9-2022

Singapore public sector AI applications emphasizing public engagement: Six examples

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Singapore Public Sector AI Applications Emphasizing Public Engagement: Six Examples

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Full-length working paper, updated as of 27 September 2022

An abridged version of this paper will be published in the forthcoming Management and Business Review journal https://mbrjournal.com/ special issue on "AI for Customer Engagement."[1] Expected special issue publication date: early to mid-2023.

The Singapore Context for Public Sector Applications of AI

In November 2019, Singapore's Smart Nation and Digital Government Office (SNDGO) announced the National AI Strategy with the stated ambition that by 2030, Singapore would be a leader in developing and deploying scalable, impactful artificial intelligence (AI) solutions in key economic and social sectors of high value and relevance, and it would do so in ways that would serve the needs of its citizens and businesesses.[1] It added that the government would embark on an initial set of national AI projects in five domain areas deemed crucial for smart nation efforts. The National AI Office, the coordinating government unit under SNDGO for these efforts, subsequently updated the scope and expanded the portfolio of strategic national AI initiatives to include two additional domain areas, financial services and government services. Figure 1 shows the resulting seven national strategy AI domain areas.[2]

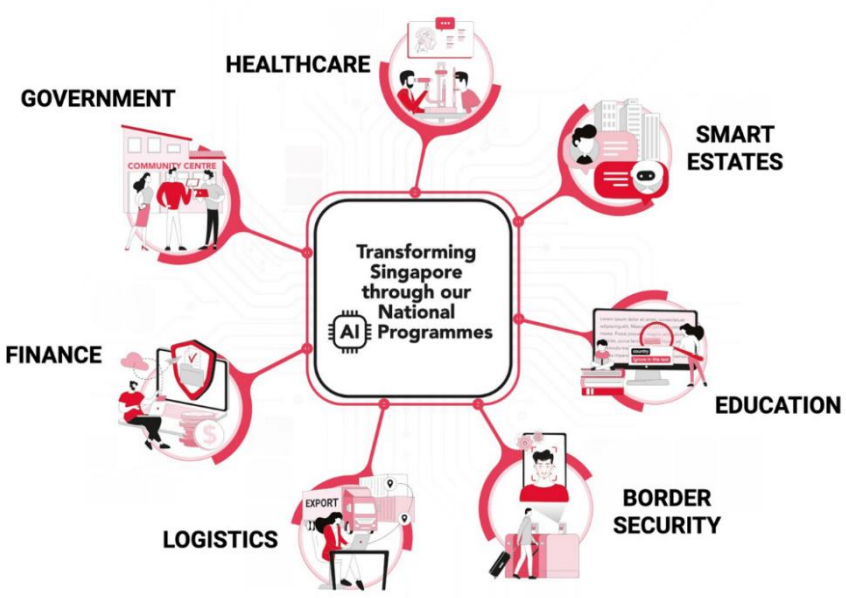

Figure 1. Set of seven domain areas for National AI projects. Source: Smart Nation and Digital Government Office (Singapore).

This article provides an overview of six examples of public sector AI applications in Singapore that illustrate different ways of enhancing engagement with the public. The examples are summarized in Table 1.[3] Four examples (indicated by * in Table 1) are designated by the SNDGO as national AI projects falling under one of the seven domain areas shown in Figure 1.

[1] A special expression of appreciation to Yoram (Jerry) Wind, the Lauder Professor Emeritus and Professor of Marketing at the Wharton School, University of Pennsylvania, for his substantial guidance on shaping and improving this working paper version, as well as the abridged version for publication, in his capacity as lead co-editor of the MBR special issue on AI for Customer Engagement.

The other two examples in Table 1 are also aligned with the overall government strategy for public sector AI efforts; they are important to include because they illustrate that many other public sector AI efforts are underway besides the much smaller subset of efforts specifically designated as national AI projects.

Example	Public Sector Settings as per Figure 1	AI Application	Impacts on Public Engagement
1	Government, Everyday Services	Managing Crowd Levels at Parks, Especially During COVID-19	• Elimination of tedious crowd counting by National Park staff frees up staff time for other park work and public engagement. • Web portal provides visibility of park crowd conditions to the public for self-management.
2*		Job Search and Matching in Support of Future Economy Transformation	• Reduced mis-matches and missed matches for both local job seekers and potential employers based on more contextualized local labor market information and data. • Expanded range of recommendations ("adjacent" job options, upskilling courses) to broaden range of new career possibilities.
3		Mass Transit Urban Rail System Management with a Customer-Centric Monitoring Approach	• Faster and better means of responding to service disruptions and crowded commuter conditions across entire urban rail network.
4*	Smart Estates, Seamless and Efficient Municipal Services	Municipal Services Office and the OneService Chabot	• Easier to submit complaint reports on municipal issues via a new chatbot system with a more flexible interface and more intelligent back-end processing capabilities.
5*	Education, K – 12	Adaptive Learning and Assessment for Personalized Public-School Education	• AI systems that provide greater personalization of learning for each student in selected subject areas. • Teacher's time can shift towards more customized and targeted engagement with both individual students and groups.
6*	Border Security	Contactless ("Breeze-Through") Immigration Clearance at Border Control Checkpoints	• Less waiting time for travelers at immigration checkpoints; less physical contact with documents or equipment for both travelers and checkpoint staff. • More consistent, evidence-based approach underlying which travelers are subjected to special screening.

(*) Applications designated as National AI projects falling under one of the seven National AI domain areas shown in Figure 1.

Table 1: Summary of the six Singapore public sector AI examples described in this article.

These applications demonstrate ways of enhancing engagement with the public by providing greater accessibility to government services (access anywhere, anytime) and speedier responses to public processes and feedback. Some applications make it substantially easier for members of the public to do things or make choices (examples 1, 2 and 4), while others reduce waiting time, either across an entire public infrastructure (example 3), or for an individual transaction (example 6). Some provide highly individualized coaching to guide a person through the process of doing or mastering complex tasks (examples 2 and 5).

Following the description of these six examples, this article provides a synthesis of key learning points, observations on building the capacity to be a city-scale lab for AI deployments, and a summary of important leadership factors.

Example 1: Managing Park Visitors

AI Application	Impacts on Public Engagement
Managing Crowd Levels at Parks, Especially During COVID-19	• Elimination of tedious crowd counting by National Park staff frees up staff time for other park work and public engagement. • Web portal provides visibility of park crowd conditions to the public for self-management.

Singapore's National Parks Board, known as NParks, oversees the various parks, gardens and nature reserves and strives to make Singapore "a city in nature."[4] Providing and maintaining park access is an important public service that is especially appreciated in a small city-state with a high population density.

In early 2020, restrictions related to COVID-19 safe management measures drove more people to outdoor park areas, and this sudden surge caused operational issues for NParks staff. They had to be diverted from their regular work to support manual crowd counting as well as safe distance patrolling and enforcement in the more than 500 green spaces they managed. The challenge was to quickly create a solution that would not only help NParks manage this situation, but also enable the public to self-manage their own choices of which park to visit and when in a more informed way.

An AI-enabled system called Safe Distance @ Parks was created and deployed using input from multiple video streams and relevant car park occupancy data to determine near real-time crowd sizes at green spaces across Singapore (Figure 2).[5] However, there were challenges. Not all the video cameras already installed at park sites could live stream back to a central cloud platform for analysis. Also, there was insufficient video coverage to meet the operational needs of this new system. NParks and the Government Technology Agency of Singapore (GovTech, their government technology partner) prioritized the more popular park sites where they addressed these problems.

