched or manually extracted articles were not included in the systematic literature review. The review only evaluated studies published after 2017. This approach was taken because the evolution of healthcare 5.0 started in the year 2020 [30]. The years preceding this time experienced industry 4.0 evolution. Hence, an integration of the literature after 2017 should not contort the analysis.
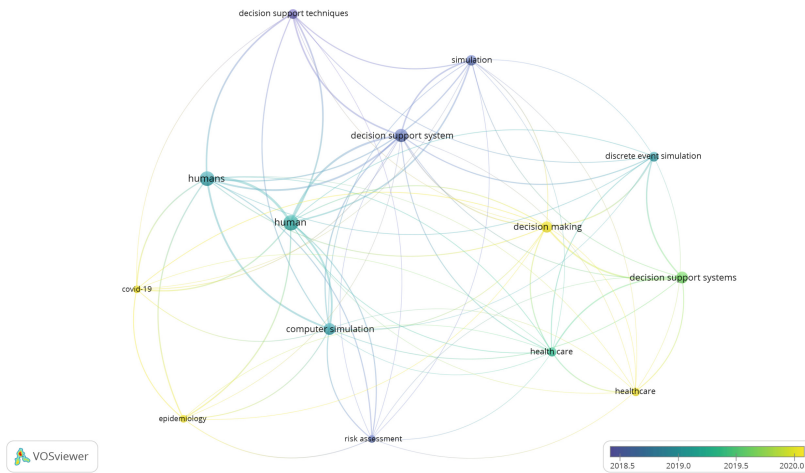
Fig. 2. Availability of articles on the search data base using the keywords

5 Conclusion

This study explored a systematic literature review, covering studies that addresses the overall improvement of decision-support in healthcare 5.0 using simulation-based techniques, and answering the research questions described in the literature review planning protocol. As a result, it was possible to identify that to have KPIs that will aid decision support will have to cut across all classifications of the KPI consideration and not only patient-centered or time related KPIs. This review showed that the studies that employed a hybrid simulation approach had a more formidable result as compared to the single approach [31, 32]. For future work, it is necessary to have a robust hybrid simulation approach that will account for all ramifications of the health system i.e. diagnosis and intervention for specified illnesses, human factor and infrastructure.

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