

# Lecture 3: Design Processes & Methodologies in the Age of Automation

## Design for Automated Assembly/Dis-assembly (DFA/DFD)

### Overview

Design for Automated Assembly/Dis-assembly, often abbreviated as DFA/DFD, embodies a design approach aiming to simplify product structures to ensure a seamless fit for automated assembly and disassembly processes. As the world shifts its gear towards Industry 4.0, these design principles are gaining traction and have become quintessential.

### Notes

**Economic & Environmental Impacts:** Two of the driving forces behind DFA/DFD are the prospects of cost efficiency and sustainability. A well-executed design for automated assembly can drastically cut down on production costs. When parts are optimized for automated assembly, the production line experiences fewer hiccups, leading to decreased instances of waste and rework. On the flip side, DFD focuses on crafting products that are not only durable but also easier to disassemble, promoting an environmentally friendly end-of-life cycle.

**Key Principles:** A successful implementation of DFA/DFD revolves around a few core principles.

- **Minimized Complexity:** The aim is to curtail the number of components without compromising the product's functionality. Such a model expedites the assembly process while reducing the chances of error.
- **Standardization & Simplification:** By creating a universal standard for components, like screws or other fasteners, the assembly becomes more streamlined. This not only facilitates automated assembly but also simplifies manual interventions if needed.

**Challenges & Considerations:** The journey towards a complete DFA/DFD approach isn't without its challenges. One major challenge lies in balancing. As designs lean towards simplicity, ensuring the product remains user-friendly and retains its core functionality becomes vital. A significant change like DFA/DFD might also demand an organizational culture shift, which can be a steep hill to climb, especially in industries deeply rooted in traditional assembly practices.

### Case Study: LEGO Group's Journey towards Automated Assembly

The LEGO Group, known worldwide for its iconic toy bricks, offers a fascinating insight into the benefits of DFA. The company's design philosophy has been consistently geared towards optimizing its bricks for automated assembly. In the past, Lego pieces were manually assembled, but as demand surged, the company realized the need for automated assembly. The design of Lego bricks was standardized, with precise interlocking features that not only allowed children to effortlessly build but also facilitated rapid, error-free automated assembly. Through DFA, LEGO managed to scale up production, meeting global demand while maintaining a high standard of precision and quality in every brick produced. The changes were not just in design but also in materials and manufacturing techniques used. This overhaul made LEGO one of the pioneers in its industry, leading the way in showcasing the tangible benefits of DFA.

### Reference:

- Lipkowitz, D. (2012). *The LEGO Book*. Dorling Kindersley. This book delves into the history and design evolution of LEGO bricks, providing insights into their manufacturing and assembly processes.

## Role of AR/VR in Refining and Enhancing Design Processes

### Overview

Augmented Reality (AR) and Virtual Reality (VR) have evolved as revolutionary technologies, transcending beyond the realm of entertainment. When embedded into the design processes, AR and VR promise a significant overhaul in how engineers and designers envision, simulate, and test products and systems.

### Notes

**Enhanced Prototyping and Visualization:** Traditional prototyping can be resource-intensive and time-consuming. AR/VR has eliminated many of these bottlenecks, allowing for rapid prototyping in a virtual space. Engineers can now visualize complex machinery, infrastructure, or product design in a three-dimensional space, foresee potential issues, and adjust accordingly without investing in a physical prototype.

**Collaborative Design:** One of the significant advantages of AR and VR in design is the capability for real-time collaboration. Tools that harness AR/VR capabilities can bring together designers from different geographical locations into a singular virtual design space. They can collaboratively engage in real-time design modifications, discuss challenges, and arrive at consensus faster than traditional methods.

**Training and Skill Development:** Especially in sectors where the assembly or operation of machinery is complex, AR/VR serves as an invaluable tool for training. By immersing trainees in a realistic yet controlled virtual environment, companies can offer hands-on training without the associated risks of actual machinery operation.

