

CS620 Important Topics

◆ What does *Imminent Event* mean?

An **imminent event** is the **next event that's going to happen** in a simulation. It's the one with the **closest (earliest) scheduled time**.

□ **Think of it like:** In a to-do list, the task with the nearest deadline is your "imminent task" — same for events in simulations.

◆ What is a *Complex Adaptive System*?

It's a system made of **many parts (agents)** that interact and adapt to each other and the environment.

✦ Properties:

- **Emergence:** New behaviors appear from simple rules.
- **Adaptation:** System changes over time.
- **Non-linearity:** Small changes can cause big effects.
- **Feedback Loops:** System gets feedback from its own actions.
- **Self-Organization:** No central control, system organizes itself.

□ **Example:** Ant colony, traffic system, stock market.

◆ Role of *Verification* in Model Correctness:

Verification checks:

☞ “Are we building the model **correctly**?”

It ensures:

- No coding mistakes
- Logic flows correctly
- Model works as per design

□ **Simple Tip:** “Verification = Checking code logic”

◆ Example of Distribution in Physical Basis:

Example: The **Normal Distribution** is used to model:

- Height of people
- Measurement errors
- Temperature changes

☐ It's based on **natural/physical behaviors** that are common in real life.

◆ What is *Imperfection Debugging*?

It's the process of **fixing errors** or **unexpected behaviors** in a simulation model caused by:

- Logical flaws
- Wrong assumptions
- Programming mistakes

☐ Think of it as **finding bugs** that make your model give wrong or weird results.

☐ Long Questions (Explained Simply)

✓ Macro-validation of Agent-Based Modelling:

Checks if the **overall behavior of your agent model** matches **real-world data** or expected patterns.

✦ Example:

If you simulate traffic, macro-validation means checking if your simulation matches **real-world traffic trends** — not just individual car behavior.

✓ What is *Common Random Number (CRN)*?

A technique used to **compare two models or systems fairly** by giving both the **same random inputs**.

✦ Used in:

- Simulation experiments
- Reducing variability

- ☐ Like giving two players the same dice rolls to compare their strategies.
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✓ Bernoulli Distribution:

It's a **distribution with only two outcomes**:

✓ **Success (1)**

✗ **Failure (0)**

✦ Used when:

- Tossing a coin (Heads/Tails)
 - Yes or No type problems
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✓ Chaos Theory:

It studies systems that:

- Are **deterministic** (rule-based)
- But behave in **unpredictable** ways due to **sensitivity to initial conditions**

☐ Small change in input → Big change in output

✦ Example: Weather forecasting, Butterfly Effect

🔥 Paper Questions (Simplified)

✓ Agent-Based Modeling (ABM) Properties:

- Agents act independently
 - They interact with each other
 - Behavior is rule-based
 - System behavior emerges from agent actions
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✓ Definitions:

- **Agent**: A self-acting entity in a simulation (e.g., a car, person, etc.)
- **Observer**: Watches the simulation, doesn't take part

- **Environment:** The space where agents live and act
 - **Interaction:** How agents affect one another
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✓ **Operational Analysis as Simulation Tool:**

Used in military/logistics to test:

- How a system performs
- Without needing to run it in real life

✦ Example: Simulating battlefield scenarios to improve decision-making.

✓ **Functions of Sheep and Wolves (ABM Example):**

- **Sheep:** Agents that try to survive, move, eat grass
- **Wolves:** Predators that hunt sheep

□ Used to show **interaction, survival, and population dynamics** in agent-based models.

✓ **Module 7: Military, Logistics & Traffic Simulations**

◆ **Military Simulations:**

Used for **training, planning, and analyzing** military operations.

Example: Simulating a battlefield to test strategies without real-world risks.

◆ **Logistics and Supply Chain Simulations:**

Used to **optimize delivery routes, inventory, and warehouse operations**.

Example: Amazon simulates product flow to minimize delivery delays.

◆ **Traffic/Transport System Simulations:**

Simulating **airports, ports, firefighting, public transport** to improve safety and efficiency.

◆ **Business Process Simulations:**

Used in **call centers, hospitals**, etc., to reduce waiting time and improve services.

