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**Abstract**

The digital era is characterized by fast development, growth, innovation, and disruption. Organizations that want to survive must be ready to adapt to the new digital landscape. The digital transformation process is more than just implementing new technology, investing in tools, or upgrading existing systems. These steps are important, but they are not the whole picture. If an organization wants to stay competitive, it wont just be able to respond to changes, it should expect them and stimulate innovation itself. To do this, companies need to plan ahead and be active designers for their future. This is where the digital transformation strategy comes in. The digital transformation strategy helps leaders answer the questions for their business such as the current digitalization level, future vision, and how to get there. To be protected from digital disruption, companies need to develop three core competencies related to awareness, informed decisionmaking, and rapid implementation. The development and implementation of a digital transformation strategy have become a key concern for many organizations across manufacturing industries, but how such a strategy can be developed remains an open question. In this paper, we will be discussing how manufacturing could develop a digital transformation strategy that including a different aspect of the strategy tailored to the nature of the manufacturing sector.

# Introduction

In recent years, Digital Transformation (DT) has appeared [1] as an important phenomenon research topic related to companies. Digital Transformation is the integration of digital technologies and new business models into all areas of resulting in major changes to how industries function and how they provide value to customers [2]. DT incorporates the changes taking place in the world and industries through the use of digital technologies [3]. In order to produce the capability to generate new paths for value creation in the digital era, there is a need to have different culture, processes, structure, and strategies [4].

Most of the benefits in manufacturing from digital transformation could be summarized under five groups. First benefit related to improvement in productivity where the development and design processes are faster and better informed using tools such as augmented reality (AR) and 3D printing by leveraging interactive data from users in realtime. Improvement in production with minimal downtime could be achieved due to better machine connectivity by sending vital maintenance data that can help to prevent machine faults and enhance output. The second one is related to quality with the highresolution measuring of production parameters and products throughout the entire process. New machine learning tools for quality assessment of the products [5] are applied to production data to automatically indicate quality defects root causes and predict wasterelated issues before they occur. The third benefit related to cost where data capturing and analyzing the manufacturing process across all stages, including machine data, production line, transportation, and logistics. This analysis helps to identify cost reduction opportunities and better management of inventory to meet demands while machines offer a high level of flexibility that allows for fast alterations between products. The fourth benefit related to having more product customization, which is an important selection factor for customers [6]. Manufacturing lines with digitalization can offer customers customization with attractive options while still producing on a big scale and efficiently with competitive prices. The last and very most important aspect of manufacturing is related to safety [7] at workplaces in which hazardous tasks can be performed by robots. Staff can be notified about the potential and possible hazards in advance by making use of installed sensors throughout the workplace.

Digital transformation strategy is seen as a structured and formal plan that directs a company throughout its digital transformation journey [2]. It thus extends the practical analysis and discusses the benefits and risks associated with digital technologies comprehensively. The distinctive essence of being inclusive of all business segments and the characteristics of the organization includes multiple coordination mechanisms: first, alignment with the business strategy; and second, alignment with other operations.

In this paper, we will be discussing how manufacturing could develop a digital transformation strategy that includes different aspects of the strategy tailored to the nature of the manufacturing sector. The rest of this paper is organized as follows. Section 2 reviews the digital transformation of valuable players for manufacturing. Section 3 presents the challenges faced by manufacturing in implementing digital transformation. Section 4 presents the guidelines for strategy development. Finally, we summarize the paper and highlight the future work directions in Section 5.

# Digital Transformation Valuable Players for Manufacturing

In this section, we list some of the most common valuable players and use cases of the digitalization in manufacturing. In the introduction, we have mentioned categories for those benefits and in this section will briefly elaborate on the top use cases that help Manufacturing to benefit from digitalization technologies and initiatives. The first digitalization valuable player for manufacturing is the Additive Manufacturing [8] which is commonly referred to as 3D Printing. The additive manufacturing combines a wide variety of processes and materials that share a common feature of translating 3D data directly into the physical realm. This mode of production enables design flexibility that has never been possible before, and as this technology advances, we are witnessing the proliferation of applications in sectors like, but not limited to medical, automotive, aerospace, and lifestyle.

