

A Framework for the Adoption of Bring Your Own Device (BYOD) in the Hospital Environment

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Abstract—The ongoing reform efforts and an aftermath of increasing regulation in the Swiss healthcare sector make it imperative for hospitals to develop strategies to work more efficiently and have better control over their medical, nursing, and administrative processes. In recent years, the perception, usage and efficacy of mobile devices and related services have changed. Related technologies have become potential drivers for new businesses, increased productivity, higher employee satisfaction and lower costs in IT procurement and maintenance. These endeavors make hospitals to enhance and integrate the concept of Bring Your Own Device (BYOD) in their IT environment. This work proposes a novel method for the introduction of mobile strategies with respect to closely-meshed organizational and social structures within hospitals. One key contribution of this method is its hybrid approach to combine collective know-how of existing BYOD frameworks with an iterative process model approach. The application of this BYOD framework under real-world conditions within different Swiss hospitals has led to a positive outcome whereby all hospitals concurred that the method allows for the adoption of BYOD principles while taking into consideration the individual styles and patterns of behavior.

Keywords—healthcare, method, BYOD, EMM, framework

I. INTRODUCTION

The demographic development of the society, the medical technical progress, and the change of values are faced with limited resources for healthcare. Legislative reform efforts, for that reason, primarily aim at the increase of productivity within healthcare, while ensuring the quality of care. However, the therein justified changed conditions issue continually a challenge to actors in the hospital market, making it highly dependent on the political priority of the day. Central catalyzer of these changes is the setup of incentives in inpatient care by diagnostic related groups (DRGs) [1] (p.14). Since 2009, hospitals in Switzerland have been transitioning to a new remuneration approach providing case-based payments. The 'SwissDRG' is being introduced in 2012 and is becoming the dominant payment mechanism for hospitals in Switzerland. Motivated by on-going reform efforts in the Swiss healthcare sector, for the affected hospitals it is necessary to develop concepts to work more efficiently and have control over their

medical, nursing, and administrative processes. When it comes to enhancements of the treatment chain, IT has proven to be a driver for improved process quality such as patient records were collected and communicated more easily across admitting physicians or medical and nursing staff was relieved from compulsory documenting tasks. The efficient use of IT thereby has shown a direct effect on the quality of care and patient safety [2] (p.64). This endeavor requires, besides a vast understanding of related medical, nursing, and administrative processes, a proper utilization of given IT resources, the ability to deal with innovation as well as far-sighted alignment of IT issues with hospital objectives. This calls for effective IT usage. In recent years, the perception, usage and efficacy of mobile devices and related services have changed. Related technologies have become potential drivers for new businesses [3], increased productivity [4], higher employee satisfaction [5] and lower costs in IT procurement and maintenance [6]. New mobile strategies, along with the concept of Bring Your Own Device (BYOD) – the usage of personally owned devices for business purposes [4] – have already proven the potential to fundamentally increase both, effectiveness and efficiency in business organizations [3]; [5]. Therefore, an integrated and comprehensive approach to the implementation is becoming critical to more effectively sustain the strategic and tactical direction and value proposition of IT supporting departments and clinics within the hospital. This approach to BYOD in the hospital environment is the subject of this work.

The paper at hand is structured as follows: In the second section the problem statement is presented, outlining current research in the fields of BYOD and the hospital environment. Section 3 summarizes the research question the methodology applied in this work. In Section 4 the meta-model is discussed. The related framework for the adoption of BYOD is outlined in Section 5. Section 6 discusses the evaluation of the method under real-world conditions in three Swiss hospitals. In the final section, conclusions are drawn and an outlook on further research is given.

II. PROBLEM STATEMENT

The difficulties to deal with in order to set up the Swiss healthcare system for the future are multi-layered and complex and come from two directions: the (1) Swiss hospital environment and the (2) nature of BYOD and related frameworks and best practices.

A. The Swiss Hospital Environment

Given an aging society, other challenges to be met by the endeavor toward a fundamental reorganization of the healthcare sector are investigated such as (1) legal constraints caused by Switzerland's federal structure with a complex system of powers and responsibilities [7], (2) the political tradition of direct democracy and governance through consensus [8], (3) closely-meshed organizational and social structures within the hospital and between its stakeholders [9], and (4) an underrepresented standing of the IT department characterized by over the years increased heterogeneous IT systems [10].

The functional organization in hospitals is characterized by a hierarchical tripartite mostly performed according to given jobs or varieties of provided services [8]. Medical care, nursing service, and administration are the prevailing job classifications, which influence to a great extent the organizational design. In practice, the functional organization causes not only physical separation of the departments, but, more often, a *'life of its own'* caused by partial-autonomous decision-making [10]. Most of the clinical divisions have their own divisional director usually staffed by a senior consultant, their own nursing care, and their own administrative staff, along with their own information systems and budget responsibility [9].

