

Module : Design for Industry 4.0 [ACPA7001]

Assignment - Reflective Essay

***"Product design consideration of
Industry 4.0 manufacturing technologies"***

Course : MSc Industry 4.0 Advanced Manufacturing

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Date : 19 July 2023

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1. Summary / Overview

The following piece of work shows a reflective essay on existing Industry 4.0 manufacturing systems. During this module, a broad range of manufacturing considerations of the product and its design solution with new industry 4.0 technologies were studied. Analysis of various technologies and their implication captured such as automated disassembly, recycling, and maintainability with appropriate design features were investigated.

This reflective essay shows the investigation of the current design approach in terms of developing any new product/component. Analysis of its impact on society and the potential opportunities within the aerospace industry has been captured. Mainly concentrated on emerging technologies like Additive manufacturing, Artificial intelligence (AI), and Digital twins. With reference to the aerospace industry, these technologies are interconnected during its implementation. Also highlighted the implications of new and advanced materials in Additive manufacturing technologies.

2. Introduction

Industry 4.0 or the fourth industrial revolution consists of rapid change in technologies, Industries, and social patterns. In this, the process has been interconnected with smart automation. This change in technologies has been widely spread in all sectors which is also known as smart manufacturing, digital manufacturing, and digital transformation. The core components of I4.0 do not depend on the tool or technology. Developed digital innovations in recent decades. [Klaus. S (2015)].

The Industry 4.0 market is segmented into technology type and End-user. Based on the technology it is segregated into automation, 3D printing, digital twin, artificial intelligence (AI), Machine learning (ML), Block chain, Extended reality (XR), Industrial internet of things (IIoT), and others.

The graph shows the market analysis in upcoming years by technology type. The outcome shows that the technology will be widely beneficial and used in upcoming years. [Akanksha P (2023)]

The global Industry 4.0 market was valued at \$115.4 billion in 2021 and is projected to reach \$608.4 billion by 2031, growing at a CAGR of 17.8% from 2022 to 2031. [Akanksha P (2023)].

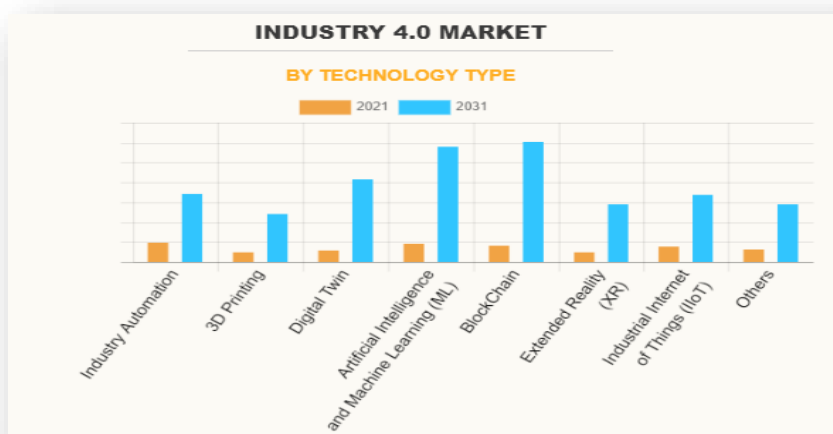


Fig 1 : Industry 4.0 Market analysis

3. Existing manufacturing technologies in Industry

Manufacturing is becoming more and more advanced due to this technologies all of the time. Below are the list of technologies currently used in the industry.

- Robotics or Artificial Intelligence
- Big Data.
- Augmented reality.
- Nanotechnology.
- 3D printing.
- Cloud computing.
- Internet of things.
- Digital twin and simulation.
- Block chain etc.

For reference, the image shows all the Industry 4.0 technologies currently implemented as a smart factory. This results in an increase in production rates and maintains excellent customer satisfaction, by providing them with the required output without any defects. [Anwar.S (2022)]