Asset Performance Management (APM) [9] is another use case and common player for manufacturing and being offered by most of the digitalization solution providers as a standard product. With the emergence of Industry 4.0, APM includes a wider range of functions due to the possibility to do data analytics, the ability to get equipment from OEM and integrate data from multiple plants and sites. APM provides several tools to improve the equipment and

plant availability of manufacturing equipment. APM tools gather, consolidate, visualize, and then analyze collected data from all equipment. APM helps predictive forecasting, condition monitoring, and reliability maintenance of equipment systematically and easily. Industrial Internet of Thing (IIoT) [13] is evolving at a rapid pace as manufacturers are realizing the huge potential of this technology approach to completely change the way they operate. Some of the leading use cases of Industry 4.0 are predictive maintenance, condition/status monitoring, digital twin, databased research and development, and fleet management.

Analytical insights of Associated Products and Services [11] enable customers to monitor their machines consumption patterns and improve operations by optimizing replenishment schedules. Another example is predictive maintenance services, which help customers reduce machine downtimes and lower maintenance costs. Remote ordering services give customers the ability to verify stock and offer restocking from anywhere via applications. Appliance manufacturers can also leverage data insight from appliances and switch to ondemand production and inventory management.

Cloud Platforms [10] are new technologies for creating and hosting application as compare with the clientserver methodology. This new technologies for creating and deploying application has numerous advantages over clientserver in term of management and maintenance cost. It is much cheaper and faster to acquire additional processing power if needed as compared to clientserver methodology. Edge Computing [12] improves in processing power allowing more tasks to be handled by user enddevices. This reduces latency by reducing the load connected to the Internet of Things and the cloud, reduces data security risks, and reduces delivery costs. This processing ability opens many possibilities within the scope of the Internet of Things such as avoiding obstacles, language processing, object detection, face recognition, and other machine learning applications. Fog computing [13] inhabits the distance between the Internet of Things endpoints and the cloud. In other words, Fog computing is a network that connects data entry points and cloud machines where that data is stored. Fog is a midway processing area that takes care of data from the edge and manages tasks that do not require cloud machines but cannot be handled by edge devices.

Advanced Analytics and Machine Learning [14] is one of the industrys most important digital applications. It can receive and analyze continuous updates from sensors and other data collection points in realtime and be able to respond with immediate action. In this way, machine learning a very powerful mean in leveraging the IoT for industrial applications. By using machine learning and predictive maintenance, staff will be able to understand the behavior and performance of machines in setting up manufacturing as algorithms adapt based on new information. This allows us to identify unusual behaviors and to predict errors and malfunctions with high accuracy.

Open Process Automation [15] aims to provide a new and open architecture of automation solution that is flexibly adapted for industrial application and noninstallation application scenarios. Many of the automated manufacturing are control using a Distributed Control System (DCS) or Programmable Logic Controllers (PLCs). Those types of controllers are inconvenient for the new technology trend since their architecture is suited for traditional control. Also, it is difficult to make changes in those systems since they are very dedicated to a specific production facility.

The use of robots [16] in industrial manufacturing is common today with approximately 2 million industrial robots operating around the world. The motivation behind robots is high due to their competency what they are offering since they can do monotonous, unpleasant, and dangerous work instead of humans. Internet of Robotic Things (IoRT) takes technology to the next level and will be a major part of the manufacturing future. Robots used in production will be provided with instantaneous data that will be used to make decisions regarding synchronization and performance on the factory floor. IoRT will allow manufacturers to better meet and exceed customers requirements of their and react accurately to deviations in the supply chain.

# Digital Transformation Strategy

A welldefined digital transformation strategy is critical for the overall success of digital implementation in a manufacturing setting. The strategy should cover every aspect of business activity from development and production to advanced quality control, delivery, and analysis.