Considering the role of IT in the functional organization, it becomes obvious that IT is usually organized around the administration which reports to the director of finance or infrastructure and, thus, is considered a support function as it is not directly represented in the hospital management [11]. The demand for IT integration challenges the traditional organization of the hospital as an entity divided by politics and competences according to medical functions. In the past, this has led to a monolithic information island with a great number of point-to-point connections between vast amounts of specialized applications across the hospital, representing the prevailing fact that hospitals today are still not considered one entity, but rather as a collection of fragmented, mostly autonomous acting entities with departmental targets, budgets, and personnel responsibilities.

B. BYOD Frameworks

On the other hand, a range of best practices, proprietary frameworks as well as standards and norms have been developed, which are also summarized in a stricter or broader sense under the topic of BYOD. Notably, these frameworks are not alternative treatments of the same issue, and indeed, there is considerable overlap between them, which make a clear assignment to the individual aspects of BYOD more difficult. Most of the approaches lack methodical sound validity,

claimed scientific rigor, and merely provide vague hints about their underlying conceptions and structures.

In this section, an outline of related BYOD frameworks and best practices is provided.

1) BYOD – 8 Steps [12]

Ernst & Young (EY) describes eight steps to improve and secure a BYOD program. According to EY, the basis of a BYOD strategy is to set a business case and define a goal statement. The second step is to involve stakeholders and form a mobility group to examine the needs. The third step is to build an overall business case for BYOD. The fourth step covers the risk analysis. In the fifth step the creation of a BYOD policy is explained. In the sixth step, the security of devices and apps is mentioned which should be effectuated with a Mobile Device Management (MDM) solution [15]. The seventh step mentions the testing and verification of security. The eighth step is dedicated to the measurement of success using ROI and continual improvement measures.

2) BYOD: Planning and Implementation Framework [13]

The framework describes nine steps to implement a BYOD program in schools. According to this framework, the first goal is to engage the community to achieve consensus. The second step is to build a team which is pushing the BYOD strategy forward. This includes the setting up of a test group. The third and most important step is to develop the infrastructure to provide a fast, stable and highly available network. Providing multi-platform tools represents step four. This comes along with the fifth step intending to develop a portal to download necessary tools. Moreover, the framework addresses the development of a BYOD policy. This is covered in step six. The seventh step is to build a curriculum which means to provide content that can be used with the devices of the students. The framework also covers the consideration of which device might be needed. The final step mentions the ongoing development of the BYOD implementation.

3) BYOD Security Framework using MDM [14]

The framework describes the requirements of a secure BYOD implementation. It is composed of two main elements: the enterprise view and the BYOD view. It specifies that a MDM solution is required, and the BYOD device must be split into two isolated spaces: a personal and a corporate space. The framework describes enterprise architecture with a BYOD solution. How to implement the described enterprise architecture is not mentioned.

4) Framework for BYOD Adoption [15]

The framework describes three phases to adopt BYOD. The first phase contains the analysis of the expectations, the environment and the resources. The aim of this phase is to set the right setting for a BYOD implementation. The second phase is *'Action'*; it covers the planning, the implementation and the evaluation of the BYOD implementation. The third phase *'Design'* contains further analysis, the development of strategies as well as the selection of the best strategy. After the selection, it is important to update current policies.

5) *BYOD Framework considering Organizational and Cultural Aspects* [16]

The framework considers the organizational culture and on the other hand employee’s privacy concerns. Based on the organizational aspects and the privacy concerns, the BYOD policy is developed. The proposed framework is lacking details how to implement the organizational and cultural aspects.

6) *7 Phases: BYOD Security* [17]

The framework describes seven phases to implement BYOD securely and covers three different aspects of a BYOD program. The first phase of the framework is ‘*Planning*’. It contains the coordination across multiple disciplines, across all stakeholders as well as the understanding of the business environment. The choosing of a MDM system, the setup of the asset management for BYOD devices, the preparation of the network environment and governance are also covered in this first phase. The second phase ‘*Identify*’ covers the registration of the BYOD devices and the training of employees. In the third phase ‘*Protect*’, the protection of the information on the BYOD devices is covered. This includes device encryption, sandboxing, virtualization, mobile operating system and application patching. The detection of vulnerability, malware and attacks is covered in phase four ‘*Detect*’, as well as the consideration of a data loss prevention system. In phase five, ‘*Respond*’, arrangements to respond to threat events are set up. How to recover from a threat event is defined in phase six. The final phase of the framework ‘*Assess and Monitor*’ covers the continual review and evaluation of the BYOD program. In each phase, the aspects policy, technology and people are considered.

