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SYMBIOTIC USE OF DIGITAL TWIN, SIMULATION AND DESIGN THINKING APPROACH FOR RESILIENT ENTERPRISE

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ABSTRACT

Enterprises are increasingly facing the need to be resilient in the face of uncertainty and dynamism. Simulatable digital twins have become critical aids for analyzing and adapting complex systems. Design thinking and service design methodologies, in contrast, are gaining momentum for ideation, subjective evaluation, and innovation. A systematic application of these methodologies to explore innovative ideas and a faithful virtual environment to test and fine-tune those ideas without impacting real systems could be transformational. This paper presents an approach that establishes a symbiotic relationship between these two approaches to introduce precision and innovativeness to make enterprises resilient. We describe the key characteristics of resilient enterprises, present our approach, and illustrate its effectiveness with a case study focusing on a transformation toward a new normal to address the Covid-19 pandemic induced disruptions in the IT industry.

1 INTRODUCTION

Enterprises are facing increasing threats from a wide range of digital and social disruptions due to technological advancements, dynamic operating environments, and rapidly evolving stakeholder expectations. To navigate this volatile, uncertain, complex and ambiguous (VUCA) environment, enterprises are expected to be more resilient than ever before (Hillmann and Guenther 2021). However, many contemporary enterprises are grappling with fundamental questions, such as: "*what*" does resilience mean for an enterprise, "*what*" needs to be done to make an enterprise resilient, and "*how*" can the desired degree of resilience be achieved (Duit 2016)?

Literature (Duchek 2020; Boin and Van Eeten 2013; Sanchis and Poler 2013) reveals that resilience refers to an ability of a system (also referred as firm, organization, enterprise, ecosystem) to recover from stresses and instabilities, and prevent deviation from its desired state of equilibrium. It also indicates that an excellent set of core capabilities addressing tangible expectations of the stakeholders and consumers from the contemporary context is not enough for an enterprise to be resilient. Instead, a culture of periodic comprehensive evaluation of the current situation, anticipation of possible disruptions and prediction of future trajectories from a transdisciplinary perspective is necessary (Rouse 2015).

We introduce a comprehensive analysis aid to introspect an enterprise, predict its potential future states under various disruptions and evaluate the efficacy of various interventions from the perspectives of multiple stakeholders using a combination of qualitative and quantitative analysis techniques as discussed in (Mustafee et al. 2020). Here, we employ a qualitative human-centric problem-solving technique that leverages the core concepts of design thinking (Brown 2008) and service design methodology (Stickdorn et al. 2018). We further augment rigorous analyses and quantitative decision-making capabilities using the concepts of digital twin complemented with established concepts from system theory and modelling & simulation research. Supported qualitative techniques guide stakeholders to explore innovation ideas in a systematic way bringing in more focus on human aspects, such as experience and employee satisfaction. Digital Twin based simulation, in contrast, enables in-silico quantitative analyses of disruptive situations and precise evaluation of ideas in the context of emerging and uncertain environment. A seamless symbiotic relation of two complementary techniques enables innovation culture with desired degree of precision and quantitative rigor.

In this paper, we present our approach and demonstrate its efficacy using Covid-19 pandemic induced disruptions in IT industry, i.e., defining a new operating model to break the Work From Home (WFH) versus Work From Office (WFO) dichotomy. The paper is structured as follows: Section 2 reflects on the literature and presents the key characteristics of resilient enterprise, associated complexities, and foundational concepts used in our proposed approach. Section 3 describes our approach, with a case study in Section 4 on transformation towards a new normal to deal with Covid-19 pandemic related disruptions in an IT company. We conclude with a critical evaluation of our approach and future work.

2 BACKGROUND

2.1 Resilient Enterprise

The concepts of stability and resilience of evolving system were explicitly studied by Holling (1973) in the context of ecology, where he defined system resiliency as a continuous effort to remain persistent by maintaining flexibility above everything else. Over the years, the concept has been contextualized and evolved for enterprise. Dalziell and McManus (2004) and Gallopín (2006) have described enterprise resilience as a function of vulnerability (a property that describes how easily a system can be moved from its desired state) and adaptative capacity (an ability to withstand the internal and environmental disruptions). Somers (2009) has argued that "resilience is more than mere survival; it involves identifying potential risks and taking proactive steps to ensure that an organization thrives in the face of adversity". Erol et al. (2010) have defined enterprise resilience as an enterprise's capability to reduce the degree of its vulnerability to expected and unexpected threats, its ability to recover from various disruptions and adapt to its changing operating environment. Lengnick-Hall et al. (2011) have described enterprise resilience as "a firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organization survival".

Chiefly, a resilient enterprise is expected to continuously evaluate its status-quo with respect to its goals (*i.e.*, vulnerability assessment), introduce proactive interventions so that it remains stable with respect to the desired state (*i.e.*, adaptation capabilities), and advocate reactive interventions to reestablish the desired state if it is moved to an undesired state due to internal and/or external factors (*i.e.*, recovery ability).

