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ABSTRACT

Purpose: The pandemic has reinforced the need for revamping the healthcare service delivery systems around the world to meet the increased challenges of modern-day illnesses. The use of Medical Cyber Physical System (MCPS) in the healthcare is one of the means of transforming the landscape of the traditional healthcare service delivery system. The purpose of this study is to critically examine the impact of MCPS on the quality of healthcare service delivery.

Methodology: This paper uses an evidence-based approach, the authors have conducted a systematic literature review to study the impact of MCPS on healthcare service delivery. Fifty-four articles were thematically examined to study the impact of MCPS on eight characteristics of the healthcare service delivery proposed by the world health organization.

Findings: The study proposes support that MCPS will positively impact a) comprehensiveness, b) accessibility, c) coverage, d) continuity, e) quality, f) person-centredness, g) coordination, h) accountability, and efficiency dimension of the healthcare service delivery. The study further draws nine propositions to support the impact of MCPS on the healthcare service delivery.

Practical implications: This study can be used by stakeholders as a guide point while using MCPS in healthcare service delivery systems. Besides, healthcare managers can use this study to understand the performance of their healthcare system. This study can further be used for designing effective strategies for deploying MCPS to be effective and efficient in each of the dimensions of healthcare service delivery.

Originality: The previous studies have focussed on technology aspects of MCPS and none of them critically analysed the impact on healthcare service delivery. This is the first literature review carried out to understand the impact of MCPS on the nine dimensions of healthcare service delivery proposed by WHO. This study provides improved thematic awareness of the resulting body of knowledge, allowing the field of MCPS and healthcare service delivery to progress in a more informed and multidisciplinary manner.

Keywords: Healthcare, Health / Safety, Industry 4.0, Service Operations

1. Introduction

The healthcare system is undergoing a transformation and the use of information technology has helped to improve healthcare delivery systems (Lu *et al.*, 2021; WHO, 2018). The recent pandemic has seen the increased usage of Medical cyber-physical systems (MCPS) in the healthcare system, than ever before in both developed and developing countries (Javaid and Khan, 2021; Mujawar *et al.*, 2020). In a traditional setup, standalone healthcare service delivery systems were independently designed, certified, and used to treat patients without cyber connectivity (Dey *et al.*, 2018; Haque *et al.*, 2014). MCPS has brought in distributed systems that were designed to concurrently monitor & control multiple aspects of the patient's physiological characteristics. It is a combination of embedded software controlling the medical devices, networking capabilities, and complicated physical dynamics using state of art healthcare systems (Lee and Sokolsky, 2010; Qiu *et al.*, 2020) which is used in preventative, curative, palliative and rehabilitation healthcare services. Besides, the medical usage of CPS became known as MCPS. MCPS are "*critical integration of a network of medical devices*" (Dey *et al.*, 2018) and they are used in hospitals for improving continuous high-quality healthcare. In other words, MCPS are a "*platform in which the patient health parameters are acquired by the use of emergent technologies and processed via advanced machine intelligence algorithms in the cloud"* (Shishvan *et al.*, 2020). The adoption of MCPS in hospitals results in remote monitoring of patients, control, drug development acceleration or treatment, and improved quality of care (Grispos *et al.*, 2017). The adoption of MCPS also comes with challenges in terms of performance, security issues, cost, acceptance by doctors & patients, and safety issues (Almohri *et al.*, 2017; Jimenez *et al.*, 2020; Leite *et al.*, 2017; Li *et al.*, 2018). MCPS is used in the healthcare system to improve the quality of healthcare service delivery. The hallmark of a good healthcare system is the quality of healthcare service delivery. The world health report (2008) and WHO (2010, 2018) reports that the key characteristics of the healthcare delivery system are a) comprehensiveness, b) accessibility, c) coverage, d) continuity, e) quality, f) person-centredness, g) coordination, h) accountability, and efficiency. Previous works have deliberated on MCPS from a technology perspective (Al-Jaroodi *et al.*, 2020; Dey *et al.*, 2018; Grispos *et al.*, 2017; Lee and Sokolsky, 2010; Leite *et al.*, 2017), but none of them has studied how it impacts the key characteristics of healthcare delivery system developed by WHO (2010, 2018). Healthcare though sprightly in its overall advancement, but when it comes to technology, it is still lagging with other industries like manufacturing. The technology though a boon to society from a healthcare perspective, but it can also be a disadvantage at times, due to its poor management and system-wide application (Bhandari *et al.*, 2020). In this study, we aim to provide an integrative and organising lens for viewing the various contributions to knowledge production in MCPS. Specifically, we intend to collect, collate, and critique those research communities addressing concerns associated with the MCPS and its impact on healthcare service delivery. Furthermore, this study is particularly interested in better understanding how MCPS will impact the different dimensions of healthcare service delivery. Therefore, the primary purpose of this study is to investigate the research question *"What is the impact of Medical CPS on healthcare service delivery?"*. A systematic literature review is used in this study. As healthcare systems around the world are undergoing an abrupt transition in terms, of efficiency, quality, capacity, reach, comprehensiveness, accessibility, coverage, continuity, quality, person-centredness, coordination, accountability and efficiency. This study will help the stakeholders to better design and implement medical cyber-physical systems. Besides, we also aspire to move the body of knowledge on MCPS and healthcare service delivery forward and progress both within-community and cross-community understanding. This study takes principles originating from the MCPS and applies them to healthcare service delivery for the understanding of the mechanisms of its impact. Through this process, we have performed a thematic analysis of 54 academic papers from international peer-reviewed journals. The outcomes of this review are an understanding of where knowledge resides on MCPS and its impact on healthcare service delivery. Besides, it will help the research communities., where interactions and communications are stronger and where the common areas of inquiry are located between MCPS and healthcare service delivery. The paper is organised as follows, the next section is devoted to the literature review, followed by methodology, results and discussion. At last, the conclusion, future research direction and limitation of the study is explicated.

