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Integrating Wearable Devices and Recommendation System: Towards a Next Generation Healthcare Service Delivery

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Abstract:

Researchers have identified lifestyle diseases as a major threat to human civilization. These diseases gradually progress without giving any warning and result in a sudden health aggravation that leads to a medical emergency. As such, individuals can only avoid the life-threatening condition if they regularly monitor their health status. Health recommendation systems allow users to continuously monitor their health and deliver proper health advice to them. Also, continuous health monitoring depends on the real-time data exchange between health solution providers and users. In this regard, healthcare providers have begun to use wearable devices and recommendation systems to collect data in real time and to manage health conditions based on the generated data. However, we lack literature that has examined how individuals use wearable devices, what type of data the devices collect, and how providers use the data for delivering solutions to users. Thus, we decided to explore the available literature in this domain to understand how wearable devices can provide solutions to consumers. We also extended our focus to cover current health service delivery frameworks with the help of recommender systems. Thus, this study reviews health-monitoring services by conglomerating both wearable device and recommendation system to come up with personalized health and fitness solutions. Additionally, the paper elucidates key components of an advanced-level real-time monitoring service framework to guide future research and practice in this domain.

Keywords: Wearable Health Gadgets, Health Recommendation Systems, Healthcare-monitoring Service, Health Service Delivery, Health Risk Mitigation.

1   Introduction

Society continues to push boundaries in terms of technological progress and societal affluence. However, today's automation-driven urban life has given rise to fresh challenges that themselves have arisen from reduced physical activity, change in lifestyle habits, and higher societal affordability. These lifestyle changes have resulted in a new set of ailments in society (Gupte, Ramachandran, & Mutatkar, 2001) called lifestyle diseases that include ailments such as hypertension, cardiac ailments, diabetes mellitus type II, and hyperlipidemia. Adding to our perils, researchers have projected an average annual rate of change (age-standardized death rate) of +1.1 and +1.3 percent for diabetes mellitus and -5.4 and -5.3 percent for tuberculosis for the entire male and female patient population in the world from 2002 to 2020 (Mathers & Loncar, 2006). World Bank data also points to a decline in deaths from infectious/communicable diseases but a rise in deaths from noncommunicable diseases across the world (see Figure 1) (The World Bank, 2016). This pattern for noncommunicable diseases remains true regardless of a nation's economic condition. As Figure 2 shows, lifestyle disease mortality has escalated into a steeper pattern for low-income brackets.
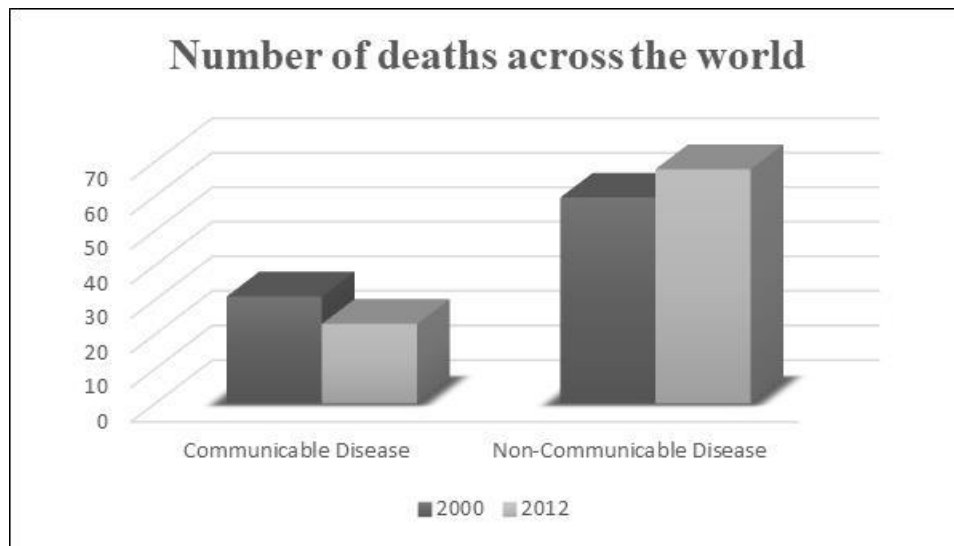

Figure 1. Total Number of Deaths Caused by Communicable and Noncommunicable Diseases (The World Bank, 2016)

We can trace the etiology of these diseases to an unhealthy lifestyle and defective metabolism (Vallgarda, 2011). As such, healthcare providers cannot completely treat these diseases with medicine since the medicine can only help to maintain patient wellbeing. The medication largely depends on the progression level of the disease at a given point of time (Brunton, Chabner, Knollmann, 2011). For this reason, individuals need to continuously monitor themselves to control their condition and to prevent it from turning into something worse (Pantelopoulos & Boubakis, 2010).

Contribution:

This paper focuses on a novel health monitoring service for providing personalized health solutions. We conducted this study due to the limited literature on the use and integration of state-of-the-art technological advances such as wearable devices and health recommendation systems. We provide a comprehensive blueprint for operationalizing such unique service and describe each segment of the service provider by assimilating our current knowledge of medicine, information technology, engineering, and business studies to depict a prospective window for service-oriented business. Our detailed illustration contributes to both academics and practitioners who want to venture into the health-monitoring services domain.
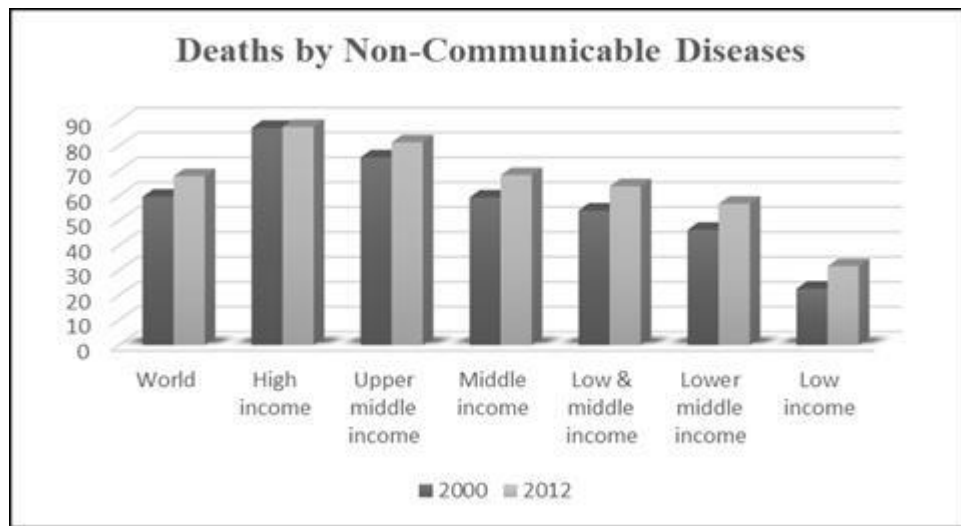
Figure 2. Number of Deaths Caused by Noncommunicable Diseases across Different Income Group Level

The key biomarkers to monitor these lifestyle diseases include measuring the amount of glucose in the blood for patients with diabetes or the pulse rate for hypertension patients (World Health Organization, 1997). In this context, new health-monitoring services have emerged around the world (Jones, Gay, & Leijdekkers, 2010). These services provide expert health advice to anyone who subscribes to them. State-of-the-art technologies such as wearable health devices can also continuously monitor health in real time (Pantelopoulos & Boubakis, 2010). These health devices have already made their presence felt in the market. They provide real-time health status data, which makes it possible for the wearers to self-monitor their health. This self-monitoring factor has made these gadgets extremely popular (Timmerer, Ebrahimi, & Pereira, 2015). Also, these multi-sensor devices can capture different facets of human health and ailment conditions simultaneously, a factor that can help the service provider to also recommend the way forward (Teng, Zhang, Poon, & Bonato, 2008). Anogianakis et al. (1998) have argued that these devices can even provide a timely alarm or pre-signal for the diseases as nine out of ten cases of sudden health aggravation simply represent "neglected" cases by the patient that worsened afterwards. These health gadgets can help individuals mitigate any potential risk of lifestyle diseases via real-time monitoring (Lymberis, 2003). Continuous health metrics data generated from monitoring an individual in real time provides a health service provider an opportunity to suggest real-time health recommendations. In this way, these recommendations rely on the recommender system (RS) information technology (IT) concept. A RS constitutes an appropriate, efficient tool for delivering information depending on user preference (Dao, Jeong, & Ahn, 2012).

We also consider the medical system delivery framework (MSDF) (Weeks, 2013) to understand its current limitations and how one can use RS to expand and augment the MSDF to come up with an improved health recommendation system (HRS). Further, we refer to the integrated service-oriented MSDF (Weeks, 2013; Yao et al., 2014) because it integrates technology as a key component. Although Weeks (2013) and Yao et al (2014) have addressed the technology perspectives in the medical application, they have seldom dealt with the question on how contemporary technology such as recommender systems can broaden the MSDF's scope. Moving in the proposed direction, we increase the extent to which MSDF integrates technology. Thus, we focus on MSDF that augments advanced technology components and identify RS as an IT-oriented information system (IS) to contribute to healthcare service. Primarily, we create a conceptual framework that considers the MSDF literature (Weeks, 2013) and RS theories to expand the scope of HRS. Specifically, we address the following research questions:

RQ1: Can a RS convincingly expand the scope of the MSDF to deliver a better medical/health service delivery?