2.2 Emerging Complexities towards Achieving Resilience

Contemporary enterprises face challenges in assessing their vulnerability and developing effective interventions for adaptation capability and recovery ability. They are vulnerable to internal dynamics, external environment changes, and shifting priorities. The complexity of internal dynamics is due to the large number of systems and subsystems (*i.e.*, system of systems) with non-deterministic behaviors and multiple non-linear interactions (Barat et al. 2022). The system of systems nature of enterprises further complicates the situation with different stakeholders with varying (and possibly conflicting) goals managing constituent systems and subsystems.

Growing competition and external disruptions make enterprises sensitive to their operating environment. Enterprises are expected to have suitable responses to their competition (*i.e.*, innovative products and services from competitors) and external disruptions, such as technology advancements and technology adoption, changing customer behaviors, and changing geo-socio-political factors. The change of priorities and focus areas change with evolving expectations from internal and external stakeholders is another challenging dimension. For example, tangible aspects like product features and price are no longer the sole evaluation criteria for consumers (*i.e.*, external stakeholders). The entire product lifecycle and intangible values like product and service experiences are also crucial. Focus on work-life balance, convenience, satisfaction and flexible work culture in addition to salary and career path to retain their employees (*i.e.*, internal stakeholders) is a new normal. Focus on sustainability requirements from social and environmental perspectives is also becoming a norm.

To consider all these aspects in a comprehensive way, enterprises need to a) understand situations from transdisciplinary perspectives involving tangible and intangible values of their capabilities and b) generate effective interventions (for adaptation and/or recovery) that satisfy the latent intent of all involved stakeholders rather than merely meeting business objectives.

2.3 Design Thinking and Service Design Methodologies: from Concept to Applications

Design thinking methodology (Brown 2008) is a human-centric non-linear process that challenges existing assumptions and produces innovative solutions to various contemporary problems. It considers an iterative process involving multiple stakeholders for understanding concerns, constraints and expectations, ideating new ideas, qualitatively testing them using design prototypes, and revising ideas until an optimal and agreeable solution is obtained. Service design methodology is an extension of the design thinking methodology with a focus on the concept of *service* (i.e., actions, tasks, or offerings that satisfy tangible and intangible needs of consumers and stakeholders). These human-centric qualitative methodologies have been successfully applied to enterprise transformation initiatives (Kurtmollaiev et al. 2018).

Design thinking is relevant for a resilient enterprise as it helps addressing *wicked problems* (Carlgren et al. 2016) by analyzing situations from transdisciplinary perspectives and developing solutions that addresses intent of involved stakeholders. We find service design methodology specific extensions relevant as the concept of *service* is an important factor because both tangible and intangible aspects are becoming equally important in the context of contemporary enterprises. We adopt two key concepts from design thinking methodology: a) iterative and creative problem-solving process steps that seek alternatives to a problem and generate ideas, and b) the virtue of participatory design or co-creation process. We rely on service design methodology to introduce balanced focus on tangible and intangible aspects.

2.4 Digital Twin from Modelling and Simulation Perspective

A digital twin is a purposive, virtual and analyzable representation of a system (Grieves and Vickers 2017). A digital twin framework contains four building blocks: real system, virtual representation, sensing mechanism and recommendation. A virtual representation is a purpose specific model of the real system, which helps to perform in-silico what-if and if-what analyses. Modelling and simulation to mimic real system and analyze it are the key focus of this block. The sensing block helps to synchronize data from the real system to the constructed virtual representation. Digitization and advancement of IoT based solutions are key enabling technologies for the sensing block. The recommendation block is a mechanism to close the loop and act as an actuator to bring analysis outcomes to the real system.

Industry has seen a wide adoption of digital twins for a range of purposes including gaining insight, monitoring system progress, predicting failures, and optimizing and controlling systems. However, the adoption was largely limited to the manufacturing domain and for various physical systems that are well-understood by scientific laws and characterized by relatively less uncertainty. Recently, there has been an increasing trend in the adoption of digital twin technology across other domains, such as enterprises and social systems (Kulkarni et al. 2022). The reasons for this upward trend are twofold: firstly, the demand for rigorous analyses is growing for these systems as they face increasingly complex and uncertain situations, and secondly, advancements in modeling and simulation techniques, artificial intelligence, and sensing technologies are relevant for representing and analyzing complex systems like enterprises.