7) *BYOD Framework for HEI (Higher Education Institutes)* [18]

The framework, designed for schools, consists of four phases. The first phase covers the planning of a BYOD implementation. It includes the setup of policies, the determination of supported platforms and devices, the consideration of a MDM solution and the financial planning. In the second phase ‘*Build*’, the preparation of the infrastructure, the education related with the BYOD program and the aspects of data security are covered. In the third phase ‘*Run*’, the management of the connected BYOD devices is described. In the last phase ‘*Monitor*’, the monitoring of compliance and the maintenance of supported platforms and devices as well as policy reviews are covered.

8) *BYOD Management Framework* [19]

This framework, designed for Small, Medium and Micro Enterprises (SMME) consists of six sections. The first section covers the BYOD security requirements including risk determination and identifying legal and organizational issues. The second section ‘*BYOD Role Players*’ covers risk management and the security of organizational information. The third section covers the setup of the BYOD strategy. This includes the determination of allowed devices and the registration of them, the selection of employees for the BYOD program and the preparation of the IT environment. The fourth section covers the setup of a BYOD policy. The implementation is covered in the fifth section which includes

training and device management. The sixth section includes the monitoring of the compliance for BYOD.

9) *Policy-Based Framework* [20]

The framework is a rough list of various aspects of a BYOD implementation. It includes the setup of a policy, device registration and provision, the control, monitoring and tracking, employee privacy, encryption and virtualization.

The following table summarizes the frameworks and best practices outlined.

TABLE I. OVERVIEW EXISTING FRAMEWORKS

Framework	Target group	Focus	Relevance
A	General	Security, mdm, business needs, policy, continual improvement	high
B	Schools	Stakeholder, network, policy, continual improvement	medium
C	General	Security, mdm, network	low
D	General	Stakeholder, business needs, strategy	medium
E	General	Stakeholder, privacy, culture	low
F	General	Security, stakeholder, mdm, network, business needs, policy, continual improvement, training	high
G	Schools	Security, mdm, policy, continual improvement	medium
H	SMMEs	Security, policy, strategy, training	medium
I	General	Security, policy, privacy	low

C. *BYOD in the Hospital Environment*

When it comes to BYOD in the hospital environment, the study by Moyer revealed that many hospitals are already having some sort of BYOD and that every hospital should conduct its own assessment to find out whether they should implement BYOD for their own organization [21]. However, no further hint has been given how this assessment should be conducted or what kind of aspects of BYOD should be covered.

Pugliese et al. found out that an application is used more often if installed on a personal device [6]. The work showed that the frequency and duration of the application usage has more than doubled in comparison with an enterprise-issued, when used on a personal phone.

A case study conducted in an Ottawa based hospital outlined that security, governance, legislation, device type and internet dependency are the greatest challenges for a BYOD implementation in healthcare [22].

Stephens et al. examined how a mobile communication app can improve workplace communication using their own devices in an US hospital [23].

A study about a data collection system conducted in hospitals in South Yorkshire (U.K.) revealed that the hospitals did not have any BYOD policy in place [24]. The adoption of BYOD within the National Health Service (NHS) was found to be slower than in other industries. It showed that there is large potential within the BYOD field for rapid data collection across multiple NHS organizations. Data protection is still a concern and users need to be aware of their responsibilities.

A recently published study about 450 healthcare organizations in North America identified three main challenges dealing with BYOD: concerns about data security, IT support and costs [25]. The drivers to allow BYOD in an organization have been investigated: (1) better communication, (2) more time and (3) cost savings. 51% of all the analyzed organizations had a defined BYOD policy. As part of the policy device security, consequences for non-compliance, device types and the cost aspect were defined.

It turned out that BYOD related contributions can be found in both academia and practice. However, the current demand for an integrated approach to BYOD has been predominantly boosted by business itself, namely large corporations and affiliated industries, such as accounting firms, technology suppliers, analysts, and consultants, and has become object of research in the aftermath. This inverse approach has possibly contributed to the fact that in comparison to the individual consideration of BYOD aspects such as security or data protection, academic research for integrated BYOD especially in the hospital environment can be classified as underdeveloped.

III. OBJECTIVES

Given these complexities in both the hospital environment as well as in the field of BYOD, a *'one size fits all'* approach is questionable and calls for a profound approach to the adoption of BYOD principles, considering given conditions, particularities, and constraints within the hospital environment. Although the research work at hand focuses on the Swiss healthcare system, it may be applicable to different countries that share the same kinds of problems. Based on the research motivation and the design-oriented objective of this research work, the following research question is addressed:

'How shall a method be designed and constructed with respect to the lack of expertise dealing with BYOD principles, the IT's underrepresented influence on decision-makings, the considerable fragmentation of the hospital organization, and the advance towards incremental changes for the purposes of generating valuable benefits for all stakeholders and contributing to on-going reform efforts in the hospital environment?'