2. Background Theory

The healthcare system's efficiency and effectiveness is measured by the quality of healthcare service delivery (lo Storto and Goncharuk, 2017). The key characteristics of the healthcare delivery system elucidated by the world health organization are a) comprehensiveness, b) accessibility, c) coverage, d) continuity, e) quality, f) person-centredness, g) coordination, h) accountability, and i) efficiency (The world health report, (Theworldhealthreport, 2008) and WHO(2010, 2018)). The *comprehensiveness* dimension of health care service delivery targets the complete range of health services offered to meet the needs of the target population. This could be for preventative, palliative, curative, rehabilitative and health promotion activities. The *accessibility* dimension explicates the accessibility of the health care service delivery in terms of accessibility to all target populations in terms of cost, language, culture, or geography. The *coverage* dimension is designed so that all people are covered whether they are young, old, sick, healthy, poor, rich, and all social groups. *Continuity of care* is the ability of the health care system to provide the continuity of care across the network of services, health conditions, levels of care, and over the lifecycle. The *quality of healthcare* service delivery revolves around effective, safe, and it is centred on the patient's needs and when given promptly. *Person centredness* revolves around solutions that are organised around the person, not the disease, or finances. The *coordination of health* care service delivery revolves around the ability to coordinate with local area healthcare service networks. This will help in better resource management, routine and emergency preparedness, levels of service delivery, and types of care. *Efficiency* refers to the ability of the health care service delivery to efficiently deliver the services with minimum wastage of scarce health care resources. The *accountability* in terms of achieving the planned objectives of the healthcare system (WHO, 2010). The last few decades have seen the use of technology to improve healthcare service delivery. The infusion of technology has resulted in improved health care service delivery (Chakraborty *et al.*, 2021). The health service delivery quality has also improved greatly due to the adoption of ICT technologies (Cheung *et al.*, 2019). The main challenges of the healthcare service delivery system are sub-standard care, limited insurance coverage, high out-of-pocket expenditure, inefficient use of scarce resources, higher medical cost, and inadequate awareness level (Shan *et al.*, 2017). Technology was used to overcome these challenges in terms of telemedicine (Wootton, 2001), telehealth (Tuckson *et al.*, 2017), Ehealth (Van Gemert-Pijnen *et al.*, 2013) and mobile health (Wu *et al.*, 2021). In developed countries, private hospitals using technology have been a great success in improving healthcare service delivery. This can be seen in the success stories of Teladoc (Uscher-Pines and Mehrotra, 2014), CareClix (Lee and Hughes, 2017), Visionflex (NEW, 2018). In developing countries initiatives such as Kenyan firm, Ilara Health, providing artificial intelligence-powered diagnostic devices to needy hospitals or clinics in noncity locations (Chakraborty *et al.*, 2021), Apollo hospital in India has established telemedicine services in hilly areas of Jammu and Kashmir (Dasgupta and Deb, 2008), and the use of telemedicine during Covid-19 in India and various parts of the world (Ghosh *et al.*, 2020) substantiates the importance of the use of technology in health service delivery in both developing and developed countries. The CPS is a new generation of systems with integrated control and communication capabilities (Wang *et al.*, 2011) and it has the potential to transform how people interact with the physical world. The recent advances in ICT have made availability and affordability of sensors, data acquisition systems and computer networks (Lee *et al.*, 2015). The application of CPS in healthcare service delivery is in the infant stages (Haque *et al.*, 2014). In health care, a special type of CPS known as Medical cyber-physical systems is used (Lee and Sokolsky, 2010). It is based on smart healthcare which includes physical and cyber systems. In health care, the physical systems include wearable devices, medical diagnostic equipment etc. The user space includes doctors, nurses, paramedics etc. The main unit of MCPS is cyberspace and it receives information from the physical space through a network transmission system. The main function of cyberspace is it identifies, stores, analyses, processes, and generates feedback control information, which is subsequently used to send control information to physical space, through network transmission (Shu *et al.*, 2020). The patients' physical signs data are collected through wearable devices and medical devices, to monitor the physical and mental condition of the patient. This helps in the precise tracking of the physical and mental data of the patient (Zhang *et al.*, 2019). Besides, the MCPS usually controls the medical equipment through a wireless network, which senses and monitors the patient's data in real-time. Any abnormality is detected and concerned stakeholders are intimated in time (Shu *et al.*, 2020). Thus, the use of MCPS in healthcare service delivery has a huge potential and can impact the key characteristics of healthcare service delivery. Hence, there is a need for a study that collates and critically analyses the impact of MCPS on different dimensions of healthcare service delivery systems.

3. Research Methodology

The systematic literature review is used in various disciplines to synthesize and organise the research findings from multiple studies**.** To bring transparency to the review process we used a systematic methodology suggested by Tranfield *et al.* (2003). Besides, the systematic literature review also brings in rigour, comprehensiveness and replicability (Al-Odeh *et al.*, 2021; Guraja *et al.*, 2022; Lightfoot *et al.*, 2013; Rousseau *et al.*, 2008). Figure 1 and Figure 2 depicts the research protocol used in this study which was adapted from Tranfield *et al.* (2003). The literature search process was designed to answer the research question, using base level studies.

3.1 Identification

A method suggested by Booth *et al.* (2016) was used to identify the literature. It consists of using a combination of query strings for the titles, abstract, keywords of studies. The search strings for this study were divided into three parts. Part 1 was used for healthcare service delivery, part 2 was used for medical cyber-physical systems and part 3 was used for key characteristics of the healthcare service delivery system which was adapted from WHO (2010). The keywords used in the study are given in Appendix A. The database used in this study is depicted in Figure 1. MCPS is an emerging research area hence we have included conference proceedings and other peer-reviewed articles. The reference list of each article was used to improve the search criteria.

