ANNEXURE I

MODULE-WISE COURSE CONTENT AND OUTCOME				
SL.NO	**MODULE NAME**	**MODULE CONTENT**	**MODULE LEARNING OUTCOME**	**DURATION (HRS)**
1	Introduction to Digital Twin	Introduction - Overview and evolution of Digital Twin technology - Key components: physical systems, digital systems, and data integration - Applications in industries like manufacturing, healthcare, and smart cities - Benefits of Digital Twins in predictive maintenance and operational efficiency - Challenges and ethical considerations in Digital Twin implementation.	• Apply the concept, evolution, and components of Digital Twin technology. • Explore applications and benefits in industries like manufacturing, healthcare, and smart cities. • Identify challenges and ethical considerations in implementing Digital Twins	9hrs
2	Foundations of Digital Twin	Data acquisition from physical systems using IoT and sensors - Real-time data streaming and processing techniques - Creating virtual models using CAD and simulation tools - Communication protocols for Digital Twin systems - Integration of AI/ML for predictive and prescriptive analytics.	• Build and visualize virtual models of physical devices. • Apply IoT protocols for seamless data communication between systems. • Evaluate and interpret system data to create virtual twins.	9hrs
3	Building and Implement	Steps to design and deploy a Digital Twin system - Tools and	• Create functional Digital Twins with synchronized real-	9hrs

	ing Digital Twins	platforms for Digital Twin creation - Synchronizing real-time data with virtual models - Case studies of successful Digital Twin implementations - Troubleshooting and maintaining Digital Twin systems.	time updates. • Simulate system behavior using advanced tools like Unity or MATLAB. • Integrate real-world data streams with virtual environments effectively.	
4	Future Trends	Exploring advancements in Digital Twin technologies - Scalability and interoperability in large-scale systems	• Develop prototypes for innovative Digital Twin applications.	9hrs
5	Innovation in Digital Twin	- Potential impact on Industry 4.0 and beyond - Sustainability and environmental applications - Emerging opportunities and career pathways in Digital Twin development.	• Incorporate eco-friendly and sustainable practices in Digital Twin designs. • Explore next-generation technologies like AR/VR to enhance user interaction.	9hrs

ANNEXURE II

OVERALL COURSE LEARNING OUTCOME ASSESSMENT CRITERIA AND USECASES			
LEARNING OUTCOME	**ASSESSMENT CRITERIA**	**PERFORMANCE CRITERIA**	**USECASES**
• Understand how digital twins enhance building energy efficiency and system optimization. • Develop skills to simulate and optimize building systems. • Learn predictive maintenance for building equipment. • Apply real-time data for energy conservation and operational improvements.	• Ability to model building systems effectively. • Successful implementation of energy optimization algorithms. • Improved efficiency in HVAC, lighting, and electrical systems. • Reduction in energy consumption and operational costs.	• Create a digital model of the building, including floor plans and HVAC systems. • Collect real-time sensor data (temperature, humidity, occupancy). • Analyze energy usage patterns and optimize HVAC control. • Implement predictive maintenance for building systems. • Monitor and optimize resource consumption and comfort levels.	**Use Case 1 - Smart Building Management** **Scenario:** A facility manager wants to optimize energy usage and improve building efficiency. **Task:** Create a digital model of the building's structure and systems (HVAC, lighting, etc.). Collect real-time sensor data (temperature, occupancy). Analyze energy usage and optimize HVAC control. Implement predictive maintenance for building systems. Monitor and optimize resource consumption and comfort levels.
• Understand digital twins' role in optimizing traffic flow in urban environments. • Learn how to manage and predict traffic	• Successful creation of a digital city traffic model. • Demonstrated reduction in traffic congestion. • Effective route optimization for	• Build a digital model of the city's traffic infrastructure (roads, signals, and sensors). • Collect traffic flow data from sensors,	**Use Case 2 - Smart City Traffic Management** **Scenario:** A city needs to improve traffic flow and reduce congestion. **Task**: Build a digital

