NTT Smart Solutions

Empowering data to inform better business decisions

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Intro

Digital models of physical things promise to provide tremendous economic value across both public and private sectors by delivering real-time insights into all aspects of a business, including operational processes, asset utilization/performance, product development and even event management.

Yet, the real value of digitally modeling material things is providing insights into potential future design and process improvements or anticipating operational issues with predictive modeling and "what-if" scenario analysis. Approaches range from modeling a simple object or process to the more sophisticated and complex "system of systems" with multiple connected objects working together in a broader ecosystem. The business value of simulating operational scenarios before placing them into production drives increased design innovation, quality of service and efficiency while reducing system downtime and maintenance cost.

NTT Smart Solutions leverage the concept of a "data twin" to calibrate and curate data from different sources to reveal trends, insights and generate predictive analytics. This whitepaper explores the architecture behind NTT Smart Solutions and describes how IndyCar leverages this to improve the fan safety and experience at the Indianapolis Motor Speedway. It also focuses on how other industries can benefit from NTT Smart Solutions, including improved public transit services and a live project from a major Department of Transportation in Australia.

A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes.

Gartner® IT Glossary. – Digital Twin, as on 3rd November, 2021

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Data twin value brought to life with INDYCAR
enhancing the sporting experience using Smart Solutions

The below section provides an example of how an organization can create a digital representation of a physical system and gain real value. It describes the challenges faced by IndyCar and the Indianapolis Motor Speedway (IMS) and illustrates how a data-first approach helped to transform and enhance the sporting experience for both fans and operators.

Leveraging NTT Smart Solutions helped provide attendees with a more positive and consistent experience at the world's largest sports venue, the Indianapolis Motor Speedway (IMS). Solutions provided event operations and security teams with the ability to make informed decisions, have visibility over the entire venue, and have faster response times to potential risks and accidents. This was enabled by fast, data-driven decision making made possible by predictive insights on crowd congestion, vehicle traffic, and more.

INDIANAPOLIS MOTOR SPEEDWAY AND THE INDY 500

CHALLENGE: Increase visibility to manage crowd control.

For the INDYCAR fans the Indianapolis 500 isn't just a one-day race. It's an entire experience involving the community and fans all over the country. It lasts for over a month and requires year-round preparation by organizers and race competitors. And for a lot of fans, it's the event they most look forward to every year. With nobody allowed in the grandstands in 2020 due to a global pandemic, the 2021 Indy500 proceeded at 40% capacity or about 135,000 fans. This made it the largest in-person event of 2021 to date.

The challenge for IMS operations and security teams was to understand and process all the data from numerous gates (400,000 fans in a typical year), many different data sources and numerous potential security threats. For the 2021 Indy500, the NTT team focused on simplifying the data flow for gate entry, crowds outside the gates and identifying crowd related dangerous situations. The operations team also wanted to react to future events, not waiting for a dangerous crowd situation to develop before the safety team started to mitigate the issue.

SOLUTION: Real-time data to inform quick, critical decisions.

The NTT team started working with the operations team utilizing design thinking workshops to identify the target application and intelligence to the IMS operation team's challenge. It became clear that there were two distinct areas to address for the IMS team: a real-time status of the gate area and a digital twin of each gate for the near future.

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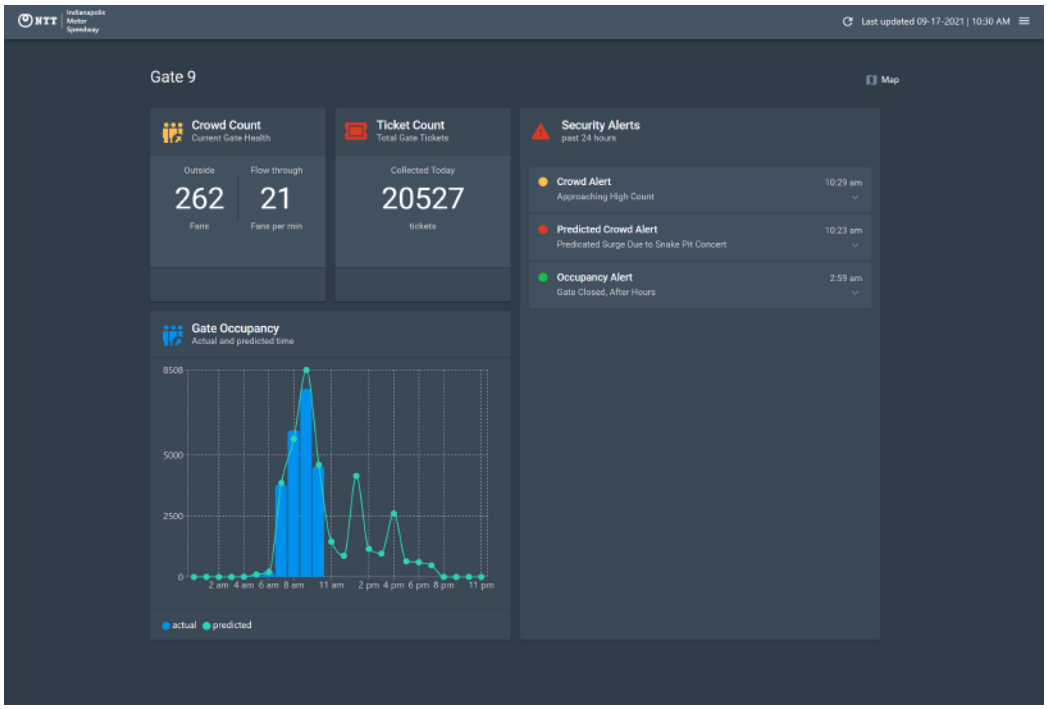
Once the desired outcome was set, NTT engineer teams worked with the customer's technical teams to identify the sensor locations and the required infrastructure for the outcome. The deployment teams worked closely with the customer to get all the sensors in plan and connected to the NTT Smart Solutions. In parallel, the User Interface team quickly put together the dashboards that were initially identified in the Design Thinking workshop.