**Design Validation and Customer Interaction:** Before finalizing a design or layout, engineers and architects can employ VR to give stakeholders a virtual walkthrough. It ensures all parties have a clear understanding and can provide immediate feedback. For consumer products, this can even be used to gather preliminary user feedback before a physical product is launched.

### Case Study: Siemens Tecnomatix and the AR-Driven Plant Simulation

Siemens, a global powerhouse in the realm of industrial manufacturing and automation, incorporated AR into its Tecnomatix Plant Simulation software. This tool aims to virtually model, simulate, and optimize production systems and processes. By leveraging AR, Siemens has enabled engineers to virtually commission and validate automation systems in a life-like augmented environment before their physical implementation. It's not just about visualizing the system; engineers can test different scenarios, predict possible system bottlenecks, and understand spatial requirements – all in real-time. Tecnomatix's AR capabilities have redefined the initial phases of production line setups, eliminated costly physical iterations, and ensured that once a production line is set up, it operates at maximum efficiency from day one. The result? Faster commissioning times, reduced initial setup costs, and production lines that meet efficiency benchmarks sooner than traditional setups.

### Reference:

- Siemens AG. (2020). Tecnomatix Plant Simulation: System requirements. Siemens Digital Industries Software. This document provides insights into the software's capabilities, with specific sections detailing its AR-driven features and their applications in real-world industrial settings.

## Importance of Fool-Proofing

### Overview

Fool-proofing, commonly referred to in manufacturing circles as "Poka-yoke" (a Japanese term that means "mistake-proofing"), is an essential design methodology that aims to eliminate errors by preventing, correcting, or drawing attention to human mistakes as they occur. Its primary goal is to ensure reliable and error-free production.

### Notes

Essentiality in Modern Manufacturing: With the increasing complexity of products and the demand for higher quality, there is very little tolerance for errors in modern manufacturing. Even minor mistakes can have significant repercussions in terms of cost, reputation, and safety. Fool-proofing techniques act as safeguards, ensuring that processes are robust and reliable.

### Techniques and Applications:

- **Error Prevention:** Making it impossible to make a mistake in the first place. Examples include designing parts that can only be assembled in one orientation.
- **Error Detection:** If a mistake occurs, the system detects it instantly. For instance, modern car assembly lines have sensors that immediately flag if a bolt hasn't been tightened to the correct torque.
- **Facilitation:** Making the correct actions easier to perform or more obvious. Examples are color-coding or the use of guiding shapes and grooves to ensure components fit in a specific manner.

### Benefits:

1. **Quality:** Reduced variability and errors directly translate to better product quality.
2. **Cost:** Reduction in rework, waste, and returns, thereby saving costs in the long run.
3. **Safety:** Where errors can lead to serious safety concerns, fool-proofing can be a lifesaver.

### Case Study: Toyota and the Birth of Poka-Yoke

Toyota, recognized globally for its lean manufacturing and high-quality products, has been at the forefront of integrating fool-proofing methods into its production lines. In the 1960s, Toyota engineer Shigeo Shingo developed several Poka-yoke approaches after observing that a small error (like a missing spring) during the assembly process could lead to significant problems later. One iconic application was in the design of a switch assembly for cars. An operator occasionally forgot to insert a required spring under one of the switch buttons, which would only become apparent after the entire assembly was complete. To rectify this, Shingo designed a modified chute for springs that would only release the next switch button to the operator once they had picked up and used the spring for the previous button. This simple redesign ensured that it was impossible for an operator to miss placing a spring. The impact of this approach was profound. Not only did it rectify the immediate problem, but it also shifted the focus from quality control (identifying defects after they occur) to quality assurance (preventing defects in the first place).

### Reference:

- Shingo, S. (1986). *Zero Quality Control: Source Inspection and the Poka-Yoke System*. Productivity Press. This book delves deep into Shingo's pioneering work on fool-proofing at Toyota, offering insights into the philosophy and practical applications of the approach.

