Visualization of Industrial Production Processes using 3D Simulation Software for Enhanced Decision-Making

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Abstract

This paper explores the use of 3D simulation software for visualizing industrial production processes and its potential to enhance decision-making for improved production efficiency, quality, and profitability. Industrial production processes are complex and involve many variables and factors that can interact in unpredictable ways. Visualization helps to simplify these complex interactions, identify patterns and relationships, and enable more informed decision-making.

The research question that guides this paper is: *How can the use of 3D simulation software for visualization of industrial production processes improve decision-making and optimize production efficiency, quality, and profitability?* This paper will investigate the benefits and challenges of using 3D simulation software for visualizing industrial production processes, including the ability to identify bottlenecks, and optimize the production process. Further, the paper examines the role of visualization in enabling more informed decision-making, including the ability to analyze production data and make data-driven decisions. To illustrate this, an industrial automation case study consisting of a manufacturing industry modelled in a 3D simulation software has been presented.

The results of this 3D-simulation model provide insights into the advantages and disadvantages of utilizing 3D simulation software to visualize industrial manufacturing processes. The article further presents the significance of these findings for production managers, engineers, and decision-makers. Thus, the purpose of this study is to help readers understand how using 3D simulation software for visualization of industrial production processes can improve decision-making and optimize production efficiency, quality, and profitability.

Keywords: Industrial production processes, 3D simulation software, visualization, decision-making, production efficiency, industrial automation, data-driven decisions, manufacturing industry, optimization.

1. Introduction

Industrial production processes are central to the production of goods in the manufacturing industry. A series of activities involved in converting raw materials into finished goods using various equipment, tools, and machines are referred to as industrial production processes. Material handling, assembly, packaging, and quality control are examples of these processes. Optimizing industrial production processes is critical to achieving better production efficiency, quality, and profitability. This is because inefficient and suboptimal production processes can lead to bottlenecks, delays, and errors, which can result in increased costs, decreased quality, and reduced competitiveness (Xu et al., 2021). To overcome these challenges, manufacturers are increasingly turning to technology to improve their production processes. 3D simulation software is one such technology that has been gaining popularity in recent years, as it enables manufacturers to visualize and analyze their production processes in a virtual environment before implementing changes in the physical world (Abidi et al., 2020).

Visualization is the use of graphical or pictorial representations to convey complex information in an intuitive and easily understandable way. In the context of industrial production processes, visualization help to simplify complex processes, make patterns and relationships more evident, and enable more informed decision-making (Wang et al., 2015). In the context of industrial production processes, visualization helps to provide a clear understanding of the process flow, identify bottlenecks, simulate, and test different scenarios, and optimize resource allocation. Additionally, visualization can help decision-makers to understand the impact of different decisions on production processes and outcomes and choose the best course of action accordingly (Molenda et al., 2019).

In industrial production processes, there are often a large number of variables and factors to consider, such as machine parameters, production rates, and quality metrics (Xu et al., 2021). These factors can interact in complex ways, making it difficult to understand and optimize the production process (Molenda et al., 2019). Visualization can help to simplify these complex interactions by presenting the information in a way that is easier to understand

and analyze. Furthermore, visualization is used to identify patterns and relationships that may not be apparent from raw data. For example, by plotting machine performance over time, it may be possible to identify recurring issues that are impacting machine production efficiency (Atmakuri et al., 1993). By presenting this information graphically, it is easier to identify patterns and make informed decisions about how to address the issues.

Through displaying information in a way that is clear and accessible, visualization also aids in enabling more informed decision-making (Atmakuri et al., 1993). This can assist stakeholders in making more informed decisions by helping them understand the effects of various actions on production efficiency, quality, and profitability (Yang et al., 2021). Therefore, the topic of visualization of industrial production processes using 3D simulation software for enhanced decision-making is important because it enables manufacturers to optimize their production processes, leading to better production efficiency, quality, and profitability. By visualizing production processes in 3D simulation software, manufacturers can identify bottlenecks, test different scenarios, and make data-driven decisions before implementing changes in the physical world. This can lead to reduced costs, improved quality, and increased competitiveness, all of which are critical factors for success in the manufacturing industry. Hence, the research question has been formulated as follows:

How can the use of 3D simulation software for visualization of industrial production processes improve decision-making and optimize production efficiency?

