Construction Operation Simulation

Lecture #2

Discrete Event Simulation (DES) modeling concepts

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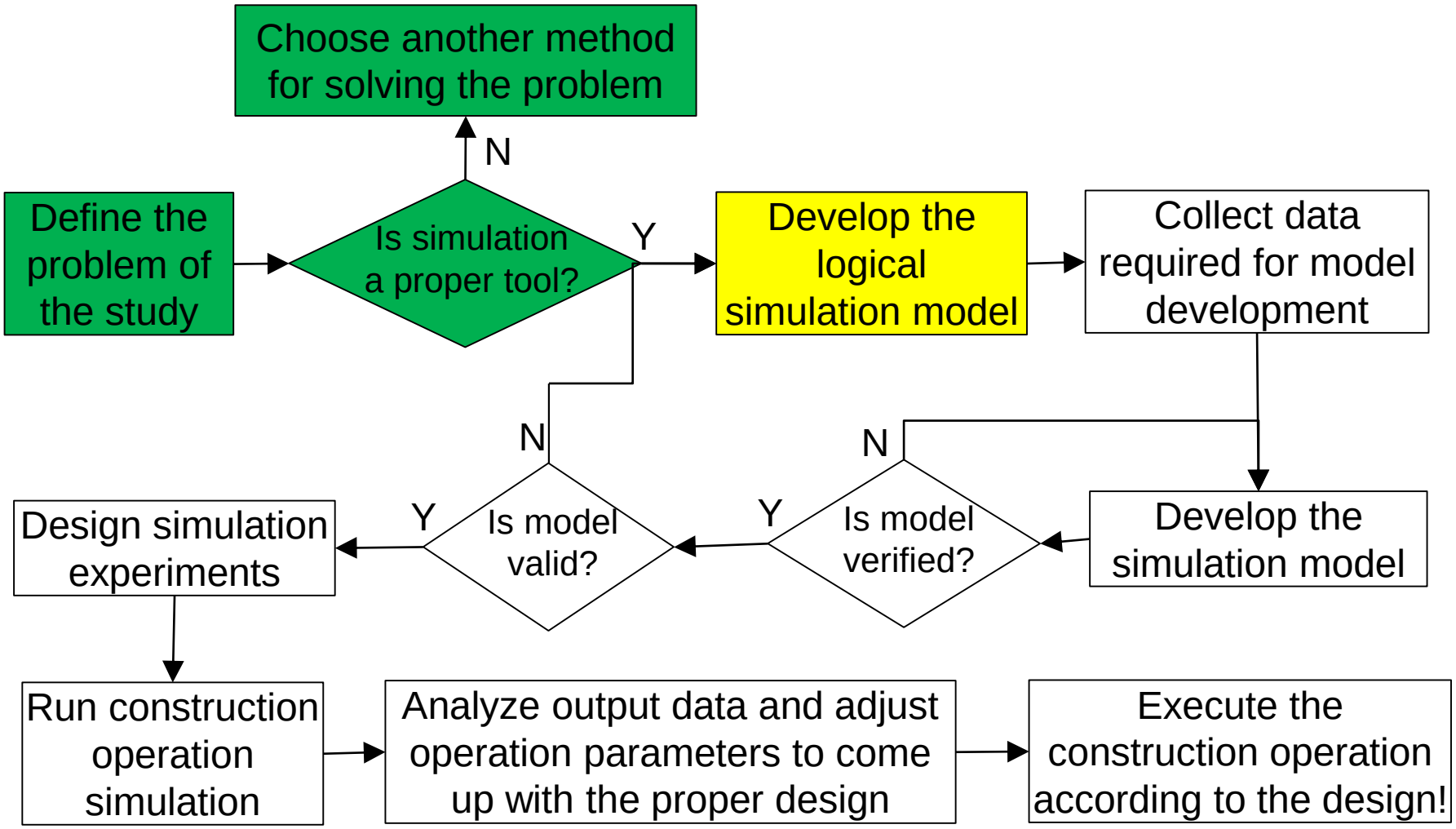
Outline

