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Stakeholders' perceptions of digital health platform ecosystem generativity

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Full research paper

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Abstract

This paper discusses findings from a study of healthcare stakeholders' perceptions of the enablers and barriers of core-periphery systems and solutions in the digital platform of a Private Tertiary Health Service (PTHS). Using critical realism as a lens, the study involves an embedded case study of three departments in PTHS. The findings show that the platformisation of digital health infrastructure enhances generativity, including innovation, adoption, and scaling. Further, the research identifies platform governance as an area that requires enhancements. Our findings add to the limited digital health platform ecosystems literature by reporting healthcare stakeholders' perceptions. Our findings offer potential for strategy for health organisations seeking platformisation of their digital infrastructures. Further, state and national digital healthcare policymakers can use this research to address digital health platform ecosystem challenges, especially in the private sector.

Keywords

Digital health platform, Healthcare stakeholders, Innovation, Adoption, Scaling

1 Introduction

In the digital age, producing and using high-quality clinical data are essential in addressing healthcare challenges (Yang et al. 2020). However, to date, attempts at digital change in healthcare have been slow, focusing more on standards, stability, and scalability (Aanestad et al. 2017). Digital health infrastructure, which was established in Australia in the early 1990s (Hambleton and Aloizos Am 2019), is formed by installing and using several silos (Christensen 2017). Overtime, as these systems become integrated, new issues arise, such as increased complexity, cost, user dissatisfaction, and reduced adoption (Hanseth and Bygstad 2018), with data entry in the siloed systems reportedly taking up to 50% of clinicians' time (Wachter and Goldsmith 2018). Further, storing centralized and governed data in siloed systems increases the challenges associated with innovation (Aanestad et al. 2017).

In addressing these problems, one solution in the healthcare sector is platformisation (Aanestad et al. 2019). A digital platform refers to a software-based, modularised architecture with three main components: a core, a periphery, and interfaces (Gawer 2014). Herein digital platform ecosystems are not designed but evolve through dynamic interactions between stakeholders (Van Alstyne et al. 2016). Typically, digital platform ecosystems are owned by solo organisations, enabling several app developers to operate on and expand the platform. However, in large complex organisations, such as health organisations, hundreds or maybe thousands of Information Technology (IT) systems and solutions interact (Rodon Modol and Eaton 2021), creating an issue in the healthcare industry (Iden et al. 2021).

Platformisation is a governance model that enhances the generativity of digital health infrastructure (Rodon Modol and Eaton 2021) by modularising it (Tiwana 2014). Herein generativity has three main components: *innovation, adoption*, and *scaling* (Henfridsson and Bygstad 2013). Generativity is a sociotechnical concept involving users, developers, and their interactions and thus is an outcome of the interactions between IT and its relevant stakeholders (Grisot and Vassilakopoulou 2013). Limited research has been conducted on multi-stakeholders' perceptions of digital health platform core-periphery systems and solutions.

We investigated an embedded case study of a digital platform ecosystem of a Private Tertiary Health Service (PTHS) in Australia the generativity of core-periphery systems and solutions for healthcare stakeholders. Based on perceptions of six healthcare stakeholder groups, this research identified a total of 23 enablers and 24 barriers to the digital platform's core-periphery. In particular, governance was identified as a significant barrier within the ecosystem. Further, the research shows that generative mechanisms are interrelated rather than linear. Platformisation of digital health minimised the siloed system by interconnecting core-periphery, which provides further efficiency and effectiveness.

2 Generativity in a digital health platform ecosystem

This section describes the components of platform ecosystems and generative mechanisms in digital health infrastructure. Further, we present a conceptual model for analysing data from our case.

2.1 Digital health platform ecosystem

In platform architecture, rather than rebuilding or reinventing core systems to create new services, major *innovations* occur in the periphery layer through interfaces between the core platform and the periphery. The interface layer makes the *innovation* process faster and financially viable by enhancing interconnectivity. Change and evolution in the interface layer are essential to platform governance (Tiwana 2014). Although platform ecosystems should be free of tight control (Paparova and Aanestad 2020), the emergence of a dominant vendor within a platform dictates how others follow the design (Anderson and Tushman 1990). In such an ecosystem, governance is defined by who makes which decision and how the platform is shared among the owner and the periphery developers (Tiwana 2014). The platformisation of digital health infrastructure enables health service providers to cooperate with various third parties to innovate constantly rather than relying on limited vendors (Rodon Modol and Eaton 2021). Further, ecosystems enable platform owners to switch their focus from developing applications to providing resources that third parties can use for innovation (Bygstad and Hanseth 2018).

