Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 181 (2021) 127–134

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2020

TSD: A Research Platform for Sensitive Data

Egil Øvrelid[a,*], Bendik Bygstad[a], Gard Thomassen[b]

[a]*Dept. Of Informatics, University of Oslo, N-0176 Norway*
[b]*University Center of Information Technology, University of Oslo, N-0176 Norway*

Abstract

Digitalisation has led to a strong increase of research data, but most of these data are managed in unsatisfactory ways, and research data management has been characterized as a "wicked problem". Several research data platforms have been launched, but security and privacy issues remain. Our research question is how can a research platform for sensitive data be built and used? Based on platform research, we propose a framework to analyze requirements. Our empirical evidence is a research platform called TSD, i.e. a platform for sensitive data. We analyze the development of TSD and offer two contributions; first, we discuss a framework to understand the architectural requirements for a research data platform, and second, we show how a research platform can be developed through a process of platformization.

Keywords: Research platform; platformization; data management; boundary resources

1. Introduction

Digitalisation has led to a strong increase in research data, with unprecedented opportunities for analysis. It is however an uncomfortable fact for researchers and universities that most of these data are managed in unsatisfactory

* Corresponding author.
E-mail address: egilov@ifi.uio.no

10.1016/j.procs.2021.01.112

ways. Although there are exceptions, most research data are conveniently stored on PCs and servers, in different formats and technologies, with only simple or rudimentary security mechanisms. Further, most research data are used only by the individual researcher or by a research group, despite large costs in collecting the data. In the era of *open science* [1], most researchers and institutions agree that this situation is problematic [2]. Adding to this, it is an open question whether researchers want to share or re-use data [3]. Overall, this made some researchers characterize research data management as a *wicked problem* [4].

Research has dealt with these issues in various ways. A global initiative is the Research Data Alliance, which aims at developing solutions that enable data sharing, exchange, and interoperability for researchers in all countries [5]. This is a long-term approach, with several work groups. The FAIR principles, i.e. Findable, Accessible, Interoperable, Reusable, were suggested in 2014 to assist researchers and institutions in data management [6]. In the past decade, several library initiatives have been launched, but available services are still limited, mainly focused on advisory and consultancy services instead of technical solutions [7]. Several initiatives for *research data platforms* have been launched [8]. Some of them are portals, providing access to different datasets based on metadata, such as EUDAT [9]. Some of them are large domain-specific networks, such as DataONE, an American search engine for environmental data, providing access to a large number of partner datasets [10]. Others are more integrated initiatives, such as the LTER platform in Korea [8] and the German portal for biomedical research [12], combining metadata management with various forms of data integration and interoperability.

A central issue with research data is security and privacy; the EU Commission [13] expressed its research data policy as "as open as possible, as closed as necessary". Much research data is collected under strict governance regimes (such as GDPR and clinical research regulations) and the possible sharing of data must be governed accordingly. Thus, in much research, there are two conflicting forces; the need for security and privacy versus the need for availability and reuse. Particularly, there is strong growth in sensitive clinical research data, such as patient records, DNA sequences, MR and CT images, patient video, and behavioural data. A research data platform needs to support all phases of data management, i.e. data collection, data analysis (including advanced computation), storage, and sharing. Our research question is: *How can a research platform for sensitive data be built and used?*

We proceed by reviewing the literature on research data platforms. Then we suggest a framework for *platformisation*, i.e. a process for creating a research data platform. Our empirical evidence is a platform from the University of Oslo, called TSD. We analyse the development and use of TSD with the framework.

2. Related research

Research data management is both a practice and a discipline, with rising importance with increased digitalisation; an unprecedented rise of data volumes has triggered needs for a more systematic approach [7]. Likewise, the push for *open science* and the FAIR principles [13] are global and institutional drivers. We first review the research data management literature, and then we discuss the concept of research data platforms.

