Healthcare testbed activities as a modular construct

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Abstract

In recent years, modularity has received increasing attention when discussed about complex services, such as healthcare, which are not only provided by multiple providers but also require unique customization. This study explores possibility to deploy benefits of modularity in testbed services provided for health and welfare technology companies. Ten testbed cases were analyzed and modular service construction was drawn as well as interfaces were recognized. Although the validation of the results is recommended as future studies, possibility to reduce the complexity of testbed services with modular service architecture seems promising.

Keywords: Modularity, Testbed services

Introduction

Modularity has been considered beneficial when multiple providers are providing multiple services which needs to be aligned into coherent service packages (Peters et al., 2020a). Modularity also supports customization and responsiveness to individual requirements (Voss and Hsuan, 2009) which is increasingly important not only due to better customer experience, but also due to efficient use of resources. Furthermore, modularity also alleviates challenges in coordination of complex service systems (Brax et al., 2017).

Testbed activities in healthcare represent complex environment which requires extensive coordination in order to create coherent services. Testbeds are typically described as platforms that offer companies a setting for testing their products, systems and services in a real clinical or simulated environment. Testbed services have been considered important in supporting development of technological innovations (Schuurman et al., 2016) and their application in healthcare. Testbed platform combines services from multiple stakeholders, such as technology companies, clinical testing environments (public, private, NGOs), their personnel, healthcare professionals as well as patients, stakeholders related to jurisdiction, for example, data protection officers, local device register officers, national medical device (MD) regulation officers and ethical committees, among others. These stakeholders come from different organizations, institutional and cultural backgrounds and have different recourses and interests as well as deep, while rather narrow, expertise. In this kind of complex environment, seamless coupling is required creating coherent services and connecting different services and professionals (Silander et al., 2017; Peters et al., 2020a).

Thus, this study explores how modular service architecture can promote flexible and fluent combination of testbed activities. More specifically, this study describes what are the modules and components in testbed activities and what kind of interfaces are required in order to ensure the coherent but also flexible service entities.

Background

Modularity

Modularity origins from operations management while it has been applied in services already several years. More recently, increasing interest has been to deploy whether modularity is beneficial in complex services, such as in healthcare. Findings from latest studies indicate that, indeed, modularity is beneficial in environments where multiple provers provide their services with perquisite to ensure efficient flow of services combined with high requirement of customization (Fransen et al., 2019; Peters et al., 2020a; Peters et al., 2020b).

Benefits received are related to modular structure consisting of modules and components and their ability to function independently while still being compatible. Modules can be defined as separate, independent parts of the services with a specific function. They can be offered either individually or in combination. (Rajahonka, 2013.) Modules consist of standardized components that formulate smallest element to which module can be divided (De Blok et al., 2014). Furthermore, ability to combine modules and components flexibly is based in standardized interfaces. Interfaces have key role on configuration of modules. They enable both variety and coherence of service packages (De Blok et al., 2014). This structure altogether enables flexible arrangement of modules and components while still supporting efficiency through standardization. Complex services benefit especially from their decomposition into modules and components as the structure comes more transparent and manageable.

Testbeds

The term Living lab origins from early 2000s and was launched by Massachusetts Institute of Technology (Ballon & Schuurman, 2015). Later The European Network of living labs (ENoLL) has defined living labs as *"user-centered, open innovation ecosystems based on a systematic user co-creation approach integrating research and innovation processes in real life communities and settings."*(ENoLL, 2021) Testbeds are typically used as synonyms for living labs although some make distinction between concepts by arguing that living labs require always a real-life testing environment (Ståhlbröst & Holst, 2012) whereas testbeds operate in laboratory settings (Fortier & Michel, 2003). In this study, as well as in welfare technology sector in Finland in general, no distinction is made between living labs and testbeds. In this study the concept of testbed is deployed while yet relying on ENoLL's definition.

Testbeds has been considered as highly promising, user-centered, open innovation systems that combine scientific research, development, co-creation and knowledge exchange in real-life settings. They aim leverage stakeholder collaboration and shared ideation to solve social problems. (Archibald et al., 2021.)

