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Architecture and Design of National Digital Identity Platforms

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Research Paper

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Abstract

Digital identity systems are mandated to be established by all countries as part United Nations Sustainable Developmental Goals (SDG 16.9) However, globally, over a billion people are still without a digital identity. Digital identity projects, across continents, have achieved underwhelming results and are facing implementation hurdles. This research examines the architecture and design of digital identity platforms which enable achieving platform objectives. Design science approach of General Morphological Analysis (GMA) has been employed for such examination. Cases of both- a successful and another moderately successful digital identity program implementation have been examined to validate testable propositions regrading optimal architecture/design aspects of such platforms. Research learnings are relevant for policy makers and technology designers to incorporate such platform design aspects in respective national digital identity initiatives. In addition, this research contributes to design science body of knowledge by empirical generalization of a configurable template and design factors in respect of digital identity platforms.

Key words: Digital Platform, Public Services, Architecture, Design, National Identity

1 Introduction

Provision of digital identity to residents of a country has got much attention in current discourse on public governance (Mir et al., 2019). United Nations 16th Sustainable Development Goals (SDG 16.9) recommended that every country will provide its citizens a digital identity and extend public services by year 2030[1]. Public governance is effective if the system has ability to ensure that welfare measures undertaken by government reaches intended beneficiaries. Digital identity can facilitate this aim (Melin, Axelsson and Söderström, 2016). This is possible because digital identity ensures targeted delivery, less leakage and reduced overhead cost (Mukhopadhyay, Bouwman and Jaiswal, 2019). Digital identity also helped in better management of COVID pandemic in countries like India. (Martin, 2021). However, at present, very few countries across the globe are having fully functional and comprehensive digital identity systems[2]. More than 1 billion global population is still without any digital identity. Almost 30 countries across the globe are at different stages of implementation of digital identity projects, several of which are facing major difficulties and are unable to achieve mandated population coverage[3]. Digital identity system implemented as digital platform are called digital identity platforms.

Digital identity projects implemented in different parts of world have achieved mixed results ranging from National e ID program of Ethiopia (10 % population coverage[4]) to Unique Identification Program of India (UIDAI) Aadhar (99% population coverage[5]). Several countries have abandoned digital identity

[1] UN SDG 16.9; available at https://www.undp.org/sustainable-development-goals
[2] https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/digital-identification-a-key-to-inclusive-growth
[3] www.id4d.org
[4] https://id.gov.et/en/press/
[5] https://uidai.gov.in/aadhaar_dashboard/

projects after massive amount of money and effort were already invested e.g., United Kingdom digital. identity program (VERIFY), which was abandoned after spending £ 200 million[6] in eight years (Mir et al 2019). Major part of success achieved by digital identity platforms is attributable to platform architecture and design which needs to be optimized and aligned with platform objectives (Ansell and Miura ,2020). Authors argued that public digital platforms derive public value from its architecture and design. Extending this argument for digital identity platforms, it can be argued that, *inter alia*, success factor of digital identity platforms may be design and architecture of such systems. Digital impact alliance, a world bank group, in its document on technology landscape of digital identification, has stated that technology and design choice are critical to success of digital identity systems[7] .

To extend this argument, digital identity programs of two countries with near identical socioeconomic and technology development levels can be compared focusing on platform architecture and design. For example, digital identity program of India and Nigeria can be compared on these yardsticks. Both are developing countries with almost similar per capita GDP (India $ 2256; Nigeria $2057)[8] , adult literacy rates (India 74 %; Nigeria 62 %)[9] and Internet penetration (India 50 %; Nigeria 55 %)[10]. Digital identity program in both countries also started almost at same time (India -year 2009; Nigeria -year 2007). However, UIDAI Aadhar has achieved 99 % population coverage -1.36 billion out of 1.4 billion population [11]; Nigeria 45 % population coverage - 90 million out of 200 million residents[12]. UIDAI Aadhar based authentication stands at million plus transactions day and 8 billion financial transactions are carried out per month[13]. India's digital identity platform UIDAI Aadhar has performed better despite modest socioeconomic landscape and apparent digital divide existing in India. Certain architecture and design choices may have negatively impacted Nigerian digital identity program. These include selection of proprietary database which has hit capacity ceiling at 90 million enrolments.[14] compared to open-source database in UIDAI program which successfully holds 1.36 billion enrolment data. Another notable design aspect is absence of true service-based architecture in Nigerian e ID program which enabled innovation and interoperability with other systems in case of UIDAI Aadhar. Thus, it is seen that, other factors remaining same, architecture and design of digital platforms is central to success of digital identity systems and hence, needs to be examined accordingly by researchers.

In view of such background, research objective is to determine key architecture and design aspects which enable digital identity platforms to achieve its goals. This research is relevant as digital identity platforms are curiously understudied in the Information Systems literature, largely because of a limited focus on the properties that underscore their nature as platforms (Maserio and Arvidsson,2021).