The solution started with delivering a real-time fan flow rate for every ticket scanner at every gate. Operations staff easily understood this by summarizing fans per minute at each entrance to quickly assess how the ticket scanning was proceeding for the event. This was then coupled with a crowd counting solution outside each gate that delivered how many fans congregated there. This was measured every 30 seconds and delivered again as a simple consumable crowd count for each gate. The operations personnel could easily see the live gate flow rate and crowd count and their relationship to identify emerging choke points and potentially dangerous crowd situations.

NTT Smart Solutions used intelligence built for stadiums that consumed the recent history of gate flow and crowd events and automatically identified any potentially dangerous crowd events. This analyzed the gate flow against the crowd building outside the gate, looking for specific events. One example of these events is the gates not processing the fans faster than the fans were arriving at the gate.

NTT Smart Solutions utilized its data twin intelligence to simulate every gate's flow rate and crowd gathering outside the gates of the IMS.



The dashboard provided to the operations team

OUTCOME: An easy-to-use interface to understand capacity better and predict crowd flows.

A simple, easy-to-use interface allows the operations staff to look across all of the gates in the stadium and quickly understand the status. Each gate could be further analyzed for current, historical and future gate flow rate and crowd count outside that gate. Providing a concise 'what it was', 'what it is' and 'what it will be' in a single view. During the event, NTT Smart Solutions accounted for all 135,000 tickets for the event within 5 minutes of the ticket being scanned, giving the operations staff a clear picture of how many fans were present in the stadium. To provide the predicted crowd and ticket counts, the Smart Solutions ran about 500 predictions per minute for the entirety of the 18-hour event, with a high accuracy rate.

Additionally, the operations team was provided with Indy500 specific tools. A health hub showed how many fans were in the stadium, how many tickets were still to be scanned to meet the tickets sold, and an estimated flow rate required to arrive at capacity for the event start. A timetable countdown that mapped the sub-events and tasks that led up to the start of the indy500. These tools were also provided in a mobile interface for staff to utilize their smartphone during the event.

USER EXPERIENCE

Through the Design Thinking Workshop, the NTT and Indy teams determined the challenges needing to be solved and the people for whom the solutions would be designed. The Indycar and IMS team of participants included a cross-functional group of individuals from Marketing, Operations, Safety and Security, IT, Fan Experience and Ticketing. From NTT, participants included Smart Solutions UX and UI Designers, Technical and Solution Architects, and Business Analysts. Having this cross-functional team brought a variety of perspectives to hear one another, inform and collaborate during the workshop to yield many different ideas. Understanding how the representatives from the different roles think about the challenges and their thoughts on what would work well allowed the NTT team to progress those ideas even further into a solution meeting the users' needs and providing Indycar/IMS with data and predictions they never had access to before.

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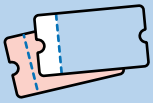
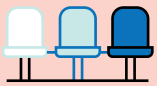
- **How might we...**
  determine adequate staffing levels per gate to ensure the highest throughout?

- **How might we...**
  identify dangerous crowd conditions venue - wide?



- **How might we...**
  predict surges of ticket holders entering the gates?



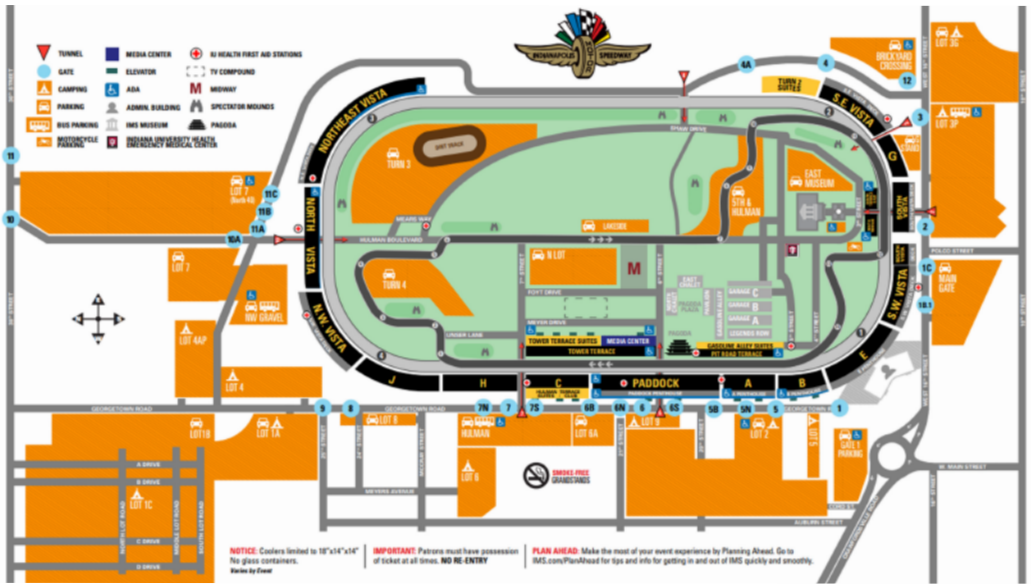
- **How might we...**
  determine if we are on-pace for the number of spectators in their seats before the green flag?

- **How might we...**
  understand the status of a gate for all gates around the venue?