The method to be developed is understood as a structured guideline, which aims at enabling IT executives in hospitals to achieve greater value in the planning, implementation and control of BYOD issues. In order to develop the method, two subordinated tasks are performed: (1) design and (2) construction of the method (cf. Figure 2). Outcome of the design task of the method is a meta-model based on the method engineering approach by [26]. The construction of the method takes up on the designed framework and applies the underlying meta-model and the elements specified therein to the context of BYOD in the hospital environment. The construction of the method entails a content model and related concepts such as a process model ensuring that experts form the hospital environment can more likely understand and implement the method.

IV. META-MODEL

A. Metaization Principle

A model can be an instance of a meta-model and at the same time can be used *'as a meta-model of another model in a recursive manner'* [27] (p.18). Consequently, various hierarchies of model levels exist, each (except the top) being characterized as an *'instance of the level above'* [28] (p.38).

The *'metaization principle'* for this research work follows the linguistic meta modelling approach describing three hierarchy levels (L_0 to L_2) (cf. Figure 1). The meta-model on level L_2 is abstract in nature and determines the *'basis'* of the method representing related method elements and their relations. Level L_1 takes up on the designed basis and applies the underlying meta-model in terms of *'instance-of'* to the context of BYOD in the hospital environment representing a *'BYOD framework'* (Section 5). Ensuring that the environment can more likely understand the objectives and courses of action of the method, the content model (Level L_1) consists amongst others of activities, results, and techniques allowing for the actual application within a certain hospital corresponding to the artefact type *'instantiation'* (Level L_0). The instantiation arises in the context of this research work as an outcome of the evaluation phase and thus has a strong relation to the given hospital environment (cf. Section 6). Figure 1 illustrates the relation between the method to be developed, consisting of a meta-model and a BYOD framework, and the instantiation according to the approach by [29] (p.10).

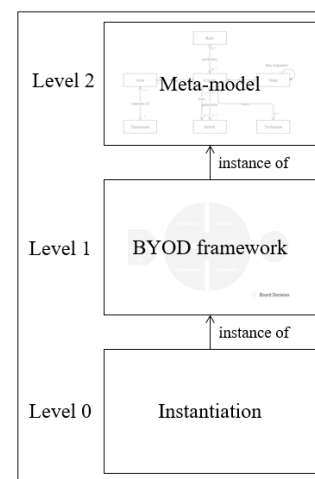


Fig. 1. Metaization principle according to the linguistic meta-modelling approach, adapted from [28] (p.10)

The actual novelty of the method development primarily lies within the design task represented through the meta-model (L_2), rather than the application of existing principles in the field of BYOD within the construction of the artefact (L_1).

B. Elements of the Meta-Model

The different method elements within the meta-model (L_2) are modelled according to the UML 2.4 specification applying related style guidelines according to [27] (p.120). All relevant UML 2.4 elements, their description, and the notation utilized

for the meta-model are summarized. The underlying meta-model of the method is based on the approach by [26]. His approach is characterized by universal applicability and shows a broad acceptance in the IS world, as it has been applied by various researches for different purposes and therefore promises a suitable base for the adaptation to requirements within the context of BYOD in the hospital environment. In order to demonstrate validity and increase the acceptance of the meta-model, the approach follows the goals of formal specification in terms of accepted modelling principles proposed by [30] (p.436).

The key element of the meta-model is the ‘activity’ (cf. Figure 2). An activity is either performed in a stage (during the goal definition, proof of concept (PoC) or implementation stage) or is covered as part of a dimension (technology, security, organization or stakeholder) (cf. Section 5).

An activity generates results and, at the same time, uses one or several results as input from other activities. An activity may be based on techniques and is performed through different roles. A dimension is relevant for one or several stages.

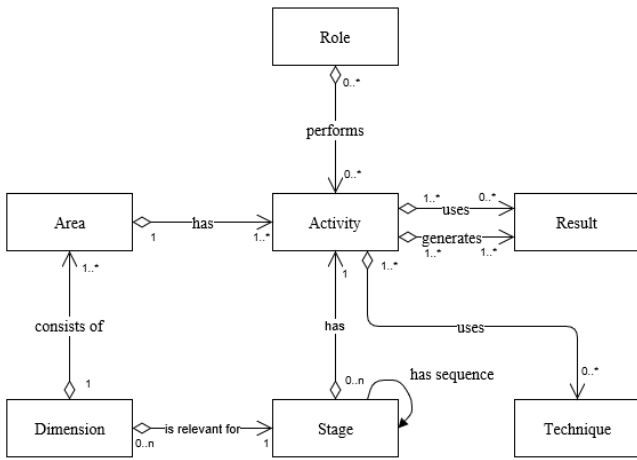


Fig. 2. Meta-model of the method, based on [26] (p.13)

The construction of the method entails a BYOD framework (cf. Section 5) and related concepts such as a process model ensuring that experts from the hospital environment can more likely understand and implement the method. This content model is presented in the next section.