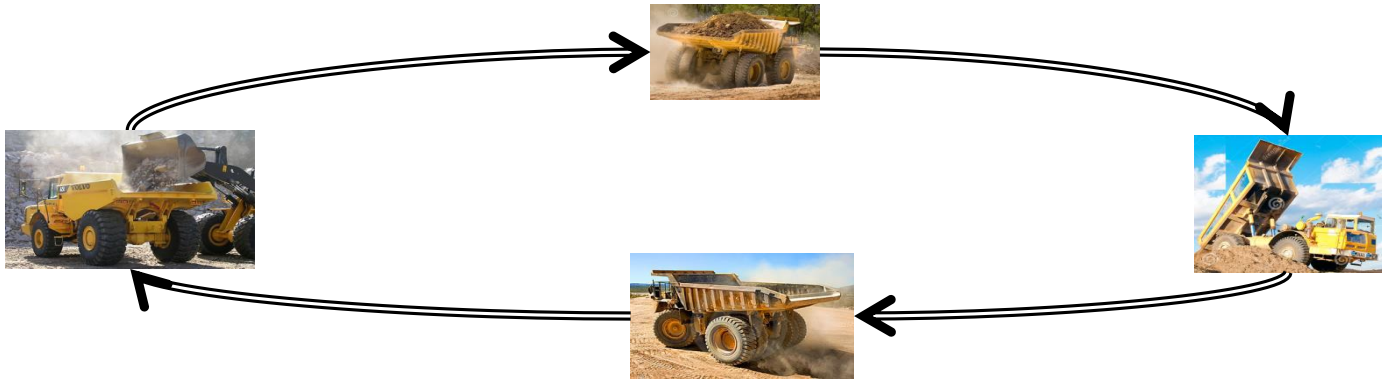
- Introduction
- Discrete concept
- DES modeling concept
- DES modeling elements

Main steps in simulation studies



Discrete concept

- Simulation is an abstraction (or a model) of the real world processes/ systems for studying (or reflecting) specific aspects of them. According to the Discrete Event Concept, for dynamically modeling the process/ system we *do not necessarily need to continuously model every motion in the system*; though, we need to capture important process/ system updates which occur in a *discrete* manner!
- **Example**: We are going to do a simulation study of an earth moving operation to be able to supply a proper set of earth moving equipment (including trucks and loaders) which gives the most productive combination. Among different updates to the system which of following system updates are important to be captured?



Discrete concept

- **Example (cont'd)**:
  - A truck arrives to the operation site
  - A loader starts loading a truck
  - A loading truck is half full
  - A loading truck is 80% full
  - Loading is complete
  - A truck leaves the site to the dumping area
  - A truck has left the site for 5 minutes
  - A loader is idle and waiting to the next truck to arrive for 10 minutes
  - Truck driver is waiting on the traffic light on his way to the dumping area
  - Truck driver arrives the dumping area
  - Truck mud is half-dumped
  - Dumping is complete.

Discrete concept

- **Example (cont'd)**:
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  - Truck driver is waiting on the traffic light on his way to the dumping area
  - **Truck driver arrives the dumping area**
  - Truck mud is half-dumped
  - **Dumping is complete.**

DES modeling concept

- Modeling is a combination of knowledge and art!

  (Who is a more knowledgeable modeller? Who is a better model artist?)
- To become a strong modeller you need to continue building models; from simple to complex; every new modeling experience adds to your modeling skill (the art aspect of the model)!
- There are specific guidelines to be followed for developing a simulation model; however, these guidelines do not necessarily make all model developers of a similar system to end up with the same model; different CORRECT models of a system can be developed by different modellers!
- To develop the conceptual DES model we need to:
  - First, determine the DES model elements
  - Second, develop the logical model.
- DES model elements include: *System State, Event, Entity, Resource, Queue, Activity (Task), Delay*
- Before we start developing a DES conceptual model, we need to recognize DES model elements. In conceptual model development we basically draw the interactions between different modeling elements!

DES modeling elements-system state

- ***System state and system state variables***:

The system state is the collection of all *information needed* (or system state variables) from different aspects of the system which defines what is happening within a system at a ***given point in time***.