RQ2: If so, what principal components of this integrated MSDF and RS result in a viable HRS?

RQ3: How should we operationalize this novel HRS with available resources and technology to deliver the health service?

By integrating health-related data obtained from the sensors in wearable health devices and recommendation systems, we suggest a service delivery framework to provide a comparatively new health service for controlling lifestyle diseases. Our research mainly contributes to the literature on health service delivery by conceptualizing and elaborating the present status of this service in the industry with probable future directions.

2   Wearable Health Device

A wearable device refers to a portable communication device that attaches to a Velcro-type strapping system that users can loosen or tighten (Patel, Dalvi, Kuzhiyil, & Tashakkor, 2015). While initial wearable health devices attached to the wrist, they have since progressed to encompass smart glasses (Wiederhold, 2013), smart shirts (Lee & Chung, 2009), and even a wearable hemo-ultrafilter for hemo-dialysis for nephrotic ailment patients (Gura et al., 2008). As one can see, the previous definition does not include these novel wearable devices. However, Pyattaev, Johnsson, Andreev, and Koucheryavy (2015, p. 12) defines wearable devices as "the pinnacle of miniature wireless technology which has allowed the user to carry it inside a wristwatch that can be found typically in a mobile phone". Currently, these gadgets can monitor activity (e.g., walking, running, climbing), enumerate an overall result, and inform users about the total amount of calories they have burned in a particular time period. This information helps individuals to meet a set exercise target. Many of these gadgets also provide recommendations to perform activities based on a pre-planned exercise target.

The wearable health devices market seems to represent a promising business opportunity in today's era. Future projections also suggest that organizations can obtain lucrative opportunities from entering the wearable device market in the developing phase (Park, Choi, & Kim, 2015). Indeed, Hayward, Chansin, and Zervos, (2016) have forecasted the market to reach over US$140 billion by 2026 (see Figure 3).
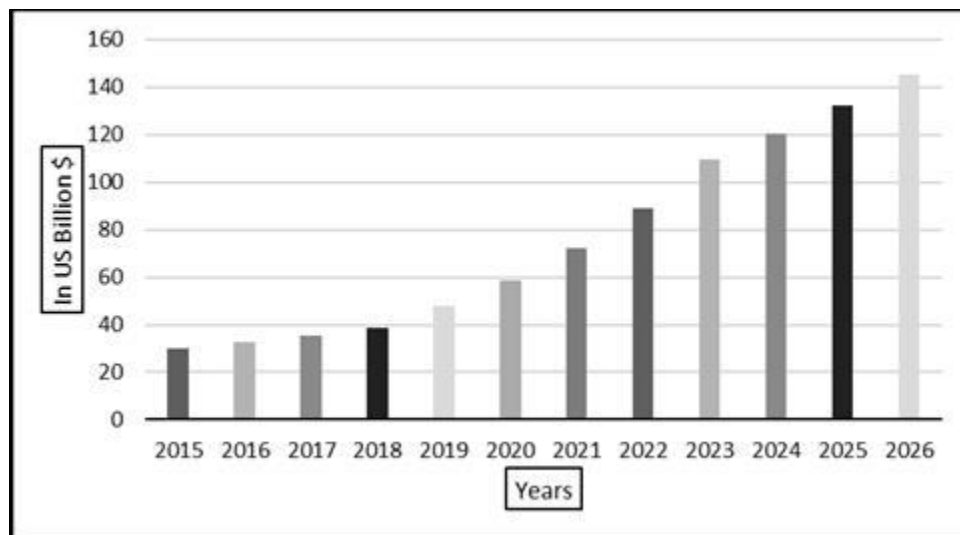

Figure 3. Predicted Market of Wearable Devices (Hayward, Chansin, & Zervos, 2016)

Also, they projected the growth until 2026, and the industry growth pattern shows that it will reach its pinnacle within the span of 2019-2023. Figure 4 captures the growth trend in suggesting a nine percent growth rate for the time span 2015-2018 followed by a boom with a growth rate of 23 percent for the 2019-2023 period and 10 percent growth for 2024-2026. Thus, entering this market may prove a profitable venture for organizations that rely on manufacturing or providing services that use wearable health devices.

Wearable health devices essentially comprise a significant portion (38%) of the entire wearable device industry (see Figure 5).
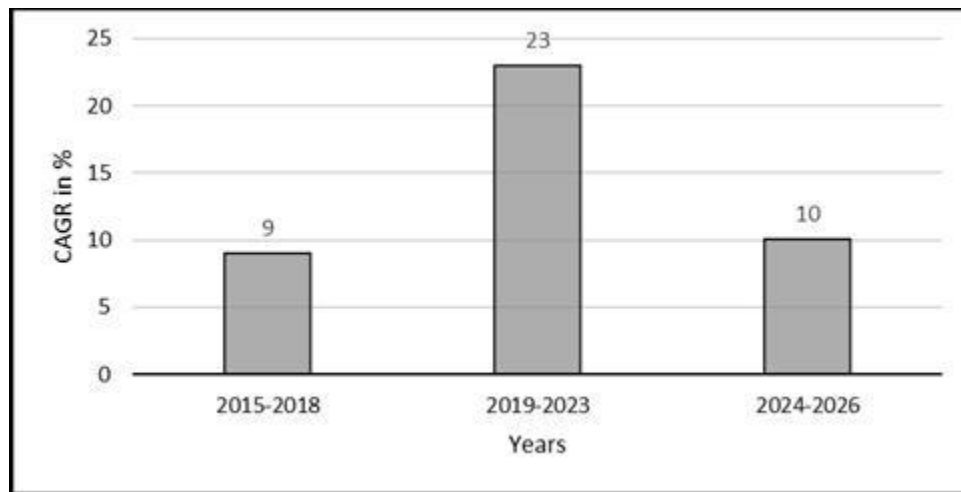
Figure 4. Expected Growth Rate of Wearable Devices (Hayward et al., 2016)
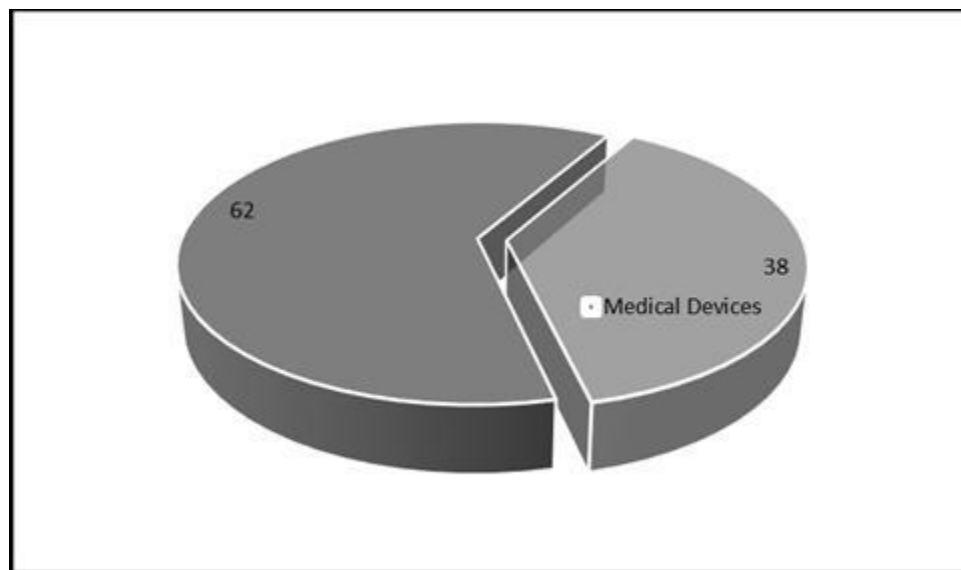

Figure 5. Wearable Devices: Proportion of Medical Devices (Statista, 2016)

The literature contains different kinds of studies in the wearable health gadget domain such as studies that clinically trial newly developed devices (Lee & Son, 2011), studies that compare a device with existing gadgets (Choi & Jiang, 2006), studies that introduce and test novel wearable devices (i.e., prototype studies) (Angius & Raffo, 2008; Cavalleri, Morstabilini, & Reni, 2004), and studies that use human volunteers to pilot wearable gadgets (Davenport et al., 2007). Further, studies use these gadgets to, for example, monitor blood pressure (Lee & Son, 2011; Zheng, Yan, Zhang, & Poon, 2014), ECG (Hung, Zhang, & Tai, 2004; Martin, Jovanov, & Raskovic, 2000), sleep patterns (Angius & Raffo, 2008; Choi & Jiang, 2006), heart rate (Hernandez, Li, Rehg, & Picard, 2014; Walthanawisuth, Lomas, Wisitsoraat, & Tuantranont, 2010), energy expenditure (Almeida, Wasko, Jeong, Moore, & Piva, 2011), vital signs (Lmberis & Dittmar, 2007), and dialysis for kidney diseases (Davenport et al., 2007) and to identify patients or staff members in a hospital.