congestion. • Apply real-time data to optimize traffic signals and routes. • Gain skills in creating and testing traffic management models.	vehicles. • Improved traffic flow and reduced travel time.	cameras, and GPS devices. • Implement algorithms to predict traffic congestion and optimize signal timings. • Simulate and test various traffic management scenarios. • Implement dynamic traffic signal control and adaptive routing.	model of the city's traffic infrastructure. Collect data from traffic sensors, cameras, and GPS devices. Implement algorithms to predict traffic congestion and optimize signal timings. Simulate and test traffic management scenarios. Implement dynamic signal control and adaptive routing.
• Understand the application of digital twins in predictive maintenance for industrial machines. • Learn how to monitor equipment in real-time. • Develop skills in fault detection and anomaly prediction. • Optimize maintenance schedules and reduce downtime.	• Creation of effective digital twin models for industrial equipment. • Accurate detection of faults and system inefficiencies. • Reduced machine downtime through predictive maintenance. • Improved asset performance and cost savings.	• Create a digital twin of factory machinery. • Collect operational data (temperature, vibrations, power consumption). • Train predictive models to identify potential failures or inefficiencies. • Set up alarms and alerts for anomalous behavior. • Implement real-time monitoring and predictive maintenance.	**Use Case 3 - Industrial Equipment Monitoring** **Scenario:** A factory wants to monitor and maintain machinery to prevent breakdowns. **Task:** Create a digital twin of factory machinery. Collect real-time data on machine performance (temperature, vibrations, power consumption). Train predictive models to detect potential failures or inefficiencies. Set up alerts for anomalous behavior. Implement real-time monitoring and predictive

			maintenance.
• Learn to apply digital twins for continuous health monitoring. • Develop predictive models for patient health risks. • Gain insights into real-time patient care optimization. • Understand the role of digital twins in personalized medicine.	• Successful integration of real-time health monitoring data. • Effective predictive models for patient condition forecasting. • Demonstrated improvement in patient care management. • Reduced health risks and optimized treatment plans.	• Develop a digital model of a patient's health metrics (heart rate, blood pressure, etc.). • Collect continuous health data via wearable sensors. • Analyze data to predict health risks (e.g., heart attack, stroke). • Notify healthcare providers in case of critical health issues. • Provide real-time updates to doctors and patients.	**Use Case 4 - Healthcare Patient Monitoring** **Scenario:** A hospital wants to continuously monitor patient health data and predict health risks. **Task:** Develop a digital twin of a patient's health metrics. Collect continuous data from wearable sensors. Analyze data to predict health risks (e.g., heart attack, stroke). Notify healthcare providers in case of critical health issues. Provide real-time updates to doctors and patients.
• Learn how digital twins simulate autonomous vehicle behavior. • Understand how to optimize autonomous vehicle navigation. • Gain expertise in testing and validating autonomous algorithms.	• Creation of a digital twin of the vehicle's sensor systems. • Successful optimization of autonomous driving algorithms. • Effective simulation of driving scenarios for algorithm testing. • Improved vehicle	• Build a digital twin of the vehicle and its environment. • Collect data from sensors like LIDAR, cameras, and GPS. • Simulate different driving scenarios and traffic conditions. • Test the vehicle's autonomous	**Use Case 5 - Autonomous Vehicle Simulation** **Scenario:** A company is developing self-driving cars and needs to test their behavior in various environments. **Task:** Build a digital twin of the vehicle and its environment. Collect data from sensors like LIDAR, cameras, and GPS. Simulate different

• Develop skills in vehicle safety and performance enhancement.	performance and safety metrics.	navigation algorithms. • Continuously update and improve the vehicle's capabilities based on real-world feedback.	driving scenarios and traffic conditions. Test autonomous navigation algorithms. Continuously update and improve the vehicle's capabilities based on real-world feedback.
• Understand the role of digital twins in supply chain visibility and management. • Learn how to predict demand and optimize inventory management. • Gain skills in logistics optimization. • Understand how to reduce costs and improve supply chain efficiency.	• Creation of a digital twin of the supply chain. • Effective use of demand forecasting and inventory optimization. • Improved logistics management and reduced delays. • Demonstrated cost reduction and faster order fulfillment.	• Create a digital twin of the entire supply chain (warehouses, inventory, suppliers). • Collect real-time data on stock levels, shipments, and production status. • Use predictive analytics to forecast demand and optimize stock levels. • Monitor logistics and optimize routing of goods. • Implement real-time tracking and visibility into the entire supply chain.	**Use Case 6 - Supply Chain Optimization** **Scenario:** A retailer wants to optimize its supply chain to reduce costs and improve delivery times. **Task:** Create a digital twin of the supply chain, including warehouses, inventory, and suppliers. Collect data on stock levels, shipments, and production status. Use predictive analytics to forecast demand and optimize stock levels. Monitor logistics and optimize routing of goods. Implement real-time tracking for supply chain visibility.
• Understand how digital twins optimize energy distribution and grid performance.	• Successful modeling of the energy grid infrastructure. • Effective demand forecasting and	• Create a digital twin of the energy grid, including power plants, transformers, and distribution	**Use Case 7 - Energy Grid Optimization** **Scenario:** An energy provider wants to optimize power distribution and

