Untangling the Complexity of Connected Health Evaluations

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***Abstract*—Societal changes are forcing us to reconsider how healthcare is delivered and ICT can support this reimagining of healthcare delivery. One of the emerging trends in this area is Connected Health. However, the evaluation of Connected Health technologies is crucial to assess whether their implementation has had a positive impact on healthcare delivery. To support this assessment process, we developed, an exploratory framework for the evaluation of Connected Health technologies in healthcare settings.**

This framework was developed after having critically appraised the existing findings of health information system evaluation studies. It also builds on previous models of Information Systems evaluation, in particular, the Information Systems Success Model. Our framework incorporates the concept of assessment from multiple perspectives. Furthermore, the framework identifies the primary stakeholders and extends the assessment based on their concerns.

Finally, we elaborate on the framework, detailing its application to a Connected Health solution for primary care based dementia patients in Ireland.

I. Introduction

Societal and demographic changes internationally, coupled with economic challenges, forces reconsideration about how we deliver health and social care in our community [1]. This includes the challenge of providing care to older people through alternative methods. Over the past 30 years, in all OECD countries, there has been a dramatic increase in the populations aged 65 years and over [2]. In addition, due to longevity, people over the age of 85 are the main users and place the biggest demand on health services. In addition, healthcare places considerable financial burdens on the public purse. Health expenditures are noticeably higher in countries where there are stronger primary care structures [3], placing what the World Health Organisation [4] describes as the growing need for homecare in Europe as prominent in health care systems. Consequently, there is a growing demand for care to be delivered closer to the patients home [5], causing additional pressures on home family carers to act as principal healthcare providers [6]. This is a challenge to health and social care systems globally [7], and healthcare services delivery, particularly for long-term conditions (LTC), needs to be radically reformed.

ICT can play a critical role in supporting this reform of healthcare delivery. And one of the biggest emerging trends in this area of Health ICT landscape is Connected Health [8]. Connected Health encompasses terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed around the patient's needs. Health related data is shared in such a way that the patient can receive care in the most proactive and efficient manner possible. All stakeholders in the process are connected by sharing and presenting accurate, timely and pertinent information regarding patient status. This is achived through smarter use of data, devices, communication platforms and people [9].

Considering the growth in the emerging field of Connected Health, it is pivotal that comparative studies identify the benefits of Connected Health over traditional healthcare delivery models. Such comparative studies should examine benefits from a number of different perspectives including healthcare modelling, technological innovation and assessment methodologies.

By delaying the point where people require help with daily living activities, Connected Health technologies and services may have significant economic and social impact on assisted persons, their families and caregivers, health service providers, and society as a whole. Regardless, the distribution of Connected Health is limited. Most of the European Connected Health projects have failed to accomplish real progress in the adoption by Health Providers and to create a body of evidence to support Connected Health adoption.

Limited adoption of Connected Health type technologies may partly be attributable to the considerable resources needed for implementation [10]. Further, evidence is lacking about how Connected Health technologies impact users and other stakeholders [11]. There is also limited evidence as to what are the best practices for assessing impact [11]. Therefore, to support adoption of Connected Health an evaluation model is needed.

The aim of this paper is to untangle the complexity of Connected Health evaluations. Therefore, we propose the following research question: *How can we holistically evaluate the impact of Connected Health technologies from different stakeholder perspectives?*

We adopted a three-phased research approach to address this question. In the first phase, we drew from the extant literature on Health and Information System Evaluation to derive an explanatory framework of factors in a Connected

Health evaluation. The resulting framework can be used by organizations to assess the extent to which these factors are in place. During the second phase we held a workshop in which Connected Health practitioners participated. In the third phase, we analysed the application of the framework in an industry case study on a Irish Connected Health deployment. This provides us with a rich description of how these factors can be seen in practice.

II. Related Work and Background

Evaluation is performed to improve Health Information Systems (HIS) by learning from the experiences and identifying more effective ways to improve systems [12].

A review of the literature revealed that while specific instances of the evaluation of Connected Health exist [13] [14], there is no evidence of generic Connected Health evaluation models that have been successfully implemented and applied across the area. Therefore, we have looked within the Health Information Systems literature for evidence of evaluation of technology in healthcare.