Platform ecosystems require extensive stakeholder engagement to achieve *innovation, adoption, and scaling*. Herein it is essential to create shared value among the stakeholders rather than a trade-off (Freeman 2010). According to Freeman et al. (2007), stakeholders are categorized as primary and secondary. Primary stakeholders include those vital to business operations, i.e., employees, customers, suppliers, financiers, and communities. Secondary stakeholders are present in the broader organisational environment, such as government, competitors, special interest groups, and media. The

engagement of primary stakeholders is essential in overcoming barriers to evolving digital platforms and addressing stakeholders' priorities. Stakeholder engagement increases the chance of developing helpful solutions and engenders a greater sense of ownership (McCabe et al. 2012). Schiavone et al. (2021), in a study looking at a digital health platform ecosystem, found adequate core-periphery interconnectivity maximises shared value among the stakeholders. Related, in the context of the evolution of health information systems, a systematic review identified key stakeholders as patients, users, designers, developers, administrators, nurses, and managers (Eslami Andargoli et al. 2017).

2.2 Generativity of digital health platform

Platformisation has been a solution to address generativity in digital health infrastructure (Rodon Modol and Eaton 2021). Generativity, which encompasses *innovation, adoption,* and *scaling* mechanisms within a platform ecosystem, is essential to satisfy existing and future needs (Rodon Modol and Eaton 2021). Herein *innovation* concerns the flexibility that exists within sociotechnical systems to extend business propositions beyond their initial capacities and design new services (Barrett et al. 2015). The flexibility in a digital platform plays a vital role in enhancing *innovation*, which requires multi-stakeholder engagement. It often involves combining technical, business, and stakeholder resources to yield a new solution (Henfridsson and Bygstad 2013). *Adoption* shows users' ease of adjusting their skills and using the provided service. As the number of users grows, more revenue and resources become available to invest and offer more services; thus, services are more likely to expand. Hence, a digital platform becomes more helpful if more users adopt it (Eck et al. 2015). *Scaling* shows the scope to which the provided service is expandable to enable connection to the other service providers' digital infrastructures, which offers more services and engages more networks of stakeholders (Henfridsson and Bygstad 2013). Scaling requires system integration and digital infrastructure interoperability (Rodon Modol and Eaton 2021). While siloed systems are essential in satisfying stakeholders' needs, they are not generative to innovate new solutions for care coordination, communication, and localisation (Bygstad and Hanseth 2018).

2.3 The conceptual model

Based on a systematic review of the literature, we derived a model of the key conceptual factors that impact generativity (see Figure 1). In examining the sociotechnical aspects of Context, Mechanisms, and Outcomes (CMO) in this model (Pawson and Tilley 1997), we adopted the philosophical lens of critical realism. Application of CMO leads to understanding the events or outcomes instantiated by structures and the causal power of generative mechanisms (Koutsikouri et al. 2017). Context refers to the pre-existing factors that affect the change process (Melloni et al. 2016). In this study, we consider the health service's core-periphery systems and solutions in the digital platform as contextual factors, including their interconnectivity. Mechanisms refer to drivers of generativity, including *innovation, adoption,* and *scaling,* through looking at the platform's core-periphery (Henfridsson and Bygstad 2013). Outcome refers to the changes that occur due to changes in the context and causal generative mechanisms (Melloni et al. 2016).

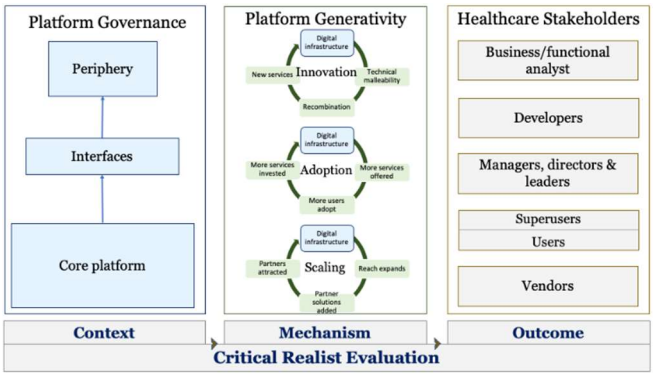

Figure 1 Conceptual model of this research

In exploring the conceptual model, we address the research question: *what are the enablers and barriers to innovation, adoption, and scaling of core-periphery systems and solutions in a digital health platform?* This question was answered from multi-stakeholder perspectives, which addresses a limitation within the body of knowledge.