V. BYOD FRAMEWORK

This section aims at answering the question how hospitals can implement BYOD in a successful manner. An iterative framework based on use cases is proposed. Every new use case, whether directed top-down or evolved bottom-up, will incrementally run through a staged approach leading to an enhanced BYOD initiative resulting in a PoC phase. The framework presents an incremental approach allowing hospitals to find an individual, however, constantly growing way of dealing with BYOD.

It becomes apparent that any BYOD implementation has a clear starting point but rarely has a strict finishing line. A

hospital’s BYOD surrounding is therefore a constantly evolving suite of functionalities that can be enhanced with new demands, requirements or use cases. In addition, the functional coverage of BYOD is individual to every organization. While some common grounds such as a functioning mobile device strategy may build the basis, there are many facets individual to an organization (cf. Section 2). The differences may be dictated by regulations, by specific data protection laws or simply by the industry in which a company is acting in. The following BYOD framework is approach is considering these given constraints (cf. Figure 3).



Fig. 3. BYOD framework

The framework represents a combination of an incremental lifecycle model and an iterative cycle. Within the iterative part the identified dimensions of a BYOD initiative are covered. The lifecycle model follows a step-by-step approach starting with the ideation to an approved decision followed by the definition of goals to be achieved with a new initiative. Once the objectives are set, the PoC stage is completed before a final decision can be made. This procedure is followed by the productive deployment of new functionalities into the evolving BYOD knowledge base of functionalities. The following chapters are intended to provide more contexts to this approach.

A. Stages

Often in traditional project management methodologies or in software development cycles, it is a step-by-step approach to find a solution to a problem, validating it and setting the result productive. Despite the recent popularity of agile development and project management methods, a linear approach is proposed that shall be completed with every new use case set to be BYOD’zed. However, the fact simplicity stands in the foreground rather than trying to bring the entire process landscape of a hospital onto mobile devices at once – an approach using agile software development principles is proposed [24]: quick response to changing requirements, continuous development, frequent delivery, prototyping and close interaction between the project team and the internal customer. Rather than rolling out one large project, an evolutionary approach is proposed. It is the idea of small bites, small fragments of functionality that shall be implemented continuously. It is a living organism supposed to grow not only by senior management directives but by involving the folks

directly affected by such change. It is the hospital’s facility manager, the neuro-surgical nurse or the hospital’s kitchen chef that can trigger innovative ideas to be thrown into the staged implementation approach for BYOD. This step-by-step approach is appropriate for the hospital environment since the IT department is characterized by an underrepresented standing and by over the years increased heterogeneous IT systems [10] (cf. Section 2). Figure 4 shows the defined stages, which are explained in more detail in the following sections.

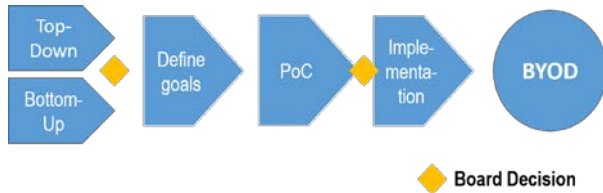


Fig. 4. Framework stages

Every new initiative starts either ‘top-down’ or ‘bottom-up’. In both cases, the underlying reason for launching an initiative should be clearly expressed using a business scenario (use case) from the daily routine of the hospital. Top-down, it is a decision by senior management to build an initial BYOD suite or enhance the existing. Such an initiation approach can be seen as a compulsory directive by senior management. The latter initiation approach shall be seen as the bottom-up approach whereby any employee or even the patient can trigger an enhancement request by placing a new use case into the cycle. Once a new business case is officially stated, a board shall decide on running a PoC or denying the idea right of the start. Reasons for not allowing an idea to pass through the PoC stages can be, for example, caused by an insufficient cost-/benefit-ratio or an advance that may compromise data protection laws.

The second part of the lifecycle is to materialize the idea. Since the functional organization is hospital causes not only physical separation of the departments, but, more often, a ‘life of its own’ caused by partial-autonomous decision-making (cf. Section 2) [10]. Every initiative shall run through a prototype stage to prove the practicability and benefits of the idea. To do so, the first step for a project team is to define the goals this new use case shall fulfill. That can be manual and routine business processes (e.g. ward rounds) that can be simplified or made more efficient by integrating them into the BYOD knowledge base of functionality. Following the definition of goals and objectives, the next step required is to build a prototype or run through a PoC phase. Once the board that approved the idea also approved the PoC stage, the initiative shall be rolled out organization-wide to all interested stakeholders (such as i.e. physicians, nursing staff or even patients).

In this second phase of the lifecycle model, the already mentioned iterative cycle consisting of four dimensions shall be used for assistance. As such, the steps ‘Define Goals’, ‘PoC’ and ‘Implementation’ can all be built around these four pillars. Further these pillars are presented to add context to the model.

