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The impact of legacy systems on digital transformation in European public administration: Lesson learned from a multi case analysis

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ABSTRACT

Legacy systems have continued to pose a major challenge to digital transformation efforts in public administration. A comprehensive review of literature suggests seven levels of complexity in transforming legacy systems, including, being a stand-alone system, being part of a larger system, and data incompatibility, each depicting unique criteria and challenges. Nonetheless, very little is known as to what degree these complexities implicate the implementation of digital transformation efforts in public administration (PA). To address this gap, this research conducted an analysis on four cases of digital transformation in three European PA settings (i.e., Denmark, the Netherlands, and the UK). The findings revealed complexities that pose the key challenges to systems interoperability and integrability, which are crucial in any digital transformation project. In addition, a comprehensive understanding of the systems to be transformed, the policies which they are serving, and the broader PA setting in which they are implemented were deemed central to succeeding in digital transformation efforts.

1. Introduction

Legacy systems cause many challenges to the modernisation of public services, and several European countries have hindered their vision of realising the principles of 'digital by default' in public administration (PA) (Al-Muwil, Weerakkody, El-Haddadeh, & Dwivedi, 2019). A review of the academic literature and secondary practitioner-oriented writings identify multiple barriers to replacing PA legacy systems to realise these agreed principles. For most public administrations, IT systems are developed over time in a non-sequential way and in the silos of public policy domains. These systems are usually developed to fulfil various statutory functions of government and in most cases linked to public policies and legislation that are introduced by successive governments. In the present day, this means that there is a scattered IT landscape in PA that is based on outdated technology where data cannot be exchanged seamlessly across multiple institutions to support the modern agenda for digital government (Weerakkody, Janssen, & El-Haddadeh, 2021). In a 'digital world' where governments are striving to offer transparent digital public services to user (i.e. citizens, businesses, and other public administrations) using a single point of interaction, these legacy systems continue to act as a major obstacle to innovation and transformation in PA. Moreover, the cost of maintaining these legacy systems continue to multiply with their age together with the added burden of security threats they pose to both the government and citizens using them (Kuldell, 2019).

With the aim of tackling these issues, the European Commission's e-Government action plan 2016–2020 outlines an ambitious agenda to realise a 'no legacy principle' where all IT systems older than 15 years will be replaced. This strategic vision is urged by the need of having more efficient, secure, and interoperable public services across the union, for economic and social benefits maximization (The European Parliament and of the Council of the European Union, 2015). In the initial stage, the achievements of countries such as Estonia who has pioneered the 'once-only principle' where a true one-stop service is provided for citizens through digital government, have aspired this vision. Many challenges were cited as impeding the realisation of this plan, depending on the modernisation strategy - i.e. incremental, partial, wrapping or complete migration (Althani & Khaddaj, 2017). For example, in the context of complete migration where the entire old system is converted into a new infrastructure due to its low quality and high maintenance costs, resources (i.e. time and special skills) are cited as the main constraint. Because of this, replacing them is a risky

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proposition, as high technological and social inertia will make decommissioning these systems difficult. Adversely, if the system is not fully replaced, a complex system architecture emerges with multiple hidden dependencies that result in further technical debt (TD) (Rinta-Kahila, Penttinen, & Lyytinen, 2022). TD occurs as the result of making poor design choices during the system migration, development or maintenance (Nielsen, Østergaard Madsen, & Lungu, 2020). Albeit impossible to be completely removed, TD can be managed by approaching the socio-technical challenges (Wouters, Janssen, & Crompvoets, 2020). However, very little is known about the extent of how such complexities implicate the implementation of digital transformation in a PA context. The European Commission's *E*-Government Action Plan 2016–2020 sets out a vision to assess the implications of a possible implementation of the 'no legacy principle' – i.e. to renew IT systems and technologies implemented in public administration after a certain period of time, to keep in line with the ever - changing environment and development of technology (European Commission, 2016). Against this backdrop, this research is commissioned under the 'Interoperability Solutions for European Public Administration 2', ISA^2 (ISA square) programme to explore the challenges brought by legacy systems in implementing digital transformation in the public sector (in order to successfully deliver the 'no legacy principle). The EU also anticipates a move towards several other principles, of which the once-only-principle where citizens and businesses are required to submit the same information only once for different public services. To evaluate the context in which the public sector has to realise this vision and the complexities it needs to overcome, this paper sets out to answer the following research question: *what are the current legacy systems related challenges and good practices evidenced in digital transformation projects in Europe?*

A systematic review of the literature suggests that migration of legacy systems to the modern ones in the public sector is inevitable to realise this vision, as technology gets superseded, falls out of maintenance contracts and, becomes redundant over time (Abu Bakar, Razali, & Jambari, 2020; Ali, Hussain, Ashraf, & Paracha, 2020; Büttner et al., 2014; Khan et al., 2021; Sivagnana Ganesan, Chithralekha, & Rajapandian, 2018). Furthermore, legacy systems are frequently associated to vendor lock-in situations (Bouzerzour, Ghazouani, & Slimani, 2020; Gomes-Barbosa & Maia, 2020).

Following the review of literature, this research investigates the case of digital transformation in four European public administrations (PA) to gain a deeper understanding on the challenges and complexities faced in association with the legacy systems. To do so, the paper is structured as follows. In the next section we characterize legacy systems and define the 'no legacy principle' for public administration based on existing academic and practitioner literature. Following an overview of the research methodology, four case studies are presented as real-life examples where public administrations had to deal with legacy systems challenges. The paper concludes by proposing a set of research propositions for further exploration.

2. Literature review

Our review of the literature shows that the public sector is heavily reliant on legacy systems. Alexandrova and Rapanotti (2020) and Alexandrova (2012) suggests that government organisations rely extensively on legacy systems for their operations due to the complexity of their operational environment. Often, when implementing a new system to transform an existing process, it is common to maintain parts of existing legacy systems to ensure user experience and mitigate risk of service disruption (Abu Bakar, Razali, & Ismail, 2018). This results in inefficiencies and missed opportunities for transformation and innovation of services. In the public sector, this occurs for several reasons: existing processes are being recreated so that users do not have to be retrained, old data schemas are being retained and extended for purposes of compatibility with other legacy systems, and old features are being preserved to comply with existing legislation (Alexandrova, Rapanotti, & Horrocks, 2015). On top of these, the replication of functional and data specifications happens due to Public Sector organisation's fear of change that may lead to operational destabilization, chaos or unintended outcomes; both for internal users of the system, and the public. Scholars refer to this phenomenon of risk aversion, and uncritical acceptance of an organisation's operational/business process as 'status-quo' in the Public Sector, which leads to the de-facto "transcendence" not only of legacy technology and data models, but also of antiquated organisational governance (Alexandrova et al., 2015; Alexandrova, Rapanotti, & Horrocks, 2016).

2.1. Definitions of 'legacy systems (LS)'

According to the academic literature, legacy systems have various contextual-related definitions, which can be divided into two views, i.e., Information System (IS) and Computer Science (CS) perspectives. From the perspective of the Information Systems (IS) scholars, a Legacy System is defined as any information system that significantly resists changes and modifications (Brodie & Stonebraker, 1995). Unlike the IS scholars, Computer Science (CS) researchers suggest that a legacy system's definition is relatable to the organisation's governance (Wang, Hu, Haq, & Garton, 2007). A system can be new in technology but at the same time inherit the legacy governance due to the replication of legacy system functions without improvement to the business process. While the more meaningful approach would be to improve governance and replace any associated legacy, this may not always be possible in the public sector. The reason for this is that most processes in public administration are a result of public policy implementation to support statutory services, so there is a need to follow specific design specifications. The CS perspective is therefore, arguably the most relevant, although in practice the challenges are multiple due to the complex nature of public administration and the interconnected nature of legacy systems where there is dependency and interdependency across systems. However, regardless of the disciplines, majority of the literature tends to define legacy systems as: *Obsolete ITC systems still in use because its data cannot be changed to other format, or its application programs cannot be upgraded.* However, Brooke and Ramage (2001) explain that a legacy system is much more than the software and is a wider system of which the software and hardware is merely parts of the system. They argue that the study of legacy systems has tended to be biased towards a software engineering perspective, concentrating primarily on technical properties. They state that "a legacy system is made up of technical components and social factors (such as software, people, skills, business processes) which no longer meet the needs of the business environment" (Brooke & Ramage, 2001, p365). This interpretation suggests that personal agendas could be considered as a roadblock removing legacy systems.