3 Methodology

Through an embedded case study, we explore the research question by collecting diverse data from different sources, which enables a deep understanding of the chosen phenomenon under investigation (Yin and Campbell 2018). As aforementioned, the selected case is PTHS digital platform in Melbourne, Australia. The PTHS was chosen because it is a health organisation that is transitioning its digital infrastructure into a digital platform. Our sub-units of analysis are three departments: palliative care, emergency, and pharmacy. These departments implemented and used the core-periphery systems and solutions presented in Table 1.

Table 1 Platform core-periphery systems and solutions at the PTHS

System/solution – Go live date	Platform core-periphery
Patient Administration System (PAS) - 2008	PAS is a core platform system that automates administrative working processes.
Electronic Medication Management (eMM) - 2016	eMM is a core platform system that makes the medication prescription and administration process electronic.
Electronic Whiteboard (eWB) - 2019	eWB is a periphery solution interconnected to the core systems.
Electronic Form (eFM) - 2020	eFM is a core platform system for data storage and access to clinical information.

This study interviewed six primary stakeholder groups engaged with the core-periphery systems and solutions. These include: business/functional analysts (BFAs); IT developers; managers, directors, and leaders (MDLs); superusers; users; and vendors. Multi-stakeholder engagement allowed us to acquire diverse perceptions regarding *innovation*, *adoption*, and *scaling*. More specifically, using critical realism as a philosophical lens, multi-stakeholder engagement enabled us to get closer to reality in the specific context. To ensure data credibility and mitigate bias, we sought to triangulate our findings using various data sources (Merriam and Tisdell 2015). Table 2 summarises the data collected, which started in January 2020 and concluded in September 2021.

Table 2 Data sources at the PTHS

Data source	Description	Use of data
Documentary information	Documents related to eMM, eFM, and eWB design, implementation, data flow, and feedback were collected and reviewed.	Facilitated an understanding of the context, including systems/solutions hierarchy within the digital platform.
System walkthrough	System walkthroughs of PAS, eMM, eFM, and eWB workflows.	Used to identify systems/solutions workflow and functionalities provided to stakeholders.
Semi-structured interview	Fifty-six (56) semi-structured interviews, amounting to over 50hrs. The shortest was 30 minutes and longest 140 minutes. Interviews per group: BFAs (6), developers (7), MDLs (5), Superusers (10), users (27), and vendor (1).	Provided depth in exploring the enablers and barriers of the platform for the stakeholders.
Observation	Observed three departments over 8hrs.	Aided in gaining further insight into adoption (e.g., hardware) and systems/solutions issues in scaling, e.g., bidirectional interconnectivity.

The data was analysed via an abductive approach using Nvivo 12. Through the lens of critical realism, an abductive approach enables understanding of how generative mechanisms work in our healthcare context. Herein we moved from available mechanisms in the empirical domain (i.e., generativity) to reach mechanisms in the real domain (Mingers et al. 2013), resulting in a theoretical extension.

4 Findings

4.1 Enablers of the core platform systems

Overall, the healthcare stakeholders identified ten enablers associated with the core platform systems' generative mechanisms. Some enablers were specific to one department (see Figure 2).

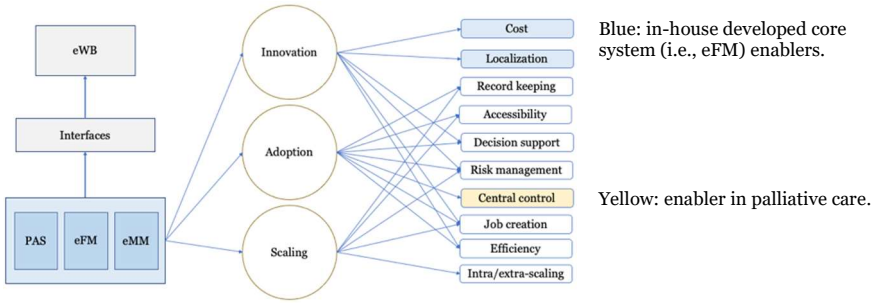

Figure 2 Enablers of the core platform systems according to the generative mechanisms

4.1.1 Innovation

Two enablers were specific to palliative care: *cost* and *localisation,* where eFM was in place. Unlike other core systems, eFM is a low-cost *innovation* that is highly localised and developed in-house. In-house *innovation* enabled stakeholders to ask for changes. *"What about this and that, they said can do that because it had been developed and individualised to the [PTHS]" (User 4).*