B. Dimensions

Following the in-depth review (cf. Section 2), it can be concluded that any new BYOD undertaking requests four dimensions to be considered: technology, organization, stakeholder and security.

Each of these four categories carries a set of areas which in turn consist of multiple activities and tasks to be completed in order to establish a new initiative (cf. Figure 2). Following an approved idea (cf. Figure 4), goals shall be defined surrounding these four dimensions. The PoC shall address these four pillars as defined within the goals but do so in a ring-fenced, prototype-like environment; for example by implementing the solution only for a dedicated set of users. Once the trial period of the PoC has been successfully completed and rated as such by the board, the decision can be taken to implement in production. The iterative cycle illustrated in Figure 5 shall depict the mentioned four pillars overlaying certain stages of the lifecycle model.



Fig. 5. BYOD dimensions

1) Technology

In this dimension, it is about setting or changing the technical set-up and boundaries to enable BYOD (at initiation) or changes and enhancements to the existing and growing knowledgebase. In general, there are three technology areas that need to be covered:

- Maintaining a WIFI infrastructure
- Maintaining a system architecture
- Maintaining an application architecture

Each of these areas contains further activities presented as follows:

a) Maintaining a WIFI infrastructure

- Enhancing/amplifying the WIFI infrastructure (WIFI segmentation, network configuration, coverage, bandwidth)
- Defining/enhancing network access (VPN, VDI, WLAN)

b) Maintaining a system architecture

- Introducing/enhancing MDM/EMM (i.e. license management)
- Ensuring/enhancing systems integration (Hospital Information System)
- Defining portfolio of devices and operating systems to be supported
- Creating/enhancing inventory of devices
- Examining security holes in systems and installing software updates
- Defining/enhancing backup solutions
- Defining/enhancing device registration and enrollment measures (i.e. provisioning)

c) Maintaining an application architecture

- Ensuring/enhancing integration of specialized apps
- Virtualization of apps and sand-boxing/ring-fencing of content

2) Organization

This pillar is intended to organize proper governance and in the context of this paper, set parameters for an internal regulatory framework. In addition to rules and regulations, this dimension is a placeholder for standards, procurement and other internal billing measures as well as definitions around an internal support model including SLAs. There are five areas to be covered within this dimension:

- Scanning external rules and regulations
- Ensuring internal rules and regulations
- Defining/enhancing quality standards
- Analyzing/enhancing procurement and internal billing
- Maintaining a mobile infrastructure

Each of these areas contains further activities presented as follows:

a) Scanning external rules and regulations

- Clarifying country-specific legislations

b) Ensuring internal rules and regulations

- Defining/enhancing data ownership
- Controlling adherence to internal rules and regulations

c) Defining/enhancing standards

- Defining/enhancing quality standards
- Defining/enhancing security standards

d) Analyzing/enhancing procurement and internal billing

- Adjusting procurement (i.e. new supported devices, enrollment, etc.)
- Defining/adjusting compensation models and billing

e) Building up mobile infrastructure

- Ensuring/enhancing IT-support, servicing and maintenance
- Adjusting service model (SLAs, role definitions, etc.)
- Defining/enhancing SLAs for mobile device usage
- Defining/adjusting role-specific device usage and work space functionality

3) Stakeholder

The next dimension is focusing on stakeholders. Various areas are covered; most importantly trainings, user guides and other documentation shall be specified in this section or enhanced in case of new BYOD use cases to be made available on mobile devices:

- Managing project-specific measures
- Ensuring/enhancing user-specific measures
- Maintaining/enhancing documentation
- Maintaining/enhancing trainings

The above areas can further be split into the following activities:

a) Managing project-specific measures

- Sustaining senior management support for any new initiative

b) Ensuring/enhancing user-specific measures

- Identifying stakeholders (to a new use case)
- Validating patient-specific usage (i.e. wearables, IoT, etc.)

c) Maintaining/enhancing documentation

- Creating/enhancing user guides and user documentation

d) Maintaining/enhancing trainings

- Creating and conducting awareness trainings
- Creating/enhancing trainings for IT security, data exchange and other mobility topics
- Creating/enhancing trainings for end-users (i.e. provisioning, enrollment, etc.)
- Creating/enhancing trainings for system administrators

4) Security

Security is about how well hospital data shall be protected, how internal BYOD policies are defined and enhanced and how risk assessments are conducted. Also, this dimension specifies access-related topics and internal data encryption regulations:

- Scanning external data protection laws
- Ensuring internal data protection rules
- Analyzing/enhancing access
- Analyzing/enhancing data protection and data security

a) Scanning external data protection laws

- Validating data protection laws and security regulations
- Scanning hygienic regulations

b) Ensuring internal data protection laws

- Creating/adjusting internal BYOD policy and -guidelines
- Defining/enhancing internal controls and risk assessments
- Validating/enhancing BYOD-specific risks

c) Analyzing/enhancing access

- Ensuring authentication means (IAM: PIN guidelines, Single SignOn, etc.)
- Defining/adjusting system, file and data access

d) Analyzing/enhancing data protection and data security

- Introducing/enhancing encryption standards
- Defining/enhancing internal communication and data exchange concept
- Defining/enhancing data type guidelines
- Defining/enhancing data storage

Having shown the four dimensions of the iterative cycle, the attention shall now be drawn to some illustrating examples.