Ballon and Schuurman (2015) argue that European Living Labs are based on five key elements: active user involvement, a real-life setting, multi-stakeholder participation, a multi-method approach, and co-creation. Active user involvement emphasis end user participations and encourage them to thoroughly impact the innovation process. A real-life setting means that most tests, experiments and evaluations are conducted in authentic setting or authentic-like settings i.e., simulation environments. Multiple stakeholders are fundamentals of testbeds. They include i.e., the involvement of technology companies, service providers, relevant institutional actors, professional or residential end users. Tests typically require a multi-method approach. This means combining methods and tools from different disciplines and foundations, for example, ethnography, psychology, sociology, strategic management, engineering and service design. Co-creation bring all relevant stakeholders together and requires understanding across the disciplines, institutional logics and work traditions. These perquisites of testbed activities create a complex environment for provision of service offerings. (Ballon & Schuurman, 2015.)

Testbed offer services for companies to test their services in different phase of development process, thus the maturity of the technology varies from early ideation to medical devices in market. Consequently, large variety of different testing designs is required. Due to the ethically challenging context and vulnerable end users, the field is highly regulated even in development phase. As a result, testbed services are organized in large consortium of different organizations representing different disciplines and motivations.

Material and methods

This study explored testbed services by analyzing ten testbed cases, their service structure, test process and documents needed for the processes. In order to obtain a wide perspective to the topic, the selected cases represent different types of testbed services such as piloting prototypes, usability testing and conducting register studies.

Analysed data consisted of documents related to ten testbed cases coordinated by one testbed service provider during autumn and winter 2021. In addition, data included memos from testbed coordination team’s meeting. Coordination team handles companies contacts and discusses the most appropriate testing environment. Essential characteristics of analysed tests are presented in Table 1. Based on the documents and memos, service architecture was created and interfaces were recognized.

Table 1. Essential characteristics of analysed tests

Technology	**Maturity**	**Testing environment**	**Testers**	**Feedback/data collected from**	**Focus of feedback**
Diary application for reporting feelings	Beta version	Child welfare outpatient care	Professionals, children and their families	Professionals, children and their families	Usability, user experience
Sleep tracking	In market (non MD)	Nursing home	Professionals, elderlies	Professionals	Usability, effect on employees’ night time work load
Relaxing pillow	In market (non MD)	Nursing home for people with disabilities	Professionals, people with disabilities	Professionals	Professionals’ opinion about effect on relaxation
Balance meter	In market (MD)	Hospital’s rehabilitation department	Professionals, patients	Professionals, objective measures	Effectiveness
Entertaining and rehabilitation content for elderly	In market (non MD)	Elderlies’ own homes	Students, elderlies	Students	Usability, user experience
Physical and cognitive rehabilitation carpet	In market (non MD)	Rehabilitation outpatient clinic	Physiotherapists, clients	Physiotherapists	Usability, user experience

Fall risk meter	Prototype	Primary care's balance group for elderly	Physiotherapists, elderlies	Physiotherapists	Usability
Mobile robot	In market (non MD)	Hospital logistics	Professionals, students	Objective measures	Usability
Surgery robot	In market (MD)	Hospital	Doctors	Patient data	Effectiveness
Weight evaluation device & software	Prototype	Simulation environment	Students	Objective data	Efficiency validation

Results

Based on the analysis of operations, practices, and documentations each testbed cases were described in modular terms. Altogether seven modules were identified, and separate service elements conducted under them were labelled as components. Some of the cases included all the modules whereas some cases included only some of them. Three of the modules "Test activities preparation", "testers/feedback providers" and "environment" were included in all cases (Figure 1). Rest of the modules were included if required. Inclusion of optional modules was based on national and international guidelines, such as legislations related to GDPR or medical devices, or organization's policy, such as permissions. Characteristics of tests described in Table 1 effected on the component selection. For example, maturity of the technology effected the environments available. Non-MD devices have very districted possibilities to be tested in clinical environments and thus simulation environments or environments with healthy volunteers in real-life situations were chosen for those cases. Further, testing environment, testers and data collected affected on the permissions needed. Hospitals require other permissions than associations, patients' involvement requires other permissions than professionals' involvement and structured questionnaire for participants requires other permissions than patient data screening.

Although the components were given standard labels, some of them could be further customized. As an example, after selecting "Simulation environment" component, an extensive list of different types of simulation environment were available. Similarly, possibilities in "real life situations" are endless. "Testers/ feedback providers" module's components could be also further customized, e.g., "patients" could be defined to be anyone with a patient status or highly specialized group of patients such as heart failure patients or anything between depending on aim of the testing.

