Model Answer
End-Sem Examination-I, Winter 2025

Academic Year: 2025-2026	Semester: Sem III
Class: PG II	Program: MBA
Branch Code: 10	Pattern: 2024
Name of Course: TPS and Industry 5.0	Course Code: 2410612D

Q. No.	Details	Max. Marks
Q.1	Describe the "4P" model of the Toyota Way. Explain with examples on 'creating continuous process flow'. (6 marks) The Toyota Way's 4P model organizes 14 principles into four pillars: Philosophy (long-term thinking), Process (right processes create results), People and Partners (develop exceptional individuals/teams), and Problem Solving (continuous improvement through root-cause analysis). **4P Model Breakdown** • Philosophy (P1): Base all decisions on long-term customer value over short-term profits (e.g., Toyota's 50-year EV commitment despite initial costs). • Process (P2-8): Create continuous flow, pull systems, level production, standardize tasks, build quality in, use visual control, adopt tech selectively. • People & Partners (P9-11): Grow leaders who live philosophy, develop teams following it, respect extended networks. • Problem Solving (P12-14): Go see (genchi genbutsu), decide by consensus, become learning organization via hansei/kaizen. **Continuous Process Flow (Principle 2) Examples** Continuous flow eliminates batching/waste by making one piece at a time, creating takt time-aligned production: • Toyota Engine Assembly: One-piece flow on U-shaped cells—worker A installs piston, B immediately adds rings (no WIP queues), cutting lead time from days to hours vs. Western batch lines. • Supermarket Kanban: Small buffers trigger pull (e.g., 20 valves stocked; when depleted, signal upstream production), preventing overproduction while maintaining flow. • Heijunka (Leveling): Mix high/low-volume models daily (e.g., 60% Corolla, 40% Camry) on same line via quick SMED changeovers (<10 min), smoothing demand vs. Ford's model-specific lines. This principle drives 90% inventory reduction and 50% space savings, foundational to JIT and lean globally	[6]
Q.2	Explain Principle 9 of the Toyota Way: "Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others." Discuss how leaders embed long-term philosophy in manufacturing operations.	[6]

(6 marks)

Toyota Way Principle 9 emphasizes developing internal leaders who deeply understand shop-floor operations, embody the company's long-term philosophy, and mentor others to perpetuate it.

Principle Explanation

Leaders must master "genchi genbutsu" (go and see), spending time on the gemba to grasp daily challenges rather than relying on reports. They live principles like kaizen and respect for people, serving as role models. Unlike Western "hire superstars," Toyota grows talent through rotations, ensuring cultural continuity—e.g., no external CEOs since 1950.

Embedding Long-Term Philosophy

1. Gemba Leadership: Managers lead daily stand-ups and kaizen events, solving problems hands-on (e.g., plant managers audit takt time adherence).
2. Mentoring Culture: Leaders coach via nemawashi (consensus-building), teaching root-cause analysis (5 Whys) during andon pulls.
3. Philosophy Integration: Annual hansei reflections align operations with P1 (customer-first); e.g., rejecting short-term profits for quality investments.
4. Succession Planning: Team leaders rotate across functions, building versatile experts who teach TPS globally.

Q.3

a) i) Differentiate between Lean Vs Agile Manufacturing.
ii) Explain flexible manufacturing

(8 marks)

[16]

8+8

i) Lean vs. Agile Manufacturing

Aspect	Lean Manufacturing	Agile Manufacturing
Core Focus	Waste reduction (muda), just-in-time production, stable efficiency	Speed, flexibility, customer responsiveness via iterations
Approach to Change	Stability; gradual kaizen improvements	Embraces volatility; quick pivots and cross-functional teams
Inventory	Minimal (zero-stock ideal)	Buffer stocks for rapid reconfiguration
Best For	High-volume, predictable demand (e.g., autos)	Low-volume, customized/variable demand (e.g., fashion/tech)
Metrics	Cycle time, defect rates, throughput	Time-to-market, customer satisfaction, adaptability
Tools	Kanban, 5S, SMED	Scrum sprints, modular lines, rapid prototyping

ii) Flexible Manufacturing

Flexible manufacturing systems (FMS) use computer-controlled machinery (CNC, robots) and modular tooling to produce varied products with minimal retooling, enabling small-batch customization at mass-production speeds. Key elements include programmable logic controllers (PLCs), automatic tool changers, and AGVs for material handling, integrated via MES for dynamic scheduling. Applications span electronics (quick model switches) and automotive (variant assembly), cutting setup times 70-90% via group technology and reducing costs through economies of scope.

OR

b) Compare Japanese approaches with Western methods. Evaluate their impact on efficiency, quality, and adaptability in modern factories.