✓ **Module 8: System & Environment**

◆ **Definitions:**

- **System:** A group of components interacting with each other for a purpose.
 ◆ *Example: Traffic System*
 - **Environment:** Everything outside the system that interacts with it.
 ◆ *Example: Weather affecting traffic*
 - **Boundary:** Line that separates the system from the environment.
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◆ **Examples:**

- **BMW Production System:** A system to optimize car production.
 - **Storm System:** Natural weather system.
 - **Cyber-Physical System:** System integrating computer & physical processes (like smart traffic lights).
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✓ **Module 9: System Concepts**

◆ **Key Definitions:**

- **Homeostasis:** The system's ability to remain stable.
 ◆ *Example: Human body temperature*
 - **Adaptation:** How systems change in response to the environment.
 ◆ *Example: Animals growing thicker fur in cold climates*
 - **Feedback Loop:** When system output influences its future behavior.
 ◆ *Example: Thermostat regulating room temperature*
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◆ System Levels:

- **Microsystem:** Small scale (e.g., individual)
 - **Mesosystem:** Interaction of microsystems (e.g., school and home)
 - **Exosystem:** Indirect influence (e.g., parent's workplace)
 - **Macrosystem:** Culture/society level
 - **Chronosystem:** Time-based changes (e.g., life events)
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✓ Module 10: Components of a System

◆ Key Terms:

- **Entity:** Object being simulated.
 ◆ *Example: Customer*
 - **Attribute:** Property of an entity.
 ◆ *Example: Age of customer*
 - **Activity:** Action done by entity.
 ◆ *Example: Buying a product*
 - **State:** System's condition at a time.
 ◆ *Example: Bank queue is full*
 - **Event:** An incident that changes system's state.
 ◆ *Example: New customer arrives*
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◆ Event Types:

- **Endogenous Event:** Comes from **within the system**.
 ◆ *Example: Machine breakdown*
 - **Exogenous Event:** Comes from **outside the system**.
 ◆ *Example: Power failure*
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✓ Module 11: Discrete vs. Continuous Systems

◆ Discrete System:

- Changes occur at **specific times**.
- **Example:** Customer arrivals, ATM transactions.

◆ Continuous System:

- Changes occur **continuously over time**.
 - **Example:** Water level in a dam, vehicle speed.
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✓ Module 12: Modeling a System

◆ Why Use Models?

- To study **complex real systems** without risk or cost.
 - Safer than experimenting on the real system.
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◆ When Not to Experiment on Real Systems:

- Dangerous
 - Too expensive
 - Impractical
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◆ System vs. Model:

- **System:** Real-world structure (e.g., hospital).
 - **Model:** Simplified version for study (e.g., simulation of hospital operations).
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✓ Module 13: Types of Models

◆ Model Types:

- **Physical Models:** Real objects.
 ◆ *Example: Globe*
 - **Mathematical Models:** Based on equations.
 ◆ *Example: Physics formula*
 - **Simulation Models:** Computer-based.
 ◆ *Example: Hospital simulation*
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◆ More Classifications:

- **Static Models:** No time-based change.
 ◆ *Example: Pie chart*
 - **Dynamic Models:** Change with time.
 ◆ *Example: Traffic simulation*
 - **Deterministic Models:** Fixed input → fixed output.
 ◆ *Example: Calculator*
 - **Stochastic Models:** Randomness involved.
 ◆ *Example: Weather model*
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✓ Module 14: Discrete Event Simulation (DES)

◆ DES:

Simulation where the **state changes at specific events**.

◆ Methods:

- **Analytical Methods:** Using formulas (math-based)
 - **Numerical Methods:** Step-by-step computations
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◆ Manual vs. Computer Simulation:

- **Manual:** Paper/pen method (slow)
 - **Computer:** Fast, automated, better for large systems
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✓ Module 15: Steps in a Simulation Study

1. **Problem Formulation:** Define problem clearly
2. **Objectives & Plan:** What you want to achieve
3. **Model Conceptualization:** Sketch how the model should work
4. **Data Collection:** Gather system data
5. **Model Translation:** Convert concept into code
6. **Verification:** Check if model works as designed

7. **Validation:** Compare model with real-world behavior
 8. **Experimental Design:** Decide how to test the model
 9. **Production Runs & Analysis:** Run and analyze the simulation
 10. **More Runs?:** Repeat for improvement
 11. **Documentation & Reporting:** Record all findings
 12. **Implementation:** Use model to support decisions
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✓ **Module 16: Model Conceptualization**

◆ **Key Ideas:**

- **Abstraction:** Focus only on important details
- **Simplification:** Keep it simple, but accurate
- **User Involvement:** Involve actual users to ensure the model is useful
- **Complexity Management:** Don't make the model too complicated