L&T Technology Services

ENGINEERING INNOVATION AT SCALE

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From the CTO's Desk

The journey of innovation is never a linear one. It involves discussion with stakeholders to streamline and create a workable innovation model, coupled with an ability to align the innovation process with the overall strategy and success of the organization. For technology companies, there is the added aspect of keeping a tab on the exponential growth in new technologies and always staying a step ahead.

At L&T Technology Services (LTTS), we are in the middle of a very interesting phase where the pace of innovation is not only driving a relook at our whole approach to work but also redefining our overall relationship with technology.

An amusing aspect of the current phase is that globally, an unprecedented number of people and organizations–developers, tech companies, customers, academia, and other stakeholders, are all engaged, almost simultaneously, in the discovery of these new-age technologies.

While the saga of change continues apace, the challenge of differentiation persists. How does one build differentiation and that too early in the cycle when we are competing and collaborating on a much larger scale with people across the globe on similar technologies and related use cases?

Differentiation is a much sought-after aspect for all businesses. We all want to have a decisive edge over competitors while empowering our clients to adopt new technologies proactively. Though this is what we all desire, it is unfortunately not a discreet event. Building differentiation in our way of conducting business is an outcome of the ability of an organization to think and of its culture, namely the *Culture of Innovation.*

Today, our clients are involved in creating new products across segments. While it is fascinating to observe and learn from their ideation and creation of new products, it is also equally exciting, as we become part of that process indirectly or sometimes directly. Our partnership has yielded close to 1,000 patent opportunities to date, and we are confident of expediting this rate even further in the days to come.

The *Culture of Innovation* in LTTS is inspired not only by the need to build differentiators and the excitement of working with new technologies but also by working with our clients as they invest and explore newer avenues.

We have worked and continue to work on making the *Culture of Innovation* at LTTS an inherent part of the learning journey of every employee.

LTTS provides various platforms for its engineers to encourage them to ideate and contribute to filing patents. We also have dedicated programs wherein we invest in shaping these ideas to convert them into pragmatic solutions. We have forums and support systems through which subject experts can channel their guidance and mentorship to budding inventors.

Our leadership from various levels fosters the *Culture of Innovation* through the encouragement of nurturing activities. We have also placed a rewards system that recognizes employee contributions and enables investments in ideas that bloom into ready-to-market solutions. The present collection of monographs directly results from this sustained focus and contains a selection of five papers on new, innovative ideas by our engineers. We hope to pursue publishing more such collections soon to continue building on our core of innovation.

Thomas Edison often remarked, *"The value of an idea lies in the using of it."* At LTTS, we have always sought to engineer ideas into reality. The following collection offers a peek into the minds of our engineers and the inherent potential to build new solutions out of these riveting concepts.

Happy Reading!

Ashish Khushu
CTO, L&T Technology Services (LTTS)

L&T Technology Services

Battery Thermal Management of an Electric Vehicle Using Pulsating Heat Pipe

VIPUL M. PATEL

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Abstract

Every year, air pollution kills about seven million people worldwide. Rising global concerns about the air pollution level combined with the growing scarcity of fossil fuel reserves and the cumulative climate challenges posed by emissions from hydrocarbon combustion have therefore emerged as the key driver for the transition towards Electric Vehicles (EVs) over conventional alternates.

However, the EV transformation journey has its own set of challenges with optimal battery thermal management as a key component of the matrix.

Long-term efficient battery performance in an EV is vital for the widespread adoption of these vehicles. This can only be achieved within a pre-defined operating temperature range. Fast charging or discharging, extreme ambient conditions, and high current application can have a significant impact on battery life, and therefore, impede the forward momentum of this vital technology offering.

The current monograph discusses the significance of thermal management of EV batteries with active and passive cooling techniques. To address the battery thermal management issue, a Pulsating Heat Pipe (PHP) constructed battery thermal management system is proposed due to its lightweight, simple and compact construction with low manufacturing cost. A noise and vibration-free operation with no external power requirement is an added benefit from the proposed solution.

Introduction

To meet the challenges posed by environmental pollution, fossil fuel depletion, and global warming, automotive manufacturers worldwide are transitioning towards adopting Hybrid Electric Vehicles/Electric Vehicles (HEVs/EVs). The conventional internal combustion engine is rapidly being replaced by battery-driven alternatives in EVs to reduce emissions.

In this transition phase, Lithium-Ion batteries emerged as the ideal candidate for EVs due to their long lifespan and high energy storage capacity. The overall efficiency of an EV has therefore come to depend on the performance of its battery.

However, current technology can only ensure optimal battery performance if its operating temperature is maintained between a range of 59°F - 104°F. Fast charging or discharging process, extreme ambient conditions, and high current application can result in a significant amount of heat being generated within the battery, which can lead to rapid energy capacity degradation, performance reduction, and overall shorter battery life **[Figure 1]**.

Studies have found that a 50°F - 59°F temperature non-uniformity within battery modules can result in a 30 percent to 50 percent reduction in overall battery efficiency. With this scenario in mind, we must henceforth focus on ensuring efficient thermal management of the EV battery, as these continue to be expensive.

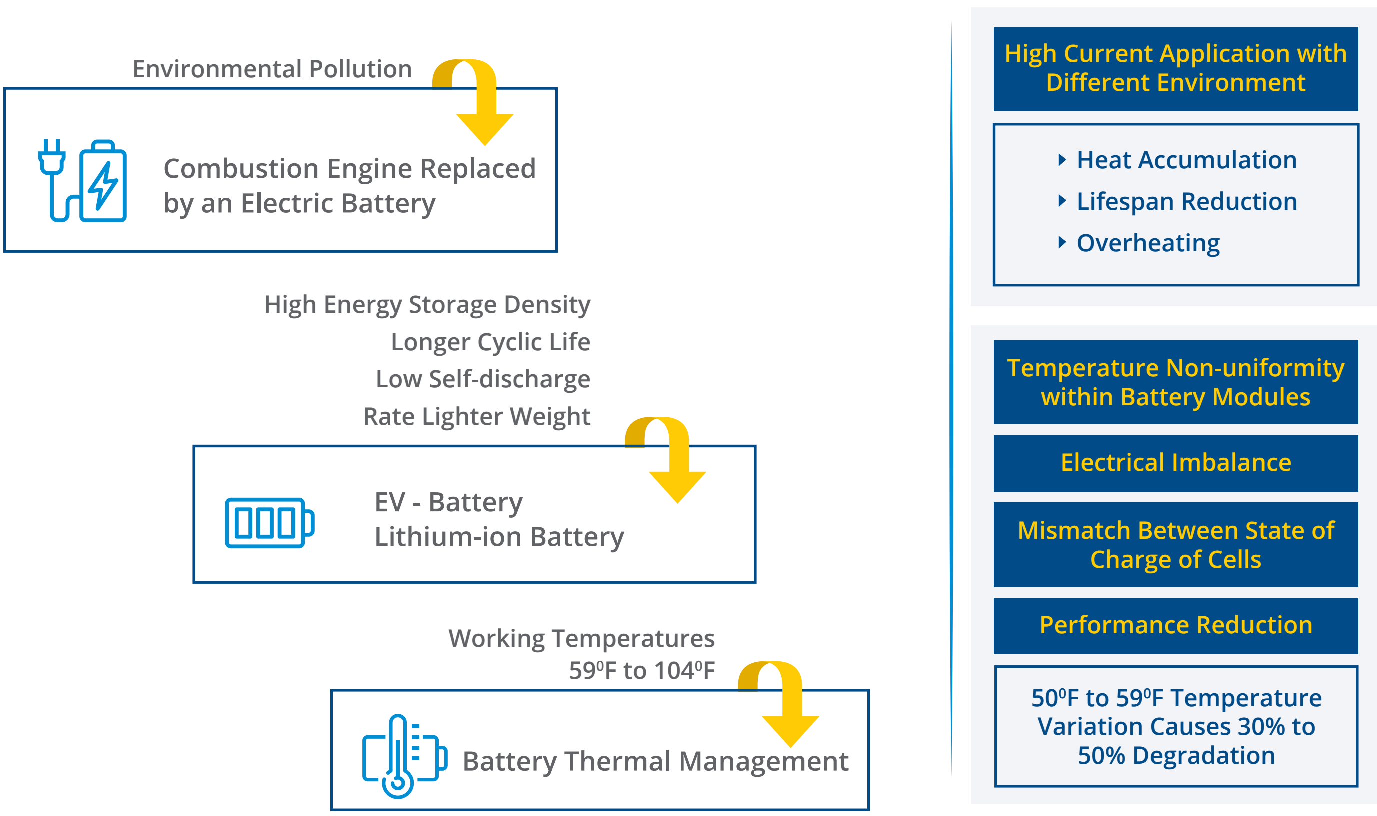


Figure 1: The Importance of Battery Thermal Management

Battery Thermal Management Techniques

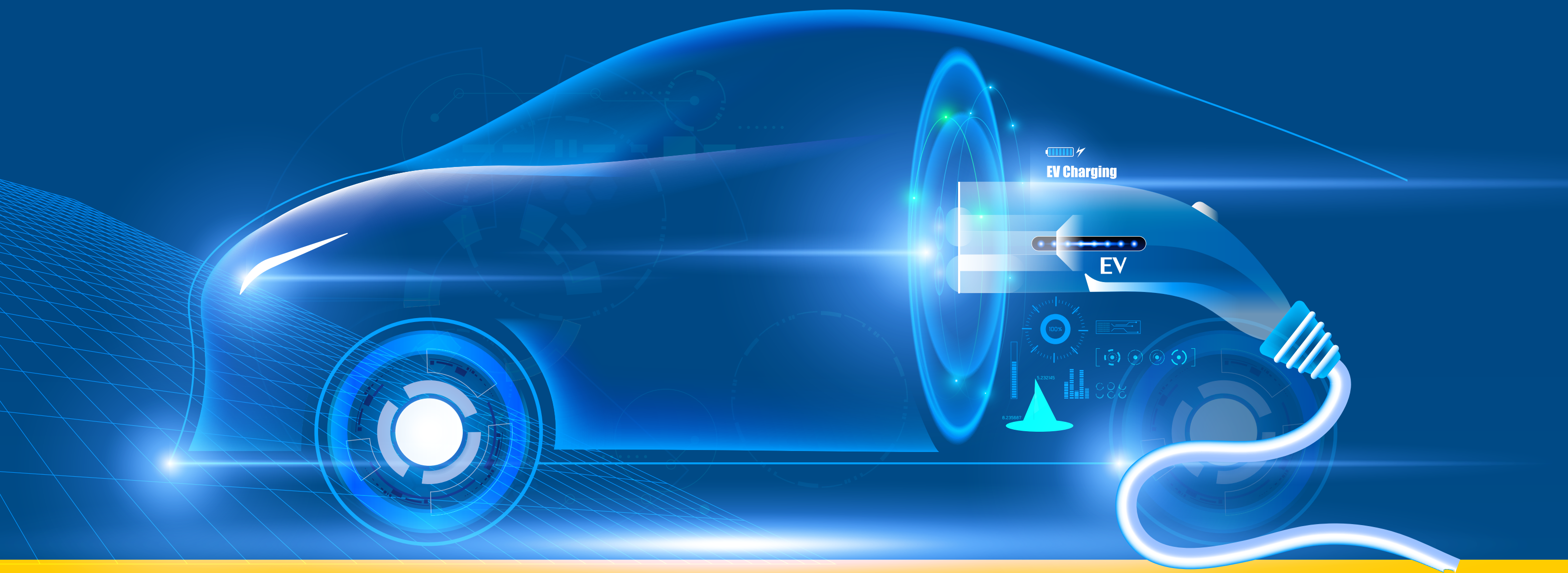
Battery thermal management techniques can be classified into two categories–active and passive. While both these systems are in use, a growing view seems to support the adoption of passive systems.

Let us see why.

Active Battery Thermal Management

Air-based and coolant-based battery thermal management systems are some examples of active thermal management techniques. This requires electric power to operate a fan/pump to cool the EV battery. However, the low heat transfer efficiency of air and the high ambient temperatures that might occur during the vehicle's operation can undermine the overall effectiveness of air-based battery thermal management systems.

Liquid cooling systems offer better heat transfer capabilities as compared to air-based systems. They, however, are stilted by a need for constant leakage protection and maintenance of components (pump, heat exchanger, valves, tanks, etc.).



Passive Battery Thermal Management

A Phase Change Material (PCM)-based battery thermal management system and heat pipe constructed battery thermal management system are some instances of passive thermal management techniques that can cool EV batteries without any driving energy. The low thermal conductivity of the phase change material restricts its application for efficient heat transfer.

In the heat pipe family, one member is Pulsating Heat Pipe (PHP), a wickless two-phase passive heat transfer device. To address the battery thermal management problem, PHP has emerged as a suitable applicant because of its lightweight and compact construction with low manufacturing cost, and noiseless and vibration-free operation without any external power requirement.

Pulsating Heat Pipe

The Pulsating Heat Pipe/Oscillating Heat Pipe (PHP/OHP) is a meandering capillary tube folded in such a way that it alternatively passes from source to sink, forming closed loops, as shown in **Figure 2**.

A PHP is evacuated with the help of a vacuum pump and filled with a working fluid according to the filling ratio. Vapor bubbles and liquid slug are formed inside the tube due to capillary action. On being heated during the engine operations, the vapor bubble and liquid slug start moving back and forth and enter the heat sink and heat source.

Latent heat transfer and convective heat transfer occurs through the vapor bubble, and the liquid slug that releases the heat into the sink and accumulates heat from the source.

PHP thermal performance is affected by geometrical parameters (inner diameter, outer diameter, number of turns, length of the evaporator and condenser portion, bending radius, etc.), working fluids (pure fluids, binary fluids, surfactant solutions, nanofluids, etc.), and operational parameters (filling ratio, orientation, heat flux, etc.). Thermal resistance is calculated based on the average temperature difference between source and sink divided by total heat to evaluate the thermal performance of PHP.

The overall PHP thermal resistance is reduced with an increase in the heat flux. Hence, an appropriately designed PHP constructed battery thermal management system helps maintain battery operating temperature within the working range through better temperature uniformity at high heat flux.

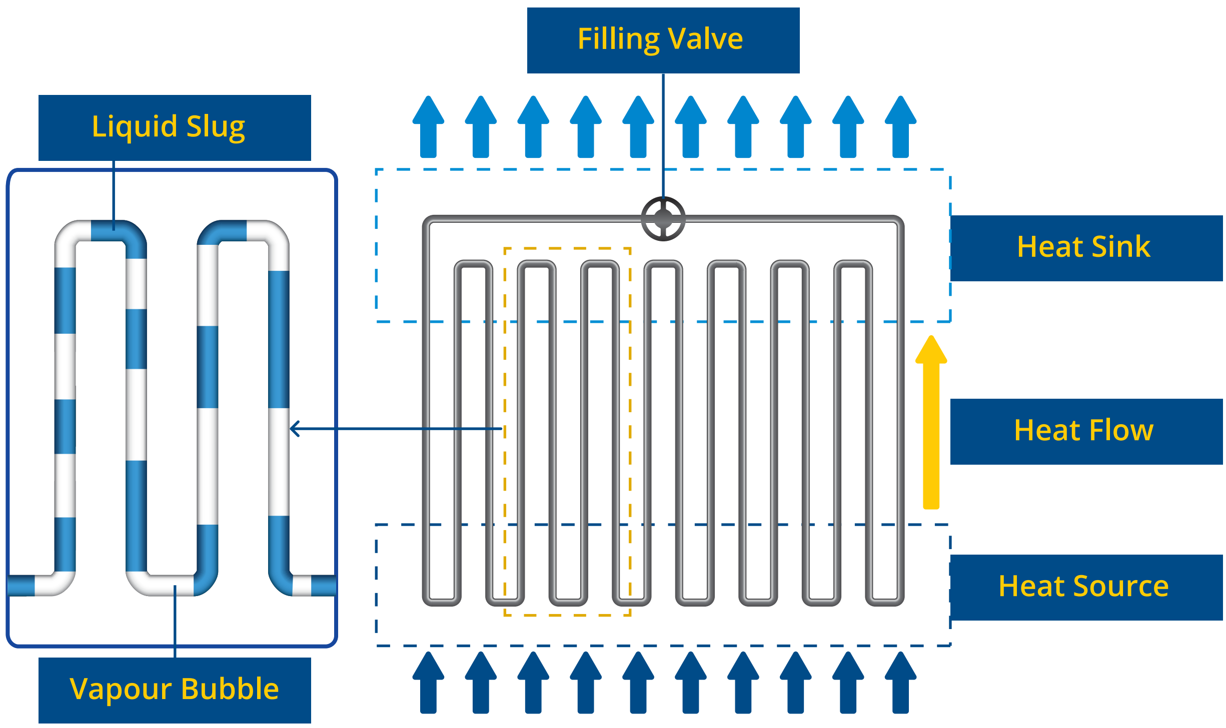


Figure 2: A Pulsating Heat Pipe

Conclusion

A systematically designed pulsating heat pipe-based system can address the high heat flux dissipation requirement of an EV battery under all possible operating conditions. It also helps ensure temperature uniformity and avoid the emergence of hot spots under extreme environmental conditions.