Factors that affect evaluation include organization factors and human factors. Human factors include a range of issues like training, personnel attitudes, ergonomics (the study of people's efficiency in their working environment) and regulations affecting employment [15]. Organisational factors relate to the nature of the organisation, its structure, culture and politics affect an evaluation [15].

Approaches to HIS evaluation have been developed for a variety of domains considering the various technical, sociological, economic, human and organizational requirements. These frameworks have been explicitly designed to be used for Health Information Systems evaluation. These various frameworks are as follows.

The 4Cs framework is developed from the Social Interactionist Theory, which stands for Communication (interaction within department), Care (medical care delivery), Control (control in the organization), and Context (clinical setting) [16]. CHEATS is a generic framework for evaluating IT in healthcare that has six evaluation aspects: Clinical, Human and organizational, Educational, Administrative, Technical and Social [17].

The TEAM (Total Evaluation and Acceptance Methodology) is constructed based on systemic and model theories [18]. It has three categories: Role, Time (evaluation phase) and Structure (strategic, tactical, operational management level).

Overall, these frameworks evaluate different aspects of HIS. However, these frameworks do not provide a unified approach to evaluation. To move closer to a universal starting point, we must look outside of the Health Information Systems literature.

A. The IS Success Model

In order to organise research on success categories for Information Systems, a comprehensive taxonomy was introduced by DeLone and McLean (see Figure 1) [19]. The model consists of six success categories that are linked causally and temporally as success is viewed as a dynamic process instead of a static state. The multidimensional relationships among the measures of IS success were tested extensively in a number of IS studies [20].

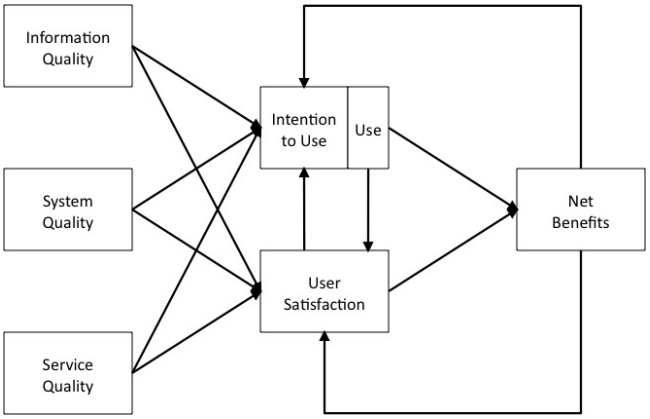

Fig. 1. Information Systems Success Model

Later, this model was self-evaluated and the dimensions modified were Information Quality, System Quality, Service Quality, Use, User Satisfaction, Net Benefits [21].

Out of 40 papers, we identified, referencing evaluation of health technology, the DeLone and McLean model of IS Success (original and updated) ([19] and [21]) is used by 7 studies as a basis for their research. It is furthermore the case that our research and analysis did not identify an alternative model to that proposed by DeLone and McLean that has been adopted by more than a single related research endeavour, thus supporting the decision taken by this research to adopt the DeLone and McLean model as a solid foundation.

B. Why DeLone and McLean

The literature identified a trend of modifying the DeLone and McLean model for particular studies in order to derive context specific evaluation frameworks (examples include [22] [23] [12]). From the literature, we can see that the DeLone and McLean model of IS Success dominates the health evaluation literature. This leads us to consider that the original dimensions were considered important for evaluation.

The IS Success model provides a holistic view of success and can address both the technical requirements (accurate, timely and available); and the more recent requirements, that data be fit for use. In essence, the IS Success Model proposed that increased *User Satisfaction* will lead to a higher intention to use which ultimately affects *Use*.

By adopting the IS Success Model, we can identify the key success factors for Connected Health though a holistic evaluation framework. Further motivation for choosing the IS Success Model was its comprehensive, specific evaluation categories, extensive validation and its applicability to HIS evaluation. It is the model of choice for inclusion in a Connected Health evaluation framework but research will have to be conducted to assess its impact across the broad spectrum of systems.