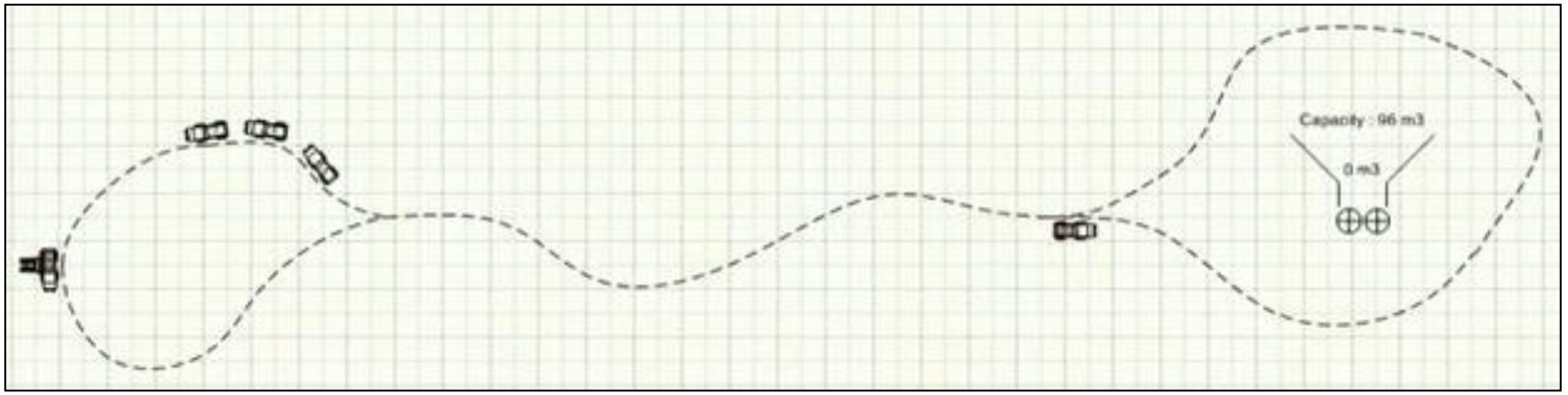
System state = Collection of (State variables)

= {Value of state variable 1, Value of state variable 2, ...}

- Each system state variable describes the specification of an aspect of the system!
- Just pick the system aspects which are important for your simulation study; for our model development practices we do not need to reflect all system aspects!
- System state is the way that we describe the system for our modeling practice! It is supposed that we can redraw the system by having the system state.

DES modeling elements-system state

Example: What are state variables for a typical earth moving operation?



DES modeling elements-system state

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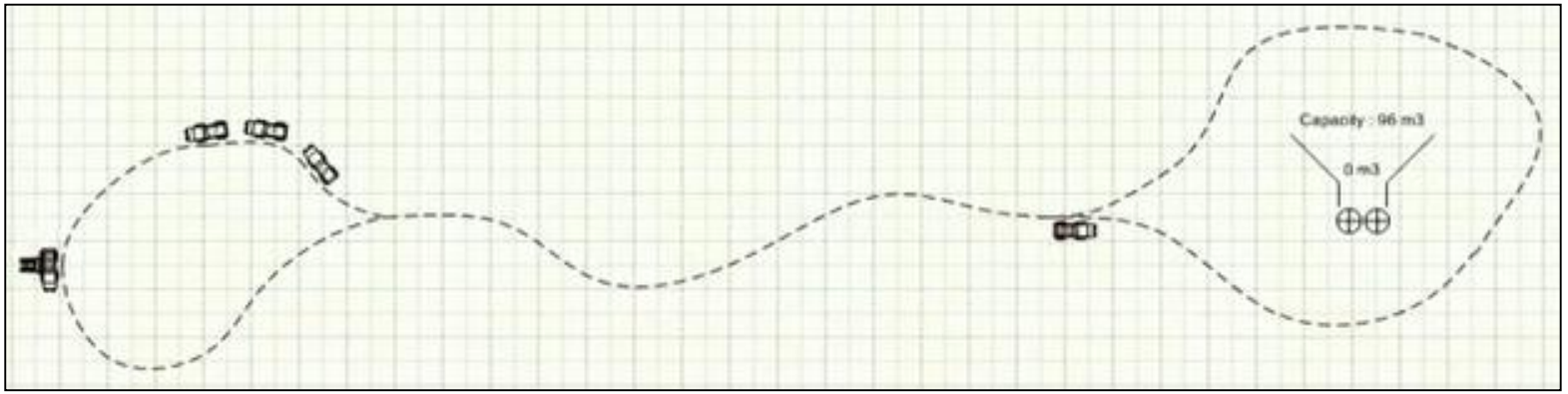


