Digital Twin in the Automotive Industry: Driving Physical-Digital Convergence

Abstract

In the past few decades, mass production, lean adoption, and globalization were the key enablers for the automotive industry to drive growth and profitability. However, with data becoming the new oil and Industry 4.0 taking hold, future growth of the industry is expected to be fueled by data-led manufacturing. Under this model, enterprises leverage data across the product life cycle to build faster, cost effective, and high quality products.

A key enabler of data-driven manufacturing is the concept of digital twin. It represents a pairing of virtual and physical worlds underpinned by emerging technologies such as IoT, 3D simulation tools, and predictive analytics. The result: enhanced ability to analyze data and monitor systems to solve the problems even before they occur.

The paper explores the role of digital twin in addressing the current challenges of the automotive industry, especially with regards to vehicle product design, manufacturing, sales, and service.

Digital Twin: Steering the Auto Industry towards Data Maturity

The digital twin is composed of three components - the physical entities in the real world, their virtual models, and the connected data/view that ties the two worlds together (see Figure 1). The left half of the figure represents the physical road ahead and its virtual image on the satellite navigator (SatNav). In this scenario, the driver needs to do three things: view the satellite navigator (SatNav) for direction, view the actual road, overlay the SatNav direction mentally into the actual road to take the right turn. This requires mental effort, some degree of driving experience, and a sense of timing.

In the right half of the figure, the vehicle uses Augmented Reality (AR) capability, giving the driver a converged view of digital and physical worlds to seamlessly navigate the turns on the road. This minimizes mental effort, distraction, and chances of human error by allowing the driver to focus on the road. This concept can be extended across the automotive value chain to perform operations efficiently by leveraging different technology capabilities underpinned by IoT, Big Data analytics, and simulation techniques.