TABLE I
WORKSHOP PARTICIPANTS

Organisation	Type	Number of Participants
S3 Group	Technology Provider	1
Vu2Vu	Technology Provider	2
Enterprise Ireland	Societal	2
Vitalograph	Technology Provider	1
Two-Ten Health	Technology Provider	1
University College Dublin	Academic	6
Resmed	Technology Provider	1
ADA Security Systems	Technology Provider	1
Hermitage Medical Clinic	Service Provider	1
University Hospital Limerick	Service Provider	1

III. RESEARCH APPROACH

We followed a three-phased study to address our research question. In the first phase, we derived a framework from the literature (see Section III-A). In the second phase, we conducted an industry workshop with Connected Health participants' (see Section III-B). In the third phase, we applied the framework in an industry case study. We deemed a case study methodology appropriate since it provides a real-world case that illustrates how the framework can be used as a tool to organise and structure a Connected Health evaluation. Details of the case study design are presented in Section III-C.

A. Phase 1: Literature Review and Expert Input

A framework is useful to synthesize previous research in an actionable way for practitioners [24] which is why we deemed derivation of a framework a suitable approach to address our research question.

We first identified all relevant reports (case studies, experience reports) on the evaluation of health technologies. Given the nascent state of the connected health area as a field of research, we deemed a systematic literature review unsuitable. For the framework derivation, we adopted thematic synthesis, following the steps recommended by Cruzes and Dyba [25].

Concurrent to the review of the literature, expert opinion from the Clinical Audit Lead in the University Hospital Limerick was integrated. The Clinical Audit Lead is responsible for evaluating the success of information systems across eight regional hospitals.

B. Phase 2: Industry Workshops

We refined the initial framework based on feedback from an industry group. This industry group represented our expert users. The selected participants' were industry professionals with a large amount of practical experience in the Connected Health domain. We list these participants' in Table I.

We held two workshops with the industry participants' during which we presented and discussed the framework. Prior to each workshop we circulated an initial version of the framework. Then during the workshop, the framework was presented and discussed. The model was discussed amongst the group until a consensus was formed and the model was revised. After each workshop we returned to the literature and based upon the expert revisions and secondary research, iteratively developed the framework. A second person captured the feedback while the primary researcher debated the framework. The participants' were all working in the Connected Health space. Based on the feedback from the initial workshop, we refined the framework. This refined framework was presented to the industry participants' one month later.

C. Phase 3: Application of the Framework

The objective of this research was *to investigate how our framework for Connected Health evaluation could be used in a real world setting*. To that end, we conducted a case study. Case studies are appropriate to answer how or why questions, and to study a contemporary phenomenon within its real-life context, in particular when the boundaries between the topic of study and its context are not clearly evident [26]. Given the fact that very few studies of evaluation in Connected Health exist, the case study can act as a useful revelatory case [26].

1) Background to the case: The centre for Applied Research for Connected Health (ARCH) is an industry led Technology Centre.[1] ARCH was established in March 2013 in Ireland and is hosted in University College Dublin (UCD) with researchers also based in Lero, the Irish Software Engineering Research Centre in University of Limerick (UL) and the Health Economics team within Research Triangle Institute International (RTI), North Carolina, U.S.A. ARCH is led by a consortium of companies operating in the Connected Health sector. The ARCH research agenda is driven by the requirements of its Industry Partners and it is expected that research outputs will be commercialised by these companies.

ARCH has developed an end-to-end platform for industry to trial Connected Health technologies and solutions in a clinical and community setting. ARCH has worked with four industry partners to develop this flexible Connected Health platform, which is the first of its kind to truly connect key stakeholders in patient care on a common data-sharing hub that has been deployed into the clinical community in Ireland.

ARCH is investigating the usability, acceptability, economic and clinical impact of integrating this platform into the dementia care pathway. This research has collected experimental data on the clinical, economic, standards, quality, business and revenue impact of Connected Health systems in the care pathway.

ARCH comprises of researchers from a range of disciplines including business, medicine, economics, ethnography and engineering. This multidisciplinary approach, such as adopted by ARCH, is required due to to the varied technical, clinical and usability requirements for Connected Health.