Key Differences

Aspect	Japanese Approach	Western Approach
Philosophy	Long-term (kaizen, respect for people)	Short-term profits, shareholder value
Production	JIT, pull systems, low inventory	Push systems, high-volume stocks
Quality	Built-in (poka-yoke, zero defects)	Inspected post-production
Workforce	Teams, lifelong training, consensus	Individual incentives, specialization
Improvement	Continuous, bottom-up	Periodic, top-down projects
Flexibility	High via cellular manufacturing	Lower, rigid lines for scale

c) Define Industry 4.0. Explain core pillars like smart factories and horizontal/vertical integration, with example.

(8 marks)

Industry 4.0 transforms factories into adaptive ecosystems where machines communicate autonomously, enabling real-time decision-making, predictive maintenance, and mass customization. Core pillars include smart factories (fully digitized production with digital twins simulating operations), horizontal integration (seamless end-to-end supply chain connectivity from suppliers to customers via standardized protocols like OPC UA), and vertical integration (intra-factory layers from sensors/PLCs to ERP/MES for closed-loop control).

Example: Schneider Electric's Le Vaudreuil Smart Factory

Schneider Electric's facility in France exemplifies these pillars: IoT sensors enable horizontal integration with suppliers for JIT parts delivery, while vertical integration links shop-floor AR glasses (EcoStruxure Augmented Operator Advisor) to cloud analytics for 2-7% productivity gains. Digital twins predict failures, reducing downtime 30%, with AI optimizing energy via EcoStruxure Resource Advisor—demonstrating resilient, data-driven production.

	OR d) Review the journey of Industry 5.0 in developed countries (EU's human-centric model, Japan's Society 5.0) Industry 5.0 marks a shift from Industry 4.0's automation focus to human-centric, resilient, and sustainable manufacturing in developed countries. **EU's Human-Centric Model** The European Commission launched Industry 5.0 in 2021 as a complement to Industrie 4.0, emphasizing worker wellbeing, sustainability, and resilience via the CoP 5.0 community (launched 2023). Key developments include the Industry 5.0 Award for human-AI collaboration (cobots, AR training), Skills Agenda for reskilling (digital upskilling for 1M workers by 2025), and Green Deal integration for circular factories. Pilots like EFFRA's human-centric R&I roadmap test resilient supply chains post-COVID, targeting zero-waste via digital twins. **Japan's Society 5.0** Japan integrated Industry 5.0 into "Society 5.0" (2016 Cabinet vision), blending cyber-physical systems with human society for super-smart societies. Progress includes Moonshot R&D (cobots in aging workforces), 5G-enabled factories (e.g., FANUC's AI-human lines), and resilience post-2011 disasters via predictive maintenance. By 2025, 50% factories adopt human-robot symbiosis, focusing on personalization (custom meds) and sustainability (hydrogen energy).	
Q.4	a) Define IoT, and IIoT. Explain their roles in smart manufacturing/logistics. IoT (Internet of Things) refers to a network of everyday physical devices embedded with sensors, software, and connectivity to exchange data over the internet, enabling remote monitoring and automation in consumer/home applications (e.g., smart thermostats, wearables). IIoT (Industrial Internet of Things) applies IoT principles to industrial settings like manufacturing and logistics, using ruggedized sensors on machinery for real-time data collection, M2M communication, and analytics via protocols like OPC UA/MQTT. **Roles in Smart Manufacturing** • IIoT enables predictive maintenance: Sensors on CNC machines detect vibration anomalies, forecasting failures 72 hours ahead (e.g., Siemens Amberg factory cuts downtime 50%). • Digital twins: Real-time data feeds virtual models for process simulation, optimizing throughput 20-30%. • Quality control: Inline vision systems flag defects instantly, achieving 99.999% yields. **Roles in Smart Logistics** • Fleet telematics: GPS/IoT track trucks, enabling dynamic rerouting (e.g., DHL saves 15% fuel via traffic avoidance). • Asset visibility: RFID tags monitor pallets across tiers, reducing losses 40% in 3PL hubs.	[16] 8+8

- Cold chain compliance: Sensors ensure pharma shipments stay at 2-8°C, with blockchain alerts for deviations.

IIoT drives Industry 4.0 via IT/OT convergence, generating petabytes for AI analytics while demanding cybersecurity

OR

b) Describe the Reference Architectural Model Industry 4.0 (RAMI 4.0) with its three dimensions (hierarchy levels, IT layers, lifecycle/value stream).

RAMI 4.0 (Reference Architectural Model Industry 4.0) is a 3D framework developed by German industry (ZVEI/VDMA) standardizing Industry 4.0 components for interoperability.