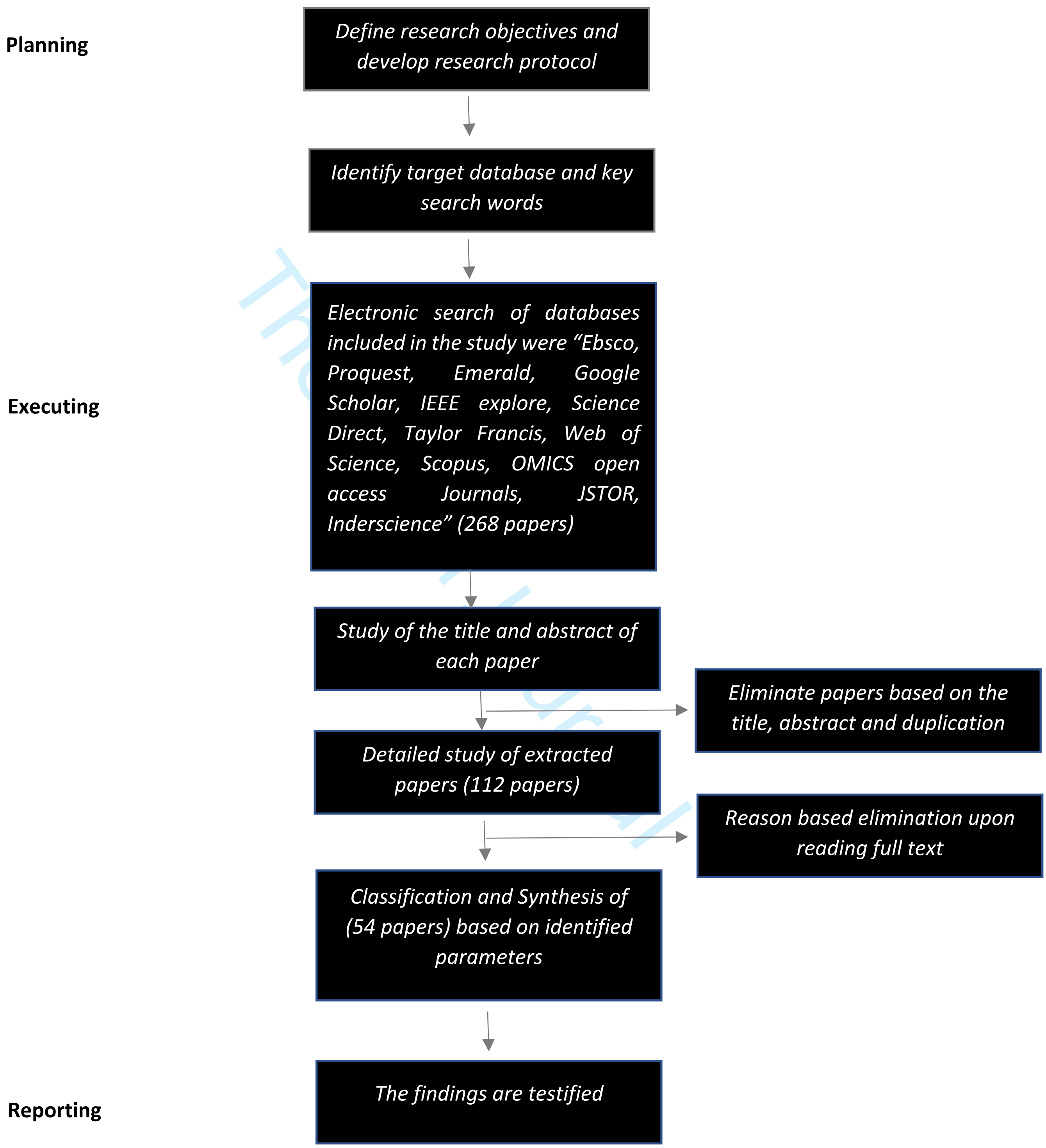

Figure 1: Systematic Review Methodology

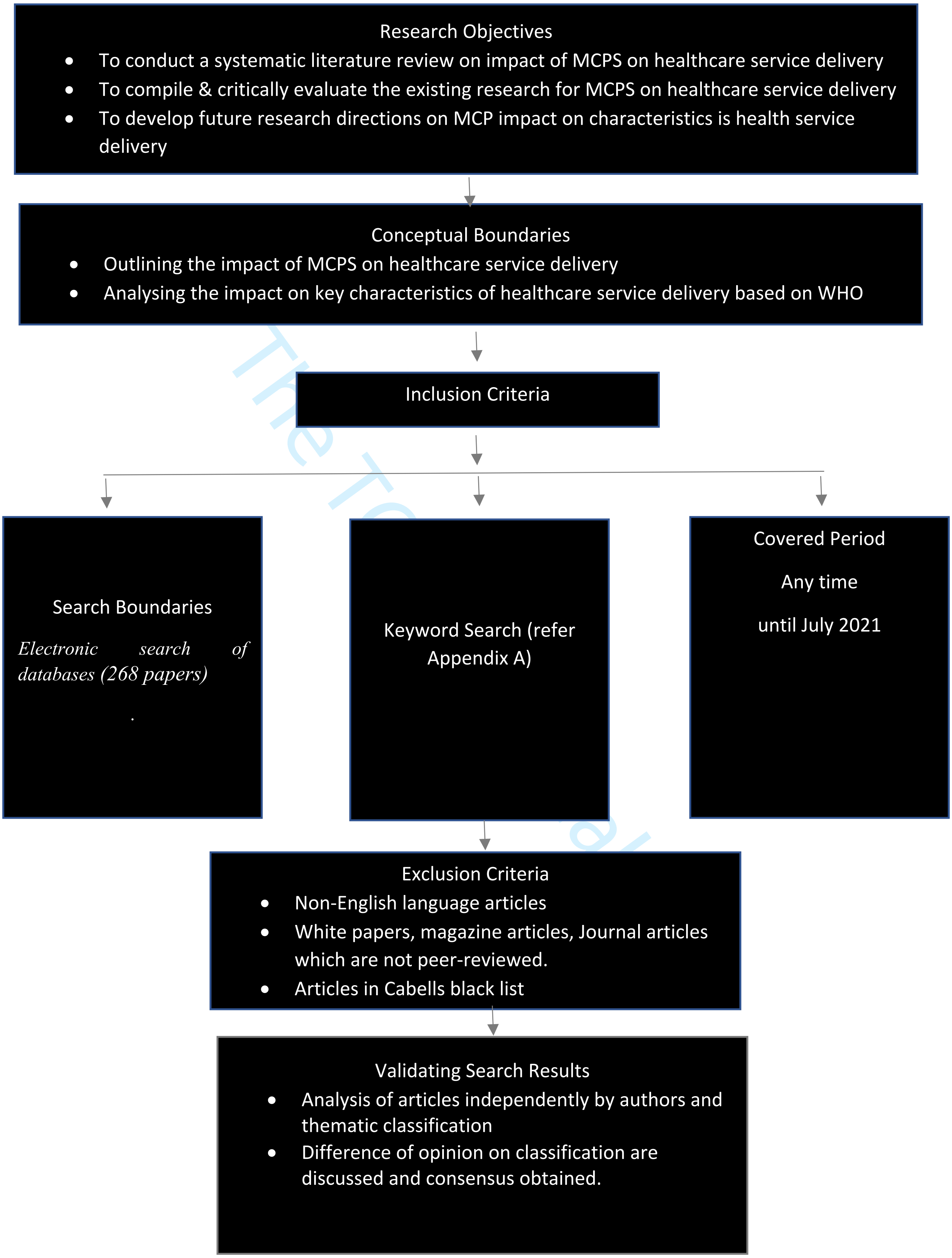

Figure 2: Literature Review Protocol

3.2 Screening Criteria

The screening of articles was carried out in this phase. To avoid any bias, a methodology suggested by Popay *et al*. (2006) was carried out. This protocol was used to obtain the final selection of articles as depicted in Figure 2. If the articles are from predatory journals it was discarded. The predatory journals were identified from Cabbells list (Das and Chatterjee, 2018) of predatory journals.

3.3 Inclusion

The titles and abstracts were analysed in detail by authors independently to validate whether the article meets the objective of the study. It further helped to remove duplicate and irrelevant articles. Each author created an inclusion and exclusion list independently by considering three criteria's 1) purpose, 2) method and 3) key findings. Subsequently, the authors discussed the inclusion and exclusion list. Where ever there was disagreement, it was objectively discussed on the three criteria and the final list of inclusion was prepared. This was done to maintain uniformity in the article selection process and also it helps to reduce reviewer bias (Voola *et al.*, 2022). The total number of articles and their breakdown is depicted in Figure 1. Fifty-four articles were extracted after review considering the research objective of the study.

3.4 Synthesis

The main goal of this study was to discover the impact of MCPS on key characteristics of healthcare service delivery. We used a two-pronged deductive and inductive approach. The articles which were identified in the previous phase was read in detail by the authors. Further, it was decided to identify the patterns, directions, similarities, and differences. These articles were further analysed to classify the articles thematically to understand the underlying patterns behind the studies.

4. Findings

The articles were analysed to understand the relationship between MCPS and different dimensions on the quality of healthcare service delivery. Figure 3 depicts the impact of MCPS on different dimensions of health service delivery.