The system is designed by considering potential failure modes such as start-up heat flux, dry out limit, and critical heat flux.

Orientation independent operation and vehicle vibration effect on the thermal performance of PHP also make the PHP-based system more robust.

We, therefore, feel that a two-phase passive cooling technique for a battery thermal management system will be an ideal solution for overcoming high heat flux dissipation issues in EVs.

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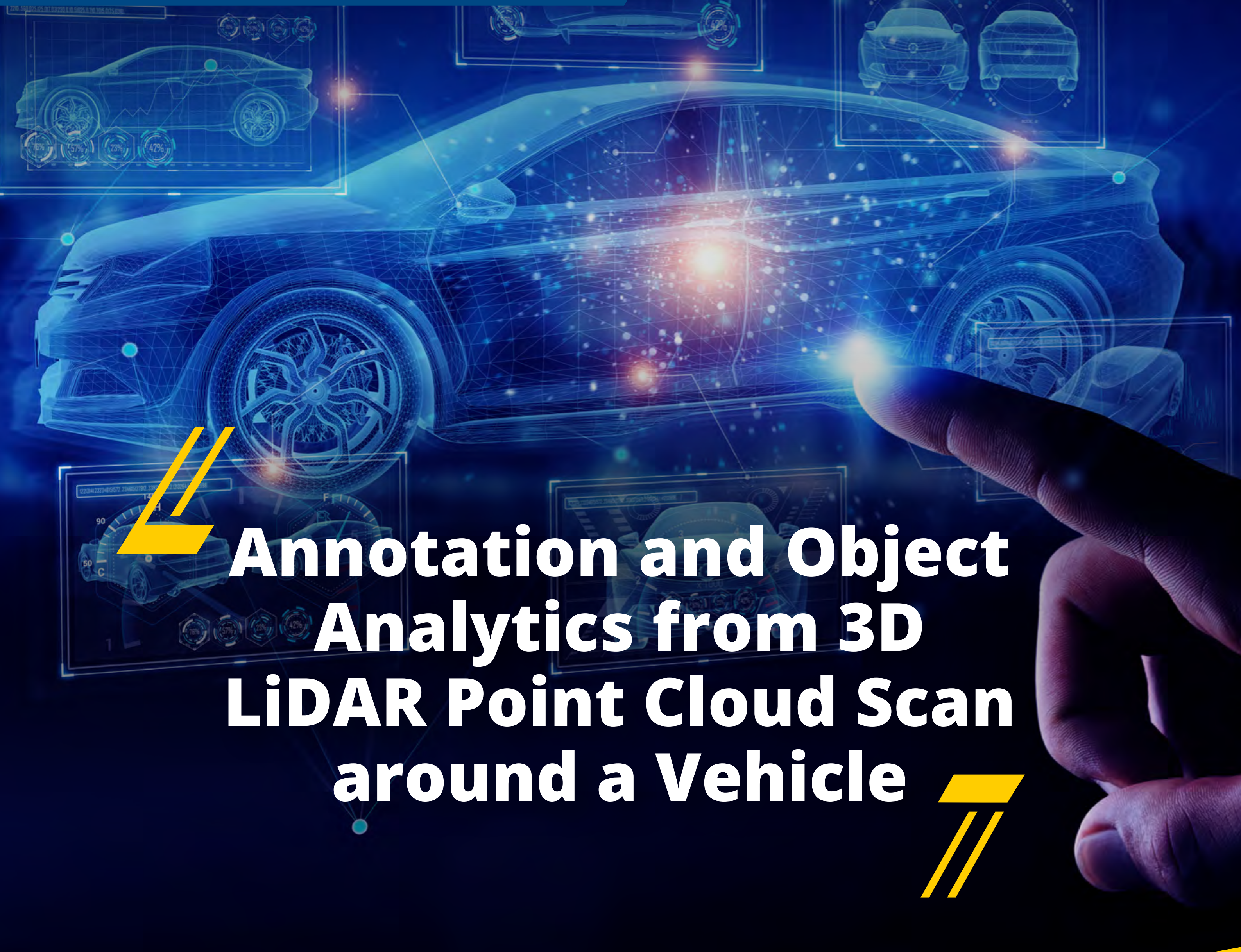

Annotation and Object Analytics from 3D LiDAR Point Cloud Scan around a Vehicle

SAHANA N

MANJU HATHWAR S

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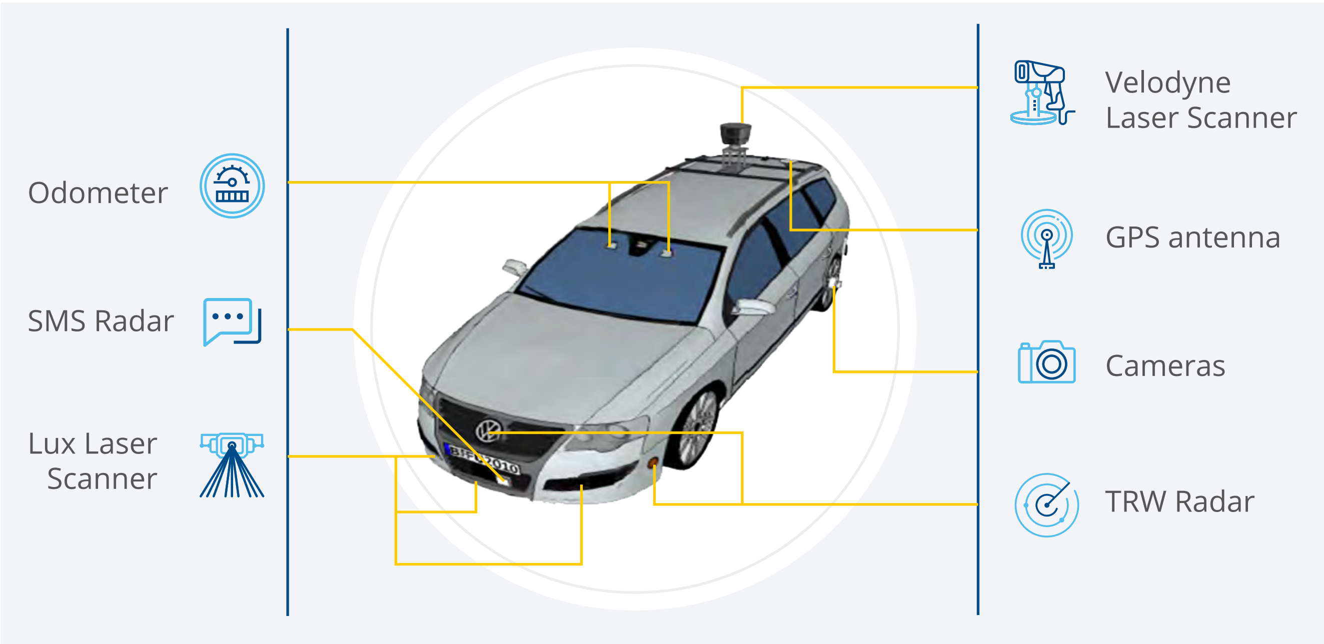
Abstract

The objective of this monograph is to outline a robust, scalable, and efficient tool or approach that helps annotate 3D Point Cloud data from LiDAR. In turn, this helps in the 3D localization of objects and their dynamic movement using full surround multi-modal (camera and LiDAR) data streams.

We propose a web-based tool leveraging WebGL to allow collaborative annotating that incorporates several smart features to improve usability and efficiency. Annotations for all available camera images can be obtained by projecting annotations from the 3D space into the image annotation domain. Along with the raw image data and point cloud feed, a master view consisting of the top-, side-, and front- views can be made available to observe the objects of interest from multiple perspectives.

Introduction

LiDAR (Light Detection and Ranging) is a widely used sensor in electric and autonomous vehicles, particularly for those operating at higher levels of autonomy (L4 - L5). Compared with cameras, LiDAR is more robust to ambient light condition changes. It can provide accurate distance measurements to nearby obstacles, which is essential for the planning and control of autonomous vehicles.



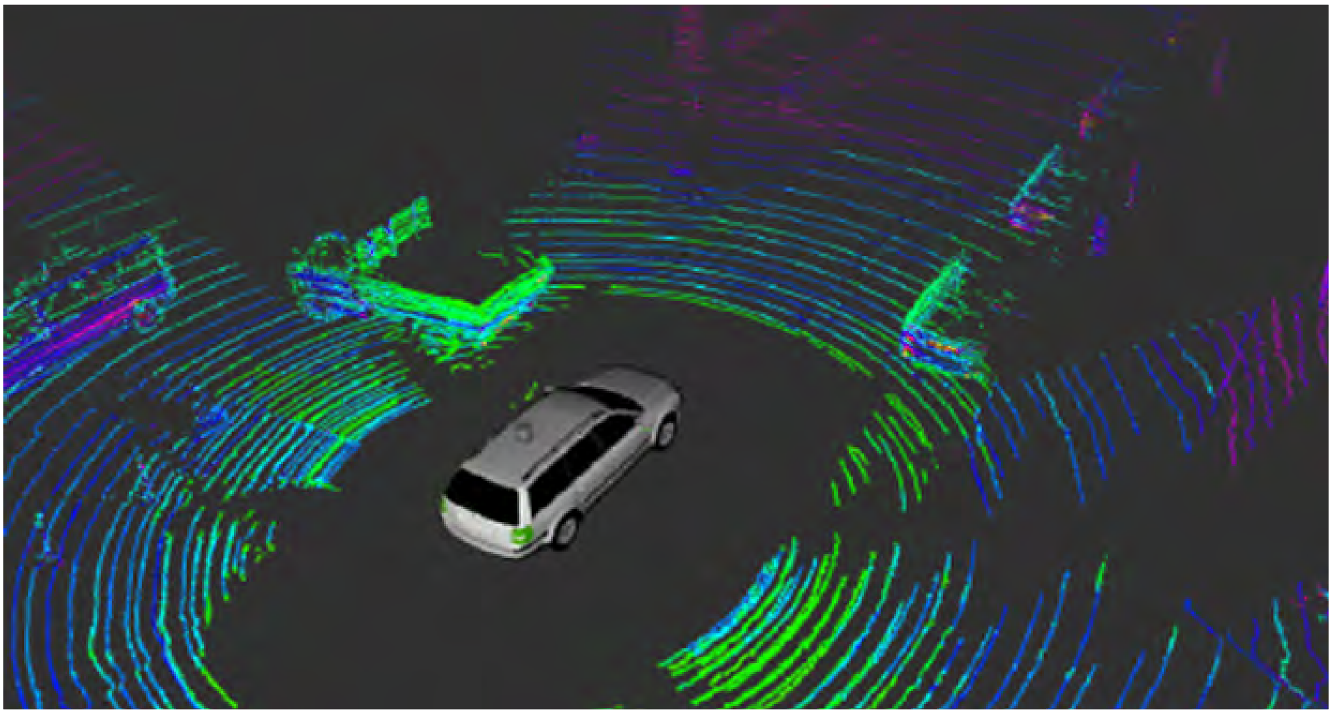


Figure 1: 3D Point Cloud Data Visualization

To understand the environment through LiDAR, autonomous vehicles need to extract semantic meaning from the point cloud and accurately identify and locate objects, such as cars, pedestrians, and cyclists. This approach is termed as LiDAR-based detection using deep learning approaches.

However, modern deep-learning algorithms that offer superior accuracy and faster speed can be extremely dependent on large amounts of labeled point-cloud data for training and evaluation. Therefore, we are faced with a growing need for broadly available 3D annotation platforms that have a labeling user interface that is intuitive enough for non-domain experts to use.

Several existing tools can annotate 2D images, but there is a growing need to also annotate 3D LiDAR data. A novel 3D annotation tool can facilitate 3D localization of objects and their dynamic movement using full-surround multi-modal (camera and LiDAR) data streams, addressing the current scenario.

HDL-64E

High Definition Real-Time 3D LiDAR

The HDL-64E LiDAR sensor is designed for obstacle detection and navigation of autonomous ground vehicles and marine vessels. Its durability, 360^0 field of view and very high data rate make this sensor ideal for the most demanding perception applications as well as 3D mobile data collection and mapping applications.

- 64 Channels
- 120m Range
- Up to ~ 2.2 Million Points per Second
- 3600 Horizontal FOV
- 26.90 Verticle FOV
- 0.080 Angular Resolution (Azimuth)
- ~0.40 Vertical Resolution
- User Selectable Frame Rate
- Rugged Design

Figure 2: 3D Point Cloud Data Visualization

The Present Scenario

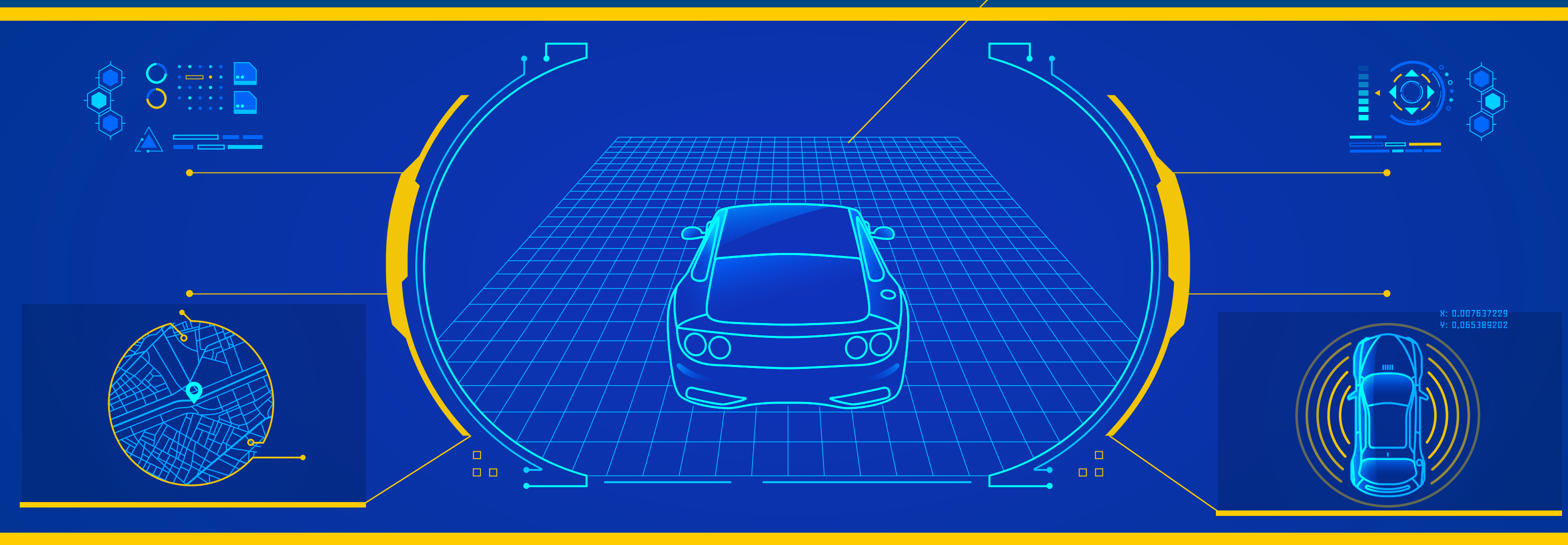
Compared to annotating camera images, annotating LiDAR point clouds is much more difficult and is challenging due to the following pitfalls:

A LiDAR point cloud is usually spare and has a low resolution, resulting in challenges for the human annotators to accurately recognize objects.

Compared to the annotations on 2D images, creating 3D bounding boxes or pointwise labels on LiDAR point clouds can be time-consuming and complex.

LiDAR data, being usually collected sequentially, can have a high correlation between consecutive frames, a scenario that can result in repeated annotations.

Without addressing these challenges, it is difficult to annotate LiDAR data efficiently over a large dataset for effective results.



Proposed Methodology

Our methodology involves developing a web-based 3D annotation tool to improve usability and efficiency that incorporates several smart features, including the following:

Front end is a web page that visualizes the 3D point cloud and camera view.

Mouse and keyboard can be used to draw a 3D cuboid bounding box around every object in the scene.

Edit Cuboid includes translation, scaling, and rotation.

3D Localization of objects on a LiDAR data.

The 3D annotation toolbox can be based on WebGL for point cloud visualization to allow collaborative annotating. This toolbox can be designed to annotate one object at a time because it is an efficient method that is highly preferred. The idea here is to display all the available camera images once so that the objects that are covered by multiple cameras and related to objects seen on LiDAR can always be seen by the user. This will avoid the situation that will require the user to switch between all camera images to find an object, leading to inefficiency.

Along with this feature, the LiDAR-based detection method has to be implemented to annotate all frames between two specific frames (the start and the end frame) that are determined by the annotator. After the implementation of this semi-automatic interpolation technique, the annotation time will drastically decrease. This interpolation can be based on a linear model and is to be used primarily for labelling small clips of the data sequence.

Additionally, projective geometry is used to create a 3D to 2D label transfer option for the user. A 3D to 2D label transfer is very useful to obtain automatically annotated camera images from already labelled 3D point clouds. The annotator places a 3D label in the point cloud, which is then projected into all camera images.

