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# Challenges in Project Execution of Manufacturing Project A Comprehensive Review

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## Abstract

This comprehensive review examines the challenges faced in the execution of manufacturing projects, a critical area for industrial advancement and economic development. The paper identifies and analyses common obstacles encountered during project implementation, including technical complexities, resource management issues, time and cost overruns, and regulatory compliance. Through a synthesis of scholarly literature and industry reports, supplemented by illustrative case studies from diverse manufacturing sectors, the research highlights key strategies for overcoming these challenges. The study emphasizes the importance of adopting modern project management techniques, investing in workforce development, enhancing communication channels, and implementing proactive risk management. Furthermore, it explores emerging trends such as the impact of Industry 4.0, sustainability considerations, and the shift towards agile manufacturing systems, providing insights into the future landscape of manufacturing project execution. This review contributes to the body of knowledge by offering a holistic perspective on the multifaceted nature of manufacturing project challenges and proposing frameworks for improved project outcomes in an increasingly complex and dynamic industrial environment.

## Keywords

Manufacturing projects, Project execution, Industry 4.0, Resource management, Risk mitigation, Sustainability, Agile manufacturing, technical challenges, Cost Management, Project communication, Regulatory compliance, Smart manufacturing, Digital twins, Circular economy, Workforce development

## 1. Introduction

This research paper focuses on manufacturing projects since such projects are key to the advancement of industrialization and economic development. Such measures may involve the construction of new production facilities or a change of a current facility, for which it requires a major undertaking that must be well thought out and effectively implemented. However, there are many barriers that can complicate the journey from conception to completion and these can affect projects in a big way.

The researchers claim that Manufacturing practitioners and academics indicated that the budget performance of manufacturing projects is relatively low – only 52% of projects meet the allocated budget while 42% meet the schedule PMI (2021). These statistics give credence to the call for improving the knowledge of the difficulties encountered in the performance of projects in the manufacturing industries.

This review also seeks to categorize and analyse some of the most frequently reported difficulties that are likely to be experienced during the handling of manufacturing projects. To achieve this paper's objective, we review scholarly articles and other relevant reports and case studies to identify and analyze the challenges that affect project management and organizations. In addition, this paper shall also discuss how some of these challenges can be managed effectively as well as look into future potential development that might affect manufacturing project execution.

# 2. Overview of Manufacturing Projects

## 2.1 Types of Manufacturing Projects

Establishment of new production facilities: Greenfield development involves setting up of manufacturing plants from scratch that entail the development of green fields.
Expansion of existing plants: Strategic development projects directed towards rising production capacities or essentially adding on fresh product portfolios.
Technology upgrades and automation implementation: There has also been an emphasis on projects relating to the industrialization of production and the use of IT.
Process improvement and optimization projects: Measures and programs that are put by an organization to increase productivity, minimize negativity, and increase the quality of its products.

## 2.2 Stages of Manufacturing Project Execution

Planning: This stage involves identifying the parameters that are available in terms of reach, goal and need from the project. Just to name a few are feasibility studies, initial risk evaluation, etc.
Design: The main structural designs include, the process layouts, equipment design, and control designs.
Procurement: It involves identifying, selecting, acquiring, and obtaining required resources which include equipment, materials and services.
Construction: During this stage, the physical infrastructure of the manufacturing site or acquisition of new tools and equipment occurs.
Commissioning: Before finalizing them, systems and equipment are subjected to tests to guarantee that they can sustain the design requirements and functional performance.
Start-up: The last phase in which the actual manufacturing starts and may take time to reach the optimum level.
These phases have their own problems that need to be resolved and have to be managed effectively to achieve successful completion of the project. According to Kerzner (2017), the stages described above have become far more extensive over the last decades due to technological progression and globalization.

# 3. Common Challenges in Manufacturing Project Execution

## 3.1 Technical Challenges

Today's manufacturing plants encompass a range of technologies and are composed of numerous systems making the engineering practice more challenging. According to Belekoukias (2014), the design phase is the most complex phase of manufacturing projects because of several dynamics inherent in it such as productivity on one hand, flexibility and sustainability on the other.