2.2. Achieving the no legacy principle: mapping of complexity

With the introduction of digital government in the 1990s, most ITC systems in the public sector have been implemented to support processes and services well beyond the internal operations of a single institution (Omar, Weerakkody, & Daowd, 2020), Often, ITC systems cross the boundaries of multiple government institutions and support the implementation of policies that require the working together of multiple public administration (PA) functions. As such, modern computer systems in PA need to interoperate with several other systems across institutions to share information to enable service delivery (Weerakkody et al., 2021). This environment has naturally made the public sector more reliant on information systems and placed IT at the heart of their day-to-day operations. Unlike the private sector where products and services are delivered for profit, in the PA services are delivered to support policy goals and deliver policy outcomes (Hood, 1983). As such, the purpose of implementing a computer system and its operational focus is different in PA compared to the commercial word. Therefore, there are multiple factors to consider when replacing an existing system

that starts to become obsolete or enters a legacy state. Certainly, evidence from across multiple projects in the public sector (e.g., National Programme of Information Technology in the Health Service in the UK, Department of Vehicles and Licensing Agency computerization project in the UK, Universal Credit computerisation in the UK) suggests that the complexity of replacing a legacy system in PA has a major impact on project success and failure. Furthermore, this relevance (i.e., "touching" the supporting ICT systems) was a major driver in the better regulation practice of the EU. As such, any proposal of European new regulations has to conduct a previous ICT impact assessment study covering the impact of digital transformation on the legacy ICT systems.

From our observations, the best criterion to assess if a legacy system is obsolescent should be based on the risks associated to its architectural building blocks. The European Commission recommends EIRA (European Commission, 2019) as the reference architecture for identifying the architecture building blocks of a digital public solution, legacy systems included.

Based on the review of literature, we have outlined in Table 1 1 the extent to which the No Legacy Principle can be realised in PA.

3. Research design

This research adopted a qualitative case study approach and explored emergent factors of implementation of digital solutions and the complexities surrounding it due to the shift from existing legacy systems in three public sector organisations. This study has sought to explore constants in process and outcome in respect of creating a cross-case synthesis of public sector legacy systems transformation projects rather than theory building or testing. Therefore, this resulted the need to consider a research methodology that captures both the depth as well as the richness of emergent factors of legacy system transformation using public sector case organisations that have been through the implementation of digital solutions. Taking into consideration the originality and exploratory nature of this research, a case study strategy was chosen (Gustafsson & Bowen, 2017). As this research sought to identify the emergent factors associated and the development of practical lessons with the complexities of implementation of digital solutions to shift away from the legacy systems, it was felt that a broad, rich exploratory approach was needed. In addition, the conclusions drawn from multiple case studies are more compelling as opposed to those elicited from a single-case approach (Cavaye, 1996; Cunningham, 1997; Gustafsson, 2017) . Therefore, a multiple-case approach was pursued. As per Gustafsson (2017) choosing the number of cases should take into consideration factors such as how much is known about the phenomenon and, what new information is likely to emerge from studying further cases. This research therefore was guided by the principles of Dyer and Wilkins (1991) as cited in Gustafsson (2017) and adopted the research strategy similar to.

3.1. Data collection

A combination of primary and secondary data has been used to develop the findings presented in this research as highlighted in Table 2, which include online interviews, illustrative materials (for example, publications that form part of the case study organisations' history) and historical project management documentations. Secondary data sources were used to collect data with regards to the development of technology management taxonomies and the extrapolation of lessons learnt.

The researchers come with extensive industrial experience and have published research of a similar nature; thus, tacit and explicit experience aided in predefining the interview protocol to delineate the research process. The interview protocol was subjected to the standard university process with regard to ethical approval of data collection methods and modes of collection. Also, care was taken to ensure that data bias did not influence the data collection process. This involved use of research team (multiple people) to code the data and also have participants review the

Table 1
Realising the no legacy principle in PA: A mapping of the complexity levels.

Towards no legacy principle[a]	Assessment of the migration process to eliminate legacy systems	References
Complexity 1	**Stand-alone** obsolete architecture containing process information that may still be in use in a government institution because its data is of relevance and value to the institution to deliver its services but can be replaced with a new architecture.	Kardan and Sadeghiani (2011)
Complexity 2	An obsolete architecture that is **part of a larger network of systems** containing process information that may still be in use in a government institution because its **data** is of relevance and value to the institution to deliver its services. This can be replaced with a new architecture and integrated within the network of the larger system with minor modifications to other systems in the network.	Alexandrova et al. (2016); Anderson (2008)
Complexity 3	An obsolete architecture containing process information that may still be in use in a government because its **data** cannot be changed to a new/current format, **or** its **application programs** cannot be upgraded due to technical and/or process related constraints within the institution.	Beane et al. (2019); Pérez-Castillo, Weber, and Piattini (2013)
Complexity 4	An obsolete architecture containing process information that may still be in use in a government institution because its **data** cannot be changed to current format, or its **application programs** cannot be upgraded due to technical and/or process related issues **caused by its integrated nature** with other public administration processes in one or more other government institutions.	Brown and Toze (2017); Karantjias, Stamati, and Martakos (2010)
Complexity 5	An obsolete architecture containing process information that may still be in use in a government institution because it cannot be changed due to the **nature of the Public Administration processes** it automates or supports across the institution. This is hugely challenging as it **may** require **disruption to an existing service and likely to need changes to an existing policy and/or legislation**.	Serrano, Hernantes, and Gallardo (2014)
Complexity 6	An obsolete architecture containing process information that may still be in use in a government institution because it cannot be changed due to the **nature of the Public Administration processes** it automates or supports across the institution and multiple other institutions. Replacing this architecture will require a significant investment and undertaking a major digital transformation project with a	Nanping and Yuan (2008)

(*continued on next page*)

Table 1 (*continued*)

Towards no legacy principle[a]	Assessment of the migration process to eliminate legacy systems	References
	medium-high level of risk. It will also result in disruptions to several services and is **highly likely** to need **changes to one or more policies and/or legislations.**	
Complexity 7	An obsolete architecture containing process information that may still be in use in a government institution because it cannot be changed due to the **nature of the Public Administration processes** it automates or supports across the institution and multiple other institutions. Replacing this architecture will require a significant investment and the undertaking of a major digital transformation project with **a high level of risk**. It will also result in disruptions to multiple services and **will certainly need changes to several policies and/or legislations** across government.	Abu Bakar et al. (2018); Sivarajah, Kamal, Irani, and Weerakkody (2017)

[a] Level of Complexity 1–7, with 1 being less complex and 7 being most complex.

interview transcripts to maintain objectivity and avoid bias with qualitative data analysis. This research followed an approach consistent with that used by Kaisara and Pather (2011) and when conducting exploratory research as part of the research design, where an iterative process of data collection, analysis, and verifying was adopted. Consequently, this aided pattern identification and explanation building that resulted in the researchers developing descriptive lessons learnt.

3.2. The data sources and process: Secondary data and interviews

The two cases of digital transformation in the UK were studied using evidence of secondary data as outlined in Table 2. This data was gathered using publicly available information, including reports, working papers, evidence published by scientific committees in the house of commons, reports published by the national audit office and the expert press over a 10-year period. The UK based cases are two of the highest profile and extensive digital transformation projects undertaken in the UK.