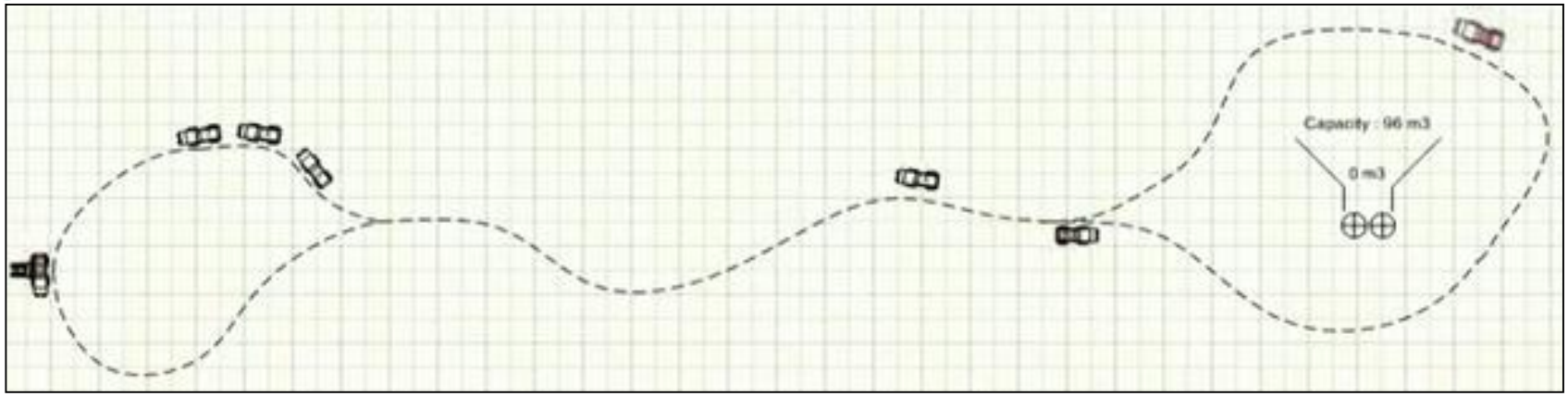
- Status of the loader (busy/ idle)
- Number of trucks waiting to be loaded
- Number of trucks on their way to the dumping area
- Number of trucks dumping
- Number of trucks waiting for dumping
- Number of trucks on their way to the loading area

-Volume of the soil dumped

Any other state variable?

DES modeling elements-system state

In class practice 1: What is the system state for the *snap shop* of the earth moving operation presented in below?



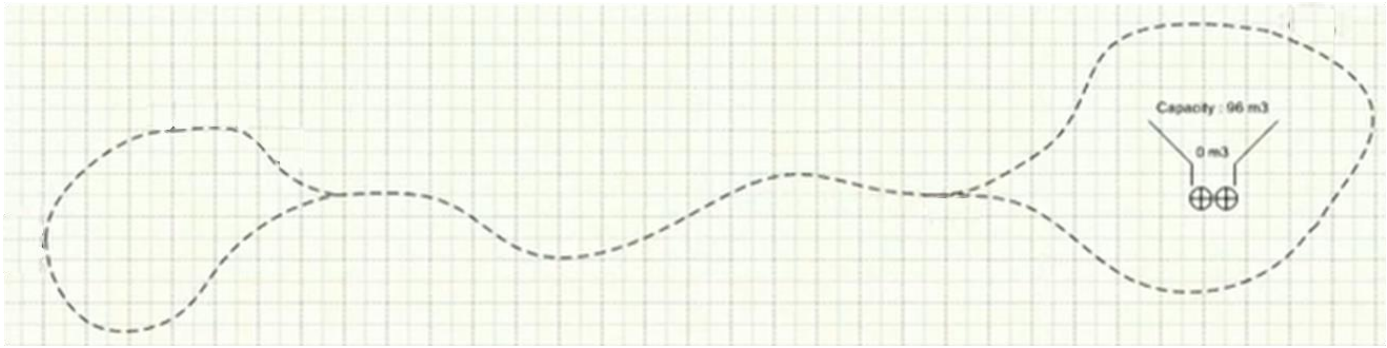
- Status of the loader: busy
- Number of trucks waiting to be loaded: 3
- Number of trucks on their way to the dumping area: 1
- Number of trucks dumping: 1
- Number of trucks waiting for dumping: 0
- Number of trucks on their way to the loading area:1

DES modeling elements-system state

In class practice 2: We have the following system state reported for our typical earth moving operation:

- Status of the loader: Idle
- Number of trucks waiting to be loaded: 0
- Number of trucks on their way to the dumping area: 4
- Number of trucks dumping: 1
- Number of trucks waiting for dumping: 2
- Number of trucks on their way to the loading area:1

According to the mentioned system state draw the different system elements (trucks and the loader) condition on the map:



DES modeling elements-system state

In class practice 3: We are going to do a simulation study on a paying operation where 1) paving machine receives asphalt from the asphalt truck loaded from asphalt plant 2) paving machine spreads the asphalt with the asphalt truck attached to it 3) paving machine releases the truck when it spreads all asphalt load and waits to the next asphalt truck to come 4) roller compactor compacts the spread asphalt.