This revolution is also known as Industry 4.0, and is characterized by considerably short cycles of technological development in manufacturing. First of all it refers to zero, which, being both positive and negative at the same time, means it holds a direct as well as an indirect potential: It is both good and evil. Deploying IIoT, AI or advanced robotics for automation and control purposes, into current or new manufacturing systems may present the main difficulties. A study by Dalenogare (2018) identified that even though these technologies are beneficial, their adoption is a challenge given that their use is complicated calling for skillful professionals.Another technical challenge is the delivery and maintenance of steady product quality as well as focus on conformity to standards across the life of the project. There is nothing as important as ensuring that regulatory standards are met especially where the regulatory environment is sensitive such as in pharmaceuticals and aircraft manufacturing and assembling Anand (2012). Concerning the assessment of quality control mechanisms into a manufacturing project, Anand et al note that it must be integrated at every phase of the project.

## 3.2 Resource Management

The skilled workers' scarcity is a never-ending issue that is experienced in many manufacturing industries. Deloitte and The Manufacturing Institute (2021) have done this report which undertakes the implication of the skill deficit to the manufacturing floor in the United States of America, estimating 2.1 million job vacancies will be created by 2030. Such a shortage may result in time overruns, compromises to the quality of the end product, and higher expenses towards labour or wages.
The right allocation of the material and its proper storage and supplies are essential to the project delivery. Some of the issues that organizations face include the availability of the physical items and materials at the right time, storage and handling of the materials as well as interruption in the supply chain. Ivanov (2019) further explain how the COVID-19 brought to the foreground issues related to manufacturing supply chains' frailty and further stresses the necessity for improvement of inventory management.
One of the paramount importance factors which should not be overlooked is maintenance of all the equipment and machinery for the success of the project and long-term sustainability of the project. However, it is difficult to

maintain machines, particularly those which are new or complex in nature of application. However, according to Fraser (2015), it is pertinent that maintenance matters be blown into the planning of manufacturing projects from the design phase.

### 3.3 Time Management

Whenever implementing manufacturing projects, there is always pressure when it comes to time due to market, contractual terms, or strategic & business objectives. Delaying a project or completing it ahead of the agreed time is arguably one of the largest problems that one can face in their projects. Olawale and Sun (2015) indicated that time management was one of the major five issues affecting construction projects, which are closely related to large-scale manufacturing.Even if one develops the most efficient plan to execute a project, some factors are unpredictable, and they include; design changes or alteration in the equipment delivery time, regulatory approval, or technical problems. If there is a time overrun in one of the project phases, this will have significant implications on the schedules and costs of a project. Love (2019) presents how these knock-on consequences are likely to result in significant time and cost impacts in a project.

### 3.4 Cost Management

Cost overruns are prevalent in manufacturing projects as most of the project's costs more than was estimated. McKinsey & Company (2015) in its research conducted across the world revealed that large capital projects are 20 percent more likely to be completed than planned and can be up to 80 percent over the cost estimates. Known variables that lead to costs exceeding budget include expansion of the project's scope, underestimation of cost and incidence of technical complexity. It is difficult to estimate the prices in manufacturing projects, especially in the ones that are intricate since there are so many factors to consider. According to Flyvbjerg (2014), optimism bias and strategic misrepresentation are some of the biases that cause cost underestimation, especially in big projects.

### 3.5 Risk Management

All technical, financial and environmental risks must be first identified and then properly managed in order to ensure the success of the project. However, risk assessment remains an extremely difficult task in manufacturing due to the intricacies of the manufacturing projects. Risk management in manufacturing projects is discussed by Rao and Thapar (2019) with focus on the idea that risk should be monitored constantly and that the strategies applied to address the risks at hand should be adjusted offers. One important consideration is how the safety and well-being of workers are to be protected during the execution of the project as well as any subsequent operation. Manufacturing facilities are dangerous by their very nature because they work with materials that are dangerous, large power machines, and often complicated processes. Occupational health and safety can be incorporated into all the stages of manufacturing projects, as has been advised by Badri (2012).

### 3.6 Communication and Coordination

Synchronizing events throughout the project work and the different phases of the project, and communication between different teams such as the engineering, procurement, construction, and operating teams is difficult but important to successful project delivery. One of the most critical success factors for any project was understood as communication Pinto and Slevin (1988).

Quite often manufacturing projects are implemented with the participation of several subcontractors and suppliers, thus increasing the number of challenges in terms of project management. One of the major challenges here is in absorbing goals, integrating quality and overseeing the interactions between the various contractors. Project relationship management supply is essential for resolving a variety of issues in a project Meng (2012).