2 Literature review and Research Gap

Literature review was conducted in six major research databases (e.g., Elsevier Scopus, IBI/Informs, ProQuest, Business Source Complete/EBSCO, Emerald Insight and Google Scholar) based on specific keyword search (Digital identity, digital identity platform, architecture and design, platforms, digital identity projects) for years 2000-20, reveals that relevant research papers on the subject can be broadly classified in three major categories. First category of research papers pertains to usage of digital platforms in public governance. Use of digital platforms for public governance has been researched by multiple authors like Janseen and Esteveez (2013); Hautamäki and Oksanen (2018), Brown *et al* (2017) etc. O Reiley (2009) posited popular concept of Government as Platform (GaaP) which is a prime example of such usage. Second category of research papers pertain to examination of current state of digital identity systems in different countries across the globe. World bank ID4D Initiative annual report (ID4D Report ,2020) provides digital identity project status in different countries. These include reports such as ITU –T digital identity roadmap guide (ITU, 2018) and McKinsey digital identity report

[6] www.telegraph.co.uk dated 19 Mar 2021.
[7] https://documents1.worldbank.org/curated/en/199411519691370495/Technology-Landscape-for-Digital-Identification.pdf
[8] https://data.worldbank.org/indicator/
[9] https://data.worldbank.org/indicator/SE.ADT.LITR.ZS
[10] https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/Digital-Development.aspx
[11] https://uidai.gov.in/aadhaar_dashboard/
[12] https://www.biometricupdate.com/202209/nigeria-reaches-90m-digital-id-registrations-as-database-capacity-issue-looms
[13] https://uidai.gov.in/aadhar dashboard
[14] https://www.biometricupdate.com/202209/nigeria-reaches-90m-digital-id-registrations-as-database-capacity-issue-looms

(McKinsey, 2019). These reports highlight immense scope of unlocking economic value by providing digital identity to citizens. Third category of research literature on subject, where very few research papers exists, pertains to architecture and design of digital identity platforms. In one of the important contributions in this category of research work, Mir et.al. (2019) determined that major system objective of digital identity platforms. These are – providing unique identity to residents, enabling government benefit transfer at scale and to ensure data privacy and protection. Fishenden and Thompson (2012) emphasised upon openness in digital identity platform's architecture.

The national digital identity projects based on digital platforms are technologically complex and expensive implementation having large number of diverse stakeholders with divergent interests. In absence of appropriate design decisions before implementation, projects may not achieve desired results (Shivmalai, 2013). Research to determine appropriate architecture and design choice in digital identity platforms, to the best knowledge of authors, is not available in extant IS literature. There is absence of a common design template which can be adapted in digital identity projects in different countries. This research outcome is expected to present such a configurable architecture / design model. This generalized configurable model can be adapted by different countries based on respective native requirements of providing digital identity and associated e governance services. This research approach offers an opportunity to solve problems and achieve socially oriented goals while creating new knowledge (De Leoz and Petter, 2018). It is essential that architecture and design template of digital identity platform is understood which can help avoid spiraling technology pitfalls, cost overruns and associated risks at subsequent stages of implementation.

3 Research Question, Theoretical Lens, Propositions, and Research Methodology

3.1 Research Question

As described in Literature Review, Mir et.al. (2019) determined major digital identity system objectives, which are provision of unique identity, enabling government benefit transfer at scale (by authenticating identity of genuine beneficiaries) and ensuring privacy and protection of resident data .Authors argued that such objectives can be achieved by appropriate architecture / design measure which need to be incorporated in digital identity platforms ab initio. Centrality of design and architecture in achieving objectives of digital identity platforms has been emphasised by several organisations like Digital Impact Alliance (DIAL), a World Bank group[15] as also by multilateral forums like G20 forum digital identity onboarding recommendations[16]. However, despite such recommendations, literature review reveals that there is a noticeable lack of relevant research literature about architecture and design aspects in digital identity platforms which enable such platforms to achieve its objectives. This research is an attempt to plug this research gap.

To achieve aforesaid objectives, digital identity platforms work as foundational identity to authenticate identity of genuine beneficiaries. Authentication and its associated activities are needed to be done with variety of different organisations with varied system interfaces and configurations. Such arrangement requires capability to make system wide changes driven from platform core. Penzenstadler et.al. (2018) recommended designers to determine leverage points for achieving software objectives whereby small changes in design at core will translate to significant system wide changes for interworking with other systems. Multiple such leverage points may be incorporated in digital identity platforms architecture and design so that changes made at one leverage point may trigger system wide compatibility. Such leverage in information technology artefacts, which is derived based on system architecture and design, is called architectural leverage (Thomas, Autio and Gann,2014). In simple terms, architectural leverage implies using architecture/ design of system to provide an impact which is much greater than inputs provided. A textual analysis of a study shows that, 40 % of research papers on digital platforms explicitly consider architectural leverage in context of digital platforms which acts as direct driver of value creation (Thomas, Autio and Gann, 2014). Ansell and Miura (2019) argued that social digital platforms (like digital identity platforms) use architecture leverage to extract public value. Setia,

[15] Technology landscape for digital alliance ,2018 downloaded from documenst1.worldbank.org.
[16] https://www.gpfi.org/publications/g20-digital-identity-onboarding

Setia,Venkatesh and Joglekar (2013) argued that digital design in any IT artefact can be leveraged to achieve customer-oriented system objectives.