To understand the current wearable device market, we thoroughly scrutinized existing devices that e-tailing companies such as Amazon, Flipkart, Snapdeal, and so on provide. We found different devices that work with iOS (Apple platform) and Android mobile operating systems (see Table 1). Also, we studied the technological advertisements to identify future wearable gadgets that will be able to monitor health metrics (see future devices in Table 1). An application-oriented paper in *Nature* highlights that such gadgets will have high viability in the commercial market in a short timeframe. The paper mentions a device that monitors monitor blood glucose, lactate, and other necessary blood ions (sodium and potassium) from sweat analysis (Gao et al., 2016). Also, we identified another device that a U.S.-based wearable health device manufacturer company, Gentag, has developed. This advanced device, known as a NFC skin patch, has diverse applications that range from monitoring temperature to serving as a painless diabetic patch.

Table 1. Wearable Gadgets Available on E-tailing Companies

S.N.	Existing devices	Platform	Measure
1	Apple showcases watch	iOS	Fitness tracker
2	Polar H7 Blue Tooth	iOS and Android	Heart rate and Fitness tracker
3	Fii iFever Smart Thermometer	iOS and Android	Temperature
4	Misfit Shine Activity Tracker and Sleep Monitor	Android	Activity and Sleep Monitor
5	Sokos Bluetooth Smart Fitness Tracker Armband | Wristband | Bracelet	iOS and Android	Heart rate and Fitness tracker
6	Philips Health Watch	iOS and Android	Activity, Heartrate, and Sleep
S.N.	Future devices	Source	Measure
1	The wearable sweat monitor	Gao et al. (2016)	Glucose, Lactate, Sodium, and Potassium
2	Gentag smart skin patches	gentag.com/nfc-skin-patches/	Diabetes monitoring

These wearable devices contribute to health-monitoring services. Based on closely scrutinizing the literature, we categorize the wearable health devices we identified as following seven service and technology trends (see Table 2). First, more gadgets focus on recognizing mobile activity than anything else. Many also provide context-aware personal health assistance when individuals need it. Other trends include assisting persons with mental disability, sensory disability, and physical disability (Ye, Malu, Oh, & Findlater, 2014). However, these other areas remain mostly at a nascent stage. In Table 2, we also list the different sensing devices, systems, networks, and practical applications that pertain to each trend.

Initially, wearable healthcare devices largely only provided algorithm-based recommendations based on sensor-captured data to users (Glaros & Fotiadis, 2005). However, as time progressed, wearable devices began to provide recommendations for heart ailments by relying on algorithms, wireless sensor networks, and efficient system architecture. The remote backend completed data processing rather than devices themselves (Yan et al., 2015). Further, although in the last decade wireless sensor networks have developed to support data analysis in the remote backend, it is still insufficient for required interoperability (Gatzoulis & Iakovidis, 2007). To achieve accurate recommendations, wearable devices need to apply contemporary data analytics to user data that devices capture and integrate it with other health systems. Further, in generating these recommendations, such devices need to consider medical information, scientific knowledge, and regulatory bodies have to approve the proposed health service. It appears that, to date, wearable gadgets poorly integrate health recommendations or use them only for fitness purposes. So, to consider health monitoring service as a potential healthcare service, next-generation HRS will require a robust and viable service-delivery model to operationalize it. As such, in this paper, we fill the gap in current literature and practice to come up with a convincing and novel health service delivery framework.

Table 2. Healthcare Service and Technology Trends and their Applications

Service and technology trends	Sensing devices	Systems and network	Applications
Recognizing mobile activity	Wearable devices Wearable displays	Wearable sensor networks. Wearable applications designed to be delivered via smartphones. Large-scale smartphone grids and clouds designed for assistive coordination.	Activity-monitoring devices (walking, working, sleeping, exercising). Lifestyle-improvement devices. Patient/individual localization. Devices that assess life-threating cases.
Providing context-aware personal health assistance services	Smart watches	Wearable applications designed to be delivered via smartphones. Smartphones/smartwatches as personal wearable communication devices. Interaction and cooperation via smartphones. Requirements for augmented context-awareness. Medical assistive devices integrated with healthcare systems.	Ambient-assisted living. Devices that monitor and provide alerts. Devices that assess life-threating cases.
Detecting human-respiration	Wearable sensors	Wearable applications designed to be delivered via smartphones. Specialized devices that can sense human respiration. Medical assistive devices integrated with healthcare systems.	Lifestyle-improvement devices. Devices that monitor and provide alerts. Patient/individual localization. Devices that assess life-threating cases.
Intra-body networks, inter-body networks	Implantable devices Wearable devices	Wearable sensor networks (wireless, on-body, near-body, Internet). System designs that combine wearable features and ubiquity. Medical assistive devices integrated with healthcare systems.	Virtual hospitals. Patient/individual localization. Devices that assess life-threating cases.
Passively sensing and detecting mental health systems	Brain-driven devices (brain signal capturing devices)	Augmentative and alternative communication devices. Smartphone technologies and specialized devices that can sense proper brain functions. Cognitive networks for medical communities.	Lifestyle-improvement devices. Devices that monitor and provide alerts.
Assisting persons with organic defects and disability	Smart/intelligent prosthetics Organ replacement devices (artificial organs)	Wearable sensor networks (wireless, on-body, near-body, Internet). Ambient intelligence-driven system requirements. Usability engineering.	Patient/individual body-driven technology (self-adaptive devices to body's conditions). Devices that detect motion and recognize activity.
Aiding persons with sense disability	Wearable displays Smart audio drivers/amplifiers	Computer-operated I/O devices for persons with disabilities. Wearable applications designed to be delivered via smartphones. Interfaces (explicit, implicit, hands free, speech-based, haptic, context aware).	Devices with services to help persons with sense disabilities (blind, immobile, etc.).

3   Health Recommendation System

Before health-monitoring devices emerged, one could not monitor health metrics and biomarkers in real time. Real-time health monitoring and the provision of medical advice became possible only with the advent of these new technology gadget and systems such as recommendation system (RS). Recommendation systems (RS) are one of the most common applications of IT in recent years (Huang et al., 2015). RS refer to systems that recommend an appropriate product or service after learning a customer's needs (Choi, Kang, & Jeon, 2006). Mavridou, Kehagias, Tzovaras, and Hassapis (2013) define a recommendation system as any system that produces individualized recommendations as output or guides a user in a personalized way to interesting or useful objects in a large space of possible options. Most RS applications include recommending products to the customers (e.g., on Amazon.com) (Linden, Smith, & York, 2003), suggesting movies to watch (e.g., on Netflix) (Koren, 2008) and MovieLens (Miller, Albert, Lam, Konstan, & Riedl, 2003), recommending music to listen to (e.g., on Last.fm and Pandora Radio), and recommending news to read (e.g., on VERSIFI Technologies) (Billsus, Brunk, Evans, Gladish, & Pazzani, 2002).

In fact, most if not all definitions for RS emphasize the ability to choose the best option from a range of alternatives. A health recommendation system (HRS) is a specialization of recommendation systems (RS) (Ricci, Rokach, Shapira, & Kantor, 2011; Wiesner & Pfeifer, 2014). Ricci et al. (2011) and Wiesner and Pfeifer (2014) define HRS as a piece of nonconfidential and scientifically proven medical information system that recommends an item of interest that is not linked to the individual's medical history. However, this definition is not consistent with the accepted definitions for RS in the literature where RS provides personalized advice based on individuals' interests and needs. Therefore, based on the existing definition of the RS and HRS, we provide a more suitable definition. We define a RS as a system that recommends health advice to individuals based on their available health-related data when they face a possible health risk.

Researchers have showed that short messaging service (SMS)-based recommendations for an antidiabetic dose reminder mechanism can effectively remind diabetes mellitus type II patients when they need to take antidiabetic drugs based on a clinical trial of six months (Vervloet et al., 2011). Other researchers have found the same result when they tested SMS recommendations for diabetes with more than 100 diabetic patients who also relied on oral hypoglycemic agents (Vervloet et al., 2012). Schwamm et al. (2017) argue that telemedicine-based reminders can also effectively aid cardiovascular and heart disease patients. Via a clinical trial, Schwamm et al. found support for the fact that real-time medication monitoring (RTMM) can improve quality of patient care, which probably a success predictor of HRS-based monitoring service.

