Data-Driven Personalized E-Government Services: Literature Review and Case Study

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Abstract. Better targeted and more personalized service offering to citizens has the potential to make state-citizen interactions more seamless, reduce inefficiencies in service provision, and lower barriers to service access for the less informed and disadvantaged social groups. What constitutes personalization and how the service offering can be customized to meet individual user demand is, however, much less clear and underdeveloped partially due to the technical and legal dependencies involved. The paper gives an overview of how personalization and customization of digital service offering have been discussed in the literature and systematizes the main strand emerging from this. It follows up with a case study of the Estonian X-road log data as one potential way to detect latent user demand emerging from an experienced life-event that could form a basis for letting users define their service needs as holistically as possible. The results show the existence of distinct service usage clusters, with specific user profiles behind them, a clear indication of latent demand that leads to a simultaneous consumption of otherwise independent digital services.

Keywords: Life event e-service · Personalized digital service · e-Service logs

1 Introduction

Improving the quality and accessibility of public services is a priority for governments regardless of their digital development level. The introduction of electronic government portals has become a widespread means of doing this. However, the interaction between the citizen and the state in such a digital gateway remains one-sided. The provision of services still has a one-fits-all approach and the state, as a service provider, does not analyze the individual needs of citizens. Personalization of service offering where user demand and supply matched by advanced

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data analytics and AI approaches have the potential to make state-citizen interactions seamless on an entirely new level [29]. At least, this is the hoped potential of applications utilizing recent advantages in machine learning and AI. In most cases, the reality is still a situation where the citizen needs to actively seek out the service from the relevant authority instead of being offered proactively based on individual needs. Often, a service needs to be pulled by the citizen instead of being pushed by the state, and seamless interactions still a faraway dream.

The technological advances in machine learning and AI are, however, can improve service delivery only when they are embedded in a service delivery design that allows for personalization to happen in the first place, i.e., capture data that is indicative of demand. It can be used to offer a tailor-made service response that overcomes legal and organizational boundaries set by a state organization that is hierarchical and horizontally organized in domains that don't cooperate nor share data. Such a situation is still very much a rarity, but this is starting to change slowly. The ongoing pandemic might paradoxically be a force that expedites movement towards more personalized service delivery in Europe.

The European Recovery and Resilience Facility (RFF), established in 2021 to overcome the damage brought about by the coronavirus pandemic, prescribes that the each recovery and resilience plan by member states has to spend a minimal of 20% to "foster digital transformation"[1], these are substantial funds that some digitally more advanced countries are planning to use to do exactly that, develop new service delivery ways that are much closer to citizen demand understood holistically, the Estonian government foresees that up to a total of 5–6% of the full RRF fund for Estonia to be spent on life-event and pro-active service delivery development.

Focusing on citizen needs is increasingly supported both in the research literature and in government development strategies. It is believed to be an important element in the process of public administration transition towards a new interaction model between the state and society. An individual approach to each citizen, as a consumer, will allow analyzing the needs, interests, and rights of a citizen to receive a particular service and create a more convenient and up-to-date list of services. Thus, the state policy is formed from a more active position as a supplier of services, moving towards the model of service state. The case of Estonia supports this statement by introducing a way to see if and how latent user demand could be detected based on the X-road log data. It opens up an opportunity for more personalization and letting users define their service needs as holistically as possible.

2 Methodology

For this paper, two methodological approaches were selected. First, to explore the relevant approaches in personalized, data-driven, and life-event strategies for electronic state portal design, a systematic literature review (SLR) was performed, which consists of consecutive steps, according to which all publications

[1] Recovery and Resilience Facility https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en.

containing the results of the studies on the phenomenon in interest are collected, followed by an assessment of their quality and the synthesis of the results. The steps are as follows: (1) planning and formulating the research question; (2) localization and searching the literature; (3) data gathering and quality evaluation; (4) data extraction and data analysis; and (5) interpretation and presenting results [5,25]. This research method helps to analyze existing studies and creates a foundation to conclude what is already known and what is unknown [24]. Using it in this study helps to identify current trends in the research literature and highlight their shortcomings.