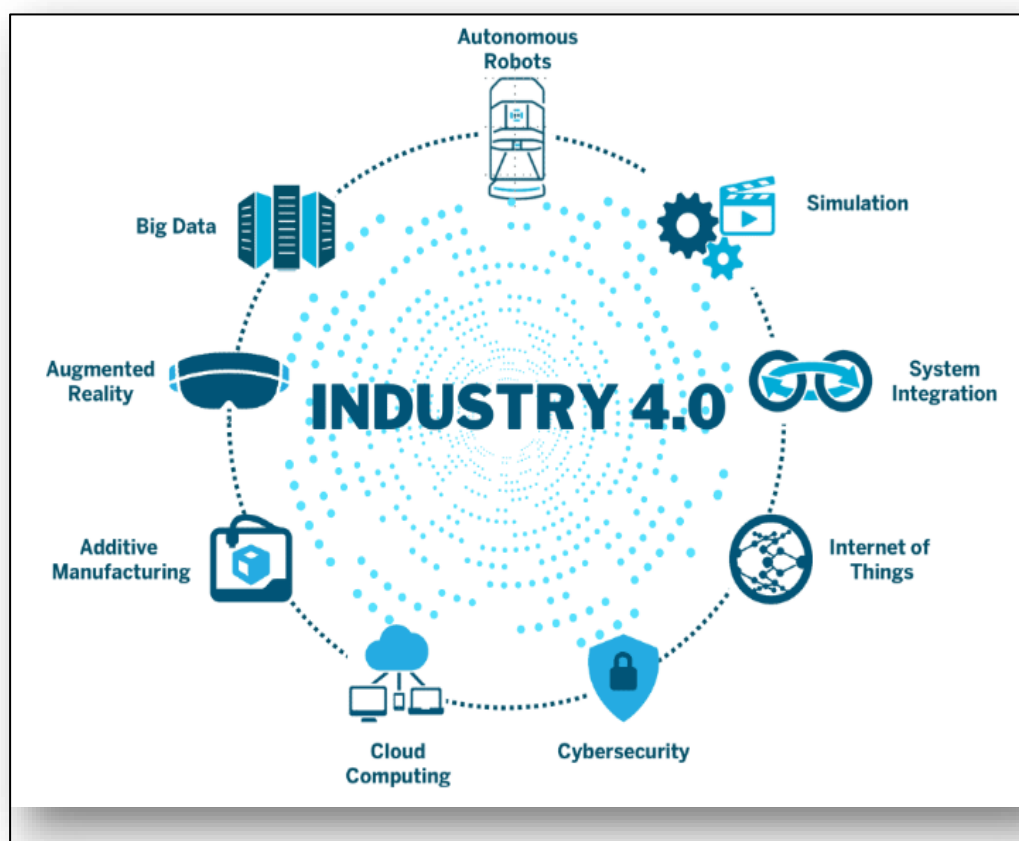


Fig 2 : Current Manufacturing system

4. Design for industry 4.0 Manufacturing Strategies

Manufacturing strategies are, to get the maximum output from the resources from the manufacturing system which is considered for the long term. These strategies strengthen the organization's performance. Strategies are utilized in order, which starts with formulation and ends with the organization's performance.[Anwar.S (2022)].

Strategies outputs are studied and listed below for understanding. This includes performance, flexibility, and delivery which are also known as competitive priorities. This plays a very important role in motivating the organization.

Cost: The ability to deliver lower cost can be measured by employee training, per unit cost, labor cost & unit material.

Quality: This is important to maintain a high level of customer satisfaction and can be measured by defective products, complaints from the customer, and satisfaction reports.

Delivery: It can be defined as the shorter lead time or the time between the collection and distribution. The measuring factors are reliability and min lead time.

Performance: This is the points or features that the product has, which are not available in other products. This can be measured with resale price, Engineering changes, and mean-time failures.

Flexibility: This is mainly measured by the customization of product and volume flexibility. Also measured with its varieties and features.

Innovativeness: Introducing new project per year & measured as per investment and consistency of research and development.

With reference to the small and medium-sized manufacturers, the below figure shows a strategic road map i.e. step-by-step sequence to perform the task, which mainly focuses on the conversion plan into action with change management practices [Melony. S (2022)].