• Learn how to predict energy demand and balance loads. • Develop skills in monitoring and preventing grid failures. • Gain knowledge in implementing sustainable energy practices.	load balancing. • Reduced grid failure and downtime. • Improved energy efficiency and sustainability.	lines. • Collect real-time data on energy consumption and production. • Analyze the grid for inefficiencies and predict potential outages. • Optimize energy distribution and load balancing. • Implement automated demand-response systems to adjust consumption patterns.	prevent outages. **Task:** Build a digital twin of the energy grid, including power plants and distribution lines. Collect real-time data on energy production and consumption. Analyze the grid for inefficiencies and potential outages. Optimize energy distribution and load balancing. Implement automated demand-response systems for better grid management.
• Understand how digital twins optimize store layout and customer experience. • Learn how to monitor inventory in real-time and optimize stock. • Apply data analytics for improving sales and operational efficiency. • Understand customer behavior patterns using digital twin data.	• Successful modeling of the store layout and inventory. • Improved stock levels and reduced product shortages. • Enhanced customer experience through data-driven decisions. • Demonstrated improvements in sales and operational efficiency.	• Develop a digital model of the store layout, inventory, and customer traffic patterns. • Collect data on sales, stock levels, and customer behavior. • Use machine learning to predict which products will sell best at certain times. • Optimize inventory management and restocking schedules. • Personalize promotions and in-store experiences for	**Use Case 7 - Energy Grid Optimization** **Scenario:** An energy provider wants to optimize power distribution and prevent outages. **Task:** Build a digital twin of the energy grid, including power plants and distribution lines. Collect real-time data on energy production and consumption. Analyze the grid for inefficiencies and potential outages. Optimize energy distribution and load balancing. Implement automated demand-response systems for better grid management.

		customers.	
• Understand how digital twins can enhance crop yield and livestock health. • Learn precision agriculture techniques for resource optimization. • Apply real-time monitoring to improve farming outcomes. • Gain knowledge of sustainable farming practices using digital twins.	• Successful creation of a digital twin model for farm management. • Improved crop yield and livestock health with data-driven insights. • Effective use of precision agriculture for resource optimization. • Reduced environmental impact and improved sustainability.	• Create a digital twin of a farm, including crops, livestock, and irrigation systems. • Collect environmental data (soil moisture, temperature, humidity). • Implement precision farming techniques for optimized irrigation and fertilization. • Use AI to predict crop yields and livestock health. • Monitor and adjust farming practices in real-time based on data.	**Use Case 9 - Smart Farming** **Scenario:** A farmer wants to increase crop yield and monitor livestock health efficiently. **Task:** Create a digital twin of the farm, including crops, livestock, and irrigation systems. Collect environmental data (soil moisture, temperature, humidity). Implement precision farming techniques for irrigation and fertilization. Predict crop yields and livestock health. Monitor and adjust farming practices in real-time.
• Understand how digital twins optimize construction project timelines and resources. • Learn how to improve worker safety through digital simulations. • Apply simulation for better construction planning and	• Successful creation of a digital twin for construction project management. • Improved project timelines and resource utilization. • Enhanced worker safety through risk simulations. • Reduced delays and improved construction	• Build a digital model of the construction site, including machinery, workers, and materials. • Collect data on construction progress and resource usage. • Monitor worker safety and site conditions in real-time. • Optimize scheduling and resource	**Use Case 10 - Construction Site Management** **Scenario:** A construction company wants to optimize project timelines and worker safety. **Task:** Build a digital twin of the construction site, including machinery, workers, and materials. Collect data on construction progress and