2) Data Collection: Informed by the established guidelines for doing case study research [27], we developed a case study protocol following the template and recommendations offered

[1]Funded by Enterprise Ireland (https://www.enterprise-ireland.com) and IDA Ireland (www.ida.ie)

by Brereton et al. [28]. We focused our data collection on identifying how the organization evaluated a Connected Health deployment, and to identify what changes were made to the framework developed during Phase 1 and 2 of the research.

We focused our data collection on identifying how the organization evaluated a Connected Health deployment for dementia. Data were collected during six interview sessions located at the organization, each lasting one hour. We collected data from various sources in order to achieve triangulation across data sources, which helps to establish reliability of the findings [29]. Sources of data were semi-structured interviews with the following staff members:

- Economist
- Business Analyst
- Clinical Nurse
- Ethnographer
- System Engineer
- Revenue Modelling

3) Execution of the Interviews and Data Analysis: We conducted the interviews onsite during three company visits. In total, we spoke to six people. The on-site interviews were conducted in three half day visits, and resulted in five hours of interviews. The interviews were transcribed with the participants' involvement. We also had access to organisational documentation on the platform.

We analysed the data using qualitative techniques described by Seaman [30]. An audit trail was established by transcribing the interviews and written notes through memoing. This in turn helped in independent analyses and cross-comparing findings, facilitating triangulation across researchers as well as peer debriefing, which are also recommended practices to increase a study's validity [29]. After analyzing the data, we sent several draft versions of our report to key informants at ARCH. This is a form of member checking, and is a recommended practice for qualitative studies [29].

IV. Key Factors for Evaluating Connected Health Deployments

The framework for evaluation of Connected Health that we derived (see Figure 1) is based on the DeLone and McLean model for Information System Success [21].

Although the IS Success Model was not specifically designed for the clinical environment, examples of its use through adaptation are reported [31] [22] [23] [12]. To fit the Connected Health context, we adapted the IS Success Model by making three adaptations to the original model. We also extended the model by considering Stakeholders.

The first adaptation was to Net Benefits. The definition of information system success according to DeLone and McLean is achieving net benefits. These net benefits are described as economical by DeLone and McLean [21]. Connected health must also work to achieve financial benefits but unlike the systems described by DeLone and McLean this is not the only objective. Connected health must also strive to improve clinical outcomes. Therefore our framework has separated net benefits into Clinical and Economic factors.

The second adaptation was to the Use elements. Clinical staff have been found to rate Usability higher than Ease of Use [32]. Therefore we merged Intention to Use and User Satisfaction to include Usability. Further, technology adoption is a key element to the success of Connected Health. Therefore, it is important to measure the effect of introducing a deployment. Therefore, we also included Acceptability. These two categories are the extent to which a technology can be used by participants' to achieve specified goals or tasks with effectiveness, efficiency and satisfaction in a specified context of use.

A. Stakeholders

The definition of Connected Health explicitly acknowledges the existence of different stakeholders [9]. This implies that there are different types of requirements for each stakeholder. A clear understanding of stakeholders and their requirements and expectations is crucial [33]. It is important to pay attention to the specific technical, use and impact concerns.

In the first phase of the research, we identified three stakeholder roles: technology provider, health service provider and patient. However, during the industry workshops it was soon acknowledged that these three roles of the stakeholder model were not distinctive enough for the evaluation framework and required adaptation. Firstly, in the model, the patient appears to only be represented in their role as beneficiaries for the evaluation, not as users of the technology. This was also the case for the informal care-givers. Therefore, we defined an Assisted Persons" stakeholder group. Secondly, the larger impact of the deployment is missing, requiring the definition of a societal group. This group is concerned with the Economic category and the Clinical category of Connected Health.

V. Applying the Framework to a Connected Health Evaluation

The framework structure of stakeholder and categories forms a matrix structure. Using this structure, each stakeholder is evaluated across the categories. These categories enhance understanding of the different evaluation needs for each stakeholder. In this section we apply the framework to our case study organisation who are conducting an evaluation of a Connected Health deployment for dementia.

