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Intensity

Digital Twin: Supply Chain Visibility

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Team Intensity:

Mr. Sunil David, [Regional Director IoT, AT&T- India (Mentor)]
Abhishek
Saloni
Bhupesh
Raj
Hanuman
Soham

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Goal

To emphasize the importance of building a digital twin of the Physical Supply Chain using technologies like IoT, AI/ ML, Blockchain etc. that will enable the enterprises to unlock data from existing systems and thereby, strengthen and improve the visibility of the Global Supply Chains to manage disruptions and expand markets.

Context Setting

A Supply Chain is an entire system of producing and delivering a product or service, from the very beginning stage of sourcing the raw materials to the final delivery of the product or service to end users. Supply chain lays out all aspects of the production process, including the activities involved at each stage, information that is being communicated, natural resources which are transformed into useful materials, human resources, and other components that go into the finished product or service.

Various challenges in SC

There are a variety of factors which increase the costs throughout the Supply Chain.

- Rising price of fuel to transport goods by road, sea or air
- Increasing commodity prices raising the cost of raw materials
- Higher labour costs from suppliers and manufacturers
- Complex international logistics leading to higher charges for storage, transfer and management of products

There is an increase in complexity in the Supply Chain due to multiple channels to market.

- eCommerce websites selling directly to consumers require fast last-mile delivery and local logistics.
- Traditional retailers and wholesalers need large storage locations close to major metropolitan areas, combined with accurate inventory control to ensure product availability.
- Third-party marketplaces like Amazon require a deep understanding of fulfilment options and close compliance with their terms and conditions.
- Drop shipping retail requires fast international services so that consumers receive goods quickly.

Today consumers have more choice than ever. These changing consumer's demand drive the need for improved speed, quality and service.

- Consumers want retail goods immediately and online goods within a few days.
- Products must meet the quality requirements demanded by consumers.
- Raw materials, goods and finished products must meet safety and other compliance regulations mandated by law, in all countries where they're available.
- The environmental sourcing of goods is becoming more important to ethically-aware consumers.

How COVID 19 has amplified the challenges

COVID-19 is probably the biggest disruption to Supply Chains that we've seen since World War II. It's affecting the entire globe. What makes the impact of COVID-19 so remarkable is how it is affecting every aspect of the Supply Chain, complicating both upstream and downstream supply lines. Companies are having trouble acquiring the materials needed to make products, and they are struggling to ship their products to stores and wholesalers. Unlike other disruptions, COVID-19 is impacting virtually every single aspect of Supply Chains.

There's now going to be a much bigger focus on building resilience, contingency plans, and risk assessment into Supply Chains

- **Supply Shock** - There were disruptions to the availability of goods sourced from China; both finished goods for sale and products used in factories in developed markets.
- **Demand Shock** - As the pandemic crisis deepened and nations have begun instituting lockdowns, Supply Chains have been experiencing something completely new: systemic demand shocks, where people are stocking up on consumer staples in order to comply with restrictions on movements, in some cases buying months' worth of goods in a single day.

The economic impacts are beginning to be felt, and many economists are predicting a deep recession of unknown length. Indeed, while some Supply Chains are spinning incredibly hard to keep up, many automotive are being forced to ramp down.

Most companies across the globe have been working to make their Supply Chains leaner. The emphasis had been on minimisation of costs and "just in time" deliveries. This has led to reduction of inventory buffers and left no room for adequate buffers or safeguards. The vulnerabilities of this system have been brutally exposed by Covid-19.

There are three impact areas which are majorly affected due to the n-CoV which are:

1. Workforce: To limit the impact of coronavirus, the government in developing nations like India, has already advised their employees to stay at home. Some of the industries depend on other industries for goods in which the Supply Chain has disrupted due to n-CoV. Now, the industries have very less workforce to meet the customer demands.

2. Products: The n-CoV has transformed the competitive landscape. Suppliers are at risk to lose their market value and share as clients are now seeing the other options when they are not receiving the good products or on time.

3. Costs: There has been an increase in the costs of the products due to increase in the shipping charges of products and industries are now also meeting their financial objectives. There is an increase in some of the products due to the n-CoV effect as it disrupts the Supply Chains.

According to a report on the Indian pharmaceutical industry, the source of APIs is a crucial part of the pharma industry's strategic plan to combat the COVID-19 pandemic. The majority of APIs for generic drug manufacturing across the globe are sourced from India, which also supplies approximately 30 percent of the generic APIs used in the US. However, Indian manufacturers rely heavily on APIs from China for the production of their medicine formulations, procuring around 70 percent from China, the top global producer and exporter of APIs by volume.

The impact of the SARS-CoV-2 coronavirus outbreak has exposed the dependency of the Indian pharma sector on China for its API procurement. Supply chain disruptions and product exportation restrictions from India resulted from manpower shortages in China's manufacturing plants. This was caused by the quarantine policies adapted and adopted by different provincial governments in China in response to the virus. Supplies were further impacted by the disruption of logistic and transportation systems, restricting access and movement of products to and from ports.

Supply Chain Resilience

In today's increasingly dynamic and turbulent world, one where the Supply Chain plays an increasingly more important role, numerous events occur each day that threaten to disrupt operations and jeopardize the ability to perform effectively and efficiently. These events include natural and man-made disasters such as equipment failures, fires, labor disputes, supplier defaults, political instability, etc.

One approach to dealing with disruptions is the development of Supply Chain systems that are resilient. Supply chain resilience is the Supply Chain's ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance.

The resilient Supply Chain requires two critical capacities: the capacity for resistance and the capacity for recovery. The first, resistance, defines the Supply Chain's ability to delay a disruption and reduce the impact once the disruption occurs. The second, recovery, defines the Supply Chain's ability to recover from a disruption.

Resistance capacity is the ability of a system to minimize the impact of a disruption by evading it entirely (avoidance) or by minimizing the time between disruption onset and the start of recovery from that disruption (containment).

Recovery capacity is the ability of a system to return to functionality once a disruption has occurred. The process of system recovery is characterized by a (hopefully brief) stabilization phase after which a return to a steady state of performance can be pursued. The final achieved steady-state performance may or may not reacquire original performance levels and is dependent on many disruption and competitor factors.

Digitization of Supply Chain

As the adoption of Industry 4.0 continues to sweep through industries around the world, the Supply Chain sector included, it brings with it never-seen-before innovative technologies that can completely transform the operations of a Supply Chain network, company or procurement process.

Two of the biggest benefits that Supply Chains can take from digitising their processes are speed and cost. Taking your operations to the next technological level can significantly cut the time it takes to make strategic decisions, whilst also boosting operational efficiency. By improving pricing and operating costs, manufacturers also believe they will see increased sales from more digital processes.

End-to-end transparency is the ultimate goal for a number of Supply Chain operators, being the crucial component to achieving significant efficiency gains. In a system with end-to-end transparency, every member of every step along the Supply Chain network will have access to all data. Digitising processes can enable improved visibility and provide real-time insights into the Supply Chain, giving people along the chain full control.

During the COVID-19 pandemic, countless Supply Chains have been crippled around the world due to their outdated systems. Traceability can fall apart when certain aspects of the network have to close due to unforeseen reasons. Many processes that revolve around deliveries still run with a face-to-face, paper-based signature. Whilst social distancing measures are in place, this can be difficult - if not impossible - to carry out, causing further disruptions to Supply Chains. Using a digital approach to these typical systems can eliminate the need for face-to-face interactions, improving business both during and after the COVID-19 pandemic.

Industry 4.0 driving the change

Industry 4.0 is fast transforming how businesses manage their key functions. Digitalization — aided by disruptive new technologies such as IoT, AI, big data & analytics, machine learning, automation and robotics, cloud computing, blockchain, 3D printing, etc. and the explosive growth of smart devices — is leaving no segment of the business untouched.

Key benefits in Supply Chain 4.0 will be:

- Going digital enables companies to track the entire Supply Chain in real time, such as finding out the exact location of goods (on order, in transit, or in a warehouse). Advanced solutions easily track inventory by combining updates from Supply Chain partners with IoT data. This improves order accuracy and ETAs (minimizing out-of-stock situations), enhances lot and batch control, optimizes inventory, and lowers associated costs.
- Advanced machine learning algorithms help to predict demand for a particular item more accurately by analyzing data (from sensors, social network trends, weather, etc.). They also provide probability distributions of the expected demand volume as opposed to providing a single forecast number. This helps enterprises to calculate both the upside potential as well as downside risks involved in the Supply Chain and plan accordingly.
- A fully integrated, digital Supply Chain software enables information to flow seamlessly between suppliers, manufactures, and customers, taking collaboration to the next level. Being a shared platform, it breaks silos and transforms planning into a continuous process.
- An interconnected platform also lowers lead times through better communication, as suppliers can provide warnings early, increasing a company's responsiveness to risk.
- Digitalization can significantly improve warehouse management capabilities — especially with regard to Supply Chain inventory and transportation logistics. For example, sensors can track goods in real time, and accurately predict how long it will take for a consignment to arrive. Such real-time tracking ensures on-time pickup and delivery. RFID technology can predict the exact location of a product, even its exact position inside a truck.
- "Thinking" Supply Chains can "learn" to recognize risks and change their Supply Chain parameters to mitigate such risks. They continuously evolve and learn to handle many exceptions without the need for any human involvement, except in case of any unforeseen risks, when human intervention is required to determine the next course of action.
- Advanced Supply Chain solutions integrate data from suppliers, service providers, etc. in a "Supply Chain cloud", ensuring that all stakeholders take decisions based on the same facts. Such end-to-end, real-time visibility will enable companies to respond more swiftly to disruptions in real time and minimize risk.