Three Dimensions

1. Hierarchy Levels (Vertical Axis, ISA-95 based): 6 enterprise levels from Field (sensors/actuators) → Station (PLC/machine) → Control (MES) → Site → Work Center → Enterprise. Maps IT/OT functions by scope.
2. IT Layers (Horizontal Axis): 6 abstraction layers per asset:
   - Asset: Physical properties (robot dimensions).
   - Integration: Digital representation (CAD/3D models).
   - Communication: Protocols (OPC UA/MQTT).
   - Information: Semantic data (temperatures standardized).
   - Functional: Services (pick/place logic).
   - Business: Processes/regulations (orders, compliance).
3. Lifecycle & Value Stream (Depth Axis): Types (design specs) vs. Instances (physical units) across phases: Requirements → Design → Implementation → Operation → Maintenance → Retirement. Enables continuous feedback loops.

c) Consider a retail company that collects customer data for better decision-making. Analyze how each of the 4 Vs of big data (Volume, Velocity, Variety, and Veracity) applies to their data collection and utilization processes. Provide practical examples for each V."

(8 marks)

Volume (Scale of Data): Retailers generate massive datasets from POS transactions, loyalty apps, and CCTV—e.g., Walmart processes 2.5 petabytes hourly across 11,000 stores. This requires scalable storage (Hadoop/Snowflake) for historical analysis, enabling trend forecasting like seasonal spikes without data loss.

Velocity (Speed of Data Generation/Processing): Real-time streams from mobile apps, clickstreams, and sensors demand instant analytics—e.g., Amazon processes 1.7M checkout clicks/sec during Prime Day. Streaming tools (Kafka/Spark) enable dynamic pricing updates within seconds, preventing stockouts.

Variety (Data Formats/Sources): Unstructured data mixes with structured—e.g., Target correlates transaction records, social media sentiment, weather

APIs, and video heatmaps. ETL pipelines integrate CRM (SQL), logs (JSON), images (computer vision), creating 360° customer profiles for targeted coupons.

Veracity (Data Quality/Trustworthiness): Inaccurate data leads to poor decisions—e.g., duplicate loyalty profiles or GPS fraud inflate churn predictions. Retailers apply ML cleansing (anomaly detection), data governance (master data management), and blockchain verification, ensuring 95%+ accuracy for reliable personalization (Starbucks' weather-timed offers)

OR

d) Anticipate the resource-based view of firm and importance of Data as a new source for organization with suitable examples.

The Resource-Based View (RBV) of the firm posits that sustained competitive advantage stems from internal resources and capabilities that are valuable, rare, inimitable, and non-substitutable (VRIN/VRIO framework), rather than external market positioning. Developed by scholars like Jay Barney in the 1990s, RBV shifts focus from industry structure to unique firm assets like patents, culture, or processes that competitors cannot easily replicate.

Data as a Strategic Resource

Data emerges as a pivotal "new" resource in RBV, fulfilling VRIN criteria: valuable for insights (e.g., personalization), rare when proprietary (customer behavioral datasets), inimitable due to path-dependency (historical accumulation), and non-substitutable for AI-driven decisions. Organizations treating data as a core asset gain edges in dynamic sectors, enabling capabilities like predictive analytics that traditional resources (e.g., factories) cannot match.

Examples

Amazon: Leverages petabytes of proprietary purchase/click data (rare, path-dependent) for recommendation engines, driving 35% of sales—rivals like Walmart cannot imitate this without equivalent history, yielding cost leadership and differentiation.

Q.5

a) Differentiate between traditional industrial robots and collaborative robots (cobots) in terms of design, safety, programming, flexibility, and typical applications. Explain how these differences influence their suitability for modern smart factories. [16]

Comparison Table 8+8

Aspect	Traditional Industrial Robots	Collaborative Robots (Cobots)
Design	Large, rigid arms; high payload (tons); fixed bases; high-speed actuators	Lightweight, rounded joints; human-scale payloads (3-20kg); mobile, ergonomic
Safety	Fenced cages, light curtains, e-stops; isolated operation	Built-in sensors (force/torque, vision); auto speed/force

	(ISO 10218)	limiting; safe co-working (ISO/TS 15066)
Programming	Expert coding (RAPID/KRL); days/weeks setup by specialists	Drag-teach, tablets, block-based; hours by operators
Flexibility	Fixed high-volume lines; long changeovers	Quick end-effector swaps; high-mix, low-volume
Applications	Welding, heavy palletizing, automotive assembly	Picking, inspection, machine tending with humans

Suitability for Smart Factories

Industrial robots drive scale in mass production but limit agility in Industry 4.0's dynamic environments. Cobots enable flexible, human-augmented lines with IIoT integration (e.g., RAMI 4.0 vertical/horizontal flows), reducing downtime 30-50% and boosting ROI for SMEs via rapid reconfiguration—ideal for smart factories blending AI, data, and human oversight.

OR

b) A Dutch tomato grower at Wageningen University pilots AI-human teams using drone IoT for real-time soil analytics and cobot harvesting, boosting yields 25% while cutting water use 30%. Discuss Agri 5.0 ecosystem: upskilled farmers with mobile dashboards, circular hydroponics, and resilient pest prediction. Evaluate worker empowerment vs. traditional labor-intensive farming.