In evaluation studies of Connected Health with a purely quantitative focus (e.g. Aanesen et. al. who focused on cost-effectiveness of smart home technology [34]) it is argued that qualitative data is equally important to support decision-making in future investments in innovation. Generally, the combined use of qualitative and quantitative data improves validity of the results and contributes to rich, in-depth knowledge [35].

Building on this rationale, the ARCH evaluation relied on both quantitative evidence as well as qualitative insight into the development, deployment and operational processes of the deployment. For the quantitative methods, ARCH researchers used questionnaires and (cost) data entry templates. The qualitative data was collected through focus groups and interviews.

	Technology Provider	Service Provider	Assisted Persons'	Society
System Quality	Is the solution built right?	Is the solution fit for purpose?	Will it work?	How will we benefit from a high quality quality?
Service Quality	How will we support the solution?	What Service Level Agreement should be in place?	What happens when if it breaks?	How will we benefit from good solution support?
Information Quality	How do we ensure users get quality information in and out of the solution?	Is the information in the solution of high quality?	Will I have access to quality information?	How will we become more informed through the solution?
Acceptability	How do we encourage the users to accept the solution?	Will the users accept the solution?	Do I want this?	Will we accept the solution?
Usability	How usable is our solution?	Will our users be able to use the solution?	Can I use this?	How has the solution impacted on their behavioural change?
Clinical	What clinical value are we offering?	What are the clinical benefits to users' and society?	How will this benefit my health?	How can this benefit us?
Economic	Can we make a profit?	What is the Return on Investment (ROI)?	How much will this cost me?	How much will this cost us?

TABLE II
EXPLANATORY FRAMEWORK FOR CONNECTED HEALTH EVALUATIONS

TABLE III
STAKEHOLDER GROUPS

Stakeholder Group	Description
Technology Provider	Provides Connected Health technology to their clients. This term also covers technology suppliers that builds soft- or hardware that is integrated into the ARCH platform.
Service Provider	Provides health services. The term also covers the individual service provider who works for a service organisation, including nurses, general practitioners, physiotherapists, gerontologists, and welfare workers. These are also called formal caregivers.
Assisted Persons'	A person who is dependent on health services due to old age, a chronic disease or a handicap. A person who is indirectly dependent due to responsibilities for an elderly parent, family member, friend or a spouse.
Societal	Government at the local, regional or national levels that allocates funds to Connected Health technologies or services.

A. Stakeholders

The first stage of applying the framework was to identify the key stakeholders in the Connected Health deployment. In this case study, the *Technology Provider* was ARCH. ARCH were providing the technology platform to patients under the care of the *Service Provider*. The *Service Provider* were two Dublin based geriatric clinics in St. Vincent's University Hospital and Mater Misericordiae University Hospital attended by *Assisted Persons'*. The *Assisted Persons'* were elderly patients with early stage dementia and their family members who formed part of the society. The *Societal* stakeholders were the net beneficiaries and indirect funders (via taxes) of the solution.

B. Quality

The *Technology Provider* was evaluated under the Quality categories. Measures for platform Availability and Security were used as the System Quality measures. The Service Quality measures are response time of system and access to technical support.

ARCH researchers deemed that for the platform data to be considered high quality it must be valid, accurate, distributed and used. ARCH assessed information quality using Data Integrity and Timeliness measures. The measures were calculated through qualitative interviews with the Service Providers (GP and Geriatric services) and Assisted Persons' (Patients with dementia and Carers).

C. Use

ARCH researchers measured platform usability from the perspectives of: effectiveness, efficiency and satisfaction.

- Effectiveness: The accuracy and completeness with which users achieve specified goals per task undertaken.
- Efficiency: The accuracy, ease, and completeness of goals achieved in relation to tasks undertaken.
- Satisfaction: Participants experience freedom from discomfort and positive attitudes towards the use of devices and system as a whole.