4.1.2 Adoption

Concerning *adoption* of the core systems, seven enablers were identified: *record keeping, accessibility, decision support, risk management, central control, job creation,* and *efficiency*. Due to intra-organisational *scaling* (i.e., expansion across the PTHS), core systems provide robust *record keeping* of administrative and medical data. This means stakeholders have anywhere/anytime access to data in a single platform. *"[PAS] creates a common platform. So, once a patient's details are entered into the system, they're immediately available to all other users" (MDL 1).* Stakeholders could access *decision support* by adopting eMM functionalities, such as alerts and prompts. A further *innovation* provided post-*adoption* is support for clinical staff in medication prescription (e.g., quick list). Palliative care uses the *decision support* functionality in eFM (i.e., prioritisation) to help nurses decide on patients' conditions based on their last three visits.

Innovation, adoption, and intra-organisational *scaling* of the core systems empower stakeholders with *risk management*. In particular, it assists with *record keeping* and *accessibility* to data via a single platform, afforded by intra-organisational *scaling*, which reduces the risks created by legibility and phone orders. Further, *innovations* in *decision support* minimise risk in medication prescription and administration as palliative care nurses could use eFM to enter data at the point of care, decreasing the risk of forgetting information, double-entry, and clinical note handovers. *"I'm not talking about just handwriting, but … dosing … previously, you just cross the original order and put a new number. Now, you must see, edit, and save things properly to sign things" (BFA 1).*

Data centralization enables stakeholders to have *central control* over administrative and medical processes. In emergency and pharmacy, where *adoption* of periphery solutions is more successful, core systems are not used for *central control*, with the eWB improving *efficiency* and effectiveness. As core systems are adopted and scaled across the organisation, more *innovation* is required, which creates new jobs for business/functional analysts. *"I guess my job probably wouldn't have existed pre-electronic applications … we need more and more people" (BFA 3). Efficiency* from *adopting* the core systems arose from: workflow change (e.g., less running around to access data), post-*adoption innovations* (e.g., quick list), and a reduction in data entry by shifting work from one stakeholder to another. *"Rather than sending out paper form getting it and then putting it into the system, now it is on the user end to do it" (Developer 3).*

4.1.3 Scaling

Scaling in the core platform varies from one system to another. Regarding intra-organisational *scaling*, eFM was only expanded in palliative care and integrated with PAS. eMM was expanded across most of PTHS. However, it was only integrated with PAS and had interconnectivity with eWB. PAS was expanded across the PTHS and had the highest level of integration/interconnectivity with the core-periphery. Intra-organisational *scaling* enabled one patient record, accuracy, and care continuum. *"PAS on a multi-campus environment. So, a patient has one record instead of three … It's a huge continuum of care" (BFA 2).* Regarding extra-organisational *scaling*, PAS has interoperability with doctors' onboarding systems, health funds, discharge list exchanges, and MyHealth Record. *"MyHealth record, the only way they do it is through PAS will send out the discharge medication chart" (User 1).*

4.2 Enablers of the periphery solutions

Concerning periphery solutions, thirteen enablers were identified (see Figure 3). Four do not exist in the core platform systems: *intuitiveness, data visibility, care coordination,* and *communication*.

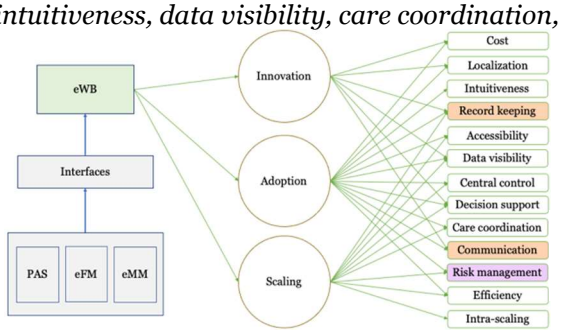

Figure 3 Enablers of the periphery solutions according to the generative mechanisms

4.2.1 Innovation

Regarding the eWB, stakeholders perceive *cost* and *localisation* as enablers of *innovation*. Herein the *cost* of *innovation* via periphery solutions is low, which post-*adoption* makes collaborative *innovations* feasible. The eWB is highly localised, which facilitates *adoption*. *"I liked it because it was customisable, and it could fit into [the PTHS] quality and safety structure" (Superuser 1).*