2.1. Research data management

The past decade library research has engaged in research data management. A large, international survey [7] found widespread engagement, but academic libraries appeared to be primarily providing advisory services, and have yet to offer robust technical data infrastructure to support research activities. Seen from an Information Systems perspective, research data management is an emerging but immature field, compared to the established field of (corporate) data management [14]. They identified three functions in data management:

- Governance: develop and implement policy, monitor, and audit
- Services: support IT infrastructure, support training, and data handling
- Research: create a data management plan, handle data lifecycle

In their study from the Netherlands, supplemented with UK studies, they found that the six sub-functions (see Table 1 below) were conducted at reasonable quality, but in a fragmented way, and lacking a clear governance.

Table 1. Findings from the Netherlands study [14]

	Description
Create data management plan	Usually done by researchers, without much support.
Handle data lifecycle	Collecting data sets has a varying degree of support. Data processing, analysis, and publication are done by the researchers themselves. Data is seldom shared.
Support IT infrastructure	Central IT department offers infrastructure.
Support training and data handling	Library offers training and consultancy.
Develop and implement policy	Formal responsibility at high levels (school, faculty), but little support at the operative level.
Monitor and audit	Little or no active monitoring

2.2. Research platform

The inspiration for research data platforms comes from the spectacular success of commercial platform ecosystems, such as Uber and Airbnb [15]. Technically, a platform ecosystem consists of a central database for large transaction volumes and connects various stakeholders (often with apps) to sell and by. Well-known examples are Uber and Airbnb. The power of commercial platform ecosystems lies in their scalability and network effects; the more Uber cars available, the more Uber customers, and so on. However, the commercial, n-sided type of platform ecosystem described above, cannot be adopted in its classic form, but some key principles can be leveraged in the research world. The most important of these are the architectural principle of splitting the ecosystem into one stable core and a dynamic periphery of user services and splitting the governance accordingly [16].

Research platforms build on the insights from the platform literature, but it remains to define what a research platform is. Research platforms may be media research platforms [17], medical platforms developed in-house [18, 19], consumer research medical platforms [20, 21, 22], and public sector platforms [23, 24]. The last references conceptualize a platform as a portal from where research infrastructures can be accessed.

The closest we come to a definition is “a research platform: mediating devices that constitute the production of knowledge across a range of geocultural settings.” [25, 303]. While they require highly distributed formats of digital communication and translation, platforms also involve necessary connection with offline worlds. “Platforms bring a strategic logic to network cultures that otherwise tend toward tactical short termism” [25, 303]. Although this perspective helps us to some extent, we need a more precise definition that includes the particular mechanisms a research platform requires. Summing-up, the requirements for a research data platform for sensitive data are:

- It should be designed to help researchers conduct their core activities, with a data life cycle perspective
- It needs to leverage the basic platform ecosystem architecture and suitable governance mechanisms
- It must flexibly deal with the balance of resourcing and securing

3. Theoretical framework: Creating a research platform

A research platform must solve two main challenges, i) improve access to core data registers, ii) provide a common storing facility where research data can be kept and maintained. Inspired by [26] we understand the platform building as a process of resourcing and securing. To reach this condition within a research platform four elements must be taken care of (see figure 1)

First, the data must be collected and stored; they need a common storing device, i.e. they need a platform core [27]. The platform core must facilitate collaboration and knowledge sharing across countries and sectors through basic storing and sharing functionality [28]. *Second*, securing is defined as “the process by which the control of a platform and its related services is increased” [26, 176], e.g. through issuing and policing requirements for performance or content. Securing policies like GDPR have both international [29], national [28] and local [30] implications, and are often based on Confidentiality, Integrity, and Availability (CIA) principals [31]

Third, resourcing is defined as “the process by which the scope and diversity of a platform are enhanced” through providing key resources to third-party developers that then produce software additions (applications) for the platform.

The architecture is important to create adequate resourcing mechanisms. The architecture needs to be modular and flexible [32], as modular programming makes it more manageable, flexible, efficient, and modifiable [33]. The modular layered architecture where physical dependencies are reduced [34], is also increasing the reusability of components making it easier to change modules in the architecture [35].

