

# ADOPTION FACTORS OF HEALTH MONITORING SYSTEMS FOR SMART HEALTHCARE: A SYSTEMATIC REVIEW

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## ABSTRACT

Although there have been several studies that focus on technical aspects of health monitoring systems, adoption of these systems remains largely unknown. A limited number of researches has explored the factors influencing users' adoption of these systems that provide successful system implementation. In this study, we reviewed articles addresses the adoption of health monitoring systems. We extract criteria that influence the adoption decision that has been made at some stage to use health monitoring systems. Then group these criteria into nine categories in terms of cost, ease of use, environment, knowledge, management, security, social influence, subjective norm, technical, usefulness, and enjoyment. By using these criteria, we develop an adoption model for health monitoring systems.

## KEYWORDS

Health Monitoring Systems, Smart Health, Technology Acceptance

## 1. INTRODUCTION

By the technological advances; "smart healthcare" has become a commonly used term in the healthcare domain. Internet of Things, Cloud Computing, Artificial Intelligence, Big Data, and High-Speed Networking are some of the enabling technologies of the smart healthcare concept. Recent advances in these technologies facilitate developing of new health monitoring systems which areas which are the main application areas in smart healthcare concept.

Health monitoring system can be explained by the devices that sense, collect and process the health status of the users and send it to health professionals and central systems for taking preventive actions and making an advanced analysis. These devices can be wearable, mountable or implantable. In the literature, some of the products designed for non-health purposes can be also used as health monitoring systems, since they can deliver healthcare services with the help of their sensing and networking capability. These technologies can be listed as wellness technologies (Misra et al., 2015), smart home applications (Townsend, Knoefel and Goubran, 2011), smart wristbands (Nelson, Verhagen and Noordzij, 2016), robots (Dagioglou et al., 2014).

While health monitoring systems are being deployed in hospitals, houses, and workplace; adoption of these technologies should be addressed for effective use of these systems. All stakeholders in terms of physicians, nurses, technicians, managers, and patients should adopt these systems to leverage the benefits of them. Previous studies show that slow adoption rates of potential users may lead to operation and project failures in healthcare while high adoption rates increase the accuracy and usefulness of health data. Therefore, studies that examine the influencing factors on the adoption of health monitoring systems are needed. In "healthcare information systems" perspective, we found some review studies that synthesize and interpret influencing factors on the adoption of health information systems. However, we are not able to find any systematic review that analyzes and summarize influencing factors more specifically in "health monitoring systems" area.

The purpose of our study is; 1) to review facilitators and barriers to the adoption of health monitoring systems, 2) investigate if there is a trend in the occurrence of the adoption criteria 3) identify most and least addressed adoption criteria among others 4) categorize adoption criteria.

To achieve this aim, we surveyed articles that focus on adoption of health monitoring systems and summarized the criteria addressed in these studies. In our study, we extract criteria mentioned in these studies and classify the criteria into nine categories in terms of cost, ease of use, environment, knowledge, management, security, social influence, subjective norm, technical, usefulness, and enjoyment. We also propose an adoption map that can help to understand the impact of criteria on behavioral intention and usage behavior.

We believe that our findings will show state-of-art of the adoption criteria in health monitoring systems area which is one of the main applications of smart healthcare. Furthermore, this review may help decision makers and academic researchers, working on “smart healthcare”, “digital transformation in health monitoring” or “acceptance of patient monitoring systems” fields, to prioritize levels of effort.

## 2. ADOPTION CRITERIA OF HEALTH MONITORING SYSTEMS

### 2.1 Adoption Criteria Listed in the Reviewed Studies

We found 135 criteria in our literature survey. We found that some criteria address the same concepts although they are defined by different terms. Therefore, we applied a refining procedure to eliminate this repetition regarding similarity and simplicity. In similarity perspective; terms that address similar meaning, are converged to a generic term while maintaining their meanings. In simplicity perspective; adjectives are removed from the terms. After the refining process, the number of criteria is decreased to 74. Refined criteria are listed in Table 1.