Such capability gives rise to another desirable feature in digital identity platform i.e., generativity. It is generativity feature which enables digital platform to provide additional services based on digital identity across multiple sectors like government welfare disbursal, financial inclusion, digital payments, healthcare, and rural wages payment, etc. These diverse applications need disparate capability incorporated in digital identity platforms e.g. In India UIDAI project, electronic Know your customer (e KYC) capability requires offline input of digital identity number to onboard a resident in diverse organizations like telecom companies, banks , mutual funds and insurance companies. Such diversity and innovative capabilities are only possible if these systems possess generativity which is defined as ability to initiate and generate new and unanticipated outputs - spontaneously and continuously (Zittrain 2006). These diverse deployments may be unanticipated as very few such applications were visualized when a digital identity project like UIDAI Aadhar was started in year 2009 and got developed as the systems implementation evolved in course of time. Generativity is achieved due to shared assets and interfaces which can be combined to produce new and scalable solutions (Mukhopadhya, Bouwman and Jaiswal, 2019). Both architectural leverage and generativity are, hence, essential two features of any technology system which is used in providing digital identity systems. Thus, in digital identity platforms, architectural leverage and generativity can be taken as constructs to represent apposite architectural and design features. Even though architecture and design characteristics of commercial digital platforms have been extensively studied (Baldwin and Clark, 2000; Tiwana, 2010), design parameters used for platforms dealing in the business may not directly apply to digital identity platforms (Schreieck et al., 2016; Ansell and Miura ,2019) primarily due to absence of any monetary agency in latter.

Research question, hence, is as follows:

Which all are architecture and design features in digital identity platforms that may provide architectural leverage and generativity?

3.2 Theoretical Lens and Propositions

As discussed, digital identity platforms need to leverage its architecture and design to achieve objectives of uniqueness in digital identity, enabling government benefit transfer at scale and privacy and protection of resident demographic and biometric data. Theory of architectural leverage states that in case of digital platforms, such leverage is exercised through architecture and design and enabled by shared assets and standards (Thomas, Autio and Gann 2014). Three types of architectural leverage have been defined related to digital platform architecture and design (Thomas, Autio and Gann, 2014; Ansell and Mieura, 2019): Firstly, production leverage is based on the (re)use of a collection of assets and the interfaces and standards that enable sharing these to drive economies of both scale and scope (Thomas, Autio and Gann ,2014). It is characterised by architectural features of modularity, scalability, network effect and sharing of common platform resources like infrastructures (Thomas, Autio, and Gann, 2014). Secondly, innovation leverage is also derived from shared resources and enables economics of innovation and complementarities. It is derived from architectural features of openness, multi-sided network effects, open API, etc. (Boudreau, 2012; Nambisan and Swahney, 2011). Thirdly, participation leverage is facilitated by architecture and design features of platform access which is based on platform openness and type of access provided (i.e., web-based or app-based access - De Reuver, Sorenson and Basole, 2018; Hagiu and Wright, 2010). Hence, the first proposition is.

> *P1: To achieve digital identity system objectives, architecture and design features in digital identity platforms should facilitate architectural leverage.*

Generativity theory is defined as the overall capacity of a technology or a system to be flexible and malleable by diverse groups of actors and in unanticipated ways (Zittrain, 2006). Digital identity provision entails value creation through multiple eco system stakeholder like enrolment agencies, authentication agencies and a host of other business stakeholders in sectors as diverse as other government agencies, banking, online payment, insurance education, healthcare, energy delivery etc. This needs decentralized working and distributed innovation capability. Interworking requirements

between core platform and each of these eco system components differ from each other. Interworking can only be done if platform and surrounding eco system possess generativity (Nambisan & Sawhney, 2011). Hence, the second proposition is:

> *P2: To achieve digital identity system objectives, the architecture and design of digital identity platforms should support generativity.*

It has been seen in several global surveys of digital identity systems that digital identity platforms, in which platform architecture and design is not well aligned with objectives, perform poorly in performance [17]. Such systems have lagged in population coverage and in enabling government benefit transfer projects. Elaborate architecture / design guidelines have been issued by different organizations for a good digital identity system e.g., Open E ID recommendations [18], Mozilla position paper on EU digital identity[19] etc. It is, hence, pertinent to examine if absence of certain design attributes like architecture leverage and generativity adversely impacts success of digital identity platforms in enabling digital identity system objectives.

Hence, the third proposition is.

P3: Absence of architectural leverage and generativity weakens digital identity platform's ability to achieve its objectives.

The conceptual model (Fig 1) shows that digital identity platform attributes of architectural leverage and generativity drives attaining digital identity system objectives, in particular enabling provision of scalable government benefit transfer.

This paper is organized in three sections. In Section I, the relevant literature has been reviewed; the research question is described, and the propositions as well as research methodology are outlined. In Section II, design principles of public digital platforms and a General Morphological Analysis (GMA) of public digital platform architecture and design has been carried out. In Section III, a case study of a successful and also a non- successful public digital platform, UIDAI Aadhar of India , and e ID of Nigeria is applied to the morphological boxes made in Part II, and the relevant results of the analysis are described.

3.3 Research Methodology

Since national digital identity systems are still an emerging field and that research question pertains to study of a contemporary phenomenon in real life context, a qualitative case study approach has been followed (Eisehardt,1989; Yin, 2009). UIDAI Aadhar and its Application Program Interfaces (APIs) have been taken as one case studies in this research. As discussed earlier, UIDAI Aadhar has been a successful digital identity program implementation having 99 % population coverage (1.36 billion digital identity issues to residents) and very high number of authentication (approximately 2000 million) carried out per month[20] .UIDAI Aadhar model may be of use to policy makers and technology designers to incorporate in their respective platform design, wherever found suitable. In addition, substantial number of associated e governance services based on digital identity (UIDAI Aadhar) are immensely successful in diverse fields of financial inclusion (480 million bank accounts[21]), digital payments (8 billion transactions per month[22]) , government subsidy disbursal (5270 million transactions in financial year 22-23[23]) etc.