The cases selected in the Netherlands and Denmark employed interviews as the data collection method. The interviews were conducted virtually and those selected for the interview process were identified based on their involvement in digital transformation in the respective cases and therefore were the most knowledgeable when it came to offering meaningful insights into the legacy systems related challenges and good practices in their digital transformation projects. Therefore, four individuals were selected for the interview based on their job roles and the level of involvement they had on the digital transformation projects as below in the two case study organisations:

- Chief Technology Officer
- IT Project Manager
- IT Infrastructure and Systems Manager
- Data Protection Manager

The duration of each virtual interview lasted between 60 and 90 min, where every interview was conducted on a 'one-to-one' basis to stimulate conversation and break down any barriers that may have existed between the interviewer and interviewee. The researchers acted as a neutral medium through which questions and answers were transmitted in an endeavour to eliminate bias.

3.3. Case study validity

The use of interviews and documentary sources required the need for internal validity to ensure robustness of the findings. Interviews were digitally recorded and subsequently transcribed which were given to each interviewee to check and resolve any discrepancies that may have

Table 2
Data collection summary.

Case study	Country	Primary data	Secondary data	Length of virtual interviews
Case 1 - Enabling Interoperability with EU System	Denmark	4 Interviews with: • Chief Technology Officer • IT Project Manager • IT Infrastructure and Systems Manager • Data Protection Manager	Project Management Documentations	60 min per each interview
Case 2 - Revolutionizing Data Landscape	Netherlands	4 Interviews with: • Chief Technology Officer • IT Project Manager • IT Infrastructure and Systems Manager • Data Protection Manager	Project Management Documentations	60 min per each interview
Case 3 - Enabling Real-time Online Transaction and Interoperability with External Systems	United Kingdom	None	Publicly Available Reports in the organisation's official blog, News Items reported in the mainstream media, Audit report published by the National Audit Office, report published by House of Common Select Committee (UK Parliament).	None
Case 4 - National Programme for Information Technology (NPfIT)	United Kingdom	None	Publicly Available Reports, News Items, Scientific Evidence published by the National Audit Committee	None

arisen and eliminate any interviewer bias. The researchers followed Pan and Tan (2011) procedures in conducting the study and use of triangulation for data collection, which is also supported by Ashour (2018) to help contribute to the reliability and validity of the study. Therefore, the researchers have confidence in the veracity of the research process and findings.

4. Evidence of obstacles in the no legacy principle in Europe: A case analysis

To obtain the answers to our key question in this research – i.e. what are the influences and challenges associated with legacy systems underpinning the implementation of digital transformation in European public administration, we draw on empirical evidence from four cases of digital transformation across three different contexts in Europe: United Kingdom, Denmark and the Netherlands. Focus was given to the challenges encountered during the development and/or implementation of a specific digitally enabled service transformation in the identified public organisations, from the perspectives of the service providers as named in Section 3.2. The cases involved are in different sector of services: inland revenue for Denmark, local municipalities in the Netherlands, and transportation and healthcare in the UK.

4.1. Enabling interoperability with EU system: A case study of digital transformation in Denmark public administration

This transformation project is an ongoing effort in one of the Danish government agencies. Evidence on this case was gathered from four different stakeholders of different roles, who are involved with the project through series of virtual interviews. Prior to this transformation, the agency uses at least 25 legacy systems whereas six of them are EU-hosted customs systems and the rest are national systems, which some being rooted since the first modernisation of the public agency in early 90s. Thus, the systems offer very limited flexibility regarding data structures and integration with other IT systems, besides having high dependency on manual data and information processing. The total cost of this system transformation is hold confidential; however, it has been described in the press as the biggest ICT project ever conducted by the Danish government.

This project was triggered by the changes in the European Union Customs Code,[1] urging the Member States to develop electronic systems for the exchange of information, such as declarations, applications, and decisions, between customs authorities and with the Commission, and the storage of such information (cf. Articles 6 and 16 of Regulation (EU) No 952/2013). As the result, a portfolio review was conducted on the existing systems to understand if the new requirements, such as registration and casework, could be supported. The review findings suggest that the existing systems are incapable of handling the new requirements due to various technical limitations, which led to the initiation of an EUTK (Unionens Toldkodeks) programme, comprising several digital transformation projects of which the digital transformation of the revenue system being the largest.

It is envisaged that the solution derived from this digital transformation is future proof, and able to support the declaration management system in use domestically and abroad, especially in the EU countries – which account for around 19.5 million declarations a year, corresponding to approximately 78 million items - a number that is expected to increase significantly due to recent legislative changes such as Brexit. To minimise project risk and avoid business interruptions, the solution must be able to accommodate the ongoing import, export and transit processes and requirements, in terms of its functionality and implementation. The major goal underpinning the transformation is that the solution offers a high degree of reuse of integrations and data across the declaration processes for import, export and transit, hence implementation and integration form a major project scope, demanding all stakeholders and suppliers to work together closely. Other project scopes include training, hyper care maintenance, users support (the agency internal users and companies) and operationalisation of the new system. Because of these intricacies, this case mimic complexity level 4 as described in Table 1.

Due to this huge scope, the agency has adopted an incremental approach towards the modernisation of legacy systems, which helps to minimise risk and complexity – i.e. all their legacy systems were mapped out and evaluated against their functionalities and real potentials of being modernised. Besides being able to successfully identify various legacy sub-systems, the findings i.e., incompatible data format and inflexible function barring compliance with the new EU Customs Code, including data transfer to the European Commission and other Member States, form a strong business case for transformation.

According to the interviews, the integration scope admittedly was the largest and the most challenging work, as it must be ensured that both the new and the old systems are able to functionally work together, while at the same time opening possibilities for future system extension. Other key challenges include the non-existence of the legacy systems blueprints including the coding source, has added more time to understand the system's technical functions, while the absence of documents capturing the tacit knowledge about core business process information and retirements, limited the understanding on the system's usability. While these challenges impeded the legacy systems integration with new systems, it is also foreseen that the new systems will affect the existing workflow and some functions in the organisation, thus demanding change management efforts from the outset; delays were seen to further exacerbate the project cost and brings about bigger implications to the country as the customs administration is expected to be working 24/7.

Although this case is an ongoing project with limited evidence to demonstrate its success, there are myriad of lessons that can be learned from it. Foremostly, an agile approach to project management is highly important in transforming a legacy system, especially in the limited presence of key documents and knowledge about the system, as it could exhibit various useful behaviours and values, including collaboration, continuous learning, and trust between the policy makers, developers, and the service providers.

4.2. Revolutionizing data landscape: A case study of digital transformation in the Netherlands public administration

Departing from interoperability challenge impeding cross-agencies collaborations, this ongoing case is conceptualised as a movement to revolutionize the Dutch municipal data landscape through digital transformation. The whole project is underpinned by tenets to eliminate data duplication, ensure GDPR compliance, and flexible for future development to meet the ever-emerging needs of the people. As such, the transformation requires breaking up the silos of current systems and processes in the government agencies, which entails the development of a new system architecture that consists of the following layers: data and its storage, services and its API,[2] integration with the legacy systems, process sequential, and interactions with other systems and platforms, which brings a focus to the 'Natural Language Platform (NLX)' use. NLX as an opensource system for exchanging peer-to-peer data based on federated authentication, secure connectivity and protocols that facilitate a large-scale API landscape with multiple organisations – i.e. the

[1] Regulation (EU) No 952/2013: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02013R0952-20161224&from=EN. More information on the Union Customs Code and its amendments, see: https://ec.europa.eu/taxation_customs/business/union-customs-code/ucc-legislation_en#ucc.