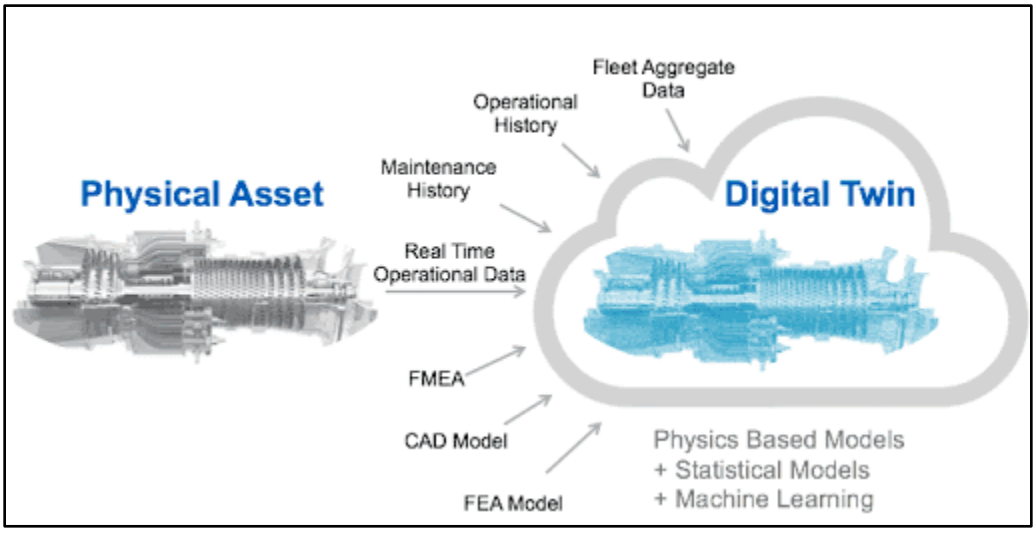
Looking at the current scenario, where Industry 4.0 is about to play a crucial part in transforming the logistics sector, in order to ensure real time visibility of Supply Chains, Digital Twins looks at an optimized solution. The use of various technology devices collaborating in a network is the feasible chance of coping up with unexpected disruptions in the operations and visibility of the Supply Chains across industries.

Digital Twin

A digital twin is a digital replica of a living or non-living physical entity. Digital twin refers to a digital replica of potential and actual physical assets, processes, people, places, systems and devices that can be used for various purposes.

Digital twins are today coming of age. Fueled by the confluence of progress in the internet of things, big data, cloud computing, open APIs, artificial intelligence, and virtual reality, once-static digital models and simulations can now truly come alive in real time to help predict future situations, the state of physical things, and even the world around us.

Today, the engineering, manufacturing, energy, and automotive industries are leading the way in leveraging digital twins to manage their most critical assets, followed by healthcare, the public sector, and even consumer retail. As the requisite technologies continue to become more readily accessible, the logistics sector is only just now beginning its digital twin journey and early examples of the first Supply Chain facilities and logistics hubs developed using digital twins are beginning to emerge.



While the digital twin concept has existed since the start of the 21st century, the approach is now reaching a tipping point where widespread adoption is likely in the near future. That's because a number of key enabling technologies have reached the level of maturity necessary to support the use of digital twins for enterprise applications. Those technologies include low-cost data storage and computing power, the availability of robust, high speed wired and wireless networks, and cheap, reliable sensors.

Technologies Enabling Digital Twin

Five technology trends are developing in a complementary way to enable digital twins:

1. **Internet of Things**

The rapid growth of IoT is one important factor driving the adoption of digital twins. IoT technologies make digital twins possible because it is now technically and economically feasible to collect large volumes of data from a wider range of objects than before using a combination of sensors and gateways.

2. **Connectivity & Communication**

The various connectivity options that can enable transfer of data between physical assets and a cloud based IoT platform are a combination of Cellular(2G, 3G, 4G), Low-Power WAN technologies (LoRa, NB-IoT etc), WiFi, Wired connectivity (fibre) and Satellite communication technologies.

3. **Cloud computing**

Developing, maintaining, and using digital twins is a compute- and storage-intensive endeavor. Developing SaaS is enabling extensive use of cloud across various industries and also reducing the costs.

4. **APIs and Open standards**

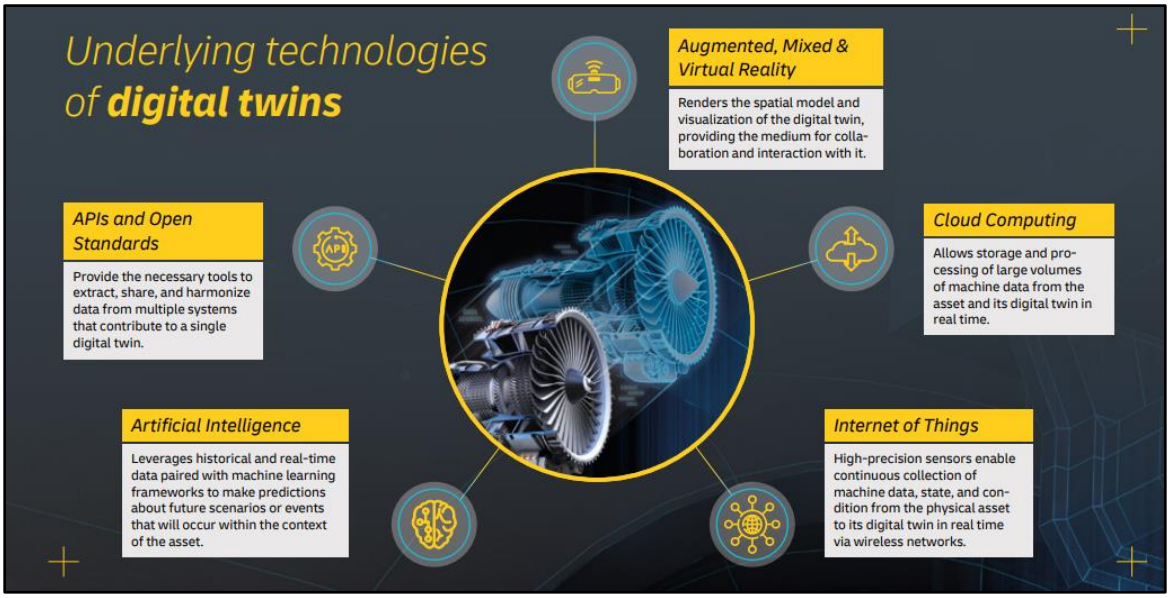
Closed, proprietary-by-design simulation tools and factory automation platforms are increasingly becoming a thing of the past. Now the availability of open standards and public application programming interfaces (APIs) has dramatically streamlined sharing and data exchange, making it possible for users to combine data from multiple systems and tools quickly and reliably.

5. **Artificial Intelligence**

Machine learning frameworks are enabling the development of systems that can make decisions autonomously as well as predictions about future conditions based on historical and real-time data.

6. **Digital Reality Technologies**

To date, most digital twins have been rendered in two-dimensional space, as the conventional computing norms of today limit us to displays on monitors, laptops, and other screens. But increasingly, augmented reality is enabling us to display digital content in 3D.



Industry Analysis

I. Agriculture

Agriculture is the primary source of livelihood for about 58 per cent of India's population. Gross Value Added by agriculture, forestry and fishing is estimated at Rs 18.55 lakh crore in FY19. According to reports, agriculture contributes around 15.4% to the Indian GDP.

The Indian food industry is poised for huge growth, increasing its contribution to world food trade every year due to its immense potential for value addition, particularly within the food processing industry. The Indian food and grocery market are the world's sixth largest, with retail contributing 70 per cent of the sales. The Indian food processing industry accounts for 32 per cent of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. It contributes around 8.80 and 8.39 per cent of Gross Value Added (GVA) in Manufacturing and Agriculture respectively, 13 per cent of India's exports and six per cent of total industrial investment.The agriculture industry is confronted with a new set of problems such as shortage of labor, pressure to feed an increasing population, and environmental degradation that are affecting the health of plants and animals and, consequently, agricultural produce. Agtech, entailing application of technology to agricultural operations and processes, is fast emerging as a solution to address these issues. Investment in digitalization in agriculture is lucrative in terms of increasing productivity, process efficiency and animal welfare. One such approach is the digital twin technology, yet to be explored in livestock farming.

Digital and analytics technologies offer a way to create value by optimizing the Supply Chain in agriculture. Companies in many industries have found they can create value by applying digital and analytics technologies to new business models and product offerings. Now, agriculture players, from farmers to end customers, are discovering that these technologies can play a role in optimizing the fiendishly complex agriculture Supply Chain.

The Digital Twin is not a new concept, but it can be applied to many industries in novel ways. In agriculture, it can be broken down into seven constituent phases:

- **Integrating Digital Platform** — Microsoft's Windows operating system fundamentally changed the way we interacted with computers. Later, Amazon fundamentally changed e-commerce. A digital platform that integrates people with the machines and data they use is the first step toward a digital representation of any industry. In agriculture, this means storing and connecting information about stakeholders, lots of data, and financial analytics.
- **Workflow Engine** — Farming is heavily driven by discrete workflows. Carefully defining the steps in this complex workflow enables us to categorize actions and their place in the value chain from farm to consumer.
- **Analytics Automation** — There's simply too much data to create useful insights based on what human beings can enter manually. Automating analytics through Internet-of-Things (IoT) and other machine-driven mechanisms can enable us to gather orders of magnitude more data from sensors and other sources without human intervention.
- **Soil, The Productive Asset** — in a manufacturing setting, one might look at raw materials as the productive asset — we take this stuff over there, assemble it into something new, and turn it into something worth more than the sum of its raw materials. In agriculture, that productive asset is the

soil. It's the constant in land-based agriculture (hydroponics represent a slight variation here, of course). An agricultural Digital Twin requires us to measure and understand everything we can about the content and capacity of the soil in which crops grow.