The selected sources for the search were Scopus, Web of Science, and Google Scholar databases. The relevant articles were searched using the combination of chosen terms as most commonly used in articles on the topic of more data-driven citizen-oriented design of electronic service provision: "data driven", "life-event", "proactive", "personalized", "public administration", "e-government", "electronic service", "e-service", and "portals" as titles and keywords. There were no limitations concerning the year of the publication. In total, 864 articles were identified; however, after duplicates were deleted and the second round of screening based on the title, 103 publications remained. The third round included the paper's abstract analysis, after which 33 papers were selected. Further examination of each article took place upon retrieving the full text, after which an additional ten articles were excluded, as they did not fit the inclusion criteria: 1) the subject of study – approaches for more personalized services provision via electronic state portals; 2) the language of the paper – English; 3) type of the paper - journals papers, international conferences and book chapters; 4) the paper is not a summarizing paper of the previous research by the same author. The final sample of articles consists of 23 studies. The studies' date of publication ranged from 2002 to 2020.

Second, the paper conducts a case study based on log file data from the Estonian x-road data exchange layer. The hierarchical cluster analysis using Ward's linkage for individual unique service usage was carried out on a random sample of 100 000 individuals. Estonia was chosen as a critical case [27], as it is one of the few countries (if not the only one) where such a large number of base registries is connected in one eco-system, whose logfiles and thus exchanges between databases can be analyzed. Limitations include, but are not limited to, the lack of comparative data and a possible bias due to researchers' location in Estonia. Due to the uniqueness of the case, these shortcomings need to be in future research.

3 Literature Review

3.1 Conceptual Foundations

Before turning to the literature analysis, it is necessary to dwell in more detail on the conceptual foundations of this study. There are quite a few theoretical approaches to personalization. In a broad sense, personalization is understood as the process of selecting suitable electronic services for a citizen on any criteria related to the citizen at a given time. It can affect different sets of the

government web portal functionality e.g., prefiltered search results, tailored recommendations, banners to match a person's interests, or links to other related to the topic of interest sites [11]. It is one of the most promising solutions that can be implemented in state electronic portals due to its' ability to establish a dialogue between citizens and the state. Sometimes personalization and customization are used interchangeably [6] or customization considered to be a part of personalized electronic service [7].

One of the most common personalization methods is a recommendation system whose task is to provide recommendations by automatic filtering of unnecessary services. In most solutions, ontology-based semantic reasoning is used for the data organization and management of information. Accurate data description, qualitative classification, knowledge management, and defined relationships between data entities create a system where information is ontologically grouped, making it much easier to process, sort, and present it [3,6,12,16,21,26]. Personal recommendations are divided into 'auto' and 'on-demand'. On-demand recommendations are performed at the user's request, such as searching for a specific service on a website. Auto recommendations are carried out by processing personal information and preferences linked to the user's profile and presenting information or changing site interface based on it [3,28].

The user profile on the state portal can be used for personalization in several ways. From all the variety, the main ones can be distinguished: content-based, CF-based, knowledge-based, and a hybrid approach [3,6]. A content-based is using historical information about the user's interaction with the site. The profile is compared with the content of the services in which the user was previously interested. Within this framework, various weighted schemes compile indices based on different indicators that help rank services for a specific user. A CF-based compares an array of users to find similar profiles and recommends services based on the preferences of the user's group. In this way, the user submits their rating or uses the service. After that, the system algorithm compares users and groups them based on the similarity of patterns. Recommendations are provided based on which services were liked or used by the group to which the user belongs. A knowledge-based approach is using a knowledge base with predefined possible interests as a reference model for content filtering. It is based on a system that contains a knowledge base with a set of specific solutions and algorithms, on the basis of which recommendations are given. A hybrid is a mixture of the listed above approaches in different configurations.

Another way to provide citizens with more personalized services and simplify access to them is the life-event approach. The life-event based state portals use a model that groups services by the most critical events in a person's life. The assumption behind this is that most users don't know what kind of service they need but assume the end result [23]. This grouping often implies a hierarchical system of services [6] connected by the fact that they are used to solve any question that arises at a particular period of life. There are different ways to define the life-event, however, it is possible to trace their similarity to the life stages of a person. This division of a person's life into stages helps separate services

using the same logic and sequence of events. Using life events to categorize services allows the user to navigate the electronic portal better, as this division is intuitive.