This method reduces annotation time and helps the user to place the annotation very accurately into the point cloud, since the projection is updated in real-time. The projection of 3D annotations into the camera images (3D to 2D label transfer) as shown in Figure 3, does not require the user to label each camera image, which increases the speed by many orders.

An automatic track assignment of objects simplifies the annotation further. Those tracks can later be used for motion planning and motion prediction. Adding the Master view which consists of the side, front, and bird's-eye-view, the user doesn't have to change into the 3D view anymore to adjust the dimensions of an object.

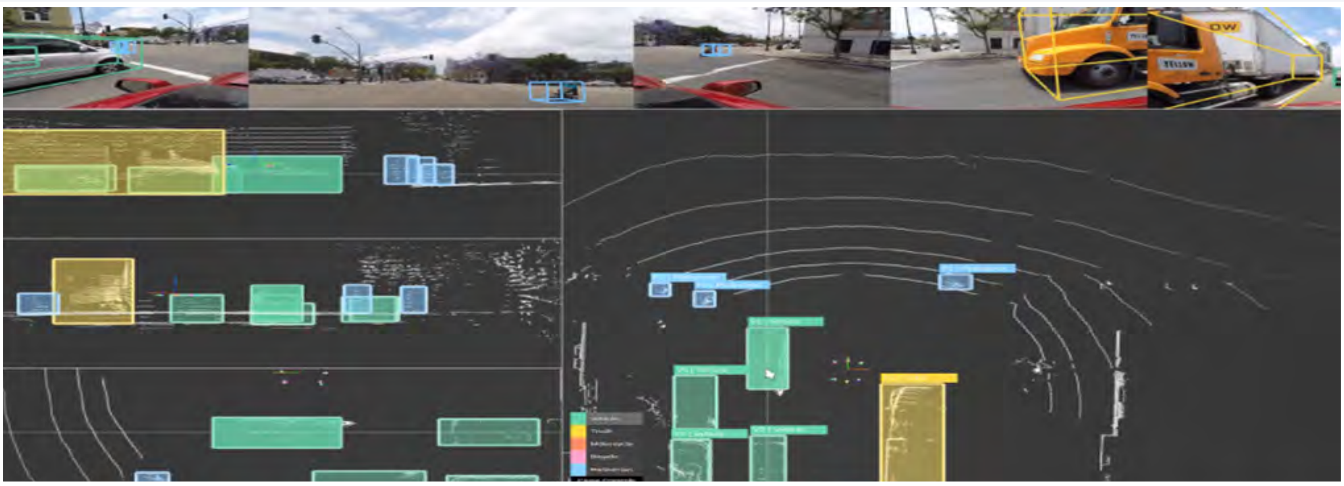
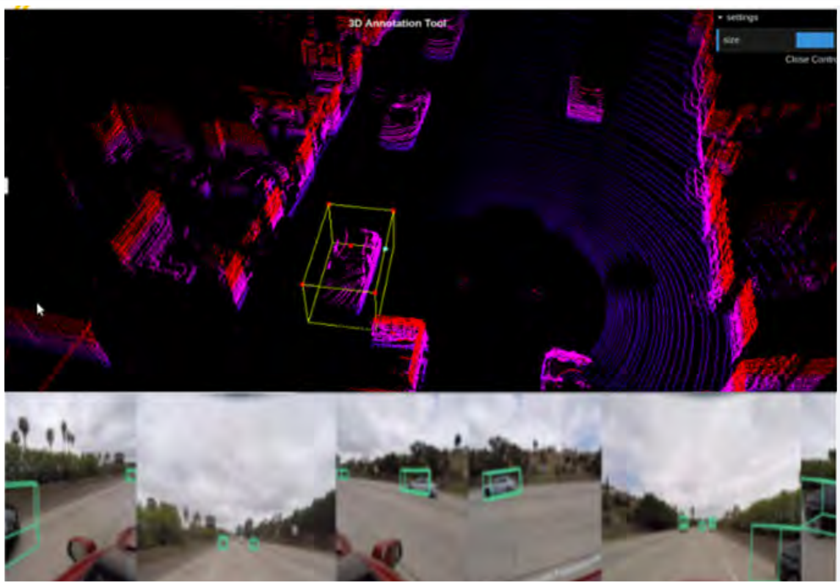


Figure 3: An Example App from a Similar Work- Projecting 3D to 2D View

Once the user selects an object in the scene, as shown in Figure 3, of a similar example application, transform controls appear on next to it. These controls allow the user to translate, scale, and rotate the selected object. The user can interactively correct wrong positions and orientations and change between those three modes. Shortcuts are provided to switch between the translation, scaling, and rotation modes. Having a limited number of choices is shown to save time and remove confusion, as it diminishes the cognitive load of the workers.



Steps

1. Extract the scene point cloud scan from LiDAR
2. Display the point cloud in the 3D visualizer
3. Use the visual tool to place the 3D bounding box on the required object/automobile
4. Visualize the bounding around the object
5. Project the 3D face of the object on the corresponding to camera view

Figure 3: Mapping Object in a LiDAR Point Cloud – Steps

We can use sensor fusion to help annotators confirm the category of a selected object. Once a 3D bounding box is chosen, we can project all the points within the bounding box to the image and show the corresponding crop of the image to human annotators for visual confirmation as shown in Figure 3. Cameras have much higher resolution than LiDAR sensors, and image-based detection algorithms are much more mature than LiDAR-based algorithms. LiDAR sensors are usually paired with cameras, and the two sensors are calibrated such that each point from the cloud can be projected to a corresponding pixel in the image. Therefore, we can apply camera-based image detection algorithms and transfer labels from an image to a 3D point cloud. The algorithm-generated labels are not perfect and are limited by the algorithm accuracy, projection, and synchronization errors, but we can use them as pre-labels to help human annotators recognize objects and 'fine-tune' the labels. Furthermore, to reduce repeated annotations on consecutive frames in a sequence, we utilize tracking algorithms to transfer annotations from one frame to subsequent ones.

Case Study

We did a case study on publicly available 3D annotation tools, as shown in Figure 4. It provides the web-based 3D annotation service of Point Cloud and a master view consisting of the top view (bird's-eye-view), side view, and front views to observe objects of interest from different perspectives.

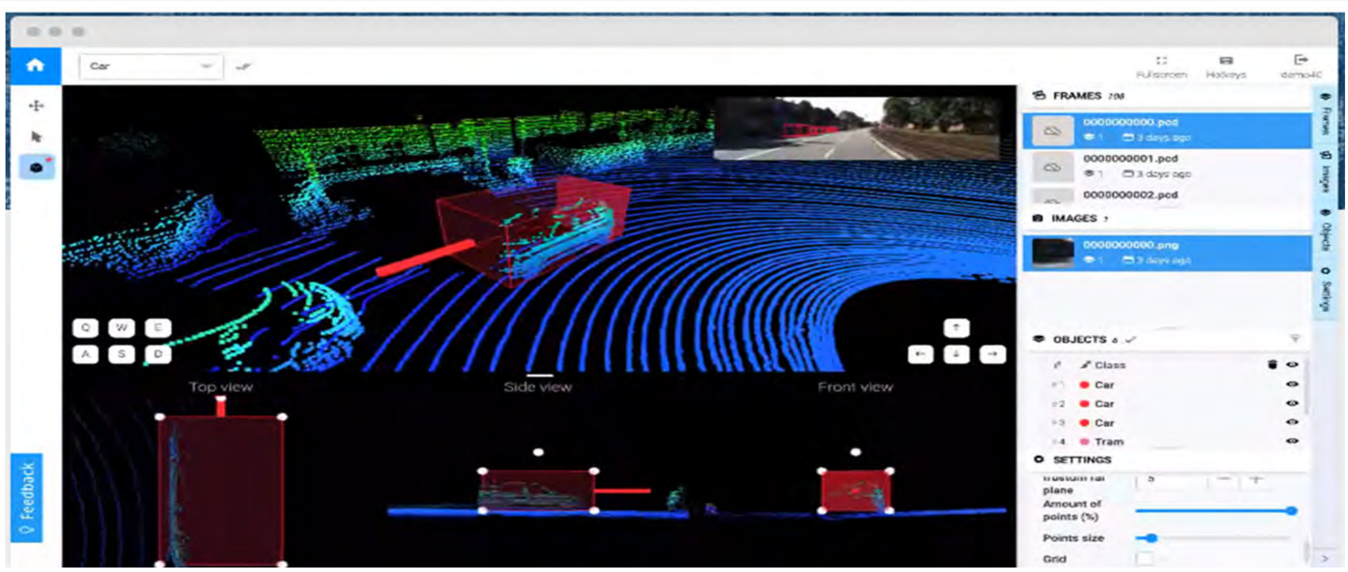


Figure 4: The 3D Annotation Tool

Conclusion

We propose a novel annotation system tool for efficient, accurate 3D localization of objects and their dynamic movement using full-surround multi-modal (camera and LiDAR) data streams. Annotators can label their own data very accurately and have full control of the toolbox and their data.

This toolbox also provides functionality to evaluate annotated data in order to obtain labels of high quality. The projection from 3D point cloud to 2D camera images can be further used to identify objects using object analytics.

Finally, human annotation tasks are very labor-intensive and sometimes require additional human resources. As a remedy, one can even consider using our toolbox to outsource the annotation tasks to Amazon Mechanical Turks - a popular crowd-sourcing platform. This is possible because of the web-based, platform-independent nature of the toolbox, capable of running on most modern browsers, irrespective of the operating system involved.

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Leveraging Digital Twin for Streamlined Virtual Commissioning (DT-O Model)

AAKASH GOHEL

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Abstract

Commissioning new equipment is a vital stage in business operations. This is the stage where the controls are integrated, bugs are found and fixed, procedures are written, and operators are trained on new equipment and new (or revised) operating paradigms. The commissioning phase can prove challenging to plan and can be hamstrung by overruns, which in turn can delay production and result in late shipments and lost business opportunities.

By combining a mechanical 3D simulation model with real control system logic, manufacturers can now create a valuable tool like a dynamic digital twin. This dynamic digital twin can enable comprehensive and accurate testing at an earlier stage in the project cycle at a lower cost when compared to testing with traditional techniques. An effective emulation tool for packaging lines with live PLC and HMI connectivity with a CAD 3D model can help address the challenges associated with the initial testing of lines and enable cost savings.

This paper describes how manufacturers can use virtual commissioning via digital twin technology, enabled by the DT-O tool, to reduce commissioning time and gain efficiencies. Companies can leverage the solution to identify errors much sooner, with little or no additional impact or cost. They can therefore look towards an enhanced resolution of emerging customer expectations, handling more complex products and variants with mass customization, and become more competitive and profitable in their operations.

Introduction

Manufacturers today are facing fierce competition amidst fast-changing consumer demands. Production speed, flexibility, and agility are crucial for staying competitive and profitable while maintaining product quality, safety, and compliance.

We see manufacturers facing these core challenges:

Conventional start-up

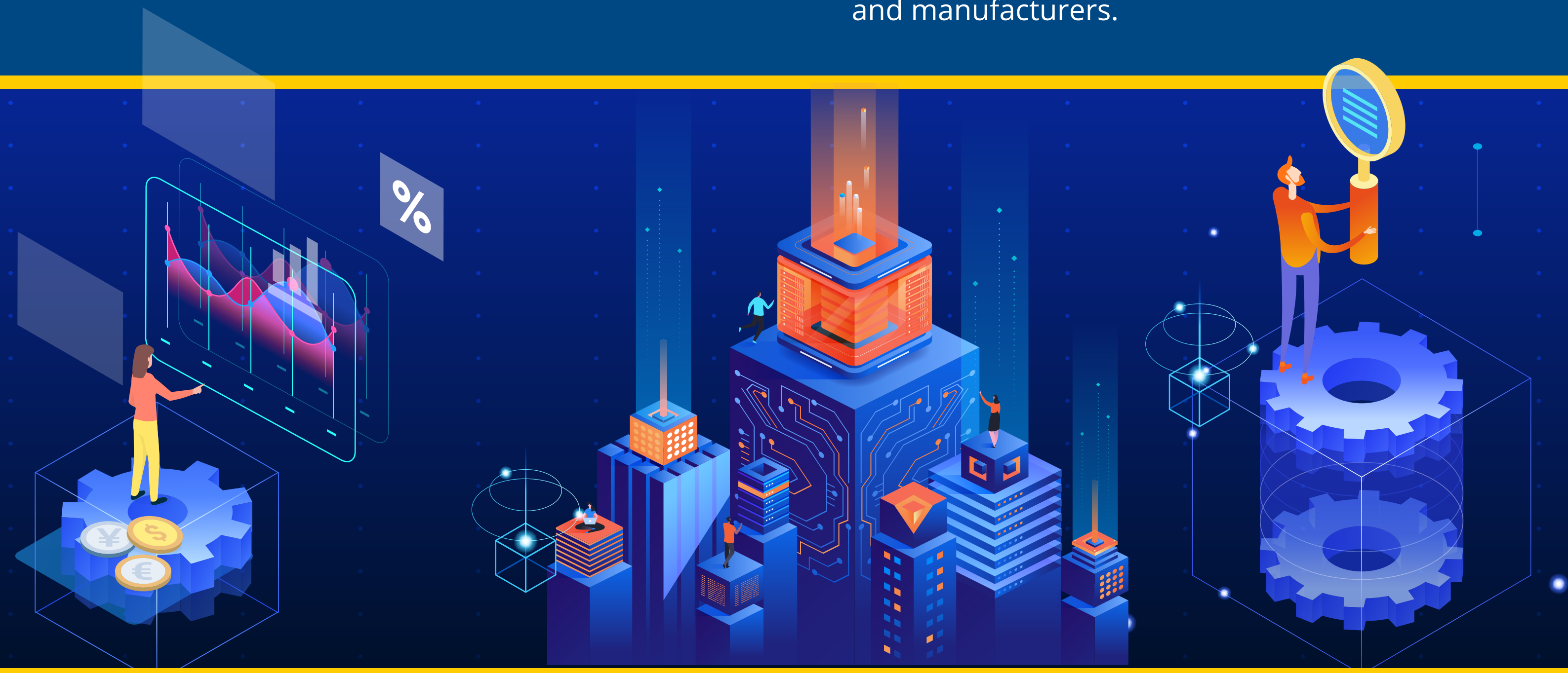
For most legacy packing/assembly lines, real-time testing with machines happens during physical start-up. When testing trials start, the engineer has to analyze sequence and line interlock thoroughly. There are high chances of unpredictable issues emerging at this stage, which can adversely impact the start-up schedule and result in lost time and revenue.

Worst and best scenario testing

During physical start-up, the squeeze schedule may not allow time to check the line with all worst and best scenarios. In the absence of worst and best scenario testing, we would therefore look at a scenario where the line is potentially running over or under its capacity.

Enhancing Flexibility

The shifting pattern of consumer demand and growing product complexity calls for greater flexibility from plant operators and manufacturers.



Material and Energy Costs

Conventional testing requires access to many resources, including energy and materials, which are ultimately used up at the end of the test run. Manufacturers need a workaround from this potential bottleneck scenario to retain their competitive edge.

Operator Utilization and Training

During start-up, most new operators do not know how to operate the new production line. They are forced to spend most of their time familiarizing themselves with the new system by fixing the emerging challenges they are not equipped to handle.

Faster Time to Market:
Virtual Commissioning via Digital Production Twins

Typically, a critical path to any successful product launch is the validation of the manufacturing process. Depending on product complexity and its required variations, the sequence of steps involved in engineering and setting up a new production line (**as illustrated in Figure 1**) can take many months.

In addition, the interdependencies across these steps can introduce significant risks to a launch. The problem here stems from the fact that unidentified errors in early engineering stages can have an enormous impact on cost and time if discovered later, especially during the manufacturing stages. According to the Six-Sigma/Quality "Rule of Tens," the costs for an unidentified error can grow by 10 times from one value-added level to the next. So, while an error found in a product's planning stage might cost $100 to fix, the same error discovered once manufacturing has started could cost $100,000 to address.