C. Examples

In this section, two examples are presented, a top-down case – namely a hospital’s initial advance into BYOD – as well as a bottom-up case.

1) Example 1: Usage of a HIS-App (hospital information system) on mobile devices

Stage 1: Ideation

The top management of a Swiss university hospital would like to introduce a mobile BYOD-strategy. The hospital’s HIS-provider has recently announced its latest add-on in the form of a mobile app supposedly linking directly to the backend HIS-system. The hospital trusts in the promised efficiency gains of the HIS-provider and launches a project based on a top-down initiative.

Stage 2: Define goals

A selected project team defines the goals of implementing this new app by drawing a number of use cases supported by the provider of the app and the HIS-system. Using the iterative cycle with its four dimensions, goals in each of the four dimensions and areas are defined including the specific activities that need to be fulfilled to enable this first few use cases. As a matter of fact, since this is the initial launch into BYOD, most (if not all) areas and activities as explained in chapter 5.3 need to be touched.

Stage 3: Proof-of-Concept

In a yearly Proof-of-Concept, the benefits of introducing such a HIS-integrated mobile app to be run on private or company-provided mobile devices can clearly be shown. The achieved cost savings and efficiency gains convince the board so that an organization-wide deployment is to take place.

Stage 4: Implementation

Following the successful yearly PoC and the approving board decision, an initial BYOD-universe has been created across the entire hospital to support selected use cases. It is important, though, that most BYOD-benefits can only be materialized if the app used on mobile devices is connected to the backend HIS.

Stage 5: BYOD

The fundament for a growing mobile device strategy is established and BYOD is now officially implemented; despite only a limited set of supported use cases (... for the moment).

2) Example 2: Integrating the process ‘patient’s menu ordering’ into the existing BYOD universe

Stage 1: Ideation

Since BYOD has officially been launched, new ideas come up frequently. As such, a nurse involved in organizing the placing of food orders by patients believes that the food-ordering-process can be improved. In collaboration with the hospital’s kitchen chef, a new bottom-up ideation is presented in front of the BYOD board to decide on taking the initiative one step further.

Stage 2: Define goals

A small project team is tasked with validating the feasibility of integrating the use case “patient’s menu ordering” into the existing BYOD universe of functionality. By completing the dimension matrix with the four pillars, the need for action can clearly be depicted by listing the areas and activities experiencing change.

Stage 3: Proof-of-Concept

A small software-provider known to the hospital is tasked to develop a new app fulfilling the defined goals and requirements stated by the project team.

Following the completion of the software development, a group of patients is selected to complete a three-months trial period testing the functionality, acceptance as well as integration of the new app in the existing system architecture.

Stage 4: Implementation

Based on the successful three-months trial period and the positive acceptance by patients measured by means of a survey, the board decides to roll out the new app to any patient wishing to use its own mobile device to order its individually-suited menu.

Stage 5: BYOD

The existing BYOD-universe of functionality could be enhanced by including the newly developed app. The integration in the existing BYOD-architecture could be confirmed and the integration of the food orders into the existing HIS-system could also be successfully achieved.

These examples shall depict the practicability and suitability of the proposed BYOD framework.

VI. EVALUATION

The evaluation includes the development of an evaluation process ensuring the method’s applicability under real-world conditions. Although the importance and benefits of an evaluation are widely perceived in the field of IS, different definitions, understandings and emphases still can be found in literature [31].

Following the approach by [32] data triangulation is applied for this research work enhancing validity, reliability, and richness of the research results. Data triangulation aims at the gathering of evaluation data on a variety of different people. The involvement of different hospitals in terms of their ownership (i.e., public and fully private hospitals), and scope of work (i.e., centralized care level 1 and 2) from the Swiss health care sector is therefore intended. Based on the approach by the Swiss Federal Office of Public Health (FOPH) three health care institutions are selected [8]. Table 2 summarizes the configuration of the selected hospitals participating in the evaluation. The related information including level of care, ownership, number of employees, and beds, are anonymized at the request of the hospitals.

TABLE II. INFORMATION ABOUT HOSPITALS PARTICIPATING IN THE EVALUATION

	Hospital A	Hospital B	Hospital C
Level of care	centralized care level 1	centralized care level 2	centralized care level 2
Ownership	public	public	private
Number of employees	7.000	2.700	4.800
Number of beds	920	530	1.400
Number of inpatient (outpatient)	37.000 (273.000)	25.000 (105.000)	80.000 (N/A)
Role of participant	CIO	IT Manager	CIO
Organizational structure	functional organization	matrix organization	affiliated doctors
Organization of IT department	centralized	centralized	hybrid

In order to allow a profound statement of the value proposition of the developed BYOD method and its related concepts from various perspectives the approach by [30] is applied. Demonstrating utility, the method is simulated and logical reasoned under real-world conditions within three different hospital environments using action research methodology.