4.2.2 Adoption

Adoption of periphery solutions created ten enablers, namely: *intuitiveness, record keeping, accessibility, data visibility, decision support, central control, care coordination, communication, risk management,* and *efficiency*. The eWB is highly intuitive in terms of being easy to adopt and having a friendly user interface (UI). Post-*adoption*, *innovations* due to local urgencies, such as COVID-19 and continuity of care, led to emergency using the eWB for *record keeping* by interconnecting the solution to the organisational data warehouse. *"The fact that we can record people's dietary status, we can record their infectious status" (Superuser 4).* Due to platformisation, through interconnectivity of core-periphery systems, stakeholders have access to real-time data, which enhances the *efficiency* and effectiveness of data access. "*It's a lot quicker than PAS to access the information*" *(Superuser 1).*

Adoption of eWB enhances *data visibility* by using real-time data on large LCDs. *"They can visualize the work they're doing. Data is quite visible" (Superuser 8).* Further, the solution's innovative functions, such as colour coding, empower stakeholders with *data visibility*. However, the root of *data visibility* is interconnectivity with the core platform. Post-*adoption*, periphery solutions provide more efficient and effective *central control* by interconnecting siloed systems and expansion across the three departments. Stakeholders, especially managers, can centrally control the flow of patients and work. Adopting an eWB provides *decision support* via its innovative localisable functions (e.g., green/red ticks and triage) and intra-organisational *scaling*. Interconnecting the core systems delivers real-time data at the point of care, enabling clinical and managerial *decision support*. *"Real-time data at the point of care to facilitate decision making… pick out what your source of truth is … from an alert point of view where you got discrepancies in the medication allergies across your different systems" (MDL 3).*

Adoption of periphery solutions enables *care coordination*. Interconnectivity and expansion in core-periphery across departments provide a seamless patient journey from admission to discharge. *"It's the only way to know where your patients are currently … and how soon they're going to move" (User 12).* Further *innovation* of the eWB in emergency facilitates care continuum post-discharge, with the emergency department benefiting from the high *localisation* of eWB and increased stakeholders' *communication* by creating a staff board. However, in pharmacy, the periphery was used for *risk management*, meaning pharmacists could triage patients via interconnectivity with PAS (i.e., patients waiting time and age) and eMM (i.e., used medications). Overall, post-*adoption*, the eWB creates *efficiency* by changing the workflow, as it can interconnect the core-periphery. *"I can look at one screen rather than going into all these different systems" (Superuser 9).*

4.2.3 Scaling

The periphery solutions led to intra-organisational *scaling*, including interconnectivity with the core platform systems and expansion across the three departments. *"PAS is feeding it information, eMM … the electronic forms will write to the digital whiteboards" (BFA 4).*

4.3 Summary of core-periphery generative enablers

Overall, ten enablers of core systems and 13 of periphery solutions were identified, most of which are facilitated by more than one mechanism (see Figure 2 and 3). An in-house developed eFM provided stakeholders in palliative care with a low *cost* and localised solution. Emergency and pharmacy found the periphery solutions more *efficient* and effective for *central control*, with more *innovation* evident here, leading to more successful *adoption* and use of the periphery solutions. For example, emergency stakeholders collaboratively designed solutions for the care continuum and staff board.

4.4 Barriers of the core platform systems

Despite the core platform systems enabling stakeholders, they created fourteen barriers (see Figure 4).

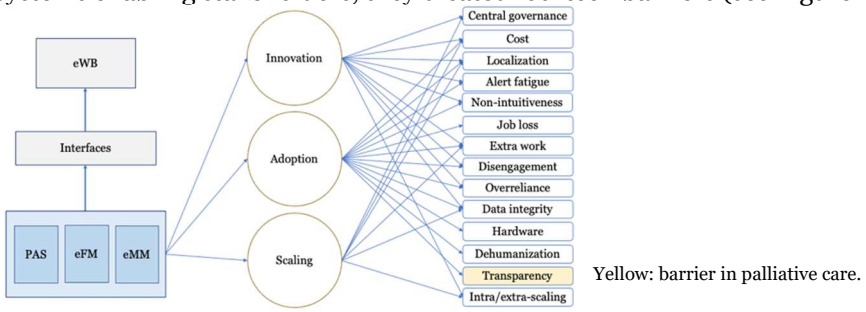

Figure 4 Barriers of the core platform systems according to the generative mechanisms

4.4.1 Innovation

Innovation via the core systems created three barriers: *central governance, cost,* and *localisation*. *Central governance* not only slowed down *innovation* but also created several challenges in *scaling*. Vendors of the core systems had a *central governance* model, which caused system and data ownership. Due to *central governance*, the PTHS had to purchase interfaces for intra-organisational *scaling*, which led to issues in the core-periphery's bidirectional interconnectivity. *"We have to get [PAS vendor] to create the A08 interface so we could write up data back into PAS" (Developer 2).*