### 3.7 Regulatory and Compliance Issues

Environmental legislations continue to be tightened hence, putting into consideration the issues of sustainability are mandatory in manufacturing projects. The biggest difficulty is to meet all these requirements without compromising on the project's speed. Zhang (2019) explains that green manufacturing has become critical in today's context and how it affects project management.

Various manufacturing industries have their own set of budget and quality standards and certifications that the projects' have to meet. These may extend from the general management systems, which include the ISO 9001 to those of specific sectors including the automotive and the aerospace industries. Meeting these standards is important in each phase of the project and can be quite a problem sometimes. Chiarini (2017) research focuses on the factors affecting the adoption of technology transfers in the manufacturing industry while probed on the difficulties of the quality management systems in manufacturing industries.

## 4. Case Studies and Real-world Examples

To illustrate the challenges discussed above and highlight successful strategies for overcoming them, we present three case studies from different manufacturing sectors:

### 4.1 Case Study 1: Automotive Plant Expansion Project

A leading automaker announced a $ 1 billion capital expenditure programme for expansion of production capability at a current factory. A new assembly line was required to be incorporated; some of the current facilities needed to be expanded, and effective automation systems had to be incorporated into the project.

**Challenges faced:**

Increased incorporation of modern automated lines with the already established manufacturing lines
Reducing interferences with production activities during construction
Leading a myriad of suppliers and contractors
Ensure that the quality and safety of the products meet certain high levels of quality and safety.

**Strategies employed:**

Applied sophisticated techniques in terms of 3D modelling and simulation of the process of new systems incorporation
Brought systematic construction strategies into the building process for the purpose of reducing production interferences
Started an employment of a special division to manage relations between various parties engaged in the project
They also performed constant safety audits and quality check on the several processes of the project

**Outcome***:*

It was done at a 5% variance to the initial budget although the project was done three months behind the estimated time. It was said that the main reason behind this delay is the incorporation problems that are regarded as technical risks, while the flexible risk management plan significantly minimized the repercussion in terms of time and costs overruns.

### 4.2 Case Study 2: Pharmaceutical Manufacturing Facility

A firm bearing a pharma business sunk $500 million for a manufacturing plant for biologics, a new improved state-of–the-art facility.

***C*hallenges faced:**

Compliance to regulations from organizations such as the Food and Drugs Agency (FDA) as well as the European Medicines Agency (EMA)
Controlling and putting into practice stringent cleanroom as well as sterile manufacturing techniques
The following is a discussion of how Palindrome can address the long lead times for some specialized equipment.

**Strategies employed**:

Hired regulatory consultants as soon as design processes began to make sure that requirements are met.
Appropriate modular construction methodologies were used, whereby cleanroom sections of the facility were constructed in other locations and then assembled on-site.
Developed and integrated an effective supply chain system that enhanced tracking of equipment deliveries.
The company cultivated relationships with the local universities for the purpose of creating pool of talents.

**Outcome:**

**T**he timely construction of the facility was as planned and the construction was done 2% below the estimated cost. Some of the success factors that were indicated were Areas of early emphasis including regulatory compliance as well as special construction methodologies. Nevertheless, there were operational issues in the early months, owing to the complex production stages of the project as these subjected the project to extra validation and a longer ramp-up.

### 4.3 Case Study 3: Advanced Materials Manufacturing Plant

A material science firm started a $300 million capital-intensive investment project in the development of a manufacturing facility for modern composite production.

**Challenges faced*:***
Introducing new concepts of manufacturing that oftentimes have very few if any similarly implemented by a competitor
Dealing with the risks of intellectual property when they involve multiple technology partners
Ample attention to environmental compliance for a process that uses a number of chemicals
Working to optimize the use of automation while at the same time maintaining the skilled manual operations.

**Strategies employed*:***
Signed a development partnership agreement with the major technology partners
Adopted an effective and efficient stage-gate process for the technology development and scale-up
Hired compliance environmental consultants to help in the formulation of a strict compliance plan.
Matured a hybrid of automation that focused on the integration of robotics and particular manual operations.

**Outcome**:
The project also incurred hold-ups and incurred 40% more time and money than planned, to be done 18 months behind schedule. The main ones were understating the challenge of new technologies diffusion and additional environmental offsets that may be needed. However, all these have not been much of a challenge to the plant as it has since gone operational and is providing the intended quality of materials.
Such cases present various kinds of issues that occur in manufacturing projects in different industries and can showcase favourable approaches and/or threats that need to be concerned in project management.