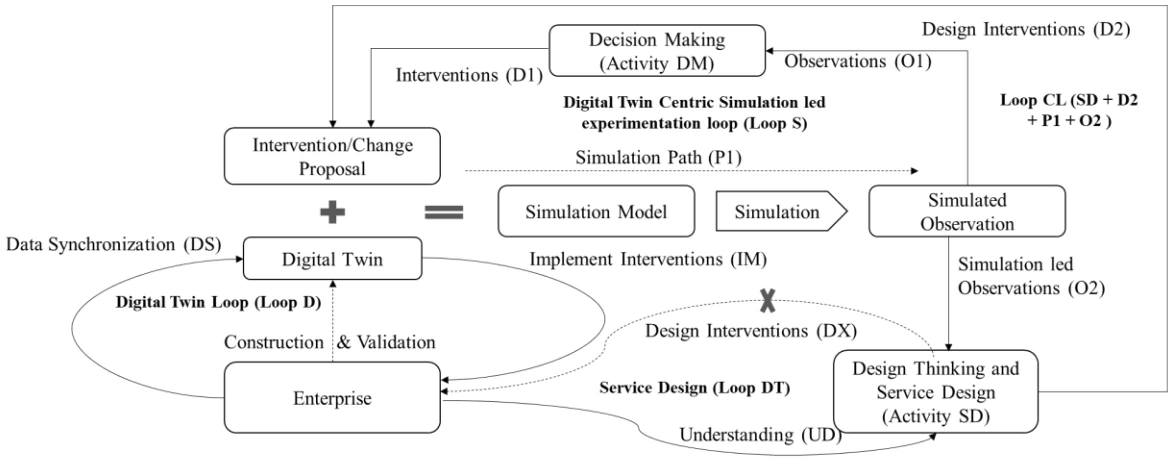


Figure 1: A schematic view of digital twin led human in the loop exploration.

From a range of existing modeling and simulation techniques, including AI-centric approaches, mathematical models, Enterprise Modeling (EM) techniques and agent/actor-based paradigms, we consider an industry-scale actor-based simulatable language called Enterprise Specification Language (ESL) by Clark et al. (2017) to represent and analyze enterprises. It should be noted that the use of a fine-grained modeling and simulation technique is the key here, as discussed in Kulkarni et al. (2022).

2.5 Synthesis

Service design and design thinking methodology can promote innovation and understand enterprises from a transdisciplinary perspective, but they lack the desired quantitative rigor for assessing vulnerability and effectiveness of potential interventions. On the other hand, simulation-aided digital twin ensures quantitative rigor but suffers from necessary innovative steps. It has limitations to explore and evaluate intangible aspects of the enterprises, such as experience and satisfaction. We argue that the symbiotic existence of service design, which includes the core concepts of design thinking methodology, and simulation-aided digital twin technology with a suitable analyzable model is a more pragmatic way forward for addressing the key requirements of a resilient enterprise.

3 OUR APPROACH

Our approach to conceptualize a human-in-the-loop decision-making aid for a resilient enterprise revolves around the concepts of digital twin, simulation, and modeling abstraction in conjunction with methodological procedures drawn from design thinking methodology, service design, and systems thinking. As shown in Figure 1, we extend the canonical iterative design thinking process as the underlying method and a simulatable digital twin as a core artifact. Our methodological extensions establish desired symbiotic relationships between qualitative and quantitative problem-solving techniques, where each step combines a set of steps recommended in service design that includes design thinking methodology, systems thinking, and the steps required for a simulatable digital twin. Broadly, our proposed method has support for: a) comprehending an enterprise (i.e., assessing vulnerability) from a transdisciplinary perspective using established human-centric techniques and a digital twin-based quantitative approach, b) ideating interventions and validating their effectiveness with rigor to achieve emerging business needs or opportunities (i.e., adaptive capacity), and c) ideating and validating interventions to mitigate existing challenges or stress (i.e., recovery ability).

Our proposed digital twin considers two design choices: a) a fine-grained actor model to precisely represent constituent elements of the enterprise (e.g., systems, sub-systems, entities) and its environment, and b) simulatable nature of the model. The actor abstraction of the digital twin makes the representation

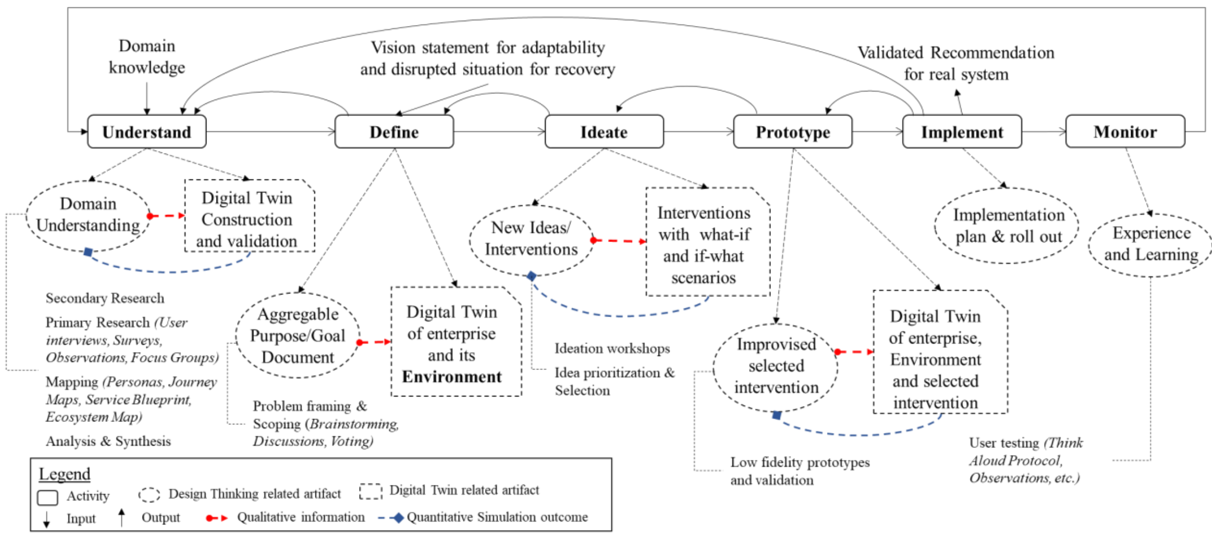


Figure 2: An overview of method steps.