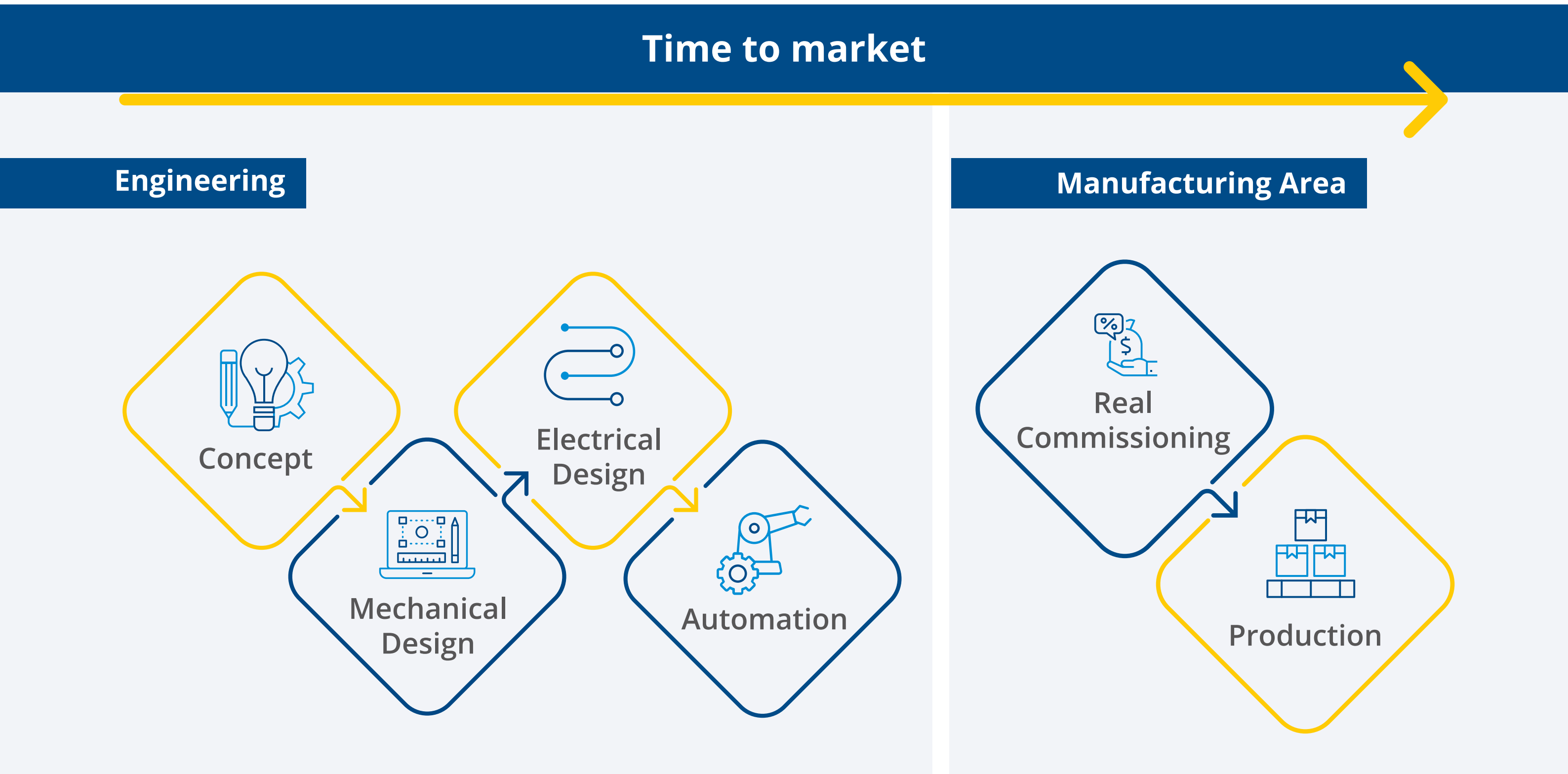


Figure 1: Typical Sequence of Steps to Set Up a New Product's Production Line which can take Months

Worse, if the product has shipped to market, the impact of an early-stage error emerging, say in the formulation of a packaged food or pharmaceutical–could be in the millions, not to mention potentially undermining a long-standing brand reputation.
Digital twins may be leveraged for addressing a whole range of requirements, including diagnostics and design adjustments. Since the twins are an accurate representation of the related physical asset, they may be leveraged for streamlining and optimizing key activities during commissioning.

Therefore, instead of implementing a new production system in the intended physical environment, virtual commissioning comprises the creation of the digital twin of the target asset. This is then tested and verified within a simulated environment before going live with the physical installation.

Adopting a digital twin therefore enables:

- Streamlined code tests and debugging within a virtual setup
- Simulation of machinery operation, the identification of potential problems, and a rapid assessment of alternative solutions
- Creation of operating methodologies
- Training of the equipment operators and supervisors
- Simulation testing of the new equipment on existing operations to identify space constraints and potential bottlenecks so that they are resolved before the installation and commissioning process is flagged off

Digital twins modeled in sophisticated software depict physical production systems both in design and operation including, controls, automation components, sensors and actuators, PLCs, and HMIs. Once a new production line is operating in the intended physical setup, data from its material handling systems, machines, and higher-level systems can constantly update its digital twin to keep the latter current.

With such a comprehensive virtual representation, engineers can conduct a wide range of simulations to evaluate their various automation approaches to find the best one, much earlier in the process. Using a digital twin, they can validate critical operations including:

With the digital twin, this validation, through virtual commissioning, can occur in parallel with production engineering **(as shown in Figure 2)** saving time and reducing the risks of traditional production engineering and setup. It can also totally transform the jobs of control and automation engineers, especially those taking part in either of these types of projects.

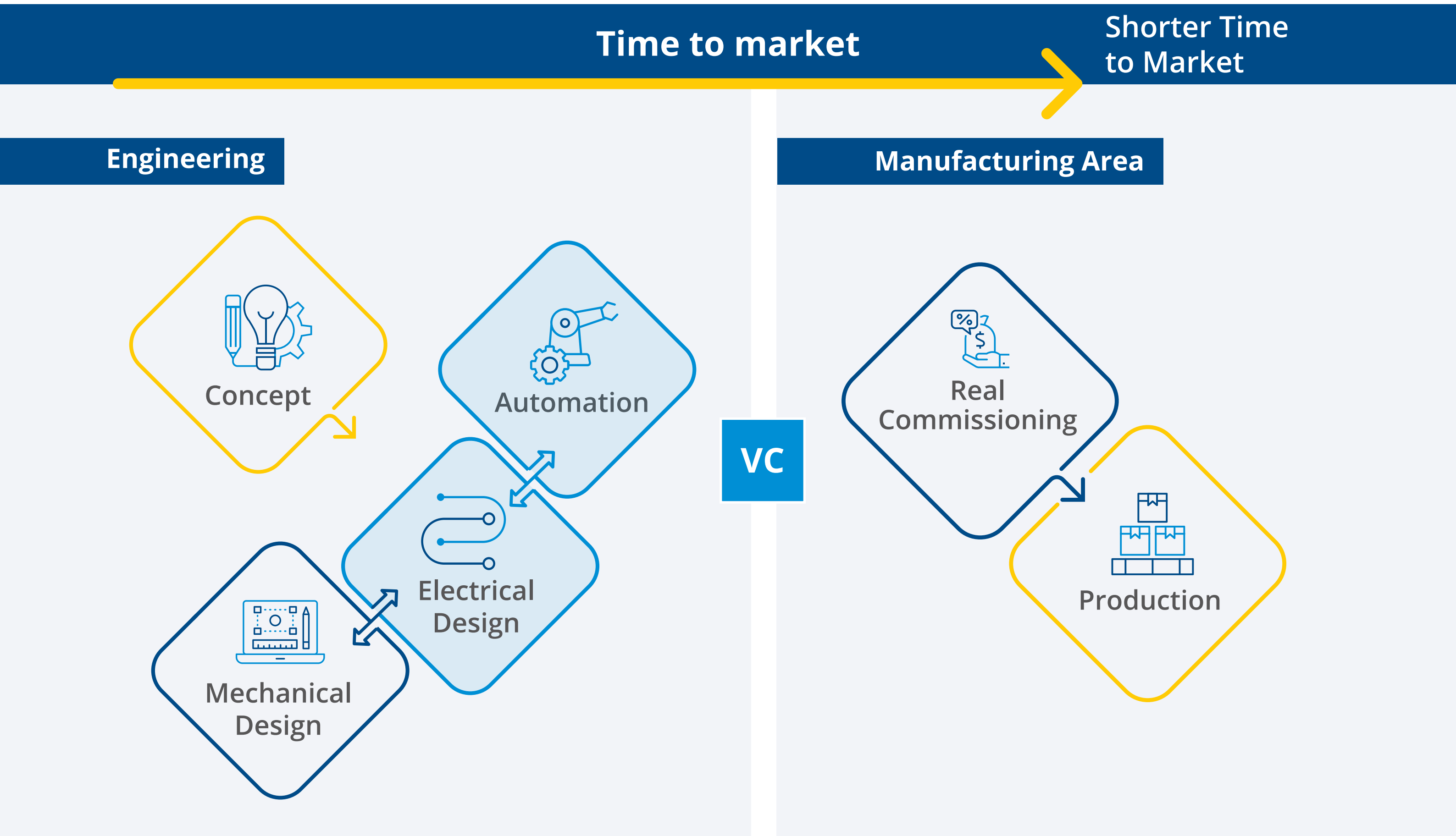


Figure 2: Virtual Commissioning (VC) can Take Place Potentially Months Sooner in the Production Engineering and Set-up Sequence, Accelerating Time to Market and Reducing Risks

As automation veterans can attest, an overall product launch timeline may give them a specific number of weeks or months to do work associated with developing and validating the production line's automation and mechatronics. But, if timelines in earlier stages slip, the project's management looks to make up the time in later stages–turning up the pressure and urgency on those responsible for making those latter stages happen.

In addition, by using a digital twin to conduct engineering and validation of automation and mechatronics, the completion of these stages can become the basis for both documentation and training of operators and maintenance technicians. Without the digital twin, this can also take weeks or months.

Another prominent business benefit of virtual commissioning's accelerating time to market is this: shorter market windows leading to faster profit windows. So, manufacturers who can get their products to the market faster, and are economically equipped to produce and offer more variations during market windows, can gain first-mover market advantage, build greater market share, and be more profitable. Figure 3 illustrates this phenomenon.

Virtual Commissioning Methodologies

There are multiple ways of virtual commissioning- most clients prefer to share their system via VPN network with the tech support team. Since physical assets are not in front of them, it is increasingly difficult to sort out issues efficiently. However, it is commonly used to support minor changes and modifications with support from the site team.

Another method that is most efficient for virtual commissioning is based on the digital twin model. Here, instead of physical assets of line, we create a twin model. This virtual line can behave exactly like a physical line. So, once we test this virtual line, we identify and sort out most bottlenecks before it happens during physical start-up. This model is the DT-O model or the Digital Twin Operational model.

How Does The DT–O Model Works?

This shows how digital production twins operate and enable virtual commissioning. Here they create a replica of the physical line in the PlantSim platform. This virtual packing line would then connect with a real-time PLC/HMI controller where it will pass all live data like how we do start-up with Physical line connectivity with live PLC/HMI controller. This is called real virtual commissioning of line with all live data connectivity.

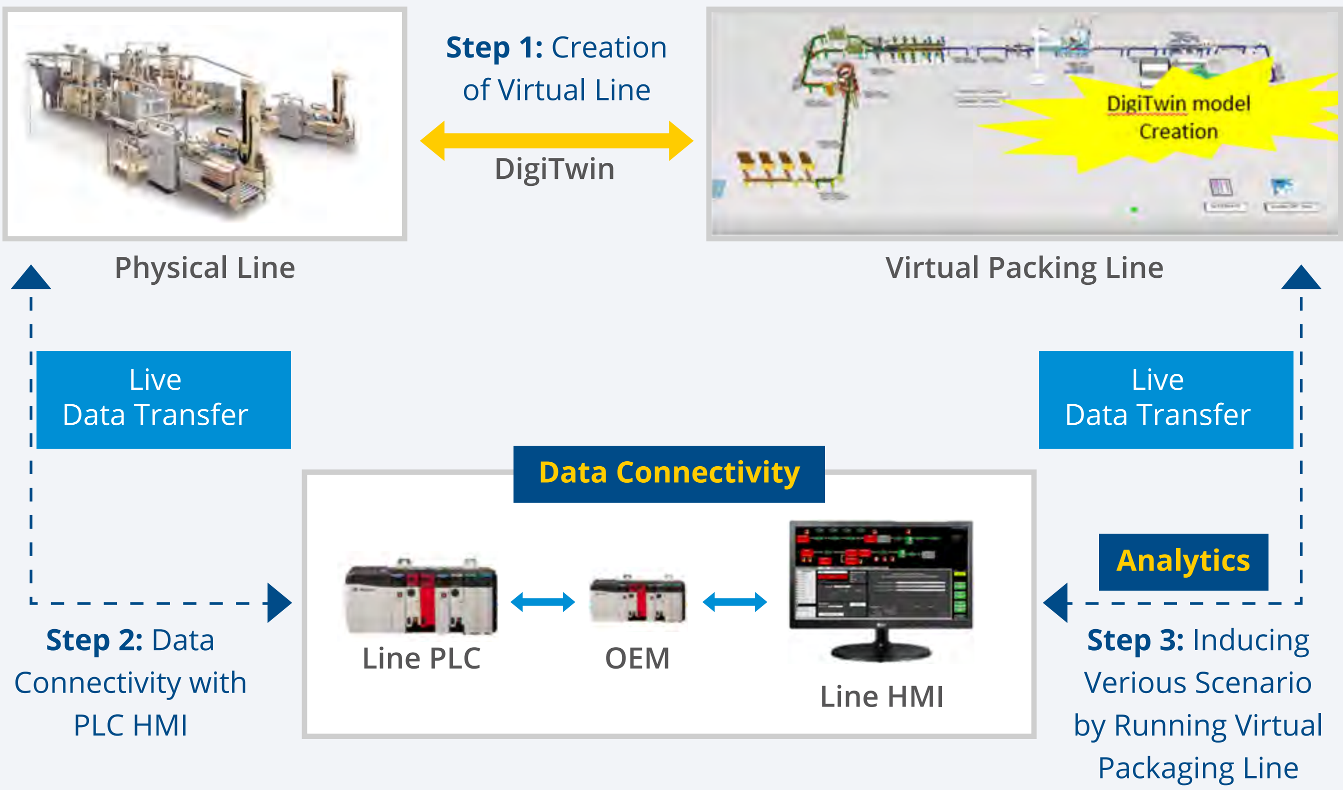


Figure 3: Digital Twin Architecture

DT-O helps in the creation of a Digital Twin setup to perform offline testing of controls by disconnecting them from the critical path reducing the operational risk. It is a real-time emulation solution with Live PLC and HMI connectivity with a 3D simulation model. The solution enables operator training and staffing calculation and provides the ability to check various scenarios such as-

- Line logic functionality check
- Line tuning
- Determination and adjustment of sensor response time and location
- Demand vs throughput calculation
- Identification of optimum machine/conveyor speed
- High-level machine functionality
- Trial and testing of the entire packaging line at different speeds and for different recipes
- Determination of accumulation/backup of product at different locations
- Machine/operator utilization
- Elimination/reduction of costly physical prototypes

Major Benefits of the DT-O Model

Better quality, by ensuring both the controller and machine functionality is optimized in advance.

Accelerated time to market, by enabling mechanical and automation engineering to be done in parallel.

Faster physical commissioning, by identifying errors and issues before they manifest at a product's manufacturing site.

More innovation flexibility, by facilitating faster and easier evaluation of alternative control concepts during the design phase.

Less cost and fewer risks, by reducing physical commissioning time.

Operator training and staff estimation– before physical start-up operators can get full hands-on training which increases their confidence. Also, we can identify and measure staff estimation and utilization, like- how many operators it would require to operate the production line.

Conclusion

This whitepaper aptly describes the challenges that CPG manufacturers face and how the remote virtual commissioning via DT-O tool can help them avoid start-up risk.

In short, virtual commissioning allows engineers and operators to test new installations and any adjustments in both the start-up and the maintenance phases before implementing them in a physical environment. The result is a smoother, more streamlined installation and integration, fewer cost overruns, and minimal chances of downtime that could affect production.

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Well RMON Solution

DEVKARAN RATHORE

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Abstract

The present paper proposes a strategic Asset Management Solution for upstream Oil & Gas (O&G) operators. It gathers Well/Well Pad data from assets distributed across the globe and facilitates consolidated dashboarding for real-time monitoring and analysis by relevant stakeholders. The proposed solution adds value to the legacy assets by leveraging a host of solution modules, including Asset Management, Geographical Monitoring System, Well Performance Monitoring, Data Calculation and Analysis, Anomaly Detection, and Demand Management. With this solution, stakeholders can improve productivity and enhance visibility in hidden areas of connected, remote assets.

The proposed solution also addresses various issues faced by O&G upstream process by utilizing solution features like asset modeling and analysis, custom application visualization suite, and solution KPIs to address major issues and challenges faced by stakeholders.

The solution can be deployed in an environment where there are interdependencies among various sensors, actuators, equipment—making it difficult to measure the degree to which the wells are producing to their maximum productivity. In such an environment, a repeated occurrence of downtime can cause maximum productivity loss.

Introduction

With global crude oil prices undergoing significant fluctuation, O&G upstream companies are focusing on reducing their production costs to stabilize bottom lines. They are looking to refresh their legacy technology platforms by adopting Industry 4.0, Big Data, and Industrial IoT (IIoT) to streamline this process.

The proposed solution applies to the stage where exploration and extraction of crude oil and natural gas are carried out. At the edge layer, the solution collects data from various connected devices, such as pressure/flow/temperature transmitters, bearing/motor winding temperature using a wide range of industrial connectors and gateway and store it in a centralized cloud database. The collected data is processed by a data processing engine and modeled and analyzed for maximizing the return on assets.

Cloud-based IoT application delivers comprehensive KPIs and analytical view to the stakeholders, allowing the data to be analyzed and used within third-party applications.