In reviewing the literature on HRS, we can see a trend towards real-time recommendation systems that rely on an individual's personal health metrics. Figure 6 shows how the HRS literature has evolved over time. The figure clarifies how HRS has become an indispensable component of real-time health monitoring, a trend that has culminated in wearable devices with such systems. In 2016, researchers performed a small-scale experiment with eight subjects who wore wearable health-monitoring devices. The researchers then used the data from these devices to develop an HRS (Chakraborty & Yoshida, 2016). Their study bolsters our claim that one needs to integrate HRS with wearable health gadget to make real-time health monitoring service practical and socially implementable. Also, the synchronization of such health gadgets with mobile phones (Android and iOS platform) has given birth to a new dimension, known as mHealth initiatives (Dobkin & Dorsch, 2011). However, in this study, we focus only on real-time health monitoring services that arise when one combines HRS and wearable devices.
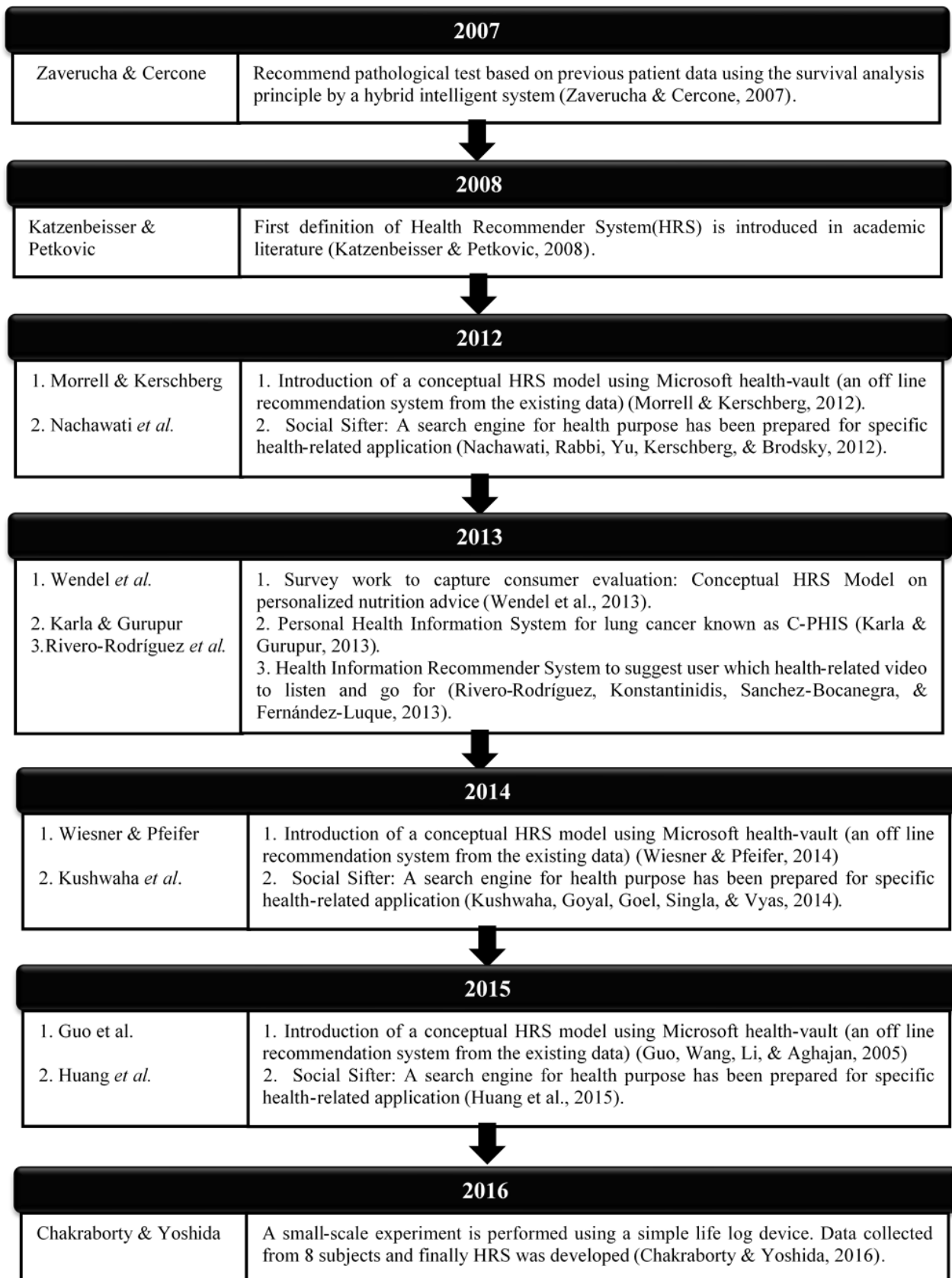
2007	
Zaverucha & Cercone	Recommend pathological test based on previous patient data using the survival analysis principle by a hybrid intelligent system (Zaverucha & Cercone, 2007).

2008	
Katzenbeisser & Petkovic	First definition of Health Recommender System(HRS) is introduced in academic literature (Katzenbeisser & Petkovic, 2008).

2012	
1. Morrell & Kerschberg 2. Nachawati *et al.*	1. Introduction of a conceptual HRS model using Microsoft health-vault (an off line recommendation system from the existing data) (Morrell & Kerschberg, 2012). 2. Social Sifter: A search engine for health purpose has been prepared for specific health-related application (Nachawati, Rabbi, Yu, Kerschberg, & Brodsky, 2012).

2013	
1. Wendel *et al.* 2. Karla & Gurupur 3.Rivero-Rodríguez *et al.*	1. Survey work to capture consumer evaluation: Conceptual HRS Model on personalized nutrition advice (Wendel et al., 2013). 2. Personal Health Information System for lung cancer known as C-PHIS (Karla & Gurupur, 2013). 3. Health Information Recommender System to suggest user which health-related video to listen and go for (Rivero-Rodríguez, Konstantinidis, Sanchez-Bocanegra, & Fernández-Luque, 2013).

2014	
1. Wiesner & Pfeifer 2. Kushwaha *et al.*	1. Introduction of a conceptual HRS model using Microsoft health-vault (an off line recommendation system from the existing data) (Wiesner & Pfeifer, 2014) 2. Social Sifter: A search engine for health purpose has been prepared for specific health-related application (Kushwaha, Goyal, Goel, Singla, & Vyas, 2014).

2015	
1. Guo et al. 2. Huang *et al.*	1. Introduction of a conceptual HRS model using Microsoft health-vault (an off line recommendation system from the existing data) (Guo, Wang, Li, & Aghajan, 2005) 2. Social Sifter: A search engine for health purpose has been prepared for specific health-related application (Huang et al., 2015).

2016	
Chakraborty & Yoshida	A small-scale experiment is performed using a simple life log device. Data collected from 8 subjects and finally HRS was developed (Chakraborty & Yoshida, 2016).

Figure 6. Temporal Evolution of Health Recommendation System (HRS) Towards Wearable Device

4   Framework Overview

We can see that providing real-time health monitoring service to patient populations has both medical and social significance. However, such services can offer correct recommendations (i.e., at the proper time and context) if they have access to complex health data, state-of-the-art service-delivery technology, and the latest information and communication technology resources (Hii & Chung, 2011). Thus, we introduce a service delivery framework for this entire complex scenario and illustrate the disparate frontend and backend components in the process.

To represent the proposed framework, we take a segment-driven service-oriented approach since we focus on understanding and identifying the different segments in an orderly fashion and how they align to one another in the entire health service delivery model (Rispel & Barron, 2010). We picture these segments as different blocks to organize the different components in this health monitoring service. Specifically, we distinguish five such segments (blocks) from the existing theories and elaborate on them.

To attain the theoretical grounding of our framework, we referred to the medical system delivery framework (MSDF) and basic recommender system (RS) theories. These theories form the foundation of our extended view of integrated HRS. We considered recommender systems because they and other similar new technologies can extend the core idea of MSDF. RS fundamentally rely on three principal IT components: input, processing, and output (Garcia-Martinez & Hamou-Lhadj, 2013). In our case, the wearable device and its mobile interface serve as the input function, the remote analysis unit serves as the processing function, and, the recommendation to the patient serves as the generated output. To integrate RS components with various complex MSDF framework parameters, we divided the remote analysis unit into three blocks: information handling, data analytics, and medical recommendation generation.

MSDF has seven major components and we integrated six of them into the framework: disease diagnosis and therapy, servitization, technology support systems, human and sociocultural systems, legal systems, and sociopolitical systems (Weeks, 2013).