## Role of Component Families in Modern Manufacturing

### Overview

Component families, or product families, refer to a group of products that share common characteristics, design components, or manufacturing processes. They are essentially a collection of variations arising from a single, base design. In the modern manufacturing landscape, the concept of component families is growing in importance as industries strive for efficiency, reduced time-to-market, and flexibility in catering to diverse market demands.

### Notes

Significance in Modern Manufacturing:

1. **Modular Design and Scalability:** Component families support a modular approach to design. Modular designs are more scalable and adaptable, allowing manufacturers to quickly respond to market changes without overhauling the entire product line.
2. **Cost-Efficiency:** Sharing components across multiple products reduces the need for unique parts, leading to economies of scale in production and procurement, thereby driving down costs.
3. **Speed to Market:** With the base design and shared components already established, rolling out variations or new models becomes faster and more efficient.
4. **Enhanced Quality Control:** Standardized components that are used across various products undergo rigorous testing and quality control, ensuring consistency and reliability in the final products.
5. **Facilitated Customization:** Especially in industries where customer personalization is essential, component families provide the foundation upon which unique customizations can be built with minimal disruptions to the manufacturing process.

### Case Study 1: The LEGO Group - Mastering Component Families

The LEGO Group provides a quintessential example of how component families can be harnessed for unmatched efficiency and creativity. The iconic LEGO brick, with its unique interlocking design, forms the basis for an almost infinite array of sets, themes, and custom creations.

At its core, LEGO utilizes a limited variety of base components (bricks of various sizes, wheels, minifigure elements, etc.), but by combining and recombining these in various ways, they've created a vast product range that caters to different ages, interests, and price points.

This approach offers several benefits:

1. **Efficiency in Production:** With standardized molds and materials, LEGO can produce billions of bricks annually with consistent quality.
2. **Flexibility in Design:** Designers are not restricted but are instead empowered by the limitations of the base components, leading to incredible creativity.
3. **Ease of Use for End-Users:** For the customers, the standardized nature of the components ensures compatibility across sets and promotes open-ended creativity.

Over the years, while the core principle of the LEGO brick has remained consistent, the company has introduced various sub-families (like Technic, Duplo, etc.) that cater to different niches but still adhere to the broader family concept.

#### Reference:

- Robertson, D., & Breen, B. (2013). Brick by Brick: How LEGO Rewrote the Rules of Innovation and Conquered the Global Toy Industry. Crown Business. This book offers an in-depth exploration of LEGO's innovative approach to product design, modular thinking, and the role of component families in their global success.

#### Case Study 2: Volkswagen Group's Modular Platforms

Volkswagen Group, one of the world's leading automobile manufacturers, exemplifies the application of component families through their development of modular car platforms, notably the Modularer Querbaukasten (MQB).

The MQB platform is an innovative strategy where the core components and the architecture of a vehicle are standardized across various models and even brands within the Volkswagen Group, like Audi, Seat, Škoda, and Volkswagen itself.

#### Benefits Achieved:

1. **Cost Savings:** By using the same base components and architectures across multiple models, Volkswagen achieved significant economies of scale, leading to substantial cost savings.
2. **Diverse Product Range:** Despite the standardization, the platform allows for a wide variety of vehicles, from compact cars to SUVs, catering to various market segments.
3. **Rapid Deployment of Technological Advancements:** Any technological advancement or update can be rapidly deployed across all vehicles using the platform, ensuring cutting-edge features reach consumers faster.
4. **Quality Assurance:** Since the fundamental components undergo comprehensive testing, the consistency in quality is maintained across all models based on the MQB platform.

This strategy, though initially demanding in terms of R&D and upfront investment, has reaped massive dividends for the Volkswagen Group, demonstrating the immense potential of a well-implemented component family approach in manufacturing.

#### Reference:

- "The Modular Transverse Matrix (MQB) – A milestone in automotive construction". Volkswagen AG. Archived from the original on 8 July 2018. This resource provides an in-depth analysis of the MQB strategy, its implementation, and the myriad benefits it brought to the Volkswagen Group.