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# SERVICE DESIGN SIMULATION USING FINE GRAINED AGENTS

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## ABSTRACT

Service design deals with methods to organize people, organizations, infrastructure, communication and resources such that macro outcome parameters of the service are achieved while also ensuring excellent individual customer experience. Services are complex, dynamic processes engaging service deliverer and customer over several interactions over multiple touchpoints. Thus designing a service well requires an understanding of the impact of the dynamics of service delivery on service outcome parameters and customer experiences. We discuss a fine-grained agent based simulation approach to service design which will allow services to be simulated in-silico. Fine-grained agent models allow us to understand the macro effect of a service design and the persona level user experiences over multiple customer touchpoints. To model the user experience we use a need based behavior model, influenced by advances in Maslow's need based hierarchy. We demonstrate these ideas on an example from the air travel domain.

## 1 MOTIVATION

Services are a series of carefully orchestrated interactions that create value for customers. A bank may offer loans as a service, Uber offer rides, and AirBnB offers temporary use of rooms. Each service involves a customer journey where carefully designed service touchpoints (Khambete 2011) offer communication bridges through which potential users and customers browse, sample, compare, buy, use and interact with the service. To better design services, it is important to realize how people interact with and experience different service components. This demands that we understand how people act physically, psychologically, cognitively and socially in physical or virtual service worlds (or servicescapes). Experience refers to a user's internal state, emotions and feelings (Law et al. 2009) while engaging with a product or service. It may be measured from the perspectives of quality, usability, customer loyalty, satisfaction etc. There are various service prototyping techniques (Passera et al. 2012) to evaluate service concepts, e.g. experience prototyping, theatre techniques and service blueprints. Yet, it is challenging to test service prototypes in real situations, as it can directly affect customers and business. Simulation and modeling of a service help bridge this issue, aiding service designers to evaluate the operational and experiential aspect of a service in a realistic manner. In this paper, we discuss the use of fine-grained human behavior simulation as a means of prototyping service designs in silico, to understand the micro and macro aspects in the service.

## 2 SERVICE DESIGN, COMPONENTS, CHALLENGES

Nielsen Norman Group (Gibbons 2017) broadly categorize service design into three key components: People, Props and Processes. For example customers and employees could be the People dimension. The props include physical spaces (servicescape), digital environments, and other objects required for service delivery. Processes include various workflows and procedures that customers or staff need to perform. The service design process is iterative and user-centered. It has an analysis phase to understand the problems and gaps in the services through user research, personas, customer journey maps, current-state service blueprints, and ecosystem maps. A synthesis stage then uses ideation techniques to arrive at solutions presented as service concepts, usually through service prototypes and blueprints.

Service Blueprints (Remis 2016) are commonly used as prototypes and to present a service specification, demonstrating the planned service encounters for a customer journey. A service blueprint is a representation mechanism which focuses on the customer (Shostack 1984). Although widely adopted for its flexibility, there are a few challenges in service blueprint representation especially for complex new age services (Lobo et al. 2019), and has led researchers to explore more communicative service blueprint notations. For example, it is challenging to clearly represent situations where the customer is concurrently involved in multiple service encounters, and when there is high flexibility in the service journey. The current representations also only show a single customer's journey through the service, and it is difficult to present activities at an aggregate level. Take the case of a passenger at an airport trying to locate the boarding gate. The airport concurrently also engages the customer with shopping outlets or other utilities. Traditionally service blueprints focus on the primary flow of the service journey, showing special cases separately, as service breakdowns and recovery situations. However, the shopping encounters at the airport can affect the gate-seeking encounter and needs to be showcased suitably. The dynamic variations and unforeseen elements in the journey are difficult to present in a simple manner. Figure 1 (section 6.1) attempts to show a service blueprint for passengers at the departure terminal of an airport.

The effectiveness of solutions for such situations is difficult to evaluate via prototypes as the actual environment and context is dynamic, but could be effectively explored through modeling and simulation.

## 3 REQUIRMENTS FOR A DESIGN SIMULATION SYSTEM

A service design simulation including the servicescape, customer journeys, service encounters and interactions with touchpoints can help in building a platform for service designers to explore possibilities in a realistic manner, allowing them to fine tune interventions or also understand and predict issues in the existing service. This lays out the requirements for a service design simulation system that are mentioned below. A service design simulation system should allow designers and architects:

- To create a digital version of the servicescape. This would include various props and artefacts.
- To populate it with a virtual population that represents both service deliverers and customers.
- To further give the virtual population the ability to experience (feelings, emotions, likes, dislikes, stresses, physical fatigue, mental fatigue).
- To be able to group people in terms of archetypes or personas.
- To be able to give rich behavior to the personas in terms of the decisions and actions they can perform. This could also include knowledge of processes in the user journey.
- To visualize the simulation in terms of both observing service delivery happen in the virtual world as well as in monitoring the impact of and reaction to the service by the population.
- To be able to change the simulation parameters to test out different service design interventions, perhaps even as a simulation is running.

## 4 SIMULATION IN SERVICE DESIGN

While service design today has a slightly different semantic, simulation has been long used for designing service capacity and flow, for example to decide on staffing of various stations in an outpatient clinic. Discrete event simulation (DES) (Banks J, 1984, updated 2006) has been used extensively for such tasks (Gibson 2007) as well as related tasks such as designing supply chains (Prosser et al. 2017). While DES have been successful in estimation and planning tasks, the simulated entities who are either servers or users of the service are represented basically in the form of distributions, of either delivering or using a service.