The aim of the Use measures within the ARCH evaluation was to understand the "lived experience" of using a Connected Health solution within the context of a dementia diagnosis. They used an ethnographic approach comprising of semi-structured interviews (and observations of the home environment) in the *Assisted Persons'* home, and a post-deployment interview in the hospital setting. They also conducted semi-structured interviews with GPs and the Geriatric team. The interviews covered a range of topics to better understand

Use of the Connected Health deployment, including: interpersonal relationships and interactions, daily routines, engagement with devices, impact on the home environment, social impact, health care delivery, quality of service, comparison with existing services, acceptability, desirability, expectations, meeting needs, impact on the disease knowledge, management of illness, and health seeking behaviours as well as topics highlighted by respondents themselves.

Validated scale measures were used to assess the *Assisted Persons'* acceptance of technology. User-acceptance is a key component in estimating the potential uptake and saleability of any technological device. ARCH researchers used the Service User Technology Acceptance Questionnaire (SUTAQ) [36] to measure the acceptability (or intention to use) and usability of the platform for *Assisted Persons'*. ARCH used the Technology Acceptance Model (TAM) [37] to measure the *Health Care Provider* intention to use, which in the ARCH case was represented by the General Practitioner. Qualitative interviews were used to assess usability of the platform for the *Health Service Provider*.

D. Impact

The framework divides Impact into Clinical and Economic categories.

1) Impact: Clinical: Health related Quality of Life (QoL) is pertinent to patients with chronic disease. Reduced Health related QoL has been linked to poorer outcomes on patient health self management, disease control, health service use, costs, and mortality [38] [39] [40].

The SF-12 is a twelve item measure of general health status and health related QoL that uses norm based scoring for the general population in the United States in 1998 [41]. The instrument is scored in two subscales, the physical component summary score and the mental component summary score; higher scores represent better health related QoL. SF-12 has shown good test-retest reliability, validity, and responsiveness [42].

The SF-12 is widely used to measure health related QoL for chronic disease and can be used for patients and carers. However, Minimal clinically important differences (MCIDs) have not been established for the SF-12. To evaluate the magnitude of any treatment effect, one large randomized trial of tele health (Whole Systems Demonstrator) is required.

Depression and stress is very relevant in chronic disease and in particular, Caregiver stress is associated with earlier transition to longterm care for the person with dementia. This transition to long term care was very relevant to the ARCH sample population, therefore for pre- and post- deployment, ARCH are using indicator to measure depression and caregiver stress:

- Carer Experience Scale (CES) [43]
- Caregiver Strain Index (CSI) [44]
- Health-related Quality of Life (SF-12) [41]
- Neuropsychiatric Inventory (NPI) [45]
- Depression (PHQ) [46]
- Pittsburgh Sleep Quality Index [47]

Behavioural and Psychological Symptoms of dementia (BPSD) [48] include apathy, depression, hallucinations, delusions and agitation and aggression. These symptoms are the most distressing aspect of caregiving. Recognizing and treating these symptoms can improve the quality of life for patients and caregivers and may reduce the risk of hospitalization and institutionalization. Additionally, treating these symptoms may improve cognition and functional ability and decrease the patients dependence on the caregivers.

Behavioural and psychological symptoms of dementia, and their effect on the caregiver, are evaluated before, during and after the deployment using the Neuropsychiatric Inventory (NPI). Depression is measured using the Geriatric Depression Scale [49] and for the person with dementias QoL is assessed using a direct and proxy measure called the dementia Quality of Life measure (DEMQOL) [50].

2) Impact: Economic: ARCH was very aware that any technology assessment for novel interventions will need to have some economic perspective if a holistic argument for that intervention is to be made.

Quality Adjusted Life Years (QALY) was originally developed as a measure of health effectiveness for cost-effectiveness analysis [51]. Using standardized measures, such as SF12, changes in the quality of life of patients/carers can be assessed and used to provide a monetary argument. QALYs are a NICE-supported measure of cost-effectiveness.

Healthcare resource utilisation looks at whether an intervention reduces or has the potential to reduce utilisation of formal healthcare services. ARCH estimated healthcare resource utilisation by assessing whether a patient was visiting their GP or contacting the public health nurse less frequently. This can be done in quantitative (standardised questionnaire) or qualitative (interview) manner.