A small-scale, end-to-end deployment with just five video cameras was completed within only two weeks, building on the foundations of GovTech's various ongoing project efforts and existing platforms. This enabled the GovTech team to rapidly verify their methods for transmitting all image and other data back to a central cloud platform for analysis, their choice of models to achieve the necessary accuracy levels for people counting, and methods for

people counting updates. Additionally, the rapid prototype enabled them to specify all necessary protocols and application programming interfaces (APIs), and to work out the integration with the Safe Distance @ Parks website and mobile app that would be used by both NParks staff and the public.[6] The first version of the public website was launched a week after the technical demonstration, and then progressively refined. Once all the technical issues were worked out, GovTech and NParks spent the next eight months scaling the solution to more park sites as well as making refinements.

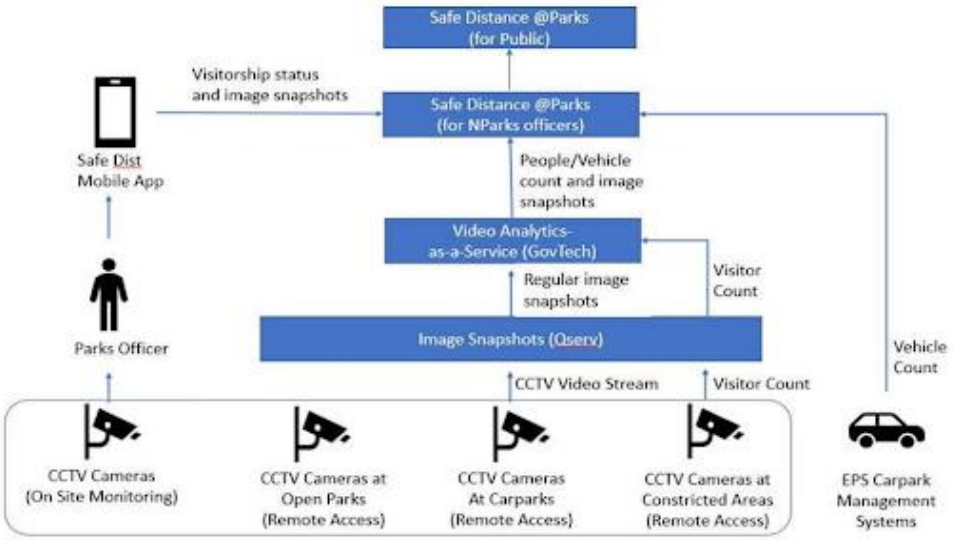

Figure 2. Safe Distancing @ Parks solution architecture overview. Source: GovTech (Singapore).

Drones and mobile robots were sometimes trialed and, when used, their inputs were integrated into the system to enable officers to get a better sense of density of visitors in specific areas for more targeted safe distancing efforts. In a few park locations, especially during periods of heightened COVID-19 concern, Spot, the robotic dog,[7,8] was used to broadcast a recorded message reminding visitors to observe safe distancing measures. The robotic dog was also fitted with cameras – enabled with GovTech-developed video analytics – to estimate the number of visitors it encountered. To allay privacy concerns and build public acceptance, the cameras and image analysis did not track or recognize specific individuals and no personal data was collected. NParks and GovTech continue to test how to refine the “behavior” of the robotic dog to further improve the nuances of engagement between the machine and humans in park settings and to achieve wider public acceptance of this approach.[9]

Figure 3: Field trial of Spot, the robotic dog, supporting enforcement of social distancing in a Singapore park during the early days of Covid-19. Source: Photo by Roslan Rahman/AFP via Getty images from a Los Angeles Times story.

NParks made the Safe Distance @ Parks application accessible to the public and created a convenient way for anyone heading out to a park to view in advance the crowd levels at that particular green space.[10] People could then make their own self-assessment as to where and when to go. Further ongoing enhancements to the public website include real-time crowd heat maps for each public park, seasonal crowd data, and inclusion of other public leisure and recreational spaces.

During the period of the most stringent COVID-related movement restrictions in 2020, monthly traffic to the Safe Distance @ Parks online application peaked at 620,000 visits per month. Towards the end of 2021, this had stabilized at around 400,000 visits per month. The Safe Distancing @ Parks application had eliminated the need for park staff to do manual people counting, which enabled a reduction in manpower specifically deployed for safe distancing measures in parks by two-thirds amidst acute manpower constraints during the pandemic. Overall, NParks management noted this AI-enabled technology support allowed for a more efficient allocation of resources and manpower in safe distancing efforts as well as for their other park and greenery management work. Based on these results, NParks is further pursuing partnerships with universities, research institutes, and industry partners to develop sensors, equipment and applications to support their specific needs.

Another benefit is that the people-counting solution developed and refined for Safe Distance @ Parks has become part of a suite of image and video analytics products provided by GovTech's Whole of Government (WOG) Video Analytics System (VAS) platform. This is a centralized and scalable cloud-based video analytics platform that addresses different government video analytics use cases.[11]

Example 2: Job Search

AI Application	Impacts on Public Engagement
Job Search and Matching in Support of Future Economy Transformation	• Reduced mis-matches and missed matches for both local job seekers and potential employers based on more contextualized local labor market information and data. • Expanded range of recommendations ("adjacent" job options, upskilling courses) to broaden range of new career possibilities.

Even prior to the outbreak of COVID-19, the Singapore government encouraged and supported working adults to upskill and reskill in response to technology changes, digital transformation, and ongoing industry transformation.[12] All segments of the population were encouraged to adopt the mindset and habits of lifelong learning.[13] Concurrently, and in a coordinated manner, the government, through Workforce Singapore (the former Workforce Development Agency under the Ministry of Manpower) launched the MyCareersFuture job portal for all citizens and permanent residents who were actively searching for jobs, and who wanted to review existing career directions and explore new job opportunities. This was also to help citizens and permanent residents who had been retrenched to find jobs, as well as to help those already employed to find better opportunities or better ways of making use of new skills they acquired.[14]

Anybody searching for a job in Singapore can use any available job search portal that lists local job openings, and the MyCareersFuture portal does not attempt to compete with the many other widely available job search related web-based search options. Rather, it focuses on providing an additional job search platform highly contextualized to Singapore's labor market in the following ways: i) only Singapore citizens and permanent residents can make use of the platform's job search services to apply for a job, though any person living in Singapore can use it to search for jobs, ii) it can identify and filter for jobs that are eligible for various government job support schemes, and iii) it has local labor market knowledge of "job roles that need more applicants" (vacancies that employers are actively seeking to fill and for which there is strong demand for the specified skills and talents) vs "job roles with many applications" (job postings already receiving high numbers of applications where the job seeker faces a great deal of competition). In short, the MyCareersFuture portal is a self-help online platform to facilitate employment of local job seekers by local employers.[15]

The initial version of the job portal launched in April 2018 used machine learning and other AI methods to prioritize search results according to the relevance of a jobseeker's skills for a particular job. AI methods were used to assess the relevance of a jobseeker's skills for a particular job opening displayed as a percentage match score from zero to 100 derived from analysis of job descriptions, identification of the skills needed, and comparison to the profile of the job seeker. In addition, it filtered results to show jobs with government training support schemes.[16]

A year later, the MyCareersFuture system was enhanced to help employers better engage with the portal and save time in identifying potential suitable candidates by making it much easier for employers to sort and list applicants, as well as to preview applicants.[17] Machine learning enhancements were used to recommend potential job candidates to consider, including those meeting the requirements but applying to jobs in other areas.