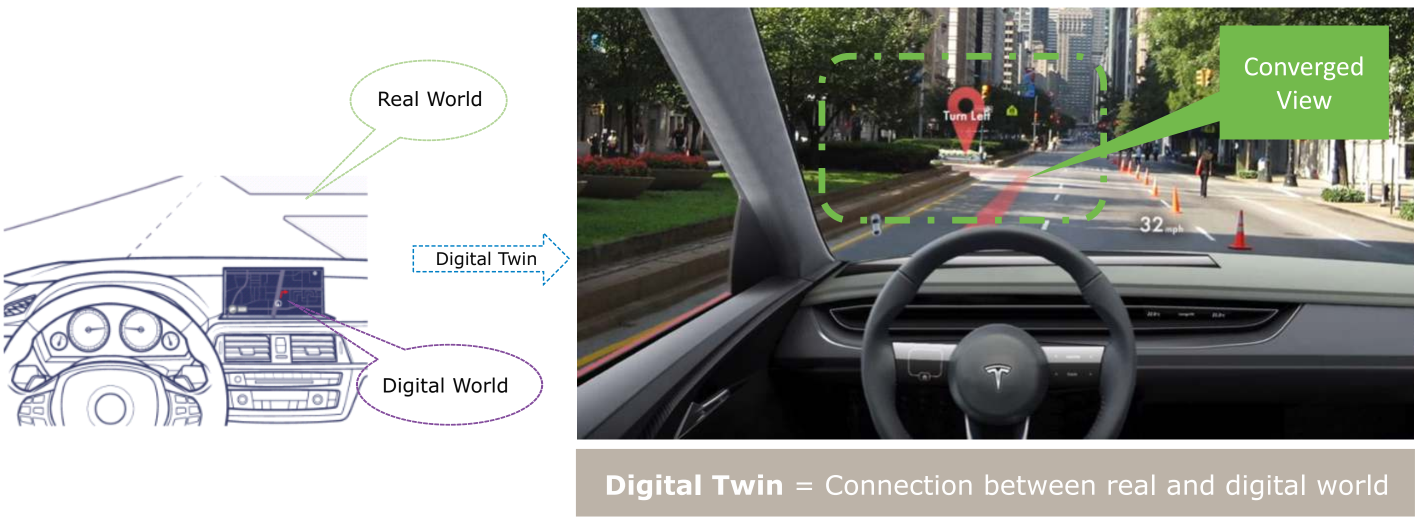
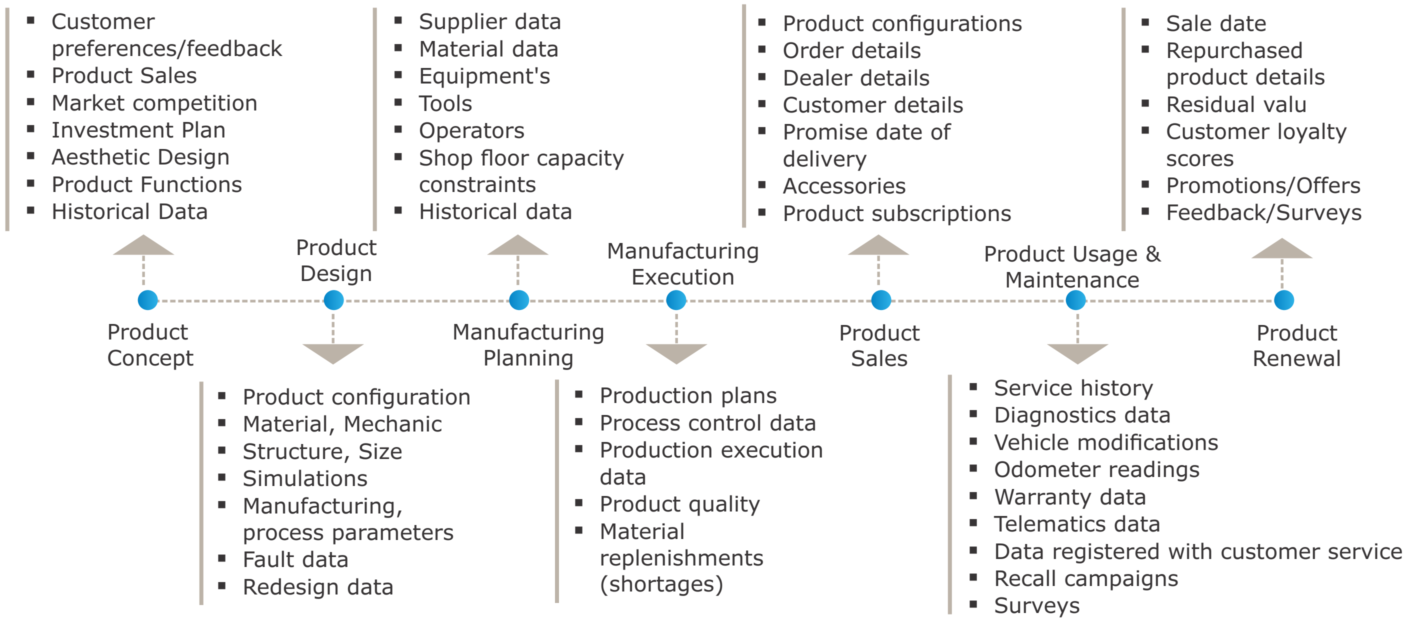


Figure 1: The concept of digital twin in a driving scenario

In the automotive industry, the product life cycle of a vehicle involves various stages - conceptualize, design, procure, build, stock, sell, service, and recycle. At each stage, an enormous amount of data is generated as part of routine activities (illustrated in Figure 2). Leveraging the available data to build faster, cost-effective, and high quality products is the ultimate goal of all organizations. However, the fact is that automotive manufacturers are at different levels of maturity in terms of effective utilization of their data.



** This list is indicative only (not exhaustive)*

Figure 2: A view of product life cycle data (automotive)

Driving Past the Challenges

Ensuring accurate vehicle design, seamless manufacturing, and exceptional sales and service have been long standing challenges for automotive manufacturers. Leveraging the digital twin concept can help turn that equation around. Here's how:

Vehicle Development

Automotive product development is a long and complex process. Typically, manufacturing a new car model takes five to six years [1] - from design to launch. In fact, effective design is the key to success and long term sustainability of an automotive organization. Even a small oversight in product design can erode the company's brand value and profitability. Take for instance Mercedes Benz. The company launched its A-Class in early 2000, at a product development cost of USD 1.5 billion[2]. After its launch, the vehicle failed a Moose test, resulting in the recall of 2500 new cars. Subsequently, Mercedes added stability control and redesigned the car's suspension to address the problem. The cost of implementing the change was a staggering USD 250 million[2].

Figure 3 details the challenges faced by design and product engineering teams during the vehicle design stage, and the role of digital twin in addressing those.