To overcome the shortcomings of single case study, three APIs of UIDAI Aadhar- enrolment API, Authentication API, and e KYC (Know your customer) API have been taken as different focal case in this research. APIs are very appropriate representation of unique case as these represent extreme cases (Yin 2009), that is, "a case that is considered to be prototypical or paradigmatic of some phenomenon of interest" (Gerring 2007) The same approach has been followed by Ghazanwah and Henfridsson (2011) where authors compared four different APIs of Apple IOS for multiple case study for

[17] https://www.itu.int/en/ITU-/focusgroups/dfs/Documents/09_2016/ Review% 20of% 20National% 20Identity%20 Programs.
[18] Htttps:/www.id.ee/en/article/architecture-of-id-software/
[19] https://blog.mozilla.org/netpolicy/2021/11/04/mozilla-publishes-position-paper-on-the-eu-digital-identity-framework/
[20] https://uidai.gov.in/aadhaar_dashboard/
[21] https://pmjdy.gov.in/
[22] https://bfsi.economictimes.indiatimes.com/news/fintech/.
[23] https://dbtbharat.gov.in/

investigating boundary conditions. Mukhopadhyay, Bouwman and Jaiswal (2015) used same methodology for studying smartphone-based portfolio of control.

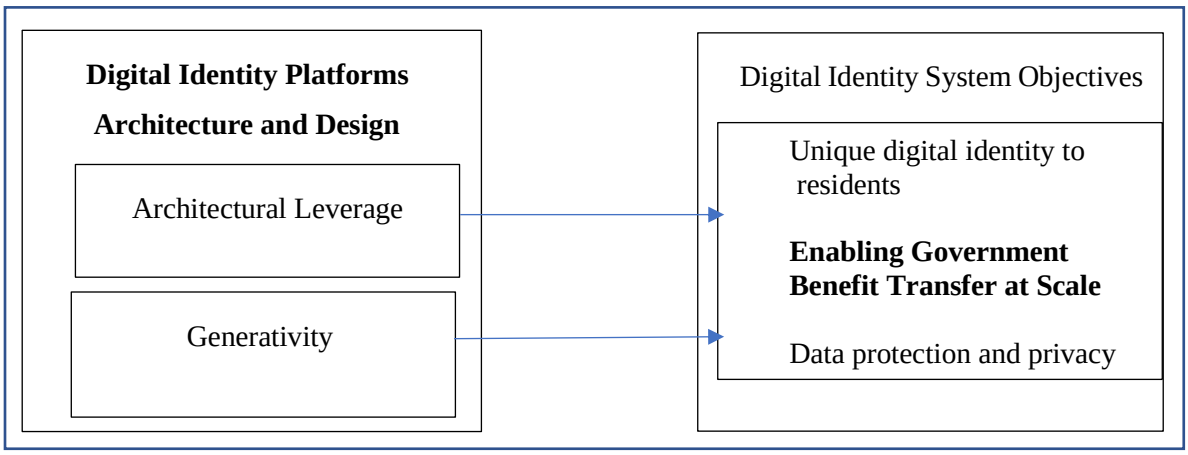

Fig 1. Conceptual Model

Nigerian e ID is second case study used in this research. Nigerian digital identity program was started in year 2007 with a mandate to own, operate, maintain, and manage the National Identity Database in Nigeria, register persons covered by the act, assign a Unique National Identification Number (NIN) and issue General Multi- Purpose Cards (GMPC) to those who are legal residents of country[24]. NIN is a 11-digit identity number and GMPC is a chip-based card having 12 applets in diverse fields of payment, travel, education, and healthcare etc., out of which five applets are functional to start with. E ID has enrolled 90 million residents, out of 200 million eligible population so far after its launch in year 2007 Compared to UIDAI Aadhar, the results achieved in e ID program has been somewhat underwhelming and modest. This case has been used largely for proposition 3.

For carrying out case analysis, a rich set of diverse data sources has been employed (Table 1). Semi structured interviews were conducted with managerial, policy planners and technical experts of UIDAI Aadhar. Apart from this UIDAI Aadhar related whitepapers, blogs, resource platforms, and online articles, public platform use cases have been employed for the case study. Thereafter, for data analysis- the deductive coding method was used employing QSR NVivo software for comparing features of general and public digital platforms. Nodes in coding were derived from digital platform dimensions provided by De Reuver, Sorenson and Basole, (2018); Blaschke et al (2019) and Constantinides, Henfridsson and Parker (2018).

To gain additional insight into architecture and design of digital identity platforms, 8 (eight) interviews were conducted with platform stakeholders and eco system partners Interviewees were carefully selected to represent platform stakeholders having knowledge of different technology and managerial aspects in different hierarchies of respective organisations. These include technology managers, program managers, and mangers from other services which are integrated with digital identity platforms List of interviews appear at Table 2. All interviews conducted were semi structured discursive dialogue-based conversations. Exhaustive interview protocols were prepared before conduct of interview for research rigor However, interviewees were allowed to speak on any additional issue, if subject needed more such explanations. Most of interviewees had technology or process related executive role and were suitable to answer such questions. Insight received from interviews appear at Table 5

3.3.1 The Design Science Approach

Design science approach is recommended for digital identity platform research where diverse government services can be provisioned using such platforms (Hautamäki and Oksanen, 2018). Accordingly, methodology is based on major recommendations of Design Science Research (DSR)