2. Methodology

The problem addressed in this study is the need for enhanced decision-making in industrial production processes. Traditional methods of decision-making may lack comprehensive insights into the complex dynamics of production systems. Therefore, there is a growing interest in utilizing 3D simulation software to visualize industrial processes and improve decision-making capabilities.

The purpose of this study is to explore the potential benefits of using 3D simulation software for visualizing industrial production processes and examine its impact on decision-making. By investigating this area, the study aims to provide valuable insights and practical recommendations for improving decision-making in industrial settings. Figure 1 illustrates the research methodology involved in the development of the simulation model. A comprehensive review of scholarly and research articles was conducted to gain insights into visualization techniques, simulation software, and decision-making methodologies. The review included a range of sources including scholarly articles, research papers, and industry reports to understand the current state of research in the field. Data collection for this study involved gathering relevant information from various sources. Keywords related to industrial production processes, visualization, and decision-making were used to identify peer-reviewed articles that contributed to the research area. These articles were carefully selected and analysed to extract valuable insights.

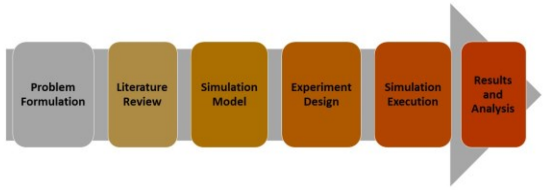

Figure 1: Research Method

The software Visual Components® has been utilized by the author to develop the 3D simulation model. The model represents an industrial production process consisting of injection moulding machines, series of conveyor belts, robots and a warehouse for storage. The model was developed based on the specific requirements and specifications of the case study and a dynamic representation of components flow has been visualized. The experiment design phase involved defining the simulation resources and parameters. Key variables, such as production volumes, cycle times, and system constraints, were determined to create a realistic simulation environment. The experimental design aimed to capture the complexities and dynamics of the industrial production process under study. The simulation model was executed to replicate the production operations. During the simulation run, process states, utilization rates, and performance metrics were recorded. This data provided valuable insights into the functioning of the production system and allowed for a detailed analysis of the simulation results.

The collected data was analysed to answer the research question posed in the study. The analysis focused on evaluating the effectiveness of the visualization of industrial production processes using the 3D simulation software. Performance metrics, such as throughput, cycle times, and resource utilization, were examined to assess the impact of visualization on decision-making. The results were interpreted to draw conclusions and provide practical recommendations. Based on the analysis of the simulation results, conclusions were drawn regarding the effectiveness of using 3D simulation software for visualizing industrial production processes and enhancing decision-making. The study provides insights into the benefits and limitations of visualization techniques and offers recommendations for further improvements in decision-making practices within industrial settings.

2.1. Simulation of Industrial Production Processes

Industrial production processes are fundamental in the manufacturing industry, encompassing a series of stages and steps that convert raw materials or components into finished products (Molenda et al., 2019). These processes involve crucial operations such as material handling, assembly, packing, and quality control (Chawla & Banerjee, 2001), which have been recognized as essential for simulating manufacturing processes. However, the complexity of these processes, often involving multiple interconnected systems and subsystems, presents challenges in comprehending and optimizing them effectively (Atmakuri et al., 1993).