Besides the initial high *cost* of *innovation*, core systems are costly to upgrade and update post-*adoption*. Further, the systems' expansion (i.e., intra-organisational *scaling*) makes *adoption* expensive as *innovation* requires superusers and users to undergo extensive training. *Localisation* is another barrier to the use of core systems, which mainly results from *central governance*. Expensive custom updates were not supported during the systems upgrades. Slow *innovation* and expansion across the organisation created a one-size-fits-all system that caused dissatisfaction in *adoption* and use.

4.4.2 Adoption

Adoption of the core systems led to ten barriers for healthcare stakeholders, including: *alert fatigue, non-intuitiveness, job loss, extra work, disengagement, overreliance, data integrity, hardware, dehumanisation,* and *transparency*. The high frequency of alerts (i.e., *decision support* functionalities) caused *alert fatigue* for stakeholders. eMM alerts were based on medication classes rather than substances. This issue was not addressed as implementation showed slow *innovations*. *Non-intuitiveness* in the core platform negatively impacted *adoption* and use. Poor design in terms of data access (e.g., number of clicks) and UIs created non-intuitive systems, with slow *innovation* (e.g., dated terminologies) adding to this challenge. Due to automation of the core systems, some stakeholders who had to work fewer hours post-*adoption* lost their jobs, while others left due to difficulty in *adoption*.

Robust *record keeping* in the core systems meant post-*adoption extra work* was created. Systems' *non-intuitiveness*, slow *innovation*, and integration limitations also involved *extra work*. Stakeholders faced with extra work shifted their work to others. *"They must review every medication … click every medication and push through to the discharge tab … it's clunky. It's time-consuming and involves logging on" (User 17).* These challenges in *adoption* disengaged some stakeholders. *Disengagement* was also caused by Low-quality training and more innovative expectations (e.g., reporting). *Disengagement* levels were higher amongst visiting medical officers, those who had worked for a longer period at the organisation, and older stakeholders. *Overreliance* on the systems resulted from trust in the systems' innovative *decision support* functions or relying on PAS as the core platform in the absence of an EMR.

Data integrity issues emerged because of challenges with *innovation*, *adoption*, and *scaling*. Insufficient training created a lack of confidence in systems use and inaccurate data entry. Similarly, low *localisation* (e.g., the eMM not capturing all of the medications) and slow *innovation* (e.g., PAS not having data validation and metadata) created further *data integrity* concerns. Intra-organisational *scaling* (i.e., limited integration) and extra-organisational *scaling* challenges (i.e., little standardisation in eFM) were the other reasons for *data integrity*. Some stakeholders did not have *hardware* (e.g., desktop computers). *"We haven't got our computer" (User 9).*

Further, core systems dehumanised care by disrupting stakeholders' verbal and non-verbal communications. In palliative care, *transparency* via the eFM became a barrier as data manipulation of paper records to meet KPIs was no longer an option. *"They were changing some of those dates to ensure they met the benchmarks" (BFA 4).*

4.4.3 Scaling

The core platform systems created some barriers for *scaling*. Concerning intra-organisational *scaling*, systems/solutions integration/interconnectivity was a barrier due to central governance not having an interface. Further, low *innovation* and *localisation* disturbed full expansion across the organisation (e.g., pre-admission and out-patients). Extra-organisational *scaling* barriers impacted the interoperability of systems, privacy, policy (e.g., unique patient identifier), and competition among private health providers. *"Patient privacy is paramount… it can't be shared … patient identifier, which is back to legislation … competition play a role in not sharing data" (Developer 2).*

4.5 Barriers of the periphery solutions

Compared to the core systems, the periphery solutions had fewer barriers. However, three unique barriers were identified: *system duplication, data storage,* and *effort duplication* (see Figure 5).

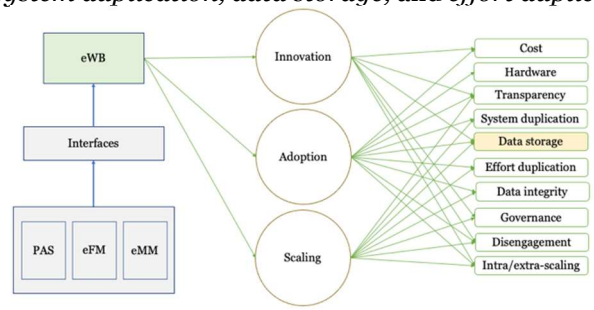

Figure 5 Barriers of the periphery solutions according to the generative mechanisms

4.5.1 Innovation

Although the upfront *cost* of eWB was low, its high tendency for *localisation* brought ongoing *costs*, post-*adoption,* as the departments constantly asked for further *innovations*.