3.2 Literature Analysis

Studying a personalized approach to serving citizens in the public sector goes in different directions, both as a purely technical solution and as something that requires more conceptualization and understanding of this process. The analysis of selected studies allows us to identify four main directions in the study of the personalization of state portals: (1) developing of models and frameworks for electronic portals personalization; (2) implementation of different techniques for better personalization of government electronic portals; (3) modelling of web portal/model/framework from end-user perspective; (4) discussion about existing cases of government electronic portals personalization.

As part of the first research direction, the study of personalization in state electronic portals is carried out based on prototypes or reference models. This category includes attempts by several researchers to conceptualize the life event and propose how it can be integrated into government systems. The main focus is on the categorization of life-even services and producing working prototypes of active web portals [16,19,22,23] and the construction of multi-level systems that take the selected categories as a basis [13]. Researchers use different classification criteria but similarly note the diversity of personalization models and the prospects for implementing them in government electronic systems. Another characteristic of this category is that the concepts of "life-event" and "user-centric personalization" presented in these works do not have explanatory power but are more fragmented and descriptive.

The second group of researchers considers personalization in the context of its implementation in electronic portals. It suggests the possibility of a better application of it by complementing various technologies and data analysis methods. One of the proposed solutions is ontology-based semantic reasoning for the data organization and management of information. Accurate data description, qualitative classification, knowledge management, and defined relationships between data entities create a system where information is grouped ontologically, making it much easier to process, sort, and present it [3,6,12,26]. Another approach is focusing on the different data mining techniques like web mining [11], association rules mining [20], mining with the use of time-decayed Bayesian algorithm [10] and algorithm for computing an item-based CF similarity [26] used to improve recommendation accuracy and coverage. This also includes works that pay more attention to the use of various user data obtained from profiles on the service [2,4,28] or from social media [1] to understand the needs of users better.

The third direction of research on personalization focuses on modeling the architecture of proactive electronic portals, taking into account the process participants' point of view on what obtaining an electronic service should look like. For a better understanding of the processes, it is proposed to get insights from civil servants and experts [15] as well as end-user [8,14,21] to create a

methodology for proactive service design. These studies are also based on the analysis of existing services, taking them into account to improve the proposed methodology. The fourth group also focuses on the analysis of implemented personalization cases. Thus, D. Linders et al. (2018) look at Taiwan's approach to proactive actions based on sending notifications to citizens based on data on the due dates for fines, fees, and taxes [9]. In turn, V. Homburg & A. Dijkshoorn (2013) consider the factors influencing the adoption and diffusion of personalized e-government services in Dutch municipalities and develop a set of recommendations for future adoption [7].

The proposed solutions are creating top-down approaches since pre-designed structural elements are used. This kind of design leads to limited personalization, as matches can mostly occur across large categories. In case if some service is not included in the logic of a predefined system, then it is likely that the search for this service will be difficult. In addition, existing research is primarily theoretical and does not use real data, which can significantly increase its applicability of proposed solutions. Thus, despite a significant amount of academic research, there is still no single approach to the personalization of government electronic portals, making it necessary to search for new frameworks and models that integrate real empirical data.

3.3 Dynamic Bundling of Services to Meet Demand

The discussion above shows that all possible approaches taken to align user needs better with the service offering and provide a seamless service consumption experience depend on distilling user needs in the first place and not simply concerning one service, but the total universe of possible services from the user perspective. In essence - the citizens need the service bundle that addresses the particular needs arising out of the experienced events. This leads to holistic service demand where the adequate supply depends on multiple organizational, legal, and technical dependencies. Overcoming these involves substantial legislative, administrative and organizational challenges. One needs to bear in mind that state portals tend to be service gateways and actual service owners are usually separate institutions. Though forming one single digital gateway, they do not include the whole digital service universe and hence also don't allow to take the personalization very far since they have limited user information, service selection, and in most cases, no access to secondary data sources to be able to complement the limited information to truly personalize user experience after authentication.