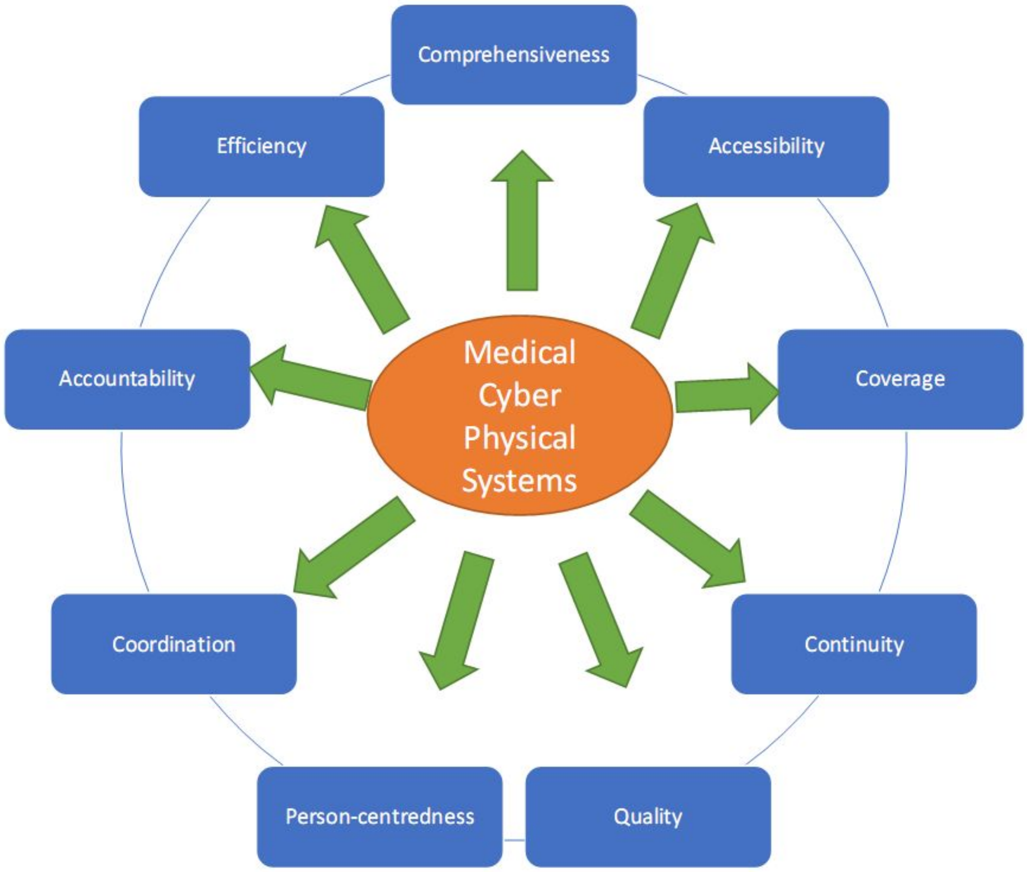

Figure 3: MCPS impact on health service delivery

4.1 MCPS impact on comprehensiveness dimension of health service delivery

Comprehensiveness is one of the most important characteristics of a healthcare service delivery system to meet the target needs of the population, by using preventative, curative, palliative and rehabilitation services (WHO, 2010). The healthcare needs of the target population are very important and not meeting those needs results in concern about equity and also the "right to healthcare" (Başar *et al.*, 2021; Sidel, 1978). Palliative care is specialized medical care for people living with serious illness and it revolves around providing relief from the symptoms and stress of the illness (Morrison and Meier, 2004). Robots and other complex CPS have been used in elderly and sick patients in applications for supporting mobility (Cooper *et al.*, 2008; Gerling *et al.*, 2016), activities of daily living (Bilyea *et al.*, 2017; Brose *et al.*, 2010), physical activity monitoring & tracking (Brose *et al.*, 2010; Costa *et al.*, 2018), medication management (Korchut *et al.*, 2017; Rantanen *et al.*, 2017; Sermeus, 2016) and also to support and monitor the nutrition & hydration of patients (Brose *et al.*, 2010; Korchut *et al.*, 2017; Łukasik *et al.*, 2018). Curative care deals with treatment and therapies rendered to the patient for resolving an illness and the goal of bringing the patient ideally to the status of health before the illness (Gardiner *et al.*, 2011). Robots and other complex MCPS have been used in curative care, especially in surgery and significant growth is seen in the last two decades. The robots have been proved to cure various illnesses through surgery because of their enhanced visualization, superior dexterity and precision during minimally invasive procedures (Morrell *et al.*, 2021). During the pandemic, healthcare robots and CPS was used to help the doctors and other healthcare professionals for monitoring patients' physiological conditions (Kaiser *et al.*, 2021). It further suggests the significance of the use of MCPS in ensuring the safety of health care workers. MCPS is used in high-risk cases such as high-risk pregnancies, wherein the sensors were placed on the patient and data was digitally relayed back to the hospital for monitoring and action (Wrobel *et al.*, 2015). In rehabilitation care services, the robots or complex CPS are used to improve mobility following spinal surgery (Holanda *et al.*, 2017; Karimi, 2013), improve limb rehabilitation following stroke (Lo *et al.*, 2017). In preventive medicine, medical robots can play an important role to prevent the spread of infectious diseases such as in Covid 19, and the spectrum of application can range from the continuum of care, ranging from disease prevention, screening, diagnosis, treatment, and home care. It has been extensively deployed and also presents incredible opportunities (Di Lallo *et al.*, 2021). Big data was also used in healthcare service delivery for classifying, identifying and preventing SARS disease. This further stresses role of MCPS in the health care domain to fetch deep insights about the nature of the disease and carry the monitoring process with early detection of infected patients (Raghav and Dhavachelvan, 2019). Social robots are used to interact with patients to take care of the psychological ill effects of illness, though it is in the initial stage of development in health domains they will have the ability to engage patients on social and emotional dimensions (Breazeal, 2011; Henschel *et al.*, 2021). Thus, MCPS along with the use of robots and interconnected with the cyber system will have a positive impact on the comprehensiveness dimension of healthcare service delivery.

Proposition 1: *The MCPS use in a healthcare delivery system may result in a positive impact on preventative, curative, palliative and rehabilitation service dimensions improving the comprehensive dimension of health service delivery.*

4.2 MCPS impact on continuity, accessibility, and coverage dimension of health service delivery

Continuity of care is the ability of the health care system to provide the continuity of care across the network of services, health conditions, levels of care, and over the lifecycle. The use of MCPS in the continuity of care varies from infusion pumps to implant sensor devices (Rahaman *et al.*, 2018). In a study, it was found that an analgesic infusion pump control algorithm was used to keep the drug concentration in the blood to a fixed level. Such studies can directly enhance the continuous monitoring of health conditions, over a lifetime, at various levels of care and across a network of healthcare services (Rahaman *et al.*, 2018). In chronic illness, it was found that when patient counselling is coupled with technology-enabled continuity of care then patient patients' skills, knowledge, and motivation to manage chronic illness improves (Queenan *et al.*, 2019).

Proposition 2: *In a healthcare system MCPS usage may have a positive impact on the continuity of care across the network of health services. It may also have a positive impact on convenient and economical monitoring of various health conditions, providing various levels of care, and over the lifecycle of healthcare service delivery.*

The coverage dimension is designed so that people of the target population are covered whether they are young, old, sick, healthy, poor, rich, and all social groups. In-home remote patient monitoring systems, is a non-traditional way of managing patients using MCPS and it is an effective way to reduce the burden on the healthcare systems. The increasing age of the target population and the increasing complexity of the disease, warrants data to be analysed in terms of various dimensions of the decision-making process in health care service delivery. Therefore, continuous monitoring of patients sensor data with historical records of patients is to be critically analysed (Shah *et al.*, 2016). The MCPS will be a boon in such a scenario due to its intelligent algorithms. Apart from that, the remote monitoring of patients has seen as an increasing trend due to the Covid-19 pandemic and it is now widely accepted by the patient and doctor to manage serious illnesses using MCPS (Loria, 2021).