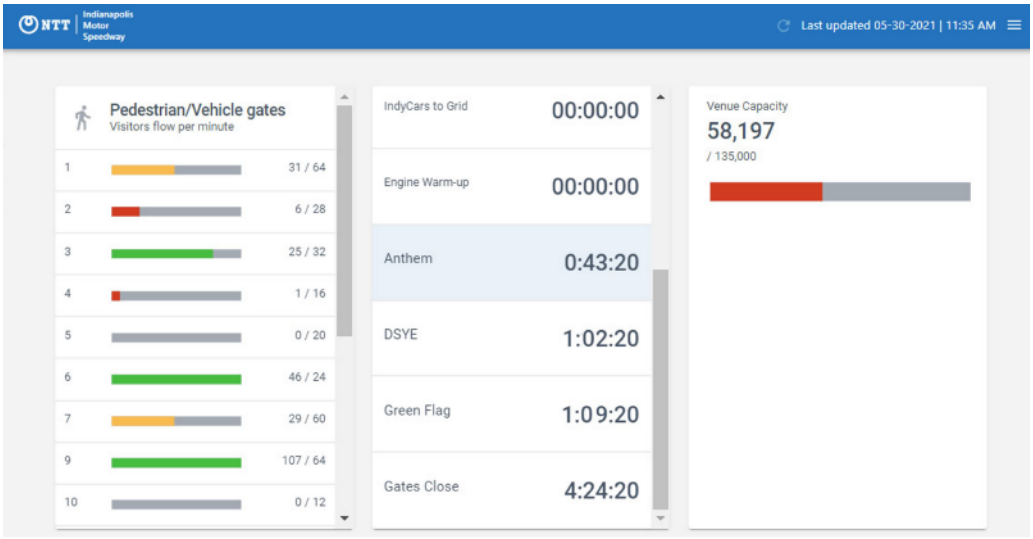
The NTT Design team had a few things to keep in mind:

- The users may be on their mobile phones, tablets, laptops or viewing the dashboard on the huge screens in the operations and command center.
- Users may be inside or outside, so the contrast will be important.
- Race day is hectic and chaotic, and users will be on-the-job from early in the morning until very late that night for several days in a row.
- The events within the Race Day are scheduled down to the minute and users will need to be aware of what's currently taking place and what they need to prepare for.
- Users must make decisions that will affect potentially large numbers of people (staff and fans).
- The accuracy of the data will inform staffing, operations, and security decisions for future races.

As a result, the NTT Design team delivered a dashboard that appeared sleek and simple at first glance. It provided a map view of the entire venue and made use of iconography to relay the status of the various gates. From here, the operations teams could understand where crowds were backing up, issues with gate flow-through or where scanners were needed. Safety and Security personnel could see where crowd congestion could indicate security issues. All users could then drill down and access gate specific information into the details for each gate, AI predictions and live look-ins to sensor views around the gate areas. At the venue level, the various teams could easily see the status of spectators entering the venue and at what point in the schedule of events they were.



A map of the Indianapolis Motor Speedway



One of the dashboards delivered to the operations team

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CONNECTED INFRASTRUCTURE TO DELIVER ON-DEMAND DATA

After describing the Data Twin and the Visual Twin components of NTT Smart Solutions, this paragraph will now focus on the infrastructure and partner ecosystem that is required to operate this system.

Collecting the data is easy. Collecting the data to display it in near real-time gets challenging. Scrape the customer's Azure instance to view 1000's of ticketing data transactions per minute and still collect critical data from 25 sensors at IMS streaming over a total of 50MB/s from the Micro Data Center (MDC).

With many data streams distributed across a vast network and multiple applications intersecting, the system needed to get efficient and fast with resiliency in mind to keep on-demand data flowing to deliver critical information. With all of this in mind, NTT Smart Solutions was purposely built on a containerized platform.

NTT Smart Solutions were deployed on a Kubernetes Cluster in NTT Ashburn data center to aggregate all data pulled from IMS and the IMS Azure Instance. The Kubernetes Platform provided the numerous abilities to deploy the software anywhere, application resiliency to always be up, and scalability to expand a cluster, to name a few. If an application needed to be updated, the old application remained active until the new application was up and running before switching to active. This was enabling true rolling update capabilities with no application downtime.

The F5 - Nginx Ingress Controller handled all inbound connections to the cluster. The Ingress Controller provided name-based routing capability and API authentication to quickly route incoming URL requests for the customer's hosted dashboard and secure incoming API calls against a customer or self-served identity provider.

All data applications, dashboards, and databases were deployed as containers via the CI/CD pipeline running on Jenkins. From Jenkins, there was a two-step deployment, first deploying NTT Smart Solutions, and second, deploying the customer configuration to connect to all the sensors or other data sources that might have been required.

Kubernetes Persistent Volumes accommodated applications that required persistent storage. This allowed to select the storage flavor for size and speed and seamlessly update the application and ensure data persistency.

When NTT Smart Solutions were up and running, it was a matter of collecting data from the data sources and MDC running the edge applications. After collecting the data, there were multiple applications doing analytics and predictions against the data and saved it into the containerized database. The external or internal facing customer dashboard then read all data via API from the database.