[2] API is the acronym for Application Programming Interface, which is a software intermediary that allows two applications to communicate to each other (source: https://www.ibm.com/cloud/learn/api).

core component of the project. This denotes that all systems or applications should be using a same platform, while data should only be kept by the organisation responsible for its administration and made available for others via API – hence a national federated system will be used to authorize access.

With a duration of 10 years, this project is estimated to cost €150 million, involving a complete overhaul of the legacy systems environment in all local municipalities, where approximately €7 million was costed for the first 3 years of the project development and implementation. Due to heavy involvements of various stakeholders across different locations in the country – i.e., at least with 355 municipalities, a huge amount if the project cost is allocated for organisational and promotional activities. This project is administered and run by a parent agency, in co-operation with all agencies underneath it on a voluntary basis. Other stakeholders involved with this huge scale transformation project include the state departments, ministries, and IT contractors. The evidence for this case was gathered from interviews with four key stakeholders involved with the project planning and development.

According to an interviewee who works with the parent agency, there is heavy reliance on legacy systems in determining the design of this new system. They include the decision on elements to be migrated and to be kept, that are based on the impact the update would bring to the business processes, and on the necessity and importance for the update. Any remaining legacy components of the system are planned to also be updated in the near future. Another interviewee working with the municipalities suggest, due to the scale of the project, there will certainly be need to re-train existing employees and upskill them to use the new systems. Meanwhile, the interviewee who are with the programme management team is anticipating that the desired overhaul of municipality legacy system will lead to various benefits, such as more compliance towards GDPR, better flexibility, better functioning market of suppliers, better facilitation of collaboration between public institutions, and enhanced data transparency.

Currently, the project demonstrated exemplary commitment from the top management, policy and decision makers, as well as high engagement of stakeholders and effective recruitment of technical expertise. The project's vision has already encouraged broad support from various public organisations, with all the 355 municipalities in the Netherlands having committed to transform their entire IT systems to the new system architecture. This is considered a huge success, as it demands a common understanding of the vision and underlying challenges.

However, the project of this scale entails multiple challenges. As shared by a stakeholder involved in the project development and implementation, these challenges revolve around reliance on legacy systems across municipalities, working together with many different organisations/legal entities, the size and scale of the legacy systems, transforming from a slow and inflexible ecosystem to a highly adaptive, innovative, secure and GDPR compliant open ecosystem thus, making it possible to supply the Dutch society with modern solutions to public issues. Reliance on old outdated software systems that were not easily upgradeable to the latest versions also offers a set of challenge as the agencies continue to retain the legacy business process and retain the some of the legacy systems, besides challenge in system integration. The legacy systems were evaluated based on their impact on the business processes, as well as their need for an update. The legacy systems that are not within this bracket receives lesser priority and lined up as future works.

As the system will be used as a single gateway to deliver myriad services to the public including residency address registration, parking permits registration and social care services, its development involves working with hundreds of IT suppliers and configuration of more than 600 legacy systems. Since the technology underpinning the legacy systems are mainly built on close source coding, the risk of encountering a system which is no longer supported by the vendors and not integrable to a new platform, is high. However, optimistic organisational culture and positive attitude towards the use of new technologies and modern systems worked in favour of promoting change and meant that staff buy-in for the transformation programme was good. Due to the scale of the changes made in the project, user upskilling and retraining formed part of the project scope and accounted for a significant budget. The programme management highlighted that an estimation conducted by a government authority suggests the IT environment accounted for the total cost of ownership (TCO) to be approximately € 1.5 billion. Therefore, a targeted 20% cost reduction potentially would impede the transformation.

Reflecting the characteristics of complexity level 7 as described in Table 1, the introduction of a new system architecture required a significant investment and entails a high level of risk. Nonetheless, there are plenty of lessons that can be drawn from this case. The most significant lesson is the importance of getting buy-ins from the stakeholders. Although more modern technologies offer strong benefits over the existing systems, user skepticism still exists. This is common in an institutionalised environment such as municipals, where users are used to particular legacy systems. A new system is often misinterpreted, and expected to perform the same function, which make process changes unwelcomed. Buy-ins, therefore are crucial to facilitate effective communications signifying the changes.

4.3. Enabling real-time online transaction and interoperability with external systems: A case study of digital transformation in the UK public administration

This case is based on a digital transformation project that has taken place in an agency under the Department for Transport, United Kingdom. The agency is responsible for maintaining a database of all drivers in Great Britain and a database of vehicles for the entire United Kingdom, and issues driving licences, organises collection of vehicle excise duty, and sells personalised registrations. It is one of the earliest public sector agencies to implement end-to-end digitally enabled public services in the UK, allowing multiple transitions to be carried out online 24/7 - such as applying for a driving licence, taxing a car, changing a driver's address or personal details, and other procedures that need to be completed when buying or selling a car. A majority of legacy systems were replaced and re-engineered, enabling integration with the internal and external systems, including those owned and used by nationwide motor vehicle dealers, insurance companies, police, the Ministry of Transport (MOT) garages (who check and authorize the roadworthiness of vehicles that are older than three years), and the passport office, and department of work and pensions. Besides allowing access to real time information such as MOT details (e.g., vehicle roadworthiness certificate) and insurance details, the integration facilitates data validation such with the Department of Work and Pensions to facilitate the needs of disabled drivers, and with the banking system for payment purposes.

The cost of changes to IT systems in 2018/19 was reported at £60 million. In 2017, it was reported that the agency has managed to realise £78 million in cost savings while the take up of its digital services increases at 92% (DVLA, 2018). The transformation has allowed the agency to issue 11.2 million driving licences, dealt with 750,000 drivers' medical applications, issued 14.2 million vehicle registration certificates, 46.5 million customers taxed their vehicle online, and collected around £6 billion in Vehicle Excise Duty (VED) between 2017 and 2018. In its 2017–2020 IT strategy, the agency committed to replace a majority of its legacy systems and complete the transition via an "incremental peel off", rather than a big-bang migration (Marrs, 2017). The project was cited as one of the most successful digital government projects in the UK, measured through the seamless interoperability that has been achieved between multiple agencies through the introduction of new IT systems, achieving the desired 'one-stop-shop' concept for users.

Prior to the transformation, the services provided by this agency (i.e., application for driving licence, taxing a car, forms that needed completing when buying or selling a car) had to be partly completed

manually. This process typically required citizens to travel to a post office to collect the relevant forms, complete them and take them back to the post office together with valid supporting documents such as insurance certificate, passport or driving licence and utility bills to confirm proof of person and/or ownership. This meant that the processes were fragmented and there was limited transparency or traceability of transactions. Moreover, it was time consuming and costly both for the citizen and the agency.

Road safety is one of the key policy outcomes of the Department for Transport, where the agency has a contributory role to play, through the provision and maintenance of complete and accurate registers of drivers and vehicles (DfT, 2014). Hence, the agency works with and supports the police, the courts and another agency to prevent vehicles that are not licensed (or not roadworthy or insured) as well as those drivers who are disqualified, medically unfit or do not have the correct entitlement to from using public roads (DfT, 2014). The agency also works closely with other government departments and agencies including Home Office, Ministry of Justice, Treasury and UK Border Force and local authorities to deliver their policy requirements, such as traffic management and reducing carbon emissions. Meanwhile, the agency's private sector customer base is also wide-ranging involving organisations within the transport and logistics industry, such as motor dealers, insurance companies, fleets and other commercial organisations that include such as data aggregators, finance companies and parking operators (DfT, 2014). In this context, the agency's digital transformation project entailed far-reaching organisational, cultural, technological and social change to transform the way the Agency offers its services to the taxpayer and conducts its business. Despite of these long-institutionalised settings, the agency has successfully abolished the physical (paper-based) tax disc after 93 years in operation. Moreover, the broader policy implications included reduced fraud, more transparency and improved real time services, all of which contribute towards the digital agenda in the UK government.