[24] National Identity Management Act 2007

approach (Gregor and Hevner, 2013). To begin with, a reference model has been designed for digital identity platform as an artefact and, then focal research case has been analyzed on this design artefact. Generalized Morphological Analysis (GMA) method has been used for developing a configurable template for digital identity platforms. GMA is a preferred method where the totality of relationships contained in multi-dimensional, non-quantifiable problem space needs to be explored to reach a complex and creative solution (Zwicky, 1969). Many aspects of digital identity have socio-technical connotations, and subtle changes in design features cannot be analyzed by causal modelling. Accordingly, the design science-based methodology in this research is developed in two parts.
Firstly, a general analytical structure is developed using data available (Table 1 and Table 2) and coding done thereafter using NVivo 12 to make a reference attribute model (Fig 2) on different architectural dimensions of the digital identity platforms. Using General Morphological Analysis (GMA), configurable attributes on each of the dimensions of the reference attribute table were identified. The characteristics are multidimensional, non-quantifiable in character and are well captured by the GMA method (Ritchey, 2006). Secondly, evaluation has been done using case analysis of the three API of UIDAI Aadhar for proposition 1 and 2 and e ID for proposition 3 on all morphological boxes to explain the design and architectural aspects of public digital platforms. A similar methodology has been followed by Tauscher and Laudien (2017) to explain business models in the digital platform marketplace as also by Hein et.al. (2018) in Mobile Service Platform eco system.

Serial No	Data Source	Description
1	Public domain Aadhaar and Nigeria E id papers	white papers, technical documents, www.uidai.gov.in https://nimc. gov.ng
2	Interviews	8 interviews with different stakeholders of UIDAI Aadhar both primary and available as secondary data
3	Blogs	http://aadhaar-articles.blogspot.com/;nimc.gov.ng/blog
4	Aadhaar resources platforms Nigeria e id resources	https://rethinkaadhaar.in/resources www.theunbiasedblog.com/tag/hackathon https://github.com/topics/aadhar; nimc.gov.ng/resource
5	Corporate Aadhar-related websites	https://www.online.citibank.co.in/portal/aadhaar/aadhaar-blog/index.htm https://www.antworksmoney.com/blog/ http://www.forbesindia.com/blog/
6	Aadhaar hackathon blogs and websites	http://khoslalabs.com/hack.html;www.hackerearth.com
7	Aadhar-related technology websites	https://indiastack.org/ https://oswaldlabs. com/accelerator/partners/
8	Online articles; Aadhar and Nigeria e id program	http://aadhaar-articles.blogspot.com/; other online newspapers and journals; newspaper and technology magazine articles; Eke et.al. (2022); ID4D for Nigeria
9	Press releases	Press releases from UIDAI, Neeti Aayog and Government of India and different state governments
10	E-mail conversations	E-mail conversations with UIDAI stakeholders

Table 1. Data Sources

Interviewee	Role	Number of Interviews	Time
UIDAI ADG (Technology)	Technology head	1	120 minutes
Biometric and demographic data manager	Support manger	1	60 minutes
UIDAI e KYC manger	IT manger	1	45 minutes
UIDAI Hackathon organizer	IT manger	1	180 minutes
Company using Authentication and E KYC services	Project manger	1	60 minutes
Technology manager digital payments	Technical manager	1	45 minutes
Technology manager Direct Benefit Transfer	Technical manager	1	60 minutes
Technology manager financial inclusion	Technical manager	1	45 minutes

Table 2. Details of Interviews

4 Results and Discussion

4.1 Proposition 1: Architectural leverage

Reference Attribute Model (Fig 2) is attribute framework for case analysis and has been developed based on digital platform dimension as propounded by Blaschke et al (2019); Constantinides, Henfridsson and Parker (2018). Attributes of each dimension has been culled from most apposite research paper and various data sources including semi structured interviews for each of the four dimensions. Four attribute dimensions of digital platforms (on which national digital identity systems are designed) used in Reference Attribute Model are: platform core, platform infrastructure, platform eco-system and platform service. These four dimensions are akin to dependent variables in this model. The predictor variables are characteristics and attributes of each of these dimensions established during iterative coding from diverse data sources. Three APIs of UIDAI Aadhar – authentication API (used for verifying demographic and biometric credential of a resident) ;e KYC API (used for verifying credential of a resident based on paper based input) and enrolment API (used for enrolling a resident in UIDAI Aadhar) have been evaluated on different configurations of four dimensions of reference attribute model (Fig 2). The results of morphological analysis are summarised in Table 3 in form of configurable checkboxes in a morphological box.