Optimizing industrial production processes holds immense value as it has the potential to improve various aspects, including production efficiency, product quality, and overall profitability (Yang et al., 2021). By identifying and addressing bottlenecks, minimizing waste, and maximizing throughput, optimization efforts can lead to significant cost savings, enhanced customer satisfaction, and increased competitiveness in the marketplace. However, achieving optimization in industrial production processes is not without its obstacles. Challenges such as demand variability, equipment breakdowns, and workforce availability can impede the optimization journey, necessitating the adoption of advanced technologies to overcome these hurdles (Chawla & Banerjee, 2001; Yang et al., 2021). In this context, the utilization of 3D simulation software and visualization techniques emerges as a powerful solution. These technologies enable a deeper understanding and effective management of industrial production processes by providing insights into complex interactions and facilitating informed decision-making. 3D simulation software allows for the creation of virtual environments where manufacturing procedures can be simulated, analyzed, and optimized (Chawla & Banerjee, 2001). By replicating real-world scenarios, these simulations enable manufacturers to test different scenarios, evaluate the impact of process changes, and identify potential areas for improvement.

Visualization techniques, particularly in 3D, offer a more intuitive and comprehensive representation of the production processes. They surpass the limitations of traditional two-dimensional (2D) images by providing a richer visualization of spatial information and enabling real-time interaction (Molenda et al., 2019). By visualizing the processes in a virtual environment, decision-makers can better grasp the flow of materials, detect inefficiencies or bottlenecks, and make data-driven decisions to optimize the system.

2.2. Building 3D Simulation Model

The use of a 3D manufacturing simulation model provides a valuable tool for simulating and analyzing basic manufacturing procedures within a virtual environment. This technology leverages 3D visualization, which utilizes computer technology to depict real-world objects in a virtual space, surpassing the limitations of two-dimensional (2D) images in representing complex spatial information (Xu et al., 2021). By incorporating real-time interaction capabilities, the 3D visualization enhances the immersive experience and enables users to engage with the simulated environment effectively. The implementation and integration of a 3D simulation model involve several important steps. Key considerations during this process include defining resource parameters, selecting appropriate equipment, establishing fundamental simulation logic, and incorporating relevant production data (Xu et al., 2021). These elements are crucial for creating an accurate and realistic representation of the manufacturing system within the simulation model.

The resource parameters encompass various factors such as material properties, production capacities, and operating constraints. These parameters define the characteristics and capabilities of the resources involved in the manufacturing process, enabling the simulation model to accurately reflect their behavior and interactions (Chawla & Banerjee, 2001). The selection of equipment involves identifying and configuring the machinery, tools, and systems that are integral to the manufacturing process. By modelling these equipment components within the simulation, their functionalities and interactions can be evaluated and optimized (Wang et al., 2015). Fundamental simulation logic refers to the underlying principles and algorithms that govern the behavior and dynamics of the simulated manufacturing process.

Creating a 3D simulation of an industrial production procedure entails multiple processes (Figure 2). First, describe the simulation's scope and objectives, outlining the precise goals to be attained. Next, collect relevant data about the manufacturing process and identify the components and processes that must be modelled. Choose a 3D simulation program that matches the project's criteria. Create the simulation model by combining the acquired data and modelling the manufacturing line's components and procedures. This includes developing 3D models, setting material flow rules, and determining timing and sequencing. Validate and improve the simulation model by comparing it to real-world data and making necessary modifications. Analyze the simulation findings to find areas for improvement and to enhance decision-making.

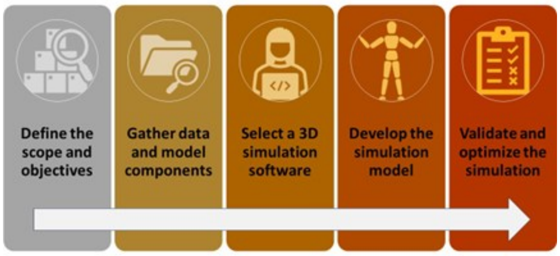

Figure 2: Building a 3D simulation model.