These simulated entities usually have no agency or decision making abilities, leave alone being able to 'experience' either delivering or using that service. Thus while DES may be good at estimating the macro parameters of a service they provide no help in understanding the experience of service delivery or use.

One such technique is Agent Based Simulation (ABS). Unlike simulated entities in DES, agents in ABS have autonomy and behavior. Due to this ABS have been used to model a wide variety of situations and systems, from modelling traffic flow (Nagel et al. 1998) to complex supply chains (North et al. 2010). ABS have also been used to model services and service delivery. Casti's SimStore (Casti 2000) was among the first to discuss how different store layouts could lead to different purchase behavior. Horl (2017) explored how autonomous vehicle fleets with distinct operational schemes would engage with a virtual population of passengers at different times of day. Jones and Scott Evans (2008) discuss using ABS almost like a DES for scheduling emergency department physicians. What is interesting is that at the end, the authors state how the system could be extended to be more 'human like' in that as physicians near the end of their work day, their processing capacities could reduce due to tiredness and fatigue.

ABS have the basic promise to come close to the requirements for a service design simulation system as discussed in section 3. However, an element that is missing from most ABS systems is the notion of internal cognitive, psychological states that can capture what we call 'experience'. This could range over a wide range of dimensions from physical states like {Energetic, Tired, Sated, Hungry} to emotive states like {Happy, Afraid, Angry} to aspects of perceptions of a service in terms of {Love, Like, Dislike, Hate} the service. This is done using a branch of ABS which we call Fine Grained Agent Based Simulation.

### 4.1 Fine grained agent based simulation

Fine-grained models of human behavior have the ability to factor in multiple dimensions of behavior such as personality, affect and stress. Silverman's work on Performance Moderator Functions (PMF) (Silverman 2004; Cassenti 2009) were among the first to explore more complex agent models. This viewed performance as having a normative quality that was moderated or influenced by aspects such as stress, affect, fatigue, etc. Similarly, there exists other methods such as the Belief-Desire-Intention (BDI) framework that provides a way to simulate human-like agent behavior. While BDI allows to model agent's internal states, it lacks to provide a straightforward means to model agent communication or other aspects of social interaction (Blake and Gilbert 2014).

We too have looked at grounded fine-grained models within the organizational behavior domain (Hayatnagarkar et al. 2016; Balaraman et al. 2016; Singh et al. 2016). Our approach is to use a repository of empirical behavioral relations mined from literature or studies as atomic elements to construct fine-grained models. Constructing such models is a disciplined process which we call behavior composition and which we discuss in more detail in (Duggirala et al. 2017). We used this approach to model organizational behavior such as workload related stress (Hayatnagarkar et al. 2016), impact of supervisory support on work outcomes and the impact of the recent demonetization exercise in India (Bubna et al. 2019).

### 4.2 Simulation in Architectural Design

Schaumann (Schaumann et al. 2016) demonstrated an approach using an event-centric approach to model human behavior patterns in built environments such as hospitals. It proposes a controlling 'narrative management system' that dictates the actors and other service elements into events, based on a pre-decided structure and priority of events. The narrative management system acts as a higher-level entity, which manages information and also handles conflicts that may arise among competing events. This approach provides a good representation of user activity patterns involving scheduled activities as well as more serendipitous activities. While the event-based approach is favorable for the purpose of repeatability and showing group dynamics, it is limited to modelling scenarios with low entropy with restrictive agent autonomy and behavior. This leaves individual agents' behavior only capable of low-level decision making such as path-finding and navigation. Such limitations are hard to ignore for a service design simulation system, where the primary focus is to understand and analyze micro-level experiences and interactions with the service, along with macro-level aggregate service efficiencies.

## 5 OUR APPROACH

In this paper, we propose an agent-centric approach to service design simulations which lays focus on designing, prototyping and testing the service and its components by taking fine-grained individual-level factors into account. The fine-grained approach enables agents to perceive the situation and decide the next set of activities by resolving conflicts between competing events based on their current state, preferences and decision styles. This provides higher autonomy to the agent in contrast to the earlier approaches, while also retaining the event structure that aligns the activities of an agent into a service-journey. Such an agent-centric approach is vital for service design simulation as it exhibits peculiar and distinct behaviors at the agent-level to provide an understanding of the individual-level experience of the users through their journey. Further, this approach allows integrating persona specific fine-grained models for different types of service users/deliverers.

In essence, a service design simulation consists of agents in an environment, who perform certain actions based on their role and purpose in the service journey. A service journey of a customer can be seen as a sequence of events that lead the customer through the different pathways of the service to fulfil their purpose. Every such event has the following three components (Simeone et al. 2012) – the servicescape (where), the actors involved (who), and the activity performed (what).

### 5.1 Servicescape – Activities – Actors

The servicescape is the physical theatre or the environment of the service journey. It consists of the topographical features of the space including appropriate dimensions, accessible areas, obstacles, etc. It holds vital elements for a service, called resources, which serve as enablers for activities performed in a service journey. The resources may be placed at specific locations in the servicescape as per the service.

The activities are the actions that happen in the servicescape, usually performed by an agent. Activities usually demand certain prerequisites such as essential skills or availability of specific resources to successfully perform an activity. As a result of performing an activity, agents may consume resources, alter their internal states, and if successful, may also fulfil their own purpose in a service. For example, to find directions (activity) at an amusement park (servicescape), the visitor (actor) should know how to read (precondition: ability/skill) and have the availability of a map or signboard (precondition: resource).