- **Digital Product Descriptions** — Similar to the description for soil as the productive assets, the seeds and crops that require that soil must be described — what is their expected yield? How much fertilizer is required? Sunlight? Water? If we are to simulate outcomes throughout a growing season, we must know everything we can about a potential crop so we can tweak those inputs to identify our best bet at a good harvest.
- **Weather Prediction** — the input we can't control, only predict. Is there such a thing as too much water for a given crop? Not enough? Can we make our water use more efficient by planning around a particularly wet or dry forecast? How will the effects of anthropogenic climate change affect our long-term outlook? Many companies are making massive investments in weather modelling and prediction using Artificial Intelligence (AI) and other technologies. These predictive models can be leveraged as part of our agricultural Digital Twin.
- **Persistent Stress Identification** — Last, we need the ability to identify where and how the agricultural system's resources are stressed, whether by invasive plants and animals, soil quality, pollution, or other factors. These stresses are consistent drags on agricultural output and tend to occur regularly in the same places. Managing them requires that we identify and measure them.

With this Digital Twin in hand, we can answer those "How might we" questions up above. We can simulate, plan, analyse, and improve the way we grow crops. We can maximize yields, reduce stresses on water supplies and soil quality, and help make farming a sustainable practice throughout the world.

The agriculture Supply Chain is further complicated by fragmented inbound and outbound networks. The typical agriculture Supply Chain involves three steps: from farmers to intermediate silos, from silos to transformation plants, and from transformation plants to clients. Each step requires multiple decisions.

To maximize value from agriculture supply chains, players must make multiple decisions.

Questions to consider

From farmers to silos

- What is the best sequencing in scheduling for crop collection to optimize the trade-off between yield-collection costs and implied value creation for farmers?
- How can grade mixing in intermediate silos be optimized, given an end-to-end perspective on expected profit for each incremental sale?
- How can the supply base be optimized and potentially rationalized with the trade-offs between new volumes and end-to-end collection costs?

From silos to plants

- What is the best sequencing to fill and empty silos, based on expected sales at a given point in time, transformation costs, and silo-management costs (typically run by temporary staff)?

From plants to end clients

- Which markets make it possible to fulfill 100 percent of demand to maximize profitability, given price curves at a given point in time?
- What should be the production mix in each plant (eg, share of byproducts)?
- How can logistics planning be optimized to decrease the required number of trucks and facilitate negotiation, given uncertainties on forecasted volumes?

For each decision, the number of possible solutions mires optimization analysis in complexity. Supply-chain fragmentation multiplies the number of possible flows at each step, giving rise to thousands of possible outcomes. For example, one company had more than 300 grain varieties, more than 300 silos, more than 7,000 other storage points, and more than 200,000 transportation options.

Inventory Management

Agricultural Inventory Management System makes agricultural production patterns accessible to the detail of agricultural parcels and farmers. Moreover, animal and agricultural mechanization assets and their details are recorded at village and farmer level. Thus, it becomes possible to produce agricultural statistics which leads national agricultural policies and strategies by using reliable, in-situ data and support national commerce policies by annually, semi-annually, quarterly and monthly periods. In addition, with online up-to-date data warehouse and data mining services, on-field checks of agricultural supports; monitoring agricultural activity seasonally; planning and timing activities like expropriation and land consolidation that can harm the crops; detection of production and farmers that are affected by natural disasters are made possible. System is controlled and managed by the Control Centre.

Advances in digital and analytics technologies offer a way to optimize the agriculture Supply Chain. The agriculture industry is capturing more data than ever, on everything from agronomy to the weather to logistics to market price volatility. Data storage capacity has increased, storage cost has plummeted, and computational power has grown. Meanwhile, both predictive data science and prescriptive optimization techniques have matured and gained visibility.

One compelling way to use digital and analytics technologies is to create a digital twin of the physical Supply Chain—from farmers to end customers—and use it to run virtual simulations and optimizations. Digital twins can include all elements of the Supply Chain and its interfaces, including procurement, production, inventory points, transportation, warehousing, and points of sale for finished goods. Players can calibrate mathematical models to include a variety of objective functions, such as profit, throughput, cycle time, or inventory optimization, depending on the organization's needs.

The value of the digital twin lies in its robust predictive power. It uses algorithms based on artificial intelligence to explore all possible planning and scheduling combinations and variables—for example, lot sizes—while performing multivariate function optimization within user-defined constraints. Planning and scheduling optimizers can then be rerun in real time when unexpected events occur. For example, rush orders or demand changes can be immediately integrated into a revised schedule.

The digital twin also offers rapid scalability, providing initial insights quickly as it adapts dynamically to user needs. Its agile approach allows for speedy digitization, starting with a minimum viable product covering 80 percent of user needs in two to three months and then continuously updating as those needs change. Short development cycles further ensure that solutions evolve quickly.

Agricultural products are sent to the farmers mainly through production, transportation, storage, sales and other stages. In the production process of agricultural products, the entire items in the product line including raw materials, products, semi-finished products and finished products should be identified and tracked to achieve a balanced and steady production. Each agricultural product is labelled with an RFID tag encoded with the EPC. The EPC code contains the information of products such as product name, manufacturer, grade (classification), and place of origin, net weight, batch number, production date, and shelf life and so on.

When the processing plant products are shipped after storage, RFID/EPC tag information in fixed locations RFID can be read into the wagon inside the product variety and quantity information. People can order this information, once found error, return the working personnel and processing factory communication; if shipment is correct, then classify products. Each batch of agricultural products will be stacked together and it is convenient for storing and linking goods.

In the transportation stage of agricultural products, installing GPS positioning systems on the vehicles enables the managers to know the location and state of the vehicles that transport the agricultural products and adjust driving direction timely in an emergency. At the same time, installing wireless data acquisition systems on the vehicles can not only learn the basic information and quantity of the goods, but also detect and prevent the lost and stolen goods during the transportation.

The application of the internet of things in the stage of agricultural products' sale can be reflected in the statistics, security and validity monitoring forms. Farmers can determine whether the agricultural product is expired according to the production date EPC tags and then judge its quality. When the accident occurred in agricultural products, manufacturers, distributors, or farmers can find the final consumer by traceability system and find the places that caused problems. This will help form a chain of efficient management and query.

Supply Chain Visibility

Modern-day technologies have introduced the concept of end-to-end traceability, with a foundation built on the internet of things, big data, analytics, mobility, and pervasive computing. Nevertheless, variations in geography and environmental conditions make the tracking of agricultural commodities highly complex. The agricultural supply ecosystem needs to embrace technologies that provide visibility into all transactions and monitor any risks of disruption.

Traceability enables the capturing of all handshakes, hand-offs, and value-added processes performed on the product as it moves from field to fork. It adds a sense of responsibility, making the owners of each step accountable for their actions.

Asset Tracking

Digital twins can be used to optimize stocks and to track and monitor them through geolocation. Digital twins enable companies to meet their Supply Chain partners' requirements to the best of their abilities.

- We can use high-tech pedometers mounted on cows to very accurately sense its movements. The solution will be scalable and directly connected to a cloud services platform with advanced algorithms for predictive analytics. This creates Digital Twins of cows that will be used to remotely monitor cows and to detect when a cow is in estrus (in heat) and to monitor its health. The Dairy Activity Monitor will be able to provide multiple behaviour detection and predictions including animal heat & estrus cycles, health analysis and also provide a forward-looking prediction of the next cycle start dates. The devices learn and tune their behaviour based on the individual movements of cattle.
- Plant pest and disease identification is critical and normally a slow process. Digital twins can provide an on-the-field and on-the-fly system for fast identification of plant pests and diseases. It will be easy to use, based on an open community and peer learning platform. Starting point will be a photo of the plant part affected by the pest or disease. Coloured, clean and good resolution photos will work better in this context. The user will describe the problem he's facing based on the photos taken and his own observation of the local conditions. The picture and the problem description will form the Digital Twin of the affected plant. Based on this Digital Twin, a community of experts will provide help to the user in order to identify the pest or disease, including discussion, asking for more details or inviting other users to join in.
- Remote monitoring of the stocks of the silos of the livestock farms and optimizing the replenishment routes. It is composed of a new generation device, installed on top of the silos, and a collaborative cloud platform that provides the apps and services needed by farmers and feed suppliers. Currently, most of the farmers control the amount of feed available in the silos of the farm in a manual and risky way. On a periodic basis, they have to climb on top of the silos to make visual estimations of the stocks. On the other hand, feed suppliers have to process the replenishment orders mostly by phone calls and lack the necessary data to optimize the delivery routes and the production plans. A Digital Twin of a silo can be made available for the farmer and other authorised users. When the stocks reach a critical level, farmers receive an alarm in their mobile phones and send the replenishment orders by a simple click. Feed suppliers process the orders in an automatic way and have access to the stocks of his customers to optimize in advance the production plans and replenishment routes

- The effectiveness of farm operation is determined by the ratio of production output and input value. Focus should be on optimization of farm inputs, such as energy needed to power agricultural machinery on the fields, energy for the transport of inputs and outputs of production. Online visualization of the current position of any machinery and also history of movement in the selected period should be made accessible. The analysis is focused on monitoring activities and utilization of individual tractors. There should be also an overview for individual farmer's fields. As such it creates Digital Twins for machinery and its relations to fields. Based on these Digital Twins, it enables to track the machinery fleet in real time, to monitor the energy consumption of the crops on individual fields, to evaluate economic efficiency of the crop management treatments within the fields and to evaluate machinery passes on the soil environment, including detailed analysis of the tractor trajectories within the fields considering the site specific conditions.