closer to the real entities of the enterprise and its environment (a one-to-one representation between real elements and actors in the digital twin can be established), and the simulatable nature of the constructed digital twin helps to perform quantitative what-if and if-what scenarios. Here, we introduce potential interventions as the structural and/or behavioral changes in actors (i.e., in the digital twin) and use simulation to understand their consequences or effectiveness. Furthermore, we visualize interventions as services to evaluate their effectiveness with respect to tangible and intangible aspects from multiple stakeholder perspectives in addition to quantitative evaluation.

3.1 Digital Twin Setup

A schematic view of our proposed digital twin based setup is shown in Figure 1. It is a canonical form of digital twin with additional focus on simulation capability and extensions to establish methodological interoperability with design thinking and service design. As shown in the figure, *Loop D* represents conventional digital twin construction, validation, synchronization and usage – a two-way connection of virtual representation with the enterprise. We use the constructed digital twin for what-if simulation through Loop S, which includes path P1, step O1 and step D1. The loop S, after successful validation of the digital twin using loop D, helps to understand the future state of the enterprise under various environmental disruptions (i.e., vulnerability assessment) and evaluate effectiveness of potential interventions before implementing them into the real enterprise. While loop D and S together serve the purpose of qualitative assessments, the ideation of potential interventions and interpreting simulation result to imagine additional options are largely vulnerable to the human-bias and cognitive abilities of decision-makers.

Our proposal is to use the CL Loop that includes path P1, step O2, and step D2 to leverage the strengths of digital twin and service design methodologies in a complementary and meaningful way. Designers arrive at innovative ideas or interventions through an in-depth study of the existing enterprise and its environment, cognizant of design science and service design related guidelines. The CL loop-based explorations, starting with activity SD (with initial understanding about enterprise using UD), followed by path D2, P1, and observations O2, help designers gain richer insights as opposed to the traditional qualitative evaluation used in service design loop, i.e., Loop DT that includes path UD and DX. It also helps designers to refine their ideas in a shorter duration as they get close to real life feedback about the efficacy of their ideas before deploying them into the real world. These extensions also address the inherent limitations of qualitative evaluation, such as the potential for failure due to practical constraints (Blomkvist and Holmlid 2010).

3.2 Method

We extend conventional five-step iterative design thinking process to an iterative six-step process and refined activities of each process step as shown in Figure 2 to establish a symbiotic relationship between the two complementary methods. The key activities of our process steps are described below:

Understand: This step starts with a design thinking mindset to gain knowledge about the enterprise and iterate over a two-step process to construct a purposive digital twin as shown in Figure 2. The first sub-step considers primary and secondary research techniques that are recommended in design thinking and service design (i.e., survey, interviews, persona journey analysis) to capture a broad understanding about the enterprise, its environment and associated domain(s) from multiple stakeholders.

The second sub-step converts the captured understanding into actionable insights, i.e., digital twin. It adopts a three-phase model construction and validation process defined by Sargent (2010). The first phase captures domain understanding in the form of a conceptual system model by reflecting on systems thinking lens (i.e., Loop D in Figure 1). It identifies actors, their relationships and inherent complexities, such as behavioral non-linearity and non-determinism, by focusing on the structural and behavioral aspects of the enterprise and its interactions with its environment. The next phase translates the constructed conceptual model into a simulatable model by converting the conceptual specification into a simulatable actor specification, termed as enterprise specification language (ESL). The third phase contextualizes the simulation model with real data collected from the enterprise. Here, we adopt data validity, conceptual validity and operational validity techniques as suggested by Sargent (2010) to establish the faithfulness of the constructed and instantiated model, i.e., digital twin of enterprise. Data validity is primarily the data synchronization between digital twin and enterprise as shown as step DS in Figure 1. Conceptual validity is a human-centric method, where constructed conceptual model is validated by domain experts using primary research techniques. This might be an iterative process that navigates between two artifacts of the *Understand* step as shown in Figure 2. Operational validity simulates known historical scenarios and compares the simulation results with historical data through Loop S in Figure 1.

Define: This step focuses on problem framing and scoping where the key objectives are to identify possible environmental disruptions (i.e., vulnerability assessment), explore possible improvement opportunities (i.e., requirement for adaptive capability), and recognize if the enterprise is in a disrupted state (i.e., requirement for recovery). This step is a service design centric step where relevant stakeholders engage in brainstorming, discussions and voting process (i.e., activity SD in Figure 1) to qualitatively assess the vulnerability of the as-is enterprise under various anticipated environmental disruptions (i.e., micro and macro uncertainties) and formulate precise requirements for adaptation and/or recovery as required (i.e., in this case primarily experiential aspects of various stakeholders). Simulation of the constructed digital twin with anticipated environmental disruptions as potential interventions using Loop CL, i.e., SD, D2, P1 and O2 of Figure 1, provides additional quantitative insights and inputs to the stakeholders for assessing vulnerability and defining requirements.