Actors are simulation agents that represent the people participating in the service as both service users and deliverers. Agents are assigned skills based on their expected role/activities in the service. Each actor-agent is modelled with an autonomous system that comprises their internal states, traits, needs and decision-making styles (Section 5.2). The role and the needs drives agents to perform activities in the service journey.

Every action, interaction, incident or ‘happening’ in a service can be termed as an event. An event can be viewed as an ‘activity’ performed by an ‘actor’ at a specific location in a ‘servicescape’. A chain of such events forms the service journey of the various participants in the service. Based on the service design blueprint the events are classified into two categories: planned events and unplanned events. Planned events are scheduled events that occur at a specific time or are procedural, i.e., they occur in a specific sequence within the overall service journey. Planned events are essential checkpoints along the journey to achieve the purpose of the service. These events are usually top-down, determined by the actor’s role (customer, staff, greeter) in the service. Whereas, unplanned events are unscheduled, characterized by uncertainty that may arise due to (bottom-up) internal needs of an individual or situational factors such as an serendipitous encounter among fellow service users; or (top-down) an operational failure, or a management decision to immediately close/deviate a service process. Unplanned events are deviations from the planned routine of events in a service journey. Service designers account for unplanned events in such a way that it leads the service journey back into the planned pathway in case of service failure (known as service recovery). The event narrative holds the information and sequence of all possible planned and unplanned events.

### 5.2 Agent Behavior and Personas

In the context of the service design simulation approach, the key components of the fine-grained agent model are internal states, needs, decision-making and action execution.

Each agent's internal states is guided by a states-need based model discussed in (Kumar et al. 2018). The need-based mechanism suggests that need-fulfilment is the primary driver of an agent's decision-making and consequently, behavior. Briefly, agent internal states give rise to needs which are attempted to be satisfied leading to changes in state and thus the cycle continues. In the context of service design simulations, needs may also arise based on the individual's role in the service, such as procedural responsibilities or necessity of doing certain tasks in the service process. The presence of active (unfulfilled) needs is often a pre-requisite / trigger for a corresponding event in the event narrative of the service. When pre-conditions of multiple events are satisfied at the same moment the decision module chooses the next event for execution based on need-preference, need-criticality, time-pressure, impulse levels or other judgement characteristics of the actor. Different actors may have distinct nuances in their decision-making styles.

Every actor-agent is assigned with a set of skills / abilities that enable them to perform various activities. Basic skills such as perception through line-of-sight, path finding, communication and walking are assigned to all. Advanced skills are assigned based on the actor's role in the service, e.g. at a restaurant, the customer has the skill to place an order whereas the waiter has the skill to carry around dishes. Actors may have additional skills such as technology-readiness, or be better at certain skills than others, such as high walking-speeds or good navigation skills – these attributes are assigned based on the persona of the individual actor.

The agent actors in our approach are categorized into distinct personas. Personas are composite archetypes based on clustering attributes of a user population or tacit knowledge (Mahamuni et al. 2018), which are representative of the user population. In our approach, every persona differs from another in the values of different attributes, such as need-preferences or decision-making styles or skills. Each agent belongs to a persona and gets its attribute values from the values ranges of the associated persona.

### 5.3 Event Narrative

The set of all possible events – planned and unplanned – in a logical coherent sequence is specified in the Event Narrative. The Event Narrative is a compositional structure that shapes how the service journey unfolds in the simulation. Along with the sequence of events, their pre-conditions and post-conditions are also a part of the event narrative. The pre-conditions are a set of requirements for a particular event to be triggered, such as agent's intrinsic parameters, availability of resources in a service-scape, ability of an agent to perform the event or time-based feasibility. Once the pre-conditions are satisfied, the event specifies the activities for execution. Based on successful execution of these activities, the post-conditions of the event are applied. The different sequences of planned and unplanned events forming distinct journey experiences for each agent is an outcome based on their role, intrinsic goals, preferences, decision biases and other unique traits and characteristics that are part of the agent persona.

### 5.4 Service Design Prototyping and Service Design Interventions

The elements of service design simulation offer a technique for digital service-design prototyping. These simulation prototypes demonstrate how individual users interact with the service, and their distinct journeys through the service process. The simulation system records micro-level service experience indicators such as stress, anxiety, excitement and analyzes them over the service journey, for actors. These indicators aggregated at the level of personas can reflect the service experience for distinct personas. Similarly, macro-level performance measures such as number of users serviced, average time spent per customer and capacity utilization can estimate the efficiency of the service. Further, techniques and metrics to evaluate services from the field of service design such as SERVQUAL (Parasuraman et al. 1988), Customer Effort Score (CES) (Corsten 2019), may also be used to formulate key performance indicators (KPIs) for services, which can be measured with use of design simulation. Simulations allows designers to test multiple versions of a service design with different service design interventions. Service design interventions can be modelled into the simulation system by making appropriate changes to the associated simulation elements such as the event narrative, servicescape, etc. For example, to test the intervention for a mobile navigation app, it would change the users' event narrative – as there is no longer a necessity to find a signboard to find directions. Interventions to re-design the service environment, to avoid congestion in the flow of users/staff, can also be tested by positioning resources differently in the servicescape. Further, simpler interventions such as increasing staff, introducing more help-kiosks can also be easily modeled to test its marginal effectivity. To sum it up, service design simulations allow designers and decision-makers to interactively design services. Designers can ideate, and customize the service design in runtime, to readily perform tests and make design decisions collaboratively. Analysis of simulation results can help to assess alternate designs and choose amongst them based on a chosen evaluation metrics.