Figure 7 depicts our proposed framework's theoretical foundation that we mapped based on the six components of MSDF and three components of RS (Garcia-Martinez & Hamou-Lhadj, 2013; Weeks, 2013). Figure 7 further clarifies how the RS and MSDF components contribute to the health-monitoring and recommendation framework. We represent blocks of our proposed framework in five separate blocks (middle column) in the figure. Specifically, in the framework, blocks 1 and 2—the frontend blocks—serve as direction interaction units with patients/users and offer health services (i.e., diagnose diseases, provide therapy, etc.). Blocks 3 and 4—the IT and computing blocks—basically manage and analyze data in the remote backend. Finally, block 5—the recommendation block—mainly comprises healthcare professionals who give health advice to patients and integrates the human, social, and legal requirement that health service delivery requires. Involvement of different health professionals in block 5 ensure patient acceptability, as most of the patient neither would like to take an emergency medicine on the basis of only machine-generated advice, nor medical regulatory bodies approve this new service to practice in society. A framework without this block would be limited to a health monitoring service for only fitness purposes. Hence, a HRS derived as an extension to MSDF with all these five building blocks connects a basic MSDF with an IT-focused RS.
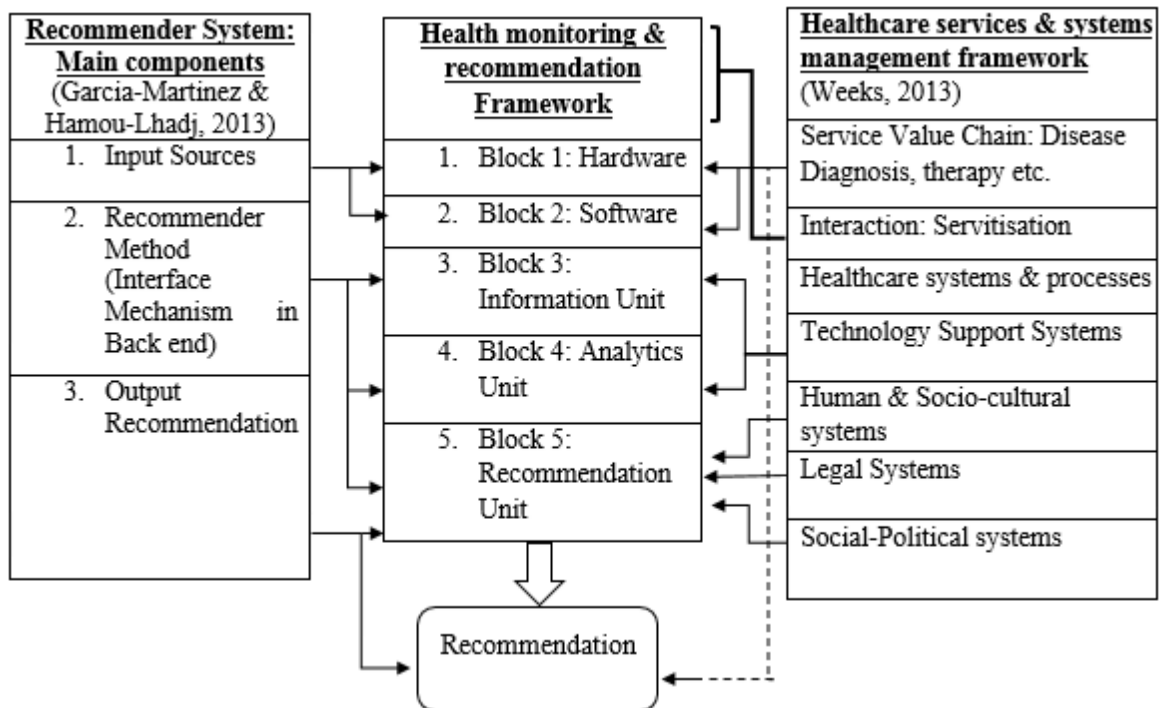
Figure 7. Theoretical Foundation for Blocks of Health-monitoring and Recommendation Service Delivery

Thus, at its core, the framework we propose explains the comparatively new health-monitoring and recommendation service domain. The framework illustrates the software (health recommendation system) and hardware (wearable health devices) involved in such a service at the frontend and shows how combining the aforementioned two technologies can achieve a next-generation pervasive health service. In this study, we build on the health metric and biomedical possibilities for wearable devices that studies have already reported. We use our five-block structure that Figure 8 shows and map the entire delivery process as follows:

- Each block represents a different segment of the service and may exist at a different abstraction level (physically existed and virtually existed). For example, block 1 represents hardware involved in the frontend of the service and block 2 represents software involved in the frontend of the service.

- Each block has some element (i.e., components that can be professionals or hardware and software, but all elements of a block shares some task-related similarity among themselves). For example, block 4 comprises people who have skills and expertise in information technology and data analysis rather than being adroit in the biomedical science like the block 5 professionals.

- Bidirectional flow among the blocks (two arrows) means that data can flow from and to each segment in the service delivery framework and, thus, that all the segments can constantly access the main data source. Unidirectional flow (one arrow) means that one segment has generated output and transferred it to the next one.

- The figure hierarchically depicts the frontend to the backend (i.e., blocks 1 and 2 represent the frontend components and blocks 4 and 5 represent the backend or decision making components).
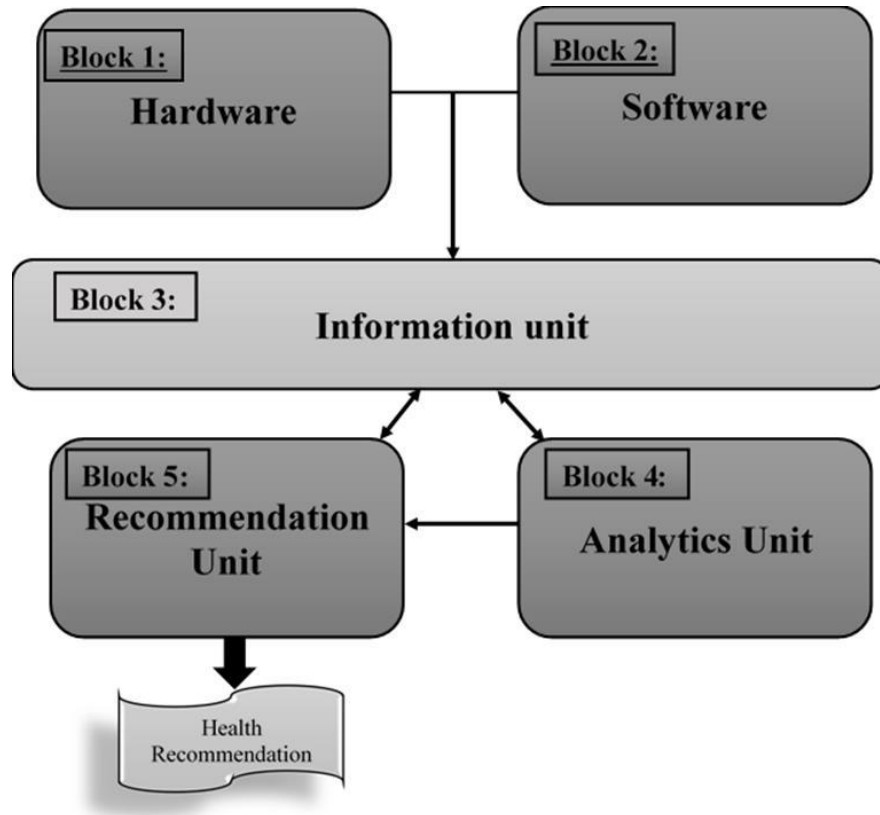
Figure 8. Basic Service Delivery Diagram for a Health-monitoring and Recommendation Service

Table 3 describes the framework and its segments in more detail. The table clearly states each block's elements, objective, and position.

Table 3. Summary of the Blocks for Integrated Health Recommendation Process based on Wearable Device Data

Block	Components	Objective	Position
1	• Smartphone/mobile smartwatch • Wearable device	To collect real-time data from users and send it to the cloud after initially screening it.	Frontend
2	• Android/iOS app • Wearable device platform (e.g., mbed IoT operating system)	To record and store limited period data generated from block 1	Frontend
3	• Cloud • Data server	To store and provide all period data for further analysis.	Backend
4	• Data scientist • Statisticians • Computer and network engineers • Health informatics professionals	To extract and clean the data that algorithms require and help individuals to make decisions with predictive, prescriptive, or descriptive modeling tools.	Backend
5	• Fitness experts • Nutritionists • Pharmacists • Medical practitioners • Health informatics professionals • Other paramedical staff	To analyze the processed data with statistical results while considering users' real-time monitoring context and previous medical history and to come up with a health recommendation.	Backend