risk management. ● Develop skills in improving construction productivity.	outcomes.	allocation. ● Simulate construction scenarios to improve planning and decision-making.	resource usage. Monitor worker safety and site conditions. Optimize scheduling and resource allocation. Simulate construction scenarios for better planning and decision-making.
● Understand how digital twins optimize water usage and distribution. ● Learn how to predict and prevent water shortages. ● Apply real-time data to improve water quality management. ● Gain skills in sustainable water resource management.	● Successful creation of a digital twin for water distribution systems. ● Improved water usage efficiency and reduced waste. ● Effective water quality monitoring and management. ● Demonstrated sustainability improvements in water usage.	● Create a digital twin of the water distribution system, including pipes, reservoirs, and treatment plants. ● Collect real-time data on water flow, pressure, and quality. ● Monitor system performance and identify potential leaks or inefficiencies. ● Implement predictive models for water demand forecasting. ● Optimize water distribution and conservation efforts.	**Use Case 11 - Smart Water Management** **Scenario:** A municipality wants to optimize water usage and prevent waste. **Task:** Create a digital twin of the water distribution system. Collect data on water flow, pressure, and quality. Monitor system performance and identify potential leaks or inefficiencies. Implement predictive models for water demand forecasting. Optimize water distribution and conservation efforts.
● Understand how digital twins optimize aircraft performance. ● Learn predictive maintenance techniques for	● Successful modeling of aircraft performance. ● Improved predictive maintenance for aircraft components.	● Build a digital twin of the aircraft, including engines, avionics, and structural components. ● Collect flight	**Use Case 12 - Aircraft Performance Monitoring** **Scenario:** An airline wants to monitor aircraft performance and predict

the aviation industry. ● Apply data analytics to improve fuel efficiency. ● Gain skills in improving aviation safety and reliability.	● Enhanced fuel efficiency and reduced operating costs. ● Demonstrated improvements in flight safety and reliability.	data (speed, altitude, engine performance). ● Predict maintenance needs based on real-time performance data. ● Implement condition-based maintenance scheduling. ● Optimize flight performance for fuel efficiency and safety.	maintenance needs. **Task:** Build a digital twin of the aircraft, including engines, avionics, and structural components. Collect data on flight performance (speed, altitude, engine conditions). Predict maintenance needs based on performance data. Implement condition-based maintenance scheduling. Optimize fuel efficiency and safety.
● Understand how digital twins optimize electric vehicle charging. ● Learn how to predict and balance charging demand. ● Develop skills in managing charging stations and infrastructure. ● Understand how to improve grid efficiency with EV integration.	● Successful modeling of electric vehicle charging infrastructure. ● Effective load balancing and charging demand prediction. ● Improved grid integration for efficient energy use. ● Reduced peak load and improved EV charging station efficiency.	● Create a digital twin of the EV charging network and vehicles. ● Collect data on vehicle battery levels, charging station utilization, and grid status. ● Implement real-time monitoring and load balancing for efficient charging. ● Predict charging demand and optimize station placement. ● Integrate renewable energy sources into the grid for sustainable charging.	**Use Case 13 - Smart Grid for Electric Vehicles** **Scenario:** A city wants to manage the charging infrastructure for electric vehicles (EVs) efficiently. **Task:** Create a digital twin of the EV charging network. Collect data on vehicle battery levels, station usage, and grid status. Implement real-time monitoring and load balancing for efficient charging. Predict charging demand and optimize station placement. Integrate renewable energy sources for sustainable charging.