Table 1. Adoption Criteria of Health Monitoring Systems

Refined Criteria	Reference
Post-adoption efforts, technical knowledge, common vision, leadership, organizational support, project management, technical knowledge	Yu, Gandhidasan and Miller, 2010
Social influence, usefulness, ease of use, time-saving	Giger et al., 2015
Security, personal attitude, social influence, usefulness, ease of use, behavioral control	Ermakova <i>et al.</i> , 2015
Device performance, ease of use, reliability, confidentiality, economic feasibility	Holekamp, 2017
Technical knowledge, awareness, need, social influence, ease of use, age, gender	Ziefle, Röcker, and Holzinger, 2011
Cost, life quality, ease of use, performance expectancy, social influence	Alaiad and Zhou, 2015
Confidentiality, facilitating conditions, ease of use, performance expectancy	Patrick Ndayizigamiye, 2016
Authentication, user fatigue, cybersecurity, privacy, simplicity, gamification	Bae <i>et al.</i> , 2017
Ease of use, usefulness, reliability	Su, Tsai and Chen, 2012
Technical complexity, privacy, relative advantage, compatibility, data quality, interactivity	Jing, 2016
Initial costs, maintenance costs, return on investment, privacy, technical knowledge	Wallace <i>et al.</i> , 2017
Human interaction	Dagioglou et al., 2014
Technical knowledge, privacy, trust	Dhukaram et al., 2011
Social influence, technical capability, manuals, privacy, ease of use, gender, technical knowledge	Schaar and Ziefle, 2011
Design, data interpretation	Korhonen, Mattila and Vam Gils, 2010

Compatibility, self-efficiency, technical support, technical knowledge, usefulness, ease of use	Su and Gururajan, 2010
Confidentiality, authentication, integrity, access control, security	Acharya, 2010
Privacy, autonomy	Townsend, Knoefel and Goubran, 2011
Integration to daily life, privacy, design	Young Mi Choi et al., 2013
Usefulness, interoperability	Jimenez-Fernandez, De Toledo and Del Pozo, 2013
Legality, organizational support, trust, return on investment, security, safety, improved medical process, real-time data access, time-saving, cost-saving, medical support, resource utilization	Yao, Chu and Li, 2010
Battery life, physical design, technical capability, configurability, data analysis, cost saving, improved medical process, resource utilization	Misra <i>et al.</i> , 2015
Technical capability, ease of use, technical knowledge, terminology, security, privacy, interoperability, portability, ownership, motivation	Alyami and Song, 2016
Interference, effectiveness, standardization, cost, privacy	Yao, Chu and Li, 2010
Motivation, ease of use, performance expectancy, financial risks, technology anxiety, resistance to change, privacy, security	Krishnan, Dhillon and Lutteroth, 2015

## 2.2 Most Addressed Criteria

Yao, Chu and Li 2010, Alyami and Song 2016, Krishnan, Dhillon and Lutteroth 2015 and Misra et al. 2015 contributed to the greatest number of criteria to the literature. Regarding refined criteria, our analysis showed that most addressed criteria are ease of use, cost, ease of use, environment, knowledge, management, security, social influence, technical, usefulness, and enjoyment. The number of occurrences of these criteria is shown in Table 2.

Table 2. Most addressed Criteria

Criteria	# of Oc.	Criteria	# of Oc.
Ease of use	11	Technical knowledge	5
Privacy	10	Usefulness	5
Security	5	Training	4

## 2.3 Barriers and Facilitators

Criteria, presented in Table 1, influence the adoption of health monitoring systems positively or negatively in any stage of usage of these systems. While many of the studies directly classified criteria as “facilitators” or “barriers”, some studies identify them by using as “influencing factor” without addressing their impact direction. However, we believe that to understand the impact of criteria on technology adoption, it is required to define them as “facilitator” or “barrier”.