Modules were provided by different professionals and organizations. For example, contracts were provided by layers, permissions were provided either from testing organizations or national officers, depending on the component. GDPR services were provided by the data protection officers. Typically, these professionals operated rather separately from each other and did not have much collaboration in their daily work. Neither were these professionals specialized for testbed service, instead it could be considered as their side job.

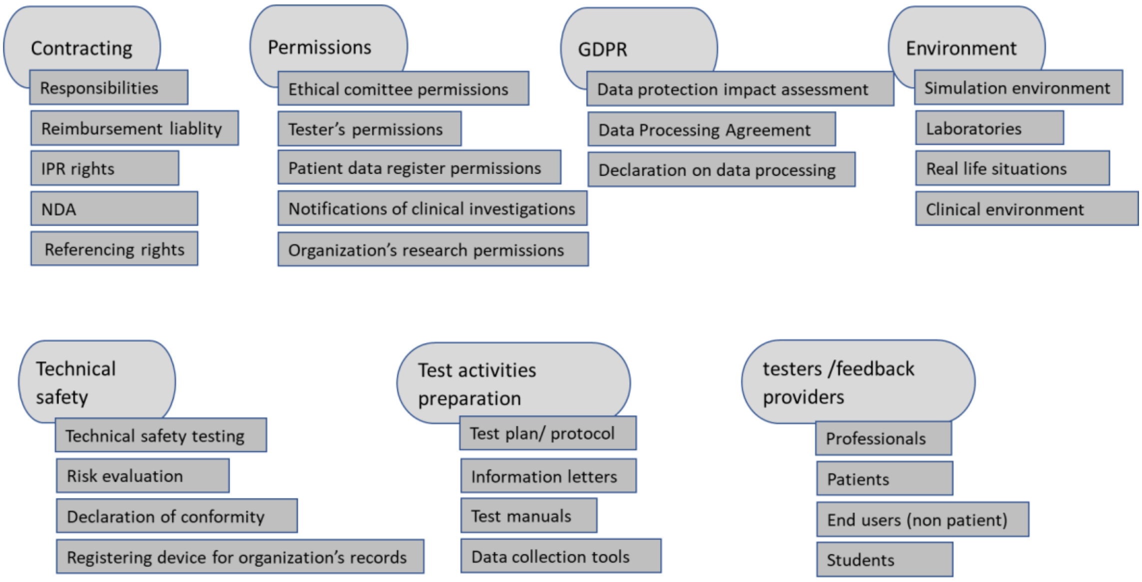

Figure 1. Identified modules and components in testbed activities

In order to combine modules and components efficiently, interfaces are needed. Based on the data, became evident that although service components were rather standardized, interfaces weren't systematically defined in testbed activities. Recognized interfaces were placed in table structured by de Blok et al. (2014) (Table 2). Interfaces supporting variety between modules were rather well described. They consisted of lists of available components and regulation concerning their use. Variety supporting interfaces between people consisted mainly of the coordination team and its meeting, where e.g., the most purposeful testing environment and testing design were discussed and selected. Coherence between modules was ensured with standardized contact policy for companies and standardized documentation related to different phases of testing. Interfaces supporting coherence between people were nearly non-existing and based on testbed coordinator's work, who had the fluency of the process in her/his responsibility. Testbed coordination team had meetings but the professionals participating actual testing were not collaborating. Thus, it was notable, that module providers had not much collaboration with each others, instead the communication was organized through testbed coordinator.

Table 2. Identified interfaces

	Entity	
Aim	**Between services**	**Between providers**
Variety	• Lists of modules and components available • National and EU regulation	• Regular meetings between testbed coordination team
Coherence	• Standardized contact protocol for companies • Standardized documentation • Service descriptions	• Testbed coordinator • Regular meetings between testbed coordination team • Regular meetings for internal evaluation