Current Challenges

The current challenges facing upstream O&G operators include:

The need to visualize data, from large geographically spread production facilities, in the absence of centralized access or visualization, is there and several free-standing production facilities. As the number of assets increases, it would become even more difficult to manage and track the equipment critical information for Well Head/Well Pad and Separator.

Lowering the response time from edge to cloud and from cloud application to the end-user will impact the analysis. Unattended minor issues on time cause a major impact on overall production, hence, these unplanned downtimes should be addressed and analyzed more effectively.

Well decline/low-performing asset data unavailability should be captured to avoid major failure/impact in the future.

Legacy device/instrument connectivity and supporting of Multiple Industrial Network Protocols-Modbus TCP/IP, Modbus RTU, ASCII, HART, DNP3, OPC.

Ensuring the maximum production, asset health, and continuous operation of all assets/equipment/instruments are necessary.

Real-time production tracking and demand management across multiple stakeholders are often challenging tasks for production companies.

The Solution

The proposed solution helps in centralizing data processing and monitoring, comparisons, and notification of the events which can cause the production losses across the Wells/Well Pads with web-based monitoring and provide a facility to go to the drill for more insights. The solution should be flexible and should fit over any existing control system.

Major features of such a solution include:

Asset Management

An Asset Management Framework is used to integrate the asset status and organize information effectively. Each asset can contain multiple static and dynamic attributes which reference the running system information, analyzed data, or static values.

The Asset Framework helps to build a plant model using a parent-child relationship with inherited properties. To compare between identical production facilities, asset-based monitoring and comparison are necessary. It can switch and compare between various assets.

A diverse set of analysis and notification management can be undertaken by the Asset Management Framework.

Geographical Information System

This feature is a web-based geo monitoring suite that can be integrated with Google Maps using Web API. It gives production information with downtime alerts and asset status information on Google Maps with drill-down capabilities for root cause analysis.

Well Performance Monitoring

Stakeholders can get detailed information for their owned assets. Major solution KPI can also be tracked. Individual asset failure or anomaly-related information can also be monitored. Interactive dashboard and KPI help to visualize major impact/anomaly in real-time. A few prime solution KPIs include Water Cut, Water to Oil Ratio, Gas to Oil Ratio, Decline Curve, etc.

Data Calculation and Analysis

This feature is used for the calculation and processing of raw data. By utilizing various functions and features, major data drift and spikes can be detected and notified over Email and SMS alerts.

Prevent the Production Loss/Well Anomalies

This solution can detect future events such as Production Variation using well decline analysis to avoid unplanned downtime or production loss. Solution built with future data option based on past data (historical data) to detect any event proactively and notify via Email/SMS alerts, to conduct the maintenance activity in advance.

Demand Management

This module allows stakeholders to plan their production by allocating wells based on work order and timeline. The module will suggest the best viable asset to be utilized for production.

Maintenance Planning

Operation personnel can plan Well and Choke Valve maintenance from the maintenance dashboard. Data can be integrated with CMMS/ERP system to generate new maintenance work orders based on the triggered event.

High-Level Solution Architecture

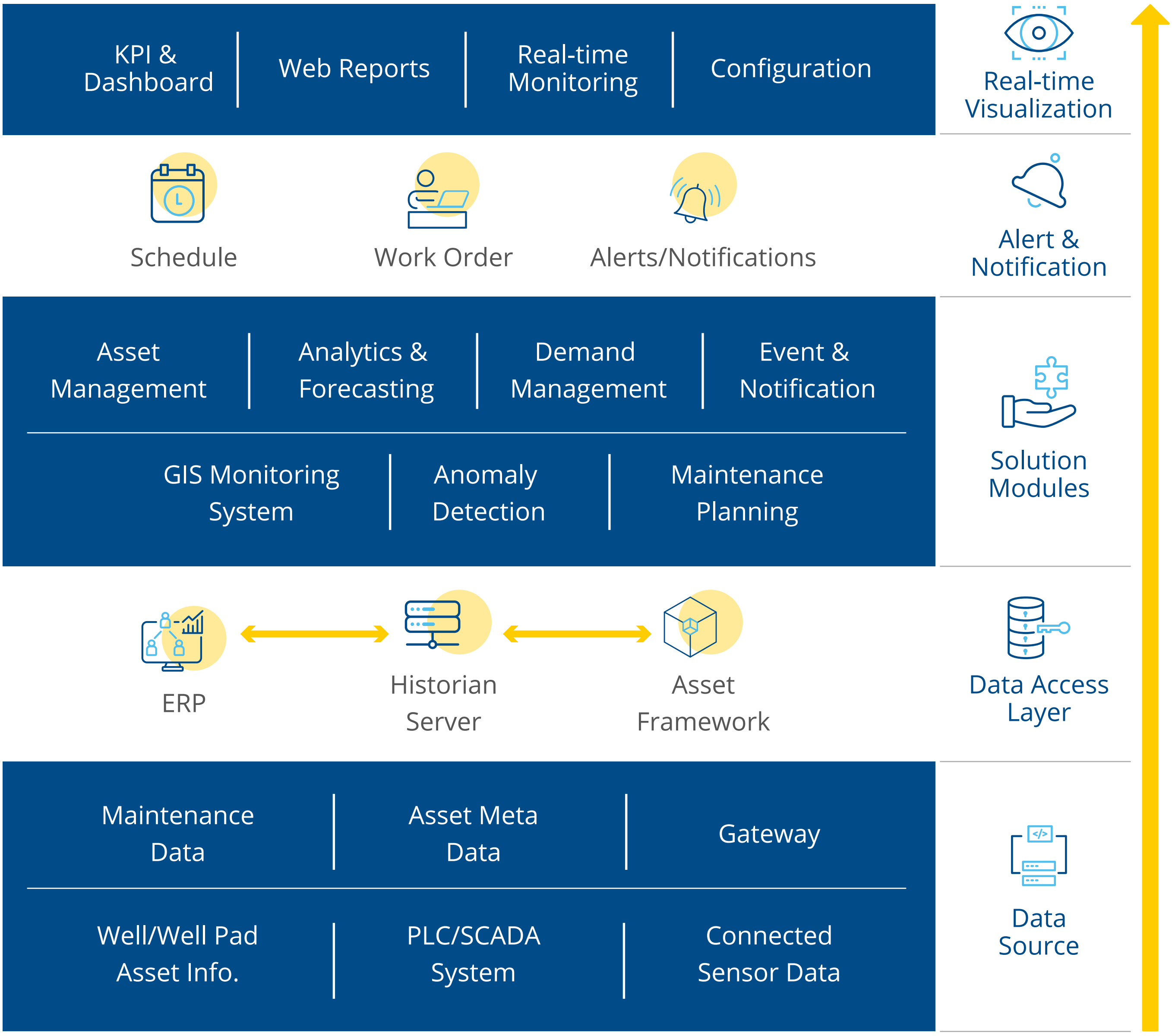

Figure 1: High-Level Solution Architecture

Conclusion

The proposed solution, when implemented, can not only help streamline O&G upstream operations but also deliver significant cost savings through better asset utilization of oil wells. With global crude prices continuing to fluctuate, the O&G companies should consider adopting the proposed methodology for strengthening their revenue streams while improving their operational paradigms.

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Lean Transformation in Manufacturing for Achieving Quality and Innovation Excellence

MANOJRAMACHANDRAN   RVS KARTHIK   VIJAYABHARATHI

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Abstract

In the present market scenario, timing is a key factor for achieving a competitive edge. The manufacturing industries have an incredible contribution in the global economic growth. Moreover, due to scarcity of the sources in the creation of goods and services, industries seek for continuous improvements in their process so as to sustain their businesses. Hence, in order to remain competitive in this challenging environment and to keep pace with market leaders, industries focus on lean manufacturing.

This paper presents a case in point for plant improvement activity carried out by modifying the existing manufacturing line using lean tools such as Operational Time Analysis, Process Analysis, Gemba as well as Digital Simulation Analysis such as Operator Work Balancing, Material Handler Optimization, Layout Optimization and Inventory Optimization. Improvements initiative identified based on as is assessment and program was carried out in five phases starting from Process Planning to Raw Material Handling.

In Phase 1, AS-IS process analysis was carried out using a LTTS in-house developed application which aids in calculating the standard time.

In Phase 2, Make vs Buy strategy was carried out with a focus to identify and reduce non-core competency activities like optimization of machines, improve machine utilization and should costing.

In Phase 3, Process flow was studied and split into defined stations.

In Phase 4, Layout planning analysis was carried out with the aid of techniques such as Affinity Analysis, Relationship Study and Material Movement Analysis.

In Phase 5, Detailed study on material handling were performed with an aim to minimize the material handling and operator movement using genetic algorithms in discrete event simulation.

The validation of lean approaches for multiple scenarios was initially carried out in digital simulation to study and eliminate bottlenecks before implementing it in actual line. Using this approach, the overall productivity was achieved within a short span of time with 25% process cycle time reduction, 76 % improvement in machine utilization and an estimated space saving of 10%.

Introduction

Lean manufacturing or lean production has become the common name for the manufacturing strategies developed by the Toyota Motor Corporation beginning primarily in the 1940s and 1950s. The Machine that Changed the World by Womack, Jones, and Roos (1990) states, “lean manufacturing is the improvement paradigm that provides for systematic identification and elimination of waste throughout the production system from the customer’s perspective of value-added processes.”

Current digital industrial age holds the promise of increased flexibility in manufacturing, mass customization, increased speed, better quality, and improved productivity.

Digital designs and the virtual modelling of the manufacturing process can reduce the time between the design of a product and its delivery. What makes a modelling effort different than a value stream map is seeing the contextual layout of the process in combination with being able to see the evolution of factory dynamics and how they play out for a given scenario.

New technologies, such as low-cost connectivity, mixed reality, and artificial intelligence, are used to build digital twins for individual products that enhance equipment capabilities. These Product Digital Twins are helping manufacturers improve performance throughout the equipment lifecycle.

Project Objective

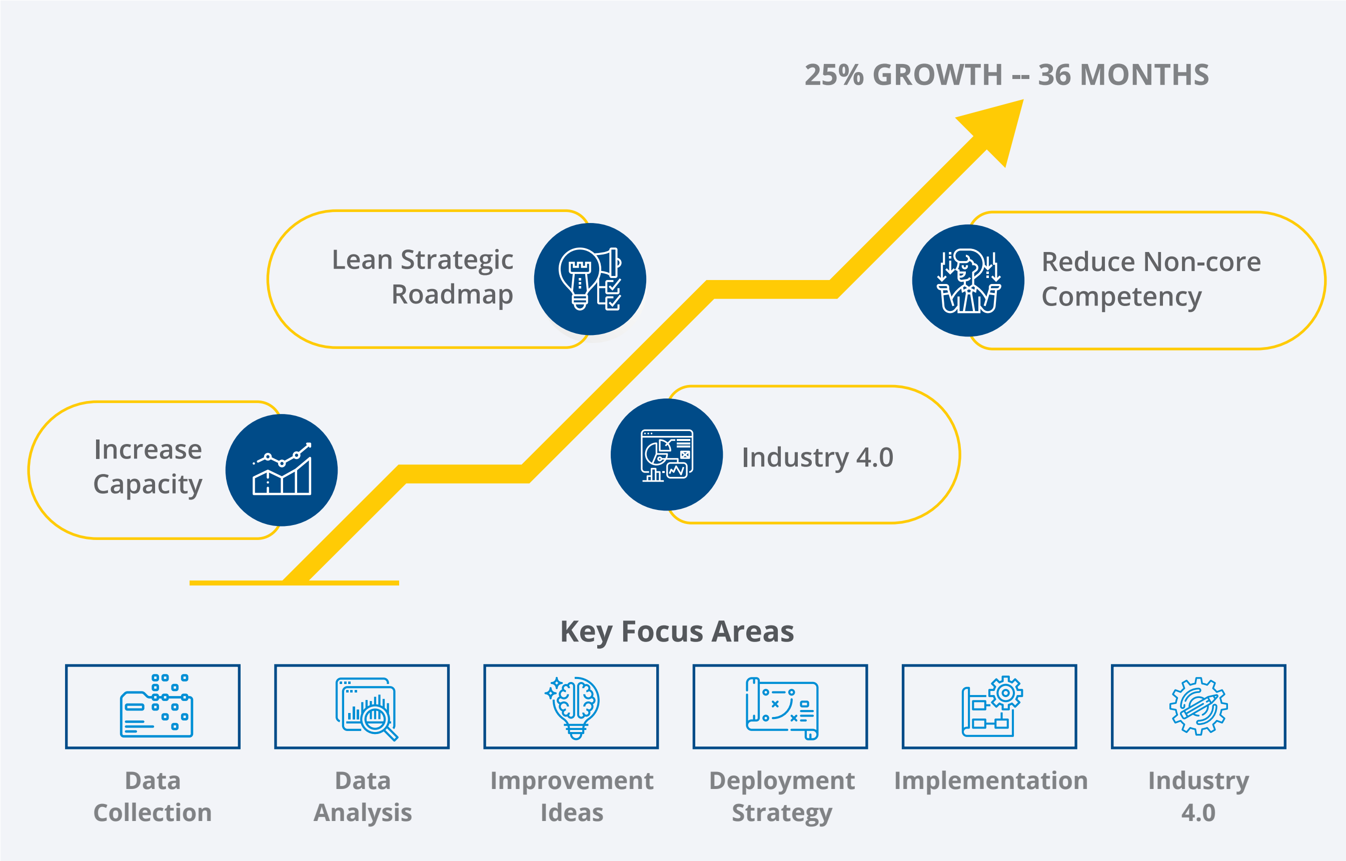


Figure 1: Overview of the Process Done

The case in point involves a pump manufacturing company which wants to increase productivity by up to 60% for meeting their demand in the upcoming year. Therefore, our team with one onsite engineer and 5 offshore engineers from various COP's (Center of Practice) were formed to study the existing process and provide the solution by design, development, solution creation, validation, and standardization of the process to meet the customers' demand and reduce the operational cost. LTTS has studied the existing process of the manufacturer and found that the station build with major rework and inconsistency in the operation is the major root cause of the efficiency loss. LTTS validated all the issues using digital approach concurrently with the cycle time, quality, operator efficiency, operator ergonomics, and data deriving factors that are focused for development.

Process Approach for Development of the Line

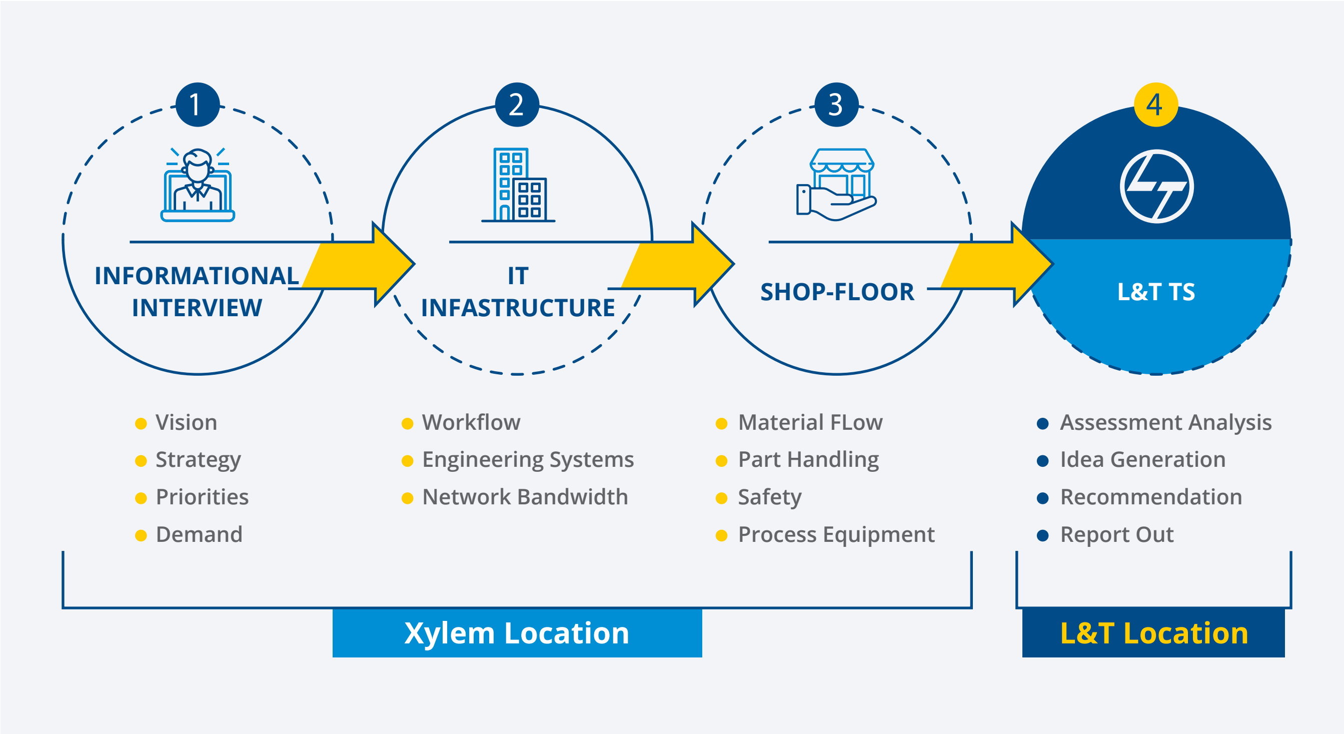


Figure 2: Procedure for the Development of the Process

The total project is split into phase wise as shown in figure 2

Phase 1: AS-IS Process analysis was carried out with the aid of special application developed by LTTS to calculate the standard time.