We categorize each criterion by using metrics such as “good”, “complex”, “high”, “low” and “positive”. Although these metrics are unmeasurable, they indicate the direction of impact. By the assistance of this categorization, we can show the main facilitators and barriers in the adoption of health monitoring systems.

Barriers against the adoption of health monitoring systems are depicted in Table 3, whereas the facilitators are listed in Table 4.

We don’t use any metric for age and gender criteria since there are so many conflicted findings of the impact of age and gender in literature. Based on these findings, age and gender can be considered as both facilitator and barrier. We believe that the context and personal characteristics are the main variables that determine the impact of gender and age on technology adoption.

Table 3. Barriers

Metric	Criteria
Complex	Manuals, terminology
High	Cost, financial risks, initial costs, interference, maintenance costs, resistance to change, security, standardization, technical complexity, technology anxiety
Low	Authentication, confidentiality, cybersecurity, effectiveness, legality, organizational support, post-adoption efforts, privacy, return on investment, security, technical capability, technical knowledge, training, trust

Table 4. Facilitators

Metric	Criteria	Metric	Criteria
Good	Data interpretation, Design, Physical design, Project management	High	Access control, authentication, autonomy, awareness, battery life, behavioral control, compatibility, confidentiality, configurability, cost saving, data analysis, data quality, device performance, ease of use, economic feasibility, facilitating conditions, human interaction, improved medical process, integration to daily life, integrity, interactivity, time-saving, training, interoperability, leadership, life quality, medical support, motivation, need, organizational support, ownership, performance expectancy, portability, real-time data access, relative advantage, reliability, resource utilization, safety, security, self-efficiency, simplicity, technical capability, technical knowledge, technical support, usefulness
Positive	Common vision, Personal attitude, Social influence		
Without Metric	Gamification		

## 2.4 Grouping of Criteria

To facilitate understanding of the influencing factors; we grouped adoption criteria under nine categories based on their similarity. These groups are cost, ease of use, environment, knowledge, management, security, social influence, subjective norm, technical, usefulness, and enjoyment. We believe that the level of abstraction and segmentation is balanced by using such a grouping methodology. Detailed information about the groups are described as follows:

**Cost:** It includes the factors related to expenditure during owning, delivering and maintaining the system and savings after installation. In our study, economic feasibility, cost expectancy, perceived financial risk, return on investment, cost saving, initial costs, maintenance costs are grouped under “cost” construct group. Factors listed under the “cost” group are addressed 10 times (mentioned %7 of the time) in the reviewed studies.

**Ease of use:** It includes the factors that make use of the required features of a system with less effort. In our study; perceived ease of use, simplicity, complexity, terminology, portability, integration to daily life, design, manuals, human interaction are grouped under “ease of use”. Factors listed under the “cost” group are addressed 20 times (mentioned %15 of the time) in the reviewed studies.

**Environment:** In our study, facilitating conditions and legality are grouped under “environment”. Members of the group are listed only 2 times (mentioned less than %2 of the time) in the reviewed studies.

**Knowledge:** Knowledge refers to the information and skills of a user which are acquired through experience or education. In our study; training, awareness, and vision are listed in this group. Members of the group are listed 10 times (mentioned %7 of the time) in the reviewed studies.

**Management:** It can be related to organizational efforts, attitudes of the managers or the initiatives of decision-makers in an organization. In our study; post-adoption efforts, leadership, organizational support, project management, ownership, and technical support are grouped under “management”. Members of the group are listed 8 times (mentioned %6 of the time) in the reviewed studies.

**Security:** Factors that can raise security concerns in users and managers are group under this category. Theft of user records, cyber-attacks, authentication qualifications of the system or any threat that make the system unfunctional may be the reasons for these concerns. In our study; privacy, confidentiality, authentication, legality, safety, cybersecurity criteria are grouped under “security”. Members of the group are listed 22 times (mentioned %16 of the time) in the reviewed studies.