Ideate: This step generates ideas about creative interventions, evaluates their efficacies and selects the most promising interventions that require precise evaluation. This step includes activity SD along with Loop CL and Loop S. In this step, activity SD leverages divergent and convergent thinking approaches (Brown 2008) from design thinking methodology for ideation, where it employs several methods, such as association and analogy-based methods (Stickdorn et al. 2018), and brainstorming, to encourage wider participation and co-creation among the stakeholders. Loop CL augmented with activity SD helps to assess effectiveness of identified ideas with respect to potential risks, consequences and feasibility.

Loop S along with activity DM provides a scope to consider and evaluate additional interventions that the management would like to evaluate for achieving desired tangible objectives, such as profitability and resource utilization. This step recommends multiple simulations considering interventions identified by activity DT and activity SD, quantitative comparison of the simulation outcomes, qualitative assessments, and a human-in-the-loop selection approach, such as voting. Coexistence of Loops DT and Loop S with quantitative observations helps to explore interventions for tangible and intangible aspects in a seamless manner. A combination of qualitative and quantitative assessments followed by human-in-the-loop selection process helps to select most promising interventions with high certainty.

Prototype: This is a preparatory step for fine-grained analysis of the identified intervention(s) and fine-tuning them to define a pragmatic implementation plan for activity IM (of Figure 1). We reuse Loop S and Loop DT to fine tune interventions and evaluate their efficacies under different operating environments by extending the constructed digital twin with various potential operating environments, such as emergence of new policies, constraints, and behavioral trends. We used simulation outcomes to depict or demonstrate post implementation scenarios as opposed to the traditional paper or role-playing based qualitative approaches proposed in conventional design thinking methodology (Blomkvist and Holmlid 2010).

Implement: This step is an implementation step that executes implementation plan defined in the prototype step on enterprise (*i.e.*, IM in Figure 1). During this phase, various changes can be introduced to the enterprise and may include structural modifications, behavioral nudges, adjustments to service delivery, introduction of new products, or enhancements to customer interaction management.

Monitor: Finally, it is important to monitor the enterprise on an ongoing basis to understand deviation from the desired state and trigger the whole process in case any deviation is observed with respect to enterprise key performance indicators (KPIs) or any changes is the environment.

4 ILLUSTRATIVE CASE STUDY

The prolonged pandemic fatigue has significantly disrupted the conventional notion of business-as-usual across industries. While many industries have recovered from the pandemic induced disruption, employees from IT companies are still comfortable with flexible work hours and WFH culture as opposed to traditional WFO culture (Bailey and Rehman, 2022). Although there are several benefits to WFH, management is finding it difficult to accept it as the new normal as it is hindering collaboration and bonding opportunities, which is further impacting productivity and operational excellence from a long-term perspective. This work preference dichotomy is causing vulnerable situations for many IT companies.

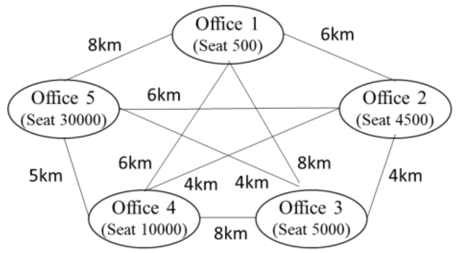
To address the dichotomy between WFH and WFO preferences, many IT companies have adopted a hybrid mode of working with flexibility to WFH and WFO. However, motivating employees to return to the office has been a challenge. The issues are multifold and non-linear, such as uneven employee attendance throughout the week and month causes inappropriate facility management for seating arrangement, food in the canteen and optimum temperature control. The ad-hoc office attendance also makes project management difficult, leading to productivity loss and inadequate collaboration. Inadequate facility management leads to dissatisfaction and inconvenience to employees, which further impacts administrative planning. These non-linear complexities make the operations of IT companies unstable and negatively impact employee satisfaction. Thus, in-depth analyses are required to develop effective interventions in terms of policies, guidelines and nudges to define a stable new normal that addresses the dichotomy while balancing employee satisfaction and operational excellence.

4.1 Context of Our Case Study

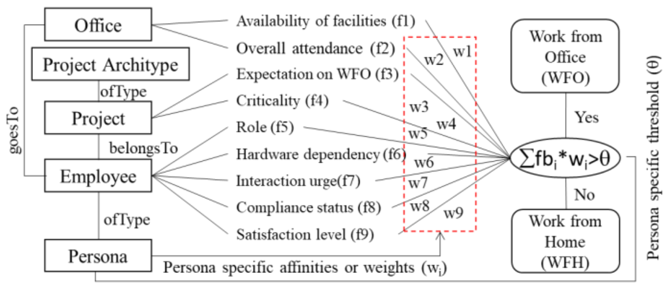
As a concrete case, we considered a branch (B) of our organization with nearly 50,000 employees across five offices in a city. In mid-2022, the average employee attendance of branch B was as low as 7-8% and employee satisfaction for office goers was also low. The situation was exacerbating over time as most of the office facilities, such as canteens and meeting rooms, were inadequate. At that time, the management was expecting at least 25% of employees to return to the office. They started sending notifications to achieve this objective. However, the situation remained unchanged despite multiple attempts, which led the management to realize that it is a wicked problem.