Discussion and Conclusion

This study applied modularity to visualize the testbed service architecture for health and welfare technology companies in order to make the complex entity of offerings simpler and more understandable. Modular lenses reduced the complexity of testbed services and potentially give testbed coordinator an opportunity to better customize and respond companies' individual needs in technology testing. Components for testbed offerings were typically provided by multiple professionals as mentioned by Ballon and Schuurman (2015). However, notable was that their main tasks are not related to helping companies in their testing, for example, hospital's equipment security officer or layer. Professionals whose services are needed in the testing process might not have a platform to collaborate with each other or they might not even be aware of the entity they are participating. Testbed processes' coordination responsibility relies on testbed coordinator. Illustration created in this study can help the coordination task. The list of components is highly informative also for professionals participating in testbed processes and it has potential to increase the understanding of the entity they are a part of. This increases also understanding towards companies testing needs as well as creates a full picture of other services and operations which they should consider, for example, due to time constrains. Consequently, testbeds' have better opportunities to leverage stakeholder collaboration and shared ideation to solve social problems, as stated by Archibald et al. (2021). Although the components would be well described, significant emphasis should be put on standardizing interfaces. Based on the analysis, it seemed that particularly collaboration between professionals relies on testbed coordination. Increased understanding regarding the services entity provides a starting point for creating more systematic flows of information between processionals participating the service production. Perhaps more standardized communication practices could be created in order to ensure the information flow between people. This could enhance the coherence of the services (see de Blok et al., 2014).

Deploying modularity for testbed activities provides an opportunity to create clarity to complex platform environment and to organize coherent services packages from multiple stakeholders, reduce misunderstandings and guarantee patient safety while at the same time enhancing technical innovations in health and welfare services. At the moment, application of new innovations in healthcare is complicated but it seems that by using modular constructions in testbed activities alleviated the complexity and increases opportunities to coordinate them efficiently. From theoretical perspective, this paper enlights how modular service construction can alleviate the challenges resulting from multiple professionals and multiple organizations.

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References

Archibald, M., Wiebe S., Rieger K., Linton, J. & Woodgate, R. (2021), "Protocol for a systematic review of living labs in healthcare" *British Medical Journal Open*, Vol. 11 No. 2.

Ballon, P. & Schuurman, D. (2015), "Living labs: concepts, tools and cases", *Info,* Vol. 17, No. 14.

Brax, S.A., Bask, A., Hsuan, J. and Voss, C. (2017), "Service modularity and architecture – An overview and research agenda", *International Journal of Operations & Production Management,* Vol. 37 No. 6, pp. 686-702.

ENOLL. (2021), “What is ENoLL?” Retrieved on April 20, 2021, from https://enoll.org/about-us/
Fransen, L., Peters, V. J. T., Meijboom, B. R., & de Vries, E. (2019), “Modular service provision for heterogeneous patient groups: A single case study in chronic Down syndrome care”, *BMC Health Services Research*, 19, pp. 720-728.
Fortier, P.J. & Michel, H.E. (2003), *Computer Systems Performance Evaluation and Prediction,* Elsevier Inc.
Peters, V.J.T., Meijboom, B.R., Bunt, J.E.H., Bok, L.A., van Steenbergen, M.W., de Winter, J.P., & de Vries, E. (2020a), “Providing person centered care for patients with complex healthcare needs: A qualitative study”, *PLOS ONE,* Vol. 15 No. 11, e0242418.
Peters, V., Vähätalo, M. Meijboom B., Barengret, A., Levinus, B. and De Vries, E. (2020b), “Elaborating on modular interfaces in multi-provider contexts”, *International Journal of Operations and Production Management,* Vol. 40 No. 9, pp. 1397-1419.
Schuurman, D., De Marez, L. & Ballon, P. (2016), “The Impact of Living Lab Methodology on Open Innovation Contributions and Outcomes”, *Technology Innovation Management Review,* Vol. 6, pp. 7-16.
Silander, K., Torkki, P., Lillrank, P., Peltokorpi, A., Brax, S.A. and Kaila, M. (2017), “Modularizing specialized hospital services: Constraining characteristics, enabling activities and outcomes”, *International Journal of Operations & Production Management,* Vol. 37 No. 6, pp. 791-818.
Ståhlbröst, A. & Holst, M. (2012), *The living lab methodology handbook,* Luleå University of Technology and CDT – Centre for Distance-spanning Technology, Sweden.
Voss, C.A. and Hsuan, J. (2009), “Service architecture and modularity”, *Decision Science,* Vol. 40 No. 3, pp. 541-569.