The simulation study is focused on optimization of the capacity and number of paving equipment.

What are system state variables in this simulation study?

DES modeling elements-event

- ***System event***: System event is an occurrence that changes the state of the system.

  Example: Earth moving operation:

  When a truck arrives to the dumping site (i.e., dumping arrival event) following changes happen to the system state:

  1- Number of trucks traveling to the dumping site is decreased by one

  2- If dumping area is free, number of trucks busy dumping on the dumping site increases by one

  3- if dumping area is occupied, number of trucks waiting for dumping increased by one.

DES modeling elements-event

Question: Name other events you can recognize in a our earth moving example? What are their effects on the system state?

DES modeling elements-event

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- Loading site truck arrival event:

- Loading completion event:

- Dumping completion event:

DES modeling elements-event

Question: Name other events you can recognize in a our earth moving example? What are their effects on the system state?

- *Loading site truck arrival event*; Changes made to the state variables by this event:
  1) number of trucks on their way to the loading site is decreased by one
  2) if there is an idle loader, number of busy loaders is increased by one (number of idle loaders is decreased by one)
  3) if all loaders are busy, number of waiting trucks for loading is increased by one
- *Loading completion event*; Changes made to the state variables by this event:
  1) number of trucks on their way to dumping site is increased by one
  2) if there is no truck waiting to be loaded, number of idle loaders is increased by one
  3) if there are trucks waiting to be loaded, number of trucks waiting to be loaded is decreased by one
- *Dumping completion event;* Changes made to the state variables by this event:
  1) number of trucks on their way to loading site is increased by one
  2) if there is no truck waiting for dumping, number of idle dumping spots is increased by one
  3) if there are trucks waiting for dumping, number of trucks waiting for dumping is decreased by one

Are there any other events in earth moving operation?

DES modeling elements-event

In class practice 4: In our paving operation example, what are the system events? How do they affect the system state on their occurrence?

DES modeling elements-entity

- Generally, in the modeling perspective any object or component in the system that requires explicit representation in the model is called **Entity**!
- **Entity element**: In DES molding an ***Entity element*** represents an *entity* which its condition dynamically gets changed and/or moves in the system (i.e., *dynamic entity*) and track its changes over time in the system is important.
- **Entity element examples:**
  - Hauling trucks in the earth moving example which get changed over time as:
    - Waiting for loading, being loaded, loaded, hauling soil, waiting for dumping, dumping and travel-back
  - Pipe modules in the pipeline projects which get changed over time as:
    - Sitting on the warehouse waiting for being loaded on the shipping trailers, being loaded on a trailer, being shipped to the site, arrive at the site, stringing beside the ditch, being fitted on its position on the ditch, being welded on the ditch, being covered with mud on the ditch.

DES modeling elements-entity

- Structural steel elements in the steel construction which get changed over time as:
  - Being drafted, being fabricated, waiting for being loaded on a trailer, being loaded on a trailer, being shipped by a trailer, arriving on site, waiting on the on site storage, being moved to its position, being erected on its position, being welded/ bolted on its position.
- **Attributes**: Properties of a given entity element (e.g., capacity of a truck, maximum speed of a truck, weight of a pipe module, dimension of a structural steel element).

In many modeling examples, proper selection of *Entity element* constitute the main part of the problem solving and model development!!!!!!

In DES modeling when we talk about *entity* usually *entity element* is meant (not general definition of the entity)!

DES modeling elements-resource

- **Resource element**: A resource element is an entity that provides service to entity elements or dynamic entities.(Banks 1998, p7)
- **Resource state**: There can be different possible states of a resource. Minimally, these states are busy (serving an entity element) and idle (not serving an entity element). Other possibilities exist, including broken, blocked, decreased capacity or starved (e.g., no electricity, empty fuel). (Banks 1998, pp7-8)
- **Resource example:** Loader in our earth moving example, dumping area in our earth moving example, paver in our paving example.
- **Resource queue (or line):** Resources usually have queues linked to them where to be served entities *wait* for their turns. It is possible that a resource has one or more queues linked to it or several resources (usually providing similar services to entities) have one shared queue!