The state of the companys legacy systems should be taken into account to identify potential challenges. As much data as possible should be collected from the machines in their current and past states before the implementation of the new system begins.

* 1. *Digital Transformation Challenges in the Manufacturing Industry*

For manufacturing organizations to effectively embrace digital technology, it is critical to understand the challenges they face along the digital transformation journey. The roadmap for digital transformation includes several challenges that need to be addressed and handled. Here are some of the challenges to look out for when implementing digitalization in manufacturing shown in Table 1 below.

Table 1. List of Top Challenges Faced by Manufacturing for DT. Challenges Description

Traditional Processes With everything connected digitally, it is challenging to rely on traditional

paperbased processes and operate in silos; there is no longer a place for manual, timeconsuming processes.

Resistance to Change Where does the organization sit on change? Most employees are so

entrenched in traditional processes of daily duties that, when the time comes to improve processes and incorporate new technology, they resist. They see change management as a challenge to their roles/responsibilities, at best, and a threat to their job security, at worst. Many people resist change to their work environment since it affects their comfort zone and since digital disruption is experienced as a threat to many employees in manufacturing.

Legacy Business Mode Manufacturers have become very comfortable in their legacy systems.

Limited Automation Many repetitive, redundant and timeconsuming tasks are performed

manually by a task force that consumes a huge number of manhours which results in high cost.

Budget restrictions A substantial investment is required to lead a manufacturing facility through

the digital transformation journey. The benefits are multiple, both short and longterm, but it is important to remember that each company is different, especially when it comes to systems of revenue and cost.

Absence of relevant knowledge

Without relevant knowledge, the introduction of technology alone is not enough to make it work. Enhancing employees knowledge is an essential part of integrating digital technologies into manufacturing

Inflexible company structure The introduction of industrial internet of things (IIoT) to a manufacturing

site is similar to the other transformation task and it is more than just small improvement. There is a need for the organization to have new technologies and business models to work properly. Although this may be scary, it can lead to a lot of positive results as the organizational structure is reset and retested, creating an opportunity to improve employee status and other improvements.

Security Cybersecurity is a major concern for any digital transformation project since the operation network and systems will be exposed to the internet.

* 1. *Digital Transformation Challenges Resolutions*

To implement DT in manufacturing the outlined challenges in the previous section need to be mitigated systematically the reduce the risk of failure or delay of DT implementation in the manufacturing site. Table 2 below suggest some of the good recommendations for each challenge.

Table 2. Recommendations for Mitigation of Manufacturing Challenges Related DT. Challenges Recommendation

Traditional Processes Manufacturers need a modern and agile digital solution that replaces outdated and errorprone paperbased processes and converts them to digital

Resistance to Change 1. Organizations should have the best digital solution in place to reduce timeconsuming processes, improve employee efficiency and reduce job stress by enabling access to work from anywhere, anytime, regardless of location.

1. High Commitment should start with executive management and be passed onto individual employees as part of the digital transformation process.
2. Transparency and effective communication are essential to get everyone motivated about the potential of this new technology.

Legacy Business Mode

Manufacturers need to leave their comfort zone, revamp their business model, and proceed ahead for more efficient and faster timetomarket business processes by employing digital technology that provides exceptional efficiency within their existing legacy systems

Limited Automation Organizations can automate or reduce manual tasks, allowing for faster product updates and response times by embracing the right digital solution.

Budget restrictions 1. Proper planning for the investment process is required and no two digital transformation programs are similar.

1. Having a longterm vision is important for reaching a truly valuable goal down the line with a big picture in mind
2. Solutions with a solid ROI should be selected and considered as a proofofconcept (POC)

Absence of relevant knowledge

Inflexible company structure

* + 1. In the case of the companys existing expertise are not sufficient, it is necessary to consider collaborating with external consultants or hiring new employees.
    2. The responsibility for IIoT introduction should be a shared goal by the whole organization and not limited few employees or departments.