Digital Twins are real-time and remotely connected to the real objects and provide rich representations of the objects and its context. Applications based on these Digital Twins enable farmers and other stakeholders to act immediately in case of (expected) deviations. The cases introduced show that Digital Twins are already used in innovative internet-based applications. The main contribution of this paper is that it has explicitly addressed the concept and the underlying mechanisms of how Digital Twins impact farm management.

It should be noticed that the application of Digital Twins as addressed, is still at an early stage of development in farm management. Existing applications mostly focus on basic monitoring capabilities or they virtualize objects at a high granularity level. Management at lower granularity levels is often still too expensive and integrated software solutions are lacking. Using generic technologies and SaaS-approaches can provide broadly affordable solutions, especially for SMEs. These developments establish a basis for the next level of virtual control: optimization, simulation and decision support based on on-line Digital Twins. Ultimately farms can become autonomous, self-adaptive systems in which smart Digital Twins can operate, decide and even learn without on-site or remote intervention by humans.

Supply Chain Sustainability

With the help of digital twin technology, companies are not only able to understand their products or processes better, but also to adapt and optimize them according to the associated customer needs. The technology also enables companies to access new business areas and drive innovation forward

Real-time data transmission not only reduces the risk of failure, but also minimizes maintenance costs. In combination with intelligent algorithms, digital twins detect faults and impending maintenance work in advance. Through continuous monitoring and real-time planning companies can assess all their decision-making possibilities and avoid imminent disruptions in the Supply Chain.

In general, this can reduce operating costs and extend the lifespan of equipment and facilities. Equipment that lasts longer automatically reduces investment costs in new machinery. For instance, a fleet manager can use multiple digital twins to monitor the location of hundreds of trucks and their current mechanical fitness, speed or fuel consumption and, if possible, intervene promptly. Situational awareness and reaction speed are significantly improved.

Installing IoT sensors can not only help the company itself, but also increase the efficiency of its Supply Chain partners and prevent possible disruptions.

Products and Services in Digital Twin

1. Polyhouse Monitoring solution
   The Bosch Polyhouse Monitoring Solution leverages the Internet of Things (IoT), machine learning (ML) and sensor technology to enable farm monitoring and maintenance within a polyhouse, anytime and anywhere. From remote crop tracking and pest threat predictions to smart alerts and expert assistance, POLYMAN provides detailed insights into plant health and expected yields across a polyhouse.
2. CoSMoS
   Cold Storage Monitoring System (CoSMoS) uses wireless sensor-based IoT technology to provide remote monitoring and tracking of produce for effective transportation and storage. It provides early warning alerts and notifications to preempt critical conditions and enables end-to-end cold chain visibility and accountability.
3. Genesis
   Our remote monitoring satellite-based solution provides farmers, growers and agronomists with end-to-end crop visibility, real-time data accessibility and in-depth insights into farm operations. Using satellite microwave remote sensing, which can penetrate through clouds, Genesis generates high-impact studies and can predict yields and analyze climatic and crop conditions.
4. Agrisense
   AgriSense solution uses LORAWAN technology - a long-range, private mesh network of sensors – to help farmers remotely access data and effectively monitor and manage their crops. This is combined with satellite technology that provides historical and real-time climatic data to generate actionable insights for the entire agriculture value chain.

Success Story of beeZon

Company Name: beeZon

Problem Statement: Climate change including high temperatures, over winter periods and intense rainfalls has affected the entire ecosystem and especially beekeeping. The timing of nectar-flows is unstable, and the natural resources are scarce. The bees are starving, or dying, and the professional beekeepers lose populations and production. Most professionals, in order to sustain their business, are forced to practice migratory beekeeping, hunting nectar flows across large geographical areas based on nothing but past experiences. But this choice comes with much cost in terms of manpower, transportations, poor supervision ability, and losses of colonies.

Solution: They provided a real-time continuous apiary monitoring system that enables beekeepers to remotely control their apiaries and make smart management decisions interacting with the bees as little as possible. This solution, called a Virtual Bee Consultant, creates Digital Twins of bee colonies based on a GPS-based tracking system and real-time data from various sensors including humidity, exterior & interior temperature, brood temperature and weight. This allows beekeepers remote monitoring and control over the following aspects:

I. Time management of nectar flows
II. Identifying the presence of diseases, pest infection, pesticide exposure and toxicity
III. Insight of colony status, colony dynamics and colony hygiene
IV. Inspection of queenless and swarming states
V. Food storage reserves' management
VI. Antitheft mechanism and tracking system

II. Manufacturing

Manufacturing has emerged as one of the high growth sectors in India. Prime Minister of India, Mr Narendra Modi, had launched the 'Make in India' program to place India on the world map as a manufacturing hub and give global recognition to the Indian economy. India is expected to become the fifth largest manufacturing country in the world by the end of year 2020. The Indian Manufacturing sector currently contributes 16-17% to GDP and gives employment to around 12% of the country's workforce. Government aims to achieve 25 per cent GDP share and 100 million new jobs in the sector by 2022. The manufacturing sector of India has the potential to reach US$ 1 trillion by 2025 and India is expected to rank amongst the top three growth economies and manufacturing destinations of the world by the year 2020.

As per the report of India Brand Equity Foundation, India has become one of the most attractive destinations for investments in manufacturing. With the help of Make in India drive, India is on the path of becoming the hub for hi-tech manufacturing as global giants such as GE, Siemens, HTC, Toshiba, and Boeing have either set up or are in process of setting up manufacturing plants in India, attracted by India's market of more than a billion consumers and increasing purchasing power. In the midst of COVID 19, the time has again come for India to become self- reliant. Many initiatives have been taken by the Government of India very recently, one of them being the Atma Nirbhar Bharat Abhiyaan initiative.

Supply Chain is an extremely important aspect of this above-mentioned sector and the time has come to overcome the challenges if the pace of the industries have to be maintained and to increase the industrial base in the country. One of the main challenges in the Supply Chain is the visibility of the entire Chain. Though much effort has been put into action but still it continues to be a pain point. With the introduction of Industry 4.0, here in this report it has been shown how one of the important next generation technologies, Digital Twin, can help in increasing the visibility of the chain and tackling the challenges.

Inventory Optimization

Inventory is the array of finished goods or goods used in the production held by a company. Inventory is classified as a current asset on a company's balance sheet, and it serves as a buffer between manufacturing and order fulfilment.

Inventory is generally categorized as raw materials, work-in-progress, and finished goods. Raw materials are unprocessed materials used to produce a good. Examples of raw materials include aluminum and steel for the manufacture of cars, flour for bakeries production of bread, and crude oil held by refineries.

Work-in-progress inventory is the partially finished goods waiting for completion and resale; work-in-progress inventory is otherwise known as inventory on the production floor. For example, a half-assembled airliner or a partially completed yacht would be work-in-process.

Finished goods are products that have completed production and are ready for sale. Retailers typically refer to this inventory as "merchandise." Common examples of merchandise include electronics, clothes, and cars held by retailers.

Supply Chain ensures and maximizes customer value and achieves a competitive advantage. Inventory plays a significant role in Supply Chain functionality, and it is one of the major parts of the total cost to the Supply Chain. Inventory optimization is the one that plays a major role in maximizing customer value. The optimal inventory control methodologies intend to reduce the Supply Chain cost by controlling the inventory in an effective manner, such that the SC members will not be affected by surplus as well as shortage of inventory.

Inventory Optimization by Different Platforms

Machine Learning and Analytics:

Machine Learning (ML) techniques are used for predicting the future state of inventory requirements (demand forecasting being the most popular use case). ML algorithms predict future behavior based on past occurrences and their associated environment.

Control Tower:

Control Towers can integrate and aggregate key information from inside and outside the enterprise regarding inventory information from all internal ERP, TMS, WMS, and other inventory planning systems and provides exact inventory requirements for optimal Supply Chain operations and provides a clear visual about the optimized inventory on the dashboard.

Digital Twin in Manufacturing Inventory Optimization

It is always good to have a proper inventory management system in order to get a better optimized manufacturing inventory. The capabilities of using the Digital Twin to improve inventory management now create the possibility for businesses of all sizes to monitor inventory in real-time. Manufacturing systems can leverage present available 3G, 4G, broadband and other technologies to construct Digital Twin for inventory optimization. Here are some ways that Digital Twin improves inventory management:

- **Real-Time Communication -** One of the fundamental benefits of deploying an inventory management system in any manufacturing plant using Digital Twin is that communication is improved. Everything, which is a reasonably-sized unit of value in the inventory management chain, is enabled with communication capabilities.
- **Precise, Detailed, Itemized, Location Monitoring -** Knowing, in real-time, exactly where every item of inventory is located, is the new standard. Delivery services already do this very well with packages. A package that is being sent is scanned into the system, tracked while in transit, and then the delivery is recorded. With the expanding Digital Twin capabilities, combined with wireless data transmission, this will enable micro-tracking.