DES modeling elements-resource

- Time an entity waits for its turn in a queue is called **Delay**!
- Calculated **Delay** or *waiting time for a resource* is a usual output of DES modeling! Why?
- When a resource starts serving an entity it is said that resource is *captured* by the entity.
- When a resource finishes serving an entity it is said that resource is *released* by the entity.

Entity and **Resource** elements are main tools in DES models for capturing physical specifications of systems.

Selecting **Entity** and **Resource** elements in DES modeling practices plays a main role, sometimes misselection of Entities and Resources can make DES modeling very complicated!

DES modeling elements

In class practice 5: In our paving operation example, which system components can be modeled as entity and resource element? What are expected changes to the entity? What attribute can you recognized for the entities? What are different states of resources?

DES modeling elements

Entity1: One batch of asphalt

Expected changes: Being loaded, being shipped, arriving on site, waiting for paving machine, dumped on the paving machine, being laid on the road surface, being compacted by the rolled

Properties: Equivalent volume to the surface area (e.g., 10 m^2)

Entity2: Hauling truck

Expected changes: Waiting for loading asphalt, loading asphalt, hauling asphalt, waiting for dumping asphalt, dumping asphalt

Properties: Capacity in equivalent volume to the surface area (e.g., 10 m^2)

DES modeling elements

Resources1: Paving machine

State: busy laying down asphalt, idle waiting for asphalt batch to arrive.

Resources2: Roller compactor

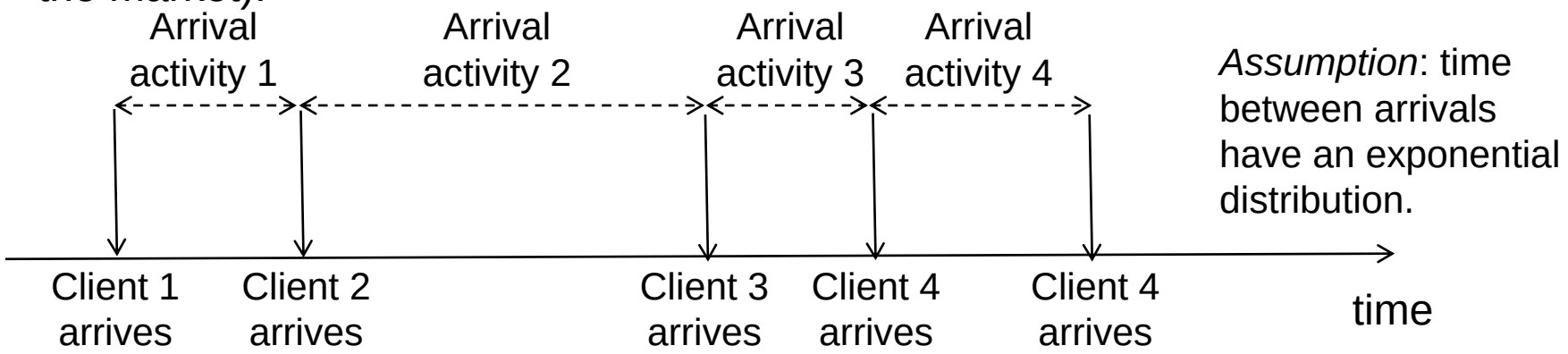
States: busy compacting laid down asphalt, idle waiting for a new asphalt to be laid down.