• Understand how digital twins optimize home automation systems. • Learn how to manage energy consumption efficiently. • Develop skills to automate household appliances based on data insights. • Understand how to improve user comfort through smart home technologies.	• Successful implementation of smart home automation features. • Demonstrated energy savings through automation and optimization. • Improved user experience and comfort with automation. • Reduced operational costs through efficient energy management.	• Develop a digital twin of a smart home, including appliances, lighting, and HVAC systems. • Collect data on energy usage, temperature, and occupancy. • Implement automation routines based on user preferences and habits. • Use machine learning to predict and optimize energy consumption. • Monitor home security and health parameters (e.g., air quality).	**Use Case 14 - Smart Home Automation** **Scenario:** A homeowner wants to automate the management of home appliances and energy consumption. **Task:** Develop a digital twin of the smart home, including appliances, lighting, and HVAC systems. Collect data on energy usage, temperature, and occupancy. Implement automation routines based on user preferences. Optimize energy consumption using machine learning. Monitor security and health parameters (air quality, temperature).
• Understand how digital twins optimize railway system maintenance schedules. • Learn to detect faults and system failures in real-time. • Develop skills to predict and prevent railway infrastructure failures. • Apply data-driven	• Creation of effective digital models for railway systems. • Accurate fault detection and failure prediction. • Improved system uptime and reliability. • Reduced maintenance costs and downtime.	• Create a digital twin of the railway system, including tracks, stations, and trains. • Collect data on train performance, track condition, and weather. • Implement predictive models to identify potential breakdowns. • Monitor train schedules and optimize	**Use Case 15 - Predictive Maintenance for Railway Systems** **Scenario:** A railway company wants to prevent breakdowns and optimize maintenance schedules. **Task:** Create a digital twin of the railway system, including tracks, stations, and trains. Collect data on train performance, track conditions, and weather. Use

insights for improving railway system reliability.		maintenance activities. • Implement real-time alerts for train malfunctions and delays.	predictive models to forecast potential failures. Monitor train schedules and optimize maintenance activities. Implement real-time alerts for malfunctions.
• Understand how digital twins monitor and optimize EV battery performance. • Learn how to predict battery health and lifespan. • Develop skills in optimizing charging behavior and energy usage. • Apply real-time data to improve battery efficiency and longevity.	• Successful modeling of electric vehicle battery systems. • Effective prediction of battery health and lifespan. • Improved battery performance through optimization techniques. • Increased energy efficiency and extended battery life.	• Build a digital twin of the EV battery system, including individual cells and battery packs. • Collect real-time data on temperature, charge cycles, and battery health. • Implement algorithms to optimize battery usage and lifespan. • Predict when maintenance or replacement is needed. • Monitor energy consumption and manage charging behavior.	**Use Case 16 - Electric Vehicle Battery Management** **Scenario:** An EV manufacturer wants to extend the lifespan of their vehicle batteries. **Task:** Build a digital twin of the EV battery system, including individual cells and battery packs. Collect real-time data on temperature, charge cycles, and battery health. Implement algorithms to optimize battery usage and longevity.
• Understand how digital twins optimize oil and gas pipeline monitoring. • Learn predictive models for preventing leaks and	• Creation of digital models for pipeline monitoring. • Accurate fault detection and leak prediction. • Reduced environmental risks and improved	• Create a digital twin of the pipeline, including pumps, valves, and sensors. • Collect data on pressure, flow rate, and temperature along the	**Use Case 17 - Oil & Gas Pipeline Monitoring** **Scenario:** An oil company wants to detect leaks and optimize pipeline maintenance. **Task:** Create a digital twin of the pipeline,

failures. • Develop skills in real-time condition monitoring of pipelines. • Understand how to enhance pipeline safety and efficiency using digital twins.	pipeline safety. • Improved pipeline efficiency and reduced operational costs.	pipeline. • Monitor for anomalies, such as leaks or blockages. • Implement predictive models to forecast pipeline failures. • Optimize maintenance schedules and repair times.	including pumps, valves, and sensors. Collect data on pressure, flow rate, and temperature. Monitor for leaks or blockages. Implement predictive models to forecast pipeline failures. Optimize maintenance schedules and response times.
• Learn how digital twins improve manufacturing process efficiency. • Understand how to optimize production lines and workflows. • Gain expertise in defect detection and quality control. • Develop skills in integrating automation into manufacturing.	• Successful implementation of digital twin-based manufacturing systems. • Improved production line efficiency and workflow optimization. • Enhanced quality control and defect detection. • Increased manufacturing capacity and reduced operational costs.	• Build a digital model of the warehouse, including shelves, robots, and inventory. • Collect data on stock levels, order fulfillment, and robot movements. • Implement automated inventory management and sorting. • Optimize space usage and product placement. • Use AI to predict order trends and optimize stock replenishment.	**Use Case 18 - Smart Warehouse Management** **Scenario:** A warehouse manager wants to optimize space and improve order fulfillment. **Task:** Build a digital model of the warehouse layout, including shelves, robots, and inventory. Collect data on stock levels, order fulfillment, and robot movements. Implement automated inventory management and sorting. Optimize space usage and product placement. Predict order trends and manage stock replenishment.
• Understand how digital twins optimize aerospace manufacturing	• Effective use of digital twins to improve part quality. • Enhanced	• Create a digital twin of the vessel fleet, including ship models and	**Use Case 19 - Marine Vessel Fleet Management** **Scenario:** A shipping