  Itemized inventory tracking continues through the warehousing and processing until the item is used in manufacturing, sold, or written off as a loss for various reasons. Micro-tracking is limited to items that can contain a physical RFID chip or have a barcode stamped on them or their packaging. To be cost-effective, the items must have an individual value that is sufficiently high enough to be worth using inventory tracking methods to account for them.

- **Touchless Data Collection -** The best practices for an inventory management system using Digital Twin are to have as little human intervention as possible. Data collection of the inventory items should be highly automated so that when each item passes through a scanner, its presence in inventory is tracked and recorded. When the item is used or sold, physically moving it out of the warehouse through another scanner (or at another checkpoint in the Supply Chain) reduces the inventory count for that item.
- **Manufacturing Store Management -** Digital Twin improves the operation of manufacturing store management. Store Management is about efficient use of the space and the activity that occurs in that space. Space in a warehouse is better allocated after considering the usage pattern. More frequently used items can be stored more closely to the access points to improve warehouse efficiency, and Digital Twin helps in this regard. **Equipment/Fleet Inventory Management -** If an organization's inventory includes equipment and vehicle fleets, then the Digital Twin is very useful. Tracking mechanisms using GPS locations to collect data about where the equipment or fleet vehicles are always by clearly visualizing on the Digital Twin dashboard. This data helps manage the utilization of the tracked items and helps prevent loss or unauthorized use.
- **Better Management of Lead Times -** Tracking of inventory using Digital Twin helps determine the lead times needed to assemble all the parts necessary for manufacturing. Excessive lead times

are identified in order to avoid bottlenecks caused by a critical part(s) being missing that stops the production processes.

Supply Chain Visibility

As Supply Chains grow in complexity and span different continents, companies need the right solutions to improve operational oversight. And in doing so, one of the important aspects is the visibility of the Supply Chain.

Visibility in the Supply Chain simply means knowing where an item is in the Supply Chain route, where a product has come from or even what materials have been used and where they have been sourced. Even though in general terms Supply Chain visibility is mostly associated with tracking and tracing fleet, it's actually so much more than that. It encapsulates the visibility of freight, customer experience, inventory availability, route planning, insights into delivery KPIs, and more. A Supply Chain and logistics visibility platform offers a holistic approach to ensuring visibility across different functions and value chains.

Supply Chain Visibility Challenges

Lack of Supply Chain visibility is a major problem in today's global Supply Chain; chains that often span across multiple enterprises and around the globe need visibility into actual consumer demand, inventory, shipments, and more. According to Geodis' 2017 Supply Chain Worldwide Survey, only 6% of respondents said they had full visibility. Moreover, 70% of those surveyed described their Supply Chains as being complex or extremely complex and cited this reason as to why they felt they lacked end-to-end visibility.

The various challenges faced are:

- Dynamic markets require strategic inventory management and need the flexibility to scale as demand grows.
- In the current scenario, the customer wants to be kept in the loop and end to end transparency of the delivery process.
- Information in most organizations exists in silos. The focus of this fragmentation of data is designed to serve the purposes of the individual departments in the organization instead of that of the entire Supply Chain. Accommodating the information proves to be challenging at times.
- In many manufacturing processes, there is a lack of a solution that covers the entire delivery ecosystem
- Changing demand patterns also prove to be challenging. Customers who expect shorter cycle times and are intolerant to late deliveries or mistakes are also contributing to logistical complexity. In a recent study by Deloitte, 40% of company executives identified "sudden demand changes" and "problems at delivery" account for the great expenses and disruptions in their Supply Chains.

Role of technology in SCV

The use of technology in Supply Chain management provides improved visibility and accountability. In order to bring efficiency to the total production process, it is important that a manufacturing company has clear sight into the current stage of in-production products, foresee any potential problems or delays they might face, and be able to align production schedules accordingly. The use of technology can bring the necessary transparency into the whole process. It allows the manufacturing companies to have better control over product flow and information flow across the Supply Chain. So, streamlining processes, integrating operations, and improving connectivity are the main areas that will empower enterprises to gain high levels of operational visibility.

Savvy businesses are aggressively exploring and investing in cutting edge technologies like Machine Learning, business analytics, and digital control towers to enhance Supply Chain and logistics visibility.

Machine Learning

Machine learning algorithms empower businesses to gain predictive intelligence by scanning through historical KPI-data of routes previously undertaken and 3PL providers availed. Knowledge about these KPIs empowers logistics stakeholders to gain predictive visibility.

Business/Cognitive Analytics

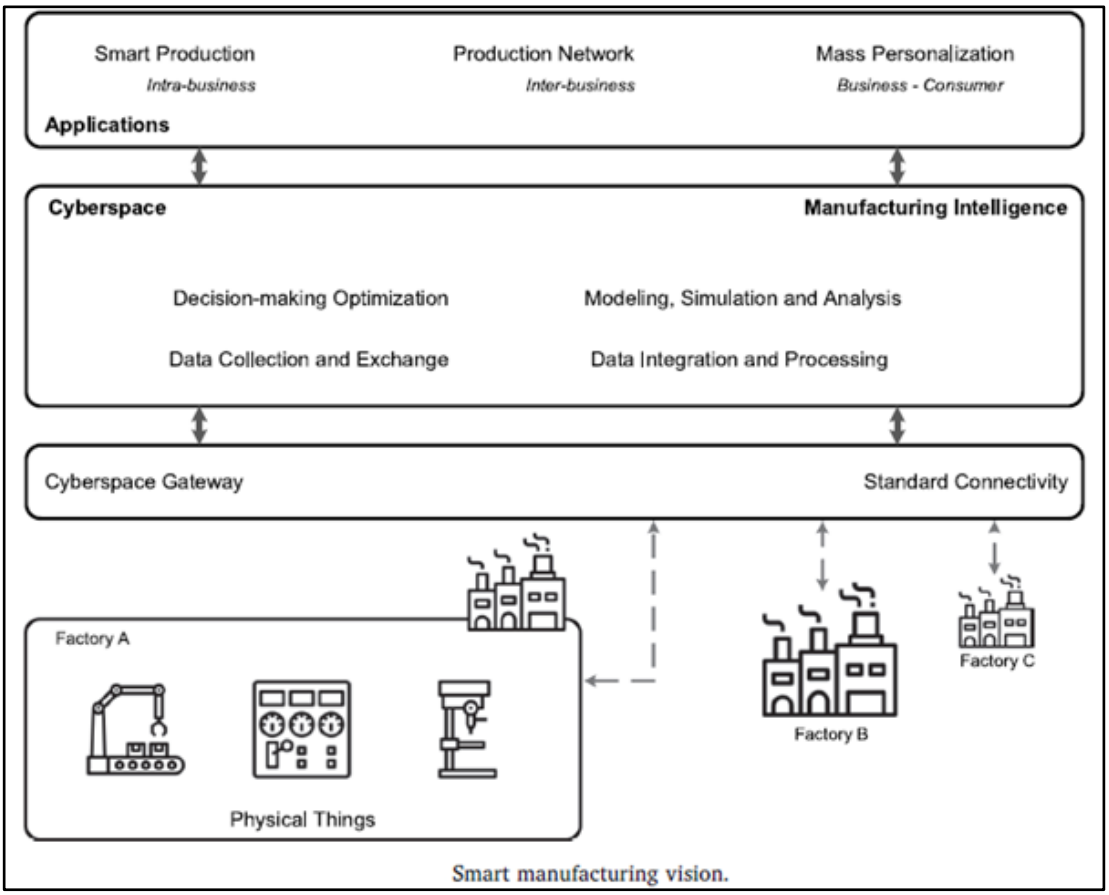
Business or Cognitive Analytics empowers businesses to mine and crunch data from disparate systems and gains critical business insights. It helps logistics stakeholders accurately benchmark KPIs, figure out inconsistencies in SLAs, identify financial holes, and other inconsistencies in the entire process of Supply Chain and logistics.

Digital Control Tower

A digital control tower (DCT) empowers businesses to gain real-time visibility that logistics stakeholders can act upon such as pick-up problems, route-wise performance, delivery delays, etc. for all orders on a single screen, drastically improving Supply Chain management.

Digital Twin in smart manufacturing's value chain

In smart manufacturing, a physical 'thing' in a factory is connected to the Industrial Internet via standard cyber gateways and abstracted as a Digital Twin in cyberspace. The cyberspace stores and processes the streamed data from connected physical objects. These data are used to model, simulate, and predict the status of each physical thing under dynamic working conditions. The pervasive use of smart technologies, such as Big Data Processing and Artificial Intelligence enables the extraction of manufacturing intelligence at every single moment of manufacturing activities. The collective intelligence in locally connected factories and cyberspace paves the way for some dramatic changes from the aspects of intra-business operation, inter-business collaboration and production model. This above mentioned is explained in the following diagram.



Smart manufacturing vision.

- **Smart Production:** Manufacturing systems augmented with cognitive intelligence can take over more and more production jobs. Connected and self-organizing manufacturing systems will tackle new manufacturing tasks with high efficiency and flexibility. The relationship between humans and machines will also change; one direction is a factory will become a fully immersed human-machine collaboration space.
- **Smart Production Network:** Connected cyber-physical production systems will form a global production network that can respond in almost real-time to dynamic changes in local production systems and external Supply Chain. A production network of adaptive and self-optimizing

production systems can enable autonomous configuration and planning of production activities for production jobs at changing scales to achieve sound economic, environmental, and social impacts.