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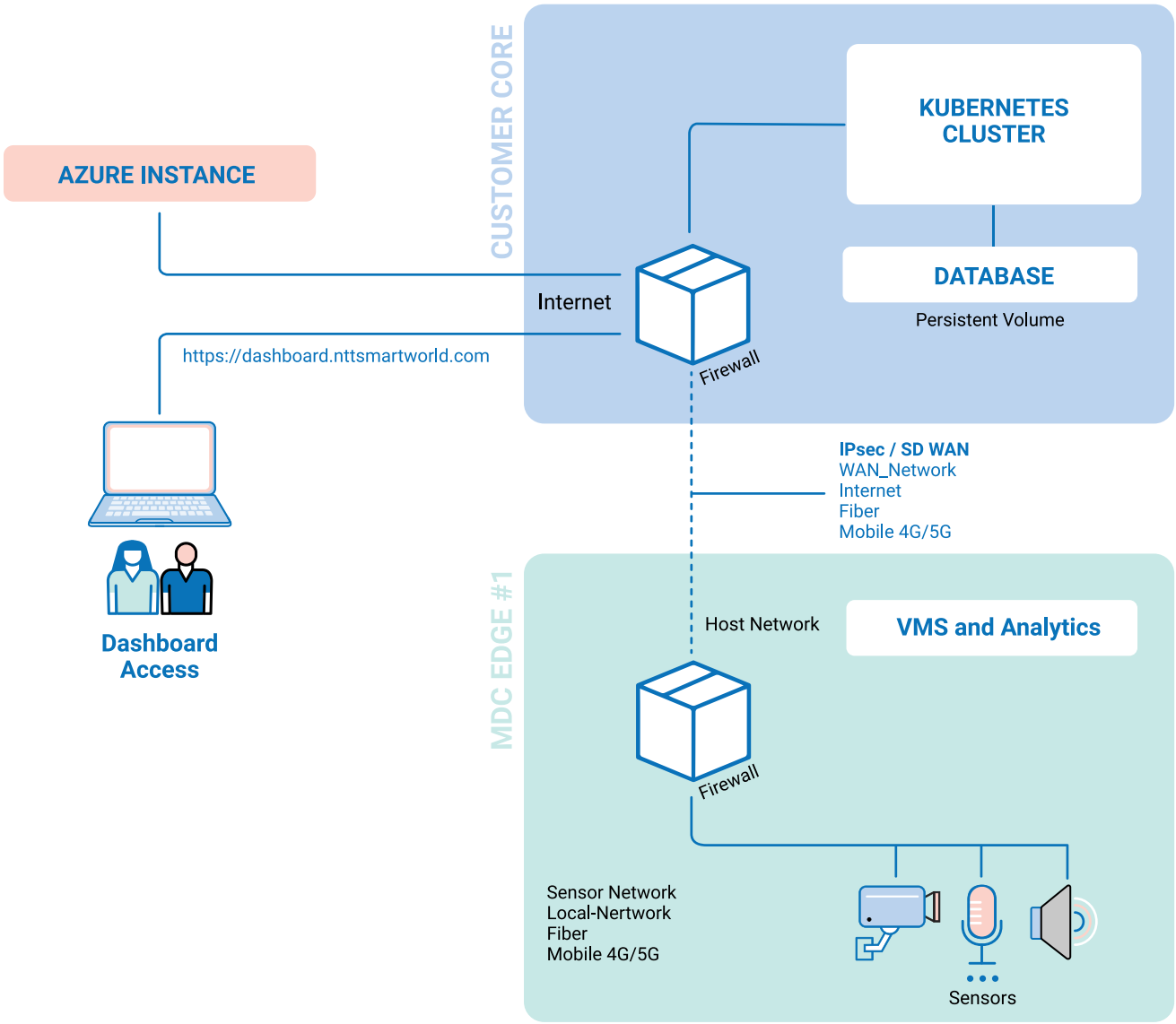
The MDC run applications that needed to connect to edge sensors. These applications might be containerized or running on a virtual machine, depending on vendor specifications. This provided the ability to extract essential data and declutter unnecessary heavy bandwidth loads.

With the flexibility of NTT Smart Solutions, the system was able to be close to the customer's Azure instance to collect 1000's ticketing data per minute and still collect critical data from 25 sensors. With data aggregation happening at the edge MDC by only extracting the metadata needed, the data streaming to the core was reduced to an average of 1MB/s. Adding the platform's ability to scale out and manage container load when compute is needed was a balance between fast compute and keeping it cost-effective.



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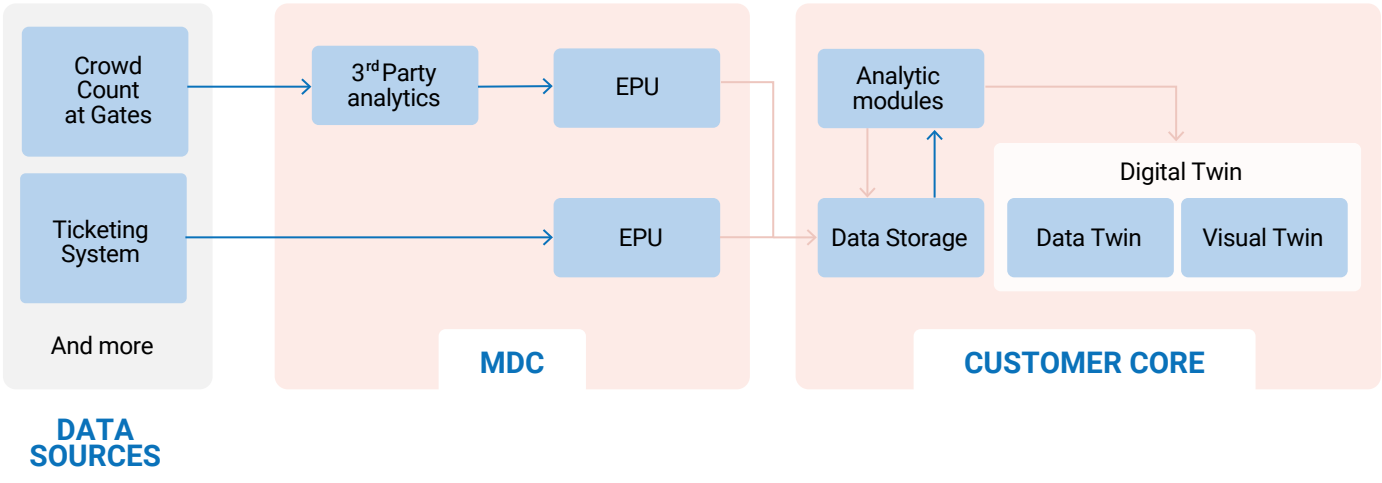
THE ROLE OF DATA ARCHITECTURE TO PRODUCE INTELLIGENCE AND INSIGHTS FOR INDYCAR

The standard features of NTT Smart Solutions have everything needed to meet INDYCAR's requirements. These features are powerful microservices and processes orchestrated together to produce the data intelligence and insights required by a customer.