4.2 Explorations

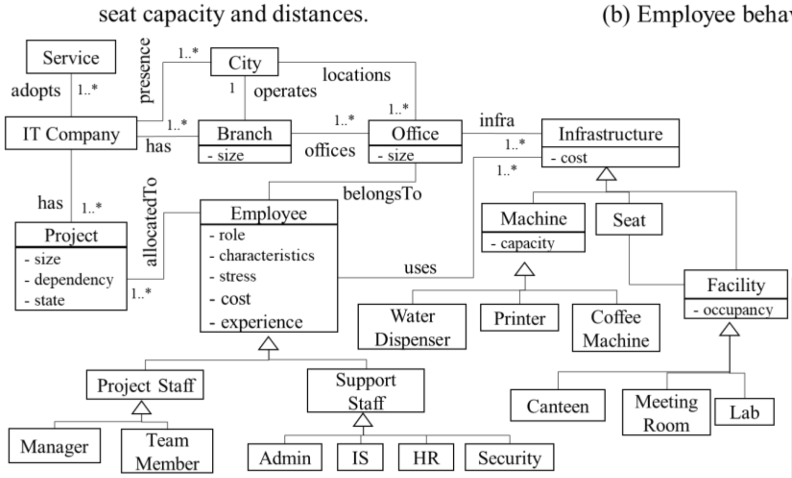
We applied our approach to assess the stated vulnerable situation and define an effective recovery strategy. A summary of our experimentation steps is described below:



(a) An overview of branch offices, their seat capacity and distances.



(b) Employee behavior



Employee Persona		
Leadership	7%	Prefer work from office
Collaborator	15%	Prefer work from office when others are in office
Virtual vanguards	40%	Prefer work from home
Office enthusiasts	18%	Work from office only if office experience is positive
Panicked junior	20%	Follow others and panicky about compliance

Project Architype	
Critical dependent (e.g., in delivery phase) : [15%]	Entire team needs frequent office visits
Interaction heavy (e.g., large team, design phase) [25%]	Need periodic in person discussions
Infrastructure heavy [10%]	Team members need frequent personal visits
Standard [50%]	No additional requirement

(c) Structural overview of constructed digital twin.

Figure 3: Branch specific details and its digital twin.

Understand: To begin, we conducted interviews with the admin team to gain an understanding of the branch B and its five offices. Figure 3(a) provides a representative view of the offices, including their seat capacities and distances between them. We examined admin and human resource (HR) data (secondary research) to create a virtual representation of the branch. As outlined in Figure 3 (c), the branch is a logical structural unit of the IT company and comprises multiple offices. Each office has employees and various types of infrastructure, such as seats or desks, machines (*e.g.*, printers, water dispensers and coffee machines) and facilities (*e.g.*, meeting room, canteen and laboratory) with varying seating capacities. Based on the work profile, we categorized employees into two broad types: a) *project staff* who are allocated to a project, and b) *support staff* such as admin, IT IS, HR and security personnel.

We reflected on HR data (*i.e.*, secondary research) and interviewed selected employees and support staff (*i.e.*, primary research) to infer employee behaviors that are relevant for this case study. Synthesis of our primary and secondary studies helped us to define employee personas (Nielsen 2004) and different project architypes. Prominent employee personas and project architypes along with their distinguishing characteristics and proportion of that persona/architype are shown in Figure 3(c). Studies also suggested introspecting three behavioral patterns for this case study: a) employee's decision to choose WFO or WFH, b) employee's behaviors and touchpoints within office, and c) employee satisfaction.

We found that the propensity of an employee e to choose a work location from WFO and WFO for a given day X is a is a multi-criteria decision-making (we term it as WLD) involving factors (i.e., f_i), such as employee's role, project situation, office environment, and other factors, as shown in Figure 3(b). Considering our secondary studies and primary studies, including persona-specific customer journeys (Temkin 2010) and service blueprint (Bitner et al. 2008), we formulated $WLD_{<e,X>}$ for employee e for day X as a decision over weighted utility function involving fv_i as shown in equation (1).

$$WLD_{<e,x>} = \begin{cases} WFO & \text{if } \sum fv_i * w_{E,i} > \theta_E \\ WFH & \text{Otherwise} \end{cases} \quad (1)$$

In equation (1), fv_i is employee specific value of factor f_i, $w_{E,i}$ is persona specific affinity for factor f_i and θ_E is persona specific threshold value (derived through secondary research) where employee $e \in$ persona E. The movements of an employee inside the office are predominantly non-deterministic, thus, their interaction, i.e., touchpoints, with different infrastructures and other employees are also non-deterministic, except few certainties, such as an employee occupies a seat when they are in office. Both the frequency and propensity of these touchpoints differ with the individual, time, situations and other factors. However, existing observed data collected from admin was sufficient to define persona specific frequencies ($F_{<E,I>}$) and propensities $P_{<E,I>}$ of these touchpoints, where E and I of tuple <E,I> indicate persona E and touchpoint with office infrastructure I respectively. In the absence of such detailed data, observing frequency and propensity of employees availing canteen facility, coffee machine, water dispenser, printer, etc. is the option that can be considered. In our case we had such data available with the admin team.