With the economic upheaval caused by COVID-19, the active job postings on the MyCareersFuture portal nearly doubled from about 87,000 in November 2020 to about 150,000 in October 2021, and then subsided to about 130,000 in the ensuring months. In this same period, the portal received over 560,000 job applications. This triggered a pressing need to improve the portal's capabilities. A key part of this improvement was the creation and deployment of a new AI job matching platform called JumpStart (Figure 4).[18] Designed and deployed by GovTech in partnership with Workforce Singapore, JumpStart realized the following four key capability improvements for the MyCareersFuture jobs portal:

First, a more flexible, microservices-based architectural approach. JumpStart was designed as a stand-alone, cloud-based centralized job search and matching platform that could easily link to MyCareersFuture through microservices. This architectural approach also made it easy to re-use Jumpstart for other government applications that required a job search and matching engine. Applying the microservices architectural approach to the entire job portal also made it easier to additionally include relevant functionality from commercial AI vendors and integrate that functionality with JumpStart capabilities as needed as part of the overall solution.

Second, better methods for filtering, matching, and recommending. With the prior version of MyCareersFuture, a search query by a job applicant could return up to 1,000 possibilities. Likewise, employers, too, received an excessive number of resumes in response to their queries about suitable applicants. Even though the earlier version of the portal used AI for filtering and matching, a more fine-grained approach was required. The JumpStart engine provided the jobs portal with improved capability to match searched words with more closely related as well as more relevant terminology, resulting in improved job-matching recommendations for both job seekers and employers using the portal.

The design was further improved by i) incorporating considerations of job openings that are highly or overly subscribed, ii) more fine-grained identification of relevant "adjacent occupations" that the person had not applied to that had a strong match to the applicant's skill set and experience, and iii) more explicit consideration of local labor market occupations and industries with forecasted good growth prospects. JumpStart also provided targeted suggestions for locally available continuing education courses to assist those with limited options due to their current skill profile.

Third, more explicit consideration of the job seeker's preferences in the context of the local labor market. Beyond using explicit signals from job seekers based on facts contained within their resume and profile, the JumpStart engine also analyzes a job seeker's "implicit signals" such as analysis of past job searches on the portal, job views, job applications, responses to prior recommendations per what was viewed or not viewed, and job opportunities they did or did not apply to. Some of the models that JumpStart has developed with this data include a:

i. Skills-Matching Model: Content-based filtering model which looks at the similarity between the jobseeker's skills and the skills required for the posting.
ii. Views-based Model: Collaborative filtering model which uses Singular Value Decomposition on jobseekers' previous views.
iii. Application-based Model: Collaborative filtering model built on a jobseekers' previous applications which identifies potential jobs based on users like them.

Because JumpStart's machine learning algorithms are trained on local data from the MyCareersFuture portal, job search related terminology, classifications and recommendations

reflect local labor market preferences, conditions and trends. Of course, the algorithms of other widely available job search portals have the advantage of being trained on much larger datasets based on a much wider global audience. While these other internationally used job portals contain local labor market job listings, they do not provide the ability for local Singapore residents to filter for listed job openings that are eligible for Workforce Singapore government support programs, or to easily link to SkillsFuture Singapore listings of relevant locally available training courses with government tuition subsidies that could help the job searching candidate achieve a stronger match with the desired job. Nor do they use government information on local labor market conditions and trends as part of their recommendations.

Fourth, better support for using multiple types of data science models in parallel. JumpStart's job recommendations are generated using a hybrid approach where multiple models (including the three mentioned above) are built and then mixed to work with one another to generate the eventual recommendations for the user.[19] The GovTech team did not want to build bespoke deployment solutions for each data science model. By integrating with the MyCareersFuture portal through a microservice architecture, the JumpStart team was able to substantially experiment with different ways of setting up a hybrid model and evaluating its performance without having to build and integrate bespoke deployments for each successive model change. In support of evaluating different mixed model approaches, the JumpStart team designed the architecture with A/B testing in mind from the onset: new models can easily be deployed, monitored, evaluated and taken down or further refined without requiring action from the development team responsible for the everyday support and enhancement of the MyCareersFuture portal.

An overview of the JumpStart Platform is shown below in Figure 4. Key functionality for data ingestion and for data processing and modelling is shown, along with a listing of the key microservices-based AI products used by the MyCareersFuture jobs portal as well as by several other government applications targeted for Singapore residents and for government employees. Future components that will provide improved functionality for talent recommendation and for AI governance are also noted.

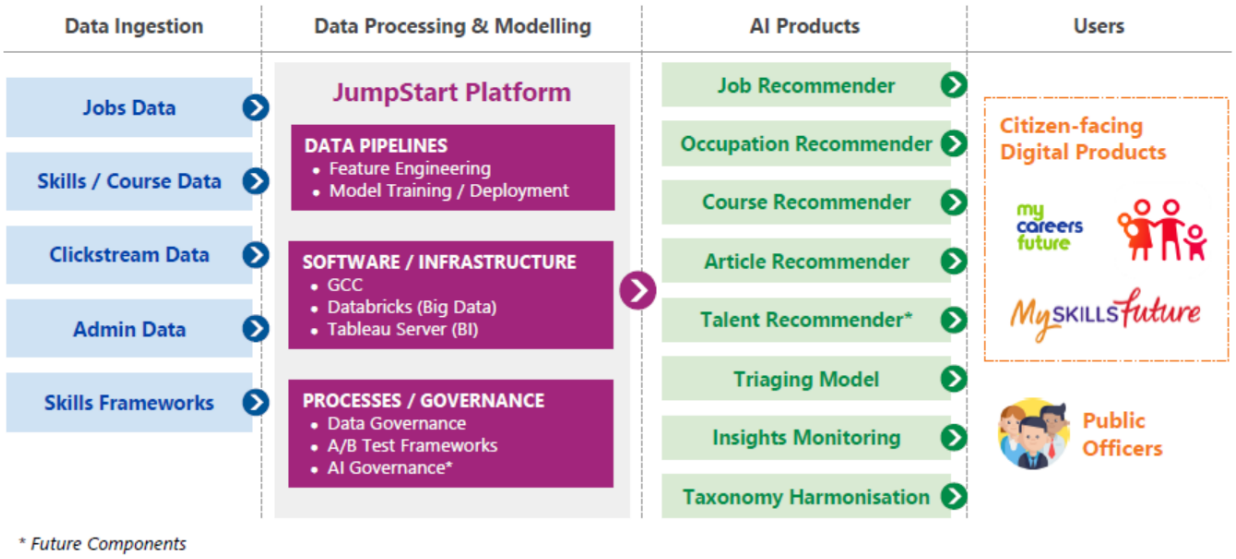

Figure 4: Overview of the AI-enabled JumpStart platform used by the MyCareersFuture job portal as well as by other government applications requiring job matching-related recommendations. Source: GovTech (Singapore).

The MyCareersFuture portal clickthrough rate doubled from 4-5% to 10-12% after deploying the JumpStart recommendation engine for search and matching. Seven months after JumpStart's launch, more than 5000 job seekers had successfully secured jobs through Jumpstart-enabled "Recommended Jobs" feature of the portal.

Example 3: Urban Rail Transit

AI Application	Impacts on Public Engagement
Mass Transit Urban Rail System Management with a Customer-Centric Monitoring Approach	• Faster and better means of responding to service disruptions and crowded commuter conditions across entire urban rail network.