# 6 EXAMPLE – AIRPORT LATE GATE CHANGE

An end-moment gate-change decision can result in a chaotic situation at an airport, causing higher levels of stress and fatigue amongst passengers. The situation can be worse at silent airports where the gate-change information is spread without explicit audio announcements but via channels such as display boards, helpdesk kiosks and airline staff. As information disseminates, certain passengers may still be unaware of the change and thus head not for the new gate but may instead choose to visit other airport facilities. This not only leads to end-minute stress and anxiety but also causes delays in aircraft departure as the passengers arrive late at the boarding gate. Such delays can have a cascading effect on airport operations and may disrupt other airport services such as baggage handling. In this demonstrator, we examine how airport services can be designed to recover from a gate-change decision while maintaining a minimum stress experience for passengers along with efficient airport operations to ensure an on-time aircraft departure.

## 6.1 Service Design Process and Interventions

As part of the service design process various interventions can be designed to ensure that the passengers are informed appropriately about the gate change, without negative impact on their experience. Different solutions could be designed keeping in mind different personas. We propose three design interventions to improve the spread of the gate-change information amongst passengers. In the first intervention, SMS alerts are sent to the passengers informing about the gate-change as soon as it is decided. In this case, active phone users are more likely to read the SMS alerts to know about the gate-change, whereas the passengers low on technology-readiness may miss the SMS alerts. In the second intervention, an airline-staff (actor) is introduced into the simulation, who locates and approaches passengers near the old-gate and other crowded areas to inform them about the gate-change. The third intervention is to strategically place more display boards in usually crowded places. This would increase the chances of passengers noticing display-boards in their line-of-sight and thus know if there is a gate-change.

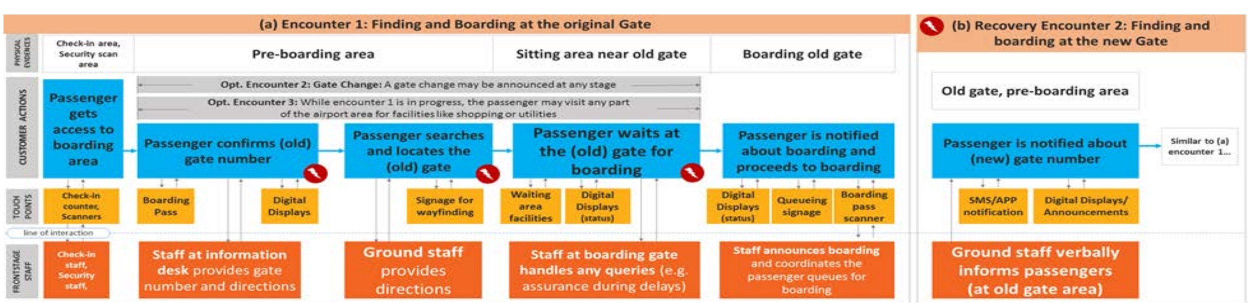


Figure 1: Service blueprints for 1. Finding the Gate; 2. Gate-change; 3. Engaging with airport facilities.

In this example we conceptualized the design interventions as an SMS alert, an airline staff's movement and new display boards. This is shown in the service blueprint in figure 1. We give only a partial representation just to get across the key points. In the first encounter, the blueprint represents the standard flow of a passenger seeking the original gate. The passenger can also be engaged with any other facilities at the airport during this time. The gate change announcement can take place at any time while the user is engaged with any activity within the pre-boarding area or waiting at the original gate. This is shown as a possible service breakdown and service recovery using the lightning symbol. Subsequent to learning about the gate change, the passenger follows the original sequence of activities.

## 6.2 Actors, Personas and Agent Behavior

As discussed in section 5.2, each actor in the service design simulation has an internal need-based model that determines the behavior of the actor. The relevant internal states being considered for this use-case are physiological: fatigue, Hunger and bladder pressure; psychological: stress (due to time-pressure) and other higher-need-level states: urge to shop, and urge to smoke. The states hunger, bladder pressure and the urge to smoke increase with time. Fatigue increases while walking and slowly reduces while sitting. The urge to shop is determined by a pre-decided shopping list that the passenger may have for purchasing at an airport. The psychological state of stress is based on the passenger's accounting of time for various pre-boarding activities at an airport. The states for hunger, bladder pressure, urge to smoke, urge to shop, trigger various needs for the passenger-actor, whereas states such as stress and fatigue are indicators of the quality of service experience for each passenger.

Passengers are known to account for the time required to reach the boarding gate from the current checkpoint (Zakay 1993). This forms the sense of 'perceived time-required' to reach the boarding gate. The accounting for the 'perceived time-required' is modelled as a non-uniform step-function, which drops as the passenger passes through the various pre-boarding checkpoints (planned events). Whereas, the 'actual time-left for departure' decreases gradually as the time passes. The comparison between the 'perceived-time required' and the 'actual time-left for departure' results in stress due to time-pressure. If the 'perceived-time required' is significantly larger than the 'actual time-left for departure', it results in a state of high-stress due to time-pressure, and vice-versa if the 'perceived-time required' is much less than the 'actual time-left for departure'. The accounting for 'perceived time-required' is expected to vary across passenger of different persona-types, as some may be optimistic and some overly cautious in their rationing for time.

The different needs modelled, based on the corresponding states, are the needs to visit the restroom, the food-court, the retail shopping area and the smoking area. The top-down role-based responsibilities for an actor is also cast as equivalent 'planned' needs. In this case, the utmost important need for an actor-passenger would be the 'need' to board the flight, which would drive the passenger-actor to complete the 'planned' pre-boarding activities. Each of the needs discussed above are pre-conditions or triggers to the corresponding 'planned' and 'unplanned' events.