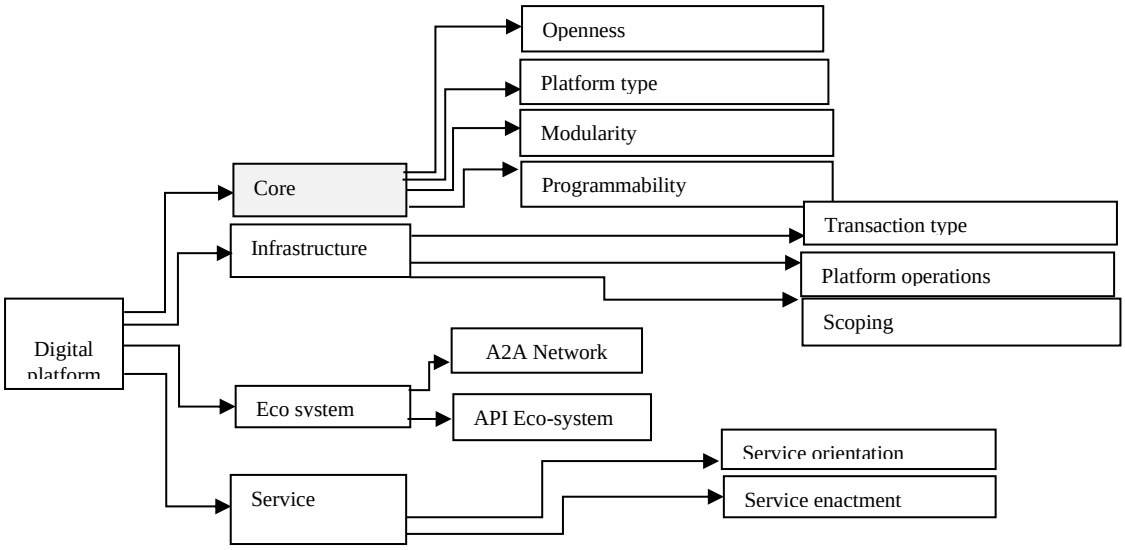

Fig 2. Reference Attribute Model

4.1.1 Dimension of Platform Core, infrastructure, eco system and services

Morphological box-based analysis for platform core dimension shows access openness for authentication and e KYC API (technologically open to the extent that core codebase is accessible to developers but is organizationally controlled as these developers need to be registered first) (Mukhopadhyay, Bouwman and Jaiswal, 2019). Enrolment API, however, provides access to resources in form of Java client . Next, platform core has 'web' type of interface, thus, making system available to developers and users in easy to access web mode and not based on some client-based server access. In platform core dimension, modularity characteristics is micro modularity. In such a design, a limited function is executed in one micro-service-based reusable independent element. This releases resources very fast for other users. Controlled extendible codebase feature enables developers to enhance feature set of platforms by deploying complementary functionalities on digital identity platforms.

In platform infrastructure dimension, transaction type characteristics, is service delivery where a layer of service module complements the device layer in a layered modular architecture (Yoo et al., 2009) and provides end-user services related to a specific task (Skog, Wimelius and Sandberg ,2018). Platform operations characteristics is multi-sided comprising of platform owner, developers and regular end users. Scoping characteristics is infrastructuring since a substantial horizontal expansion in different

domains like digital payment, financial inclusion, subsidy welfare etc. has taken place for UIDAI Aadhar. For enrolment API, in transaction type characteristics, platform attribute is product because by using enrolment API, a 12-digit Aadhar number is obtained by a resident. The attribute in platform operation characteristic is two sided, consisting of the enrolment agency and end user as stakeholders.

Actor to Actor (A2A) network characteristic is federated open loop, where multiple third-party actors provide value-added functionalities to the platform core in welfare subsidy disbursal, financial inclusion, and a variety of Financial Technology (FinTech) companies use this API to provide value-added services. API Eco system characteristics is Mashup platforms. since many platforms have come out on top of the UIDAI Aadhar platform using the using open APIs. For enrolment API, A2A network is closed loop as it is made available with the Java client to selected enrolment agencies only. In platform service dimension, outbound design characteristics exist for all three API.

Ser No	Platform Dimension	Attribute	Attribute Type	Case I : Authentication API	Case II : e KYC API	Case III - Enrolment module/API
1	Platform Core	Openness	Access Openness	☒	☒	☐
			Resource Openness	☐	☐	☒
		Platform Type	Web	☒	☒	☐
			Client	☐	☐	☐
			Hybrid	☐	☐	☒
			Cross platform	☐	☐	☒
		Modularity	Modular	☒	☒	☒
			Monolith		☐	☐
		Programmability	Extended codebase	☐	☐	☐
			Controlled extendible codebase	☐	☒	☒
2	Platform Infrastructure	Transaction Type	Product	☐	☐	☐
			Service	☒	☒	☒
		Platform Operations	Two sided	☐	☐	☒
			Multisided	☒	☒	☐
		Scope	Horizontal expansion	☒	☒	☐
			Vertical expansion	☐	☐	☒
3	Platform Eco system	Actor to Actor (A2A) network	Private	☐	☐	☒
			Federated open	☒	☒	☐
		API Eco system	API Mash up	☒	☒	☐
			Copyrighted	☐	☐	☒
4	Platform service	Service orientation	Exchange	☐	☐	☒
			Design	☒	☒	☐
		Service enactment	Outbound	☒	☒	☐
			Inbound	☐	☐	☒

Table 3. Morphological evaluation of UIDAI Aadhar and APIs

4.1.2 Morphological box-based case analysis for Architectural leverage feature

Production leverage, as discussed in morphological analysis (Table 3) is obtained due to sharing of

resources derived from attributes of micro modularity and microservice architecture (platform core dimension), open loop network and mash ups platforms (platform eco system dimension). For infrastructuring attribute, production leverage is exercised due to horizontal expansion in neighbouring domains (platform infrastructure dimension) and controlled open access in platform core dimension where different agencies can use and reuse API after registration resulting in billion plus enrolment and authentication done per year.

Innovation leverage is obtained due to controlled but extendible codebase (platform core dimension) since eco system partners can develop innovative complementary functions on such codebase, thus enabling economics of innovation and complementarities. Similarly, micro modularity feature-based containers perform one function and immediately release resources for another function. Thus, there is significant increase in resource reuse for innovation. Innovation leverage is also facilitated by service delivery and outbound attribute in platform infrastructure and service dimension respectively. UIDAI Aadhar orchestrates context-based service delivery to users in authentication and e KYC functions.