One would expect a state-of-the-art urban mass transit system to make extensive use of sensors for data collection to monitor operations and gather the data needed for AI models to predict impending disturbances. Singapore's Land Transit Authority (LTA) does all of this for the country's urban rail system. However, it wanted to supplement these capabilities with additional measures to improve customer experience through a commuter-centric approach to Internet-of-Things (IoT) sensing, situation assessment, and incident response planning.[20]

Prior to the deployment of the AI-based Fusion AnalyticS for public Transport Event Response (FASTER) system in mid-2018, the rail network monitoring and operations teams monitored engineering parameters such as the various rail signals and fault detection signals, as well as data on alignment to schedules, to determine the current and predicted state of the rail network system. These inputs did not provide a direct measurement of the commuting experience from the passenger perspective. To additionally monitor and therefore manage commuter-centric measures—such as the number of times a passenger on the platform could not board an arriving train because it was too packed, the crowd size on the train platform and in the trains, and the duration of delays faced by the commuters—the FASTER system was developed and deployed.

FASTER is an AI-enabled data fusion platform that mines a variety of IoT sensor sources (e.g., video streams, WiFi and cellular signals, farecard data, train engineering and flow data, and taxi and other transport system data) for early warning of potential rail anomalies in real-time (Figure 5). The system provides round-the-clock visibility across the entire urban rail network, detecting unusual network events and providing automatic alerts based on predictions of impending disturbances derived from trends of various commuter-centric and engineering measures moving outside of normal ranges.

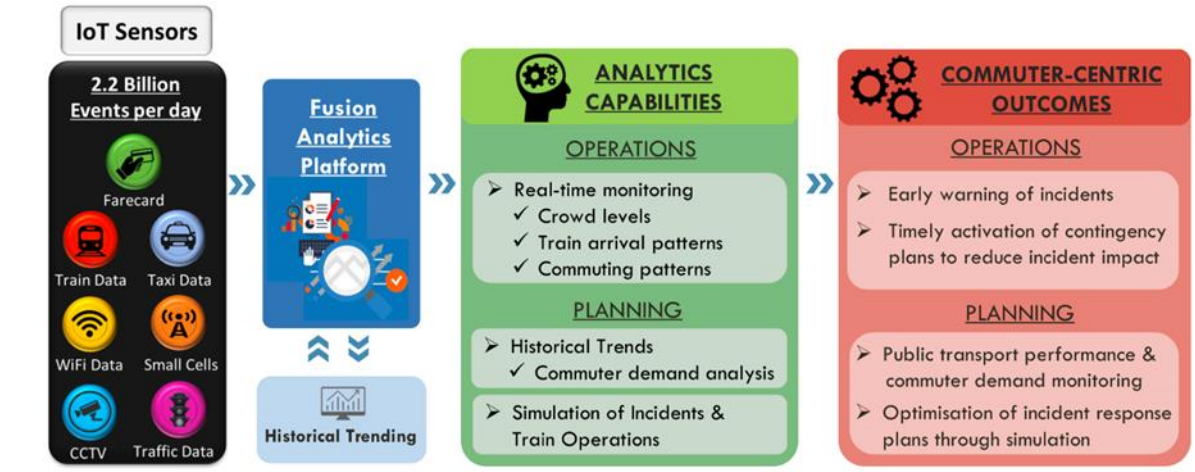

Figure 5: Summary of the FASTER system for predicting and responding to urban rail system disturbances and crowded commuter conditions. Source: Land Transport Authority of Singapore.

Once a disturbance is predicted to occur and while it occurs, FASTER provides rail operations staff with enhanced real-time visibility at the micro and macro levels, including the ability to see how the impacts are propagating to other rail stations on the network and to assess the impact system-wide. This visibility, combined with supporting real-time simulation abilities, enables the staff to make more informed decisions. FASTER also helps staff to quickly assess the impacts of alternative options, such as injecting additional trains to handle passenger backlogs, or in more severe incidents, deploying special bus services to transport stranded passengers to unaffected rail stations.

Additionally, FASTER's outcomes are fed into a broader LTA Command, Control and Communication (C3) system that draws status information and predictive insights across other land transport domains, such as roads and buses, for a comprehensive view of the land transport network to coordinate effective and quicker responses to large-scale disturbances.

When FASTER was initially deployed in mid-2018, alerts on service degradations predicted about 40% of impending incidents. With accumulated operating experience, continuous tuning and enhancements, the ability to predict an impending incident increased to 80% by end-2019 and approached 90% by the end of 2021. This predictive ability enables rail operations staff to respond to most flow disturbances pre-emptively, usually a few minutes or more in advance. Another benefit of the FASTER system is the extent to which it has increased the productive capacity of the rail operations monitoring team. At the end of 2021, the same size team of four monitoring officers per shift were managing double the number of stations compared to 2012. FASTER has clearly made the rail operations monitoring and response team more agile, productive, and efficient.

Example 4: Municipal Services

AI Application	Impacts on Public Engagement
Municipal Services Office and the OneService Chabot	• Easier to submit complaint reports on municipal issues via a new chatbot system with a more flexible interface and more intelligent back-end processing capabilities.

Although Singapore is a small city-state, a decade ago it was often a frustrating challenge for residents to identify the proper public agency to “complain to” about an everyday municipal or neighborhood issue as this depended on knowledge of internal government administrative technicalities. Moreover, sometimes multiple agencies needed to be involved, even for seemingly simple things.

In 2014, an infamous incident of a fishball stick discarded on a walkway highlighted the difficulties the public faced. People expected to report the litter and have the matter quickly resolved, but it turned out that the National Environment Agency was responsible for the slope on one side of the walkway, the National Parks Board managed the park connector in the middle, and the Land Transport Authority was in charge of the pavement on the other side. How would a member of the public know which agency to contact in order to resolve the problem? And, behind the scenes, the agencies would bicker over which of them should take the lead role for responding to and fixing the problem.

In August 2014, the Prime Minister referred to the fishball stick incident in his National Day Speech as he announced the rationale for creating a new public agency called the Municipal Services Office (MSO), focused entirely on improving the government's overall coordination and delivery of municipal and neighborhood services.[21] In October 2014, the MSO started operating. Its call center hotline became the one-stop-shop for the public to call to report municipal and neighborhood problems. Once a problem was reported, MSO staff would figure out which government agency was responsible, liaise with that agency, and handle coordination across multiple agencies as necessary. Currently, 10 public agencies and 17 neighborhood town councils closely partner with the MSO to respond to public requests and complaints pertaining to municipal services.

MSO’s OneService mobile app was launched in 2015. Described as a one-stop “all things neighborhood" community platform, residents used the app to provide feedback on municipal issues, find out more about their neighborhood, and access Government and Town Council e-services. In recent times, the call center option for contacting MSO has been eliminated, which made the app the only way to submit a case to MSO until the arrival of the new chatbot described below.

While the OneService app continues to be widely used,[22] it was limiting public engagement with the MSO in two ways. First, feedback sessions showed that there were people who just did not want to download and use the specialized OneService app; they wanted to report problems using either the WhatsApp or Telegram messaging apps instead. Second, the user experience could be cumbersome when submitting a case report through the OneService app. This was especially so if the person submitting an issue or complaint did not understand the app’s pre-defined categories, or if the submission did not cleanly fall into one of the pre-defined categories, or a complaint involved more than one issue.

The hundreds of thousands of cases that had been submitted to the OneService app since its introduction in 2015 had given the MSO a large dataset of the types of problems encountered and the related knowledge of which agencies were involved in the follow-up and which particular agency played the lead role in each type of case. This accumulated data and knowledge made it possible to embark on a major effort to use AI to improve public engagement with the MSO.