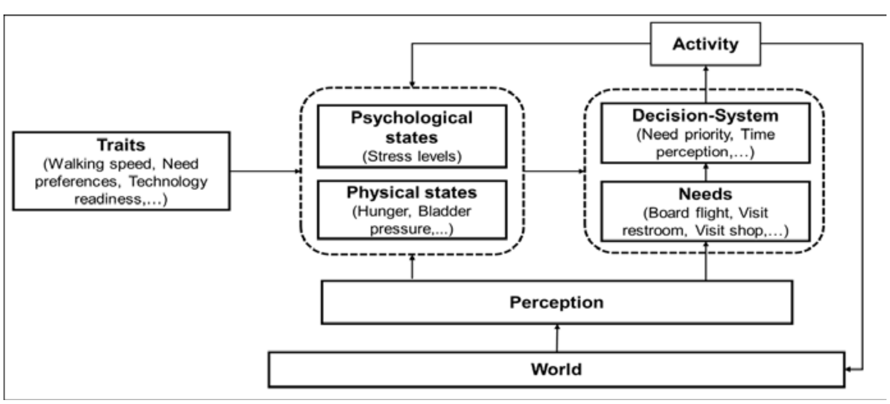


Figure 2: The need-based model for passenger-actors at an airport terminal.

In case multiple such events are triggered at the same time, the decision-making system decides the event to pursue based on the time-pressure and the need preference. In case of time induced stress, planned events are executed based on the procedural sequence of planned events. Whereas, if there is surplus perceived time, unplanned events are executed based on the need-preference of the passenger-actor. Once the event is chosen as per the decision-making system, the activities in the event are performed by the passenger.

The distinct behavioral traits of passenger-actors lead to their distinct behaviors. The passenger traits modelled for this use-case are walking-speed, skills such as technology-readiness (for SMS alerts), tendency to communicate, different need preferences and need rates, and different time perceptions. Passengers that differ by their traits are profiled into various personas. The airport terminal is expected to have passengers of numerous personas. (Nielsen 2013) provides brief guides on creating effective Personas. For this use-case five personas of airport passengers are modelled loosely based on the PASSME work (Kefalidou 2015), which are described in Figure 3 below.


Figure 3: Persona descriptions and their model parameters.

## 6.3 Activities and Servicescape

The airport servicescape is formed by the terminal's layout and its various servicescape elements (resources) such as the check-in / security counters, gate-number display-boards, gate-direction signboards and the boarding-gates. These resources enable the passengers to perform the various pre-boarding activities. Other resources such as the seating-areas, restrooms, food-courts, shopping areas and smoking areas allow the passengers to engage with various airport facilities. These resources are usually placed around the layout of the servicescape in an organized / strategic manner to serve the purpose of the service.

Figure 4 below depicts the Event Narrative for the airport departure terminal, which mentions the logical sequence of the 'planned' events for departure along with the 'unplanned' events that are expected to occur in the context of our use-case.

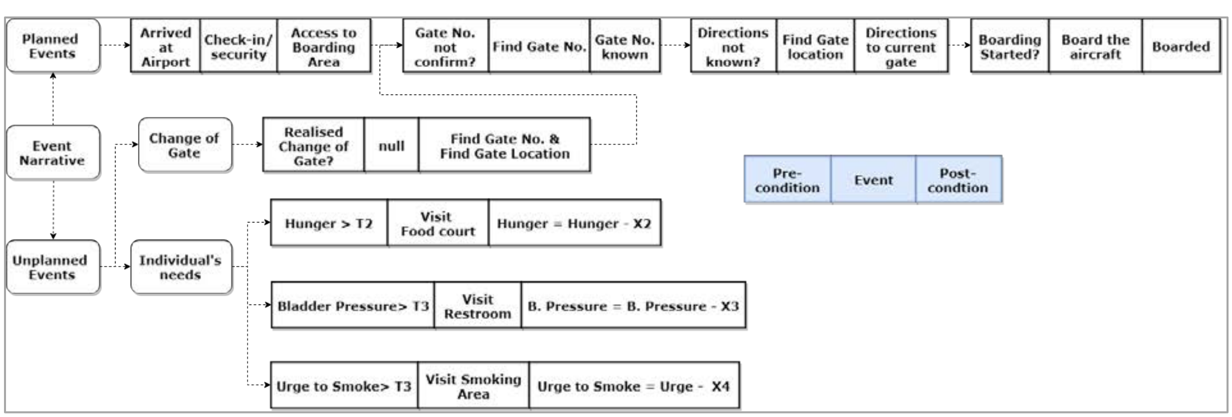


Figure 4: Event Narrative for passenger at an airport terminal for departure.

The planned events are – Check-in and Security, Find Gate Number, Find Gate Location, Board the Aircraft, in that same order. The unplanned events modelled are – Visit Restroom, Visit Food-court, Visit Shopping Area and Visit Smoking Area, and the Change of Gate announcement. When none of the other events is feasible or active, the actor-passenger waits at the seating area usually near the perceived boarding gate. Most of the events are comprised of one or more activities that is performed by the passenger-actor. For example, the event of 'Find Gate Number' involves locating and walking towards the nearest display-board and then waiting for a while to check the gate-number for the flight. Similarly, the 'Change of Gate' event loops the passenger back to the Find Gate Number (new) event when the passenger is informed if there is a gate-change decision. This information can reach the passenger through display-boards, or interventions such as SMS alerts, or communication by the airline-staff.