Students are expected to answer based on the concept and knowledge.

Wageningen University's pilot exemplifies Agri 5.0, integrating AI-human teams, drone IoT for soil analytics, and cobots for harvesting to achieve 25% yield gains and 30% water savings in Dutch tomato greenhouses.

Agri 5.0 Ecosystem

Agri 5.0 evolves from prior waves (e.g., Agri 4.0's IoT) into hyper-resilient, human-AI symbiosis via digital twins and edge computing. Key pillars include:

- Upskilled farmers: Mobile dashboards deliver real-time insights (e.g., drone multispectral data flags nutrient deficits), empowering decisions over manual scouting.
- Circular hydroponics: Closed-loop systems recycle 95% water/nutrients, monitored by IIoT sensors for zero-waste cycles.
- Resilient pest prediction: AI models fuse weather, drone imagery, and genomic data for 90% accurate outbreaks, deploying targeted biopesticides via cobots.

Worker Empowerment vs. Traditional Farming

Aspect	Traditional Labor-	Agri 5.0 (Pilot Example)

Intensive Farming		
Labor Role	Manual, repetitive (e.g., hand-picking tomatoes)	Supervisory/analytical; farmers interpret AI alerts
Skill Level	Low; physical endurance key	High; data literacy via dashboards boosts autonomy
Productivity	10-15 tons/ha; weather/labor shortages limit yields	25% uplift; cobots handle 80% harvest, freeing humans
Sustainability	High water/pesticide use; pest reactive	30% water cut; predictive AI minimizes inputs
Risks	Injury, burnout; vulnerable to shortages	Tech dependency; upskilling gap, but nets 40% ROI

c) Define Cyber-Physical Systems (CPS) and outline their key characteristics. (8 marks)

Cyber-Physical Systems (CPS) integrate computational algorithms, networking, and physical processes through embedded sensors, actuators, and feedback loops to monitor and control real-world dynamics in real time.
CPS form the backbone of Industry 4.0, enabling seamless cyber-physical interactions in smart factories, autonomous vehicles, and Agri 5.0 pilots like Wageningen's drone-cobot tomato harvesting.

Key Characteristics

- Deep Integration: Physical components (e.g., cobot arms) and cyber elements (AI analytics) are tightly coupled, unlike standalone IoT—e.g., RAMI 4.0 maps CPS across hierarchy levels for vertical data flows.
- Real-Time Operation: Millisecond responses via edge computing ensure safety, as in drone soil analytics triggering instant irrigation adjustments.
- Networking and Interoperability: Standardized protocols (OPC UA, MQTT) enable horizontal integration across factories or farms, scaling from field devices to enterprise clouds.
- Autonomy and Adaptability: Self-optimizing via ML, handling context changes—e.g., cobots detect human proximity and slow down per ISO/TS 15066.
- Heterogeneity: Diverse hardware/software (sensors, PLCs, apps) unified in architectures like 5C (Connection, Conversion, Cyber, Cognition, Configuration) for resilience.

OR

	d) Explain in detail LEAD and TIER Framework with examples. LEAD and TIER Frameworks are methodologies from Singapore's Smart Industry Readiness Index (SIRI) for guiding manufacturers toward Industry 4.0 maturity, building on CPS, IIoT, and RAMI 4.0 principles like Wageningen's Agri 5.0 pilots. **LEAD Framework** LEAD is a circular, continuous four-step process for transformation: • Learn: Assess current state via SIRI diagnostics (e.g., benchmark cobot integration against peers). • Engage: Build cross-functional teams and partners (e.g., upskill farmers for drone dashboards). • Align: Prioritize use cases aligning tech with strategy (e.g., data-driven pest prediction in hydroponics). • Deploy: Pilot, scale, and iterate (e.g., AI-human teams boosting tomato yields 25%). Example: A Dutch tomato grower uses LEAD—Learn via SIRI audits, engage agronomists/cobot vendors, align on water-saving analytics, Deploy drone-IoT for 30% efficiency gains. **TIER Framework** TIER structures Industry 4.0 technologies into progressive tiers: • Tier 1 - Track & Trace: Basic connectivity (e.g., RFID for asset visibility in logistics). • Tier 2 - Insights: Analytics on data (e.g., predictive maintenance via cobot sensors). • Tier 3 - Engagement: Human-tech interaction (e.g., AR dashboards for farmers). • Tier 4 - Agility: Autonomous optimization (e.g., CPS self-adjusting hydroponics). Example: Retailer's big data evolves—Tier 1 tracks POS volume, Tier 2 analyzes velocity for pricing, Tier 3 engages via apps (veracity checks), Tier 4 enables agile personalization.	