Contextualization of Smart Healthcare: A Systematic Review

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Abstract—*Healthcare today is reliant substantially on innovations in Information Communications Technologies (ICT) that include Internet of Things (IoT) and Artificial Intelligence (AI). Coined as Smart Healthcare, applications for integrated health services has been an integral part of focus for the Smart City initiative globally. Nevertheless, contextualization for a complete definition for Smart Healthcare is still very much obscure. In view of this gap, we conducted a comprehensive examination on the definition of Smart Healthcare via a meta-analysis procedure through systematic review of literatures from: (1) Definitions proposed from literary sources and (2) Smart City frameworks. The goal of this paper is not only to provide a closure for Smart Healthcare but also to provide a unified guideline for developers as well as governments in achieving their Smart Healthcare initiatives.*

Keywords—*Smart Healthcare, Smart City, Smart Healthcare Contextualization*

I. INTRODUCTION

As the rate of urbanization rose exponentially, a new era known as 'Smart Healthcare' has come into existence under the context of Smart City. This is due to immense advancement in Information Technology and the usage of smart devices as solutions to address problems in a city [1]. Smart Healthcare provides a significant foundation for Smart City implementation. Derived from the concept of "Smart Planet" by IBM in 2009 [1], Smart Healthcare concept is an expansion from the digital healthcare concept where the main objective is enabling medical related services to be completely digitized. However, the focus is on a comprehensive digitisation of all aspects in healthcare and to build a foundation with using Internet of Things (IoT). This will in turn enable digitalization or establish smart attributes for health services [2]. As an enhancement from digital healthcare, Smart Healthcare brings bigger contributions to the world. In diagnosis and treatment for example, Artificial Intelligence (AI) is assisting doctors to diagnose hepatitis, lung cancer and skin cancer. Its accuracy is tremendous and it improves treatment outcomes for healthcare professionals [3]-[4]. Another case that can be observed is in the development of teleradiology in healthcare. The technology utilises computers and network connectivity to exchange images and data from one location to another for specialist consultation [5]. Applications of Smart Healthcare does not stop in these two areas alone, but has expanded further and will continue to do so. Electronic medical records, e-health (electronics health), m-Health (mobile health), Hospital Information System (HIS), wireless health and electronic prescription are emerging areas [6]. Even with a vast number of application availabilities, Smart Healthcare is not conformed to a contextual comprehensive definition yet. What we observe are only variations of what practice and there are multiple variations in it. This in result, makes it difficult to determine whether a healthcare solution is completely smart, somewhat smart or not smart at all. Thus, in this study we will propose contextualization of Smart Healthcare services to address this confusion.

II. SYSTEMATIC REVIEW ON SMART HEALTHCARE DEFINITION

A. Definition Gap

A search in Google Scholar with 'Smart Healthcare' as an exact phrase option, will provide more than 20 thousand results (as of July 2021). The number is not surprising as the concept has existed since 2009 [1]. It illustrates the magnitude of research and developments that has been conducted on Smart Healthcare. However, only recently the term has become well known as the health sector propagates its benefits. Even with a vast number of papers available, there isn't any that can provide a comprehensive definition or guideline. Table 1 shows the results of a systematic review that was conducted. In total (n=962) results were obtained for the phrase search for the keyword "Smart Healthcare" AND "definition" from eight major journal databases that included title and abstract search.

Table 1: Result of Smart Healthcare Definition Search in Major Journal Databases

No.	Major Paper/Journal Database	Number of Results (n=962)	Number of Related Result(s)
1.	Emerald Insight	51	None
2.	Springer	662	None
3.	DOAJ	7	None
4.	Science Direct	19	None
5.	PudMed	2	None
6.	IEEE Explore	3	None
7.	SAGE	27	None
8.	Wiley	191	None

Results from Table 1 clearly shows that research or definition proposal for Smart Healthcare definition is almost non-existent academically in highly rated journals. Even when there are some results from the search, none of them are related papers that can be utilized.