### 6.4 Visualization and User Interface

The service design simulation for this use-case is implemented on Unity3D. It provides a platform to create the various service-design simulation elements. It runs on the C# coding environment and is integrated with compatible libraries for path finding, animation, and other AI libraries. This is useful for embedding and enhancing agent's micro-level intelligence, and simulating its interaction with the service environment.

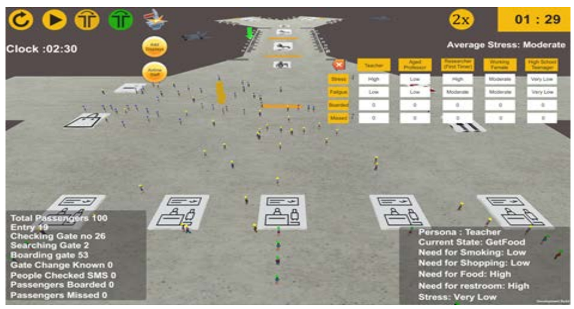


Figure 5: User Interface.

The user interface of the implementation provides a window into the airport service design simulation to display the behavior of every passenger-actor at the airport terminal, from the check-in / security until the departure at the boarding gate. The interface allows us to observe different areas of the airport as well as to click on passengers to view their current state and other related information. Persona-wise information such as mean stress-levels, fatigue can be accessed on an information panel. The information panel also displays the number of passengers in different stages of boarding such Check-in, Gate Search, Boarding and so on. Further, temporal attributes such as the current time of day and the time-left for departure are also mentioned. At the end of the simulation, the number of passengers that arrived late at boarding gate are recorded cumulatively and persona-wise. A parallel interface also plots the micro-level service experience parameters such as fatigue and stress over the period of the passenger journey. Importantly, the interface gives control to the designer to introduce the service design interventions that are modelled into the simulation. This feature allows the designer to strategically position resource elements and redesign the airport servicescape. The designer can then run the simulation multiple times with different intervention settings and servicescape designs to test and choose the best alternative as per the assessment metrics.

## 7 EXPERIMENTS AND RESULTS

We ran batch experiments (~1000 repetitions) of the simulation with 200 passengers (capacity of a typical aircraft) of five personas boarding the same flight, under the following scenarios: a) Gate-change with no interventions, b) Gate-change with SMS alerts being sent to passengers, c) Gate-change with an Airline staff approaching passengers to communicate information, d) Gate-change with more display boards and e) Gate-change with both SMS alerts and Airline staff.

Macro-level service efficiency: Figure 6 from the simulation results depicts the likeliness of a passenger to arrive late at the boarding gate in case of a gate-change. The results also signify that passengers of certain persona-types find it more difficult to be on-time in case of a gate-change, as compared to others. Passengers of persona-types – 'Young Associate' and 'High-school Teenager' seem to reach the boarding gate in time even in case of a gate-change. However, passengers of persona-types – 'Aged-Professor', 'Teacher' and 'Senior Researcher' seem to require help to reach the boarding gate in time. We test interventions that are targeted on informing passengers about the gate-change decision. The effectivity of an intervention is tested based on how significantly does it help passengers to avoid getting late in case of a gate-change.

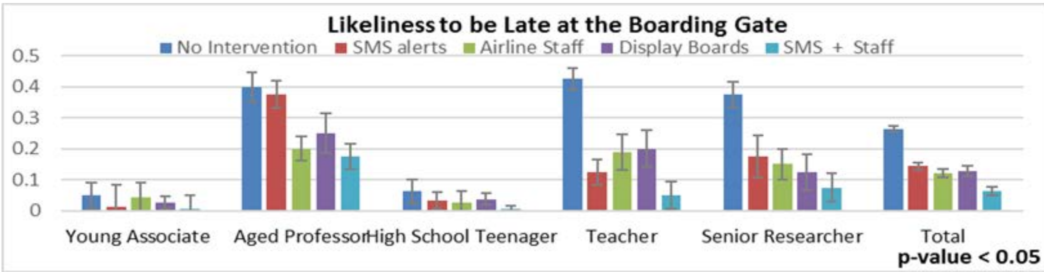


Figure 6: Persona-wise effectivity of service design interventions.

The graph depicts that broadcasting SMS alerts is a better intervention for the 'Teacher' and the 'Young Associate' persona-type, whereas the airline staff intervention is more effective for the 'Aged-Professor' persona. While, the extra displays boards are helpful for the 'Senior Researcher' persona-type. Such insights are valuable for the airport operations center to choose specific interventions, based on the knowledge of the persona-profile of the passengers, to minimize the delay in departure for an aircraft.

Micro-level service experience: The service experience of passengers can also be tracked along time and assessed at aggregate levels as well as for each persona. In this use-case, passenger stress due to time-pressure and fatigue are captured over time, to compare the usual boarding scenario and the gate-change scenario. Figure 7 depicts that in event of a gate-change, passengers experience high-levels of stress as they become aware of the gate-change. The gate-change causes end-minute rush and leaves no time for the passenger to relax at the airport, resulting in higher fatigue as compared to the no-gate change scenario.