The third behavioral pattern, *i.e.*, satisfaction level of an employee (f9 in Figure 3b), is an important factor for deciding preferred work location, WFO or WFH. Understanding satisfaction level of individual and quantifying it are extremely difficult propositions. We attempted to quantify it by considering employee's touchpoint journey as presented by Temkin (2010) in the context of customer journeys and experience scores. Conceptually, employee's satisfaction level is a cumulative value of fading memory of a finite number of touchpoint experiences, where a touchpoint experience is an experience that an employee gains while interacting with various infrastructures, such as availability of seat in the office, seat in canteen for lunch and coffee from vending machine. We score these touchpoints (i.e., SC<e,I>) from +5 to -5 based on four situations: available immediately as needed (+5), partially available when needed (+3), available after certain delay (-1) and not available when needed (-5), where availability of meeting room for a smaller number of team members than requested number is an example of partial availability whereas standing in a queue for availing a facility or machine is an example of availability with delay. We compute experience value $EX_{<e,I>}$ of employee (e) of persona E as equation (2).

$$EX_{<e,I>} = w_{<E,I>} \cdot SC_{<e,I>} \text{, where } e \in E. \quad (2)$$

In equation (2), $EX_{<e,I>}$ is a weighted score, where, persona specific weightage ($w_{<E,I>}$) for a touchpoint with infrastructure I signifies how employee e of persona E perceives an experience i.e., a score (i.e., $SC_{<e,I>}$). Employee satisfaction ES_e of employee e of persona E is a cumulative value of fading touchpoint experience journey. We define an experience journey, Q_N, as a queue with N elements, i.e., it remembers last N experience values $EX_{<e,I>}$, and compute employee satisfaction as equation (3).

$$ES_e = \sum_{i=1}^{N} qi * \beta^{(N-i)} \text{, where } q_i \text{ is the } i^{th} \text{ element of } Q_N \text{ and } \beta \text{ is a fading factor that ranges [0..1]} \quad (3)$$

A complete specification that represents all constituent elements of branch B, along with their heterogeneity (*i.e.*, personas and archetypes) and behaviors, as shown in models 3(b) and 3(c), provides a purposive conceptual model for the digital twin of branch B. We verified the completeness and faithfulness of the constructed conceptual model by presenting it to the HR and admin teams (*i.e.*, conceptual validity). We then translated the conceptual model to an ESL specification and instantiated it using historical admin data of branch B for operational validity. To assess the operational validity, we instantiated the ESL model with data from April 2022, simulated it for 3 months, and compared simulated KPIs, such as daily attendance, seat utilization, and overall employee satisfaction, with recorded 3 months admin data. The validated digital twin is then used for what-if analyses for the rest of our experimentation.

Table 1: Operating conditions and simulation results.

Scenario	Configuration			Simulation Observations					
	Seat	Meeting Room	Canteen Facility	Compliance	Daily WFO %	Seat Utilization	Meeting Room Utilization	Canteen related Satisfaction	Overall Satisfaction
Baseline	10%	~5%	~5%	NA	8.23%	90%	100%	-2.56	0.849
Improving infrastructure (I1)	50%	50%	50%	NA	12.44%	35.60%	26.53%	4.91	4.959
30% Attendance Compliance (I2)	50%	50%	50%	58.54%	20.65%	51.42%	26.68%	3.24	4.353
Weekly one Reminder (I3)	50%	50%	50%	72.86%	25.79%	60.73%	27.25%	2.02	3.924
Close Office 3 (I4)	50%	50%	50%	58.86%	20.72%	68.98%	31.22%	3.2	4.166
Weekly two Reminders (FI5)	50%	50%	50%	76.92%	27.10%	62.21%	27.36%	1.97	3.888
40% Compliance (FI6)	50%	50%	50%	51.80%	24.87%	62.62%	27.47%	2.06	3.936
50% Compliance (FI7)	50%	50%	50%	48.69%	29.13%	70.08%	27.52%	1.23	3.631

Define: We focused our study on a single branch in a city with 5 offices to understand the employee dynamics in terms of touchpoints and satisfaction, as well as their preferences for WFO or WFH with an assumption that the behaviors are broadly similar to employee from the other branches. A comprehensive study combining qualitative service design findings based on HR and admin interactions augmented with quantitative insights from an as-is simulation of the constructed digital twin shows the baseline situation as shown in Table 1. Here, Table 1 has two parts: the first part shows the as-is or hypothetical operating conditions, indicating various infrastructures available for employees. The operating condition of baseline shows an indicative state of July 2022 when offices were operating at 10% seating capacity, 5% meeting room, and 5% canteen facilities. The second part of the table presents the KPI trends indicating the desired or undesired situation. For the baseline scenario, the average office attendance or adoption of WFO was 8%, overall employee satisfaction in the office was close to 0, and the satisfaction index for the canteen was in the negative range, while the utilization of the available seats was 90% (*i.e.*, not fully utilized).