Proposition 3: *The usage of MCPS in a healthcare system may have a positive impact on the coverage dimension of healthcare service delivery because of its ability to cover young, old, sick, healthy, poor, rich, and all social groups.*

The accessibility dimension explicates the accessibility of the health care service delivery in terms of accessibility to all target populations in terms of cost, language, culture, or geography.

Cyber-health care builds upon cyber-physical health systems to provide medical services anytime and anywhere in the world. It is cost-effective, can be effective in both urban and rural areas (Bagula *et al.*, 2018). The use of MCPS in remote monitoring results in reduced cost of health care because of automated systems of monitoring, reduced mortality and the quality of healthcare is drastically improved. To cite an instance in COPD patients it was found that remote monitoring has advantages a) in terms of continuous monitoring during normal daily activities, b) prediction and early detection of exacerbations and life-threatening events, c) monitoring during the home treatment and monitoring exercise (Tomasic *et al.*, 2018). Smart vests have been successfully used for non-contact monitoring of respiratory rate by capacitive sensing in COPD patients. These applications suggest the importance and effectiveness of non-contact type technologies and how they can be linked to cyber systems for effective monitoring & management of patients (Naranjo-Hernández *et al.*, 2018). The healthcare systems are an issue in rural areas and the use of MCPS can result in bringing initiatives such as telehealth, remote patient monitoring, and access improvement for patients in rural areas (Tucker, 2015).

Proposition 4: *The MCPS in healthcare will have a positive impact on the accessibility dimension of healthcare service delivery because it will enable in providing efficient and effective healthcare delivery to all target populations in terms of cost, language, culture, or geography*.

4.3 MCPS impact on quality and person-centredness dimensions of healthcare service delivery

The quality of healthcare service delivery revolves around effectiveness, safety, and is centred on the patient's needs when given on time. The effectiveness of the use of MCPS in healthcare service delivery is found in both physical and mental illnesses. In physical illness, MCPS is used effectively in dealing with high-risk pregnancy (Wrobel *et al.*, 2015), respiratory illness, Asthma (Naranjo-Hernández *et al.*, 2018; Tomasic *et al.*, 2018), serious old age-related illness (Loria, 2021; Shah *et al.*, 2016; Walker *et al.*, 2019), injuries (Peterson, 2018), infectious diseases (Raghav and Dhavachelvan, 2019; Wu *et al.*, 2021) and so on. In mental health, telehealth technologies are used to conduct psychological assessments and counselling. This field is rapidly expanding and is found to be very effective (Luxton *et al.*, 2014). The access to treatment of mental illness is always not accessible in remote or unserved areas or areas with social constraints or accessibility. The use of technology such as video conferencing, remote monitoring in psychological therapy services may result in the effective use of these resources by patients in remote areas (Bee *et al.*, 2008). In the safety dimension, the quality of data that is interchanged between the patient and cyber systems depends on the accuracy of the sensors or other invasive or non-invasive monitoring devices, which monitor the physical characteristics of patients. Besides, the self-monitoring, diagnostic and self-correcting features of this sensing equipment make these devices highly accurate. To cite an instance, the use of remote health monitoring using Body Area Networks (BANs), in monitoring the physical activity of older adults under the supervision of their respective caregivers is found to be successful and safe (Bastos *et al.*, 2021). The wireless system in the WBAN is also used effectively to obtain physiological data from sensor nodes and is transferred to remote stations with a multi-hopping technique using the medical gateway wireless boards (Fotouhi *et al.*, 2020; Yuce, 2010). It also gives the flexibility to healthcare workers to access the patient data at any time or anywhere and is found to be highly safe.

Proposition 5: *Quality of healthcare service delivery will positively improve due to the use of MCPS as it will improve the healthcare service delivery in terms of effectiveness, safety, and timeliness.*

The high availability of patient-centric and secure data by the use of technologies such as Blockchain technologies (Dubovitskaya *et al.*, 2020) has resulted in healthcare service delivery being personalised and unique as per the needs of the patients. The large amount of big data which is gathered through IoT sensors in an MCPS provides a rich platform, which artificial intelligence algorithms can use to provide decision support for both medical professionals and patients to create a unique healthcare service model (Shishvan *et al.*, 2020). Digital twins are the digital replica of the physical object. It is a combination of Data Analytics, Artificial Intelligence (AI), IoT, Virtual and Augmented Reality paired with digital and physical objects (Al Ridhawi *et al.*, 2020). In a study patient's digital twin was used to monitor real-time health status and detect body metrics for anomalies. This was done by building an ECG heart rhythms classifier model which can diagnose heart disease (Elayan *et al.*, 2021). Another personalised application of technology in healthcare is an IoT based framework, for an accurate epileptic seizure prediction system based on deep learning. In this system, the raw EEG signals are used in Convolutional Neural Network (CNN) based model that extracts the important Spatio-temporal features from the non-stationary and nonlinear EEG signals and the model has a higher accuracy of 96% in predicting epileptic seizure (Daoud *et al.*, 2020). The use of such models creates a unique personalised solution in healthcare service delivery.