It is safe to say that proof-of-concept (POC) types of studies and trials are needed before any administrative or organizational changes to address user demand holistically are possible. But these studies are faced with difficulties, as such POCs depend on the availability of service consumption data on individuals that still spans domains, institutions, and time, i.e., combined datasets that capture the full service demand from the client point of view regardless of the service owner. As a rule such combined datasets do not exist or cannot even be created due to data privacy reasons. Next we explore one possible workaround

for solving this problem by using service call logs from a data exchange layer to determine the latent service demand structures.

4 User Defined Service Demand

4.1 Client Data Source

Short of a single super database on everything citizens do, some state information system organizational methods might allow for a potential workaround for this problem, albeit limited in nature. The possible solution stems from the need to exchange data and the subsequent interoperability inherent in providing (most) digital services. In the Estonian case, such interoperability is ensured through a centrally managed distributed data exchange layer called X-road, which allows public and private institutions to exchange data for offering various public and private digital services. As of 2021, roughly 2900 different digital services are offered over the X-road (https://www.x-tee.ee/factsheets/EE/#eng), which generate approximately 100 million service request queries a month. The cumulative service call queries stand at 7.6 billion since the inception of X-road in 2002. Though a majority of these involve machine-machine interactions, close to 3%, i.e., 3 million are human-initiated service call queries which are logged centrally by X-road Center in the central log for compliance monitoring (see Fig. 1). The actual data exchange happens between the parties, and no one outside of this has access to the data, but the identities of the parties, which mostly make up base registries and service portals, are stored centrally. Therefore, the central log stores limited information on service consumption, such as who issued when a service request to what service producer and when was that answered for traffic monitoring and compliance purposes. The byproduct of this central log is a single, albeit limited dataset that includes all service call requests by citizens. This entails a substantial share of total citizen interactions with the state.

Estonia is offering most state services also or only digitally, but they are still owned by separate institutions resulting in a fractured service delivery landscape from the client point of view. Citizens still need to: a) have a clear understanding of which services are designed for their specific needs; b) whether they are eligible for these; c) seek the service out and; d) actively pull it by requesting the service through various service portals or the central digital gateway www.eesti.ee. This state of affairs is due to different state service providers not offering services in a conjoined way even though they might be sharing data with other service providers in the back-end over X-road. Such service offering design does not reflect how the citizens' needs arise.

In reality, a life event, for example having a child, leads to a bundle of service needs – child health care needs, parental benefits registration, tax exemptions on certain benefits, and other in kind and monetary benefits requests. The state observes these as single service consumption instances consumed by the individual – the latent demand for which is determined by some life event of the citizen. While we can reasonably deduct what basic needs arise from specific life events, everything outside of this theoretical cluster is by definition excluded

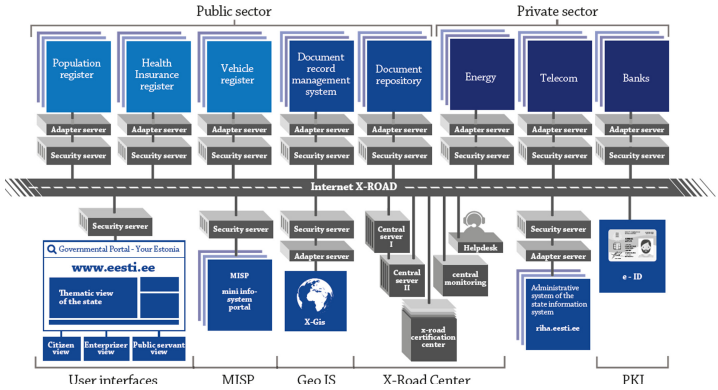


Fig. 1. Schematic picture of X-road (Reprinted from: [18])

even though additional services might be consumed in close temporal space or a particular order and be related through the latent unobserved demand triggered by the life-event. This leads to the unnecessary need to pull different services from different institutions while they could be proactively offered based on the currently unobserved latent event leading to service demand.