The data ingestion was handled by Edge Processing Units (EPU). EPU's serve the primary purpose of ingesting and normalizing data from external data sources. These microservices are typically specific to a single data source type and can be orchestrated to function in parallel to allow for massive scalability if needed. To meet the Indy500 requirements, two EPU's were constructed to ingest data from the crowd count video system and the IndyCar ticketing systems. These EPU's processed thousands of transactions per minute to capture the data required. Once the data was captured and normalized, building the data twins for each gate in the stadium got started.

The data twins are comprised of analytic microservices that work in concert to replicate the future data for each gate. The initial data twins deployed were learning models to provide instant access to predictions. The NTT data science team then enhanced these model configurations to refine the results by adjusting to surges in fan counts. The data twin modules are designed to be useable and are the same modules NTT deploys for Smart City and Venue Safety applications, just configured for the IMS venue. This resulted in deployment times less than five minutes for all the data twins and thousands of data points produced per minute.



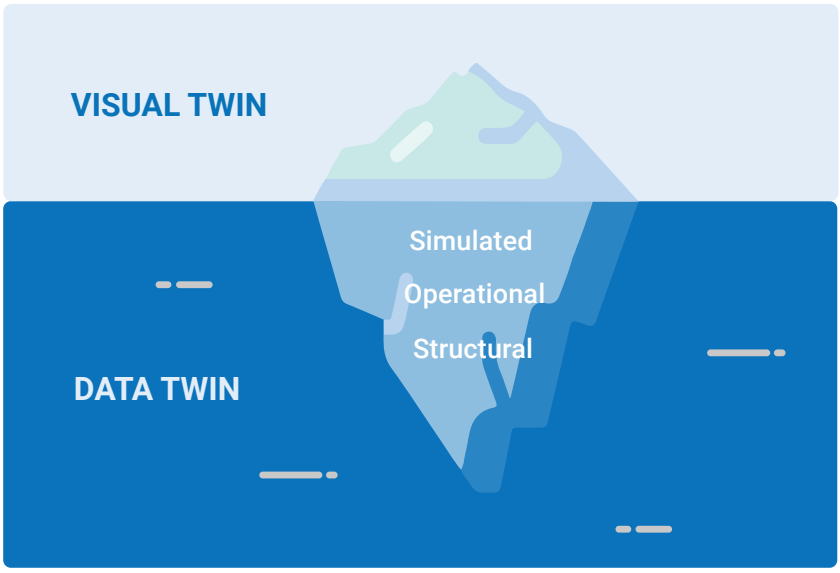
The standard components in the data architecture reduced overall development time for the EPU's and resulted deployment times is less than five minutes for the entire Smart Solutions for the Indy500. In addition, using NTT learning analytics, the customer had access to predictions as soon as data was ingested, and predictions adapted rapidly to changing conditions. This was imperative due to global pandemic conditions and restrictions put in place for the 2021 Indy 500 resulting in Indy 500 crowd conditions that required proactive management and support from the IMS Operations team.

The data components of the NTT Smart Solutions drove the User Interface used by the operations staff, so they could easily look across all the gates in the stadium and quickly see the status of each gate.

Understanding data twin typologies

Describing a Digital Twin to the casual observer is like describing an iceberg floating in an ocean. The visible tip represents only a fraction of the total mass of the structure floating underneath the surface. In the case of the Digital Twin, the visual representation—the "Visual Twin"—of the object is what is most identifiable on the surface, but there is a much larger mass—the "Data Twin"—which is hidden from view under the surface. Together the Visual Twin and the Data Twin represent a complete Digital Twin.

This section dives into the technical aspects of how NTT built the IndyCar solution. It breaks down the data requirements into three foundational categories or typologies to understand the value of the digital twin. The first two typologies represent data generated by the system or group modeled by the digital twin. The third refers to the data generated by the digital twin itself under various scenarios in simulation.



• **Type I:**

Static and Structural.

Probably the most easily understood is the representation of the physical object in a digital form. If you were building a house, your architectural plans would be represented as static three-dimensional digital images. These visual images require data that describe the static and structural form, including size, shape, and material composition. Typical uses of this type of data support wayfinding (maps and diagrams) and other forms of digital guides. Data in this typology does not change frequently and is generally stable.

• **Type II:**

Operational and Functioning.

This type of data describes how the object or system behaves when in use. For example, a water pump that consumes electricity to rotate a turbine draws water into the pump and propels it to its next destination. Here, two data elements of interest are the electrical consumption (kW) and the water flow (gpm). By its nature, this type of data is highly transactional and can generate a virtual flood of information on the real-time operation of the object or system. Each of these data elements has a measuring unit of its own that may be of interest in isolation. Still, the value comes when data is connected and correlated to represent the entire system in actual operation. Typical uses of this type of data support real-time system monitoring for anomaly detection, preventive maintenance, surveillance, and many others.

• **Type III:**

Simulated and Predictive.

The digital twin itself generates this type of data. It can be valuable in new product prototyping, testing a system's operational limits under variable conditions, or understanding the most efficient way to schedule a certain process. For example, it is valuable for the operator to know how the system responds to planned and unplanned events in transit systems. The operator gains the ability to simulate outages, maintenance events or unplanned spikes in ridership. This can support rapid responses with alternate routing for passengers, cross-agency collaboration, or explore incentives for frequent travelers to minimize disruptions and increase the overall positive passenger experience.