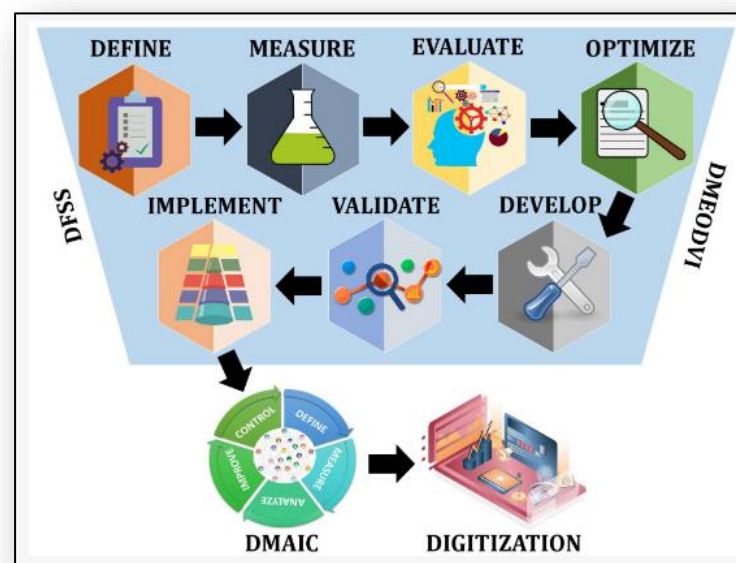


Fig 3 : Manufacturing Strategies Road map

4.1. Indicative content consists of industry 4.0 technologies like Additive manufacturing and the implication of this new advanced material. The methods of this technology are exploited through the design explained below.

4.1.1 Additive manufacturing: In product design, (Ideation) which describes the process of generating ideas normally covers an important part while developing any concept. The available knowledge of the designer at the moment plays a key role. The biggest challenge in design for additive manufacturing is knowledge about its unique capabilities. The exploitation of these capabilities requires a rethinking of conventional design processes. The different approaches such as the methodological framework applied to traditional design. [Kumke et al. (2016)].

Also the 5-phase creative DFAM method for concept generation. This framework is inspired by the design thinking methodology. The hindering factors considered in AM, result in poor exploitation of its potential. The factors are lack of knowledge, restrained creativity, and procession barriers. The below fig shows the transformation of 3d printing in various sections of aerospace interiors. [Rias et al. (2017)].



Fig 4 : 3D printing transforming aircraft interior

4.2. Implications of new and advance materials:

Advanced materials have all innovative and transformation potential & they are the most important part of this new global tech revolution. The impact of this is mainly the transformation of the material base of the economy and has a static character. Advanced materials also contribute to economic growth and environmental protection as well. The main impact of new/ advanced materials seen in investment system, on foreign trade, and necessary need of raw material and resources. The Benefits of advanced materials are listed as below for understanding purpose. [Klinec.I, (2016)].

- Design freedom to generate concepts.
- Customization / Personalization or Made to order.
- Light weighting for weight optimization.
- Efficiency in Supply chain & pre- production process elimination.
- Warehousing in control (Storage need minimum).

The following points illustrate barriers to advance material.

- Cost effectiveness with up scaling to production.
- Reliability and quality.
- Pre- and post-production.
- Standardization & Fragmented supply chains.

[International journal on interactive design and manufacturing. (2007)]

5. Design Processes and Methodologies

5.1. Design process

This can be defined as the strategy to solve the problem with constraints and specific criteria, which are used to develop various solutions to solve the problem. The list of design processes listed as below for reference. [Custer, R. L. (1999)].

- Identify opportunities and problems by gathering information.
- Brainstorming or framing a design brief by discussing with the team to generate preliminary ideas.
- Research and investigation about the subject by previous lesson learned & refer reports.
- Providing relevant solutions by identifying constraints like time and budget.
- Implementing or selecting the desired solution.
- Work in progress and its development.
- Creating the prototype and CAD modeling. This step makes models to help the idea and study aspect such as shape .
- Carried out its evaluation and testing. Once the prototype is made make models to help understand the idea.
- Improvement in the design until the required accuracy is achieved and redesigning if required.