Fourth, while platforms require a stable core, it must interact dynamically and flexibly with its context. This is why the stable foundation of the platform relies on the dynamic of apps to expand the platform's range. By apps or user services, we are referring to "an add-on software subsystem or service that connects to the Platform to add functionality to it…" [27, 7]. The core functionality and the boundary resources, allows the app developers to innovate right away, without having to create everything from scratch. In research platforms, the goal is to participate in the production and exchange of information across knowledge areas, and apps are thus fundamental in providing the research value to the platform core.

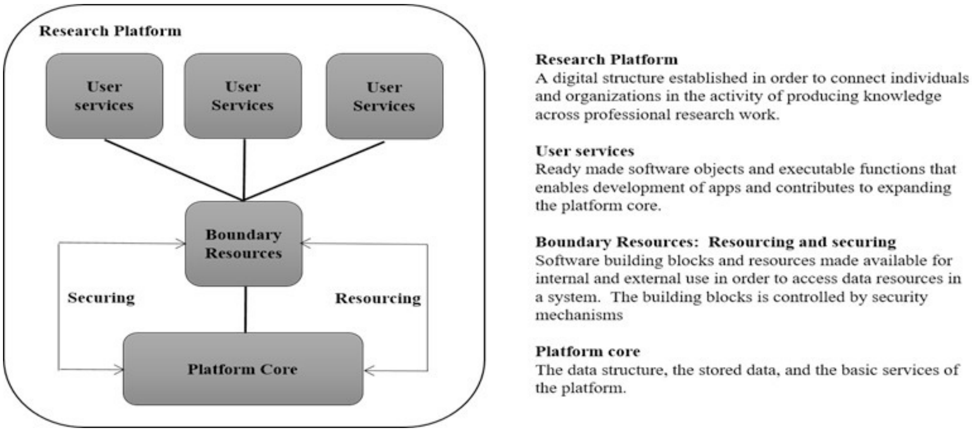

Fig. 1. A research platform

4. Case and Method

Our case is taking place at the University of Oslo (UiO), which is the highest rated university in Norway, with 28.000 students and 6.000 employees. Our unit of analysis is USIT (University Center for Information Technology), which is the University of Oslo's central IT organization with around 220 employees. USIT is one of the largest in-house government owned IT organizations in Norway, and delivers a range of services including specialist services, both locally, nationally and internationally. We use a longitudinal approach [36].

4.1. Data collection and data analysis

We performed ten interviews from August 2019 to March 2020 with key personnel from management, architecture development, and app development. In addition, one of the authors was the project manager during the development and is today head of the USIT division responsible for the research platform. We also analysed a broad range of requirement specifications, user manuals, design sketches, and white papers, and participated in web meetings.

Loosely inspired by [38], our analyses were performed in three steps. First, we identified key events leading to the establishment and use of the research platform. We noticed that there were two major challenges, first to create an agile architectural structure that enabled fast development of new services, and then to make sure that the implementations were scalable and maintained. We used the concepts of securing and resourcing [26] to analyse the platform requirements concerning the building process. Lastly, in section 6 we respond to our research questions providing two contributions.

5. Findings: TSD as a research platform

5.1. Key events

Services for sensitive data (from now TSD) is a platform developed in-house by USIT to meet the needs of UiO researchers for a lawful, secure, good, functional and remote-accessible research platform for sensitive data. The project had a stumbling start in 2010, but after a re-initiation of the project in 2012, the system was launched in May 2014 and has experienced explosive growth in the number of users (> 4,000), data volume (> 3 PiB) and a rising demand for new services. In early 2018, TSD also became the official national supplier of supercomputing (HPC) and massive storage (projects needing > 10TiB) through Uninett Sigma2 AS [37]. TSD has also evolved because of the directive from the university director, stating that TSD is to be offered as a free base platform for UiO's researchers, while the researchers from other institutions will cover both operational costs and operating costs. Further, we will first describe key events in the development of TSD before we focus on four central mechanisms in transforming the service into a platform. After this summary of TSD key events, we will describe four central aspects in creating a research platform.