2.3. Visualization Techniques for Simulation

The use of virtual reality (VR), augmented reality (AR), and visual simulation technology allows to create a simulation model that can replicate real production scenarios in a safe environment (Xu et al., 2021). By inputting actual production data into the model, it is possible mimic on-site production in real-time. This technology helps us convert complex problems into more understandable ones (Xu et al., 2021). Furthermore, the simulation model provides a visual representation of production or manufacturing processes using terminal equipment (Abidi et al., 2020). They have further presented that by analysing and optimizing data, refining the mathematical model; and a closed-loop control and monitoring system can be created. This means that it enables to continuously monitor and adjust the production process based on the information provided by the simulation model.

A new strategy to generalizing the manipulation of industrial process simulation is explored (Abidi et al., 2020), where it is possible to visualize and engage with an industrial simulation model. It also enables industrial actors to visualize the operation of their factories which is based on virtual reality technology and behavioural programming of the production flow.

Xu et al., (2021) in their research describe the frame of visualization application, where they show the entire process starting from Cyber Physical System (CPS) to formulating the visualization platform. Within this VR and AR have been utilized for visualizing the created simulation model for the purpose of scheduling optimization and real-time monitoring. This results in a 3D recreation of industrial processes that depicts the production process that cannot be seen in depth on the 3D simulation of the production site (Xu et al., 2021).

2.4. Decision Making from simulation model.

Effective decision-making is crucial in industrial production processes as the decisions made during production can significantly impact efficiency, quality, and profitability (Yang et al., 2021). It is essential to have a clear understanding of the production processes and the consequences of different decisions on the outcomes. This is where the utilization of 3D simulation software and visualization techniques proves valuable (Xu et al., 2021). These tools enable manufacturers to create virtual representations of their production systems, visualizing the flow of materials, machines, and resources. Through simulation and visualization, decision-makers can assess different scenarios, identify potential issues, and make informed decisions before implementing changes in the physical world (Yang et al., 2021).

Figure 3 presents a conceptual model for decision making which has been designed to capture an expert's knowledge using simple and understandable elements, without relying on complex artificial intelligence or process representation (Garcia-Crespo et al., 2010). Instead, real-life situations have been focused, which occur during the execution of a manufacturing process, which consider facts (data), action (resources) and verification (checking the results from action are valid) through the process of making a decision.

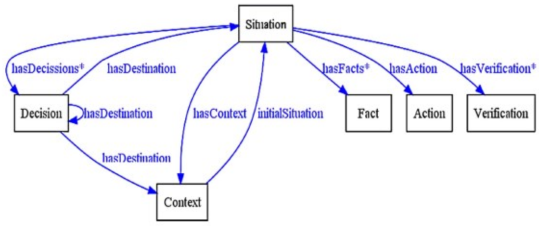

Figure 3: Decision Making Conceptual Model (Garcia-Crespo et al., 2010)

The aspect of decision making becomes important once there is an access to the real-time data through the created simulation model. Furthermore, Garcia-Crespo et al., (2010) in their research have presented this ontology for describing the automation of decision-making processes in the manufacturing process setting. In that, they have highlighted the importance of having a semantic representation of different manufacturing processes which further enable data representation strategy based on with the process of decision making is enabled.

3. Case Study

This section presents a 3D simulation model as a case study to showcase the application in real-world situation. This section further highlights the process of decision making and finally presents the results from the simulated model.

3.1. Case Description

Simulation modelling is essential for streamlining manufacturing procedures and increasing overall productivity in the area of industrial automation. Industrial systems can be accurately modelled and analysed to find opportunities for improvement using cutting-edge 3D simulation software. This study presents a simulation model of an industrial automation case in a sector of manufacturing with a focus on plastic injection-moulded basket manufacturing. The purpose of this study is to demonstrate how decision-making may be improved in the context of industrial production processes by using visualization and simulation approaches. The simulation model depicts a comprehensive representation of the production shopfloor, showcasing various interconnected components and processes.