Focusing on far reaching change to deliver short-term, large-scale savings for long term efficiency, the aim of the DVLA digital transformation project was to shift from a semi-automated service in the early 2000s to a fully digital, online service by digitising majority of its functions including: recording driver endorsements; disqualifications and medical conditions; issuing photo card driving licences; issuing vehicle registration certificates to vehicle keepers; taking enforcement action against vehicle tax evaders; registering and issuing tachograph cards; selling DVLA personalised registrations; helping the police and intelligence authorities deal with crime; and providing anonymized data to those who have the right to use the service (DVLA, 2019). Despite of these successes, followings are recognised as the main challenges impeding the project:

- Integrating several legacy and new systems across multiple organisations, both public and private;
- Retaining core business process information and minimising downtime to maintain ongoing services;
- Data protection and security considerations, particularly protecting personal information from cyber related attacks;
- Data compatibility and migration across multiple systems;
- Initial user-resistance from across both public and private sector organisations involved in the project;
- Poor take up of online services during the first five years of the projects;

Nonetheless, the Agency continues to move to more agile and cloud-based services while retaining an alternative service channel to digital for service inclusion.

The case reflects complexity level 7 as described in Table 1, signposting various lessons to be learned. If anything, the most important lesson imposed is to change the complex procurement, maintenance, and service arrangements due to dependency on various legacy systems across the multiple agencies who were part of the service eco-system. It is also worth to note that since its commencement in 2004, the transformation was delivered in an incremental way, where (arguably) the key strategic drivers for this reform have been internally focussed.

4.4. *Revolutionizing patient care service: A case study of digital transformation in the UK public administration*

The National Programme for Information Technology (NPfIT) is the largest public sector IT project attempted in the UK. Originally estimated in 2002 to cost the taxpayer approximately £6 billion, the project was dismantled a decade later in the face of implementation problems, spiralling cost reaching almost three times the original estimate and severe stakeholder opposition. The aim of NPfIT was to radically improve the delivery of healthcare services in England by transforming the information flows around the health services, i.e. across primary and secondary health care providers. By digitising patient records and making them available for patients and care providers, whenever and wherever needed, the NHS aimed to deliver a faster, safer and more convenient patient care service. It aimed at achieving this through giving patients the information they need to better manage their own healthcare needs (Connecting for Health, 2007).

The project started in 2002 and ended in 2013 and the aim of NPfIT was to provide better healthcare for patients through combining an integrated care records service with electronic prescribing, appointments booking and medical imaging, along with performance management of primary care to improve efficiency. The programme sought to develop a fast and reliable IT infrastructure, centralised electronic records for all patients, available to those authorised to see them, and support for new ways of working through electronic booking services and electronic transfer of prescriptions. Led by the Department of Health in England, the project aimed to move the National Health Service in England towards a single, centrally mandated electronic care record for patients and to connect 30,000 general practitioners to 300 hospitals, providing secure and audited access to these records by authorised health professionals (Connecting for Health, 2007). The estimated cost of contracts awarded during the first seven years of the project was over £6 billion and the final costs were estimated at over £20 billion. The cost to the taxpayer made this the largest civil IT project in the world (Fleming, 2004). This project provided storage and retrieval service and easy access to patient information for analysis and diagnostics. In doing so, allowing the tracking of clinical activity through digitisation for care givers (doctors) as well as empowering patients to take control of their health and wellbeing.

By digitising patient records and making them available for patients and care providers whenever and wherever they were needed, the NHS sought to deliver a faster, safer and more convenient patient care service, whilst giving patients the information they need to better manage their own healthcare needs (Connecting for Health, 2007). It was planned that patients would also have access to their records online through a service called HealthSpace. The core of the NPfIT programme was based on developing a *Spine* (infrastructure backbone) to define a set of national services used by the NHS Care Record Service. These included:

- The Personal Demographics Service (PDS), which stores demographic information about each patient and their NHS number. PDS stipulated that patients cannot opt-out from this component of the Spine, although they can flag their record as 'sensitive' to prevent their contact details being viewed by 831,000 staff;
- The Summary Care Record (SCR), which is a summary of patient's clinical information, such as allergies and adverse reactions to medicine; and
- The Secondary Uses Service (SUS), which uses data from patient records to provide anonymised and pseudonymised business reports

and statistics for research, planning and public health delivery (Connecting for Health, 2007)

The Spine also provides a set of security services, to ensure access to information stored on the Spine is appropriately controlled (Carr-Brown, 2004; Computer Weekly, 2008). The Spine was migrated to a new Open-Source system in August 2014 and now supports the sharing of information securely through national services such as the Electronic Prescription Service and e-Referral Service through the choose and book system.

While the overall NPfIT project aimed to create a 'single electronic patient record than can be shared across the healthcare system'. Several sub-projects were considered successful implementations across England including the Electronic Prescription System (connecting GP practices to Pharmacist) and Choose and Book system (allowing patients to choose and book their secondary care appointments). However, these sub-projects took over 10 years to be implemented and have faced teething problems along the way, including adaption issues that have resulted in high operation costs and poor return on investment. Today, although patient information remains scattered across the various primary and secondary care providers without integration, the National Digital Spine has allowed the implementation of Choose and Book (or e-referral) system and Electronic Prescription System.

Encapsulating the above, the broader vision of NPfIT was to bring the NHS' use of IT into the 21st century through the introduction of integrated electronic patient records systems, online 'choose and book' services, computerised referral and prescription systems and underpinning network infrastructure. This vison was to be achieved through the creation of a National Spine which would securely hold and exchange personal and clinical information of patients through connecting with multiple systems across primary and secondary care. However, due to compatibility and data migration problems caused by the large number of legacy systems used in the National Health Service (NHS) in England, the project started to face major technical difficulties from the start. Data transfer was difficult because methods of information input differed between existing clinical systems and the proposed new systems in NPfIT. While this prevented the implementation of electronic patient records and contributed to the derailment of the project, the Spine Infrastructure developed in the project allowed several sub-systems to be implemented including the Electronic Prescription System (connecting GP practices to Pharmacist) and Choose and Book system (allowing patients to choose and book their secondary care appointments online). In this context, although NPfIT is broadly acknowledged as a failure, it has been instrumental in driving the digital health agenda in the UK. Today the NHS is experimenting with new technologies such as Internet of Medical Things (IoMT), Block Chain and Artificial Intelligence (AI) to improve healthcare outcomes and services provided to patients.

The healthcare IT landscape in the UK was fragmented because primary and secondary care providers were unable to share patient information due to localised databases and multiple systems. Such an infrastructure severely hindered patient care and mortality rates. Indeed, at the time when the NPfIT project was started, in 2002, the inability to instantly store and share patient information digitally was a major obstacle to improving healthcare provision. For example, the inability to easily archive, and instantly retrieve and analyse automated test results, biopsies and images of X-rays to assist diagnostics was a missing facility, which provided the rationale and motivation of the NPfIT project. In addition, process inefficiencies were multiplied by fragmented IT systems across primary and secondary care.

The NPfIT programme entailed far-reaching organisational, cultural, technological and social changes to radically alter the way healthcare is delivered to patients and improve the operational efficiency of the NHS in the UK. The policy focus, from a technology perspective, for the Department of Health was on NHS information management and the technology proposed was meant to shape the strategic infrastructure. As a result, promoting integration where necessary, and setting the standards required local IT applications.

The main challenges of the NPfIT project included the following: Connecting multiple legacy and new systems across multiple organisations; Retaining core business process information and minimising downtime to maintain ongoing patientcare services; Data protection and security considerations, particularly protecting personal information from cyber related attacks; Data compatibility and migration; The massive cost overruns in the project has meant that there was no ROI; User-resistance from across both primary and secondary care providers; Different legacy hardware dependencies across the NHS spanning 3000 GP practices and 300 hospitals meant complex procurement, maintenance and service arrangements had to be changed; Lack of open communication and an overall poor change management approach contributing to human and institutional resistance to change.