DES modeling elements-activity

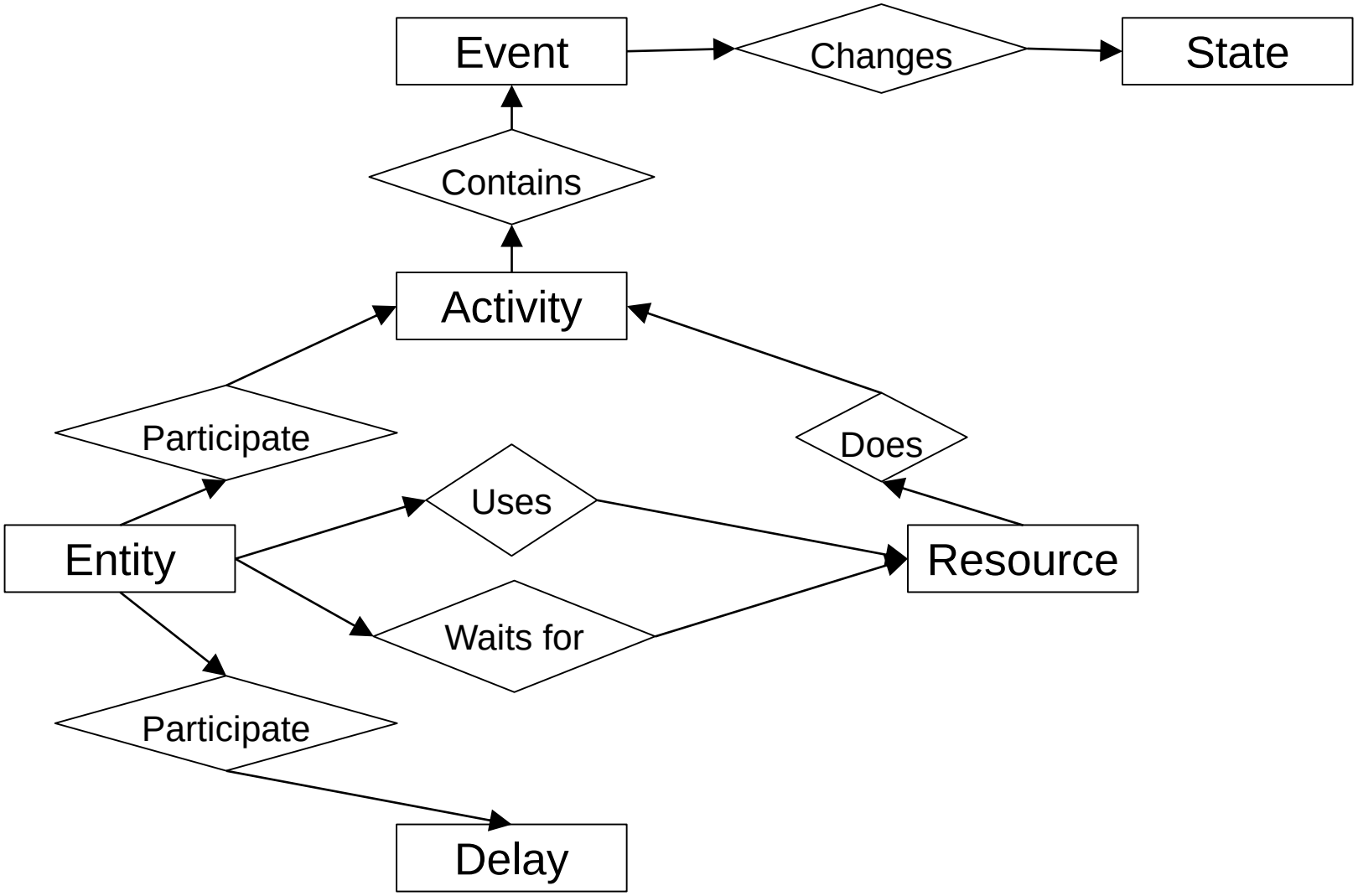
- **Activity**: An activity is a period of time whose duration is known prior to commencement of the activity.(Banks 1998, p8)
- Activity duration might be known deterministically (e.g., 30 minutes, 2 days) or stochastically (e.g., Normal distribution[mean=4h, Standard Deviation=0.5h])
- **Example:** Loading a truck, welding a steel module, hauling trip to the dump site.
- **Activity Vs Delay**: Unlike activity, delay is a period of time whose duration is NOT known prior to commencement of the delay (e.g., waiting in a line of trucks waiting for loading)
- **Activity, Entity and Resource**: Entities are motivation forces of simulation models, so expect to have entities involved in every activity!!!!!!!! However, activity might be done by use of a resource(s) (e.g., loading a truck) or without use of a resource (e.g., hauling trip to the dump site)

DES modeling elements-activity

- **Activity and Event**: Start and finish of every activity are Events (i.e., start event and finish event) where system state gets changed!
- **Activity (a wider definition)**: An activity is a period of time limited between two events where by occurrence (or determination of occurrence time) of the first event, the occurrence time of the second event will be known. The most famous activity that fits in this new definition is time to next entity (e.g., client, project, etc.) arrival to the system when entity comes from outside of our system, but time between arrivals (or its distribution) is known for the system usually based on historical data (e.g., time between new construction projects to be introduced to the market).