One methodology is to compile teams from multiple disciplines including engineers, product designers, data analysts, and service professionals as the focal teams for the digital transformation. The team will nurture new technologies, implement POCs, and then roll out successful iterations to the company after theyve been approved.

Security 1. Vulnerability issues should be recognized and documented

2. Several protection layers and failsafe mechanisms need to be deployed to ensure that the system is completely safe and secure.

# Digital Transformation Strategy Development Steps

Based on the challenges and their suggested resolution recommendations that were discussed in the previous section, a guideline for Digital Transformation strategy development could be established in steps.

* 1. *Creation of Digital Transformation Vision and Objectives*

In the initial step, organizations must outline their vision and objectives for implementing digital transformation. But instead of focusing on the problems they are trying to solve with innovations, they should look at their ultimate goal and what they want to achieve. They should define longterm goals and focus more on the experience they want to have with their clients and employees. It is necessary to reach a global vision for the future. On the other hand, this vision must deal with reality. Therefore, organizations need to build a strategic vision about the goals and shortterm resources available with their businesses today. Organizations must focus on their competitive advantage, then identify gaps in the current structure and create implementation roadmaps to improve them.

When adopting new technologies, organizations often make two mistakes. They approve any technology that is adapted by the innovation department or the IT department or is made by other departments. This may include new applications approved by competitors and other players in the industry. Second, they begin with their capabilities or ecosystem and they simply start improving without having global goals or specific problems that they want to solve. These errors can lead to the adoption of isolated and silo technologies, which are difficult to integrate and extend throughout the organization.

Organizations should start first by defining their objectives and vision they want to accomplish through Digital Transformation. It should include the definition of successful transformation and its implication to their overall business and their customers concerning customer experience and engagement. By establishing the objective, organizations can adopt technologies with a clear emphasis on business improving instead of limited improvement of individual processes. This will help in developing a comprehensive strategy that involves and transforms the entire organization and also avoids the silo adoption of technologies.

The current status of the company should be taken into account when developing a strategy for digital transformation. A good practice is to set objectives and targets for five years. The organization should start with goals with the most significant ROI as a top priority. A good approach to launching a digital transformation in manufacturing is to identify improvement opportunities in the performance that will result directly or indirectly in significant benefits to the customer and employees. This emphasizes areas such as the operations, engineering, supply chain, customer service, and support as well as the business model itself.

* 1. *Assess the Organizations Digital Transformation Capability*

In the first step, we have defined what the organization wants to achieve through digital transformation. In this step, we assess where the organization is now with respect to digital transformation. The organization should assess its infrastructure and investigate how well its system, software application, and tools in addressing current and future needs. The organization has to discover the critical components required for its DT strategy, areas that require to develop new functionality, and the necessary integration that bring them all together. This assessment will support the organization to find out what technology to be updated, processes that need to be automated or optimized, and set tools that should be changed. As a consequence, the organization will select tasks, investments, and efforts in the digital transformation strategy in the best possible way.

A good tool for this assessment is to perform market analysis and benchmarking of the organization with emerging and existing organizations of similar industries. This could be achieved with a consultant firm that has more exposure to the market and similar industries. Before making any digital transformation effort, carry out a profound analysis of the market dynamics. Because of rapid technology development and industry changes, this step is essential for creating a relevant and uptodate strategy. Not long ago, the largest yellow cab company in NY, which was a leader for ages, turn bankrupt because of Uber as a competitor. Today, almost every organization in the automotive industry invests in selfdriving technologies and electric cars. Otherwise, they risk dragging behind. As the boundaries between industries continue to blur, companies can find practical solutions and a massive portion of inspiration in other fields.