In a similar way to healthcare resource utilisation, except with a focus on chronic conditions with an older population, technology should be able to increase the time for transition to long-term care, which tend to be one of the main costs [52]. ARCH researchers had no specific measure of this, as they were trying to identify the absence of something specific. For this, one is looking at those variables traditionally related to speed or slowing of this transition. Measurable reductions or increases in direct measures relating to patients or carers, or the experience of other key stakeholders, for example medication usage, can be quantified explicitly.

Others measures used by ARCH are more indirect in nature. For example, stress or burden. These are used more to make a structural argument; for instance changes in A tend to mediate changes in B, which itself mediates an increase/reduction in C. Therefore, some % of the variance in changes in C can be attributable to A.

VI. Discussion

During the development and application of our evaluation framework, we structured and framed a holistic assessment of Connected Health technologies. A Connected Health assessment should be:

- Tailored to support insights around achieving the vision and strategy for healthcare delivery
- Holistic, covering all the systems that make up the health system
- Comprehensive in capturing how performance would change based on introduction of connected solutions
- Comparative, to allow benchmarking healthcare providers performance against relevant peer providers.

A. Tailor Assessments

A Connected Health assessment must take into account that deployments have different visions and priorities for achieving their objectives. One way of addressing this requirement is to use a weighted scoreboard that enables a tailored and comprehensive assessment. The scoreboard should contain the relevant criteria for each system. By assigning weights to individual systems and criteria, according to their importance to both the patient and the healthcare provider, it is possible to define and assess the overall status and ongoing performance of individual systems and the health service as a whole.

For example, for a deployment aiming to reduce cost of care, greater importance should be given to factors that immediately impact the services cost base, such as the equipment, cost of wages, and medications.

If the immediate concern is to become a global location for innovation and high-tech medical devices, factors pertaining to skills and the regulatory environment are relatively more important. Hence, the different priorities of the health service, and their relative importance, will have direct implications for what weights are attached to different factors.

B. Take a holistic view

As the myriad of systems in a Connected Health solution interact with and affect each other, changes to one system will invariably impact others. Thus, the assessment needs to consider the entirety of the patient care. For example if a *Health Service Provider* assesses an individual system (e.g. Labour Ward Management System), in isolation and without ascertaining how other systems, such as patient billing, appointment management and staff availability, depend upon and affect the work of the ward, the conclusions may lead to corrective action within the system which is detrimental for the hospital as a whole.

C. Assessment should be comprehensive

By definition, a Connected Health assessment should aim to be comprehensive in capturing how individual systems might be transformed when Connected Health solutions are applied. Specifying relevant criteria and variables for the prerequisites of each system, their management, the use of solutions and expected outcomes make this possible. By using well-structured criteria, a comprehensive overview of the transformation of each system can be achieved.

D. Benchmarking

As important as what and how to measure is what to measure against. Choosing appropriate peer deployments that share key characteristics, challenges and priorities can yield valuable insights and foster subsequent sharing of best practices and other useful insights borne out of the experiences of users and their communities.

VII. Conclusion

Connected Health, as discussed in this paper, relates to the application of technology to enable more effective delivery of health care across the full extent of the health care ecosystem, for example from the patient's home, to the clinician's surgery, and into out-patient support centres. To take advantage of the promised benefits of Connected Health, providers need to understand how a deployment is performing and where progress is being achieved in improving patient care. This calls for a systematic assessment of a deployment. Such an assessment can identify and help communicate emerging strengths and weaknesses. It can highlight where real progress is occurring and inform a plan for future improvements. As such, an assessment can help health care providers prioritize their actions and future focus.

The aim of this research was to develop a framework that could unfold the complexity of Connected Health evaluations. Therefore, we proposed the following research question: *How can we holistically evaluate the impact of Connected Health technologies from different stakeholder perspectives?*

The framework, which was developed through a combination of robust evaluation of the literature and expert validation, enables Connected Health providers to conduct focused and holistic assessments of their implementations, the result of which provides for an improved understanding of strengths and weaknesses which is significantly enhanced when compared with similar related techniques that have been available up to this point. As a further necessary step, we applied and evaluated the framework in a real life Connected Health trial. The results of the trial, which was based in a primary care dementia setting, indicate that the framework is an effective and useful facility for Connected Health providers.

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