Phase 2: Make vs Buy strategy was carried out to reduce non-core competency like optimization of machines, improve machine utilization and should costing.

Phase 3: Process was split into stations by analyzing the process flow and defining the stations.

Phase 4: Layout planning was carried out with the aid of techniques such as Affinity Analysis, Relationship Study and Material Movement Analysis.

Phase 5: Detailed study on material handling was performed to minimize the material handling and to minimize the operator movement using genetic algorithms in discrete event simulation.

AS-IS Process Analysis by Lean IQ Tool

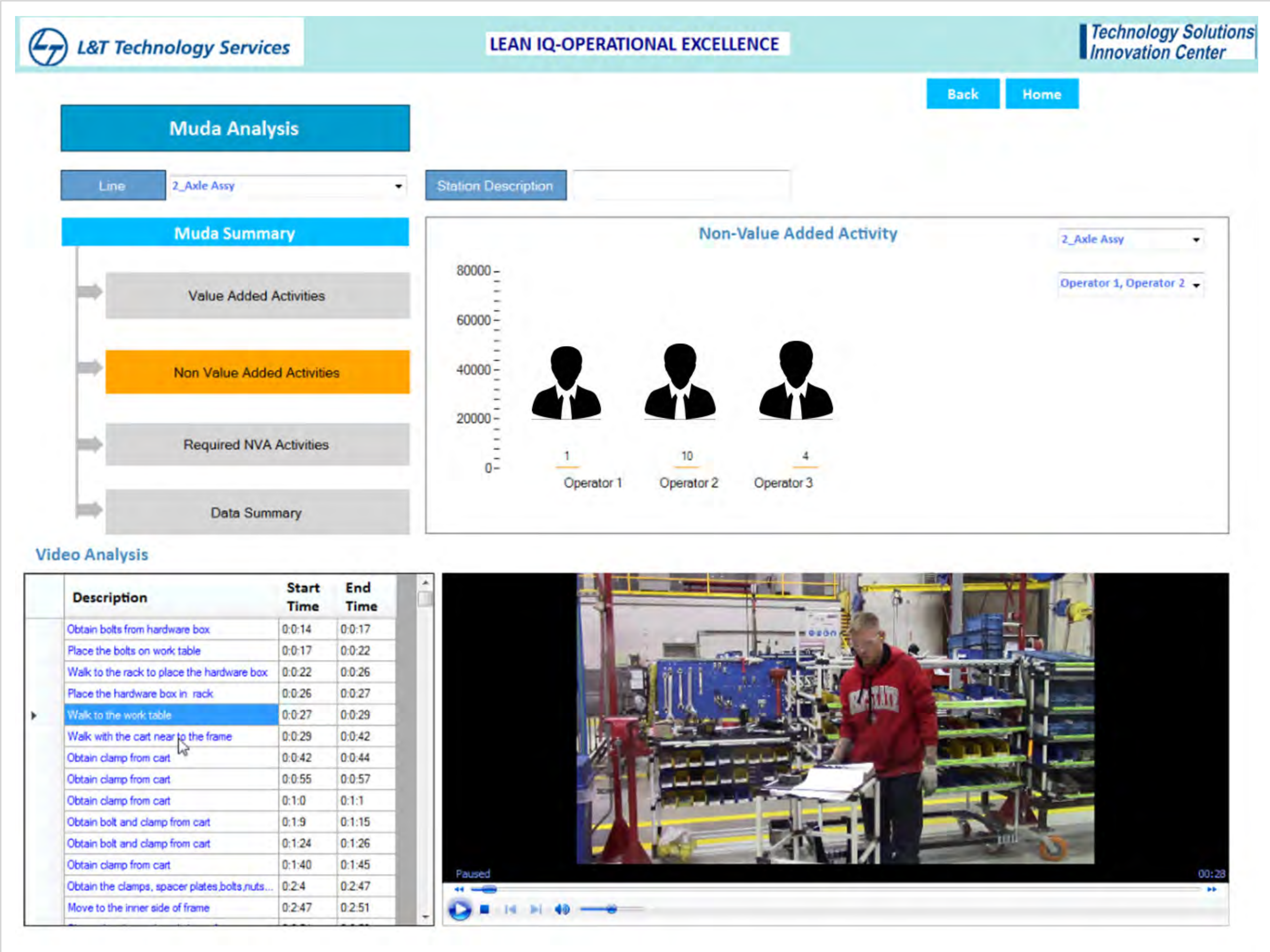
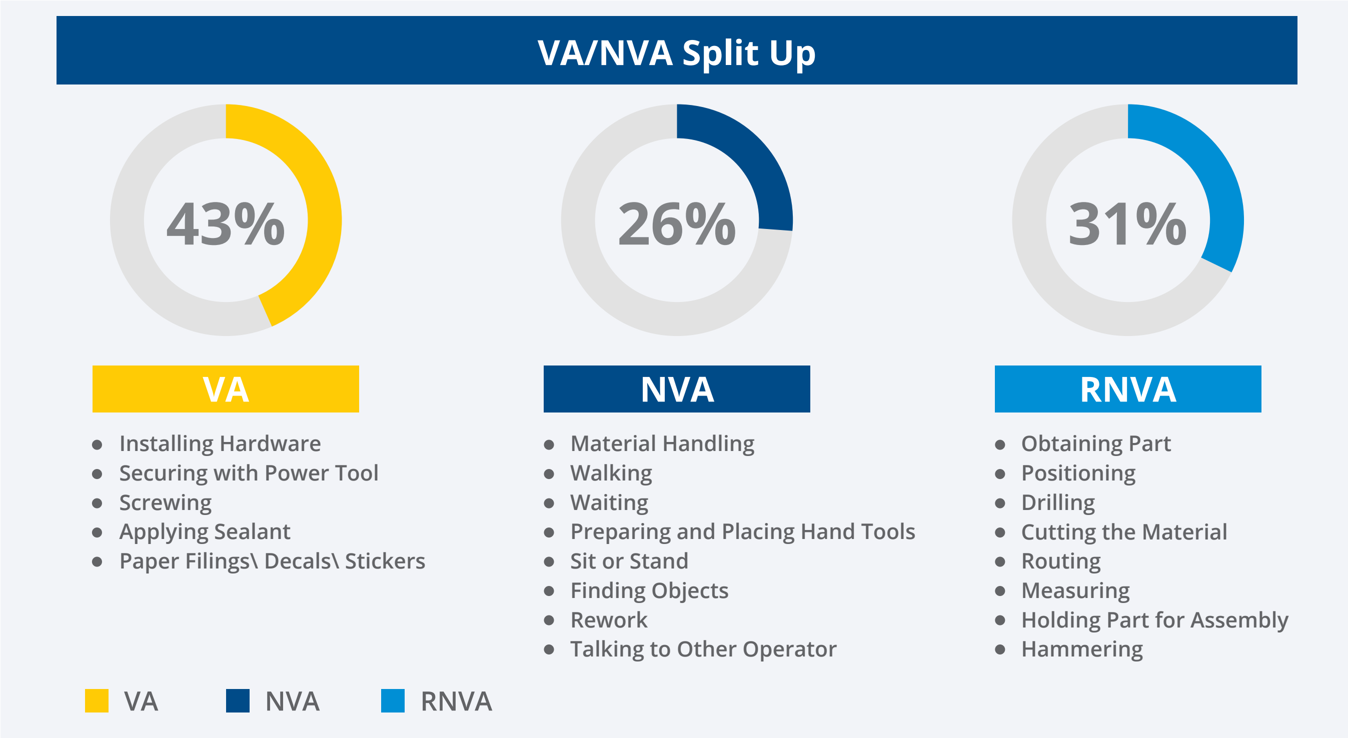


Figure 3: VA/NVA for the Process Using Digital Time Study

The execution involved taking a video of the process and leveraged lean tool developed by the LTTS team for identifying the VA/NVA /RNVA of the process. The team generated the VA/NVA based on the WCM standards and split the total percentage of the NVA. The advantage of this tool is instant accessibility and summarization of the statistics that help make the required observation. The tool will derive the dashboard and data based on the video which will be easy for analysis and identifying the key issues.



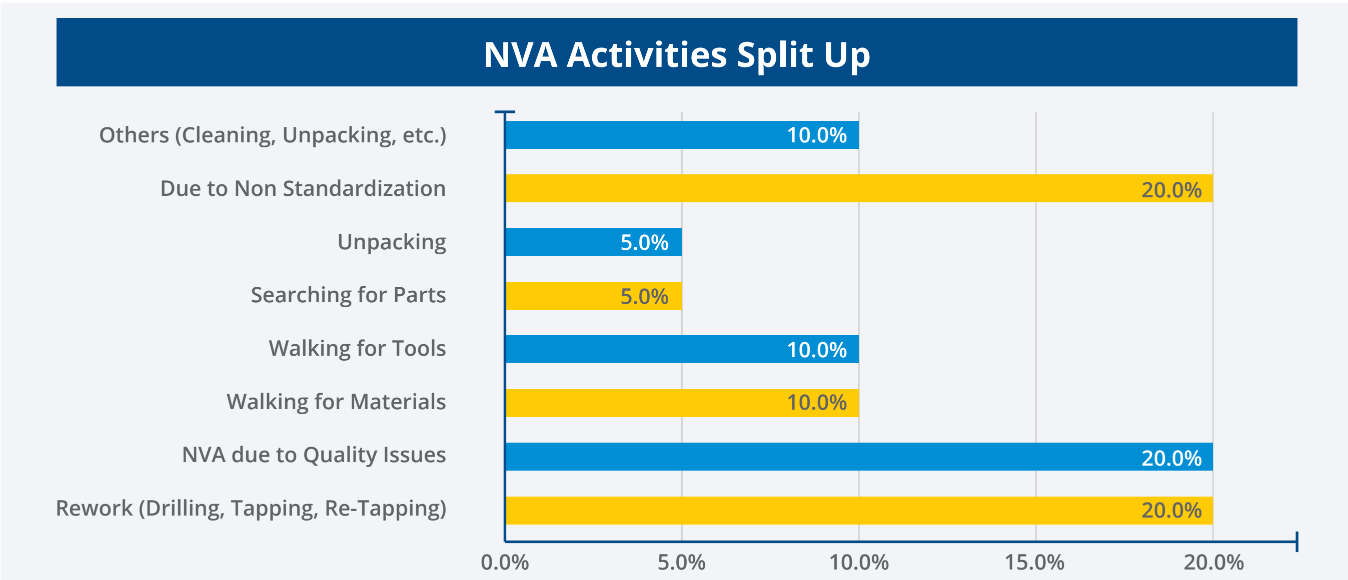


Figure 4: Derived VA/NVA of the process

From the dashboard, we derived the total VA, NVA, and RNVA as per the customer requirements and split the total percentage of the process in the NVA based on which the NVA corrective actions were provided. The solution for it is then noted down.

This report helps us focus on the process improvement and maximizing the value-added work content by eliminating the waste.

Based on the analysis it was found out that the station build was the major reason for the NVA which can be eliminated by changing the assembly sequence from the station to line build the output, operator movement, rework of operations can be easily reduced.

Make vs Buy Strategy

Make-or-buy analysis is conducted at the strategic and operational level. Variables considered at the strategic level include analysis of the future, as well as the current environment. Issues like government regulation, competing firms, and market trends all have a strategic impact on the make-or-buy decision.

Firms should therefore make items that can be reinforced or are in-line with their core competencies. These are areas in which the firm is strongest, and which gives the firm a competitive advantage.

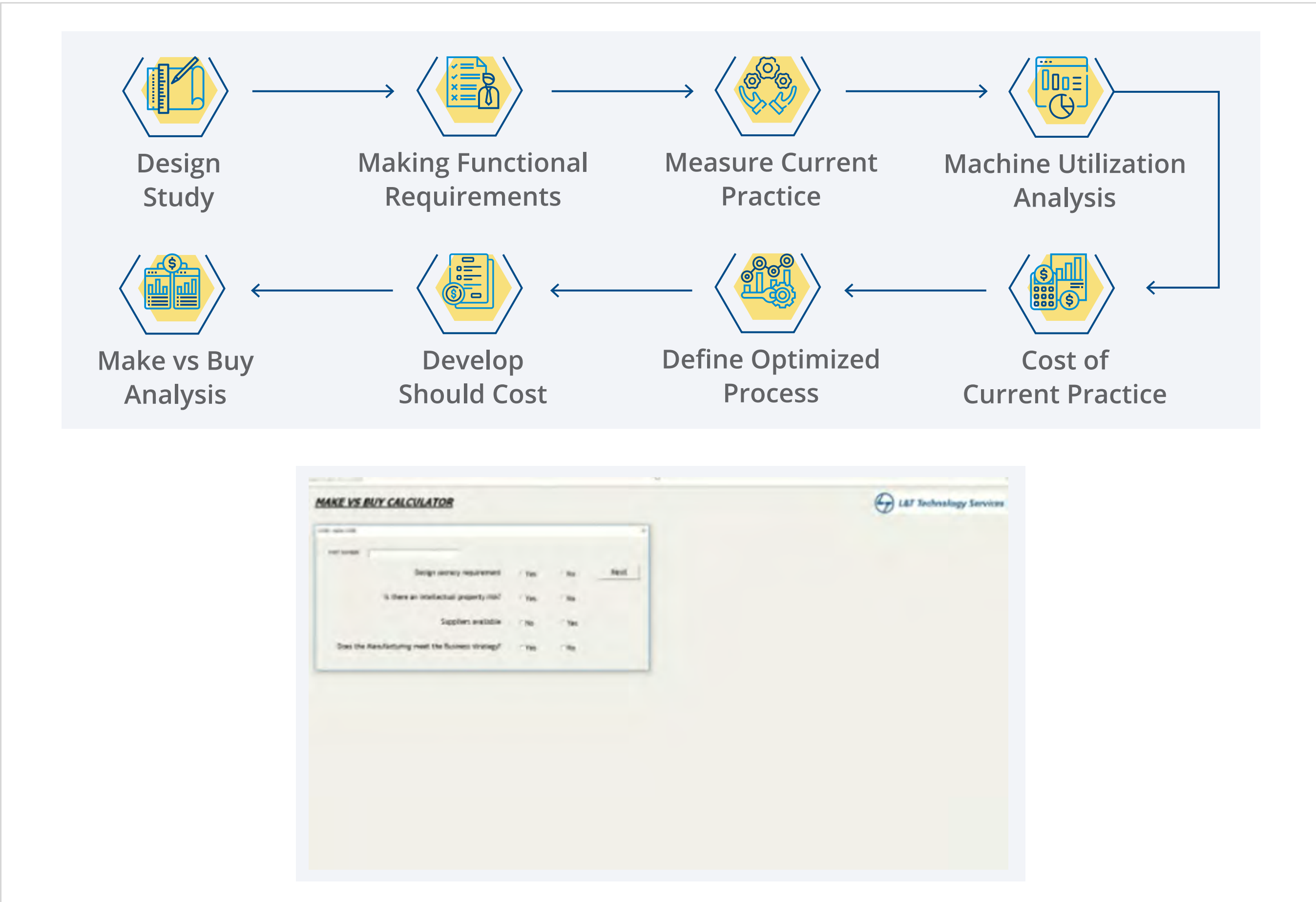


Figure 5: Make vs Buy Analysis

Make-or-buy analysis is conducted for various part numbers using above LTTS tool and from that we have conducted this analysis with the three pillar techniques as given below. We found that there is an overall cost saving of 12%.