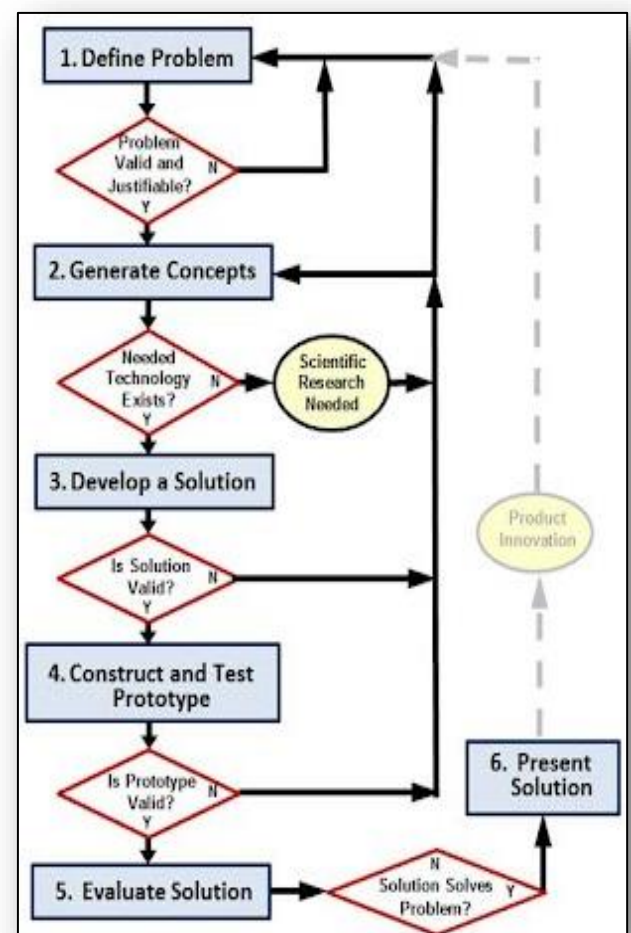


Fig 5 : Design process flow chart

5.2. Design for automated Assembly & Disassembly

As part of the design which is a very important part of the automated process, most of the development is through a selection of material. the standardized process to optimize the development of any component with respect to the production process is named Design for Manufacturing and Assembly and Design for automatic assembly. [Trommnau, Jerome, (2020)].

5.2.1 Design for the assembly process (DFA), makes product structure easy by reducing the number of components and minimizing the operating required for assy. Resulting in more productivity & less time-consuming. The basic Aim for DFA is listed below.

- Movement of the part relative to another part in assy.
- Part material where for aesthetic or functional reasons,
- Guarantee access requirement and check out repair & maintenance.
- Reduce opportunities for errors & Improve health-safety.
- Reduce the process need and its further inspection.

It's been seen that the principle for automatic and manual assy are similar. If we consider robots and humans in the assy process, there are some drawbacks. In Design for Automated Assembly (DFAA), major concentration is on tools that can be implemented on robots accordingly.

The principle involves - Minimum parts list, symmetrical parts, Mistake proofing (NO orientation), standards parts in use, reasonable tolerance , part assembled in linear motion and secured immediately after insertion. [Velling A. (2021)].

Further design efficiency is = $(\text{Number of essential parts} / \text{Total number of parts}) \times 100$

Implementation of the automated assembly is seen in seating assy line. Research shows that there are automated seat assy lines and the test system supplier for performing assembly of the seat frame, cushions, seat track, and recliner. This includes a high level of automation provider featuring multiple assy units to quickly change seat models. Also equipped with NVH-related defect inspection. Below image shows the automated line assy for seat assy. [uskoreahotlink (2009)].

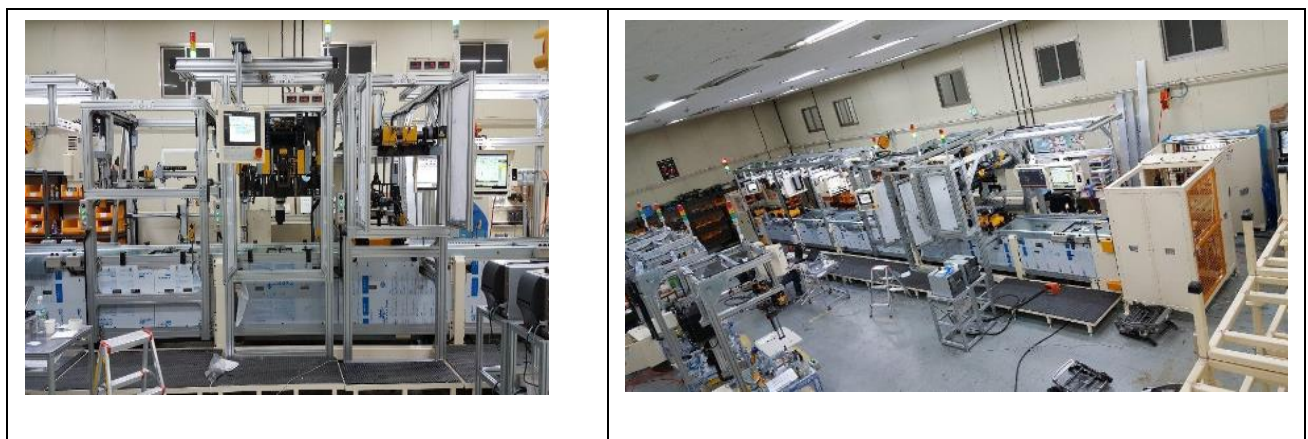


Fig 6 : Automated Seat assembly line

Assembly lines consist of automated equipment, even the semi-automatic line allows minimum cost and is very effective in mass production. Also, the automation is seen to remove the wrinkle on the seat through the robotic arm and to check all the electric installations within an assembly. The various automation process represented pictorially below.