This concludes that at the current stage, the gap is very much apparent and almost no conceptualization definition has been conducted thus far. Similar scenario is also observed from credible international bodies that are responsible for global healthcare namely the World Health Organization (WHO) and United Nations (UN). These two entities do not provide nor propose a comprehensive Smart Healthcare definition. The lack of a comprehensive definition from major journals and credible entities indicates that an accepted solid definition is non-existent at the moment.
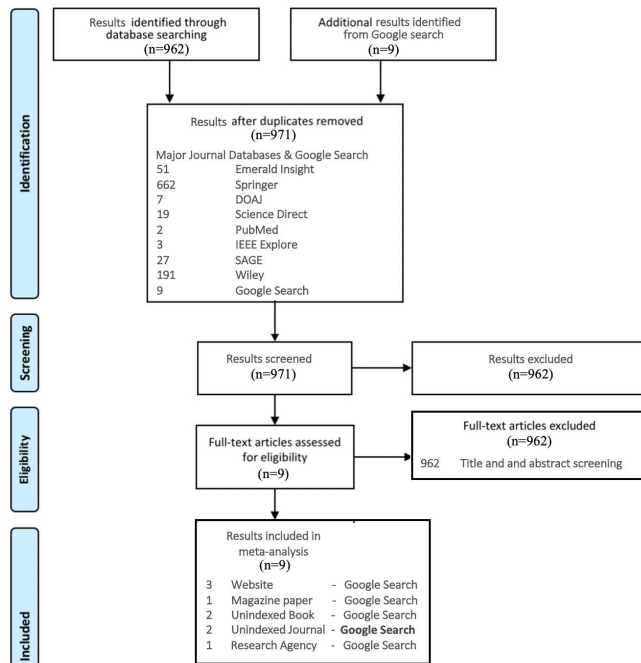
B. Systematic Review Process

Fig. 1.   Systematic Review Process for Smart Healthcare Definition

Overall process of the systematic review carried out in this study utilized PRISMA guideline is presented in Fig 1. It is a guideline that has proven and used in many healthcare related research even in telerehabilitation [7]. Google search was also conducted as were no results that could be used from major journal databases. Google search was useful to search across all unindexed sources from journals, books, book chapters, websites and others, that were not available in major journal databases. Even though these sources are not commonly popular, it provides a scope as to where the direction is for Smart Healthcare in theory and practice. As for the databases, eight relevant ones were chosen with total results obtained with n=962 in which, none of them are relatable or can be used in the screening process of title and abstract. As for the Google search, considerations taken were the definition proposal needs to possess at least three key elements which are: (1) Technological, (2) Healthcare and (3) Smart related.

C. Meta-Analysis on Available Smart Healthcare Definitions

Available resources point more towards self-definitions. Concepts coined by organizations and individuals that are related to providing Smart Healthcare services. Terms were extracted from Google search engine mainly covered non-database search sources such as books, websites, magazines,

conference papers and forums. Several definitions were also obtained from less prominent journals. Even so, the definitions given were always too broad and inconsistent with one another that makes interpretation complex. In a study conducted by [8], Smart Healthcare was defined as technology that leads to better diagnostic tools, better treatment for patients and devices that improves the quality of life for anyone and everyone. The author stressed mainly on technologies to be an enabler for Smart Healthcare, however, it does not mention specifically how it should be coordinated. On the other hand, other studies mentioned that usage of mobile and electronic technologies for better diagnosis, improvement of medical treatment and enhanced quality of lives [9], the study provides a good definition of specific technologies that must be included in the Smart Healthcare context.

[10] stated a short unique definition, where the author states that Smart Healthcare context is where Smart solutions must operate in a completely autonomous environment. As for [11], the author reported that Smart Healthcare should include technologies that utilise Implantable and Wearable Medical Devices (IWMD) together, store and process multiple types of data for daily activities. It may also rely on network connectivity to connect with external resources for better computational/storage abilities [12]. It was reported that Smart Healthcare involves latest digital and mobile devices. While so, these IoT devices should be smart enough not only to predict disease outcomes but also provide actions at the right time. Wearables devices, were highlighted as significant IoT tools with mobile internet to dynamically access information, connecting the people, materials and institutions related to healthcare [1]. Not just that, it also actively manages and responds to medical ecosystem in a smart manner. In this definition, it touches on three technologies which are wearables technology, IoT and mobile internet. Wearable technology falls under IoT while mobile internet falls under network connectivity. Indirectly, the definition also touches on Artificial Intelligence as the decision for response needs learning algorithms that AI possess.

