Tshwane University of Technology

We empower people

You Have a DREAM

That's Why You Are Here

We Are Here

To Make That DREAM Come TRUE

MODELING AND SIMULATION

MSI118G

By

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Outcome

By the end of the unit, you should be able to:

A.1.1 Define Model and simulation in a broad context.

A.1.2 Explain Modelling and simulation as problem- solving methods.

A.1.3 Explain Systems concept from real and theoretical perspectives using schematic diagram

A.1.4 Differentiate Static and Dynamic system concepts within the context of Modelling and Simulation

A.1.5 Explain the relationship between modelling and simulation as problem-solving methods on a continuum.

A.1.6 Explain Models as abstractions of simulations with a practical illustrative example.

A.1.7 Explain Simulations as dynamic modelling with a practical illustrative example.

A.1.8 Explain Modelling and Simulation as a problem-solving method with a practical illustrative example.

A.1.9 Highlight the benefits of simulation and modelling in a range of important application areas with illustrative examples.

A.1.10 Identify examples with rationale of application problem domains appropriate for modelling and simulation problem-solving

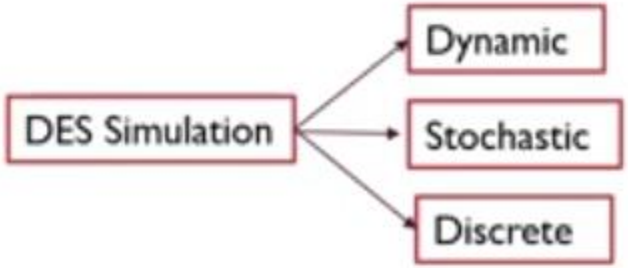
A.1.11 Identify examples of existing software tools for modelling and simulation a their salient functional features.

TO DO

A.1.4 Differentiate Static and Dynamic system concepts within the context of Modelling and Simulation.

FURTHER CHARACTERISTICS OF MODELS

- Static vs. Dynamic. Does the model have a time element, does it "move" over time? An example of Static-Numerical model is Monte Carlo Sampling; An example of Dynamic-Analytical model is Time Series regression (a linear model).
- Deterministic vs. stochastic. Does the model mimic probabilistic phenomena?
- Discrete vs. Continuous.
  - Discrete. Variables change at distinct points in time
  - Continuous. Variables change continuously.
- System Simulation: Experimenting with an abstract model over time, this experimentation involving sampling from probability distributions.



APPLICATION AREAS EXAMPLES

Explain Models as abstractions of simulations with a practical illustrative example

- A model is an abstract representation of a real-world system, capturing its key characteristics and behaviors without including every detail.
- It serves as the blueprint for a simulation, allowing analysts to study and predict system behavior under different conditions.

Key Characteristics of Models

- **Simplified Representation:** Focuses only on relevant aspects of a system.
- **Used for Analysis & Decision-Making:** Helps understand and optimize real-world processes.
- **Foundation for Simulation:** A simulation runs the model over time to test different scenarios.

Example: Traffic Management System

- Step 1: Model (Abstraction of Reality)
- A city traffic model simplifies real-world traffic by defining key components such as:

- Vehicles: Types (cars, buses, trucks), speed, and routes.
- Traffic Signals: Red, yellow, and green light timing.
- Roads: Number of lanes, intersections, and congestion points.
- Pedestrians: Crossing behavior and foot traffic.
- This model does not include unnecessary details like vehicle brands or driver emotions—it only abstracts relevant factors affecting traffic flow.

Example: Traffic Management System

- **Step 2: Simulation (Running the Model in a Controlled Environment)**
- **A simulation runs this model over time to test different traffic scenarios, such as:**

- **Peak Hour Traffic: What happens if 1,000 more cars enter a city at 8 AM?**
- **Traffic Light Optimization: How does adjusting signal timing reduce congestion?**
- **Emergency Route Planning: How can ambulances reach hospitals faster?**
- **🔷 Outcome: The simulation provides insights into which tra policies improve flow, helping urban planners make data-driv decisions.**

Example: Traffic Management System

- **Models** simplify reality by focusing on key system elements.
- **Simulations** use models to test different scenarios over time.
- **Example:** A traffic model (abstraction) is used to run a simulation predicting congestion patterns.

Explain Systems concept from real and theoretical perspectives using schematic diagram

- A system is a set of interrelated components that work together to achieve a common goal.
- Systems can be analyzed from two perspectives:
  - Real Perspective – Practical, observable systems in the real world.
  - Theoretical Perspective – Conceptual models that define system behavior, often used in simulations and research.

1. Real Perspective (Practical Systems in the Real World)

- A real system exists in the physical world and can be directly observed, measured, and tested.
- Traffic Management System
  - Components: Vehicles, roads, traffic lights, pedestrians, GPS data.
  - Interactions: Cars stop when signals are red; congestion increases with vehicle density.
  - Goal: Optimize traffic flow, reduce congestion, improve safety.

2. Theoretical Perspective (Abstract System Models)

- A theoretical system is a conceptual or mathematical representation of a real system, often used for simulation, prediction, or optimization.

- **Traffic Flow Simulation Model**
  - Mathematical Model: Uses algorithms to predict congestion based on vehicle density.
  - Computer Simulation: Runs scenarios to test different traffic policies.
  - Predictions: Helps city planners design better roads before actual construction.