- **Mass Personalization:** Production model will move from a push type mass production model to pull-type mass personalization Smart factories that are fully responsive to changes and demands from the factory, Supply Chain, and customer side can achieve batch size-of-1 production with high efficiency and flexibility. The ubiquitous manufacturing intelligence in distributed factories and production systems can sense, configure and collaborate by themselves based on near real-time production status and demands, which therefore provides the required agility for producing highly personalized products.

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[7] 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.

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

Asset Tracking

Asset tracking is one of the most required practices in becoming a successful organization in the market. Asset Tracking or Asset Management is the process of the tracking location of a physical asset with the help of barcode scanner, RFID (Radio Frequency Identification) or any other technology. It provides real-time data and the location of an asset. Each asset or product is given a number which is a unique identification number. After that, the number is scanned by scanner equipment and that equipment stores the data into the database.

Asset tracking is one of the most required practices to become a reputed and successful organization in the market. As it provided tremendous advantages to you and your company. The asset tracking software increases company productivity and utilizes an asset to the fullest it can be.

Challenges in manufacturing industries

1. In case of logistics and transportation, there are incidents regarding asset theft or damages. These costs at times have to be borne by the department handling the logistics.
2. Due to unexpected breakdown it costs a lot of money and productivity of the organisation
3. As the maintenance across has to be done on a regular basis, this generates a lot of cost which at times is higher than required.
4. As the record of assets and information maintained are very less, it becomes difficult to track important data such as an asset's serial or model number for future support and service uses.
5. It is challenging for an organisation to accurately capture, maintain and track equipment which also impacts the strategic decisions.

Advantages of asset tracking in the manufacturing industry

- Assets are either they are missing/stolen i.e. physically they are not available occurs because of non-efficient asset management practice & both affect taxation
- With Asset tracking, you get regular updates for an asset for its maintenance. As a result, life is extended to an asset
- As we have precise information, it helps us in making a better decision
- As we will get alerts & notifications for the asset maintenance
- Effectively schedule maintenance to minimise maintenance and repair costs
- Predict and budget for future equipment and maintenance costs
- Reduce asset downtime due to equipment maintenance or failures
- Produce reports on current and future asset values instantly
- It helps in better inventory management and streamlines compliance

- **Barcode Technology –** Barcodes are labels onto products or packages with optical machine-intelligible portrayal of data. Barcodes developed from one or two dimensions, and the latest of QR codes could empower the capacity of an extensive string of data to distinguish an object. Standardized barcode technology with its optical scanners to scan packages at any of the hubs, and empowered Supply Chain executives can maintain central data through ERP WMS or TMS.

- **RFID Technology –** RFID technology utilizes tags which contain smaller than expected hardware that are identifiable by radio waves. Tags can be as thin as paper labels or the span of keychains relying upon how much data strings it can store and the distance from which it can be read. RFID tags are comprehensively arranged into inactive and dynamic tags. Reading a RFID tag "does not" require "line-of-sight" as with the instance of barcodes. However, the "read-distance" is controlled by whether the RFID tag is dynamic or detached.
- **Active RFID –** Active RFID utilizes tags with in-built batteries that can assist stretch out the read-range to around 100 feet by radiating its data towards the reader simply like the mobile telephone. Active RFID technology discovered its application when it came to screen high-esteem packages or gear in warehouses, yards, and the railroads.
- **Bluetooth Low Energy (BLE) Based Beacon Technology -** Beacons, Bluetooth tags or BLE tags are like dynamic RFID tags. They have inbuilt batteries which furnish them with long read-ranges. The most interesting contrast amongst BLE and RFID is that beacons take a shot at Bluetooth Low Energy (BLE) technology which is very energy-productive. BLE is further a generally available convention that likewise happens to be an element show on most GSM chipsets (as it were, your cell phone), giving BLE Beacons the strategic favorable position as far as cost adequacy and versatility.

Tracking Systems based on visibility

- **Vehicle level tracking system –** It utilizes GPS/GSM based tracking devices that are wired for all time onto trucks. A GPS/GSM vehicle tracking device utilizes GPS satellite data to decide its position, and after that transmits its situation in real time through a GSM based cellular system.
- **Container Level Tracking System -** Container tracking is the way toward tracking a shipment at a container or trailer level by settling an IoT device inside or outside the container. By tracking containers or trailers, it gives visibility at a container or shipment-level, providing the need to depend on the vehicle that is conveying shipment. It takes care of the issue of continuous visibility on multi-modal transportation, tracking LCL payload, and the state of merchandise.
- **Package Level Tracking System -** Shipment or parcel tracking – the solution that uses GPS, GSM, Bluetooth Low Energy (BLE) Beacons, and Wi-Fi innovations to give visibility at a parcel level. This crossover innovation drew out the genuine importance of the Internet of Things, claiming each item on client dispatch notes would now be able to be checked as an individual unit.

Digital Twins assisting in asset tracking

The use of digital twins enables real-time communication between assets and different systems. With regard to logistics, data collection alone does not represent a major challenge. The decisive factor here is how this data must be further processed in order to offer real added value. In this context, the added value is created with the help of KPIs tailored precisely to the respective application. Depending on the sensors used, different KPIs can be determined from the same data sources in real-time, exactly as required for the respective process. This technology thus offers consider-able potential for logistics and contributes to targeted decision-making.

1. **Asset configuration –** The DT is used for modelling and simulating a production line, to evaluate its systemic Reliability, Availability, Maintainability performance (RAM performance), to finally predict its Total Cost of Ownership (TCO). It allows to assess the choice of the best design solution for the production line.
2. **Asset reconfiguration –** Similarly to the first use case, the DT is used for modelling and simulating a complex process production plant, to evaluate its systemic RAM performance, to finally predict its TCO. It allows the choice of the best reconfiguration alternative to increase the availability of the plant.
3. **Asset reconfiguration and planning –** The DT is used as a semantic data model within a web service-based control system for manufacturing systems. It forms the ground for an open, knowledge-driven Manufacturing Execution System architecture, which allows quick reconfigurations of the system.
4. **Asset commissioning –** The DT is used as a semantic data model, data analytics and advanced simulation, to make the virtual commissioning of the manufacturing system. Simulation of the system is based on a semantic data model and of a software structure that is able to analyse data in runtime. It allows a quick time to commission the system.
5. **Asset condition monitoring and health assessment –** The DT is used for the asset diagnosis, helping to assess its health status based on the monitored condition. The DT provides the data analytics in order to extract the features required for the diagnosis.

Supply Chain Sustainability

Supply chain sustainability (SCS) is a holistic view of Supply Chain processes, logistics and technologies that affect the environmental, social, economic and legal aspects of a Supply Chain's components. Typically, sustainability initiatives include identifying the source of raw materials, ensuring good conditions for workers and reducing the carbon footprint.

Today, more and more organizations are focused on sustainable Supply Chain management, with the emphasis on "sustainable. And while sustainability in the Supply Chain is trending, it's not a passing fad. It's quickly becoming a necessity for modern businesses. It will reduce costs, make companies more profitable, and help the environment. In addition to spurring sales, looking for ways to embrace sustainability helps companies save on energy, materials, and transportation. Whether it's switching to

electric-powered vehicles or funneling rain runoff into the landscaping, efforts typically pay off by reducing expenses.

But what does sustainable Supply Chain management mean for small businesses? Going green can involve anything from reducing the amount of packaging to sourcing locally or using sustainably harvested or manufactured materials. It's about reducing your company's carbon footprint, then communicating what you're doing to your target market.

The need and benefits of Sustainable Manufacturing:

- **Improved health and safety -** By becoming a sustainable manufacturing company, need for water and energy reduces a lot, minimizes waste and decreases hazardous emissions. Aside from the benefits that directly impact business, this decrease in carbon footprint can make a positive difference on the safety of the employees working in these conditions.
- **Boost workplace morale -** When employees at all levels are asked to identify and implement green manufacturing practices, it sparks an environment of collaboration and teamwork. When management recognizes these contributions, and even rewards those who go above and beyond, it encourages them to work harder and reminds them that they're making a positive difference in the industry and in the environment.
- **Access to government Incentives** - In addition to the reduction in carbon footprint, switching to sustainable practices can boost your opportunities of grants, tax credits and other incentives at both the state and federal level. Becoming a sustainable manufacturer also increases competitive ability for government contracts, since many of these contracts are only available to sustainable manufacturers.
- **Save money on energy costs -** Converting to renewable energy sources, such as wind or solar, can help stabilize your energy prices. These costs have declined steadily in the past few years. The cost of a solar panel, for example, has dropped almost 60 percent since 2011 and the cost of generating electricity from wind has dropped more than 20 percent between 2010 and 2012.
- **Increase sales –** Most millennials are focused on caring for the environment, a sentiment they incorporate in their purchasing habits. In fact, greater sections of the society are willing to pay more for products or services from brands that are committed to positive social and environmental impact. Not only will sustainable manufacturing make your business more marketable but ignoring the movement could actually harm your sales.

Energy Intensive Industries - Cement production

Dry, semi-dry, semi-wet and wet processes are the four main process routes used in the production of cement. Dry processes are considerably more energy efficient but the choice of technology usually depends on the availability of raw materials Due to the widespread availability of dry materials, a considerable share of their production in developed countries is converted into dry processes. Dry processes are also the main choice of new plants or for plants seeking to expand or upgrade.