Usage of mobile devices with wearables medical gadgets such as blood pressure monitors and glucometers as well as IoT devices such as implantable sensors to enable continuous patient supervision and treatment from far were also highlighted [13]. Smart Healthcare was also defined as the integration of fragmented healthcare delivery mechanism that utilised electronic patient records and an of array processes [14]. Patient-focused services such as remote monitoring was customised to each need and that had a wider reach. E-Health (electronic healthcare) and mHealth (mobile healthcare) systems, along with connected and intelligent medical equipment as well as policies that support health and welfare of its citizens were necessary [15]. Table 2 shows the literature review matrix for all Smart Healthcare's definitions discussed.

Table 2: Literature Review Matrix for Smart Healthcare's Definition

No	Source	Definition Proposed	Key Points	Limitations/ Comments
1.	[8] Website	Technology that leads to better diagnostic tools, better treatment for patients, and devices	- Usage of technology (unspecified) - Results in better	- Does not mention how will the technology leads

No	Source	Definition Proposed	Key Points	Limitations/ Comments
		that improves the quality of life for anyone and everyone.	diagnostic, treatment and quality of lives	specifically.
2.	[9] Website	Usage of mobile and electronic technologies for better diagnosis, improvement of medical treatment and enhanced quality of lives.	- Usage of technology (mobile/mHealth, electronics) - Results in better diagnostic, treatment and quality of lives	- Other technologies will be missing if the technology is limited to these two only.
3.	[10] Magazine Paper	Refers to solutions which can operate in complete autonomously	-Fully autonomous operations	- Definition is too broad that it can be interpreted in many ways
4.	[11] Book	Smart Healthcare uses technology to utilise Implantable and Wearable Medical Devices (IWMD) to gather, store and process multiple types of data for daily activities. It may also rely on network connectivity to connect with external resources for better computational/ storage abilities.	- Usage of technology (unspecified) to empower IWMD - Usage of technology (network connectivity)	- In general, it is talking on the usage of IoT and network connectivity for Smart Healthcare - Extra context still can be added in making it comprehensive
5.	[12] Website	Smart Healthcare involves latest digital and mobile devices. While so, these IoT devices should be smart enough not only to sense for diseases but also provide actions at the right time. The data then will be stored to be analysed further by healthcare professionals for better diagnosis and solutions.	- Usage of technology (electronics, mobile in term of IoT) - IoT devices to sense deceases and execute appropriate actions - Data storage for further analysis	- It is a good definition that involves IoT and cloud. - Can add further utilisation of Big Data in the cloud and AI for better diagnostic.
6.	[1] Journal (Global Health Journal)	Smart Healthcare uses technology such as wearables devices, IoT and mobile internet to dynamically access information, connecting the people, materials and institutions related to healthcare. Not just that, it also actively manages and responds to medical ecosystem in a smart manner.	- Usage of technology (wearables devices, IoT and network connectivity) - Manage and responds to medical ecosystem - Has the ability to access information, connecting the people, materials and institutions	- Good definition that covers wearables devices, IoT and mobile internet. - Indirectly touches on AI as well as decision made needs learning algorithm.
7.	[13] Journal	Smart Healthcare is the usage of mobile devices with	- Usage of technology (mobile,	- Good definition that covers

No	Source	Definition Proposed	Key Points	Limitations/ Comments
	(PSU Research Review)	wearables medical gadgets such as blood pressure monitors and glucometers as well as IoT devices such as implantable sensors to enable continuous patient supervision and treatment from far.	wearables, IoT) - Continuous and distant patient treatment	medical and mobile devices as well as IoT - Does not mention how smart is defined
8.	[14] Website	Smart Healthcare is the integration of fragmented healthcare delivery mechanism that utilises electronics patient records and array the processes. Patient-focused services such as remote monitoring is customised to each needs and that has a wider reach	- Usage of technology (electronics) - Custom patient monitoring	- The definition focusses on applications rather than what Smart healthcare encompass.
9.	[15] Research Agency	Smart Healthcare is the usage of eHealth and mHealth systems, along with connected and intelligent medical equipment as well as policies that support health and welfare of its citizens.	- Usage of technology (mHealth, eHealth) - Connected intelligent medical equipment - Healthcare support policies	- Definition is narrow with no boundaries of smartness stated.