The original NPfIT concept was to replace all of the legacy systems across 3000 primary care providers (GP surgeries) and 300 secondary care providers (hospitals). The key challenge to this project was recognised as the irreplaceability of the legacy systems underpinning the strategic NHS function. The estimated cost of the NPfIT at the start of the project was just over 2 billion pounds, which was later revised to 6.7 billion pounds, and estimated to have cost the taxpayer between 20 and 25 billion pounds when the project was stopped in 2013 (NAO, 2011; NAO, 2013). The Parliamentary Accounts Committee investigated NPfIT in August 2011 and put the total cost of the programme at £7.3 billion at the time and total benefits at that point at £3.7 billion. While there are multiple estimates of ROI by independent researchers, it is hard to estimate the real ROI of the project. However, although the NPfIT failed to deliver the ROI from purely financial terms, the momentum it introduced to the NHS has resulted in a gradual change of mindset about modernising the NHS and examples of these are being already observed across various hospitals and NHS trusts across the country.

The case indicates various complexities, resembling the description of complexity 7 in Table 1. The case failure signposts various lessons to be learned. Firstly, lack of clear directions from the project inception triggered other faults such as mistranslated project requirements and resources planning. Secondly, the lack of credibility in project management deters buy ins from various stakeholders, especially the healthcare professionals whom the way of works has long been institutionalised, causing resistant to change. Inability to understand the whole system landscape, the stakeholders, functional complexities, and ethos of the institution are among other lessons worth reflecting, signposted by this major fiasco.

5. Discussion and reflection

Although there are broad differences between the cases examined in terms of size, cost, stage of maturity, and outcome, several lessons can be learned from the cases.

a) *The disconnect between policy (or political ambitions) and organisational capacity to implement transformation*: while a majority of the large public sector transformation projects are initiated as a result of a policy decision, there is usually a huge disconnect between the expected policy outcomes and implementation realities. This is evident in the case of revolutionizing the patient care service in the UK. In most instances, the legacy systems that exist in public administration embed the institutional ethos, which shapes the user interactions with the systems, and their associated business processes. Hence, understanding of the legacy system, from both technical and 'cultural' perspectives will allow seamless design of a new system and change management process. This is also apparent in the case of Danish and the Netherland's digital transformation cases where understanding the legacy systems was made as the top priority before designing a new system, or its implementation plan. Besides this, the organisational capacity to manage complex projects is compounded

by the siloed nature of the public sector, the complexity of their legacy systems environment and the organisation's readiness for change. Hence, buy-ins and reality checks are pivotal to get commitments from both sides for the longevity of the change project.

b) *Public policy context was neglected*: The public policy context (Abril & Crompvoets, 2022) was systematically neglected. The selected implementation orientation (data driven, technology driven, etc..) was selected with no consideration to the best fit with public policy context. The case of revolutionizing the patient care service in the UK signposts a significant lesson in this realm. Its legacy systems were rooted from the 'Tatcherism' era – i.e., the era of New Public Management, where the IT systems were built to reduce costs, rather than oriented towards public service quality. Hence, the systems were transactional in nature, rather than interaction based. As opposed to this, the recent public policy context asserts an extra emphasis on seamlessness of information flow on top of the cost reduction and other priorities. Managing multiple service providers and ensuring that they appreciate the expected policy outcomes of the project and the public policy context in which the project is implemented is key to success. Moreover, the digital transformation demands may require an ad-hoc approach (potentially, to be developed) for the collaboration between public administration and IT providers.

c) *Organisational capacity to manage complex projects, including identifying and managing risks:* the right level of experience and skills is critical when attempting to transform large public administration systems where the interplay between policy, process, people and technology needs to be harmonized. The existence of stakeholders from different contexts causing influx of various ethos and culture, which determine the approach to project understanding, development and implementation. The absence of this capacity will tend to result in failure of digital transformation projects. Hence, an innovative, co-creation approach is desirable. For instance, the Danish Tax Administration is building in house skills to become agile (using the SAFE framework[3]) and, though its involvement in co-designing systems, taking on a higher level of responsibility concerning the vendors and products to be delivered. Developing such skills ensures organisational learning for future projects is retained within the organisation.

d) *Interoperability between systems in government*: Legacy systems, in most cases, are often essential pieces of infrastructure. Nonetheless, the existence of various legacy systems increases complexity of interoperability and integrability, due to their outdated nature such as inexistence of vendor supporting the upgrade or inability to be upgraded because of obsolete technologies – hence becoming barriers to a successful digital transformation. Again, the NPfIT case is a prominent example of failed project due to the existence of many legacy systems that are dependent on each other to deliver services. All cases presented in this study suggested issues in the compatibility of data standards and models between old and new systems. To align semantically, one must align the entity itself (e.g. what represents a person) and align the model of this entity (e.g. how to represent a person through attributes). Data models and entities must be standardized in order to allow interoperability of entities between different systems. Semantic interoperability of entities between systems allows using/storing/analysing information of common entities through different systems. Currently, systems need to apply mappings/transformations of entities residing in other systems with the help of domain knowledge and store these mappings/transformations locally before they can be used. This causes many forms of duplication of data which spreads across all systems and embeds redundancy. Querying at the source means that whenever information of a certain entity is required, this information can be queried from a single source of truth that holds all information of this type of entity – suggesting semantic interoperability is necessary before this can be accomplished. This is especially important given disrupting these systems becomes a barrier to transformation when the service delivered is critical (such as in the healthcare sector) as there is poor information system resilience to accommodate service interruptions. Although the Danish case which involves a large number of legacy systems is successful thus far, it is still early to comment on this given the project is still in progress.

e) *No ICT impact assessment*: giving the project a sound and healthy analysis of both technical and organisational issues before the launch is extremely important. From a technical perspective, this should be done in order to avoid the risk of blocking issues arising after implementation has started. From an organisation perspective, this entails ensuring that all internal and external stakeholders, users and suppliers are committed to both the 'pains' and 'successes' that will be following once the project is commissioned and starts.

f) *Project Management - Gradual approach, Stakeholder Buy-ins and Transparency*: the more successful projects took a step-by-step approach to the modernisation of legacy systems. The underlying idea is to minimise risk and complexity in order to have many successful small projects, rather than one big failure. This also allows to build momentum and buy-in from stakeholders. The case of enabling real-time online transaction and interoperability with external systems in the UK public administration demonstrates the incremental approach to system transformation is more likely to success, as this approach provides space and capacity for change management. Buy-ins from stakeholders involved are also critical. Transparency and clarity in communication is therefore critical to ensure that employees and users buy-in to the transformation effort and contribute to it. Moreover, strong commitment is needed from top management, policy and decision makers, as what was exemplary in the case of the Netherlands case. Accountability ownership is also crucial in order to ensure value for money and/or delivery against the project's objectives, where the absence of this will lead to weak project management such as the case of NPfIT.

g) *Succeeding from failure*: when large transformation efforts fail, usually, there will always be sub-projects that can offer radical improvements to some areas of the business and help reduce long term costs. For instance, despite the overall failure of the NHS NPfIT project, two sub-system 'Choose and Book' and 'Electronic Prescription System' were successfully created (and are still in use today), and the project contributed to the change of perception of new technologies in the organisation. Identifying these opportunities is important.

A summary analysis of the case findings is outlined in Table 3 capturing the technical, organisational and people implications and outlining the main benefits, impacts and financial outcomes together with a mapping of the cases against their level of complexity (based on Table 1).

6. Implications

Previous studies highlight the various complexities of legacy systems in PA. This study complements this knowledge by outlining and mapping these complexities to various implications, based on four cases of digital transformation. This offers insights into the recent literature and present the concepts and a research agenda to digital government and public administration scholars.