Figure 4: 3D model of the production shopfloor

Figure 4 provides an overview of the shopfloor, offering a visual representation of the industrial automation case. The simulated model consists of two injection moulding machines, which are coupled by a conveyor system. This conveyor system facilitates the seamless transfer of the manufactured items (plastic baskets), between the machines. Subsequently, the baskets undergo a visual inspection process to identify any poor-quality elements. The conveyor system also enables the transportation of the approved baskets for further processing. To streamline the packing process, a robot is strategically placed between the two conveyor systems. This robot plays a vital role in efficiently packing the baskets into boxes. Once the baskets are securely placed in the boxes, they are seamlessly transferred to the palletization process. Here, another robot is responsible for picking up the boxes and organizing them on the pallets.

The palletization process incorporates its own conveyor system, ensuring a smooth flow of operations. Within the palletization process, the plastic wrapping and pallet stacking procedures take place, further enhancing the stability and protection of the palletized goods. Once the pallets undergo the stacking process, a stacker crane is employed to hoist them and place them in the designated warehouse for storage. This ensures efficient utilization of space and ease of access when retrieving the pallets for distribution or subsequent production stages. Through the integration of 3D simulation software, this case study showcases the visualization of an industrial automation scenario in the manufacturing industry. The subsequent sections of this paper will delve into the benefits, challenges, and decision-making aspects associated with the visualization of this simulation model.

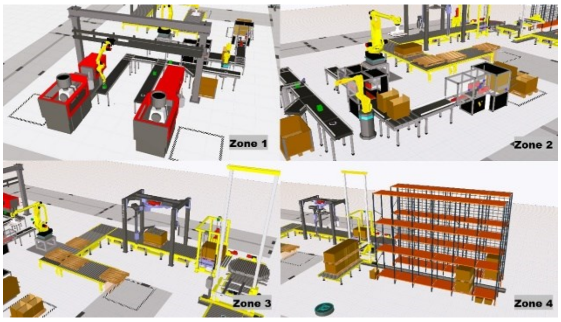

Figure 5: Different zones in the production shopfloor

The production shopfloor in the simulation model has been divided into four distinct zones: Zone 1, Zone 2, Zone 3, and Zone 4. Each zone encompasses specific functional procedures and components that contribute to the overall industrial production process. Figure 5 provides a visual representation of the layout and arrangement of these zones within the production shopfloor. The division of the production shopfloor into these zones and the incorporation of specific components and processes within each zone provide a comprehensive representation of the industrial production model.

Zone 1 serves as the initial stage of the production line, comprising two injection molding machines, a robot positioned overhead between the machines, and a conveyor transport system. The robot efficiently picks up the moulded baskets from the injection molding machines as the machine doors open. Subsequently, the robot places the baskets onto the conveyor belts, which then undergo a visual inspection process. During the visual inspection, any poor-quality baskets are identified and removed from the conveyor belt line to ensure product quality. Moving on to Zone 2, this area is dedicated to the packaging system, which is constructed along the conveyor system. The packaging process begins with an automated machine that prepares folded boxes. These prepared empty boxes are then transported on the conveyor belt and stop near the robot. With the box in place, the robot organizes the baskets by picking and placing them in an organized sequential order within the box. Once the box is filled, it is transported to another automated machine, where it is sealed before being moved to the next conveyor belt.

Zone 3 represents the palletization process which involves a conveyor system. In this zone, the boxes filled with baskets are placed on pallets with the assistance of a robot. Once the pallets are filled with the boxes, the conveyor system transports them to an automated plastic wrapping station. At this station, the pallets undergo a plastic wrapping process, ensuring their stability and protection during transportation and storage. After the plastic wrapping is complete, the pallets are transferred through the conveyor line to an automated pallet stacking machine. This machine lifts the pallets and stacks them on top of one another, optimizing space utilization and facilitating efficient storage. Finally, Zone 4 is dedicated to the storage of the pallets in the warehouse. An automated stacker crane system is employed in this zone to hoist the pallets and arrange them in an organized manner. The design of the stacker crane system ensures that the warehouse storage racks are within the crane's reach, enabling seamless storage operations.