From Table 2, summary of key points matrix was formed in occurrence frequency format as shown in Table 3 for better understanding of the definition. It has been coded using the key points obtained from the definition provided by the authors.

Table 3: Smart Healthcare Definitions' Key Points

No.	Key Points	Source(s)	Frequency
1.	Usage of technology (unspecified)	[8], [11]	2
2.	Usage of technology (Mobile / mHealth / mobile in term of IoT)	[9], [12], [13], [15]	4
3.	Usage of technology (electronics/eHealth)	[9], [12], [14], [15]	4
4.	Usage of technology (IoT)	[1], [13]	2
5.	Usage of technology (wearables)	[1], [13]	2
6.	Usage of Technology (network connectivity)	[11], [1]	2
7.	Fully autonomous	[10]	1
8.	Utilisation of Implantable and Wearable Medical Devices (IWMD)	[11]	1
9.	Action execution by devices	[12], [1]	2
10.	Data storage for further analysis	[12]	1
11.	Ease of information access	[1]	1
12.	Connected people, materials and institutions	[1], [15]	2
13.	Continuous and distant patient supervision	[13]	1
14.	Custom distant patient monitoring	[14]	1

Examining Table 3, it shows that definition varies from one author to another while some can be too broad that gives multiple interpretations. It should be noted that grey areas in Table 3 indicate items that fall under IoT as a category even though the sectors are different. The areas were shaded to indicate that majority of sources expressed about IoT in Smart Healthcare. From the results gained, there are several patterns, boundaries as well as commonality that can be identified. Firstly, all sources state the usage of technology for Smart Healthcare. Secondly, Internet of Things (IoT) and Artificial Intelligence (AI) were core technologies to enable digitization and digitalization. One main idea that kept arising was the need for minimal human interference or being autonomous. While so, a trend can be observed where several authors state that devices should be able to exert actions from decisions made. The making of decisions can come from two sources. One is the medical professionals and another is from machine enabled decision making using AI. Ability to reason by machines was relevant for smart solutions. In summary, if self-learning algorithms were not put in place then autonomous solutions cannot be regarded as smart solutions. Thirdly, actuators or sensors were relevant in Smart Healthcare or to collate, transfer and compute a predefined function before passing it on for data processing.

Results from Table 2, largely highlights use of IoT devices and large amount of data to be sent for processing to. Large data sets require more processing time. Therefore, a sensor that can process a predefined function, can help to ease operations for the service needed at the right time. This is highlighted as timely response or actions [12]. Fourthly, the server or cloud that handles the data needs should be able to handle multiple source of data types of data with various formats. Majority of the sources from literature review mentioned that smart devices to be used in Smart Healthcare. Therefore, the storage platform needs to be able to handle multiple sources of data. Smart indexing is greatly desired for this process.

Each result obtained from Table 1 to 3 produced several insights that can be constructed into a contextualization. Table 1 shows that an accepted solid Smart Healthcare definition is not yet available at the moment. Table 2 presents various comments and limitations in each of the definitions proposed. It shows that definition without a proper research to obtain it will bring un-unified vision with many loopholes in it. Table 3 on the other hand highlights on the big spread of definitions' key points across the sources. This means that an accepted and comprehensive definition is yet to be available as the difference in the definitions are substantial. Even though there are some similarities in the context such as the use of technology, it is still not enough to makes it whole. With that being said, a conclusion can be made that, a solid as well as comprehensive and accepted Smart Healthcare definition is non-existent at the moment. Table 4 shows the summary of conclusions made on the Smart Healthcare gap existence.