Participation leverage is achieved due to web type interface (platform core) and service delivery type transactions (platform infrastructure). Web access in platform core dimension enables simple and easy participation of eco system stakeholders. Thus, in all four platform dimensions of core, infrastructure, eco-system, and service; for three platform APIs of enrolment; authentication and e KYC - individually and in combination, facilitate, production, transaction, and innovation leverage (Table 4). This validates proposition 1.

4.2 Proposition 2: Generativity

Morphological analysis shows that generativity features in digital identity platform is derived from three attributes – Firstly, open access (resource openness in platform core dimension) which facilitates rapid integration of Aadhar in other domains and makes it generative. Secondly, attribute of mash up platforms (Platform eco system dimension) which results in Platform over Platform (PoP) structures. Such arrangement in which a platform engenders another digital platform provides immense generativity. Isckia, Reuver and Lesckop (2018) has termed PoP as a great enabler making platform generative .Thirdly, service orientation attribute of digital identity platforms (platform service dimension) also makes such platform generative e.g. digital payment application Unified Payment Interface (UPI) and Indiastck services like digital signature and digital locker work over Aadhar. These applications were not visualised when Aadhar system was conceived and were developed in course of time as need arose, and thus are prime examples of unanticipated generative capability of digital identity platforms. It is remarkable that due to generative capabilities, only with three API, digital identity platform integrate with thousands of applications. Presence of these three attributes (open standards, Platform-over-Platform, and service orientation) in digital identity platform validate proposition 2. Results are summarised at Table 5.

Ser Number	Feature	Attribute	Platform dimension
1	Production Leverage	Micro Modularity /Microservice architecture Controlled open Access. A2A network & mash up Platforms.	Platform core &infrastructure
2	Innovation Leverage	Extendible codebase Micro modularity Outbound Service Multi sided operations. Federated open loop network	Platform core, service & eco system
3	Participation Leverage	Controlled open access. web type interface service delivery type transactions; multi sided and two-sided operations and service design	Platform core infrastructure & service
4	Generativity	Open source / open standards Mash up / Platform over platform Service type platform Federated open loop network	Platform core, eco system & service

Table 4. Digital identity platform features enabling design and architectural leverage.

4.3 Corroborative insights from interviews

Major morphological analysis aspects(based on secondary data), was also directly corroborated through some of the responses received from interviews (Primary data) as shown in Table 5.

Interviewee	Statement	Leverage / generativity
Interviewee No 1	Large-scale social problems require 'unbundling of the problem' and creation of 'shared digital infrastructure' as a 'public good' on top of which 'innovative solutions' can be 'assembled' to meet diverse contextual needs. Unbundling is breaking the design of a system into many micro-services	Production and innovation leverage
Interviewee No 2	Open source software, global open standards and interfaces helped UIDAI Aadhar to interoperate with other systems seamlessly	Innovation leverage
Interviewee No 3	Use of Open APIs led to creation of several mash up platforms which are pillars of Aadhar based public governance system	Generativity
Interviewee No 4	After much debate it was decided that unlike several other countries Aadhar shall not be issued as chip based card but just as a number with no intelligence. This led to number of service oriented innovation.	Innovation leverage
Interviewee No 6	All access to UIDAI Aadhar was web based lightweight systems which eased process of authentication and e KYC. This also laid foundation for UIDAI to enable many applications	Participation leverage

Table 5. Interview insights

These corroborative insights include- micro service architecture as a source of both production and innovation leverage (Interviewee Number 1) ; Use of open source software, standards, and interfaces as major drivers of innovation and integration (interviewee No 2 and Interviewee Number 3). UIDAI Aadhar as a virtual number instead of a chip based card provided service orientation (Interviewee Number 4) and enabled innovation leverage. Use of digital identity to be foundational authentication factor for India stack (digital payment through UPI, digital signatures, digital lockers etc) was also spoken as source of innovation leverage by interviewee No 5. This was corroborated by interviewee number 6 who attributed leverage based generativity which gives rise to number of mashup platforms.

4.4 Proposition 3: Absence of architectural leverage and generativity

For examining proposition 3, there is a need to examine a not so successful digital identity system from a country with comparable socio economic and technological level as was the case with system examined in previous propositions. Presence of attributes enabling architectural leverage and generativity can be checked in such digital identity systems to validate proposition 3. Indian and Nigeria digital identity systems are comparable cases. Human development Index of India was 129 and Nigeria 163 in pre covid pandemic year of 2019[25] . Similarly for comparing technological development, World bank Digital Adoption Index for India is 0.22 compared to Nigeria .17[26] (people sub index). Nigeria digital identity program, launched in year 2007, is operated under the aegis of National Identity Management Commission (NIMC) for electric identity (e Id) and National Identity Number (NIN). While e ID is a chip based card having NIN is a 11 digital national identity number having separate applets for various ancillary functions like authentication, health, driving, passport, travel etc . For analysis, mainly secondary data sources were used for Nigerian e ID program (Table 1). Morphological analysis of Nigerian e ID program using same Reference Attribute Model (Fig 2) is shown in Table 6 using configurable check boxes.

Morphological analysis of Nigerian e ID program reveals some similarity in architecture / design but there are major differences which affects outcome. In platform core dimension, e ID, unlike Aadhar, provides hybrid access having both client and web types of functionalities. Client access, wherever used, makes platform features access dependent on hardware and restricts architectural leverage.