In July 2021, the OneService Chatbot, named Kaki (the local Singlish and Malay expression for "buddy" or "companion"), was released (Figure 6).[23] During real-time, live chat sessions, the chatbot can automatically identify the nature of the complaint and classify it into the appropriate category (e.g., litter, illegal parking, broken toilet, dead animal, etc.). It can also extract the relevant details of the incident needed to automatically generate the case report, as it has knowledge of the types of attributes needed to describe different categories of problems. If the chatbot is unable to fill in one of the needed attributes based on the user's inputs, it will prompt the user for the required input. Also, if the chatbot is uncertain about a required attribute, it will ask questions to resolve its uncertainty. Therefore, users are not required to classify their feedback into predetermined categories as is required when complaints are submitted using the OneService app. Also, users who are unable to fit or match their feedback into one of the existing OneService app reporting categories can use the new chatbot to make a report because it has a more flexible and intelligent interface.

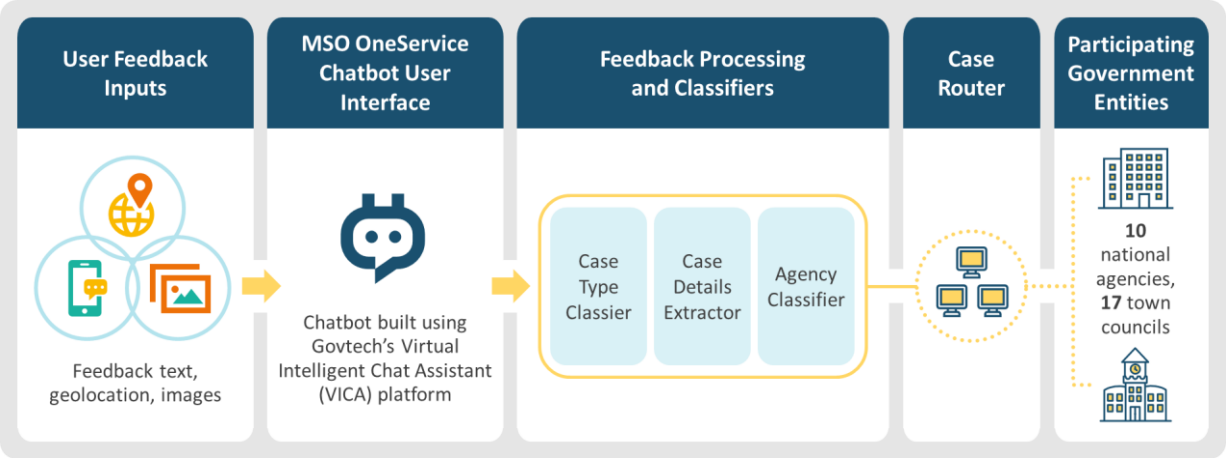

Figure 6: Overview of the OneService chatbot system used by the Municipal Services Office to solicit and process municipal-related feedback and complaints from residents. Source: GovTech (Singapore).

After the chat session is concluded, and there is additional time available for computational post processing, the supporting back-end system identifies the appropriate government agency to receive the case report. For this, the system uses everything it has derived from the text-based chat input as well as inferences made from the photo and/or video input provided by the submitter. This step of processing the accompanying visual media is done afterwards so as not to interfere with the fast real-time responses needed for live chat sessions.

An important capability of the chatbot system is being able to recognize the nature of the feedback or complaint based on a user's chat description, and then use that recognition as a means of determining which agency to route the complaint to. The GovTech solution design team structured this as an AI text classification problem where the chatbot dialogue about the complaint was the text to be classified and the prediction of which agency should receive the complaint was treated as the class label for the text. The design team used a lightweight version of the transformer-based BERT method for their natural language processing as the "ALBERT" light-weight version achieved better results with less memory consumption and run-time.

As BERT and other large-large transformer-based models are pre-trained on standard English language text corpuses like Wikipedia, the design team needed additional iterations of fine-tuning training to familiarize the chatbot with common colloquial Singapore expressions. Prior to

the MSO chatbot project, the GovTech team was already in the process of building a chatbot interface and platform with more general capabilities to route other types of questions arising from residents in their interactions across various government websites to appropriate government agencies. This ongoing effort was used as a foundation to create the new MSO chatbot for the Municipal Services Office to handle resident complaints and feedback via OneService app.[24]

When the Kaki chatbot was introduced in July 2021, the initial accuracy rates were: for categorizing the problem (80%), for auto-generating the problem report with all required attributes (85%), and for assigning the appropriate government agency to handle the feedback report (85%). While the accuracy rates remained about the same over the next year of usage, the chatbot has been able to scale in two important ways — it can handle many more types of complaint cases as well as a much larger number of users — without degradations in accuracy rates.

The more intelligent chatbot interface results in a more complete complaint report submission (in conjunction with the geo-location information, image and video information analyzed during post-processing). Because of this, more than 90% of cases received by the chatbot can be automatically routed to the appropriate agency without manual intervention. Overall, complaint cases submitted via the new chatbot interface require substantially less manual effort and staff time compared to submissions made via the mobile app because of reduced needs to do post-submission follow ups for clarifications and missing information, and the automated ability to triage and route the submissions. Over time, these types of AI enabled efficiency improvements will be incorporated into the OneService mobile phone app interface and its related back-end processing of complaint reports.

Nine months after deployment, the chatbot was handling over 300 user sessions per day, and over 4,000 unique users had made use of this new channel. Even though these usage numbers are not yet large, they are viewed by MSO and GovTech as an important demonstration of the ability to provide residents who have different user interface needs and preferences with an appropriate type of platform for providing municipal feedback. It was also viewed as a successful demonstration of building on and adapting GovTech's Virtual Intelligent Chat Assistant (VICA) platform for providing a higher capability and more standardized starting point for all of the different chatbot projects across the government.[25,26]

Interestingly, even with the introduction of the chatbot, the number of registrations and active users for the OneService mobile phone app has continued to increase steadily from its user base of 350,000 people as of mid-2021.[27] Some people still prefer the more structured report format of the mobile phone app. In addition, MSO has been progressively adding additional resident-centric features to the app so that it has become much more than a complaint reporting tool. For example, residents can use the mobile phone app to participate in surveys about local municipal issues as a means of co-creating a better living environment, to book community spaces, and to find and pay for car parking.

Example 5: Personalized Public-School Education

AI Application	Impacts on Public Engagement
Adaptive Learning and Assessment for Personalized Public-School Education	• AI systems that provide greater personalization of learning for each student in selected subject areas. • Teacher's time can shift towards more customized and targeted engagement with both individual students and groups.

Using AI to provide personalized education through adaptive learning and assessment for primary and secondary level public school students was one of the projects highlighted in Singapore's National AI Strategy. The objective is to help all students, including those making slower progress, to proceed at their own pace so they may learn more effectively, and also to support the teacher's ability to meet the personalized learning needs of each student.