Rather than redesign the administrative structure of state service provision, we propose to study and pilot the applicability of service call query clustering to identify if certain service needs cluster together temporally or follow a specific temporal sequence. We also look for lead events that can seem to be triggering more service consumption events. By identifying actual service consumption bundles from the service consumption logs, we pinpoint single domains and domain crossing areas in which service consolidation could bring the most significant value for both the client and the service provider. Value for the citizen would be a reduced need to pull services, reducing informational inequalities on knowledge of and eligibility for services, and more seamless interactions with various service-providing state organizations. Value for the service provider would be to reduce customer support need and channel more clients directly to service provision gateways/portals.

4.2 Service Consumption Patterns

Logged Information. Table 1 shows how a service call query looks like by example of the query 5875968103, the data is available as open data at https://logs.x-tee.ee/EE/gui/, this particular one is a service request made on the 16th January 2021 by the East Tallinn Central Hospital (client) for a digital health record made to the Health and Welfare Information Systems Center (service provider logged as a member in the log) which maintains this particular service under the auspice of the Ministry for Social Affairs. When an individual

makes the service request, the client ID is anonymized in the open data, but a pseudonymized version of the logs has been made available to us for academic research. The individual only shows in the logs if he or she has accessed the service personally through authenticating before requesting the service, if a medical health record of a patient was accessed by a doctor in a hospital or private practice through a mini-information system portal (MISP) then this is recorded a service request by the owner of this particular MISP. As told above, the actual data exchange happens between the two parties to the exchange, and only the metadata of the request is logged by the X-road Center.

The fields of interest for us are marked in the table and are client ID, timestamp, and the service type based on which we can connect individual logs and see which services are consumed either temporally close together or in specific temporal sequences empirically without any theoretical priors to what should go together theoretically.

Table 1. Example of a X-road log from central log (not all fields shown)

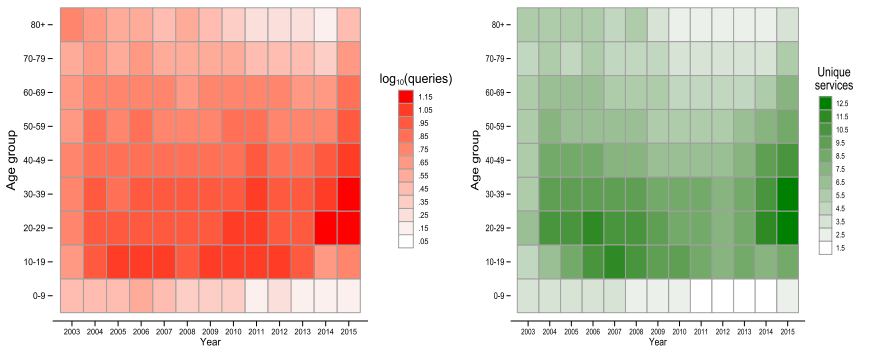

```
{
  "id":                          5875968103,
  "clientMemberClass":           "COM",
  "clientMemberCode":            10822068,
  "clientSubsystemCode":         "ehealth",
  "clientXRoadInstance":         "EE",
  "messageProtocolVersion":      4,
  "requestAttachmentCount":      0,
  "requestInDate":               16.02.2021,
  "requestInTs":                 1613509200000,
  "requestMimeSize":             "None",
  "requestSoapSize":             4348,
  "responseMimeSize":            "None",
  "responseSoapSize":            23578,
  "securityServerType":          "Client",
  "serviceCode":                 "hl7",
  "serviceMemberClass":          "GOV",
  "serviceMemberCode":           70009770,
  "serviceSubsystemCode":        "digilugu",
  "serviceXRoadInstance":        "EE",
  "succeeded":                   "TRUE",
  "totalDuration":               1122
},
```


Service Usage Groups. A prior look at the service usage depth and duration showed two wider user groups emerging [17]. People who use a large number of services on a large number of days over the duration of a year and user with a small amount of service consumed over a few days a year. Solvak et al.

[17] speculate that the former group is mainly civil servants for whom some of the work is organized around digital services. However, the latter is most likely regular citizens who need to pull such services to interact with the state and solve everyday issues related to the service.