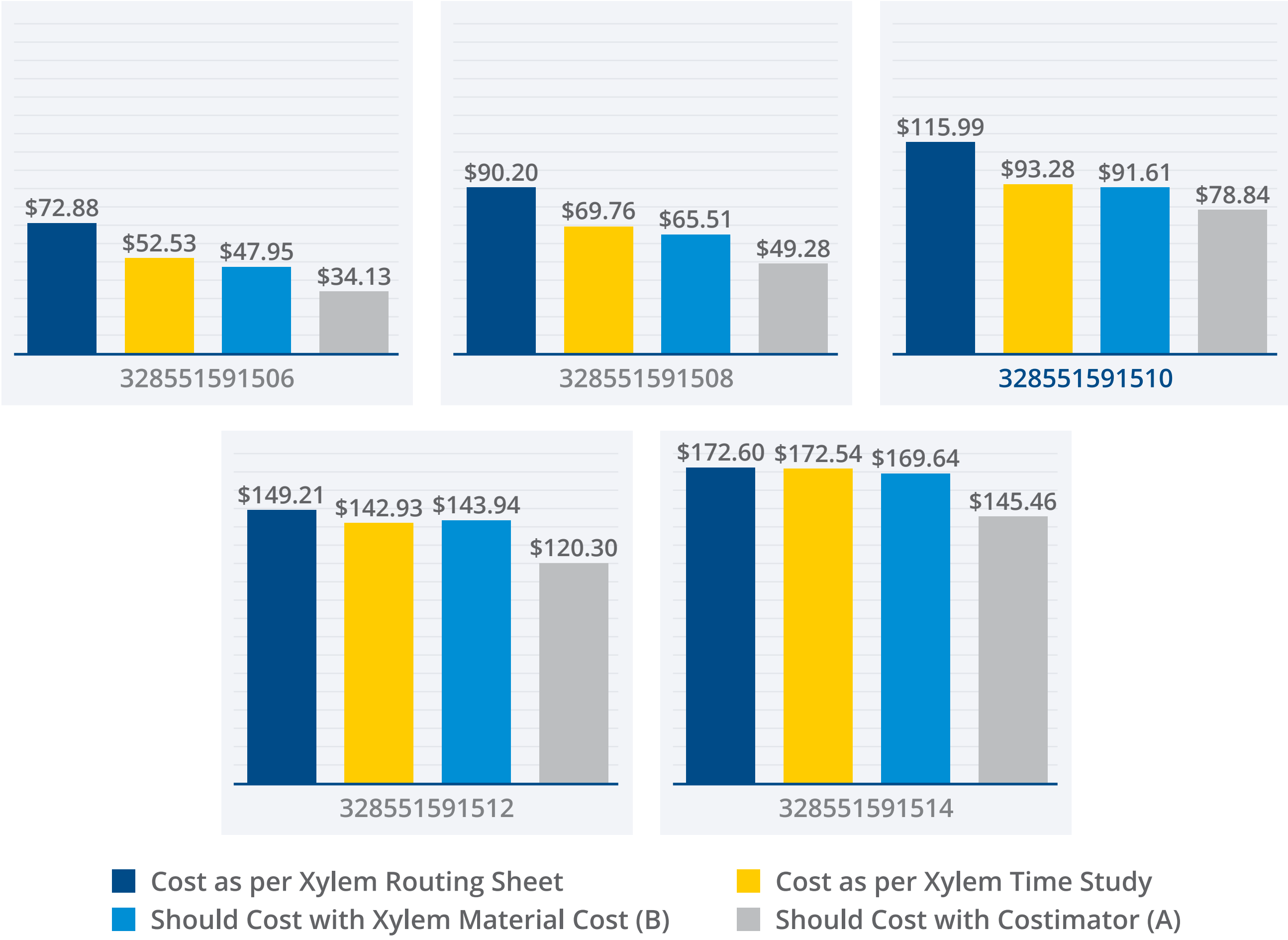


Figure 6: Make vs Buy Analysis Improvement

Layout Creation Using Systematic Layout Planning

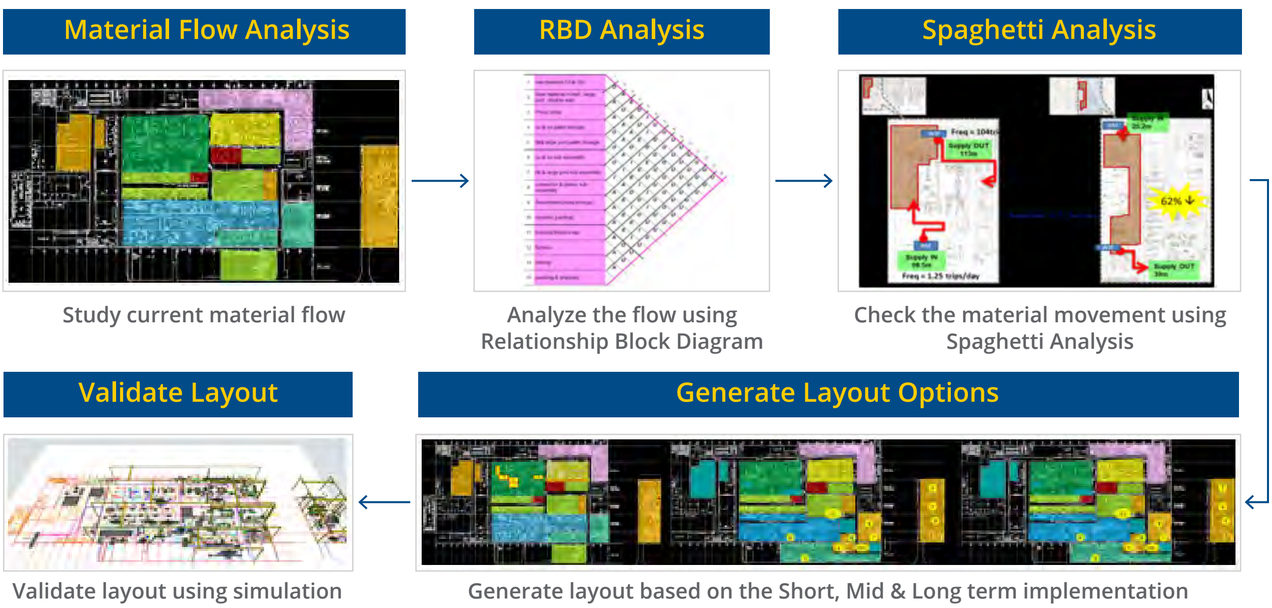


Figure 7: Analyzing the Existing Layout

The main objective of a good layout creation consists of organizing equipment and working areas in the most efficient way, and at the same time ensuring satisfactory and safe work area for the personnel. The plant layout process starts at an aggregate level, considering the different departments. Getting into the details, different issues arise, and the original configuration may be changed through a feedback process. Most layouts are designed properly for the initial conditions of the business, although if the company grows and has to be adapted to internal and external changes, a re-layout is compulsory. The reasons for a re-layout are due to changes in production volumes, changes in processes and technology, or changes in the product.

Layout planning was executed in two stages.

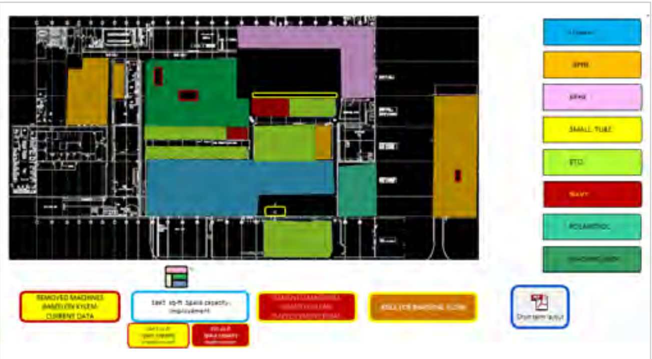
In the initiation and planning stage, input such as AutoCAD layout, process flow diagram, variant list and details were analyzed and consolidated. In this stage, data to be fed to simulation was designed.

In the Execution stage, simulation model building was carried out. Gemba visit to the plant was arranged to revisit on inputs mentioned earlier. Based on updates from visit, data was redesigned for simulation purpose.

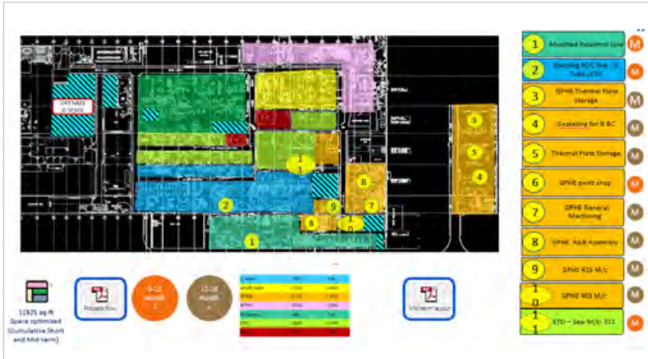
S. No	Layout Evaluation Parameters		Definition	Unit
1	Material Movement	COST BENEFIT	Approx. materials travel distance within line	Meters/ cab
2	Turn Around Time	COST BENEFIT	The interval from process start time to the process end time	Hours
3	Space Productivity	COST BENEFIT	Optimized Productive Area	%
4	Safety		No. of safety exists for an operator to evacuate from line side	Count
5	Accessibility		Providing easy access to racks & worktables from all the sides which includes easy maintenance	Yes/No
6	Flexibility		Accomodate easily the parts on other stations in the same assembly line	Yes/No
7	Future Expansion		Possibility of expanding facility for future demands	Yes/No
8	Order per Sequence		Order materials as per build sequence	Yes/No
9	Lineside Inventory Management		Dedicated racks for inventory storage near stations	Rack Count
10	Ease on Implementation		Easily accomodate the layout modifications with less effort	Yes/No

Figure 8: Finalizing the Criteria for Layout

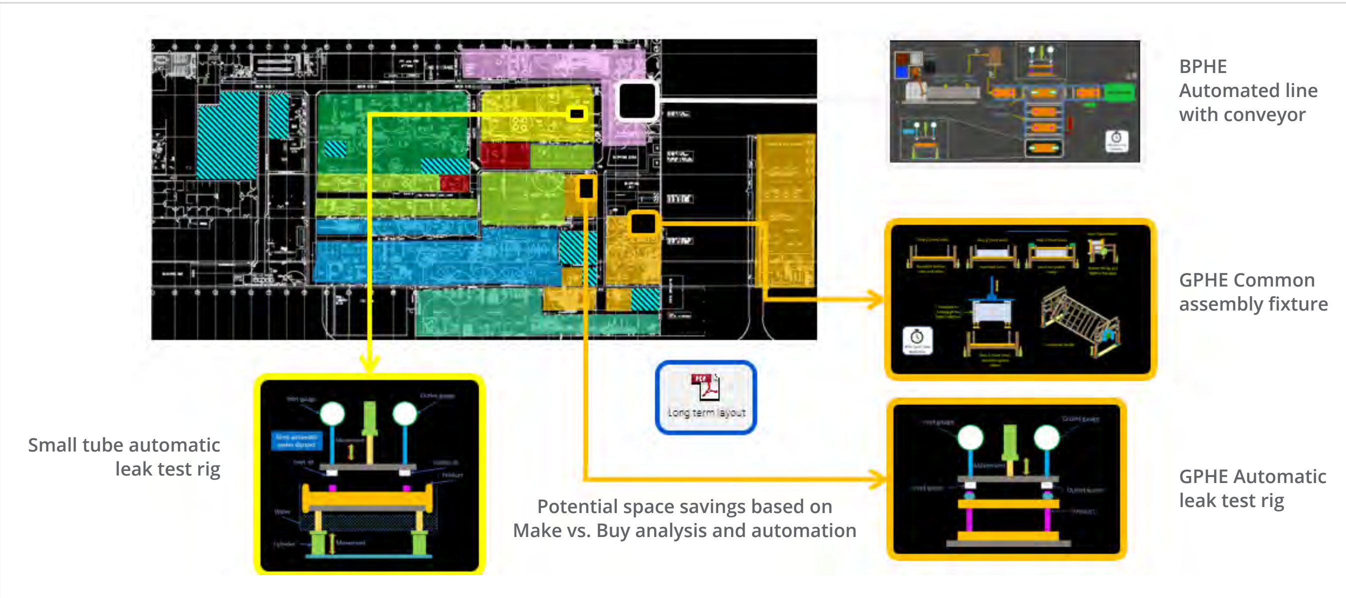
Based on the cost of the movement of the machines and racks the disruption level is derived and they have been used for checking the feasibility of the future expansion



Short Term Layout



Medium Term Layout



Long Term Layout

Figure 9: Building Options with Disruption

- Three options were built based on the disruption level moving on to improve each department internally.
- Affinity analysis and relationship matrix for machines were done.
- From analysis, internal placement of machines inside the department is fixed.
- The study provided value additions such as WIP reduction, unwanted space removal, space for new machine, and elimination of crisscross part flow.
- As shown in Fig 9. a similar study was carried out for all departments to arrive at the final optimized space and boundary requirement for that department.

Layout Validation Using Discrete Event Simulation

AS-IS

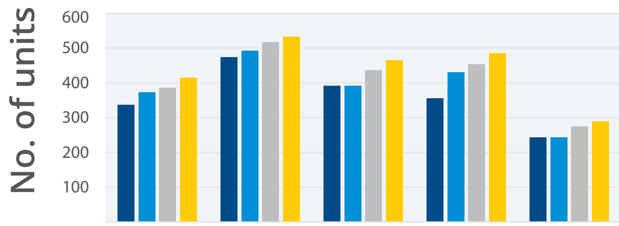
Long Term

Figure 10: Validating the Material Touches

As part of developing the ideal layout, collision analysis for material handling was performed with simulation. With several iterations and 'What-ifs', the best department placement with minimal possibility for collision was arrived movement and collision points in current and proposed layout.

Thus, discrete event simulation technology allows us to minimize the investment cost for production lines while meeting the required production demands, detect and eliminate problems that otherwise would require cost and time-consuming correction measures during production ramp-up, improve the performance of prevailing production systems by instigating measures that have been verified in a simulation environment prior to real-time implementation.

Line-wise Throughput

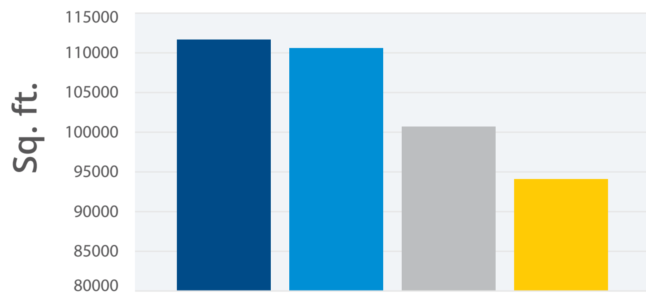


	Rolaitrol	Utube	Small Tube	BPHE	GPHE
AS-IS	348	485	398	358	243
Short Term	386	497	398	425	243
Mid Term	391	510	432	459	277
Long Term	412	523	463	494	292

Lines	Rolaitrol	Utube	Small Tube	BPHE	GPHE
Throughput %	18%	8%	16%	38%	20%

Overall Average 20%

Space Utilization



	Space Utilization
AS-IS	112476
Short Term	110483
Mid Term	100551
Long Term	94053

15% Space Optimization

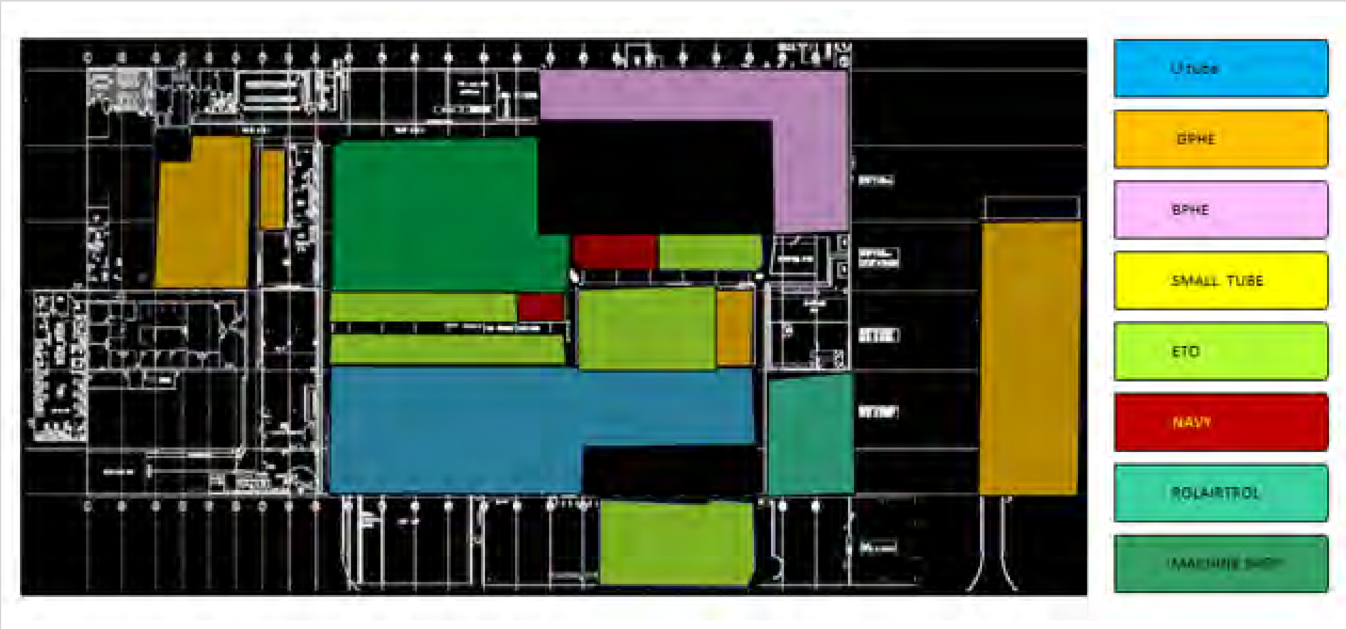
Figure 11: Checking the Operator Movement

The total movement of the operator for performing the operations in each option is simulated through discrete event simulation (option 3 gives the optimized result as shown in fig 14 where the total travel distance is reduced and all the operator movements are balanced). This helped in identifying the better option on the layout with respect to movement of the operator for collecting the parts, tools, and materials which is a major contributor for the process time.