Schematic Diagram of a System (Real vs. Theoretical)

- **A simple schematic representation of how real systems and theoretical models interact**

```
          +------------------------+
          |     Real System        |
          | (Physical Traffic Flow) |
          +------------------------+
                     ↓
Sensors & Data Collection (Traffic Cameras, GPS)
                     ↓
          +------------------------+
          |  Theoretical System     |
          | (Traffic Flow Model)    |
          +------------------------+
                     ↓
       Simulation & Optimization (AI Algorithms)
                     ↓
      Decision Making (New Traffic Rules, AI Signals)
                     ↓
          +------------------------+
          |   Updated Real System   |
          | (Improved Traffic Flow) |
          +------------------------+
```

Schematic Diagram of a System (Real vs. Theoretical)

- **Traffic management uses sensors to collect real-world data, which is fed into theoretical models to optimize road networks.**
- **Real Systems exist in the physical world and can be observed.**
- **Theoretical Systems are abstract models that predict and optimize behavior.**

```
+-----------------------+
|     Real System       |
| (Physical Traffic Flow) |
+-----------------------+
           ↓
Sensors & Data Collection (Traffic Cameras, GPS)
           ↓
+-----------------------+
|  Theoretical System     |
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+-----------------------+
           ↓
Simulation & Optimization (AI Algorithms)
           ↓
Decision Making (New Traffic Rules, AI Signals)
           ↓
+-----------------------+
|  Updated Real System  |
| (Improved Traffic Flow) |
+-----------------------+
```

Static and Dynamic System

Feature	Static System	Dynamic System
Definition	A system where the variables do not change over time.	A system where the state changes over time based on inputs, interactions, or external factors.
Time Dependency	Independent of time; analyzed at a single point.	Dependent on time; evolves over continuous or discrete time steps.
Examples	- Structural analysis of a bridge. - Financial risk assessment at a fixed point. - Solving algebraic equations.	- Traffic flow simulation. - Weather forecasting. - Population growth modelling.
Computation Type	Often uses algebraic equations.	Uses differential or difference equations.
Simulation Type	Monte Carlo methods, optimization models.	Discrete-event or continuous-time simulations.
Complexity	Generally simpler to analyze.	More complex due to state changes over time.

Illustrative Examples

- Static Systems are useful for analyzing a snapshot of a system at a given time.
- Dynamic Systems focus on time-dependent changes and interactions.
- Both static and dynamic systems play crucial roles in various industries
- Many real-world problems require a combination of both for comprehensive analysis (e.g., predicting weather requires both historical data (static) and real-time simulation (dynamic)).

Illustrative Examples

- Mathematical Models – How static and dynamic systems are represented mathematically.
- Real-World Applications – More examples in fields like AI, healthcare, economics, or engineering.
- Simulation Methods – How static and dynamic simulations are conducted.
- Comparison with Practical Scenarios – Case studies demonstrating both systems.

Real-world applications & their practical significance.

1. Engineering & Structural Analysis

- **Static System: Structural analysis of buildings and bridges.**
  - Engineers use static models to assess load-bearing capacity and safety at a specific point in time.
  - Example: Calculating how much weight a bridge can support before construction.
- **Dynamic System: Earthquake-resistant building simulation.**
  - Models how a structure responds over time to external forces like earthquakes or wind.
  - Example: Simulating earthquake waves on skyscrapers to design shock-absorbing structures.

Real-world applications & their practical significance.

2. Healthcare & Medicine

- **Static System: Disease risk assessment models.**
  - Analyzing a patient's risk of heart disease based on fixed health metrics (e.g., blood pressure, cholesterol levels).
  - Example: Using risk prediction models to determine the likelihood of diabetes in a patient.
- **Dynamic System: Epidemic spread modelling (e.g., COVID-19).**
  - Predicts how diseases spread over time under different scenarios (vaccination, quarantine measures).
  - Example: SIR Models (Susceptible-Infected-Recovered) simulate how a virus spreads across populations.

Real-world applications & their practical significance.

3. Finance & Economics

- **Static System: Stock portfolio risk analysis.**
  - Examines the current risk and return of an investment portfolio.
  - Example: Monte Carlo simulations assess financial risk under different market conditions.
- **Dynamic System: Stock market trend prediction.**
  - Uses time-dependent data to predict future stock prices based on trends, interest rates, and economic indicators.
  - Example: Machine Learning-based trading algorithms that adjust strategies dynamically based on real-time data.

Real-world applications & their practical significance.

4. Traffic & Transportation Systems

- **Static System: Road network analysis.**
  - Studies the current state of traffic congestion at a given moment.
  - Example: Google Maps analyzing the shortest route based on real-time conditions.
- **Dynamic System: Smart traffic light control systems.**
  - Simulates traffic flow changes throughout the day and adapts signals accordingly.
  - Example: AI-driven adaptive traffic lights that change signal timing based on real-time vehicle density.

Real-world applications & their practical significance.

5. Climate & Environmental Studies

- **Static System: Carbon footprint calculation.**
  - Estimates emissions at a specific point based on energy usage, transportation, and industry.
  - Example: Companies using static models to measure their yearly CO_2 emissions.
- **Dynamic System: Climate change modelling.**
  - Simulates long-term temperature and weather changes due to greenhouse gases.
  - Example: Global Climate Models (GCMs) predict sea-level rise based on CO_2 levels over decades.

Benefits of Simulation and Modelling in Various Application Areas

- 1. Engineering and Manufacturing
- 2. Healthcare and Medicine
- 3. Traffic and Transportation Systems
- 4. Finance and Economics
- 5. Climate and Environmental Studies
- 6. Military and Defense
- 7. Education and Training

- **Simulation and modelling provide cost-effective, risk-free, and highly efficient ways to test, optimize, and predict outcomes across diverse fields.**
- **As computational power grows, their applications will continue to expand, making them indispensable tools in research, decision-making, and innovation.**

TO DO???

- **A.1.11 Identify examples of existing software tools for modelling and simulation are ith their salient functional features.**

I REST MY CASE

THANK YOU
Q & A

VAMBE
WILLIAM T