5.2. Four central aspects in the platformization of TSD

Based on 2.1 we will describe four central activities that led TSD from a service to a platform. Three central requirements for TSD was to make information accessible (through collecting and connection data from various sources), secure (adapting to regulations from EU like GDPR and internal security programs like EIR), and shareable. To make it shareable and flexible a new architecture was created. We will highlight the four central activities necessary to transform TSD into a platform.

Create a platform core

The first step was to establish a platform core both to address the fragmented storing practice and to enable the sharing of data. The need to enable more efficient sharing, while at the same time making sure that data is handled with care, led to the development of a new national strategy [28]. This strategy stated that "to improve accessibility and increase reuse of research data, researchers need the skills and tools to handle data in a good and secure manner throughout all stages of the research process" [28, 1]. This required that researchers "must be able to find and access relevant data from existing sources. They must have an infrastructure for both collection, analysis, archiving and sharing of data, and access to clear information about it. The infrastructure must facilitate collaboration and knowledge sharing across countries and sectors." [28, 1] To deal with these challenges the TSD group at USIT developed a SAPEIN (Secure API for E-INfrastructures) architecture. SAPEIN offers a foundation for TSD by providing: i) a flexible model for implementing access control, ii) a secure and modular architecture, and iii) a development framework for the implementation of application servers and API clients, as well as API semantics for offering multi-tenant services. We will describe these issues further in the following. We start with the security issue

Securing TSD

As mentioned above, the internal security system group (EIR) stated, "All sensitive research data shall be stored in TSD" [30]. This also indicates that the work on TSD on a certain point converged with the work from the internal revision. Research data in medical and health research projects are classified as "red" or "black" data. Only sensitive data services (TSD) is approved for storing and handling "black data. The SAPEIN architecture made TSD conform to security regulations. *First,* two-factor login through using TSD Active Directory (AD) with Kerberos for password verification and the TSD FreeRadius server for the second factor was implemented. *Second,* all TSD hardware is kept within USIT server-rooms where only a very limited number of trusted USIT and Estate department employees are granted access (card and code). All the rooms are surveilled and kept clean and cool. This also means that hardware, equipment, and modules that in one way or another interacts with TSD has to conform to the same regulations as TSD is suffering. All data traffic in TSD traffic is encrypted and uses SSL certificates compliant with Uninett AS [11].

Resourcing TSD

Any service developed by USIT needs to use the user admin and resource management engine called "Cerebrum" when establishing file communications and integrations on user data or computer resources. Cerebrum is a result of many years of work integrating systems and files/registers at UIO, and many of the communication services it performs use batches of flat files as the basis of integration. This process is both cumbersome and slow as it prevents fast development. Cerebrum therefore easily becomes a bottleneck when new services are to be developed.

> “We definitely needed something else than what we had. Our challenges lie in defining an optimal architecture and then getting there. We had to use Cerebrum as the point of departure, but we created a layer above and gradually established new integrations. We needed to move away from a monolithic system towards more modular interfaces based on SOA and Web Services, where services interact more seamlessly and are unhindered by the complexity. While we were building TSD we have to make sure that reliability and security were maintained”.

The SAPEIN architecture enabled faster development. Within the SAPEIN architecture, USIT built up the necessary APIs in Rest. In this way, TSD became more autonomous and detached from Cerebrum's somewhat more "old-fashioned" integration logic. The TSD group also imposed certain rules saying that all teams must expose their data and functionality through service interfaces and that these interfaces should be accessible by external actors if needed. This was to set the minimum standard of any API developed. The use of REST services facilitated a more effective development of TSD in several ways, and a Project manager summarizes:

> “By using REST to handle the file transfer has TSD not only introduced a new type of architecture, but also an integration mechanism that gives an effect on the pace of development and opportunities that overshadows former “stand-alone” and case-by-case solutions.”