Proposition 6: *The use of MCPS will enable the acquisition and use of personalised data, enabling healthcare service providers to provide person-centredness dimensions of health service delivery.*

4.4 MCPS impact on coordination, accountability, and efficiency dimensions of health service delivery

MCP will benefit from the information exchange of patients through various service providers. The security of the patient data would be ensured through technologies such as blockchain (Feng *et al.*, 2016). By networking and coordination with various local area health service networks, through MCPS, there will be better delivery of healthcare service, as the resources can be shared among service providers, resulting in optimum use of scarce resources (Patan *et al.*, 2020; Sharma and Kumar, 2019). Additionally, it will also help the healthcare systems to be interconnected as a digital ecosystem, which will result in better meeting the large demand for healthcare services, in times of pandemic or other high demand scenarios (Chowdhury *et al.*, 2020; Liu *et al.*, 2012). One of the main challenges MCPS design experiences is security/privacy, inoperability, and high assurance in the system software (Dey *et al.*, 2018). However, this challenge can be managed if local area healthcare service providers operate cooperatively to meet the needs of the target population. The MCPS usage in healthcare systems promotes the use of E-health systems can positively impact the efficiency and quality of Healthcare service delivery (Saleh *et al.*, 2016).

Proposition 7: *The use of MCPS will improve information interchange between patient and service providers and also between service providers. Thus, MCPS will positively impact the coordination dimension of healthcare service delivery.*

Another point to consider is that eHealth using MCPS increases the efficiency of integrated care. This is because it facilitates the coordination of professionals and improves patient accessibility and empowerment (Lizana, 2015). E-health systems using the innovative application can improve accessibility, effectiveness and efficiency of healthcare delivery (Dumay, 2007), and hence MCPS should be innovatively integrated into E-Health Systems. The resources in healthcare service delivery are very scarce and the use of MCPS can help in better usage of resources (Lee, 2015; Lee and Sokolsky, 2010). The goal of the healthcare system is to deliver improved, value-added, good quality, timely, reliable, and cost-efficient healthcare service delivery. MCPS can enhance the effectiveness and efficiency of the healthcare Industry (Al-Jaroodi *et al.*, 2020).

Proposition 8: *The efficiency of the healthcare system will positively improve due to MCPS because it will help to deliver value-added, good quality, timely, reliable, and cost-efficient healthcare service delivery.*

MCPS helps in promoting transparency in the health care system. This is due to the availability of big data (Qiu *et al.*, 2020), which can be used to design patient targeted applications, resource management applications, applications supporting healthcare professionals, and high-level healthcare systems management applications (Al-Jaroodi *et al.*, 2020).

Proposition 9: *The use of MCPS will help to effectively use scarce resources due to transparency resulting in achieving the planned objectives of healthcare service delivery.*

5. Discussion

In any healthcare system, good service delivery is perennial for the wellbeing of the health of society (Baine *et al.*, 2018). The health service delivery can be thought of as an output of the healthcare system. Increasing inputs to health systems such as the use of MCPS may have an impact on the healthcare service delivery, this is because the healthcare system can be thought of as a combination of deterministic and randomness-based systems. A deterministic system in health care has predictable outcomes. Similarly, a randomness-based system is due to various factors which are highly variable and the outcomes cannot be predicted successfully (Litaker *et al.*, 2006). To cite an instance healthcare system is a socio-technical system, wherein technical and non-technical systems interact in a goal-directed manner to create a health delivery service system (Litaker *et al.*, 2006). Therefore, MCPS in a healthcare system should interact with non-technical systems such as humans to create an efficient and effective health delivery system. Thus, MCPS should be studied in terms of how well the existing healthcare service delivery system is strengthened. This study finds that MCPS may have a positive impact on all the key characteristics of the healthcare delivery system such as comprehensiveness, accessibility, coverage, continuity, quality, person-centredness, coordination, accountability, and efficiency. In terms of the comprehensibility dimension, the use of MCPS can meet the needs of the target population. Strategic use of MCPS is advised in healthcare systems because the needs of stakeholders may vary in terms of its requirements in terms of preventative, palliative, curative, rehabilitative and health promotion activities (Høiseth and Keitsch, 2015; Panda and Mohapatra, 2021). In terms of accessibility, the use of MCPS may make health care service delivery assessable to the target population in terms of cost, language, culture, or geography. However, the healthcare providers should examine the techno-social-economic analysis, as it may vary in different countries (Mushi *et al.*, 2015; Schoen *et al.*, 2010). The MCPS usage can meet the coverage needs of healthcare systems service delivery in terms of meeting the needs of young, old, sick, healthy, poor, rich, and all social groups. However, the response of various social groups towards technology may vary considerably (Esmaeilzadeh, 2020; Facey *et al.*, 2010; Krugman, 2011). Hence, health service providers will have to first study the use of MCPS on a pilot basis on each social group, and subsequently make a decision to implement the same on a large scale. The use of MCPS can provide continuity of care for all stakeholders in terms of the network of services, health conditions, levels of care etc. The continuity of care will vary in terms of the type of disease, socio-economic conditions of the persons, physical and mental condition of the patient, and so on (Alazri *et al.*, 2007; Fouladi *et al.*, 2014; Sparbel and Anderson, 2000). Thus, healthcare service providers should strategically implement the usage of CPS for continuity of care. The usage of MCPS can improve the quality of healthcare service delivery in terms of being effective, safe, and centred on the patient's needs and timing. Healthcare service providers should also consider the expectation and perception of patients(Nadi *et al.*, 2016) on the usage of MCPS in various diseases, health conditions, age, educational background, and economic conditions. The usage of MCPS can result in person-centred treatment because of big data availability. This will enable personalised diagnostic, therapeutic and management of the disease. However, healthcare service providers need to acquire technical and knowledge management capabilities to harness the potential of personalised healthcare service delivery by using MCPS. The use of MCPS improves the coordination of health care service delivery. The data generated by these MCPS can be used to coordinate with local area healthcare service networks resulting in better resource management, routine and emergency preparedness, levels of service delivery, and types of care. However, healthcare service providers will also need safe and secure data acquisition, data transmission, data processing and management systems (Shahid *et al.*, 2022; Terry, 2017) for effective coordination. The MCPS usage can improve the efficiency of healthcare service delivery, as it will help the healthcare service providers to effectively use the scarce health resources. However, healthcare service providers should examine the efficiency of healthcare delivery in various contexts such as health conditions, nature and type of illness etc, before setting the efficiency standards for the usage of MCPS. The MCPS system usage in healthcare service delivery will enable accountability in terms of achieving the planned objectives of results. This is because there would be transparency at various stages and also objective evaluation of results, resulting in better chances of meeting objectives. However, healthcare service providers should also consider human-induced variability in health systems(Vredenburg and Bell, 2014), while evaluating the overall accountability of meeting the health objectives.