	Vehicle Concept	Detailed Design	Design Verification
Activities	▪ Target Market Definition ▪ Competitor vehicle benchmarking ▪ Expansion of design (Feature USPs) ▪ Vehicle concept finalisation	▪ Refinement of product design (functions ,appearance, styling, configuration parameters) ▪ Development of tools and equipment to be used in commercial production ▪ Simulation tests to align the product prototype with the desired performance	▪ Feasibility and validation of detailed design through production of vehicle in small lots ▪ Physical testing of the vehicles (road tests under various climate conditions) ▪ Marketing activities (collaterals, teasers, press, media etc.)
Challenges	▪ Designers need to deal with the variety of data which is scattered across the organisation. ▪ Integration of information from previous generation vehicles (customer usage of features, feedback, failures) is traditionally missing at this stage. ▪ This stage in current context is more centred around designers than the end customers in the industry	▪ Refinement of product design involves multiple iterations of simulation tests which are time consuming and often lacks comprehensive coverage of scenarios under real environment conditions. ▪ Any alterations in the design in the later stages impacts multiple tracks of design including (tools, equipment, material sourcing , launch timelines)	▪ Small volume trial production to confirm the feasibility of design extends the timelines of product launch and add burden on company's balance sheet. ▪ It is too late a stage for the company to work retrospectively , if they need to accommodate any major change in the design.
Role of Digital Twin	▪ Digital twin can potentially integrate all the data between previous generation vehicles and current vehicle concept in its digital model. ▪ Communication between designers, stakeholders and end customers (product clinics) can be more interactive and faster ▪ Data led decision making to finalise the vehicle concept can be enabled in the organisation.	▪ Digital twin is expected to hold the complete data of product lifecycle. Leveraging digital twin at this stage can bridge this data gap to improve the performance of simulation tests. ▪ Reusability of proven models and simulations can enable rapid assessment of change impacts and early discovery of issues	▪ Digital twin can potentially integrate all the data between previous generation vehicles and current vehicle concept in its digital model. ▪ Communication between designers, stakeholders and end customers (product clinics) can be more interactive and faster

Figure 3: A snapshot of the product development life cycle, its challenges, and the role of digital twin in mitigating them

Vehicle Manufacturing

More than a century ago, Henry Ford's innovation reduced the time to build a car from more than 12 hours to two hours. Since then, the industry has seen multiple disruptions and innovations. Now a car comes out of the assembly line every 30 seconds, and not all of them are 'black'. The machine under the hood has evolved from a modest mechanical marvel to a complex and intelligent system comprising an array of technologies, electronics, and materials.

A fast and smooth manufacturing process depends on the robustness of resource management, production plan, and process control. Today, models and variants in production have increased manifold to keep up with the demand for customized vehicles. The pressure to improve Overall Equipment Effectiveness (OEE) parameters like 'first time through', is forcing leading automobile manufacturers to consider digital manufacturing. Well-executed digital adoption is now emerging as a critical success factor for the industry. This involves gathering and analyzing extensive data in a virtual context to enable superior, and in many cases, predictive decisions.

Figure 4 details the classic challenges in the vehicle manufacturing cycle and how a digital twin can help alleviate them.