Expanding the platform core through user services

A key feature of TSD enabled through the SAPEIN architecture is the ability to act as the backend of any app (in-house or third party). Central to the development environment is “nettskjema” (“webform”), a modular resource with a variety of features and which easily can be integrated within apps.

> “We have created a set of libraries [in webform] that we distribute ... the apps that are created are not very complicated, they may consist of 4-5 questions. However, this means that scaling is rampant and building basic apps is cheap”

Data from web form and apps can be stored in TSD. One of the main objectives of the project was for the customer to be able to create apps themselves:

> “Customers can create the apps since we give them access to an input and output API. Calculations and the like can be stored in the app. However…we do not accept all kinds of apps, we need security routines. Further, the hospital's main trust is in us, and they like us to create the apps” (rather than any third party company).

This has been a success. “One hypothesis at start-up was that one could get 50 projects in TSD…now we have more than 1000 active projects.” Examples of apps in TSD are medical solutions for specialized medication, nutrition oriented apps to improve the diet, clinical apps to improve self-treatment. Other examples are apps to improve the development of language skills amongst children, research on everyday-life of teens, and research on techniques for improving the memory of elderly people. Examples do also include the filming of psychiatric therapy sessions, apps for enabling secure data collection from informants, and library apps to identify literary resources.

A recent example of the agile potential of TSD is the fact that a research study regarding the Corona-pandemic was developed within TSD in less than 24 hrs. The modular structure of the platform and its resources enabled a scalable solution that was put on air and used by more than 100.000 citizens within a couple of days.

TSD has become a marketplace for research on sensitive data, and USIT has extended the number of TSD employees. Despite the potential in sharing research data, however, most of the data stored in TSD are not shared between researchers from different knowledge areas. One obvious reason is the actual legal constraints regarding sharing sensitive data. Metadata should be shared.

> “The researchers have their own networks… and the various forms of data (numbers, text, film, and sound) are separated in TSD. However, one can apply for access to other's data. It is, however, still the case that some people dump their data from the TSD onto their servers after the data collection is over.”

The webform and app development is organized in the web-applications group at USIT while TSD platform development and maintenance is done by the Department for Research Support Services (FT) USIT. The FT department consists of 12 people, the department head is the operational manager of TSD, and is the main systems architect of all development. The department head reports to the head of the division who is a member of the top management of USIT. The governance consists of regular meetings (user fora’s) and additional meetings with the most complex environments every other month. After 4 years of app development, the web-applications group has become an experienced support and development organization specialized in apps and online data collection. TSD is also concerned with sustainable business models, so time is spent investigating whether the concept the researchers want is feasible. The TSD group governs the solutions that have been developed. This is part of the security and governance aspect mentioned above.

6. Discussion and conclusion

In this section, we return to our research question: *How can a research platform for sensitive data be built and used?* Answering this research question, we provide two contributions. *First*, in 6.1, we describe the basics of a platformization process in building a research platform. Then, in 6.2, we describe how a research platform can obtain data life-cycle governance.

6.1. Building a research platform through a platformization process

We propose that a research platform is created and emerges through a process of platformization. We define platformization as *a process where a research platform is created through collection, securing, resourcing and expanding*. By collecting (and connecting), we refer to the activity of creating a platform core where data can be stored and shared [27]. By securing, we refer to how the various international, national and local security requirements are translated into mechanism protecting the platform core. By resourcing, we refer to the architectural mechanisms that provide access to the platform core [27]. By expansion, we refer to the development of apps that extends the scope of the platform. The four steps correspond with existing platform literature [16, 27], but expansion has some differences compared to commercial platforms [15]. The research platform is designed to help researchers conduct core activities, which is sharing knowledge with patients (enabling self-monitoring), and receiving data from patients (medical research and similar). An important part of the core activity is to effectively establish a research study using TSD without having to start from scratch every time. An example regarding TSD is the corona-study developed, implemented and deployed in less than 24 hrs.