6. Implications

The healthcare systems service delivery will vary based on various socio-economic factors of a country (Vertakova and Vlasova, 2015). Thus, the policymakers and stakeholders of healthcare systems should be tasked to assess their existing healthcare service delivery systems, before implementing MCPS. A detailed deliberation and systematic study should be carried out as regards the impact on how each of the dimensions of their respective healthcare service delivery will be strengthened, after implementation of MCPS. The MCPS should be systematically incorporated in existing health care systems, for providing health service delivery in terms of the right care, at the right time, by responding to the patients' needs and preferences for treatment, while minimizing harm and resource waste. In addition, efforts should be made by health policymakers and healthcare providers by designing a roadmap to implement MCPS systematically and sustainably so that universal health coverage of the society (Rosenquist *et al.*, 2013) is ensured. Also, MCPS should be further incorporated to ensure that all individuals within a society can use the quality, effective efficient and cost-effective preventive, promotive, curative, rehabilitative and palliative health services. The service providers should also consider the social context where the MCPS is used in a healthcare system. This is important because social context such as service climate, nature of interactions, healthcare information, education level and technology level of the society can influence how customers behave in a healthcare system (Osei-Frimpong *et al.*, 2020). Customer coproduction of service is an important aspect in healthcare service delivery and it impacts the outcomes of service delivery in the healthcare system (Temerak *et al.*, 2018). Therefore, the service providers should design MCPS integration in the healthcare systems, to encourage customer coproduction of health services using MCPS, so that healthcare service delivery dimensions are further strengthened.

7. Scope for future research

Increased usage of MCPS in healthcare service delivery is noted in the last decade, however, most of the studies were devoted to the technical implementation of MCPS. A healthcare system is a socio-technical system (Berg *et al.*, 2003; Eason, 2007), hence for the optimum utilisation of technology, human and technical elements should work in tandem to meet the key characteristics of healthcare service delivery. Therefore, future studies should explore the perception of stakeholders through a qualitative study as regards the lived-in experience of usage of MCPS. The prominent stakeholders which should be considered in this study are patients, doctors, paramedics, nurses, and other stakeholders which are directly or indirectly connected with the patient or service provider (Høiseth and Keitsch, 2015). This is because the impact of MCPS on each of the stakeholders would be different in terms of its impact. Another factor to consider is an empirical study to understand the benefits, challenges, critical success factors for the implementation of MCPS in health care service delivery. These factors could be different based on the continent, type of hospital, socio-economic status of the country/region, user acceptance of technology, cultural factors (Dixon-Woods *et al.*, 2012; Kasthuri, 2018; Shilo *et al.*, 2020) and so on. Another area of research would be conducting case studies to understand the longitudinal impact of the MCPS and the adaptability of various stakeholders towards the MCPS. There is also an urgent need for an empirical study on MCPS and the nature of the relationship between the key characteristics of healthcare service delivery. The studies should also explore the use of MCPS in preventative, curative, palliative, and rehabilitation healthcare services in terms of SWOT analysis. A multi-case approach would be a good starting point for this study, as it will help to understand the variations of SWOT with each of the sub-functions of healthcare service delivery. Also, it will help to understand the similarities within each of these subfunctions. To understand the impact of MCPS studies should include diverse settings such as children, the elderly, persons with disability, socio-economics-educational status, non-WEIRD (Laajaj *et al.*, 2019) samples and so on. This will help us to understand the diverse viewpoints on the use of MCOPS in healthcare. The impact of MCPS in terms of hospital operations, financial, environmental, and social dimensions will help us to understand the viability of MCPS in a real-life setting. This is because the sustainability of healthcare service delivery is the main criteria for its continued sustenance and hence such studies will help to understand the dynamics behind it.

8. Conclusion and Limitation

In recent years MCPS are seeing increased usage in healthcare service delivery. In this paper, an SLR was conducted to understand the impact of MCPS on the key characteristics of health care service delivery, through the published works in the last decade. The main purpose of the review was to identify the existing state of the art information on MCPS and its impact on key characteristics of healthcare service delivery. The literature was classified and analysed on the impact on dimensions classified by WHO. The findings suggest that MCPS may have a positive impact on a) comprehensiveness, b) accessibility, c) coverage, d) continuity, e) quality, f) person-centredness, g) coordination, h) accountability, and efficiency. The limitation of this study is that it represents a theoretical analysis of literature. In addition, only English language literature was considered. It is also limited by the databases considered in this study. This study can be used by the stakeholders while implementing MCPS in the healthcare service delivery system. Besides, healthcare managers can use this study to understand the performance of their healthcare system and use effective strategies by deploying MCPS to be effective and efficient in each of the dimensions of healthcare service delivery.

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Appendix A: Search Keywords		
Part 1	Part 2	Part 3
Health care service delivery Or Health care delivery Or Health care systems Heath care Or Health Or Hospital Or Public Health	Cyber physical system Or CPS Or Medical Cyber Physical System Or MCPs Or CPS for health Or Cyber physical systems for healthcare	Comprehensiveness or Accessibility Or Coverage Or Continuity Or Quality Or Person centredness Or Coordination Or Accountability Or Efficiency