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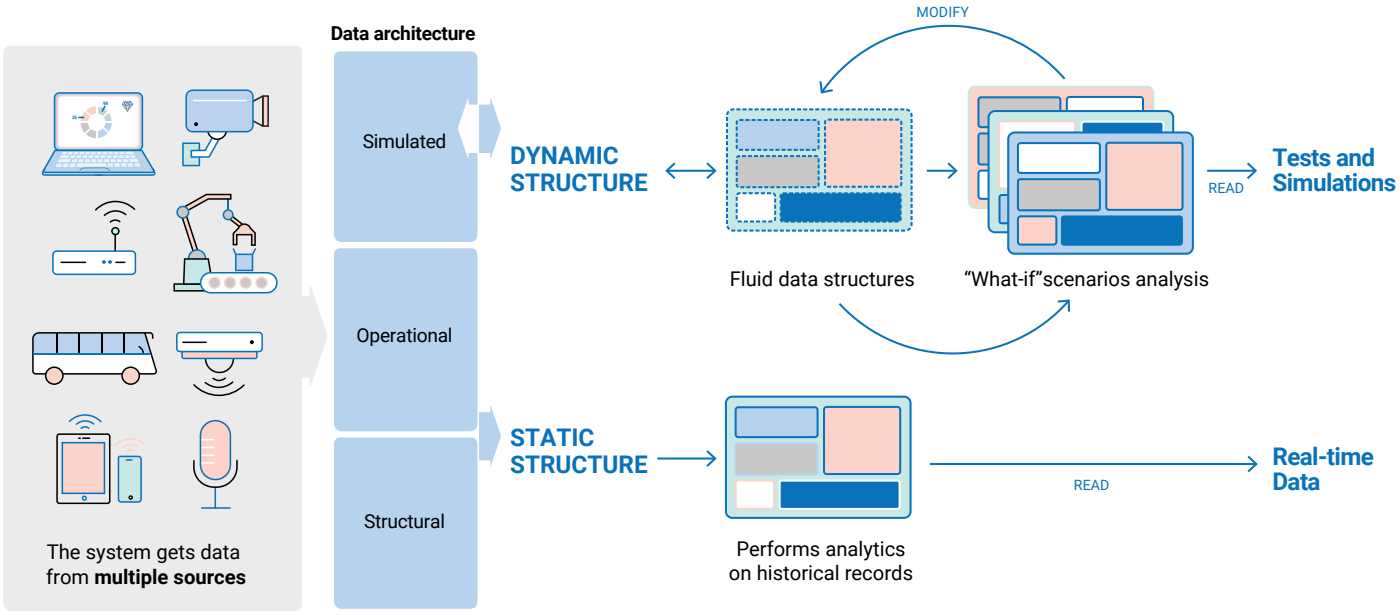
The importance of data twin architectures and interoperability

A “data first” approach means identifying the data requirements across the above typologies. Ensuring that the underlying data architecture is designed to support and manage the complex inter-relationships of these different data typologies is essential.

Data architectures that can flex between static and dynamic data structures and handle complex multi-variant relationships will perform the best under the demands of the digital twin. For example, typical analytic data architectures are read-only and may not have the ability to capture changes to the underlying data elements or their relationships as a core function.

While these structures are valuable for analyzing historical events, they do not provide a method for incorporating the “what-if” scenario management functionality at the core of a digital twin solution. Having the ability to “write back” changes to the underlying data structures or save different versions of a configuration or process to test hypothetical scenarios under varying operational conditions is critical for any data twin architecture.

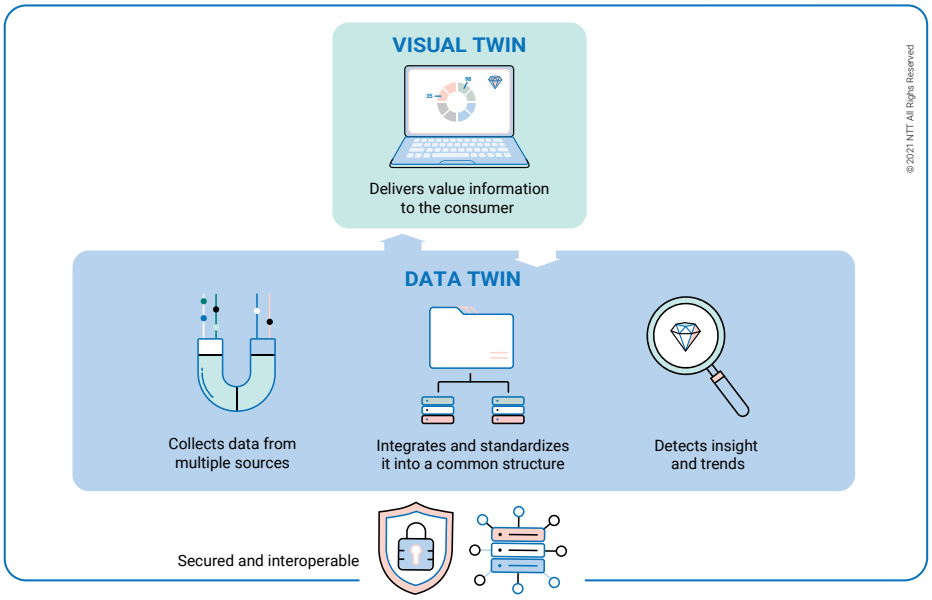


The system curates and calibrates data according to the different data typologies

Another critical component of a data twin is its ability to command and deliver data seamlessly and securely. On the consumption side, the system must be able to connect to and ingest from relevant data sources at the edge using purpose-built API’s. Sources generally include multiple, non-standard IoT data streams and almost always at varying volumes, frequencies, and granularity.