	Challenges in Automotive Manufacturing Value Chain			
Challenges	Deep personalisation, autonomous driving and electric cars are adding complexity to the current manufacturing facilities. These facilities are still driven by conventional fixed conveyor belts	Skilled labour shortage in manufacturing sector (22% skilled manufacturing workers will be retiring in next 10 years)[4]	Machine down time during production hours (1 minute of downtime costs $22000[5] due to unexpected stoppages)	178 work related accidents every 15 seconds, and 374 million non-fatal injuries every year is recorded in the manufacturing sector. Zero incidents is the goal.[6]
'Role of Digital Twin' in the Potential Solutions	Automakers are considering flexible-cell manufacturing[3] as an alternative; where automated guided vehicles (AGVs) will transport car bodies individually only to those assembly workstations that are relevant to the specific model. All equipment (including machines, AGVs, and tools) on the shop floor and in the logistics area are connected and continuously send status and location data to the factory's digital twin. There the data is processed in near real-time and used to centrally steer all the operations on the shop floor. These intelligent systems can tell AGVs which workstation to approach and how to react to problems.	Digital twin is already seeing large deployments in training the workforce by providing real-time, on-site, step-by-step visual guidance on tasks such as product assembly, component design, machine operation, etc. Augmented Reality (AR) also referred as the "skin" of the digital twins is catching up the trend to augment the capabilities of the operator to reduce the stress and manage variability on the shop floor. This technology provides a detailed experience of the internal features of the equipment/machine to the operators , that would otherwise be difficult to see, thus enhancing the understanding of fundamental principles of operation and design.	The digital twin can draw on experiences to predict when a certain failure or other unwanted event will occur on the machine, and it can learn how to avoid that event. Gathering real time data from the machines (sensors) and overlay this information on the digital version of the machine is the first step to observe the trends in the machine behaviour. The more machine performance data is analysed and interpreted through digital twins, the more IoT enabled maintenance strategies will be enabled and resulting in the overall performance optimisation and the avoidance of unplanned downtime.	Attaching Bluetooth beacons with sensors to assets and employees, organisations can digitally see the manager, the employees, the accidents. Information on the present whereabouts of assets can be crucial especially in manufacturing where split-second changes can be a sign of an emergency. What-if scenarios during process changes can be incredibly expensive and time consuming to predict the potential hazard scenarios. Therefore idea of using beacon data for predictive analytics on Digital Twin can improve the safety and well being of employees on the shop floor.

Figure 4: A snapshot of the manufacturing value chain, its challenges, and the role of digital twin in overcoming them

Vehicle Sales and Service

New vehicle introduction involves innovation in terms of research, engineering finesse, network planning, and marketing campaigns. It is a colossal effort that typically spans five years. Translating investments into revenue for the manufacturer, however, occurs only during the actual sale at the retail outlet. After-sales revenue from parts, accessories, and services also depends on actual sales, making the sales floor an ideal candidate for implementing a digital twin.

The modern auto sales floor is witnessing various trends and paradigm shifts. These are primarily driven by the emerging model of servitization, customer demand for superior, personalized, and omni-channel retail experience, and tightening regulatory guidelines such as the GDPR. Auto manufacturers, operating at a global scale, have an even bigger challenge of dealing with macro environmental factors and geographical peculiarities. Little wonder that OEMs are eager to leverage operational insights from customers, and vehicle (product) and channel partners, to continuously improve product performance.

Figure 5 illustrates the challenges around vehicle sales and service and how the digital twin can help OEMs tackle them faster and more efficiently.

Vehicle Sales		**Vehicle Service and Parts**	
Challenges	**Digital Twin Role**	**Challenges**	**Digital Twin Role**
Future car ownership model will be servitized, where customers will prefer to pay to the OEM based on the feature usage of the vehicle instead paying upfront for the entire vehicle	OEMs can maintain a vehicle twin of each VIN and software updates over the air (SOTA) can enable/disable features for a period of time when customer requests	Total cost of ownership (after sales ownership cost i.e. TCO) is a key criteria for customers to decide on automotive brands . Keeping TCO low from OEM standpoint is a constant challenge	Every critical part can be monitored by creating its vehicle twin. It can predict and plan for breakdowns by putting the virtual vehicle/component twin into real world environmental conditions
Number of configurable features in a car has increased and this leads to a vast number of unique combinations and special orders. Building some would result in a negative margin	Real time field insights can be captured with the help of a Digital Twin of the vehicle. It will highlight the features that are widely used and rarely used by customers	When a customer relocates or vehicle ownership changes, the service history of the vehicle gets lost due to scattered IT landscape of OEMs and their dealers.	Vehicle twin can hold the service history of a vehicle and therefore this data can be leveraged by multiple stakeholders (dealers to fix the car 'first time right' and other third parties)
Effective Customer data management is missing at the retailer and OEM end. Manufacturer and channel partners stand to loose potential revenue from customer	OEMs and dealers see boost in revenues by building a 360° view of customer. Digital twin can bring up insights on driver preferences and attributes to build this view to upsell/cross sell	Warranty claim expenses on avg. represents 2.5%[7] of total sales turnover of OEM. Reduction in warranty expenses can significantly improve the bottom line of OEMs	Warranty data when linked with the vehicle twin will highlight failure patterns. Based on this, field inspections or pro-active recalls can be enabled. OEMs gain on time, money and brand image
New as well as repeat customers visiting a dealership demands retail (B2C) like experiences. They expect an improved and personalized sales experience	Sales experience can be enhanced by closely connecting AR (skin of digital twin) with the well evolved digital twin. This can create a more interactive and immersive UX on the sales floor	Residual value of a vehicle slips due to lack of transparency of car usage history and performance. Current mindset of residual value in general is driven by market perceptions rather than actual condition of the vehicle	Vehicle twin will hold all the real-time performance data, sensor data, and inspection data along with the service history, configuration changes, parts replacement and warranty data.