Two types of AI-enabled solutions are the starting points for pursuing this ambitious long-term goal. One is an Adaptive Learning System for teaching mathematics, which uses machine learning to make recommendations on problem solving and error response that are customized for each student, based on how the student responds to learning materials and activities. By analyzing the student's responses to the system's learning content and questions, it makes inferences on how well the student has mastered a concept. The AI engine will then make recommendations on the content and assessment items that the student is ready to learn next. The other solution is a Learning Feedback Assistant for English Language writing which would provide feedback to students on their grammar, sentence structure and language errors. These AI systems will be delivered through the Ministry of Education's (MOE) Singapore Student Learning Space, the national online learning platform for grades 1 through 12.[28]

MOE is introducing the AI Adaptive Learning System for primary and lower secondary school mathematics in a progressive and systematic manner by starting pilot trials with a few schools in 2022.[29] MOE had previously shared in 2020 on the experiences of two secondary schools in an early small-scale trial of commercial off-the-shelf adaptive learning systems with some of their mathematics classes.[30] Some teachers noted that they were able to use student performance and information from the adaptive learning system to encourage and facilitate peer teaching and learning. Teachers could also identify those students who were struggling the most and offer them more of their attention and guidance. Another teacher noted that some students responded to the different learning stages as if they were levels of a game, and this motivated them to keep climbing upward to the next "game level." Such students appeared to enjoy this game approach regardless of their level of math skill.

As for the AI-Learning Feedback Assistant for English Language, in August 2021, MOE released a procurement tender call for the development, piloting, and implementation of an AI system to provide feedback on English Language writing. The system, targeted to be deployed in 2023, will provide personalized feedback to improve the basic aspects of a student's English language writing skills by correcting the grammar, sentence structure and expression.[31] An MOE official also noted that it would consider rolling out similar systems for other languages at a later stage.

In November 2021, MOE received a question in parliament inquiring whether the use of this type of automated AI solution could routinize a student's approach to English language writing

and undermine students' potential to write (and implicitly, think) in ways that exhibit creativity, cadence, personality, and flair.[32] MOE responded that its use of educational technology, including this AI application, is a means of complementing and not diluting the central role of the teacher in guiding students to learn and master different subjects, especially the higher-level skills. It added that by relieving teachers from having to spend time checking and correcting basic elements of English language writing, they would be able to better engage with students on more complex aspects of language construction and on developing higher-level writing skills like creative expression, persuasiveness, and tone.

Example 6: Border Checkpoints

AI Application	Impacts on Public Engagement
Contactless ("Breeze-Through") Immigration Clearance at Border Control Checkpoints	• Less waiting time for travelers at immigration checkpoints; less physical contact with documents or equipment for both travelers and checkpoint staff. • More consistent, evidence-based approach underlying which travelers are subjected to special screening.

Singapore is deliberate about not only maintaining but always improving its image as a welcoming and safe destination for both tourists and businesses. The challenge is to provide an ever faster and hassle-free immigration clearance experience for all inbound and outbound travelers without compromising border security. Towards these twin objectives, AI support for border security and border crossing management is one of the designated national AI projects; the 2019 National AI Strategy states, "We aim to deploy AI to achieve 100% automated immigration clearance for all travelers, including first-time social visitors. Singaporeans and departing visitors will experience 'Breeze-Through' immigration clearance, without the need to present their passports."

Contactless immigration clearance using AI methods to analyze iris and facial scans to verify a traveler's identify is currently in use at Singapore's land border checkpoints and at the airport (Figure 7). Based on verified identify, linkages to backend systems can verify passport status and other border checkpoint relevant information. Many other countries perform facial matching using the facial biometrics within the chip in the traveler's passport. Singapore chooses instead to use their own backend databases for biometric matching as it is more secure and not subject to the possibility of a 'forged' passport with supporting biometrics.

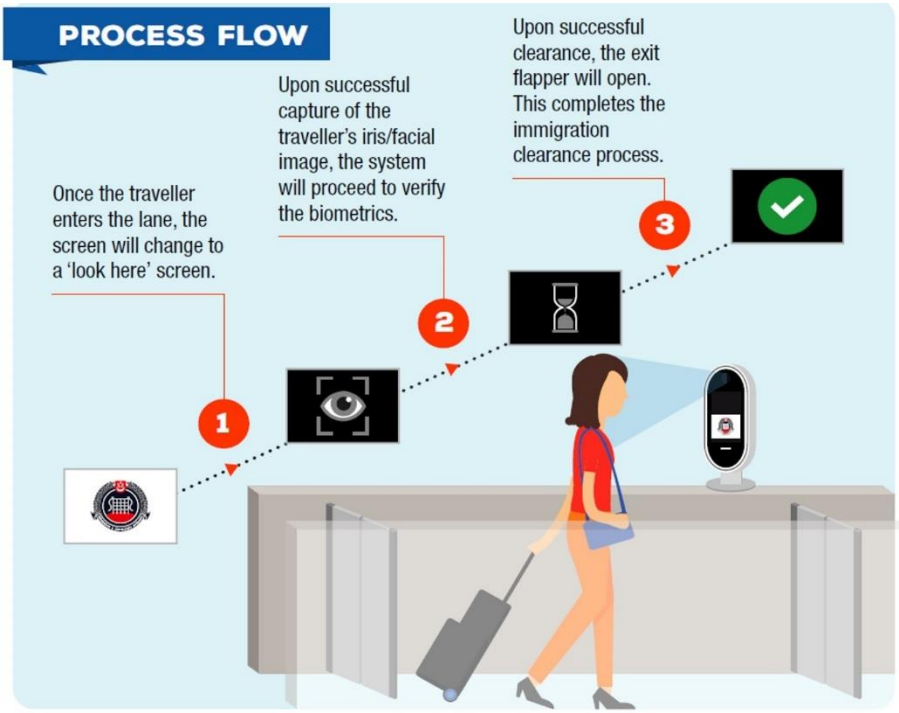

Figure 7: Contactless "Breeze-Through" immigration clearance at border checkpoints based on iris and facial scans. Source: Immigration & Checkpoints Authority of Singapore.

A big challenge inherent in this type of effort is capturing the necessary iris and facial scan data. The Immigration & Checkpoints Authority (ICA), an agency under the Ministry of Home Affairs, started enrolling the iris and facial images of Singapore citizens and permanent residents in January 2017 as part of the process of issuing, renewing or updating passports or national identity cards. Additionally, Singapore citizens, permanent residents, long-term pass holders, as well as international travelers on ICA's Frequent Traveler Program who have enrolled their iris and facial biometrics are eligible for the new Breeze-Through clearance.[33] First-time foreign visitors to Singapore can also make use of the Breeze-Through option if they enroll their entire set of biometrics on-site at the border crossing point. If, for any reason, the iris and facial scan is unsuccessful, travelers are prompted to scan their fingerprint as a backup.

Breeze-Through clearance also makes it possible to handle the growing volume of travelers passing through the various border checkpoints. This has been especially helpful as border crossing volumes rapidly increased from suppressed levels after the roll-back of many COVID-19 travel restrictions. By using AI-enabled technology to reduce the amount of time immigration officers spend on routine low-value tasks, it allows officers to spend more time on higher value tasks such as analytics driven sense-making and following up with travelers of "special interest" as indicated by ICA databases with information on international or domestic watch lists.

State-of-the-practice methods for iris and face detection are created through a combination of vendor procurement and internal development by the Home Team Science and Technology Agency (HTX), the technology agency dedicated to supporting the needs of the Ministry of Home Affairs and all its various agencies. Within HTX, staff from the Immigration & Checkpoints Program Management Center and the Biometrics & Profiling Center of Expertise[34] work together to create, deploy and continuously enhance contactless border checkpoint solutions and other supporting behind-the-scenes technology for border checkpoint security.