Table 4: Summary of Smart Healthcare Definition Gap Discussion

Item	Item Name	Result(s)	Conclusion
Table 1	Result of Smart Healthcare Definition Search in Major	A total of n=962 literitures screened.	- Solid and comprehensive Smart Healthcare definition is not available at the moment and no reseeach has been conducting it.
	Journal Databases		
Table 2	Literature Review Matrix for Smart Healthcare's Definition from Google search	A total of n=9 resources gained from various sources such as books, magazinesz, companies and others.	- Many limitations and weaknesses were identified in each of the definitions proposed - Majority of the proposed definitions were from authors' own understanding without proper research making results to lose its solidity - Results in Table 2 cannot be used or taken as comprehensive Smart Healthcare definition
Table 3	Smart Healthcare Definitions' Key Points	A of n=14 items were identified.	- Big spread of difference in the Smart Healthcare's definition key points - Results in Table 3 further indicates that accepted comprehensive Smart Healthcare definition is really does not exist at the moment.
Overall conclusion			A comprehensive, accepted and solid Smart Healthcare definition is non-existent. It is clearly shown by lack research papers in prominent journals and diverse spread of definition key points by available sources.
Insights Gained			1. All sources state the usage of technology in Smart Healthcare. Thus, a solution must utilise technology. 2. Internet of Things (IoT) and Artificial Intelligence (AI) will be the core technologies of Smart Healthcare. 3. Sensors in Smart Healthcare needs to be smart (need to be able to minor pre-processed before sending data to cloud). 4. The server or cloud that handles the data needs to be able to handle multiple source of data types of data with various formats.

III. SMART CITY FRAMEWORK – SYSTEMATIC REVIEW AND META-ANALYSIS

In constructing the definition for Smart Healthcare, it is crucial to have a framework as a guideline. It is because, the framework will serve as technological foundation that lays the boundaries. Not just that, due to the fact that Smart Healthcare is a construct under Smart City context, it is only logical that it will follow attributes of what constitutes a Smart City. The framework will give an understanding of what Smart Healthcare characteristics should be or consists of in term of technology related matters. Not just that, a framework will also give boundaries on the specific elements that must be included as well so that it can be considered as smart. Thus, in selecting the best and most suitable one, a thorough systematic review was conducted using the same process for the definition search. For this study, Smart City framework from [16] was selected to be the guideline after careful review for the construction of Smart Healthcare definition as shown in Fig 2. [16] exerted extra highlight in the paper that a Smart City must consist of two elements which are, (1) Learning algorithm and (2) Fully autonomous. These two elements will be made possible by two prominent technologies which are, (1) Artificial Intelligence (AI) and (2) Internet of things (IoT).

AI will give the system ability to learn from data amassed while IoT will make all the devices to be fully autonomous. Table 5 shows the functionality of each layers of the selected framework where it highlights several key points.

They are, (1) The need to have excellent data indexing as there will be hefty amount of data coming in from multiple sources that needs to be accessed and stored in a fast manner. (2) Analytics will be an added value if not a requirement. As big amount of data will accumulate continually through Smart Healthcare devices, the need for the data to be analysed also increased. It is because, it will be a waste of resources if the data were not utilised. Not just that, data analytics will provide better insights on the overall system as well. Overall, the framework was chosen for two main reasons. First, it is the latest and most comprehensive technological framework for Smart City that are available.
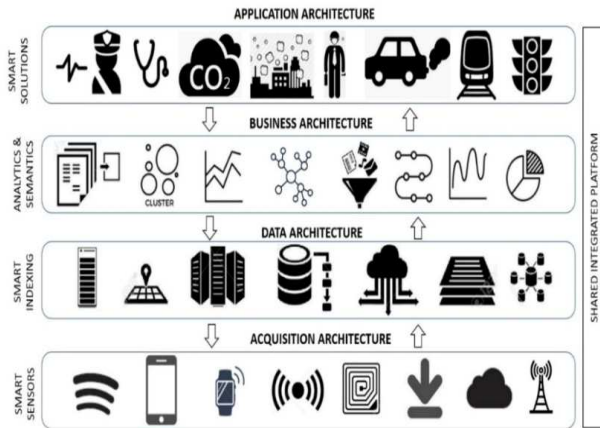

Fig. 2. Overarching Autonomous Learning City (Smart City) Framework by [16].

Other sources have several years in existence since their publication making it less relevant as technology changes rapidly. Secondly, the framework has several research supporting it, or in other words, has its own building blocks making it solid. The framework also covers comprehensive aspects from acquisition up to application architecture. Summary of available literatures of other Smart City architectures are as shown in Table 6 after systematic review.