As a result, the simulation model described here provides a comprehensive picture of an industrial automation case in the manufacturing industry. The simulation model provides a full portrayal of the industrial production processes involved in making plastic injection-moulded baskets by dividing the production shopfloor into discrete zones and adding various components and processes. The 3D simulation software's representation of the production shopfloor allows for a clear knowledge of the interconnection and operation of each zone. This visualization helps in the identification of potential bottlenecks, areas for improvement, and the overall optimization of production efficiency, quality, and profitability. The simulation model demonstrates the importance of visualization and simulation approaches in improving decision-making in industrial manufacturing processes. Decision-makers can analyze the impact of many aspects on the production line, such as throughput, resource usage, and system performance, by modeling the different zones. This enables educated decision-making, which leads to better planning, optimization, and overall improvement of industrial manufacturing processes.

3.2. Decision Making

Creating a 3D simulation model for visualizing and optimizing industrial production processes necessitates a number of crucial decision-making elements. The creation of discrete zones on the production shopfloor gives an organized structure for analysing and improving each phase of the production line. The structure and arrangement of the production shopfloor is the first key decision-making component. The shopfloor is divided into particular zones, such as Zone 1, Zone 2, Zone 3, and Zone 4, allowing for a systematic approach to understanding and optimizing the many functional procedures involved. Choosing the best combination of resources, machinery, and equipment for each zone is a critical choice that affects the overall efficiency and productivity of the production line.

Decisions about the arrangement of injection moulding machines, the overhead robot, and the conveyor transport system were made within Zone 1. To ensure seamless operation and efficient material flow, factors such as machine capacity, cycle times, and coordination between machines and robots were taken into consideration. Moving on to Zone 2, the decision-making process constituted of creating an efficient packaging system along the conveyor system. Choosing the right automated machine for folding boxes, deciding the positioning and sequencing of baskets by the robot, and ensuring effective box sealing are all important factors that affect the overall packing process. Decisions in Zone 3 revolve around the palletization process. The selection and location of the robot for palletizing the boxes, optimizing the conveyor system for efficient box transfer, and constructing the plastic wrapping station to ensure secure and stable pallets for transit and storage are all important considerations. Finally, in Zone 4, the decision-making process revolves around pallet storage in the warehouse. Choosing the right automated stacker crane system, customizing the crane's reach and movement, and correctly organizing the storage racks are all critical decisions in order to maximize space utilization and streamline storage operations.

It is essential to examine elements such as system throughput, resource usage, material flow optimization, and overall production efficiency throughout the decision-making process. Simulation modelling provides for the testing of numerous scenarios, the evaluation of the impact of various choice alternatives, and the identification of potential bottlenecks or areas for improvement.

3.3. Simulation Results

During the simulation, a total run time of 8 hours was chosen to align with the duration of a typical daily shift in the industrial production environment. This time frame allows for a comprehensive evaluation of the production processes and the performance of the simulation model. In the simulation model, three robots were strategically positioned at the junctions between the zones to facilitate the smooth transfer of baskets and optimize the overall material flow.

The first robot, Robot 1, was placed overhead, directly above the two injection-moulding machines in Zone 1. This robot plays a crucial role in picking up the moulded baskets from the machines and transferring them to the conveyor belts. Robot 2 was positioned between Zone 1 and Zone 2, acting as a key component in the transition from the injection moulding process to the packaging system. It assists in organizing the baskets and placing them in the boxes in a sequential order. Similarly, Robot 3 was placed between Zone 2 and Zone 3, facilitating the movement of the filled boxes from the packaging system to the palletization process. This robot plays a vital role in placing the boxes on pallets, ensuring efficient palletization. Figure 6 provides valuable insights into the utilization of these three robots throughout the 8-hour simulation run. The utilization is represented as a percentage, indicating the proportion of time each robot was actively engaged in performing its designated tasks.