To best address these data synchronization challenges, the data twin must have the ability to integrate and standardize the inbound data stream into a common structure so the data science and AI algorithms can readily study the relationships and recommend potential fine-tuning to optimize the system or process. This data standardization process is a key component as it minimizes customization and maximizes reusability.

A similar approach is recommended for the bi-directional transfer of process between the data and visual twin for interpretation, insight, and action. This approach promotes user experience flexibility and allows the visual twin to deliver purpose-built value based on needs. A robust set of standard APIs that allow for secure and scalable access to the valuable curated data collections in the data twin is a critical element of a successful digital twin deployment.



Once established, a strong and scalable data twin architecture forms the foundation for real-time operational management and continuous evaluation, analysis, prediction, and improvement.

Designing the right data strategy and architecture up-front will enable and drive better results and insights from the advanced modeling and scenario management functions that are the ultimate appeal of building a digital twin.

Wrapping any data twin with the right set of APIs to ensure that it will interoperate effectively in a complex ecosystem both at the IoT Edge and the delivery to the UI/UX visual twin is also critical. Taking on a digital twin project is not a trivial endeavor, but following a few basic rules as suggested can get a project started on the right path with a strong “data first” foundation.

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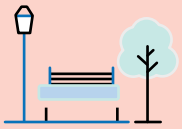
How data twin is transforming other industries

This section explores how the technical approach of NTT Smart Solutions can be applied to any industry. Thanks to their modular and interoperable structure, the solutions can be applied across many use cases. Whether monitoring crowds in public transports and retail spaces or analyzing traffic patterns at busy city crossroads, understanding people flows in buildings or monitoring safety and security in manufacturing plants. NTT Smart Solutions can provide valuable insights to improve operations, incident response and planning while delivering better services for citizens and employees.

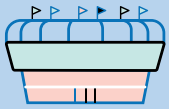


CITY/CAMPUS

Usage analytics Use of amenities e.g. parks, litter bins
Public safety Unsafe situations, incident response and prevention
Unsafe driving Road incident response & prevention
Traffic predictions Traffic trends for better planning and mobility
Transportation occupancy Adjust service and inform travelers
Crowd monitoring Situational awareness for planning purposes

MANUFACTURING

Worker safety monitoring Ensure correct PPE and no trespassing of yellow lines



EVENTS/VENUES

Occupancy and crowd monitoring Regulate spectator flow
Fan experience Personalized viewing and accurate sports statistics

HEALTHCARE

Patient observation Detect patients leaving their beds when it's unsafe to do so or asking for help

BUILDINGS

People flows Energy efficiency and safety
Health checks Non-intrusive temperature check

The case study from a major Department of Transportation in Australia is a great example of how NTT Smart Solutions have been used across other industries.

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TRANSIT OCCUPANCY CONDITIONS

CHALLENGE: Ensuring passenger safety and improving the experience.
This major Department of Transportation (DoT) in Australia regularly services over 500 million trips per year for citizens across 265 trains, 490 trams, and 2,200 buses. The effective and efficient operation of the transit system is critical for the citizens and organizations. However, in 2020, ridership dropped to almost non-existent usage as COVID-19 lockdown restrictions were put in place and traveler preferences for social distancing advanced. The transit authority needed to act swiftly to increase commuter confidence, ensure passengers enjoy a safe experience and allow the agency to monitor the occupancy of various stations and vehicles. They identified the need to give customers better information about the occupancy of transport locations and services to make informed choices about their travel during COVID.

220
metro train stations monitored for current and predicted occupancy

28 million
unique travel patterns detected

4 million
multi-modal changeovers and 300,000 journey schedules

50 TB
of real-time data analyzed in the first three months

SOLUTION: Leverage data twin intelligence to simulate passenger patterns.
NTT worked with the DoT to deploy its Transit Occupancy solution using NTT Smart Solutions. NTT was able to take in data from the myki smart card and other multiple sources and use machine learning and artificial intelligence to determine the occupancy of stations, platforms, and individual trains in real-time and predict future volumes. The application uses tap on/tap off data gathered from over 24,000 edge devices located on transit platforms, trains, trams, and buses to improve planning and transportation efficiency. The application provides travelers and the transit authority real-time and predictive occupancy to help comply with social distancing requirements and traveler preferences. The application identifies over 28 million unique travel patterns, including 4 million multi-modal changeovers in single/multi-modal handoffs, and has aided in scheduling over 300,000 journeys since launch in late 2020. The travel patterns, including expected occupancy, are displayed using a dashboard.

NTT Smart Solutions utilizes its data twin intelligence to simulate how travelers go through the network and provide occupancy data for the aggregated numbers of people in all locations and vehicles of the service trains. This also creates logs of travelers and their journeys from the origin station to the destination station, including any transfer stations.

The DoT application includes a mobile application, website, and General Transit Feed Specifications used by commuters to access occupancy information. After going live, Google also became a partner utilizing data streamed from the NTT Smart Solution to update Google Maps in real-time with occupancy information to broaden the accessibility of the application to more travelers.

The challenges encountered during this project revolved around the vast amount of data being captured instantly by 24,000 edge devices and 20 million smart cards and accounting for tap-off at destination stations not being fully enforced. NTT Smart Solutions demonstrated its ability to scale up data processing to accommodate this level of data. In addition, the application can scale as necessary and incorporate new data/respond to new conditions such as new vehicles, edge devices, and smart cards that are added daily.

OUTCOMES: An application to identify millions of travel patterns to predict occupancy.

The benefit of the application for the DoT was unique at the time of implementation as the ridership dropped to near zero at the height of the pandemic and returning passengers safely to the public transit system was the top priority.