Figure 5: A snapshot of the vehicle sales and service value chain, its challenges, and the role of digital twin in overcoming them

Bridging the Gap for a Connected Future

An efficient automotive product life cycle requires data inputs from various stakeholders in the value chain to effectively manage the end-to-end process. However, most of the data used or generated at each stage remains isolated and barely integrated with the subsequent stages of the product lifecycle. This leads to wider gaps between the physical products and their digitalized versions. By enabling seamless convergence of physical and virtual versions of product prototypes, shop floor, and actual vehicles on the road, the digital twin has the potential to address multiple challenges that exist in the automotive value chain today. Organizations that become early adopters of the 'digital twin' in the automotive industry will be able to unify design and manufacturing, and warranty departments under a single umbrella to reap superior gains and outperform the competition.

References

1. CNBC, Vietnam's first automaker is quickly getting ready to debut a sedan and a SUV, Sep 2018 (accessed Dec 2018), https://www.cnbc.com/2018/09/10/is-fast-fast-enough-for-vinfast-vietnams-first-automaker.html
2. Drive.com https://www.drive.com.au/motor-news/milestones-mercedesbenzs-aclass-mistake-20140403-3620e
3. BCG, Will Flexible Cell Manufacturing Revolutionize Car making? Oct 2018 (Accessed Dec 2018), https://www.bcg.com/publications/2018/flexible-cell-manufacturing-revolutionize-carmaking.aspx
4. Forbes, U.S. Manufacturing Labor Shortage: How To Make Your Company A Happy Exception, Mar 2017 (accessed Dec2018) https://www.forbes.com/sites/maryjosephs/2017/03/15/u-s-manufacturing-labor-shortage-how-to-make-your-company-a-happy-exception/#190cfda17e13
5. Due.com https://due.com/blog/understanding-the-financial-cost-of-downtime-in-manufacturing/
6. Unric.org https://www.unric.org/en/latest-un-buzz/29758-every-15-seconds-a-worker-dies-from-a-work-related-accident-or-disease
7. Warranty Week, Automotive OEM Warranty Report, Apr 2018 (accessed Dec 2018), https://www.warrantyweek.com/archive/ww20180405.html

About The Authors

Munish Sharma

Munish Sharma is heading Customer Experience Management (CEM) value engine of the Innovation and Transformation Group at TCS UK & Ireland. He has over 17 years of automotive industry experience focusing on digital transformation of manufacturing industry. He completed his bachelor of engineering degree in industrial production and specialization in supply chain from Indian Institute of Technology, New Delhi.

Joe Paul George

Joe Paul George is a Consultant with the Customer Experience Management (CEM) value engine of the Innovation and Transformation Group at TCS. He has over eight years of experience working in the automotive industry and has a postgraduate diploma in management, specializing in manufacturing and operations.

Contact

Visit the Manufacturing page on www.tcs.com

Email: manufacturing.solutions@tcs.com

Subscribe to TCS White Papers

TCS.com RSS: http://www.tcs.com/rss_feeds/Pages/feed.aspx?f=w
Feedburner: http://feeds2.feedburner.com/tcswhitepapers

About Tata Consultancy Services Ltd (TCS)

Tata Consultancy Services is an IT services, consulting and business solutions organization that delivers real results to global business, ensuring a level of certainty no other firm can match. TCS offers a consulting-led, integrated portfolio of IT and IT-enabled, infrastructure, engineering and assurance services. This is delivered through its unique Global Network Delivery Model™, recognized as the benchmark of excellence in software development. A part of the Tata Group, India's largest industrial conglomerate, TCS has a global footprint and is listed on the National Stock Exchange and Bombay Stock Exchange in India.

For more information, visit us at www.tcs.com

TCS Design Services I M I 12 I 18