We examine the potential latent demand structure based on log data from 2003 to 2015, i.e., the first 13 years since the establishment of the X-road system. Figure 2 shows the average annual service call queries (on a logarithmic scale) and the average number of unique services consumed. The query heatmap (Fig. 2a) indicates that the most active user groups are 20–29 and 30–39 year olds[2].

The average number of unique services by age groups (Fig. 2b) shows a roughly similar picture indicating that not only is this group using services more intensely as indicated by the query number, but they also have a wider selection of services which they use. Therefore, there is variance in service usage depth and number. Moreover, it is non-randomly distributed across age groups, which already indicates that demand differs substantially and could be driven by life events.



(a) Average queries **(b)** Average services

Fig. 2. Annual averages of service call queries and unique services used by age group

Clusters of Service Usage Time-Series. We further selected a random sample of 100 000 individuals out of the total dataset and performed a hierarchical cluster analysis using Ward's linkage for individual unique service usage time-series' by the year the individuals first appeared in the logs. Figure 3 shows the four biggest and most distinct clusters that emerged out of this exercise for each year of first appearance in the logs. We computed four independent clusters for the usage time series that started in the given year.

[2] Minors show in the graph when parents are using some services - mainly health record-related - as legal custodians in their name.

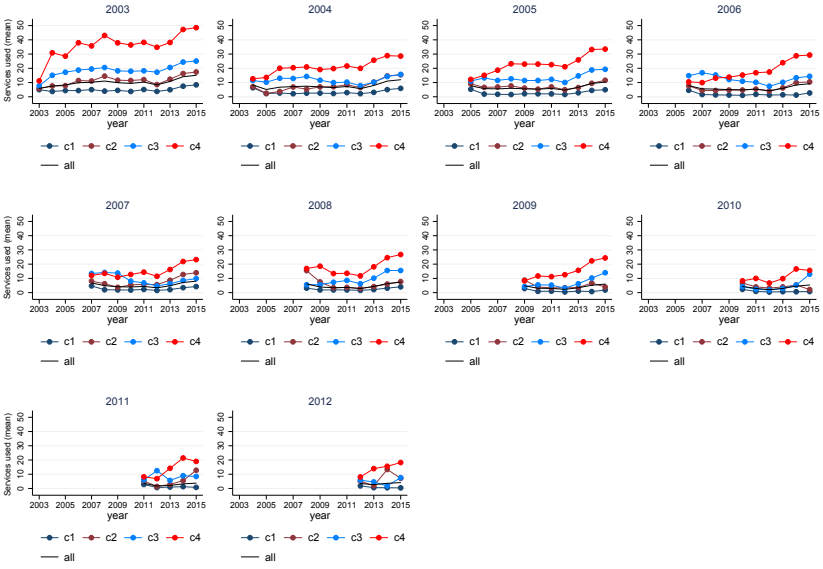


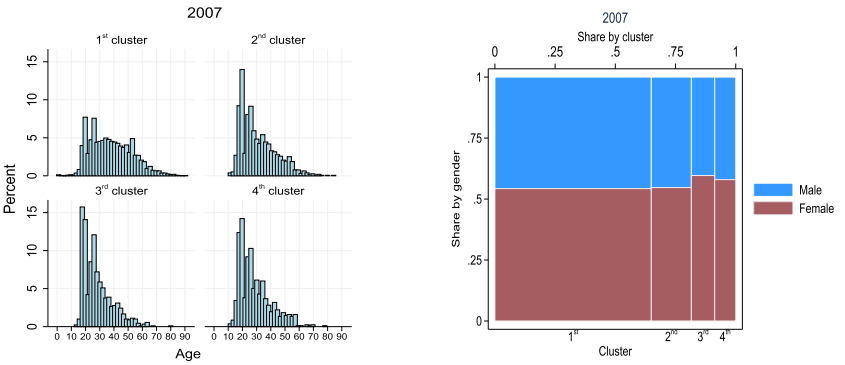
Fig. 3. Clusters in individual service usage time-series, calculated according to the time series that starts in the given year.