Hospital A. Both impulses, the top-down and the bottom-up approach are assessed as relevant. However, the interviewee pointed at the fact that if an initiative is triggered bottom-up, the support and leadership from senior management is crucial for the initiative’s success. According to the interviewee, two aspects were clearly missing in the proposed framework: MAM (Mobile Application Management) and Mobile Analytics. MAM is intended to manage and organize aspects in relation to the development of in-house apps with the help of external software developers (integration, data exchange, etc.). Therefore, the dimensions ‘*technology*’ and ‘*security*’ need to be enhanced since data exchange of such in-house app needs to be clearly governed. Furthermore, Mobile Analytics discusses security-related facts in relation to certificates and particularly in relation to the renewal of such certificates: who coordinates renewals of certificates, whose responsibility is it, who establishes and manages contact between external development companies and internal security aspects?

Hospital B. When asked about the feasibility of the proposed framework, the interviewed person at hospital B pointed at the PoC concept which had proven positive in their hospital environment. The interviewee also mentioned that in the sensitive surrounding of a hospital, it often seems necessary to deactivate a phone’s camera to avoid pictures of patients being taken. Also, hospital B is apparently evaluating ‘*Geofencing*’ to steer individual user rights and allowed functionalities according to an individual’s location. Furthermore, when considering a use case based approach, the interviewee insists on appointing the necessary severity to the internal communication and definition of regulations when incrementally increasing the scope of BYOD. Also, if a PoC phase does not prove to be successful, the removal of hard- and software from test objects needs to be coordinated. Two specific points have been highlighted as desirable: the consideration of hygienic aspects when examining a new

initiative as well as the inclusion of certain medical devices (ie. a medical-PC) which are in use in close proximity of patients.

Hospital C. The interviewee believes a BYOD implementation to be comparable to any other software implementation project. Under the dimension ‘*organization*’, the interviewee misses a section for processes: business processes need to be examined when enhancements to the existing BYOD environment are proposed. Also, the consequences to change and release management in the context of hard- or software shall not be neglected. The interviewee proposes further to correct the ‘*technology*’ dimension by including GSM as an alternative access media. Depending on a hospital’s architecture, GSM may need to be implemented. In addition, the activity ‘*defining/enhancing backup solutions*’ should be named ‘*defining backup and recovery*’ as the interviewee sees the recovery to be a greater challenge than the backup. Furthermore, the questioned person advises that solutions must be in place in case of blackouts, means a ‘*business continuity process*’ has to be implemented. Any EMM implementation shall keep a strong independence between the main functions of a hospital (care) and the possible outage of BYOD devices or the internet. At last the interviewee advises that regular reviews through independent advisors and experts need to happen in order to uncover security leaks.

VII. CONCLUSION

The evaluation of the method with a large statistical population, as often required for the evaluation of theories to empirically evidence the truth, is therefore only limited. Considering the application of the method as part of the evaluation, it becomes obvious that the derived opportunities affect the entire hospital environment, their effects, however, may not immediately perceptible, which may lead to a long-term and resource-intensive study and may therefore only be conducted in a few hospitals. The basic limitation of the evaluation approach was the use of a small statistical population constraining the representativeness and reliability of the results. Although all hospitals have assessed the learnability of the method as manageable in practice, the initial involvement of an BYOD expert as part of the evaluation process contradicts, however, to the claimed objectivity of the evaluation results representing another limitation of the research. Although further evaluations with more hospitals are out of the scope of this research work, they are highly recommended for future research works.

The psychological aspect of BYOD in the hospital environment is covered only in a basic manner (i.e. BYOD as a barrier in the relationship between physician and patient). Also, hygiene-aspects of a BYOD implementation framework should be covered more prominently and could pose a continuation of research in this context.

Finally, the scope of the research work constitutes another limitation. The entire problem identification, specification of related requirements, method development, and evaluation focused on the Swiss hospital environment. Whether the method is applicable to different countries that share the same kinds of problems remains an open issue, however, its

validation is highly recommended for future research works. The discussed health care systems in the United Kingdom (U.K.), Germany, and the United States (U.S.) make the placing of the situation and the discussion of derived challenges in the Swiss health systems according to an international context possible and allow for a preliminary estimate. The three outlined healthcare systems, in addition to the Swiss health system provide comprehensive insights into all kinds of systemizations ranging from state-run (U.K.), to social state principle (Germany), and on the other extreme, to a free market system (U.S.).

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