[25] https://hdr.undp.org/data-center/specific-country-data
[26] https://www.worldbank.org/en/publication/wdr2016/Digital-Adoption-Index

Ser No	Platform Dimension	Attribute	Attribute Type	Nigerian e ID platform
1	Platform Core	Openness	Access Openness	☒
			Resource Openness	☐
		Platform Type	Web	☐
			Client	☐
			Hybrid	☒
			Cross platform	☐
		Modularity	Modular	☒
			Monolith	
		Programmability	Extended codebase	☒
			Controlled extendible codebase	☐
2	Platform Infrastructure	Transaction Type	Product	☒
			Service	☐
		Platform Operations	Two sided	☐
			Multisided	☒
		Scope	Horizontal expansion	☒
			Vertical expansion	☐
3	Platform Eco system	Actor to Actor (A2A) network	Private	☒
			Federated open	☐
		API Eco system	API Mash up	☐
			Copyrighted	☒
4	Platform service	Service orientation	Exchange	☒
			Design	☐
		Service enactment	Outbound	☒
			Inbound	☐

Table 6. Morphological Analysis of Nigerian e ID system

Similarly, platform core is modular in nature whereas it is more granular micro modular in case of UIDAI. Lastly, in platform core, both UIDAI and e ID have extendible codebase. However, UIDAI codebase extension by developers is controlled as only registered developers can use extension features. In case of e ID, such control over codebase extension is more regulated by private platform eco system partner requirements. In platform infrastructure dimension, e ID is a product type (a physical chip based card is provided to residents unlike a virtual number in case of UIDAI). This does not provide much desired service orientation to e ID platform architecture and design. In other two aspects of both e ID and UIDAI are capable of multisided operations with horizontal integration capability. In platform eco system dimension, e ID is a closed private eco system with most of proprietary interfaces. This is a major difference with UIDAI which is completely based on open standards, software, and interfaces.

This morphological analysis shows two key aspects. Firstly, absence of micro modularity (reduced production and innovation leverage), product orientation (reduced production and innovation leverage) and client based access in some cases (reduced participation leverage) decreases extent of architectural leverage of e ID . Similarly, limited use of open standards and interfaces due to eco system dependence on private providers (like Mastercard for digital payment) limit generativity of e ID platform. It has been argued by several authors that openness is key to generativity. Thus, e ID systems has partial architecture leverage and limited generativity feature in platform artefact. This limits potential to achieve digital identity system objectives in providing unique identity and enabling government benefit transfer. This validates proposition 3.

5 Research Contribution, Limitations, and future research

5.1 Conceptual contribution

It has been pointed out in recent research literature that there is a tendency in information system research community to treat digital platforms as one single homogeneous group and classifications are merely based on organizational arrangements (Gawer, 2014). In addition, De Reuver, Sorenson and Basole (2018) asked that IS researchers to distinguish different platform genres and conduct a sociotechnical analysis with a focus on social applications which such platforms might be put to use. This research answers calls of such authors by conducting design science based morphological examination of "not for profit" "public good" digital identity platforms.

5.2 Contribution for government and policy makers

The research also has implication for government and public policy practitioners. The importance of national digital identity platforms, for holistic national development has been underscored by several international organizations and eminent IS researchers (UNDP, 2016; Miserio, 2020). By discovering key aspects of digital identity platform design aspects, this research will be of use to governments, policy planners and executives for incorporating such design feature in their respective platforms.

5.3 Contribution to design science research

Gregor and Hevner (2013) argued that contribution to knowledge could be partial theory, incomplete theory, or even empirical generalization in the form of a new design artefact. On this account, this research contributes to knowledge base of digital identity platforms by providing a configurable template in form of morphological boxes. This may be a step towards development of a more complete theory and hence this research makes an important contribution. Assertion of such contribution is further corroborated by Niederman and March (2012), who argued that construction of an artefact and its description in terms of design principles and technological rules are steps in the process of developing more comprehensive bodies of knowledge or design theories. Up to that extent, this research, by highlighting design aspects of digital identity platforms makes a substantial contribution to design theory. In terms of Gregor and Hevner (2013) description of degree of contribution to design science research, this work will be categorized as Level 1 (Situated implementation of artifact) and to some extent Level 2 (Nascent design theory—knowledge as operational principles/architecture) research contribution.

This research makes a methodological contribution by employing General Morphological Analysis (GMA) approach for design science research. Morphological boxes have been constructed to get a comprehensive perspective of design features of digital identity platforms. The morphological evaluation box of successful digital identity project is a configurational template and can be used by other digital identity projects in different countries.

5.4 Limitations of this research

One limitation of this research is single case study for a successful digital identity platform which has been taken from one country i.e., India. This has been compensated by examining three different APIs of Indian case of UIDAI Aadhar. Similarly, only moderately successful case study of digital identity platform is from one country i.e., Nigeria. Generalisability of this research can be further increased by taking other cases from different countries and geographies.

6 Conclusion

National digital identity systems are key to socioeconomic development of society and has proven potential to enable many public services like digital payment, rural wages disbursal, government benefit transfer and a large number of e governance services. That is the reason it finds a prominent place in recommendation of United Nation Sustainable Development Goal (SDG 16.9) Basic design aspects of digital identity platforms have bene examined in this research, both for a successful and a partially successful digital identity systems to ascertain kay factors which enable these platforms to achieve its social objectives. In addition, this research contributes to design science body of knowledge by empirical generalisation of a situated implementation of an artefact.

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