Moving forward, HTX's Biometrics & Profiling Center of Expertise is looking to improve the detection of suspicious travelers by automating the analysis of behaviors and physiological reactions exhibited by people who may be harboring malicious intent and translating these tech-enabled Tell-Tale Indicators (TTI) into prediction algorithms to identify and highlight such abnormal behaviors. TTIs are markers usually associated with a person's observable behavioral and physiological non-verbal cues; more obvious examples include fidgeting or excessive sweating. The development of an automated TTI detector is expected to increase the level of consistency and objectivity in profiling at border checkpoints and in associated decisions related to which travelers should be questioned in more intensive ways.

In terms of public engagement, travelers using Breeze-Through now have a contactless way to provide their biometrics for verifying identity. Eliminating the need to verify fingerprints or to handle passport speeds up the border checkpoint clearance process for both the traveler and the immigration officer. Faster processing time reduces overall waiting queue time for all travelers passing through the border control checkpoint. Using the various types of behind-the-scenes AI systems for screening and profiling, the immigration officers receive augmented guidance on which very small subset of inbound and outbound travelers are candidates for additional security questioning and more intensive "engagement."

Key Learning Points

Based on these six examples and informed by additional background information on the Singapore government's digital and AI journey[35], key learning points are as follows:

a. **Three important dimensions of engagement for interaction with the public are accessibility, responsiveness, and personalization.** The six examples presented here demonstrate the ability to improve public sector engagement across all three dimensions. Of course, accessibility on a 24/7 basis or through multiple channels can be provided through regular digital technologies, AI enablement of these channels provides the ability for more intelligent retrieval, processing, and evaluation of large amounts of data from various sources, and also supports or sometimes even automates the triaging of complex problems. This results in more responsive and personalized interactions with the government's "customers" through more accessible channels. Another aspect of personalization is the AI system's ability to share relevant information with the user so members of the public can make their own informed choices (e.g., as is done with Safe Distancing @ Parks, and JumpStart/MyCareersFuture).

b. There is no one "best" type of AI solution to deploy in a given public-facing situation as there are such a wide range of use cases and domain settings, and so many different types of AI methods that can be used. Early versions of an application will often not need to use the most sophisticated (state-of-the-art) technical AI methods or have the highest possible degree of delegation to the automated system. **A very careful balance has to be struck across the potential benefits of further enhanced and automated accessibility, responsiveness and personalization on the one hand versus potential risks of lack of public trust, perceived overreach, lack of understandability, and excessive complexity on the other.** These trade-offs influence the choice of the AI approach. One example is the adaptive learning system that the Ministry of Education is in the early stages of deploying. Parents will be concerned if the system takes over the teaching role from a human teacher. However, if

the system is deployed as a teaching/learning aid to support teacher-student interaction, parents and students are likely to be more receptive. Given the nascency of AI usage for consequential interactions with the public, deployment projects need to be chosen carefully to grow public mindshare of the usefulness of AI. For now, it is best to focus on use cases that are not overly controversial and where high-impact decisions are not fully delegated to the machine. Over time, members of the public will develop more trust and comfort with engaging with AI-enabled systems. In parallel, the capabilities of solutions deployed in specific (and almost always highly complex) domain settings will gradually improve. As this happens, government decision makers will expand the range of use cases deployed and also gradually allow AI system to take on bigger roles through a carefully chosen and closely monitored approach of increasing both task automation as well as augmentation.

c. The key to success for each of the six examples was a focus on solving a clearly identified problem related to meeting an important everyday need of a resident. None of these applications were motivated by using AI methods just for the sake of "using AI." Rather, AI methods were employed because they happened to be the methods that made it practically possible to create digital solutions to address the user's needs. **A clearly defined use case is more important than the degree of sophistication of the AI method, as long as the AI method and supporting data is adequate for a "good enough" result that can be improved over time.**

d. Once the use case is identified, a good starting point is to determine the broad types of AI functionality required for the initial minimal viable product and for envisioned version updates over the first 18 months. This would usually include one or more of the following families of functionality: prediction/recommendation, planning/optimization, modeling/simulation, natural language understanding, image or video understanding, or work process automation. **This integrated consideration of the use case and the broad types of AI functionality initially required provides an overall problem context framing. Within this framing, selection of the specific types of AI methods that would be appropriate to use will be influenced by careful considerations of: i) data availability, ii) the degree and nature of explainability and auditability required, and iii) the nature of the risks and consequences associated with AI model output errors and inaccuracies (e.g., false positives, false negatives, and other types of output errors).** Even in the early stage of planning for the AI approach, it is important to consider user experience (UX) and user interface (UI) needs and challenges. While there needs to be good UX/UI support for the data scientist team designing, testing and validating the AI model prior to its production deployment, an even more important need is for good UX/UI for the ultimate end users of the overall application, as in most cases, the results of an AI model are used within the setting of another IT application and its interface. This also requires thinking through early on how the results of the AI model will be integrated into the supporting IT and digital technology environment.

e. For a public sector entity, initially focusing AI deployment efforts on improvements that address existing and common – even very basic – needs of residents is a good way to get started. It provides an achievable way to build up internal capabilities with deploying AI-enabled solutions while also building up residents' experience with using these systems. The first step in being a "smart city" is to enable residents to do everyday, basic things in smarter (as in simpler and easier) ways. This type of starting point for capability development serves as the foundation for further evolution that leads to the ability to use more sophisticated AI methods and models – in conjunction with

supporting IT and digital technology – to implement entirely new types of services that can engage residents in entirely new ways. **Companies, especially those in an earlier stage of deploying AI-enabled digital solutions, should follow this same pathway. Start simple, with a focus on addressing basic customer needs.**

f. Five of the six examples described in this article (examples 2 to 6) are the result of steady, iterative efforts extending over multi-year time periods. These extended time periods were required to build up the necessary data sets within each specific setting, to iteratively refine AI model performance, and to iterate on how to effectively integrate the AI model outputs into the overall end-to-end solution to attain the needed levels of usability and performance. **As such, an organization's leadership must allow for and support a patient and iterative approach over multi-year time periods, though with the requirement of demonstrating a steady learning curve on key performance metrics at each step.** The remaining Safe Distancing @ Parks application (example 1) demonstrates that once the organization builds up a strong capability base, there are, in fact, specific situations where targeted solutions can be designed and deployed very quickly.

g. Parallel efforts to put in place policies and governance, as well as enabling technology platforms, are essential for the organization to move from an ad hoc approach for each separate AI project to a portfolio approach of deploying multiple AI solutions across all parts of the organization. Organizational clarity on usage of the commercial cloud, internal cross-functional data sharing, data quality accountability and ownership, data and privacy protection, and use case review and approval are equally as important as AI technical competency. Building up the underlying internal infrastructure and software platforms for capturing, cleaning, curating, managing and distributing data across all parts of the organization, and also the related platforms for managing and executing the machine learning DevSecOps pipeline[36], are necessary prerequisites for getting increasingly efficient at deploying as well as supporting an expanding portfolio of AI projects. These policies and underlying platforms also provide the foundation for the next layer of "AI product platforms" — such as JumpStart (example 2), FASTER (example 3), and the virtual interactive chatbot assistant which provided the foundation for the MSO chatbot (example 4) — that enable re-use of "AI product engines" for specific families of tasks such as language understanding, vision-based analysis, recommendations, or anomaly detection. **Technical aspects of AI-model choice and implementation for a specific application, while critical steps, are just a small part of the entire end-to-end effort to create, deploy and operate the AI-enabled total solution. AI-enabled solutions for customer engagement or for any type of application, involve a lot more than "AI".**

Building the Capacity to be a City-Scale Lab for AI Deployments

Public sector AI use cases and deployments have proven to be good starting points for interagency partnerships across government as well as for public-private AI partnerships. Both types of partnerships are essential for making Singapore a resident- and business-friendly AI application testbed. Singapore's strategy is to rapidly test new ideas for AI applications in a city-scale field setting. Compared to other larger countries, Singapore can often move more quickly to iteratively build up a base of common understanding across the multiple realms of technology, infrastructure, management, policy, and governance required to build better and more complex public sector AI capabilities and services. As such, Singapore's government is

committed to continue encouraging responsible and innovative field trials and follow-on deployment efforts for existing and emerging AI technologies. Despite the country's small size in terms of geography and population, it attracts the attention of leading global commercial companies providing AI solutions as well as AI-focused start-ups because of this approach to field trials based on carefully considered use cases and a well-orchestrated approach to follow-on deployment efforts.