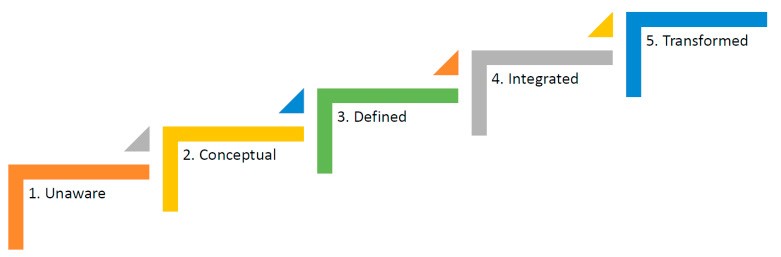


Figure 1. Digital Maturity Levels

Digital maturity assessment is a common methodology done by most of the consultants [17], which include several dimensions such as strategy, leadership, operations, culture, people, products and technology. Digital

maturity level in each dimension need to be assess based on a scale from one to five with five as highly mature as shown in Figure 1.

* 1. *Design the End User and Employee Experience*

Once the organization created a vision and assessed its current status of digitalization, it is time to develop a type of experience for its employees and customers. Digital transformation values and prioritizes customer experiences as much as it adds and introduces new capabilities and functions. The organization must concentrate on the experiences they want to provide their employees and customers instead of concentrating on the need for new solutions and the limitations of existing technologies.

After the development of highlevel DT objectives, detailed goals are required to be developed at this stage. These goals could include the simplification of employees work and ease of through new applications, functions, or systems. In addition, it should include how to improve customer access to a companys product and services catalog with a more attractive shopping experience through the use of mobile or web applications. Good use cases to help employees with better engage, collaborate and interact with each other. Also, new digital platforms and technologies for customers interface. The focus is not on the new application or technology but on the experience, they will provide to customers.

* 1. *Review and Select Solutions and Vendors*

The next step in the Digital Transformation strategy is the assessment and selection of candidate solutions to meet the developed objectives, deliver the anticipated experience, and close the gaps of current technologies.

This step requires the organization to perform a thorough and careful evaluation of candidate solutions and offerings from different technology providers. The provider solutions should be accessed based on their capabilities, functionalities, proven deployment records with provider accomplishment and reputation. An important factor for the selection of technology providers is the capability of aftersales support with the required response time with the required competences. A good tool to use a comparison matrix of solutions and vendors with their DT capabilities, which will help the organization with an objective tool for making informed and better decisions.

* 1. *Creation of Implementation Roadmap*

The final step is to compile the overall business digital objectives, anticipated experiences, current technologies, potential solutions then unified them into an actionable plan. Developing a digital transformation initiative require time and resources from human and capital. This is one reason for DT often done in stages. It is important to plan carefully for each action such as vendor meeting and technology assessment, should be taken to ensure the required availability of human and capital resources. A plan with a timeline will help organizations ensure the smooth implementation of the DT initiative.

An implementation schedule will also help the involved and related stakeholders, from toplevel executives to rankandfile employees and customers, to provide required support for the Digital Transformation initiative and minimize disturbances in exiting business operations. A Digital Transformation project, like any other project to ensure its success, it needs continuous support from every related stakeholder of the organization. Also, an implementation schedule makes it possible for the organization to benchmark and compare actual results with planned results. It also aids the project leaders in governing and managing the project.

* 1. *Adjust Organization Culture and Infrastructure*

The last step in the digital transformation strategy development is the preparation of the infrastructure. Initially, the organization must create a dedicated group of digitally qualified experts and create specialized leadership such as a digital officer and other qualified professionals to ensure a successful transformation. External support is required if existing human resource is not available with the inhouse team by hiring a reliable partner to implement the digital strategy for your company effectively. It is very important to develop the team with required skills for

future changes though launching of training, qualification upgrades or hires outside agencies. It is significant to

make digital transformation an essential part of the companys highlevel objectives.

# Conclusion and Future Work

We presented a guideline for developing a digital transformation for the manufacturing sector by starting to address all challenges faced by manufacturing in the journey of the transformation. We have suggested some recommendations to handle those challenges.

Those challenges are generic ones for most of the manufacturing industry. There could be limited and specific challenges for the subcategory of the manufacturing industry such as oil/gas, chemical and petrochemical, and metal industries. In future studies, we would consider those industryspecific challenges and list some of the uses cases related to those industries.