Fig 7 : Automation in Seat sub-parts

Below example shown as an application of technologies for aircraft seating geometry scan, developed by GOM inspect software that capture 100 % of surface geometry on the entire aircraft seat in half the time and cost of traditional method. The measuring areas consist of high resolution and quick measurement with quality measures. [GOM Metrology, (2019)]

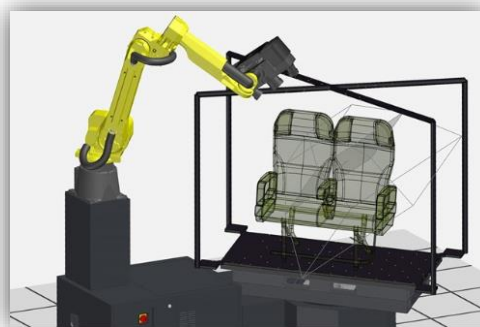


Fig 8: Automated measuring process for Aircraft seat

5.2.2 Design for disassembly can be defined as processes that help the product to easily disassembly, repaired, upgraded, or recycle. Also, using this method will increase the product life and the same component can be replaced. The reasons are as follows,

- Reduce production costs and Build customer loyalty.
- Create for the planet (it should not against it).

The product can be easy to disassemble by considering product lifecycle duration. Avoiding the glues on any electronic component. Quality fasteners should be used like screws. Some examples of products that can benefit from DFD are Electronic, which waste contains valuable resources which can be recovered. The building consumes a large amount of material and often generates demolition waste. Furniture is another product (seating furniture can also be considered), designing this for disassemble will increase the life of the product. Many organization has opted for a circulation process by which the product can be easily repaired or replaced. Few example shown below for better understanding the concept.



Fig 9: Design for disassembly examples

Methodologies:

The methodology DFMA' is been used in the manufacturing sector for decades. It is a powerful tool for analysis and finalizing the design concept into a fully developed design and helps to optimize time and cost. Both methodologies one is Lucas Hull Method and the second one (Boothroyd & Dewhurst) method used the idea of fundamental and essential parts. The below chart shows the Functional analysis flowchart, which is adapted from the reference. [Lucas Engineering & Systems Ltd and University of Hull, (1994)].

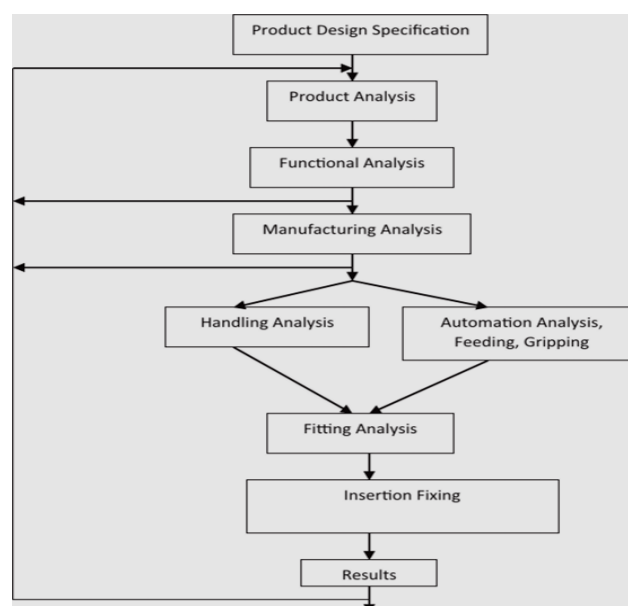


Fig 10: Assembly flowchart for Lucas DfA evaluation model

6. Design techniques quality and analysis

As quality is the important factor in product innovation in this global market to check its functionality and versatility. To accelerate the quality of process many tools available in terms of reducing time and cost & there application varies as per there sectors. Many of it is link to Lean and agile design methodologies. The primary reason of failure corresponds to need of customer and secondly due to high labored / material and energy. This piece of work shows the overview of design for quality and product design. This can be linked to our design activity to avoid future discrepancies on product development. [Abihana. S, (2012)].