The Singapore government's approach to developing AI capabilities is a mix of "building-your-own" and relying on the strongest as well as most innovative vendors around the world. Simpler (e.g., no need for major customization), less sensitive, smaller impact use cases more easily allow for the use of commercial off-the-shelf products and open-source library modules to achieve quick wins (e.g., Safe Distancing @ Parks). More complex, highly integrated, and novel use cases usually necessitate deeply contextualized and highly customized approaches requiring local knowledge and locally driven innovations (e.g., the JumpStart platform for the MyCareersFuture job search portal and the MSO chatbot, both internally developed by GovTech). Some of the more complex and novel use cases also require joint development partnerships with local and global vendors and research institutions (e.g., the AI assistants for supporting personal learning in public education, the Breeze-Through system for contactless border clearance, and the FASTER system for rail management involving a multi-year partnership with IBM and ST Engineering, a local engineering firm).

Even though the Singapore government has substantially boosted their internal capability to develop digital and AI solutions since 2014, they still outsource about 70% of their total IT and digital technology related spend and handle the remaining 30% internally. Public-private partnerships are essential not only for the majority of the work that is outsourced but also for the work done internally that makes use of vendor software packages and tools or requires special applied R&D support. In order to keep the private sector up to date on Singapore government directions for IT, digital and AI initiatives, as well as up-to-the-mark per best as well as emerging industry practices, GovTech runs a series of external events in the form of frequent informal meet-ups called Stack-X[37] and more structured and larger-scale periodic conferences called Stack where the government organizes a developer conference just as leading global tech companies do.[38] Leading industry practitioners often participate and present at these events. Such events provide useful background on government IT/digital/AI directions as well as on specific technology initiatives of interest. These sessions provide local and international industry with useful background context for responding to specific government tenders, and also help orient the developer community and education community so they know how to participate in the ecosystem of smart nation and digital government (including AI) initiatives.

Experience to date with the public sector AI efforts has helped the government to better understand the intricacies of the necessary ecosystem and working relationships required across government, private sector tech solution providers, business users, and research institutions to successfully execute on end-to-end solution development and deployment. Especially important has been the government's learning on how to steer the trajectory of relevant regulation to navigate the delicate balancing across public and societal protections while at the same time supporting R&D, innovation, and learning-by-doing. A closely related area is that of policies, regulations and protections related to providing access to public data for AI projects, as data-driven machine learning is the basis for most contemporary AI applications. Not too many decades ago, Singapore was known for being especially tight with government information; even data sharing within the government was often cumbersome. It is a very

different situation today – with much more open and easier access to data (though still with some notable exceptions) both within the government as well as with the public.

Leadership Factors

The Singapore government's journey with AI deployments, including AI for public engagement, has required the judicious combination of the following four factors:

- **Progressiveness:** There needs to be a "dare-to-try spirit" supported by senior leadership within the horizontal units of government (e.g., everything under the Prime Minister's Office or central executive office) as well as within the various vertical units (the ministries and their agencies). Such a spirit is a pre-requisite in order to break new ground with using digital technology and AI for improving and enhancing customer engagement and experience.
- **Pragmatism:** There must be a no-nonsense evaluation of whether an AI approach is even warranted to create a solution for a particular use case. And whether the essential prerequisites are available for proceeding with an AI solution. If the quality or quantity of data are insufficient, data-driven machine learning methods won't perform well. Also, if there is insufficient human expertise available about the domain setting and specific problem, it will be precarious to proceed with creating an AI model as it would be difficult if not impossible to know how to carefully test, validate and improve the results. When starting to address a new use case, choosing the simplest AI solution that best fits the problem statement will be an effective way to initially move forward. That might even lead to starting with rule-based or logic-based ("good old-fashioned AI") approaches despite "current wisdom" these days to always start with more complicated machine learning methods. Hard-headed pragmatism is also needed by leaders to push back on projects that do not have a clearly defined use case, or that have a use case that is likely to be considered highly controversial or sensitive by segments of the public.
- **Patience**: Leaders and senior management must realize that when deploying AI-based solutions, the system will be far from perfect at the get-go of initial deployment. They must look longer term and be willing to support sustaining investments needed to keep iterating so that the solution's performance improves over time as more data is collected and as refinements to AI models and to supporting IT system modules are made. These iterations to get to the desired levels of performance can extend over multiple years.
- **Persistence:** One important aspect of introducing a new technology is being properly prepared to hold steady and persist in the face of internal organizational as well as external public resistance. As with efforts to deploy any new type of technology, launching new types of AI-enabled systems and associated new processes will disrupt established practices. Projects which are "first movers" on new types of efforts for the organization are going to face opposition from internal and external stakeholders citing a variety of concerns (e.g., privacy, job loss, fairness). To be successful in AI deployment and adoption, leaders need to have the evidenced-based conviction to responsibly address the opposition voices that will inevitably arise. There is a second aspect of persistence that is more operational and closely linked to the above point on patience. AI systems of all types — whether rule/knowledge/logic-based, data-driven machine learning-based, or using other methods, as well as a hybrid of multiple methods — require a substantial amount of ongoing monitoring, adjustment and maintenance to ensure that the results remain reliable and responsible. Without this persistent and patient approach to ongoing post-deployment support, system performance "drifts" due

to various changes in conditions. Also, biases and errors – overt and subtle – that were not initially detected nor previously understood often emerge over time and need to be addressed. Leadership must put in place the necessary persisting organizational mechanisms to handle the longer-term time lifecycle commitments associated with deploying AI systems and products, as they cannot just be deployed and forgotten. A mistake that is often made is to treat an AI production deployment effort as if it is a one-time project with a clearly defined and fixed end date. The reality is different. AI production deployment efforts need to be viewed as product efforts that require extensive and persisting "post-release" product support for making ongoing improvements and for responding to unanticipated "product problems."

In summary, the Singapore government's approach to building AI capabilities and deploying AI applications across the public sector has in itself been a national level engagement effort across all parts of the government and spanning the boundaries of government, the private sector and local society. This has resulted in a steadily expanding portfolio of AI-enabled applications that are important enablers for changing how the government operates and how it engages with the public. The progress with overall digital government efforts, including AI application efforts, is reflected in the results of Singapore's annual survey on satisfaction with government digital services.[39] For the survey of citizens, on a scale of 1 to 5 with 5 being "very satisfied", the overall satisfaction score increased from the 2016 level (95% satisfied or above, 73% very satisfied) to the 2021 level (99% satisfied and above, 85 % very satisfied). For the corresponding survey of business entities, digital government satisfaction scores increased from the 2016 level (92% satisfied or above, 64 % very satisfied) to the 2021 level (98% satisfied or above, 76 % very satisfied). AI applications like the ones described in this article are only one part – and realistically, still only a small part – of a much large overall digital government effort, though they are an increasingly expanding and important part.

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