Similarly, the service experience of passengers can also be captured persona-wise. These insights can help designers to formulate interventions targeted at particular personas. Figure 8 depicts persona-wise stress due to time-pressure and illustrates how different passenger experience stress over time in the scenario of a gate-change at an airport. This illustrates that passengers of various persona-types experience stress differently through their airport journey. Passengers of persona-types - 'Young Associate', 'Senior Researcher' and 'Teacher' experience the highest stress-levels in event of a gate-change, whereas the 'High-school Teenager' seems relaxed throughout the airport journey. The variations in stress due to time pressure for different personas are based on their distinct styles of time accounting.

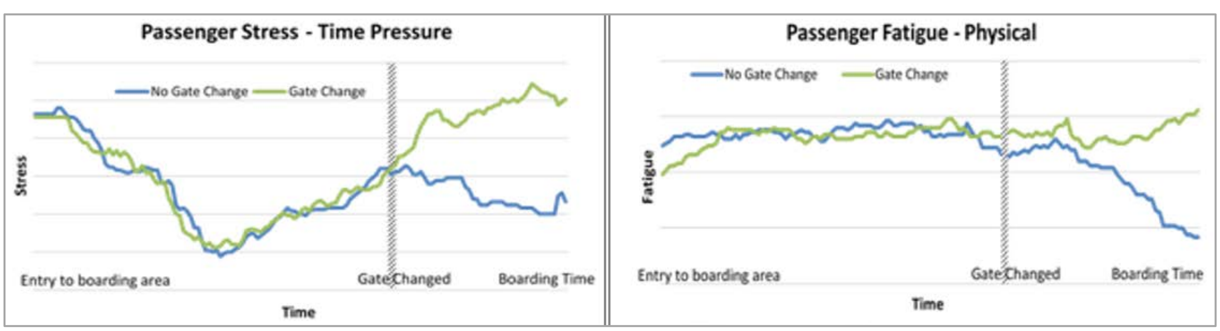


Figure 7: Micro experience in terms of Time pressure stress and Physical Fatigue.

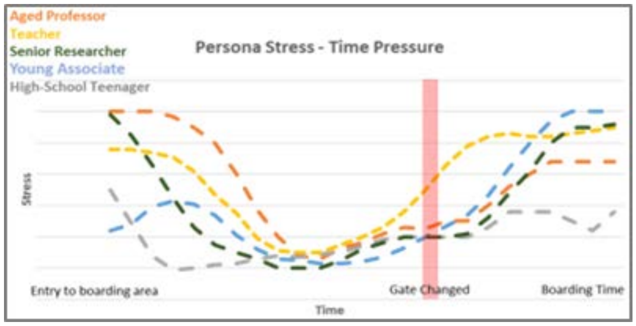


Figure 8: Persona-wise stress due to time-pressure in case of gate-change.

## 8 DISCUSSION AND FUTURE WORK

This paper demonstrates how some of the challenges in service design can be resolved through the use of service design simulations. The study explores how fine-grained agent modelling can be used in service design simulations to capture and understand micro-level service experiences as well as overall macro-level service efficiencies. The approach presents a way to digitally prototype and test service designs and service design interventions before it is applied in the real world.

The implementation on the air travel example demonstrates how this approach can be used for a real-world problem. The analysis of results highlights the effectivity of various interventions on distinct persona-types, to help service designers formulate better persona-targeted service-design solutions.

Model validity and calibration is currently a challenge given the limited data we had at hand. However, the various elements of the passenger behavior model are connected based on previous research as well as inputs from subject experts to maintain theoretical validity. The simulations have also been demonstrated to subject matter experts who were impressed by the realism of the passenger movements.

In future, comparison of simulation results with field measurements via personal informatics apps can lead to improved model calibration and validation. The approach can also be discussed alongside the service design process, detailing how it can be a valuable for service designers at every stage of design. We are working on the architecture that will allow such simulations to be created rapidly and let the designer try out design interventions on the fly.

## REFERENCES

Balaraman, V., H. Hayatnagarkar, M. Singh, and M. Duggirala. 2016. “Towards Better Crisis Management in Support Services Organizations Using Fine Grained Agent Based Simulation”. *International Conference on Principles and Practice of Multi-Agent Systems (PRIMA 2016),* August 22th -26th, Phuket, Thailand, 366-375.

Banks, J. and Carson, J. S. 1984. *Discrete-Event System Simulation*. Upper Saddle River, New Jersey. Prentice-Hall, Inc.

Blake, T. and N. Gilbert. 2014. "How Do Agents Make Decisions? A survey". *Journal of Artificial Societies and Social Simulation,* 17(4): 13.

Bubna, R., J. Raveendran, S. Kumar, M. Duggirala, and M. Malik. 2019. “A Partially Grounded Agent Based Model on Demonetization Outcomes in India”. In *Summer of Simulation,* edited by J. Sokolowski, U. Durak, N. Mustafee, A. Tolk, 247-275. Cham: Springer International Publishing.

Cassenti, D. 2009. “Performance Moderated Functions Server’s (PMFserv) Military Utility: A Model and Discussion”. Army Research Laboratory.

Casti, J. 2000. “BizSim - Business in a Box”. *Artificial Life Robot*, 4(3), 125-129.

Corsten, N. 2019. Six Ways to Measure the Impact of Your Service Design Efforts. https://word.tips.net/T000273_Numbering_Equations.html, accessed 5th February.

Duggirala, M., M. Malik, S. Kumar, H. Hayatnagarkar, and V. Balaraman. 2017. “Evolving a Grounded Approach to Behavior Composition”. In *Proceedings of the 2017 Winter Simulation Conference,* edited by V. Chan, A. D’Ambrogio, G. Zacharewicz, N. Mustafee, E. H. Page and G. Wainer, 360. Piscataway, New Jersey: IEEE Press.