Therefore, the overall findings indicate that the offices can accommodate a higher number of employees, but employees are not willing to come to the office and those who are coming to the office are not satisfied with the available infrastructure. Further studies revealed that a major part of the attendance was from leadership personas. This is an undesired situation from a management perspective. To address this, the management initiated an in-depth analysis to introduce effective employee-friendly policies and guidelines to improve WFO adoption across different personas, the utilization of office infrastructure, and employee satisfaction, *i.e.*, two tangible aspects and one intangible aspect.

Ideate: We conducted ideation workshops (Stickdorn et al. 2018) considering different personas and scenarios to arrive at effective interventions for achieving the key objectives. We first used Service Design methodology to qualitatively evaluate various interventions and subjectively feasible interventions were used for quantitative evaluation using digital twin simulation. The KPIs considered are office attendance or daily WFO %, compliance of WFO mandate, seat utilization, overall employee satisfaction in the office, and the satisfaction index for canteen. Considering the baseline situation, our first logical intervention was to focus on *'Improving infrastructure'* (*i.e.*, I1) by increasing seats, meeting rooms, canteens and other facilities available to employees. As in Table 1, intervention I1 helps to improve daily WFO % but it is still a distance away from the expectation. Further ideation for defining interventions was carried out by focusing on multiple dimensions, such as emotional benefit, psychic costs, and wellbeing impact. Along with several types of interventions, three other types of interventions were explored as shown in Table 1: (a) introduction of compliance policy expecting minimum days of WFO in a month, *i.e.*, *'30% Attendance Compliance'* (I2), (b) sending a reminder to employees about WFO, '*Weekly one Reminder*' (I3) and (c) closing an office for better utilization (I4). Experimentation setup for experimenting these interventions and simulated observations is shown in Table 1. While closing an office was initially considered as an intervention, it was not considered further as it negatively impacts Daily WFO % and the seat utilization is not significant. Moreover, it has practical limitations.

Prototype: We used service design prototyping techniques like roleplaying and the digital twin simulation to evaluate and fine-tune the interventions. For example, we evaluated *'weekly one reminder'* for its influence on compliance, attendance, utilization and satisfaction (Table 1) and found the need for additional reminders, hence fine-tuning to *'weekly two reminders'* (FI5). Similarly, while the intervention of *'30% Compliance'* (I2) showed an improvement from the baseline Daily WFO %, with some impact on utilization and satisfaction, we fine-tuned to find a better balance with *'40% Compliance'* (FI6) and *'50% Compliance'* (FI7), with the former more acceptable (though there was drop in employee satisfaction from baseline).

Implement: We rolled out the interventions in a staggered fashion across the five offices—primarily *'40% Attendance Compliance'* and *'Weekly two reminders'*, along with a few additional interventions not illustrated here, *e.g.*, *pre-ordered meals*, *timing of reminders*, and *clear desk policy nudges*.

Monitor: In this step, HR, admin and management observed the real impact of implementing interventions and recommended a few refinements. For instance, implementation of *'Weekly two reminders'* worked nearly as expected but HR found sending reminders in the morning fetched better results.

5 CONCLUSION

This paper has argued that achieving enterprise resilience is often a wicked problem that requires a transdisciplinary perspective. We explored the strengths and limitations of human-centric qualitative problem-solving methods, which include design thinking and service design, as well as quantitative techniques aided by digital twin and advanced modeling and simulation. Our analysis revealed that the growing complexities of modern enterprises, such as size, dynamism, uncertainty, and emergentism, make these techniques inadequate when used in isolation.

We presented a pragmatic approach that uses digital twin, modelling and simulation, design thinking, and service design techniques in a symbiotic manner to achieve enterprise resilience in the face of uncertainty and dynamism. In this context, we have also shown how qualitative aspects can be comprehended in a quantitative setting and quantitative evidence can be used in conjunction with subjective analysis during the ideation and prioritization processes. To demonstrate the value of our approach, we applied it to an industry-scale contemporary disruption situation of an IT company. The results show that interventions derived from simulation-aided digital twin helped to understand the problem space in a factual manner, while service design helped to focus on multiple improvement areas and explore innovative ideas to overcome the situation including intangible experiential aspects. It also helped decision-makers to break the dilemma of which problems to focus on first and why.

Although constructing the digital twin and repeating ideation steps were initially found to be cost and time-consuming, our approach is effective in the long-term perspective. Making an initial investment in developing effective interventions and implementing them with necessary precautions helps to reduce real experimentation and avoid the irreversible negative effects of implementing ineffective interventions.

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