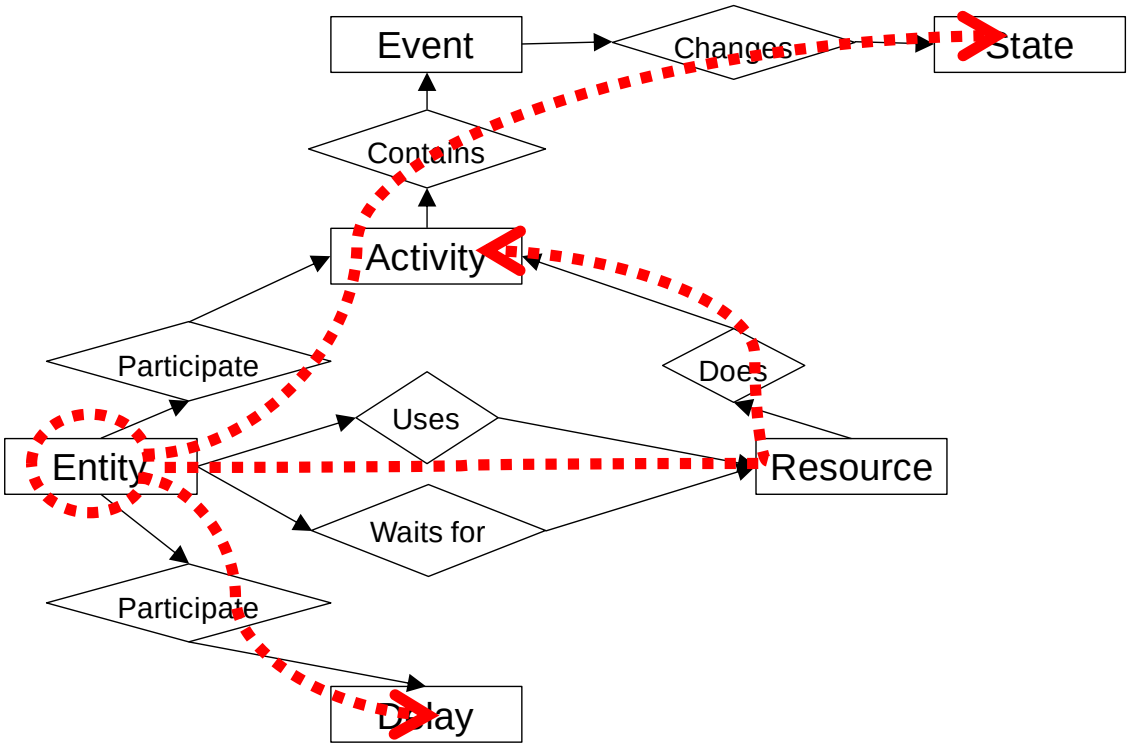
DES modeling elements-relation



DES modeling elements-relation

Looking at elements relation map, it is seen that relations are initiated from Entity element! This gives a clue that when we are going to model a system we first need to determine Entity elements and then recognizing other elements. This is the reason why Entity has the key impact on our DES model development!

- By having different Entity elements represented different system components, DES model can significantly change!



Home assignment 2

We are going to do a simulation study on a structural steel installation job where 1) structural steel elements arrive at the site from steel fabrication shop 2) structural steel elements are stored in order based on their arrival time 3) a tower crane moves the elements to their erection location 4) iron worker crew first temporarily stabilize the steel element on its location to let the crane off and can serve other steel element installation 5) Iron worker crew finish the installation by bolting and welding the steel elements

How do you determine entity elements in the system? Is there any important attribute you want to add to the to the entity? What are resources and their states? Is there any queue required for the resources? What are activities and events? What are expected system state changes by events occurrence?

Due: One week

Reference

- Banks, J., Carson, J.S., Nelson, B.L. And Nicol D.M. (2004) “Discrete event simulation” Prentice Hall, ISBN: 0131446797.
- Banks, J. (1998) "HANDBOOK OF SIMULATION, Principles, Methodology, Advances, Applications, and Practice” John Wiley and Sons, Toronto, Canada. ISBN 0-471-13403-1.

Thank you!