**Social Influence:** Views, attitudes, and behaviors of the individuals in the neighborhood on the use of system have impacts on system users. Therefore, any factor that may be the source of this impact is classified under “Social Influence” group. Common vision, word of mouth, social contacts, social pressure are grouped under “social influence”. Members of the group are listed 6 times (mentioned less than %5 of the time) in the reviewed studies.

**Subjective Norm:** Factors mentioned in this group are related to the characteristics, values, knowledge level and other personal features of a user. Lack of vision, training, attitude, norms, interest, awareness, age, gender, motivation, technology anxiety, resistance to change, digital skills, expertise, and technical knowledge are grouped under “subjective norms”. Members of the group are listed 22 times (mentioned %16 of the time) in the reviewed studies.

**Technical:** Most of the criteria listed in the reviewed articles belong to the technical group. Performance, reliability, simplicity, technical complexity, compatibility, data quality, interactivity, interference, effectiveness, standardization, trust, real-time data access, battery life, design, technical capability, configurability, data analysis, capability, terminology, interoperability, portability, autonomy, integration to daily life, manuals, authentication, integrity, access control, data interpretation and human interaction level are grouped under “technical”. Members of the group are listed 37 times (mentioned more than %27 of the time) in the reviewed studies.

**Usefulness:** Perceived usefulness, time-saving, need for medical operations, life quality expectancy, performance expectancy, improvement of medical operations, resource utilization and usability are grouped under “usefulness”. Members of the group are listed 17 times (mentioned %13 of the time) in the reviewed studies.

**Enjoyment:** Factors mentioned in this group are related to the impacts to which the users deem the technology used as a fun experience regardless of outcome (Davis et al). User fatigue, Gamification and Motivation are listed under “Enjoyment”.

The number of occurrence of criteria per group and the percentage of the groups is depicted in Table 5. It is shown that technical, security and personnel are the most addressed groups in literature. Least-mentioned groups are environment and social influence.

Table 5. Number of Occurrence of Criteria Per Group

Criteria	2010		2011		2012		2013		2014		2015		2016		2017		Total	
	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%	# of Oc.	%
Cost	3	8	-	-	-	-	-	-	-	-	3	12	-	-	4	25	10	7
Ease of use	2	5	2	11	-	-	1	20	1	100	-	-	-	-	1	6	7	5
Enjoyment	-	-	-	-	-	-	-	-	-	-	1	4	1	4	2	13	4	3
Environment	1	3	-	-	-	-	-	-	-	-	-	-	1	4	-	-	2	1
Knowledge	3	8	3	16	-	-	-	-	-	-	1	4	3	11	1	6	11	8
Management	6	16	-	-	-	-	-	-	-	-	-	-	1	4	-	-	7	5
Security	8	22	4	21	-	-	1	20	-	-	3	12	4	14	5	31	25	19
Social Influence	-	-	2	11	-	-	-	-	-	-	2	8	1	4	-	-	5	4
Subjective Norm	1	3	4	21	-	-	-	-	-	-	1	4	3	11	-	-	9	7
Technical	6	16	1	5	1	33	1	20	-	-	5	19	8	29	2	13	24	18
Usefulness	7	19	3	16	2	67	2	40	-	-	10	38	6	21	1	6	31	23
Total	37	100	19	100	3	100	5	100	1	100	26	100	28	100	16	100	135	100

## 2.5 Barriers and Facilitators

It is revealed that most of the barriers shown in Table 3 are related to cost and security issues. The percentage of security-related criteria among barriers is %48, while the percentage of security-related criteria is %16 among all type of criteria. Similarly, the percentage of cost-related criteria among barriers is %19, while the percentage of cost-related criteria is only %7 among all type of criteria. In addition, none of the criteria listed under the social influence are mentioned as a barrier in the reviewed studies.

It is found that the positive impact of criteria listed under the usefulness and technical is higher than the other groups. In addition, the percentage of the criteria belongs to these groups is %55 among facilitators, while the percentage is %12 among all barriers. Note that, the analysis described in this study may change if the metrics of the criteria would have defined in opposite direction. Our analysis is shown in Table 6.