6.1. Implication to research in the public sector

Majority of the existing studies on digital transformation are conducted in non-public sector context, which signposts the importance of this paper. Due to the nature of the public sector, the implementation of digital transformation demands specific considerations, despite some

[3] For more information see: https://www.scaledagileframework.com/.

Table 3
Summary of the case study findings.

	Case 1	Case 2	Case 3	Case 4
Project name	Enabling interoperability with EU system	Revolutionizing data landscape	Enabling real-time online transaction and interoperability with external systems	National programme for information technology (NPfIT)
Country	Denmark	Netherlands	United Kingdom	United Kingdom
Project description	Implementation of a system to comply with the changes required by the new EU's Customs Code for the exchange of information between customs authorities and with the Commission. A new system will be implemented due to the limitations of the existing systems. The project is currently in the study phase, and a call for tender is going to be launched.	Overhaul of the legacy systems used by Dutch municipalities for many administrative processes, in order to create a new ecosystem of information systems which is based on microservices, user-friendly, flexible and privacy friendly. Currently, several proofs of concepts have been developed (of which NLX is the first) and the production tests are expected to start in 2019 and 2020.	Gradual digitisation of all services delivered by the agency, to offer a full online experience to citizens and replace all legacy systems used by the Agency by 2020. This entailed replacing most legacy systems and re-engineering other systems in the Agency. These have then been integrated with multiple other stakeholders, such as motor vehicle dealers, insurance companies, police, passport office, department of work and pensions and the Ministry of Transport (MOT) garage, banking systems, etc. The Agency's digitisation is still ongoing.	The NPfIT was the largest public sector IT project attempted in the world It aimed to improve the delivery of healthcare services, through creating centralised electronic records for all patients, available to those authorised to see them, and supporting for new ways of working through electronic booking services and electronic transfer of prescriptions. Due to implementation issues and spiralling costs, the project was stopped. However, some sub-systems were developed and implemented: the Electronic Prescription System (connecting GP practices to Pharmacist) and Choose and Book system (allowing patients to choose and book their secondary care appointments online).
Start/end date	2018–2023	2017–2027 (expected end date)	2004–2020	2002–2013
Level of complexity	Level 4	Level 7	Level 7	Level 7
Challenges & outcomes	The main challenges are in relation to finding knowledge about old systems and business processes, integrations with old systems, costs, change management, and the required continuity in the operation of the system. As the project is still in the development phase, the full outcomes and is yet to be realised.	The main challenges are related to the reliance on legacy systems, which are of large size, retaining core business process innovation, the ability to migrate data, and integrations with new and existing systems. The outcomes of this project are still being measured, but the main success to date is the commitment of many stakeholders (of which 355 Dutch municipalities).	The main challenges were linked to integration with external systems, retaining core business process information while minimising downtime, data security and protection, data compatibility and migration across systems, initial user resistance and poor take up of services, and the use of legacy hardware. All core services are now delivered via online platform, 97.6% of the interactions with the agency are carried out digitally. The digitisation effort is now expanded to ancillary services.	The following challenges led to the project failure: Connecting multiple legacy and new systems across multiple organisations; Retaining core business process information and minimising downtime; Data protection and security considerations (particularly protecting personal information from cyber related attacks); Data compatibility and migration; Massive cost overruns; User-resistance; Different legacy hardware dependencies; Lack of open communication and an overall poor change management approach.
Technology implications	Ensure the system is integrable and interoperable with the current and future systems and IT landscape.	The systems that will be replaced are mainly traditional proprietary closed source on premise client/server solutions (based on outdated standards), which causes security risks, makes integration with new systems difficult. The new architecture will separate data (stored in the original source and accessed through APIs) and business processes (enabled though micro services), with NLX acting as an integration layer.	The system uses an Open Services Landscape (OSL), thereby exposing its services and data using standard APIs to allow businesses and government to develop new services on top of its existing systems, fully controlled under data protection legislation. The project required the seamless integration and interoperability across multiple systems to enable real-time data sharing. It required implementing new hardware at the start of the project and, continuous and measured phasing out of legacy hardware thereafter. Security requirements are embedded into business requirements, business logic, application, data and technology. Increasing elements of IT are commoditised including adapting a commodity cloud where security and costs and monitored continuously.	The core of the new system was going to te based on an open-source stack of Riak NoSQL system (managed by BT). However, different legacy technology was used by the primary and secondary health care providers, which could not be replaced. This caused integration and date migration challenges not considered at the beginning of the project. These systems also depended on legacy hardware.
Data implications	New system needed to adapt to the new data formats required by law. It is also expected to ease the processes for data management and governance. No migration needed.	In the new landscape, data will only be stored once in its original source and accessed through and API-based service layer. Due to the personal nature of the data handled, the architecture is designed to be GDPR-	Data formats between old and new systems were incompatible, which had to be implemented in the project. Legacy data was cleansed before it was migrated to new systems. Data management guidelines were	There were incompatibilities between the data formats required by old and new systems, and the data dealt with was extremely sensitive. Data management guidelines and information standards were

(*continued on next page*)

Table 3 (*continued*)

	Case 1	Case 2	Case 3	Case 4
Project name	Enabling interoperability with EU system	Revolutionizing data landscape	Enabling real-time online transaction and interoperability with external systems	National programme for information technology (NPfIT)
		compliant. A new data governance model was also implemented.	also in place from the start of the project. A clearly defined governance structure has also been in place to guide the implementation and migration of systems from the start of the project.	implemented from the beginning of the project, as well as a defined information governance structure. However, they were many challenges to their implementation.
People implications	Many stakeholders are involved. Appropriate change management will need to be applied.	There is enthusiasm from the many stakeholders involved. However, change management and an appropriate communication strategy need to be implemented.	Many stakeholders were involved. Changed was managed through efficient planning, assessment of the complexity of tasks and risks, assembling the right team and taking a step by step – incremental approach to change (rather than a radical-big bang approach).	One of the biggest problems of the NpfIT project was poor change management and lack of open and transparent communication. This resulted in resistance by current users (doctors, nurses and management staff in the NHS) to adapt the proposed new systems.
Organisation implications	The Danish Tax Administration has a long history of introducing new technologies. The change of system will also imply changes in the related business processes.	There was buy-in from the municipalities to embrace emerging technologies as long as they bring a real benefit. Some business processes are expected to change.	The DVLA was open to new and evolving technology including shared services and cloud based open services.	At the time of the project, the NHS was resistant towards the use of new technology. If the new system were implemented, the operational workflow across primary and secondary care providers would have also fundamentally changed.
Impact (benefits, costs & ROI)	Benefits: compliance with new EU Customs Code, improved efficiency and service quality. Costs are confidential but are estimated to be very high.	Benefits: easier GDPR compliance, increased flexibility, collaboration and more transparency. Total costs are estimated to be € 150 million over 10 years, and a TCO[a] of € 1.5 billion for the new IT environment.	There were many benefits including cost saving, transparency, 24x7x365 availability, efficiency, convenience, ease of use and access, time saving etc. Costs: the estimated annual cost of changes to IT systems in 2018–2019 is £ 60 million, however the DVLA has realised £ 78 million in cost savings and increased the take up of its digital services by 92%.	The estimated cost of the NPfIT at the start of the project was just over £ 2 billion, which was later revised to £ 6.7 billion and estimated to have cost the tax payer between 20 and 25 billion £ when the project was stopped in 2013.

[a] Total Cost of Ownership.

challenges mimicking those in private sector organisations. Because of this, future research is proposed to consider the implementation strategies, their managements and key performance indicators to improve its governance and increase the chance of success. Absence of theory to explain the relationship between the challenges or complexities and how they resulted into certain implications is another gap to be tackled. In this context, the use of imported theory is envisaged given the hybrid nature of the discipline.