Figure 9 expands on Figure 8. It shows how we integrated wearable health devices and health recommendation systems to form an overall monitoring service framework.
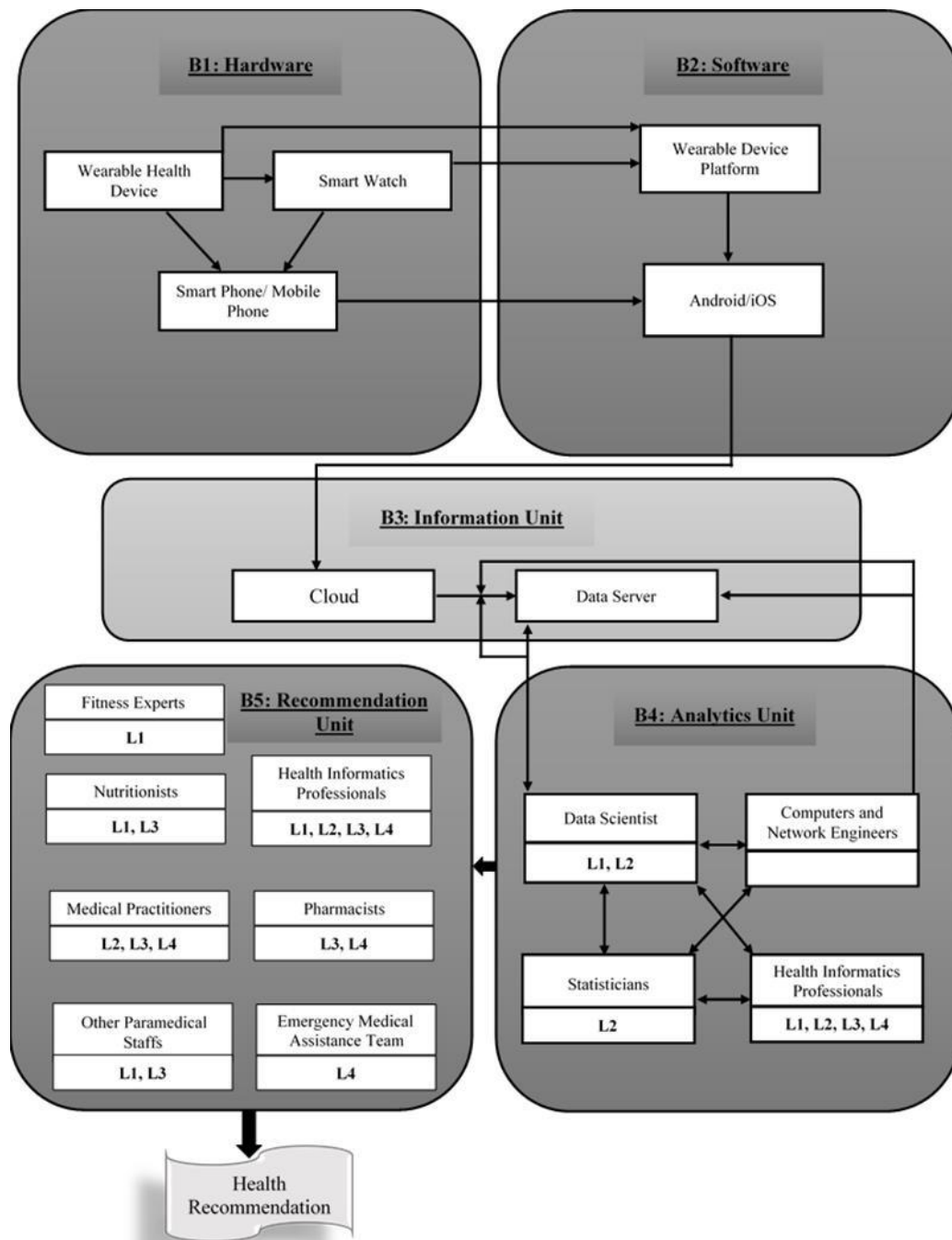
Figure 9. Detailed Framework of Health-monitoring and Recommendation Service

In this framework, the flow of the information and connectivity also represents how the main concepts of the framework deliver the health-monitoring service. The figure depicts the elements of the framework, their relationship, and categorization under a particular segment or block to explain the inter-block subfunctions.

4.1   Blocks and Components of the Framework

4.1.1   Block 1 (B1): Hardware

The hardware involved in the frontend includes the devices that collect data for any individual or patient. Depending on user preference, this hardware can come in various types. However, the main elements in

the block 1 include wearable health devices that collect data and smartphones that use different software platforms and synchronize with each other to serve as a physical device for data collection. Thus, this block contains the following elements:

- Wearable health device: mainly acts as a data-collection device with various sensors.
- Smartwatch: can serve as both data collecting, initial screening and recommendation receiving device depending on the advanced version of the smartwatch (Boletsis, Mccallum, & Landmark, 2015).
- Smartphone or mobile phone: smartphones (Krishna, Boren, & Balas, 2009; Mosa, Yoo, & Sheets, 2012) synchronize with the wearable gadget and serve as a physical device to send data to the cloud (which a health-monitoring service provider provides). These phones also receive the final recommendation from the cloud that the backend surveillance team at the health service provider sends.

4.1.2   Block 2 (B2): Software

Software refers to the user interface operating systems that passes collected data through to the mobile and then to the cloud. Here, we consider only the frontend software and not the computer programs or software that bolsters the analysis and helps the backend team store data, instruct data extractions, and make decisions. Thus, this block contains the following elements:

- Wearable device platform: combines the operating system and software inside the wearable device, records the data, and sends it to the mobile phone it syncs with. It may or may not have the capability to store the generated data that a hardware device's sensors capture. The mbed IoT operating system represents one real-life example of such a platform (ARM, 2016).
- Android or iOS app: depending on the mobile phone operating system platform, a certain number of apps record and store limited period data before the wearable health gadgets transfer it (Obiodu & Obiodu, 2012). They also initially screen the data before sending for further processing. Their screening algorithm reduces the unnecessary information by retaining only the required health data.

Combining blocks 1 and 2, the entire frontend sends data for processing and conveys the recommendation to the user for a healthier life. The data that blocks 1 and 2 send eventually reach block 3.

4.1.3   Block 3 (B3): Information Unit

Block 3, the backend block, stores and provides all period data for individuals who have subscribed to a particular service provider's health-monitoring service. This unit keeps data both in an organized and in unorganized form. Thus, this block contains the following elements:

- The cloud: holds most data for all subscribers for a subscribed period. However, the cloud may encrypt the data for privacy and security reasons (Lane & Schur, 2010). Backend professionals might clean, decrypt, and extract the data via various techniques such as data mining.
- Data server: comprises both meta-data for all subscribed periods and all subscribers that exist in the cloud. It also comprises of the extracted data that were required or requested by other professionals for medical decision making earlier.

The information unit block serves as a digital form of a healthcare service provider organization's medical records department. The data's paperless nature makes it more convenient for highly technologically oriented medical decision making (Detmer, 2003) such as in health-monitoring service organizations (Parente, 2000). Also, the encrypted data that the cloud stores ensures data's privacy and security against hackers or other stakeholders who might be interested to know about a subscribers' personal health data (Ameen, Liu, & Kwak, 2012). Block 3 serves as data reservoir for the backend professionals in blocks 4 and 5.

4.1.4   Block 4 (B4): Analytics Unit

Analytics professionals represent the technological face of any health-monitoring service provider. As such, the professionals in this block require data and information technology expertise. On the whole, this segment extracts data from the cloud, keeps it in an organized form, and prepares meta-data for the future reference so that, on request, it can fetch the necessary information from the cloud. Thus, this block contains the following elements:

- Data scientist: the most versatile human resource for this service industry since they have expertise in all types of data-related exercises, such as preparing data and extracting it via algorithms. They work closely with computer and network engineers who look after the encryption and decryption of data.

- Statistician: have mainly contributed as data analysts for a large volume of data. They can significantly help in data-driven decision making with predictive modeling, prescriptive modeling, and descriptive modeling as and when they need to (e.g., such as when another professional in the health monitoring service asks them to).

- Health informatics professionals: have unique training with biomedical data and often act as an intermediator between the medical team and information technology professionals to bridge the gap of scientific knowledge on both sides, which makes them absolutely essential to all levels of medical decision making.

- Computers and network engineers: they maintain and repair the networking issues from reception to deception (i.e. from storing data in cloud to generating health recommendation). These engineers are information technology professionals who also help data scientists in data mining and in building database architecture to store medical records.

Block 4 mainly deals with data and provides analytics-based recommendations using a particular subscriber's data. This block also forwards the decision and the necessary data to the professionals in block 5 who have better skills and expertise to deliver clinical and nonclinical health advice.

4.1.5   Block 5 (B5): Recommendation Unit

The recommendation unit mainly comprises biomedical professionals and represents the medical face of the organizations that provide healthcare-monitoring services. These professionals finally deliver the medical advice for an individual and include specialist doctors and other paramedical staff who also help patients in case of a medical emergency. Thus, this block contains the following elements:

- Fitness experts: deliver medical advice about healthy living habits and wellness to patients. They often work with nutritionists to help a subscriber to attain a healthy lifestyle.

- Nutritionists: provide both medical and fitness health advice, and, depending on the diagnostics test results, they even advice end-users on their food habits.

- Medical practitioners: physicians who form the heart of the medical team. They provide all clinical advice and nonclinical recommendations about preventing or curing any health indication to patients.

- Health informatics professionals: act as a bridge between blocks 4 and 5.

- Pharmacists: suggest and determine the dose or administration of any medicine that the medical team suggests.

- Other paramedical staff: often contribute to both wellness and clinical advice in case of normal subscribers and emergency medical cases.

Thus, blocks 4 and 5 act as a surveillance backend unit to provide final health recommendation, which the backend forwards to the subscriber's mobile phone. The advice provides a timely signal to end users to take appropriate action and monitor their health.

4.2   Information Flow and Application of the Framework

Wearable devices generate multifaceted data by processing a subscriber's captured health parameters in multiple stages as it passes through the entire service delivery framework. By and large, we can categorize this data into four different classes depending on its utility in the healthcare-monitoring service. Table 4 describes these four categories: 1) activity recognition-related data, 2) health metrics (e.g., blood pressure, heart rate, and sleep pattern), 3) endogenous compound measures (different ailment biomarkers, such as amount of glucose in blood or sodium, potassium, and lactate concentration), and 4) locational information (i.e., a user's global positioning (GPS) data). The table also clearly mentions data types that any backend surveillance team can get from these four aforementioned classes of generated data. Thus, depending on this data, the backend team delivers the aptest clinical or fitness-related health recommendation to individuals.