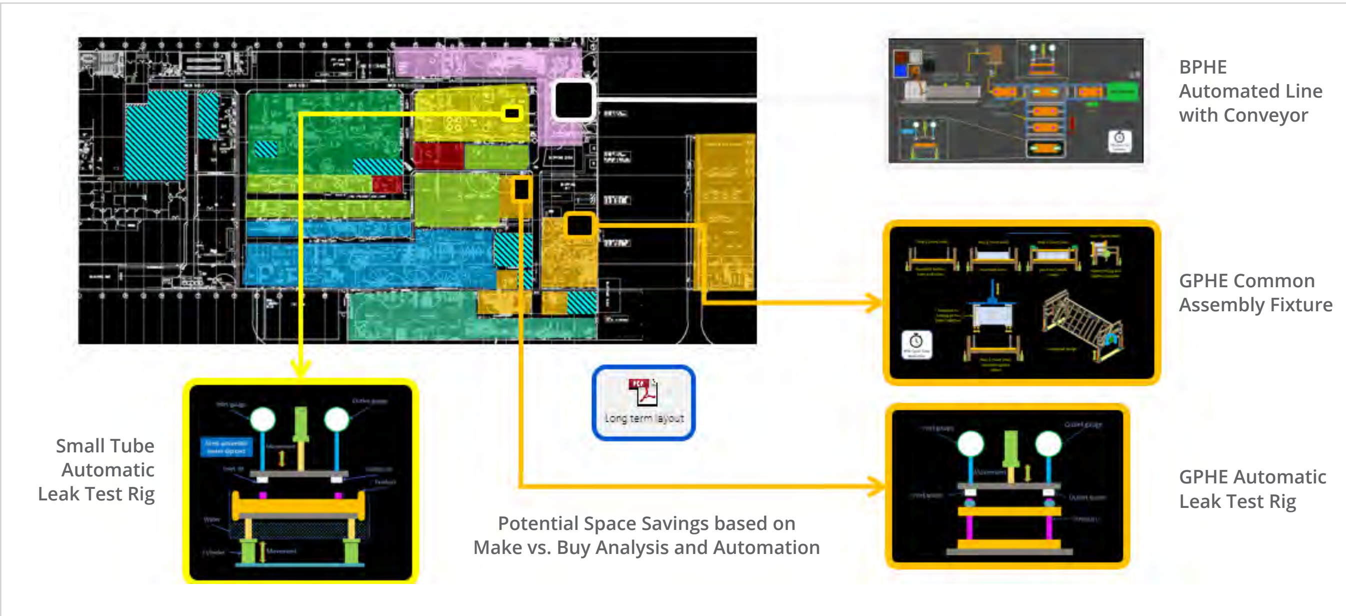
Through Discrete event simulation it was found that the result in the long-term layout has more impact and is better utilized compared to remaining options (refer fig 14)

and by fixing the maximum limit for each variant, the inventory space required was calculated according to its size. Thus, an overall picture on the space required, pallets required, and storage stacking methods can be defined.

Digital simulation has empowered to holistically understand the impact of inventory policies and variability on inventory levels and identify improvement opportunities. It has also given the ability to model and quickly run 'What-if' scenarios to understand key inventory drivers and evaluate trade-offs between customer service level and inventory investment to plan for changing business requirements.



AS-IS Layout



Proposed Layout

Figure 12: Finalization of the Layout

Based on the result of various evaluations, the layout is finalized and the station wise rack, safety equipment, worktables are incorporated, and the final layout is delivered to the customer.

The automatic leak test rig and assembly fixture has been designed commonly which will increase the productivity and space constraint.

Standardization of the Product

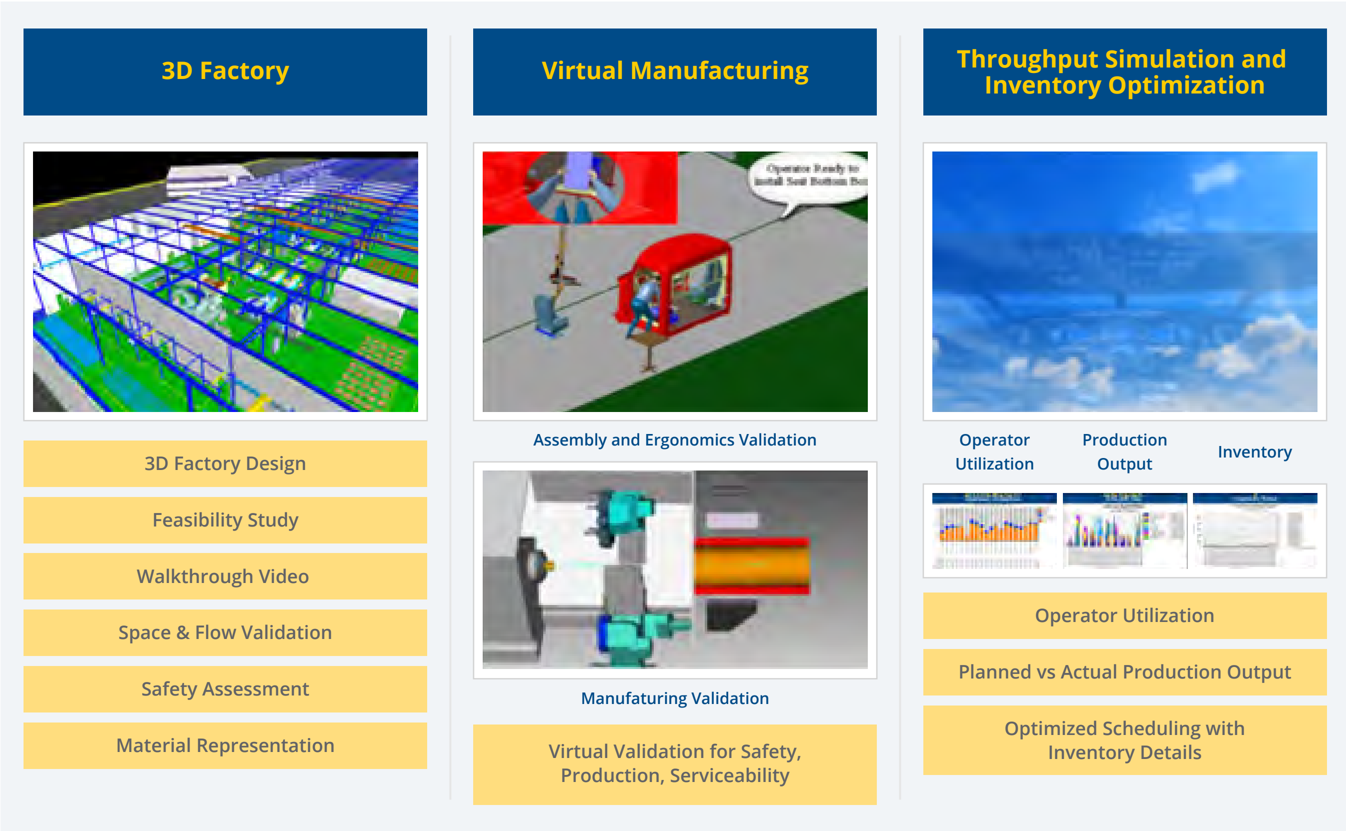


Figure 13: Digital Creation in MES

Standardization is done by following:

- Process metrics
- Work instructions
- General plant information

These standardizations are done in the MES system where the process is routed from one step to another with each task to be performed with time, tools, specifications, operator etc.

The total facility planning and the control location for deriving the data are specified simultaneously. The specifications for the process is provided in the application.

These are linked with the PLM and ERP system. If there is any new order, the MBOM will be generated to the ERP, and the routing sheet in the application will tell the operation sequence with the operator work, the operator will be specified by the plant. As soon as operator is specified, the work will be allocated to him in queue and further operations will be done by him as per the plan.

The task is planned as per the operator where it will be allocated to the operator based on the station whereas, the time will be predetermined. The real-time data will be captured as soon as the operator starts the tasks in the application.

The MES system can also be used to check the overall progress of the process by top level management from global and if there is any deviation in the plan the data can be analyzed and corrective actions can be suggested.

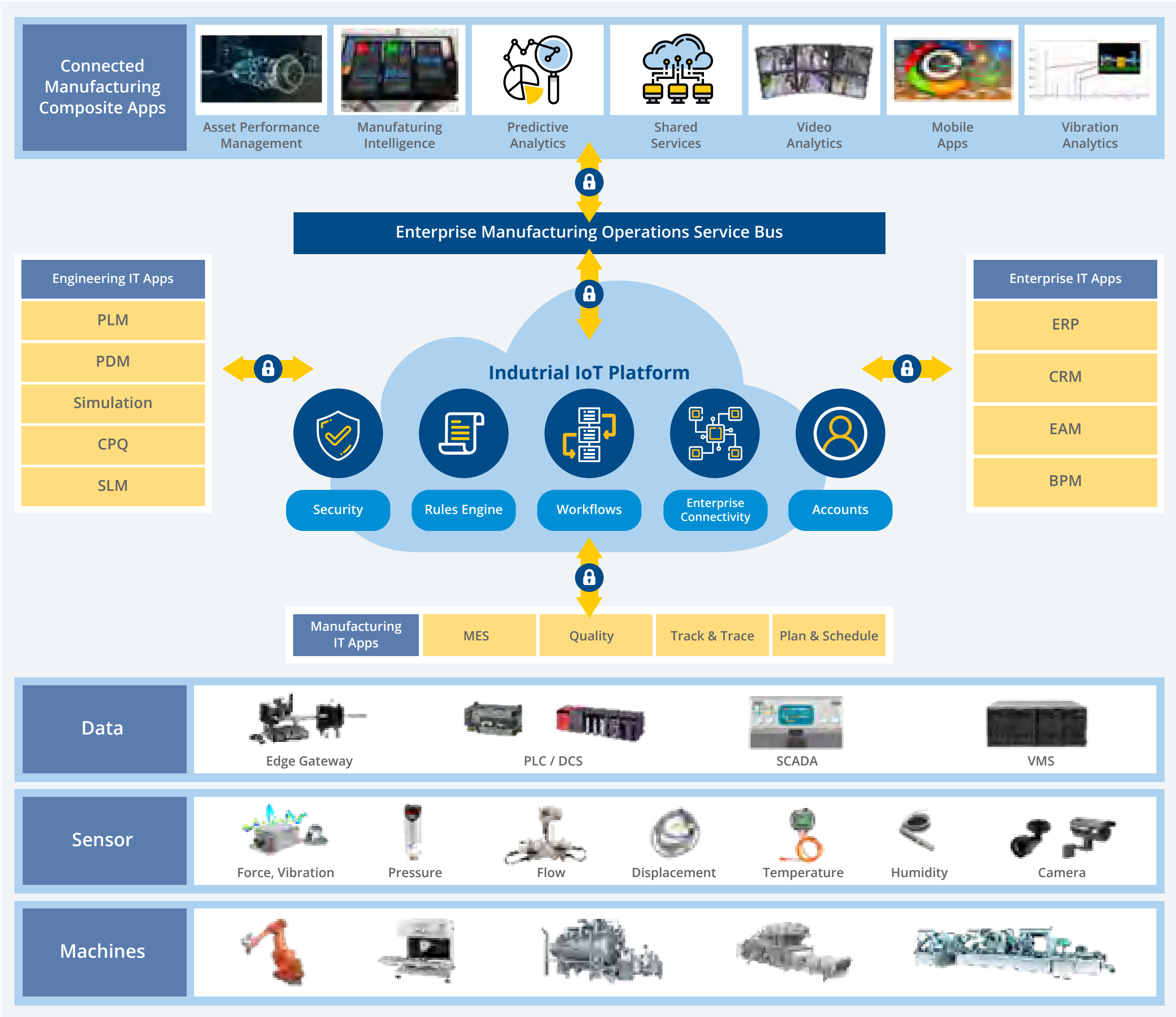


Figure 14: Inhouse Material Tracking for Deriving the Real-time Data

Inhouse material tracking (refer fig 14) is used to identify the movement of the material from one place to another using application developed by L&T technology services which links ERP and MES. The ERP triggers the pull system to the individual station and MES triggers the process for the operator for each station. Each of these processes are interlinked by the poke yokes of the tools that transfer the real-time data to the application using the Wi-Fi.

A digital twin can be implemented by replicating the entire process and thereby finding issues virtually within the system which will reduce the quality issues, increase productivity, find the issues in the repeatability process, and validate the optimized solutions virtually by using genetic algorithm before implementing them inline.

Project Summary

Digital lean tool combined with digital simulation has helped in reduction of the process time, minimized rework, and improved productivity, as summarized below:

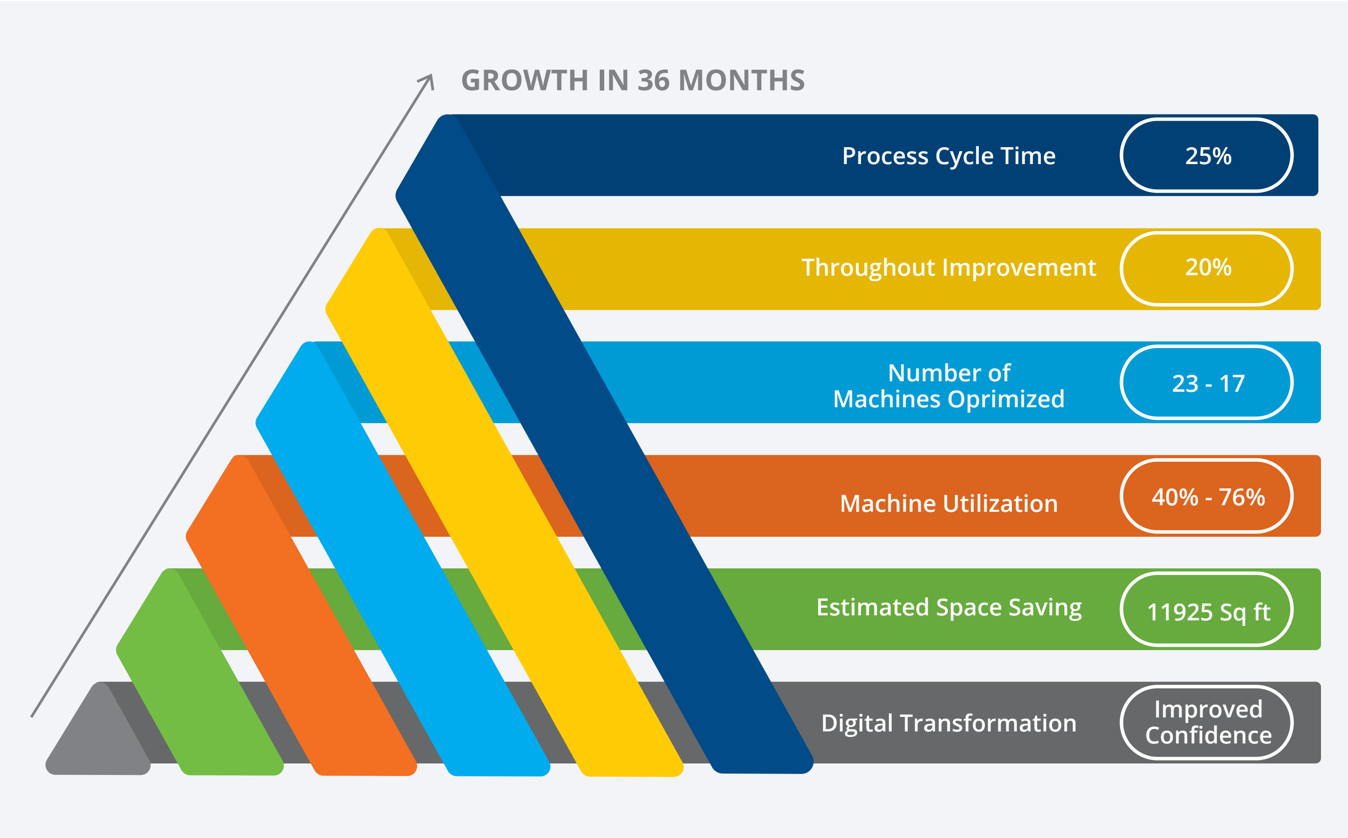


Figure 15: Cost Saving Summary

Conclusion

Virtual build has given a turbo boost to traditional lean tools, in redesigning the entire plant, eliminating the identified bottlenecks, and testing 'What-if' scenarios. This Concurrent Engineering approach of using Lean with digital validation has proved to bring an overall productivity gain of about 100% and saved a considerable amount of time, cost well before actual implementation thus paving way for First time Right on the real floor.

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L&T Technology Services Limited is a subsidiary of Larsen & Toubro with a focus in the engineering services space, partnering with a large number of Fortune 500 solutions through the entire product development chain, across various industries such as Industrial Products, Medical Devices, Transportation, Telecom & Hi-tech, and the Process Engineering Services, Embedded Systems & Applications, Engineering Process Services, Product Lifecycle Management, Engineering Analytics, Power Electronics, Machine-to-Machine (M2M), and the Internet-of-Things (IoT).

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