Table 6. Percentage of Groups as Barrier and Facilitator (\* Age and gender are not defined as barrier or facilitator)

Criteria	Barrier		Facilitator		Total	
	#	%	#	%	#	%
Cost	7	17	3	3	10	7
Ease of use	2	5	5	6	7	5
Enjoyment	1	2	3	3	4	3
Environment	1	2	1	1	2	1
Knowledge	4	10	7	8	11	8
Management	1	2	6	7	7	5
Security	20	48	5	6	25	19
Social Influence	-	-	5	6	5	4
Subjective Norm	1	2	5	6	9	7
Technical	4	10	20	22	24	18
Usefulness	1	2	30	33	31	23
Total	42	100	90	100	135	100

### 3. ADOPTION MAP FOR HEALTH MONITORING SYSTEMS

Based on the criteria mentioned above, we developed an adoption map that presents the potential relations between factors. The adoption map is presented in Figure 1. Although much research has been done on developing technology adoption models such as TAM (Davis, 1989), TAM-2 (Venkatesh and Davis, 2000) and UTAUT (Venkatesh et al., 2003), our adoption map is a conceptual representation of the adoption factors mentioned in surveyed articles addressing health monitoring.

Arrows, depicted in the adoption map, show the potential impacts between factors, behavioral intention, and usage behavior. Arrows are shown as bi-directional since each criterion is a potential influencer of another one. “+” and “-“ symbols depicted on the arrows indicate “positive” or “negative” impacts of criteria. Although most of the factors generally influence use behavior indirectly, some of the factors may influence use behavior directly. This relation is shown by the relation between the two “influence” point.

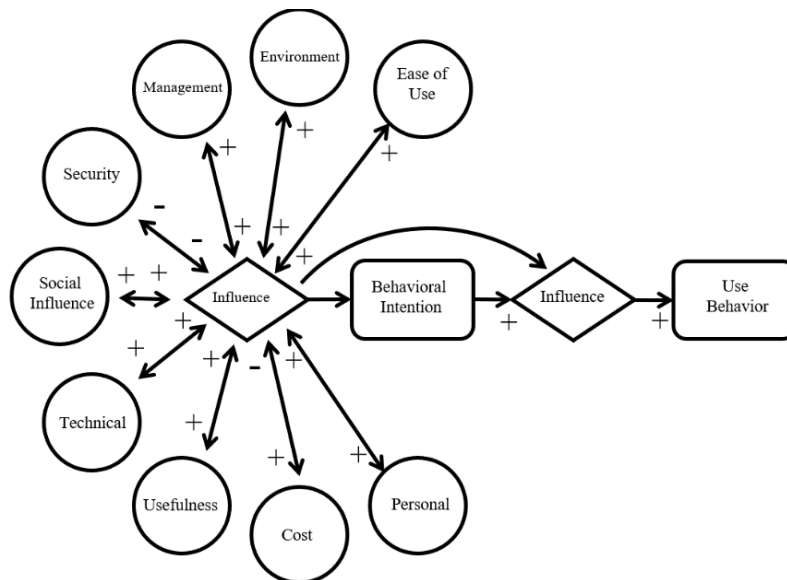


Figure 1. Conceptual Adoption Map for Health Monitoring Systems

## 4. DISCUSSION AND CONCLUSION

In this study, we reviewed articles that address adoption of health monitoring systems. We extracted criteria from the articles, summarized them as barrier and facilitator and classified them into nine categories. Usefulness, technical and security were found as the most addressed criteria in the articles. On the other hand, environment criteria were found as the least addressed article in our study. It was found that cost is not the main barrier while technical and security-related issues remain as the main factors that influence technology adoption in healthcare information systems, which was also mentioned in (Cicibas and Yildirim, 2018)

In this research, an adoption map is developed for the health monitoring system. We believe that such a map would assist to understand the factors that influence technology acceptance and usage decision. The findings of this study would serve as a guideline for solution developers while understanding the state-of-art of technology acceptance in health monitoring systems.

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