4.5.2 Adoption

Adopting the periphery solutions resulted in eight barriers for stakeholders, including: *hardware, transparency, system duplication, data storage, effort duplication, data integrity, governance,* and *disengagement*. Some obstacles related to the *hardware* used to access the core-periphery, such as tablet/cell phone version control and maintenance. As the pharmacy did not have an LCD on the wall, accessing the eWB was more challenging. Post-*adoption*, intra-organisational *scaling* of the eWB, including interconnectivity with the core platform (i.e., providing real-time data), and expansion across the departments created *transparency* at the organisational level. Additionally, the eWB's innovative functions of eWB (e.g., green/red ticks) enabled managers, directors, and leaders to monitor their departments, which was not pleasant for all. *"The whiteboard may create a managerial control or a big brother eye" (User 9).*

Due to *central governance*, the lack of interfaces for the core-periphery bidirectional interconnectivity resulted in *system duplication,* which negatively impacted use. *"One of the disappointments with the digital platform was not having the ability to write back" (Superuser 1).* In palliative care, challenges with bidirectional interconnectivity created a *data storage* barrier. This issue, recognised in pre-design sessions, was resolved in the emergency department by interconnecting the periphery to the organisational data warehouse. Unsuccessful bidirectional interconnectivity caused *effort duplication,* with data having to be entered twice. "O*ften it felt like, why am I doing this twice?" (User 2).*

Data integrity was another barrier, with the periphery negatively impacting use due to intra-organisational *scaling*. First, *data integrity* issues in the core systems were passed to the periphery. Second, due to the lack of an EMR, more core systems had to be interconnected, which increased data transactions in the interfaces layer and resulted in data not being real-time. Lastly, sequential data updating of the eWB interface provided static data. *"They do not use real-time data. They just use the whiteboard as some data that is shown that is entered" (Vendor 1).*

Unlike *central governance*, periphery *governance* is unclear. After changes at the PTHS's executive level, further *innovation* and *scaling* of eWB stopped. *"A few changes at the executive level … a new CEO, a new head of health operations … So, obviously the opportunity to revisit priorities" (MDL 3). Data integrity*, *system duplication*, and limited training resulted, post-*adoption,* in the *disengagement* of some stakeholders. Changes in *governance* disengaged use in the emergency and pharmacy departments, where they sought further *innovation* and expansion. The director of palliative care discouraged *adoption* to hold the department as a separate entity. *"We were a separate standalone community service that needed a system that met our specific needs" (MDL 2).*

4.5.3 Scaling

The periphery solutions did not scale extra-organisation, with two significant challenges in intra-organisational *scaling*: interconnectivity and expansion. Some difficulties with interconnectivity were recognised during the early *innovations*. For example, the eWB's interfaces did not use the international version of HL7, had sequential data updating, and were designed based on a unique patient identifier not used in Australia. Limited organisational expansion of eWB also created barriers to *adoption*. *"The adoption would be better if it was rolled out across the whole institution" (Superuser 4).*

4.6 Summary of core-periphery generative barriers

Respectively, the core systems resulted in 14 barriers and the periphery in ten, most of which are caused by more than one generative mechanism (see Figures 4 and 5). The *central governance* not providing the interfaces required to interconnect the core-periphery hindered generativity in the platform ecosystem. In palliative care, *transparency* was a barrier, wherein, unlike paper forms, palliative care stakeholders could not change the referral and admission dates. Further, *data storage* was the periphery barrier in palliative care resulting in historical data inaccessibility.