processes. • Learn how to improve part quality and minimize defects. • Develop skills in optimizing production workflows. • Gain knowledge in predictive maintenance for aerospace components.	production workflow and optimized assembly lines. • Reduced manufacturing defects and improved product quality. • Improved maintenance scheduling for aerospace components.	cargo. • Collect data on vessel speed, fuel usage, and weather conditions. • Implement route optimization algorithms to save fuel and time. • Monitor vessel performance and predict maintenance needs. • Optimize cargo loading and unloading processes.	company wants to optimize fuel usage and vessel performance. **Task:** Create a digital twin of the fleet, including ship models and cargo. Collect data on vessel speed, fuel consumption, and weather conditions. Implement route optimization algorithms for fuel efficiency. Monitor vessel performance and predict maintenance needs. Optimize cargo loading and unloading.
• Learn how digital twins monitor environmental conditions. • Understand how to predict environmental changes and natural disasters. • Apply real-time data to environmental decision-making. • Gain skills in using digital twins for sustainable environmental practices.	• Successful creation of environmental monitoring systems using digital twins. • Accurate prediction of environmental changes and natural disasters. • Improved response to environmental risks and disasters. • Enhanced sustainability and environmental impact reduction.	• Develop a digital model of the renewable energy grid, including wind turbines, solar panels, and energy storage systems. • Collect real-time data on energy production and consumption. • Predict energy demand and optimize energy distribution. • Integrate energy storage and backup systems to handle intermittent power supply.	**Use Case 20 - Smart Grid for Renewable Energy** **Scenario:** An energy provider wants to integrate renewable energy sources efficiently into the grid. **Task:** Build a digital model of the renewable energy grid, including wind turbines, solar panels, and energy storage. Collect real-time data on energy production and consumption.

LIST OF FINAL PROJECTS (20 PROJECTS THAT COMPREHENSIVELY COVER ALL THE LEARNING OUTCOME)	
SL.NO	**FINAL PROJECT**
1	Smart Building Management
2	Smart City Traffic Management
3	Industrial Equipment Monitoring
4	Healthcare Patient Monitoring
5	Autonomous Vehicle Simulation
6	Supply Chain Optimization
7	Energy Grid Optimization
8	Retail Store Management
9	Smart Farming
10	Construction Site Management
11	Smart Water Management
12	Aircraft Performance Monitoring
13	Smart Grid for Electric Vehicles
14	Smart Home Automation
15	Predictive Maintenance for Railway Systems
16	Electric Vehicle Battery Management
17	Oil & Gas Pipeline Monitoring
18	Smart Warehouse Management
19	Marine Vessel Fleet Management
20	Smart Grid for Renewable Energy

ANNEXURE III

COURSE ASSESSMENT RUBRICS (TOTAL MARKS: 70)				
ASSESSMENT CRITERIA	**DESCRIBE THE CRITERIA OF THE BELOW CATEGORY PERFORMANCE**			**TOTAL MARKS**
	FAIR	**GOOD**	**EXCELLENT**	
Practical Skills	Basic implementation with significant errors	Working simulation with minor errors.	Accurate and highly functional simulation.	20
Technical Knowledge	Limited understanding of concepts.	Strong understanding with minor gaps.	In-depth understanding with innovative applications.	15
Project Execution	Meets minimum requirements with room for improvement.	Completes project with clear understanding.	Exceeds expectations with innovative features.	25
Communication and Reporting	Communication is unclear and lacks detail	Clear and structured presentation with minor gaps.	Professional and detailed reporting with excellent visuals.	10