6.1 The Design Quality

It can define as the process to be considered while manufacturing any product that fully meets customer requirement. It varies form company to company and depends how they meet the certain objectives. Depends upon the company goals this objectives are defined like

- Previous design parts usage (%).
- Variations or variants for same parts.
- Change Management & cost control.
- Improvement of product & proposals.
- ECR (change request) before and after start of production.

6.2 Failure mode and effects analysis (design and process)

This report presents the information about, an effective tool to solve manufacturing problem of process quality by implementing process FMEA with control practices. The parameter like Severity , Occurrence number, Detection & RPN needs to be determine. Further to improve efficiency. The requirement of FMEA is to compare / check the characteristic of design with respect to planned process of manufacturing to ensure the customer requirement if fully mate.



Table 1: FMEA process chart

The benefits of FMEA are to improve the process (quality, safety), reduce potential failure, document the shared knowledge, reduce the cost as well avoid problems later in the product lifecycle, and lastly customer satisfaction.

7. Design for sustainability & value

As climate change is a very important factor in our lives which is directly linked to goods consumption and continuous production. Sustainable development is an upcoming concept that is considered while designing any product. the material section should be in line with further development. The design consideration and values involves the recycling of the part produced so that the circular economy is maintained. Depending upon the material, the weight of the component is determined, and by optimizing the weight we can make the product lighter, which will result to achieve the zero-emission target. [Hon. B, (2004)].

8. Emerging Technologies and its adaptation

8.1. Digital Twins and simulation

A digital twin is an organized way of presentation of a real physical object or asset in operation. This consists of historical data about the object. A digital twin is very effective in studying the current scenario of the component as well as the future prediction behaviour or controlled operation. It can be a model, system, or subsystem & can include approaches physically or statistically. As the industrial process is not so flexible, so digital simulation plays an important role through which, we can feel the real effect without actual scenarios in the field. [Let's Learn Aviation, (2019)].

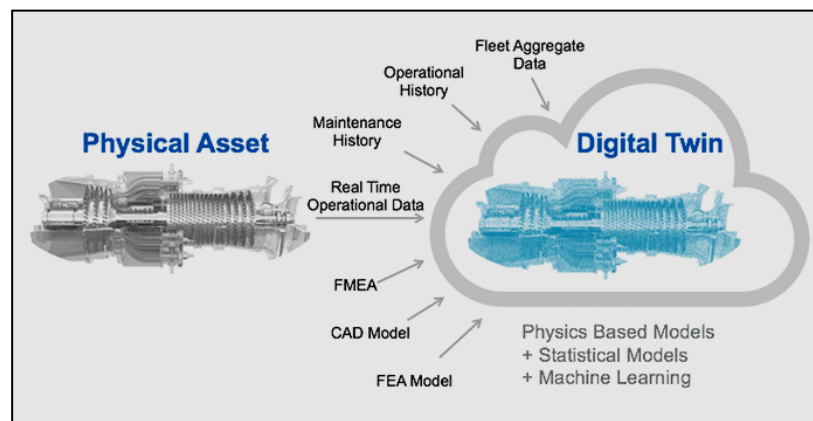


Fig 11 : Digital Twin in Industrial manufacturing

8.2 Industry adaption and considerations.

Digital twin has wide range of application & linked to various sector like Manufacturing industry (Automotive & Aerospace), Healthcare & Smart cities. Digital twins within aerospace industry "Boeing" serving as a excellent example. By using this technology the aircraft manufactures can design there aircraft and can predict the performance of sub parts and throughout their lifecycle. This result in optimise design and controlled decision on improvement rate. [Impact (2022)].