## 5. Strategies to Overcome Challenges
Based on the challenges identified and lessons learned from case studies, several strategies can be employed to improve the execution of manufacturing projects:

### 5.1 Project Management Techniques
Evaluating a better project management plan for exile developments can improve on the planning and tracking aspects of the project and the coordination of various activities within the project. Microsoft Project, Primavera P6 or other manufacturing project management software can give real-time view of the project status to identify where you are and where you may have some problems. Other authors such as Bryde (2013) identified that there is a relationship between project management information systems and actual project performance with the latter being as a result of the former.

Applying the lean theme can be used to remove waste of time or to increase productivity during the project's implementation. Continuous flow and planning under pull is also underlined by Ballard and Howell (2003) while writing on the use of Lean on project management.Six Sigma is a powerful tool which can be applied when reaching the maximum level of quality of the manufacturing processes as well as minimum variability. Irlam (2008) discuss on how the six sigma strategies can be adopted in project environment to improve performance.It meant that a number of principles of Agile that were originally applicable to software development are now being used within manufacturing projects. In their article Conforto (2014) explain a view how Agile is not restricted to pure software development and can be used in any field to enhance organizations' ability to adapt change.

### 5.2 Training and Development
Most of the times it is necessary to provide adequate procedures in training the employees in new technologies and processes. This entails the procedural competencies that are attached to certain production methodologies as well as interpersonal competencies comprising of problem solving and interpersonal communication. According to Bhatia and Kaur (2014), one has to learn continually in manufacturing to meet the ever-evolving technological experiences.
Since more projects the practical implementation of manufacturing introduces advanced technologies, special forms of training become essential. This includes training the employees on how to handle new equipment's, programs and updated safety measures among others. The subject of virtual and augmented reality technologies for training in Industry 4.0 as a detailed by Gorecky et al (2017) manufacturing environments.

### 5.3 Improved Communication Channels
Setting up a formal schedule for attended meetings/ progress reports will enhance cooperation and also help to early detect and solve a problem. Some of these are daily scumble, weekly planning, and monthly retrospectives such as an executive review. Dingsøyr (2017) talk about the possibility of adopting Agility practices such as the daily stand-up meeting for large-scale development.Effective working of the project communication depends on its enhancing by means of such tools as collaborative platforms and real-time information sharing. Instant

messaging services such as slack, MS Teams or any sophisticated collaboration software based on the industry can be enabled to enable fast flow of information and decision making. Web-based project management systems as studied by Carvalho (2015) on how it enhances the communication and coordination in large project.

### 5.4 Risk Mitigation Plans

Risk assessments must be done in detail throughout the stages of each project while risk register has to be updated frequently. These should involve technical, financial and environmental issues as well as operational risks that are involved. The conceptual framework that has been developed by Oehmen to manage risks actively in product development projects can be applied for manufacturing environments as well Oehmen (2014).Preparation of contingency strategies for each of the identified risks, besides revisiting and analysing them in case any of the risks would occur is a common practice that could help teams tackle the challenges on the ground as they emerge. This includes having some backup suppliers or some alternative technical designs.Having and refining the set plans of action for the risks which have already been pointed out can make work-team more ready and prepared to address various issues that come their way. This includes having back up suppliers, the presence of a backup technical solutions and resource flexibility options. Thus, Terje and Ortwin (2011) stress the dynamism of risk management pointing to the fact that risk estimation and risk management procedures have to be refined throughout the R&D project lifetime.

### 5.5 Cost and Time Control Measures

The application of earned value tools can assist in controlling costs as well as give early indication of potential problems in projects. Fleming and Koppelman (2010) talk how EVM can be best implemented within the manufacturing projects to control cost and time.The CPM and PERT are better ways of planning than the traditional one in planning for time management. Also, effective performance measurement is another way of assessing organizational performance by developing clear measures that demonstrate how well an organization is performing and then measuring this at regular intervals so that potential troubles can be identified. Aliverdi (2013) put forward an approach on how the main change control tools can be integrated with the EVM and balanced scorecard for assessing project performance in a non-trivial manner.