Table 4. Different Generated Data Types and Their Potential Applications

Data type	Activity	Individual health Metrics	Endogenous Compound Measure	Locational
Technical data	Walking	Heartbeat	Glucose	Global positioning data
	Running	Pulse rate	Sodium	Longitude
	Sleeping	Sleep pattern	Potassium	Latitude
	Exercising	Blood pressure	Lactate	Altitude
Potential applications	Monitoring daily fitness plan routine	Initial diagnosis of any acute lifestyle disease	Instant report on biological endogenous compounds	Locating and recommending medical service providers
	Wellbeing	Monitoring of critical conditions like cardiac ailments Customized insurance plan	Monitor aggravation of illness	Emergency backup

The mobile app platform screens this data send by the wearable device and then the cloud finally stores (block 3) to it (Hii & Chung, 2011). Then, backend professionals (analytics unit professionals) send it to the cloud and organize it inside the data server. The cloud has all a patient's data, while the data server serves as a multi-specialty hospital's medical record department. Since the entire process does not use paper, a health recommendation unit or analytics unit can easily fetch any information they need to make medical decisions and to send a health recommendation. Figure 10 graphically represents the information flow as it passes through different hardware such as the wearable device, smartphone, servers, and so on.
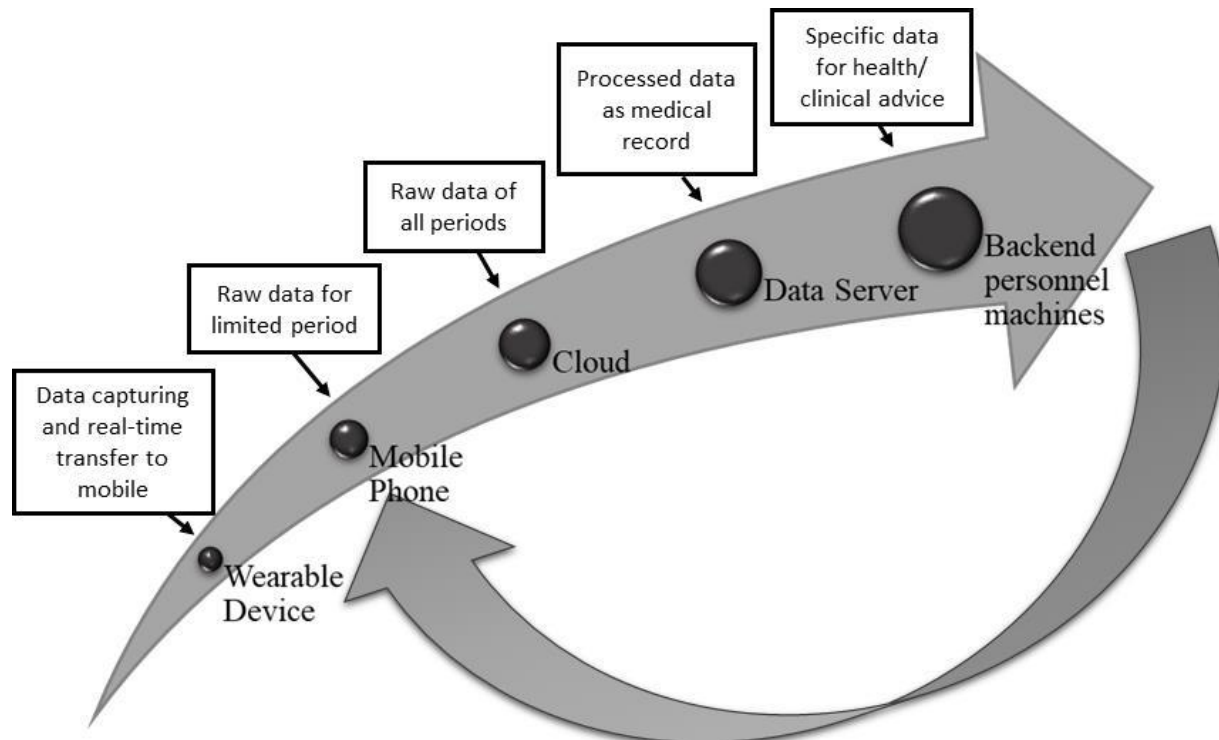
Figure 10. Data Flow Throughout the Network

The four classes of data as Table 4 illustrates and its flow as Figure 10 depicts show the path that a proper health recommendation takes. Depending on the data type and the end user's medical criticality, backend professionals eventually send four types of health recommendation to a subscriber. Cases, which are more therapy centric, often receive a clinical recommendation. We classify these wellness-related suggestions as level 1 (L1) health recommendations. Level 2 (L2) and level 3 (L3) health

recommendations that are mostly based on the health metric data and blood compound amount estimation data. Lastly, level 4 (L4) recommendations represent the most critical health recommendations. They represent a medical emergency, and a backend expert team that comprises specialist doctors handle them. Other health professionals also contribute to level 4 recommendations by tracking both the patient's location and the nearest healthcare service provider in the vicinity. We plot these four types of health recommendations against their medical criticality in Figure 11 with respect to nature of the recommendation (clinical or nonclinical).
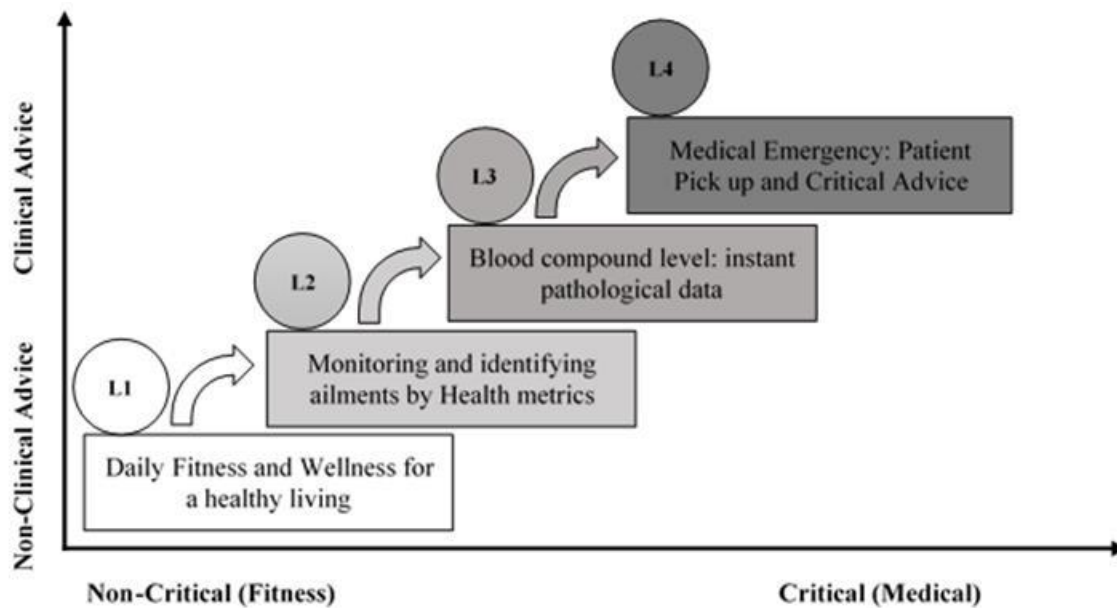
Figure 11. Stages of Health Services (Monitoring and Recommending) with Respect to Medical Criticality

Our proposed service delivery framework takes advantage of wearable gadgets that sync with mobile apps to deliver real-time data to patients about their lifestyle ailments. Thus, our framework can lead to a successful health intervention when an emergency arises. The experts who analyze the data to monitor whether a patient falls into the danger zone will send health recommendations to prevent the upcoming medical emergency. Furthermore, the healthcare-monitoring devices also capture when and where health emergencies occur. This data helps both the patient and healthcare provider organization to deliver the necessary emergency treatment. For example, if a cardiac disease patient receives a recommendation to slow down while walking, it would be a level 1 recommendation. A recommendation for the patient to sit for a while during the patient's morning walk due to the patient's blood pressure level would represent a level 2 type health recommendation. Similarly, a rise in postprandial blood glucose level would trigger a level 3 recommendation for a diabetic patient (Brunton et al., 2011) to take an oral hypoglycemic agent. Finally, in case of sudden health aggravation such as cardiac arrest, a level 4 recommendation would occur. Such a recommendation would include advice about emergency medicines and trigger the health-monitoring service backend team to give the patient's location to avoid the patient's health from worsening further.

4.3 Framework Validation

In this paper, we present a conceptual framework; as such, we still need to fully validate it. However, we developed the framework from pseudo-systematically reviewing the MSDF and RS literature (Ricci et al., 2011; Weeks, 2013). As such, it provides a solid foundation to move forward. As we note in Section 2, while many such devices exist in the market to assess health conditions continuously, the framework we propose differs from others due to a stepwise development in terms of consumers' interaction with data. As Figure 10 notes, the framework allows wearable devices to capture data in real time (similar to many existing devices available in the market) and enables them to transfer it to mobile devices in real time. Since many smart devices already come with these options, we assume the data capturing stage to be validated.

The framework also differs from others in the sense that it allows two data-retention stages—one for a limited period and the other for a longer period—because, in cases such as diabetes and obesity where

the framework would be the most useful, diet plays a crucial role. Our discussions with dieticians and physicians that manage diabetes patients clearly indicated that any conceptual framework should allow for a 14-day diet recovery and a three-month data-retention period because it is wise to maintain blood sugar averages for a three-month period. As such, we built these periodical steps in our framework.