Research shows that the aircraft manufacturer Boeing is expanding their plan to get digitized in engineering and development. Also, apply digital twins to achieve perfect cargo load balance. By using the IoT sensor and virtual simulation the ideal weight of the cargo can be determined resulting in maximum revenue while ensuring safety. Also, this technology can be optimized by the manufacturers in their quality and supply chain management to enhance efficiency and reliability. Moreover, digital twins enable manufacturers to reduce their prototype costs. Customers can modify their requirements in real-time for better outcomes and satisfaction. Types of digital twin includes : Component twins , Asset twins , System twins & Process twins

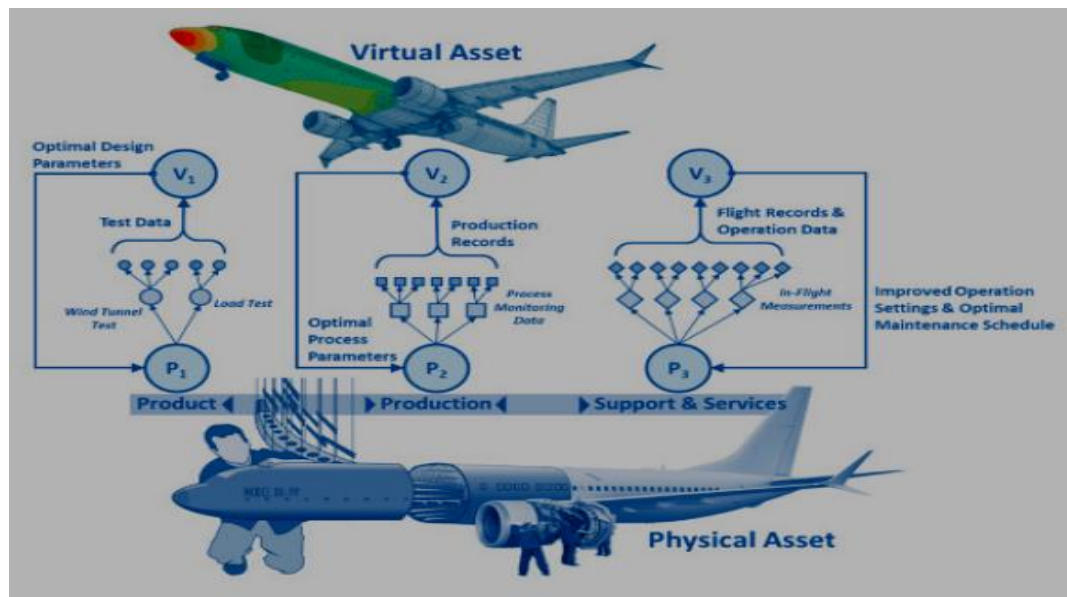


Fig 12: Representation of the Digital Twin Concept

Digital twin in interior retrofitting (Reverse Engineering)

One of the best applications of this technology is linked with Aircraft interior inspection. As each aircraft is unique in its application and design. This uniqueness comes to a challenge during the inspection entire plane, which may be linked to the original manufacturer and its blueprints. With the help of optical 3d scanning, this overload task can be simplified. A digital blueprint (or Digital twin) can be generated. [GOM Metrology, (2019)]. Below images for reference to show the automated process / method involved. This also records the real interior documentation.



Fig 13: Optical 3D Measurement

9. Conclusion

9.1 Impact Interconnected

With reference to this reflective essay, it has been understood that the industry 4.0 manufacturing technologies are interlinked with each other. They are more effective when they are clubbed together to achieve the desired output. The IIoT will work due to connection with networks & this network device is connected to the cloud. The physical environment is captured and then only the AR will work. The same simulation tools and the digital twins are interconnected which is powered by the IIoT, AI, and software which result in simulation to perform specific processes.

9.2 Customer Satisfaction & Requirement

The important factor in using this technology is to perform the task within the desired time frame and cost-effective. The benefits of this is that customer requirements are fully met. The customer can save their finance before investing in making prototypes. Technology like digital twins enables them to modify their requirements in real-time for better outcomes and satisfaction..

9.3 People role implication

It's been noticed that whenever automation is implemented there is a reduction in manpower. This digital technologies may reduce manpower in some sectors but also generate new opportunities for skilled workers. New locations may be developed. Even if robots are seen in modern automation to analyse and to manage humans are required. The organizations will be organizing the development program for their employee to upgrade their skill and domain.

9.4 Society and environment implication

The role is significant. As the smart manufacturing system, implementing the new advanced material for their product development leads to controlling the weight and results in minimizing CO₂ % and maintaining sustainability accordingly. Technologies like digital twins, AI and AM, etc can lead to the circular economy of the product. Safran seats is one working on the sustainability and weight optimization program, for which a new excellence centre is established in France to support additive manufacturing technology. [\[Safran, \(2022\)\]](#)

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