Table 5: Layer Functionality for [16] Learning City (Smart City) framework

Layers	Functionality
Application Architecture	Present data for service allocation Respond to waste, traffic, carbon emission, health care and surveillance Mitigation responses and decision-making
Business Architecture	Data analytics – prescriptive and predictive Semantic analysis with aided reasoning capabilities Agent learning capabilities supported by autonomous features
Data Architecture	Data acquisition – multiple source Data optimization and gleaning – from structured as well as unstructured data Learning and training algorithm
Acquisition Architecture	Smart readers – feeder for data architecture Smart sensors – feeder for data architecture IoT sensors – feeder for data architecture Smart contracts for participative user network

Table 6: Summary of Literatures from Smart City Architectures

No	Source	Architecture's Layers/Attributes	Limitation/Comments
1.	[17]	1. Smart City infrastructures layer 2. Data storage layer 3. Smart building	- Missing solid technological aspects to achieve Smart City - Missing comprehensive

No	Source	Architecture's Layers/Attributes	Limitation/Comments
		management layer 4. Interface layer 5. Systems layer	criteria set to select best methods or solutions for each layer
2.	[18]	1. Application domain 2. Network domain 3. IoT domain	- The architecture has too few domains that many elements are missing
3.	[19]	1. Large-scale instrumentation 2. Large-scale deployment of a high-speed network infrastructure 3. Efficient management of the aggregated data	- The architecture talks more on general functionality that needs to exist rather than framework and means to achieve it
4.	[20]	1. Infrastructure layer 2. Information layer 3. Service layer 4. Business layer 5. Application layer	- The architecture focusses mainly on mobile applications and services which may not be the solution in achieving Smart City
5.	[21]	1. Device tier 2. Gateway tier 3. Server tier 4. Infrastructure management (plane) 5. IoT experimentation (plane) 6. Smart city service (plane)	- The architecture focusses on IoT that can only be a part the solution in achieving Smart City
6.	[22]	1. City 2. Green city 3. Interconnection 4. Instrumentation 5. Open integration 6. Application 7. Innovation	- Author focusses more on the level of smartness in a city by the framework and not the means to achieve it or the architecture as a guideline.

Table 6 shows the summary of the other literatures reviewed for Smart City. From the Table 6, it can be deduced that none of the authors has achieved comprehensive framework for Smart Cities that consist of the elements such as technological requirement, means or methods to achieve it, functionality of each layers and many more. In general, everyone is building up their own versions of Smart City that creates inconsistency in the work published. Therefore, the chosen framework work as the unifying factor of all vision of Smart City as it possess comprehensive architecture framework, its functionality for each layers, the main prominent technology to achieve.

IV. PROPOSED COMPREHENSIVE DEFINITION AND FURTHER STUDIES

From the overall study conducted, the contextualization for a comprehensive Smart Healthcare definition must compose of these elements, scope and boundaries into considerations. They are shown in Table 7 below.

Table 7: Smart Healthcare Definitions' Contextualization Constituent

No.	Smart Healthcare's Definition Context Constituent
1.	Smart Healthcare solution must be a technological-based
2.	Internet of Things (IoT) and Artificial Intelligence (AI) have be the core technologies of Smart Healthcare (for autonomous and self-learning)
3.	Sensors in Smart Healthcare needs to conduct data pre-processing before sending it off to cloud

No.	Smart Healthcare's Definition Context Constituent
4.	Server/cloud must be able to handle multiple source of data types, from various formats
5.	Server/cloud must have good indexing algorithm
6.	Data analytics is an added value

From the constituents stated, it is now possible to write a comprehensive contextualization definition of Smart Healthcare.

"Smart *Healthcare refers to healthcare services that utilises Internet of Things (IoT) and Artificial Intelligence (AI) as its core. Smart contextually entails the ability to reason from information gathered via machine learning and exert actions autonomously. Intelligent sensors and astute data acquisition platforms support the process to send and receive data using accurate data indexing and analytics methods and thereby enable value creation*".

Ultimately, this study has combined empirical view of Smart Healthcare definition with concrete contextualization with the help of framework with the use of meta-analysis. The definition is comprehensive that it covers the scope, core technologies, boundaries and requirements.

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