The next stage is the integration of data into medical records. Data-retention stages are emerging slowly due to various regulatory frameworks in many countries and associated data-security aspects. Our framework captures raw data, consolidates it through analytics, and integrates the end result in medical records so that, when physicians, consult with patients, they can provide the appropriate advice. This approach corresponds to way physicians work in many countries and also provides an efficient way to manage chronic diseases. In countries such as India, where diabetes, obesity, and heart diseases continue to increase, physicians alone cannot provide the necessary care because it requires involvement of every health professionals (viz. pharmacists, nurses, healthcare administration staff, diagnostic lab staff etc.). As such, allied health professions such as nurses and dieticians become crucial to manage these diseases. Our framework provides that flexibility.

Our framework also provides personalization flexibility—an important factor in user health management because we need to accommodate so many varieties of individual conditions. To accommodate users' requirements, our framework provides specific data services for clinical advice. As such, the framework enables service providers to maintain and safeguard individuals' data since we can easily segment it, and health professionals will only receive the specific data and analytics that they need. For example, a dietician will be able to access data pertaining to their role and involvement and no other data.

Further, the entire framework matches with operational sequences as Figure 11 shows. It is essential to map conceptual framework with operational sequences in order to attain an efficient model. We conceptualize the five-stage data flow network that Figure 10 shows in a four-stage health service model in which we map the critical and non-critical aspects to clinical and nonclinical advice patterns. As Figure 11 shows, we map the four-stage service model to traditional medical diagnostic, prevention, and treatment procedures.

While we have not yet tested the model comprehensively with user feedback, one should note that we drew it from existing frameworks and it comes with an internal consistency both at in its conceptualization and procedural mappings.

5   Discussion

With our framework, we further integrate technology into the MSDF framework (Weeks, 2013) and extend the boundary of health service management literature. Also, our service delivery framework (Figure 9) enhances the scope of RS applications in the healthcare industry. We address our research questions as follows. First, for RQ1, we show how one can use RS to cater community health needs beyond different traditional and advanced RS systems such as collaborative filtering (CF), knowledge-based (KB), and context awareness-based methods (Lu, Wu, Mao, Wang, & Zhang, 2015; Turoff, Chumer, Starr, & Klashner, 2004). With the help of current HRS, we can observe different monitoring service providers assist to achieve level 1 stage of health monitoring service as referred in Figure 11. Level 1 mainly relates to delivering fitness advice for a healthy person and not a medical advice to a patient in emergency. The framework can, however, suggest that healthcare providers can scale up to level 4 (i.e., medical response recommendation to an emergency patient) and expand the scope of their business. Any service system needs to propose a value for each customer group and clearly identify consumer fragmentation for the service differentiation (i.e., what service to provide for which group) (Alter, 2012). Hence, from the service delivery perspective, our framework clearly advocates what service (fitness, medical, critical/emergency) to provide to each customer segment (healthy living, acute patients, chronic ailment cases) and offers value to each group. As for RQ2, we thoroughly explain the major components of this IT-enabled health service delivery with the aid of Table 3 and Figure 9 and discuss each component in detail. Finally, for RQ3, we describe the operationalization of the health monitoring and recommendation service and explain the information flow in the Section 4.2. However, the mere functioning of a framework does not ensure that it qualifies as a service delivery model.

A "good quality" framework should follow service delivery framework principles (i.e., efficacy, coordination, continuity, participation, and economy) (Blosser & Kratcoski, 1997; Flower, 1984). Our framework meets all these service parameters in the following way:

Efficacy: real-time health-monitoring services definitely help consumers (patients) to counter adverse health conditions.

Coordination: the framework coordinates multiple professionals involved in the service and clearly indicates and segments their contribution depending on their expertise.

Continuity: the service information flow is uninterrupted (see Figure 10). Each service process represents a stage (which we identify as separate blocks).

Participation: individual consumers can have varying needs that range from fitness issues to critical medical issues. Our framework equally caters to both kinds of issues.

Economy: real-time monitoring is a real-time IT enabled process that aid in saving patients' financial resources because they can remain in their home and yet b monitored continuously without occupying bed in a hospital. Also, availing a health monitoring service helps in saving healthcare resources as hospitals or healthcare providers can dedicate the health resource to patients require medical attention and not monitoring/checkup. Hence, resource utilization for healthcare provider goes up and the monitoring service become more economic for the service providers as well. This service is economic because the cost of routine check-up of a post-stroke patient is far higher if he/she decides to get admitted in a tertiary level health organization rather than continuously monitored by the health monitoring service. Health monitoring and recommendation serviceis even more effective because the quality of life of the patient is not compromised as he/she receives medical attention while staying with the family.

Thus, this framework not only builds a connection between a basic MSDF and an IT-focused RS such that it represents an extended MSDF but also caters to patients' needs via integrated HRS technology.

6   Future Scope

Real-time health monitoring remains in an inchoate stage and, as such, will not likely become a standard-quality health service anytime soon. As such, the few players in the current market have a unique first-mover lead in a potentially untapped market. Also, current service providers mostly provide level 1 and level 2 health recommendations, but they do not always coordinate them as well as our framework depicts. As such, one cannot validate the framework until the industry matures to an extent where health-monitoring services emerge as an established and structured service industry like other healthcare services. Additionally, regulatory bodies' regulatory stands always represent a major criterion in the healthcare market to guarantee patient safety. Such standards and regulations for real-time health monitoring remain in the processing stage. As such, future work will have to validate the individual blocks in the framework and the framework as a whole.

As society continues to medically and technologically advance, we will find new wearable gadgets with enhanced functionalities: complex pathological laboratory minions that can "test" sweat (Cooper, 2016), wearable motion chargers that can convert kinetic energy into battery power (AMPY, 2016) and products such as the "Smart Cushion" by Darma for monitoring and recommending changes to individuals' sitting posture (Darma Cushion, 2016). Indeed, these gadgets have brought the health-monitoring service to face a new question: how do we combine this health service delivery with the "Internet of things" for wearable and other gadgets such as the smart cushion to achieve better care?

Future research could also investigate the data security and privacy issues that patients can face while using such services. The United States of America has already started to ensure patient data security with "protected health information" (PHI), which pertains to all companies who provide or handle the healthcare facility or plan to ensure the patient privacy inside the country (Lane & Schur, 2010). However, in the global context, other countries have to concretize regulations to discourage companies from sharing, misusing, or promulgating patient information. Recently, the pharmaceutical and medical devices company Johnson & Johnson (J&J) warned its customers who used its product, J&J Animus OneTouch Ping insulin pump, because it has been hacked (Finkle, 2016). A slight dose or timing change in insulin administration could bring disaster for any patient. Thus, future research could also investigate how to integrate data security in the health-monitoring service framework.

7   Implications

Our research addresses new and emerging healthcare monitoring service. This service framework combines all the fragmented pieces of information about this new emerging business together as a proposition. We amass the current knowledge of medicine, information technology, engineering, and business studies to represent a promising revenue-rich service-oriented business. Given that lifestyle disease incidences continue to rise and the current treatment lines, real-time health monitoring will evidently become important for both patients and healthy individuals if they can use such a service at an affordable and reasonable price. Also, as a health service, its scalability and importance is expected to increase in the future. Thus, the service has a clear and immense potential business value. However, such value does not pertain only to the health service industry; for example, even the manufacturing sector can benefit to a great extent from manufacturing wearable devices. Thus, more specifically, health monitoring and recommendation service by using wearable device shows promise for profitable business for both the healthcare and medical device sectors. Lastly, the involvement of data scientists, health informatics professionals, and medical personals makes the backend team more enriched with scientific knowledge and, hence, versatile and better responsive to any health emergencies. Thus, it provides new avenues for the employment for professionals with interdisciplinary expertise who are trained well in the technology domain. .

8   Conclusion

In this paper, we identify that we can mitigate the health risks that individuals face to a greater extent by combining wearable devices and recommendation systems. We merge these concepts to deliver a real-time health-monitoring service. Practitioners can use our framework to see the entire service delivery model and employ this new health service in practice. This framework combines knowledge of previous literature and current industry insights to come up with five key building blocks that will aid a health service provider to deliver apt recommendations. Moreover, we delve deeper into each of the blocks and state their relative positions in the service delivery model (i.e., frontend and backend). Specifically, we illustrate five blocks: the information block, analytics block, health recommendation block, frontend hardware block, and software component block. We define each element in each block and explain how they interconnect. As a result, we explain how information flows between them and how healthcare stakeholders at each block make medical decisions. The health monitoring service and recommendation framework represents a connected elements and block and structure that finally leads to delivery of the health solution to every subscriber of this service. This paper facilitates understanding of a new and emerging health service and identifies opportunities for latest technologies such as recommendation systems and wearable devices that can be helpful for both academician and practitioners who work in the service management domain. In future work, we plan to further enhance our study by rigorously evaluating and validating the framework in a real business environment.

Acknowledgments

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Appendix

Table A1. List of Abbreviations

Abbreviation	Full form
RS	Recommendation system
HRS	Health recommendation system
ECG	Electrocardiogram
iOS	iPhone operating system
IT	Information technology
SMS	Short messaging service
RTMM	Real-time medication monitoring
IoT	Internet of things
GPS	Global positioning system
PHI	Protected health information
MSDF	Medical service delivery framework

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