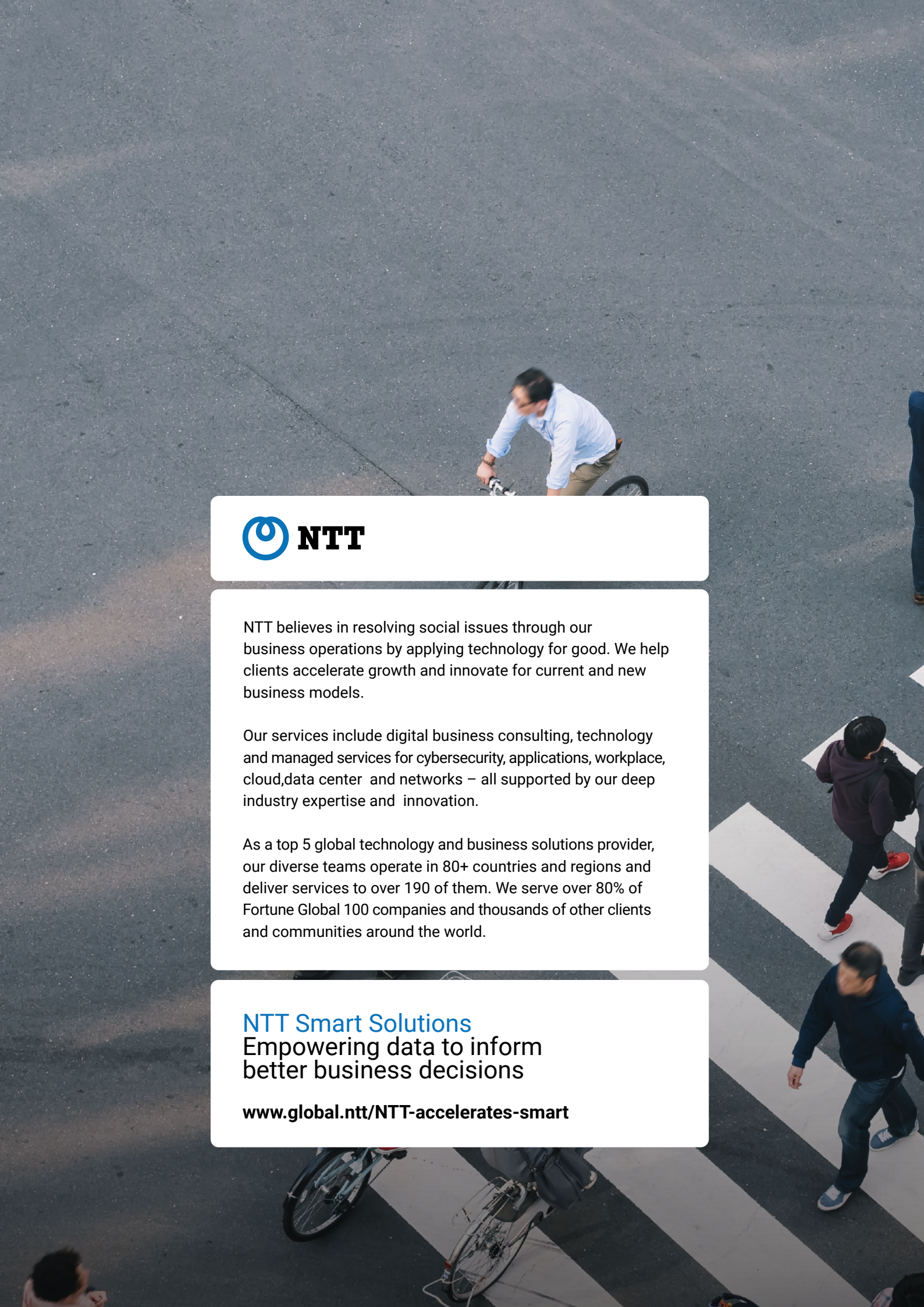
The system allows travelers to view every space's current and predicted occupancy along their route prior to departure, enabling them to make more informed travel decisions. This also helps spread out the travelers over the day and reduces the chances of overcrowding in some locations.

Transit officers can see the current occupancy of all trains passing through a specific station to determine any potential problems or issues. They can also view historical trends and weekly or monthly averages to consider how a particular day's actual and predicted occupancies compare to those of other periods. Such insights allow transit officials to plan for special events more efficiently, adjust transit staff based on traveler patterns and forecasts, and adjust cleaning and maintenance when and where necessary. City planners and transit officials can view long term trends and determine occupancy and travel patterns to help optimize the transit system schedules and services.

Conclusion

Spending time upfront to understand and explore data architecture and design is the first step on any digital twin project. NTT Smart Solutions provide the right tools to accelerate this journey and create a robust and scalable 'data first' architectural foundation. They also offer the important ability to "write-back" changes to the underlying data structures or to save different versions of a configuration or process to test hypothetical scenarios under varying operating conditions. This iterative change enables learnings from "what-if" analysis and allows users to perform various tests in the digital world ultimately shortening time to value and market.

Please contact the NTT SMART World team if you would like to discuss how to start your Digital Twin project:
acceleratesmart@global.ntt



NTT believes in resolving social issues through our business operations by applying technology for good. We help clients accelerate growth and innovate for current and new business models.

Our services include digital business consulting, technology and managed services for cybersecurity, applications, workplace, cloud,data center and networks – all supported by our deep industry expertise and innovation.

As a top 5 global technology and business solutions provider, our diverse teams operate in 80+ countries and regions and deliver services to over 190 of them. We serve over 80% of Fortune Global 100 companies and thousands of other clients and communities around the world.

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www.global.ntt/NTT-accelerates-smart