## 6. Future Trends and Considerations

Manufacturing project execution environment is unique and dynamic and has been greatly influenced by technology and changing circumstances around the globe. It is therefore anticipated that the following trends will define the future of manufacturing projects:

### 6.1 Impact of Industry 4.0 and Smart Manufacturing

Internet of Things (IoT) and Connected Systems*:* IoT devices have become common in manufacturing, and the integration of the devices in project management will enhance real-time monitoring thus avoiding potential projects downtime. Among many possible directions in the modern technological development, Zhong (2017) pay attention to the impact of IoT technologies on manufacturing systems and supply chains.

Artificial Intelligence and Machine Learning*:* AI and ML algorithms can augment decision-making processes in project management ranging from maintenance prediction to scheduling. According to Lee (2018), AI has been introduced in smart manufacturing as shown below on its benefits on productivity and quality.

### 6.2 Sustainability and Environmental Considerations

Green Manufacturing*:* Subsequent endeavours will continue to put more efforts in minimizing the imprint on the external environment including mechanical procedures and supplies. Bai (2015) present a review of the state of green manufacturing practices whilst elaborating on the barriers and enablers to the integration of green manufacturing.

Circular Economy Principles*:* Manufacturing projects may start adopting the circular economy concept, where an emphasis is put on aspects such as recyclability, reusability and minimization of waste streams. Ghisellini (2016) studying sustainable development in the manufacturing sector conceptualises circular economy.

### 6.3 Digitalization and Virtual Project Management

Digital Twins*:* As noted in the book, digital twins – the virtual representations of the physical assets involved in projects or processes – have the potential to become game-changers in project management. Tao (2018) consider the given idea of digital twin in product design, manufacturing, and service.*Virtual and Augmented Reality:* Both, VR and AR are able to improve training processes, team working in distance cooperation, and problem solving in

manufacturing projects. Nee (2012) describes his experience of different sectors that use AR and that is why such system can more effective as lesser mistakes are able to appear.

### 6.4 Agile Manufacturing and Flexible Production Systems

*Modular and Reconfigurable Manufacturing Systems:* Subsequent manufacturing strategies may involve improving the companies' ability to design production systems that are flexible to respond to the dynamic consumer trends. Koren (2018) describe the idea of reconfigurable manufacturing systems as one of the enabling technologies for mass customization.

### 6.5 Agile Project Management in Manufacturing*:*

Most of the agile project management frameworks that are in practice have been as a result of application of the same from software production. In extending the knowledge regarding agile project management, Conforto (2016) discussed the contextualisation of the methodology in physical product development.

## 7. Conclusion

The implementation of manufacturing projects remained difficult and even as of now a problem or face-driven project area with technical, managerial, and strategic issues. By reviewing literature in this area, this paper has recognized a number of these challenges as being multidimensional, where they range from the managerial aspects of resources, techniques and methodologies to time and cost factors.The case examples have shown that despite the fact that each manufacturing project is different, many of them share the same fundamental issues. The successful implementation of a project in most cases would depend on the well-coordinated development of a sound framework, which should include well-articulated communication strategies, risk management techniques and efficient use of technologies and tools.What concerns the future, growing role of Industry 4. None of the 0 technologies, the call for sustainability, and the shift to dynamic and adaptive manufacturing systems suggest a path towards traditional issues. But they also bring new challenges which are also going to present new learning as we grow and evolve in our use of technology.

***S*everal key areas emerge as critical for improving manufacturing project executio*n*:**

The combination of new technologies during work process and the control of arising complexity and skills' demands.

More efficient and sturdy methods of controlling projects and decision-making to be utilized in more detail.

Improvement on the organizational communication and interaction processes to contain developing complex multiple stakeholder relations.

Adoption of sustainability as well as circular economy at the planning and delivery of projects.

**Future research should focus on**:

Promoting frameworks for the co-ordination of digital integration in manufacturing project management.

Analyzing methods, trends, and opportunities of using AI and machine learning in project risk management and more specifically in decision making.

Exploring the project and operational consequences of using sustainable manufacturing management techniques in the long-term.

Analysing the comparative efficacy of agile and hybrid methods in an array of manufacturing environments.

Taking this into consideration one might conclude that while the problems associated with manufacturing projects' implementation are truly enormous, improving manufacturing with the help of advanced technologies, new managerial approaches, and increasing focus on sustainability, offers unprecedented opportunities. The structure of manufacturing is constantly changing, and it is the same with the approaches and methods when it comes to projects management. Thus, the focus should be given to the opportunities for embracing such changes and better adapting to new realities in order to strengthen the chances of organizations to manage manufacturing projects effectively in the context of the increasingly dynamic environment.

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