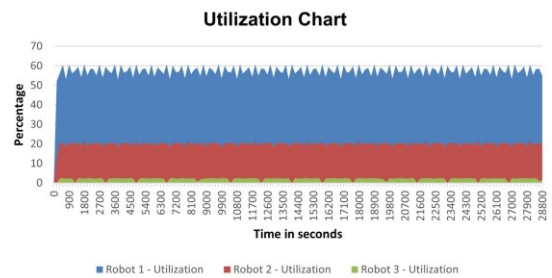

Figure 6: Robot percentage utilization

These presented results allow for a deeper understanding of the robots' workload distribution and their efficiency in supporting the production processes. By evaluating the utilization percentages, it becomes possible to identify potential bottlenecks or areas of improvement within the production line. For instance, if a robot's utilization is consistently high, it may indicate a need for additional resources or process optimization to alleviate the workload. On the other hand, low utilization may suggest under-utilized capacity that can be optimized for increased productivity. The utilization analysis of the robots provides valuable insights into the operational efficiency and resource allocation within the simulated industrial production system. These findings can guide decision-making processes to enhance the overall performance and productivity of the production processes.

The simulation model incorporates various process nodes that are programmed to operate within specific flow groups. In this particular simulation, there is a single flow group representing the production of a specific product type, which in this case is baskets. Each process node within the model has the capability to assume different statistical process states, including idle, busy, and blocked.

To establish the interconnection between different zones, four process nodes were selected in this simulation model. These process nodes serve as the critical links between the zones and play a crucial role in the overall flow of the production process. Figure 7 visually represents the state results obtained from these zonal process nodes. The results are presented as percentages, reflecting the distribution of different process states throughout the entire production or simulation run time, which was set to 8 hours in this case.

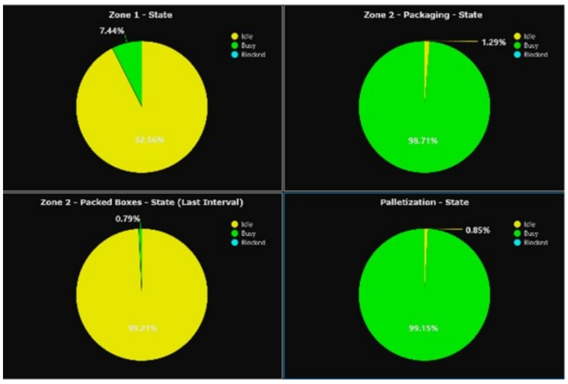

Figure 7: Idle, busy, and blocked States

Starting with the Zone 1 state process node, it represents the initial stage where the baskets arriving on the conveyor belt are picked up by Robot 2 and subsequently placed in the Zone 2 (Packaging) process node according to the programmed assembly sequence. The Zone 2 (Packed Boxes) process node captures the state of the final packed boxes. Here, Robot 3 is responsible for lifting the packed boxes and placing them onto the pallet, which is represented by the Zone 3 (Palletization) process node. Robot 3 follows a specific assembly sequence while arranging the boxes on the pallet. It is noteworthy that each pallet accommodates a total of 8 boxes, organized in a 2x2x2 stack configuration.

By analysing the state results from these zonal process nodes, it becomes possible to gain insights into the efficiency and performance of the production process. The percentages offer a quantitative assessment of the process states, indicating the proportion of time spent in each state throughout the 8-hour simulation run. These results enable the identification of potential bottlenecks, areas of improvement, or process optimization opportunities within the production flow.