5 Discussion and conclusion

By depicting the CMO and drawing on generative mechanisms, our research has identified enablers and barriers caused by the digital health platform's core-periphery in the PTHS. Although some enablers, such as *accessibility* and *central control*, were common, the periphery solutions enhanced *efficiency* and effectiveness and gradually replaced the core systems' use in emergency and pharmacy. Further, the periphery provided new solutions, such as *intuitiveness*, *data visibility*, *care coordination*, and *communication* that were not deliverable via the core systems. Applying CMO as a lens revealed that the context (i.e., digital platform) caused differences in the mechanisms and outcomes. Unlike the core systems that were difficult to adopt and timely to use (Wachter and Goldsmith 2018), healthcare stakeholders perceived that the periphery solutions were easy to adopt. The core systems were mainly used to scale the digital health infrastructure intra and extra-organisation. *Scaling* the periphery solutions is possible through their interconnectivity with the core (Bygstad 2017). The solutions were expanded across three departments and interconnected with the core platform. The periphery, known for its innovative capacities (Aanestad et al. 2019), enabled emergency clinicians to collaboratively design a solution to identify COVID-19 patients. However, being highly localised, the periphery solutions become challenging to scale. Our findings show that the core-platform systems and periphery solutions complement the platform's generativity.

Unless developed in-house, the core systems did not have any enablers created through the *innovation* mechanism. However, the in-house system (i.e., eFM) in palliative care provided stakeholders with *localisation* and low *cost*. These enablers contradict findings in the existing literature on core systems' characteristics (Bygstad 2017). By comparatively looking at the generative mechanisms of the core-periphery, platformisation of the PTHS minimised challenges associated with having siloed systems. Further, nine enablers associated with the periphery solutions resulted from the core platform making the accessibility to the interfaces crucial. Using critical realism and abductive reasoning, we provide a theoretical extension. Specifically, as shown in Figures 2, 3, 4, and 5, generative mechanisms are not linear but somewhat interrelated, with multiple generative mechanisms underpinning most enablers and barriers. The empirical data analysis demonstrates that the relationships between the generative

mechanisms are more complex and not linear. We identify *innovation*, *adoption*, and *scaling* as being interrelated and impacting one another. This theoretical extension provides a more realistic perspective toward maintaining generativity within the platform ecosystem.

The *governance* of the digital health platform is a significant obstacle to its generativity. We found two significant tensions in governing the digital health platform ecosystem. The first tension is between the core systems' *central governance* and the periphery in data *governance*. The *central governance* does not allow full integration among the core systems, as vendors do not provide interfaces. Further, without the interfaces, the bidirectional interconnectivity of core-periphery is not achievable. Therefore, barriers such as *system duplication, data storage,* and *effort duplication* emerge.

On the contrary, the periphery interfaces facilitate interconnectivity, but there are challenges with standards due to differences between countries in healthcare *governance* and standards. Facilitating interconnectivity through platform interfaces is essential in engaging ecosystems' stakeholders (Schiavone et al. 2021). Data liberalisation should be considered in platforms (Moyano and Schmedders 2019) to minimise core-periphery governance issues in healthcare organisations.

The second tension is between the department's needs and organisational IT governance strategic goals. To achieve value, investment in IT must facilitate an organisation's strategic and tactical long-term goals (Wilkin et al. 2018). In the PTHS, despite a collaborative approach to *innovation*, *governance* of the periphery became problematic. Departments with higher stakeholder engagement in *innovation* and *adoption* (i.e., emergency and pharmacy) had more use and *scaling*. For example, post-*adoption*, collaborative *innovation* with emergency yielded further implementation of solutions. However, in palliative care, the *disengagement* of director and discouraging *adoption* created challenges in use and intra-organisational *scaling*. Our findings show that *governance* of locally grown solutions and keeping stakeholders engaged and aligned with the organisation's long-term strategic goals requires careful consideration. Recently, collaborative *governance* has found momentum as a solution to address some of the difficulties in a platform's sustainability (Iden et al. 2021). As shown in our study, challenges associated with the *governance* of periphery solutions stopped further *innovation* and *scaling* at the PTHS, creating dissatisfaction and *disengagement* in *adoption* and use.

Limited research has studied, concurrently, the perspectives of multi-stakeholders of digital health platforms' core-periphery systems and solutions. Thus, we contribute to knowledge by addressing this gap. By considering multi-stakeholders' perceptions, we identify that *innovation, adoption,* and *scaling* are not linear. Interrelated generative mechanisms present a more realistic approach to enhancing generativity in digital health platforms. The identified enablers and barriers within the digital platform may benefit other healthcare providers seeking platformisation of their digital infrastructure. Similarly, healthcare providers and policymakers may use the identified challenges with the *governance* of digital health platforms to address this matter at an organisational, state, and national level.

Governance of digital health platform ecosystems is a relatively new area of research, which requires further exploration to address the existing tensions. Other qualitative studies could look at digital health platforms, in public healthcare providers, to identify data transferability. Lastly, quantitative research could be used to examine the interrelatedness of generative mechanisms.

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