Particularly interesting are the third and fourth clusters, where the service usage rate is initially the same for both, but it starts to grow continually in the fourth, whereas it starts to fall or stagnates in the third cluster. Interestingly this pattern repeats itself across the years in varying degrees. While the time series clustering does not tell us anything about the real content of the latent service demand, it nevertheless indicates clear, structured differences in usage intensity and service numbers. Given the relatively large number of unique services consumed per year in the fourth cluster (between 20 to 50 depending on the starting year) there seems to be room for consolidating service offering if these numbers are driven by some shared life-event driven latent demand.

This potential is further strengthened when one peeks into what kind of individuals cluster in the given groups. This is done in Fig. 4, which shows substantial differences in the age and gender structure. The third and fourth clusters have an age distribution peak at 20–30 years and have a significantly higher share of women. While the first cluster is biggest in terms of individuals, it has a relatively flat age distribution, combining this with the low service usage number in the cluster, we can conclude that this includes widely different individual needs across age groups with most likely very heterogeneous service demand menu.

The preliminary empirical investigation therefore points already towards promising results as we have demonstrated that usage patterns take different paths over time, with some of them - characterized by heavy demand for a wide variety of services - being taken by a quite narrow age group with an above aver-

age share of female users. The fact that the highest intense service user groups include disproportionally more women in active childbearing age (20–30 year old) points clearly towards some latent demand structure, possibly life-event driven.



(a) Age distribution **(b)** Gender distribution

Fig. 4. Age and gender distributions in four clusters of individuals who appeared in logs in 2007 for first time

5 Discussion and Conclusion

The literature review showed that the personalization of digital service offerings is not uniformly understood nor defined. There is a lack of understanding of how user demand can be correctly captured and integrated into the service delivery channel design and structure. Possible workarounds through getting additional data from outside the knowledge domain of the service owners - such as using social media data - are not viable strategies and place a heavy additional data collection and managing burden, let alone possibly infringing on user privacy. A content-based approach proposes to examine the user's prior interaction with a given site, focusing only on a small selection of services and will not be viable in a situation where the user demands are dynamic and time-dependent.

The alternative has been a knowledge-based approach where personalization patterns are fixed based on a theoretical understanding of what users want and what needs seem to go together. The live-event based approach is one of such approaches. However, here further limitations enter, as a life-event is by definition a major structuring force in the individual's life which does trigger a large cluster of potential needs hard to comprehend from the service owners point of view or even impossible to detect due to the legal and organizational barriers stopping effective data merging that might show co-consumption of widely different services by the same client. State portals tend not to include such wide selection, and hence the data captured through usage sessions on the portal is,

as a rule, not sufficient to cover all the needs that arise, as these cross many domains and are very likely leading to a sophisticated drawn out need for state support.

We propose a fully bottom-up life event definition that is purely empirical and hence also user-defined - something that combines all aspects of the personalization strategies outline in the literature - user data, data from widely different domains, major structuring events, and a dynamic sequence of combinations of service being consumed. Taking a client-centric view of a life event - something that is big and triggers a myriad of service needs only the individual can comprehend - comes with the major challenge of properly identifying the latent needs arising from it. The latent needs are by definition not observable, but the latent demand leads to observable service consumption clusters if we find ways of joining data from different service owners as it is easier to move data than it is to move institutions or people. We use limited technical service call logs of a data exchange layer for a distributed state information system to switch the view from 2000 separate service owners to one individual that has a need that can be addressed with a specific collection of some of these 2000 services.

The results show that usage is clustered, and some clusters exemplify patterns that indicate a life-vent driven demand - high service usage intensity with multiple unique services being consumed by a narrow age group. Though potentially heterogeneous in content, the service consumption bundles are not overly large when one counts the consumption events and the usage intensity. A further examination of the actual service content of such clusters plus additional clustering definitions on updated data is ongoing. This will show what type of latent demand - defined by the combination of specific services in a service shopping basket - describes what groups.

We consider this latent demand detection one fundamental building block of fully personalized service menus that are dynamic over time and adjusted underlining population dynamics change. Though the full integration of the services in the identified bundles is still a major obstacle, we can demonstrate that the demand can be empirically detected and the content exposed, which paves the way for possible integration solutions.

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