Most of the cement industry's energy use and CO2 emissions are linked to the production of clinker, the main component of cement produced by sintering limestone and clay. The electricity needed to crush and grind raw materials, the fuel required and the finished products have a high energy demand. Reduction of the clinker content of cement through increased use of other blends such as coal fly ash or blast furnace slag. Other options are also emerging in the form of alternative cementitious materials and carbon capture and storage.

Energy Intensive Industries - Paper production

The processes used to produce pulp and to dry paper are the major energy consumers in the industry. Pulp production from recovered fibres requires substantially less energy compared to virgin pulp It is a promising option in terms of reducing energy consumption and CO2 emissions, with estimates projected to be as high as 35 percent. The amount of energy used by paper machines generally depends on pulp quality and paper grade, and can vary considerably. Integrated mills can achieve higher energy efficiency by eliminating intermediate pulp drying and using better processes.

Other Methods towards Sustainable Manufacturing

Electric motors convert electrical into mechanical power and are often part of a motor-driven system. In industrial applications, electric motor-driven systems are used for pumping, compressed air, fans, conveyance and other forms of mechanical handling and processing. Electrical motors and their controls are typically the parts requiring the most electricity in a motor-driven system, their impact on the overall efficiency of the system is often limited. This is attributable to the fact that the other system components, such as pumps, fans, valves, pipes, ducts and end-users, affect both the amount of mechanical power required by the entire system and the losses that occur during the delivery of this power, which collectively have a much more significant impact on overall energy consumption. Consequently, adopting a system approach is crucial to optimize the energy efficiency of motor-driven systems. The level of efficiency of a given system depends on both the extent to which advanced solutions are used and the system's overall design. In most cases, improving the efficiency of a motor-driven system involves the following:

- Use of energy efficient motors
- Selecting the core components – e.g. pumps, fans, compressors, transmissions, variable speed drives – with the right type and size and high efficiency
- Optimization of the design and the entire system's operation

Game-Changer for manufacturing: Bridging Physical and Digital Worlds

Digital twin technology is evolving to become the next big thing in manufacturing. With digital twins in place, manufacturers will have a solid digital footprint of their products throughout the development cycle, starting from the design phase, all the way to distribution.

With precise data and compelling analytics at their disposal, the manufacturing processes will be better controlled, offering the desired output. This will not only help improve expenditures but also reduce wastage of resources. In addition, digital twins of mass-produced goods will help with product tracking and verification, which is increasingly important in distribution, especially during urgent requirements.

As the next-generation manufacturing system, intelligent manufacturing enables better quality, higher productivity, lower cost, and increased manufacturing flexibility. The concept of sustainability is receiving increasing attention, and sustainable manufacturing is evolving. The digital twin is an emerging technology used in intelligent manufacturing that can grasp the state of intelligent manufacturing systems in real-time and predict system failures. Sustainable intelligent manufacturing based on a digital twin has advantages in practical applications. Firstly, the relevant content of intelligent manufacturing, including intelligent manufacturing equipment, systems, and services, is analyzed. In addition, the sustainability of intelligent manufacturing is discussed. Subsequently, a digital twin and its application are introduced along with the development of intelligent manufacturing based on the digital twin technology. Finally, combined with the current status, the future development direction of intelligent manufacturing is presented.

Digital twin-driven intelligent manufacturing is a hot trend and has achieved good results in life cycle management, data fusion, rapid production, intelligent forecasting, and sustainable manufacturing. Intelligent manufacturing is a deep integration between artificial intelligence technology and advanced manufacturing technology. The new generation artificial intelligence technology mainly includes cloud computing, IoTs and big data, among others. Intelligent manufacturing brings great changes to all aspects of the manufacturing industry, making it capable of learning, generating, and using knowledge.

Digital twins will pave the way toward the much-needed transformation in manufacturing, giving a massive monetary upside for manufacturers who are its early adopters**.** It not only helps manufacturers to predict the future of assets by evaluating their digital twins, but also provides better insights on product performance.

Manufacturing companies can leverage digital twins to simulate various operations in the manufacturing process. For instance, a manufacturing plant can now have a digital twin—a three-dimensional computer-generated model that is connected to all the sensors of the actual plant. This gives a real-time view into the plant's operations, generating volumes of complex data in real-time.

Such detailed and valuable inputs will enable process engineers to visualize the operation, simulate and optimize parameters, perfect the batch design, and make assisted decision-making. Thus, they will be better equipped to control any anomaly that can occur during the manufacturing process.

Bottleneck Detection in a Production Line by Bosch*

Detecting bottlenecks and irregularities in production lines and preventing production delays, the task of the Line Bottleneck Detection application. The attached sensors transmit the data to browser-based terminals. Production staff always has an eye on the line. Different data of an entire line is visualized as heat maps.

An algorithm determines the weaknesses of the line so that the employees can react quickly to malfunctions. Production managers recognize short-term optimization potential based on the daily updated data. They can also quickly determine how failures could have occurred.

*https://www.bosch-connected-industry.com/en/applications/line-bottleneck-detection.html

Application of Digital Twin in Reliance Industries Ltd.

GE's digital twins in India are in collaboration with Reliance Industries to work on their pipelines. This is a 4,000-km pipeline processing 1.3 million barrels of crude each day. On this, GE has installed 30 sensors to monitor a 2.5-km stretch at the refinery. This system predicts leakages of a litre with 80-90% accuracy and prevents them. If the leakage is going to increase, then the reliability of predicting it also increases close to 100%. The value here is in terms of saving inspection cost over thousands of kilometres and avoiding massive downtimes.

Application of Digital Twin in CNH Industries

CNH Industrial, a global producer of agricultural, industrial, and commercial vehicles, has used digital twins to optimize maintenance at its plant in Suzzara, Italy, where it produces Iveco vans. The company worked with a consultant, Fair Dynamics, and a software provider, AnyLogic, on a pilot project to improve the reliability of robot welding machines on the plant's chassis line, as depicted in figure below.

While the project was partly intended as a technology demonstrator, CNH also hoped to solve a serious reliability challenge. Its welding robots rely on a flexible copper conductor called a lamellar pack to deliver electrical current to their welding heads. But these packs have a finite life and accumulated wear can cause a pack to melt, disrupting production and damaging the robot. To determine the most efficient way to maintain these critical components, the company built a digital twin model of the line. Data for the model is supplied by the plant's production planning systems and by condition monitoring sensors fitted to each robot. Using simulation and machine learning, the digital twin forecasts the probability of component failure. This system allows the company to run what-if scenarios comparing different operation and maintenance regimes in order to optimize maintenance and spare parts expenditure while minimizing both planned and unplanned downtime and improved OEE which directly improved the sustainability of manufacturing.

III. Retail

The Indian retail industry has emerged as one of the most dynamic and fast-paced industries due to the entry of several new players. Retail industry reached US$ 950 billion in 2018 at a CAGR of 13 per cent and expected to reach US$ 1.1 trillion by 2020. Online retail sales grew at the rate of 31 per cent year-on-year to reach US$ 32.70 billion in 2018 and is expected to grow to US$ 60 billion by 2020. It accounts for over 10 per cent of the country's Gross Domestic Product (GDP) and around eight per cent of the employment. India is the world's fifth-largest global destination in the retail space. India is the world's fifth largest global destination in the retail space.

Indian market has high complexities in terms of a wide geographic spread and distinct consumer preferences varying by each region necessitating a need for localization even within the geographic zones. India has the highest number of outlets per person (7 per thousand) Indian retail space per capita at 2 sq ft (0.19 m2)/ person is lowest in the world Indian retail density of 6 percent is highest in the world. 1.8 million households in India have an annual income of over ₹4.5 million (US$63,090.00). Retailers should leverage the digital retail channels (e-commerce), which would enable them to spend less money on real estate while reaching out to more customers in tier-2 and tier-3 cities.

The organised retail market has a share of 8% as per 2012. While India presents a large market opportunity given the number and increasing purchasing power of consumers, there are significant challenges as well given that over 90% of trade is conducted through independent local stores. Challenges include: Geographically dispersed population, small ticket sizes, complex distribution network, little use of IT systems, limitations of mass media and existence of counterfeit goods.

The impact of harnessing the virtual representation platform in the consumer retail sector has been humongous. As the retail industry shifts its base from the conventional podium to IoT, the demand for digital twins has been on a rise, given their deployment to track products in the Supply Chain. Enabling digital twin information to be shared among organizations and prominent stakeholders will help businesses trace products and their related details as and when they are shipped or consumed.

Contract logistics solution provider DHL Supply Chain recently joined hands with Tetra Pack recently to implement an integrated Supply Chain solution for the latter's Singapore warehouse. Reportedly, this DHL's first smart warehouse in APAC that deploys digital twin technology to better manage physical assets.

A. Inventory Optimisation

Depending on which supermarket you usually shop at, you're likely to be familiar with self-scanning technology. More and more stores are enabling their customers to tally their chosen items with a phone app or store device as they roam the aisles. It's faster, simpler and allows customers to track their spend as they go. Along with the customers it helps the stores to track the selling patter of any product across various seasons. This will help them optimize inventory and reduce excess inventory.