6.2. Maintaining a research platform through data life cycle governance.

As described in section 2, the management of research data must have a data life-cycle perspective [14]. This means that data sharing and use must be maintained, monitored, and revised continually. This also includes how data are identified, traced, and vitalized during its lifecycle, but also how they are treated if they lose their value and become degraded.

The governance of TSD has received priority within USIT, and their governance model based on DevOps have remained agile. The development of Corona-study demonstrates how a new solution is developed effectively. Data life-cycle governance also includes training and learning, and USIT has regular meetings with the various user groups to maintain the research platform according to certain quality requirements.

In **conclusion**, this paper carves out the fundamentals for a research platform, which we define as “a secure digital structure established to connect individuals and organizations in the activity of producing knowledge across professional research work.” Doing this we contribute to the platform literature in that we emphasize the specifics of a research platform, and to the data management literature by demonstrating how new solutions can be developed and governed effectively.

7. References

[1] Vicente-Sáez, Rubén, and Clara Martínez-Fuentes. (2018) "Open science now: A systematic literature review for an integrated definition" *Journal of business research*, v. 88: 428-436.
[2] Schöpfel, Joachim, Ferrant, Colline, Andre, Francis, and Renaud Fabre. (2018) "Research data management in the French National Research Center (CNRS)". *Data Technologies and Applications*.
[3] Wallis JC, Rolando E, and C.L. Borgman (2013) "If we share data, will anyone use them? Data sharing and reuse in the long tail of science and technology." *PLoS One*. 2013; 8(7)
[4] Cox AM, Pinfield S, and J. Smith (2014) "Moving a brick building: UK libraries coping with research data management as a ''wicked'' problem." *J Librariansh Inf Sci.*
[5] Treloar A. (2014) "The research data alliance: Globally co-ordinated action against barriers to data publishing and sharing." *Learned Publishing.* 27(5):9–13.
[6]Wilkinson,M.D., M. Dumontier, I.J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L.B. DaSilva,Santos, and P.E. Bourne (2016) "The FAIR guiding principles for scientific data management and stewardship." *Sci. Data*, 3 p. 16
[7] Cox, A.M., Kennan, M.A., Lyon, and S. Pinfield, (2017) "Developments in research data management in academic libraries: Towards and understanding of research data service maturity", *Journal of the Association for Information Science and Technology*
[8] Huh, Taesang, Geunchul Park, Sunil Ahn, Soonwook Hwang, and Hoekyung Jung (2017) "Design Criteria of Korean LTER Data Platform Model for Full Life-cycle Data Management" *International Journal of Applied Engineering Research* Vol(12), No(3) pp. 336-342
[9] Widmann, H., Thiemann, H. and Eudat b2find. (2016) "A cross-discipline metadata service and discovery portal." In: *EGU General Assembly Conference Abstracts*, vol (18), p. 8562.
[10] Michener W, Vieglais D, and T. Vision T(2011) "DataONE: Data Observation Network for Earth – preserving data and enabling innovation in the biological and environmental sciences." *D- Lib Magazine* Vol (17), pp 1–2.
[11] Uninett (2020) https://www.uninett.no/en, accessed 8/4/20.
[12] Suhr M , Lehmann C , Bauer CR , Bender T , Knopp C , Freckmann LK , Öst Hansen B , Henke C , Aschenbrandt G , Kühlborn LK , Rheinländer S , Weber L , Marzec B , Hellkamp M , Wieder P , Kusch H , Sax U , and Nussbeck SY (2020) "Menoci: Lightweight Extensible Web Portal enabling FAIR Data Management for Biomedical Research Projects". Accessed from https://arxiv.org/pdf/2002.06161.pdf.