6.2. Implication to PA practice

All four cases studied demonstrate lessons that can be drawn to improve current practices in transforming legacy systems digital projects. Some cases invent their approaches while others are drawn from the past experiences. It was interesting to note that there was very little uniformity in the approaches taken by the four cases. This is alarming as PA structures and internal governance mechanisms are similar in most European contexts. Also, there was little evidence of co-creation between PA and the private sector in the digital transformation efforts. Therefore, experts and decision makers in PA should reflect in future digital transformation projects on how to approach the legacy systems conundrum by drawing from a combination of past experiences, new approaches and co-creating with relevant stakeholders including technology service providers, users and employees.

6.3. Implication to PA policy

The study suggests that the 'no legacy policy' or similar policies may come to fruition if the socio-technical challenges are identified, understood and managed in digital transformation efforts in PA. In this respect, more dialog is needed between policy makers (in government), employees of PA agencies and the technology service providers leading the digital transformation projects. Often, there is a huge disconnect between the policy makers who trigger digital transformation to support their policies and the practitioners who have to deal with the complexities of the institutional structures and legacy systems in PA when implementing projects.

7. Conclusion

There is no doubt that legacy systems are in widespread use across the public and private sector. The decision to maintain their use may be less strategic but more operational or indeed tactical. Nevertheless, the literature is clear in identifying challenges of maintaining the status quo whilst optimistic about the benefits of transformational change. The European Commission's e-government action plan 2016–20 and the Digital Europe Program (2021–2027), suggest that public administrations should embrace the modernisation agenda embarked by almost all EU member states and continue their transformation journey towards realising fully integrated digital government services. Starting this journey requires a significant commitment; financially, and recognising that such an approach comes with social, political and technical risk.

A comprehensive review of the literature and secondary sources has indicated that Public Sector institutions need to carefully contemplate the far-reaching implications associated with the on-going maintenance and use of legacy systems along with considerations of when to phase them out within a structured framework of change management, project planning etc. Considerations of the strategic way forward for decision makers needs to be underpinned by political, financial, technical, business processes, security vulnerability, value added, capability and

human factors - all of which need to be captured within respective risk registers. These considerations are interconnected with the decision to maintain or replace the legacy systems being far reaching and impactful in scale to the policy and legislative context within which the systems operate. Advancements in technology and service solutions with the introduction of the cloud has increased the financial accessibility to new technology and prompted refreshed questions on the migration of legacy systems to new technology infrastructures. Such technology advancements are far less complex than previous organisational information systems but do present new and different challenges around ownership, maintenance, service, security, data storage and cost.

When seeking to describe the 'No Legacy' principle, this research did not find conclusive evidence to demonstrate how public administrations could replace legacy systems completely to support a single point of digital interaction. However, by drawing from different strategies of migration and cross referencing these with the complexity and challenges of replacing legacy system, we propose a definition for characterising the 'No Legacy Principle'. The main criterion to assess if a legacy system is obsolescent should be based on the risks associated to its architectural building blocks. Based on this criterion, there can also be a prioritization of the legacy systems to replace. Therefore, understanding which architectural building block has risk levels that are not tolerable and/or does not address business needs, is important in order to prioritize their replacement.

Furthermore, there is also a common assumption that it is easier to build new software/systems to support new or changed business requirements. The real problem is not technical legacy, but business routine legacy. Indeed, as soon as a change in regulation requires a change in business processes, the system becomes legacy. Sometimes software is already legacy when it goes live. Adding new functionalities to old systems is also building legacy. There is a need to design systems for change, which would decrease the risk of having legacy, instead of designing static systems. This is an illustration of Conway's law, which states that "any organization that designs a system (defined more broadly here than just information systems) will inevitably produce a design whose structure is a copy of the organization's communication structure". In other words, if you ask an organisation to design a perfect information system, it will be designed based on the current work routines of the people designing it, which only works when the organisation, or laws and regulations, do not change. Therefore, both software architecture and business processes need to be designed for change.

Our case findings also suggest that the public sector should outsource software projects to the private sector when appropriate and should only build a system when it is not openly available in the market or can be cost effectively developed by the private sector. Indeed, if a system is a custom development, there is one unique customer for the system (versus multiple customers for a system available on the market) so no improvements or updates are made to it, and it becomes legacy much quicker than a tool on the market. There is also a need to examine what processes from the public sector can be standardized, in order to be able to use the tools available on the market. The issue with outsourcing to the private sector, however, is the risk of vendor lock-in. This means that one might need to rethink how the public sector cooperates with the private sector. For instance, the public sector could buy engineering manpower from the private sector, instead of buying a product out of the box. For instance, two different vendors could work together to develop a government system, in collaboration with representatives from the public sector. Consequently, if there is an issue, one of the vendors could be replaced. Finally, new systems in the public sector should be transparent (i.e. open source), unless the information being built is sensitive. Transparency is needed in order to encourage growth, so that services or tools can constantly be improved, and new services or tools built upon them.

Like all research, this study has several limitations. Firstly, the study relied on four case studies, of which two were empirically investigated and two were investigated using desk research. The two cases which were investigated using desk research did not allow the researchers to delve in-depth the human centric perspective of the legacy systems and related influences on digital transformation in PA. However, these two cases are high profile and therefore there was a large volume of information publicly available on them. This study is focused on three selected European countries and therefore it is important to note that further research in Europe can complement the findings and help further refine the conclusions and recommendations presented here.

In conclusion, the key lessons learnt from this study are summarised below:

There is an explicit link between policy (or political ambitions) and organisational capacity to implement transformation: while a majority of large public sector transformation projects are initiated as a result of a policy decision, there is usually a significant disconnect between the expected policy outcomes and the implementation reality. In successful projects such as the DVLA case, clear policy outcomes were matched against delivery outcomes and expectations. Practically, this was applied through a measured, incremental approach to change, continued dialog between the various stakeholders (including policy makers) and the existence of a strong project team throughout.

The public policy context was systematically neglected impacting implementation orientation decisions to manage complex projects, including identifying and managing risks and third-party IT contracts: the right level of experience and skills is critical when attempting to transform large public sector organisations where the interplay between policy, process, people and technology needs to harmonise. Moreover, managing multiple service providers and ensuring that they appreciate the expected policy outcomes of the project and the organisational context in which the project is implemented is key to success. In successful cases the organisational capacity to manage a complex project was clearly in place from the start of the project and, as the project continued to expand through the years, this capacity has been strengthened.

Interoperability between systems in government is crucial factor underpinning a successful digital transformation: transformation efforts face a major challenge when there is a large number of legacy systems that are dependent on each other to deliver services. The approach to replacing these systems with new systems should take into consideration the continued and uninterrupted delivery of services in the respective government departments. Through parallel legacy operations until the new systems are beta tested and approved.

Obtaining stakeholder buy-in is a precursor step in any digital transformation: a good organisational change management strategy, transparency and clear communication to ensure that employees buy-in to the transformation effort and contribute to it is critical; this was clearly evident in the successful cases and was a key area that contributed to its success.

A clear accountability underscores good project governance: clear lines of accountability are needed, not only to own the project outcomes, but also to be in a position to identify signs of failure and to terminate projects when needed and to expand those areas that add value. In the successful cases, such as the DVLA digital transformation effort, clear leadership and ownership of projects and sub-projects were clearly evident (DVLA, 2018), contributing to its overall success.

Failed project as a turning point and business case for a new system: when large transformation efforts fail, usually, there will always be sub-projects that can offer radical improvements to areas of the business and help reduce long term costs. Identifying these opportunities are important as demonstrated in the NPfIT project through the choose and book and electronic prescription sub-systems that were implemented after the main project was terminated.

Author statement

Due to the confidentiality and sensitive nature of the questions asked in this study, research participants were assured raw data would remain confidential and would not be shared.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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