Gibbons, S. 2017. Service Design 101. Nielsen Norman Group. https://www.nngroup.com/articles/service-design-101.

Gibson, I. W. 2007. "An Approach to Hospital Planning and Design Using Discrete Event Simulation". In *Proceedings of the 39th conference on Winter simulation: 40 years! The best is yet to come*, edited by S. Henderson, B. Biller, M. Hsieh, J. Shortle, J. Tew and R. Barton, 1501-1509. Piscataway, New Jersey: IEEE Press.

Hayatnagarkar, H., M. Singh, S. Kumar, M. Duggirala, and V. Balaraman. 2016. "Can a Buffering Strategy Reduce Workload Related Stress?". In *Theory, Methodology, Tools and Applications for Modeling and Simulation of Complex Systems*, edited by Zhang, Lin, Song, Xiao and Wu, Yunjie 378-388. Singapore: Springer.

Horl, S. 2017. "Agent-based Simulation of Autonomous Taxi Services with Dynamic Demand Responses. *Procedia Computer Science*, 109:899-904.

Jones, S., and R. S. Evans. 2008. "An Agent Based Simulation Tool for Scheduling Emergency Department Physicians". *AMIA Annual Symposium Proceedings*, 338-342.

Kefalidou, G. 2015. Overview of the state of the art (SoA) requirements. Public Deliverable D1.2 of the H2020 European project PASSME. https://passme.eu/passme-project-deliverables/, accessed 4th April.

Khambete, P. 2011. "A Pattern Language for Touch Point Ecosystem User Experience: A Proposal". In *Proceedings of the 3rd International Conference on Human Computer Interaction,* April 7th -10th, Bangalore, India, 68-74.

Kumar, S., M. Malik, M. Duggirala, V. Balaraman, and R. Bubna. 2018. "Evolving a Canonical Human Behavior Model of Well-Being". In *Proceedings of the 50th Computer Simulation Conference*, July 9th -12th Bordeaux, France, p. 17.

Lobo, S., S. Sharma, U. Hirom, R. Mahamuni, and P. Khambete. 2019. "Extending Service Blueprint for New Age Services". In *Research into Design for a Connected World*, edited by A. Chakrabarti, 809-821. Singapore: Springer.

Mahamuni, R., P. Khambete, R. M. Punekar, S. Lobo, S. Sharma, and U. Hirom. 2018. "Concise Personas Based on Tacit Knowledge-How Representative Are They?". In *Proceedings of the 9th Indian Conference on Human Computer Interaction*, December 16th -18th, Bangalore, India, 53-62.

Nagel, K., P. Stretz, M. Pieck, R. Donnelly, S. Leckey, and C. Barrett. 1998. "Transim Report Series: Transims Traffic Flow Characteristics". Los Alamos.

Nielsen. L. 2013. "Personas". In *The Encyclopedia of Human-Computer Interaction, 2nd Ed.* Aarhus, Denmark: The Interaction Design Foundation.

North, J., C. Macal, J. Aubin, P. Thimmapuram, M. Bragen, J. Hahn, . . . D. Hampton. 2010. "Multiscale Agent Based Consumer Market Modeling. *Complexity*, 15(5), 37-47.

Parasuraman, A., V. A. Zeithaml, and L. L. Berry. 1988. "Servqual: A multiple-item scale for measuring consumer perc. *Journal of retailing*, 64(1), 12.

Passera, S., H. Kärkkäinen, and R. Maila. 2012. "When, How, Why Prototyping? A Practical Framework for Service Development". In *ISPIM Conference Proceedings*, June 17th -20th, Barcelona, Spain, p. 1.

Prosser, W., P. Jaillard, E. Assy, S.T. Brown, G. Matsinhe, M. Dekoun, and B.Y. Lee. 2017. "System Redesign of the Immunization Supply Chain: Experiences From Benin and Mozambique". *Vaccine*, 35(17): 2162-2166.

Remis, N. 2016. *A Guide to Service Blueprinting*. San Francisco: Adaptive Path.

Schaumann, D. M., M. Gath, E. Pilosof, N. P. Pilosof, H. Sopher, M. Brodeschi, D. Kartikeya, and Y. E. Kalay. 2016. "A Computational Framework to Simulate Human Spatial Behavior in Built Environments. In *Proceedings of Symposium on Simulation for Architecture and Urban Desig*n, May 16th-18th, London, UK.

Shostack, G. L. 1984. "Designing Services That Deliver". Harvard Business Review, 133–139.

Silverman, B. 2004. "Towards Realism in Human Performance Simulation". Bradford: Emerald Group Publishing Limited 469-498

Simeone, D., Y. E. Kalay, D. Schaumann, and S. Hong. 2012. "An Event-Based Model to Simulate Human Behaviour in Built Environments". In *Digital physicality: proceedings of the 30th eCAADe Conference*, September 12th-14th, 525-532.

Singh, M., M. Duggirala, H. Hayatnagarkar, S. Patel, and V. Balaraman. 2016. Towards Fine Grained Human Behaviour Simulation Models. In *Proceedings of the 2016 Winter Simulation Conference*, edited by P. Frazier, T. Roeder, R. Szechtman, E. Zhou, T. Huschka, S. Chick and J. Jimenez, 3452-3463. Piscataway, New Jersey: IEEE Press.

Zakay, D. 1993. "The Impact of Time Perception Processes on Decision Making Under Time Stress". In *Time Pressure and Stress in Human Judgment and Decision Making*, 59-72. Boston: Springer.


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