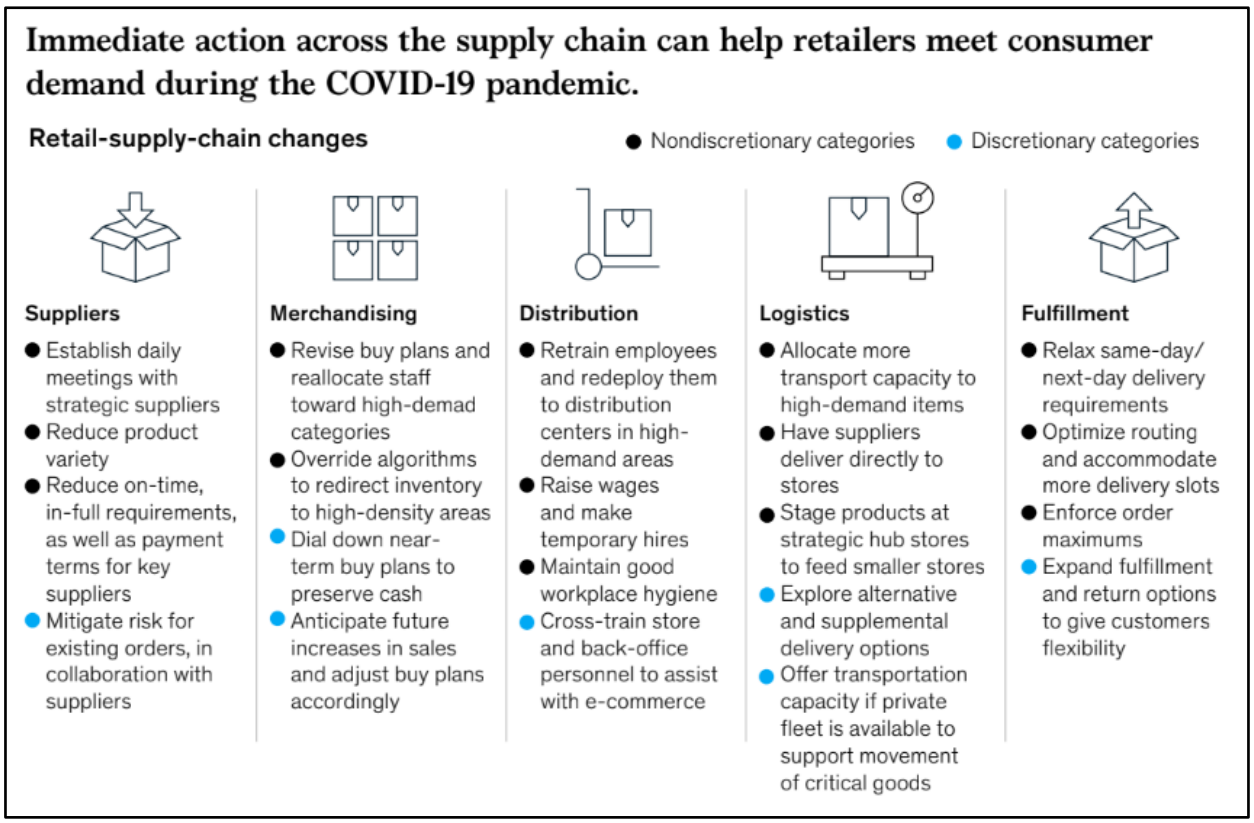
B. Supply chain visibility

Consumer products present a different set of opportunities and challenges for digital twin technologies. Instead of a few large and complex assets, consumer markets often involve millions of much simpler objects. So players in this sector have a different focus – they are exploring the development of digital twins that track the flow of products through Supply Chains, for example, or building systems that can extract valuable insights from aggregated data produced by large numbers of comparatively simple models.

C. Asset tracking

Customers using a retailer's app could log in upon entering the store. Bluetooth beacons throughout the store could identify where the shopper is and guide them to the items on their digital shopping list. As more data about the customer is received and modelled over time, and more is learnt about their shopping behaviours and habits, the more tailored we can make their shopping experience. For example, if an individual is known to be a 'grab and go shopper', then we can show them the most direct route to their shopping items, perhaps with a short diversion to products that we know they like, but haven't purchased in a while.

Other shoppers might be diverted to brands and products that data science predicts they will like, and promotions and offers can feature as 'real time' alerts when a shopper is in the right location. Of course the aim is to encourage shoppers to put more in their basket, but at the same time there is plenty of 'value add' activity for the customer. For instance, it will be possible to suggest products that will complement the items that they have in their basket – we could even go as far as pairing wine with food items!



Exploring New Avenues

The implementation of digital twins is also expected to majorly resolve the logistics-related issues for retailers and distributors. Often, retaining items past their expiry dates, goods that are not aesthetically pleasing for consumers, unsold items after sales, overproduction, and stock management errors lead to retailers ending up with unused food. In this context, digital twins are likely to be a great help – storing expiry dates electronically on a digital twin will help retailers access information about products through NFC readers, RFID readers, and smartphones, that will not only read and process the data but also generate periodic alerts ahead of time.

Retailers will then be able to have a vivid archetype of their inventories and schedule actions to redistribute food. Robust advancements in sensor technology and data science are also likely to further empower this groundbreaking confluence of physical and virtual representations, giving rise to the evolution of more state-of-the-art digital twins within the next decade or so.

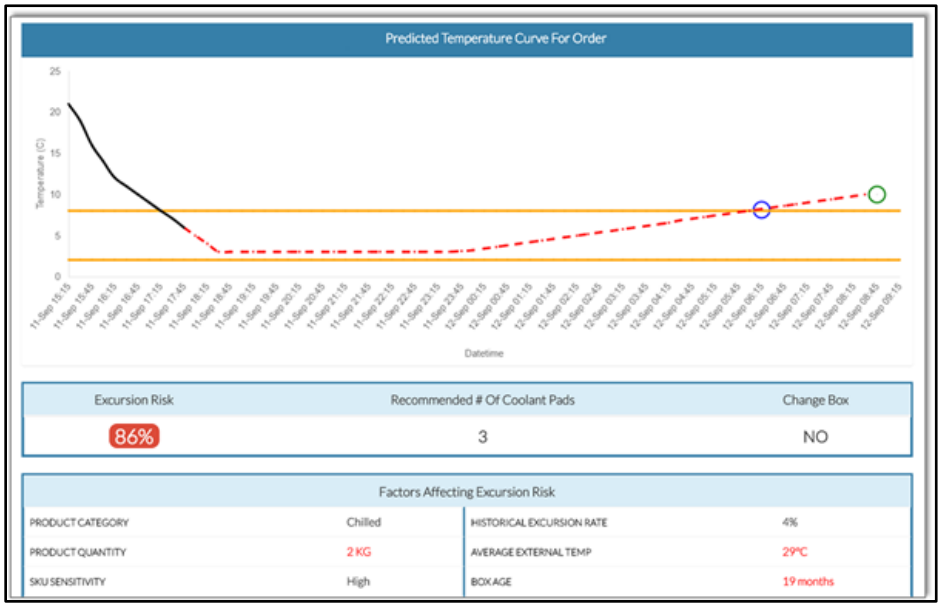
Success Story of TagBox Solutions Pvt. Ltd.

Company: Large Online Groceries in India

Problem Statement: Creating a digital cold chain to enable higher quality and operational efficiency. Improving temperature compliance of cold chain orders to enhance customer trust. Reducing cold box loss and improving utilization. Also, during the multi-hop Supply Chain operations, the cold boxes were sometimes misplaced, leading to order fulfilment issues and boxes going missing.

Solution Proposed: Each cold chain box was fitted with a Tag360TM temperature sensor and a barcode was fixed, thereby uniquely identifying it. BoxLensTM APIs were integrated with the company's ERP, giving them the ability to track temperature of every order. TagHubTM FX gateways installed at all warehouses read 1000s of cold boxes real-time while being packed, stored and dispatched.

During the transit from warehouse to DC, the sensors continue to record temperature. On arrival at DCs, TagHubTM FX scan & transmit recorded data from upto 200 boxes in a small inward scan window of 5-7 minutes. During the last mile, TagLinkTM App on delivery person's mobile phone reads temperature until the customer doorstep, thereby creating complete order health traceability. Also, throughout the chain, the boxes are read on arrival, dispatch and during transit. Hence, any missing box can be easily tracked using the last known location and all details associated with the previous order it was used to deliver.



Impact: TagBox's aggregated analytics is helping the client monitor KPIs like % orders delivered at right temperature and identify reasons for temperature excursions like cold chain infrastructure capacity, variability in SOP compliance across sites or cities and specific staff performance issues etc. The solution is expected to deliver at least 30% reduction in product spoilage due to temperature excursions and hence lower customer returns. Box loss could reduce by 80% and improvements in box utilization and rotation are expected in the medium term.

Conclusion

Adoption of Digital Twin techniques vary widely across the Supply Chain. Many companies still trade paper invoices and faxes on a daily basis. At the other end of the spectrum, a progressive few have embraced digitization and have done so not only to cut costs but to elevate the Supply Chain's contribution to growing revenues.

The maturity curve for companies applying the digital twin concept to the Supply Chain can look like this:

- Real-time mitigation—Understand which parts of the Supply Chain are under threat right now, and use digital awareness to make the best, fastest decisions possible. Start anywhere and continue to expand the digital connections when and where possible.
- Long-term optimization—Analyze historical Supply Chain strengths and weaknesses to improve overall performance. Extract best practices from areas of favorable key performance indicators (KPIs) while learning lessons from areas that aren't producing the speed, transparency, and accuracy demanded by empowered consumers.
- Strategic impact—Make the Supply Chain a strategic contributor to the boardroom. Instead of treating it as a cost center, create a Supply Chain that senses where the strongest market opportunity is, who's buying the product, and how they're using it, and uncovers global trends that can facilitate new products and services.

Many companies that work in the Supply Chain are hard-pressed to envision such a dramatic change in a short period of time. But those who study the industry say the change is indeed coming, and it will accelerate at an unprecedented rate.

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