4. Analysis and Discussion

The simulation model focuses on improving decision-making in industrial production processes, in the context of plastic injection-moulded basket manufacturing. The simulation model provides a visual representation of the production shopfloor, encompassing various related components and processes, using 3D simulation software Visual Components®. This was further tested in Virtual Reality (VR) environment (Figure 8) to analyse the simulation model and to initiate the decision-making process within the different zones which are representing different stages of the production line. The simulation model's decision-making process included identifying the structure and layout of the production shopfloor, selecting the necessary resources and equipment for each zone, and optimising aspects such as material flow and system throughput. Additional VR analysis enabled the process of deciding how much space to be available so that operators can use it for maintenance.

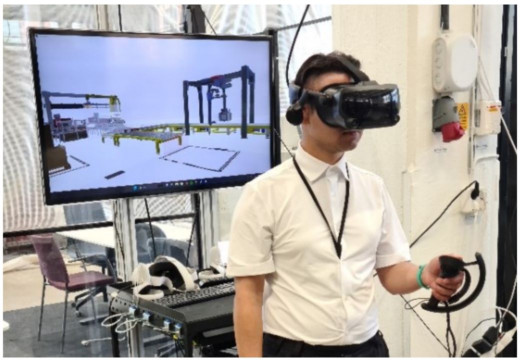

Figure 8: Simulation model testing in VR

Simulation results show the utilization of robots positioned in different zones, allowing for the identification of potential areas for improvement. It was observed from the robot utilization chart (Figure 6), that the utilization percentage for Robot 2 was less and Robot 3 was much lesser. This tells us that there is a possibility for further expanding Zone 1 with more injection-moulding machines. The analysis of process states within the zones provided insights into the efficiency and performance of the production process. Similarly, it was also observed in Zones 1 and 2, the idle time amounted to more than 90% of the total simulation run time. Because of this, it is possible to advise the business management that the current process will be able to support any future investments in additional injection moulding machines in the case concerning increasing the production capacity.

Therefore, to answer the research question, the use of 3D simulation software and virtual reality (VR) in visualizing industrial production processes provides useful insights to decision-makers for optimizing production efficiency. It enables informed decision-making by providing a comprehensive picture of the production flow, resource utilization, and system performance.

Decision-makers can increase the overall efficiency and profitability of manufacturing processes by identifying areas for improvement and resolving potential bottlenecks. The validation of the simulation model was done during the development phase through the immediate testing of simulation animation results in the 3D world environment within the software. This validation was in the form of correlating and checking if the flow components were in accordance to the set requirements.

5. Conclusion

In conclusion, this study highlighted the significance of 3D simulation modelling and visualization techniques in improving decision-making and optimizing production efficiency in industrial manufacturing processes, with a specific focus on plastic injection-moulded basket manufacturing. The utilization of 3D simulation software, coupled with VR testing, allowed for a comprehensive and immersive representation of the production shopfloor, showcasing interconnected components and processes.

Decision-makers can examine and comprehend the production flow, resource allocation, and system performance with the help of the simulation model. Additionally, the developed model is flexible in order to accommodate future modifications. By examining the utilization of robots in different zones, potential areas for improvement can be identified, leading to enhanced resource utilization and increased production efficiency. The analysis of process states within the zones further contributes to identifying bottlenecks and optimization opportunities within the production process.

By offering visual context, dynamic interaction, and the capacity to test possibilities, 3D simulations and VR technologies transform shopfloor decision-making. They uncover complicated relationships, possible bottlenecks, and ergonomic difficulties that statistics overlook. These systems detect problems early, improve communication, and provide a visual knowledge of shopfloor processes. They alter structure, throughput, and efficiency decisions by displaying the shopfloor layout, equipment, and processes. Unlike traditional numerical analysis, 3D simulations and VR provide decision-makers with immersive insights, allowing them to make educated decisions that lead to optimised industrial production processes. The findings from the simulation model and visualization techniques demonstrate the importance of informed decision-making in industrial manufacturing. Decision-makers can leverage the insights gained from the simulation model to make educated decisions regarding the structure and arrangement of the production shopfloor, selection of appropriate resources and equipment, and optimization of material flow and system throughput.

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