[13] EU commission (2018) Final Report and Action Plan from the European Commission Expert Group on FAIR Data. Accessed from https://ec.europa.eu/info/sites/info/files/turning_fair_into_reality_1.pdf
[14] Lefebvre, A., E. Schermerhorn and M. Spruit. (2018). "How Research Data Management Can Contribute to Efficient and Reliable Science." In: *The 25th European Conference of Information Systems*. Portsmouth.
[15] Parker, G. , Van Alstyne, M. , and S. P. Choudary (2016) *Platform revolution: How networked markets are transforming the economy–and how to make them work for you*. New York: W.W. Norton Publishing.
[16] Baldwin, Carliss. Y., and Jason C. Woodard (2009) "The Architecture of Platforms: A Unified View" Platforms, Markets and Innovation. 19 44. Research Collection School Of Information Systems. Available at: https://ink.library.smu.edu.sg/sis_research/2452
[17] Ipsos Digital (2020) accessible from https://www.ipsos.digital/3/3/20
[18] Askeland, C., Solberg, O.V., and J. B. L. Bakeng (2016) "CustusX: an open-source research platform for image-guided therapy". *Int J CARS* 11, 505–519. https://doi.org/10.1007/s11548-015-1292-0
[19] McGrath, M., and T. Dishongh (2009) "A common personal health research platform – Shimmer and biomodus", *Intel Technology Journal* Vol (13), Issue 3, pp.122-147
[20] Thieme (2020), accessed from https://www.thieme-connect.com/products/ejournals/html/10.1055/s-2005-858235, 3/3/20
[21] Berlin Institute of Health (2020), accessed from https://www.bihealth.org/en/about-us/strategy/ 3/3/20
[22] Eureka (2020), accessed from http://info.eurekaplatform.org/ 2/3/20
[23] OECD (2017) accessed from https://www.oecd-ilibrary.org/docserver/8288d208 en.pdf?expires=1583234185&id=id&accname=guest&checksum=CFAA43B03EDFF3AC91931810B6348299, 1/3/20
[24] University of Melbourne (2020), accessed from https://research.unimelb.edu.au/infrastructure/research-computing-services/services/data storage-management/mediaflux, 1/3/20
[25] Kanngieser A, Neilson B and Neil Rossiter, (2014) "What is a research platform? Mapping methods, mobilities and subjectivities". *Media, Culture & Society* 36(3): 302–318
[26] Ghazawneh, A., and O. Henfridsson (2013) "Balancing Platform Control and External Contribution in Third-Party Development: The Boundary Resources Model," *Information Systems Journal*, 23(2): 173–192.
[27] Tiwana, A.: Platform Ecosystems, Aligning Architecture,Governance, and Strategy, Elsevier Inc.(2014)
[28] Norwegian Government (2017), https://www.regjeringen.no/no/dokumenter/nasjonal-strategi-for-tilgjengeliggjoring-og-deling-av forskningsdata/id2582412/sec1
[29] European Comission (2020) https://ec.europa.eu/info/law/law-topic/data-protection_en accessed 8/4/20
[30] UIO (2020A) https://www.uio.no/om/organisasjon/los/eir/index.html, accessed 8/4/20
[31] ISO (2020) https://www.securastar.com/iso-27001-faqs.php accessed 8/4/20
[32] Parnas, D.L.(1972) "On the Criteria to be Used in Decomposing Systems into Modules", *Communications of the ACM* 15(12): 1053-1058.
[33] Yourdon,E., and Constantine L. L. (1986) *Structured Design: Fundamentals of a Discipline of Computer Program and System Design* Prentice Hall
[34] Yoo,Y., Henfridsson,O., and K. Lyytinen (2010) "Research commentary –The new organizing logic of Digital Innovation: An agenda for Information Systems research". *Information system research* 21(4): 724-735
[35] Gamma, E. , Helm, R. , Johnson, R. , and J. Vlissides (1995) *Design Patterns: Elements of reusable object-oriented software*, Reading, MA: Addison-Wesley, Reading.
[36] George, A, L, and A. Bennet (2005) *Case studies and theory development in the social sciences*, Cambridge, MA: MIT Press
[37] Sigma (2020) https://www.sigma2.no/, accessed 8/4/20
[38] Bygstad, B., Munkvold, B. E., Volkoff, O. (2016) "Identifying generative mechanisms through affordances: a framework for critical realist data analysis," *Journal of Information Technology* (31): 83-96.