COSMOS Simulator

COSMOS Simulator: A Software Tool for Construction-Process Modelling and Simulation

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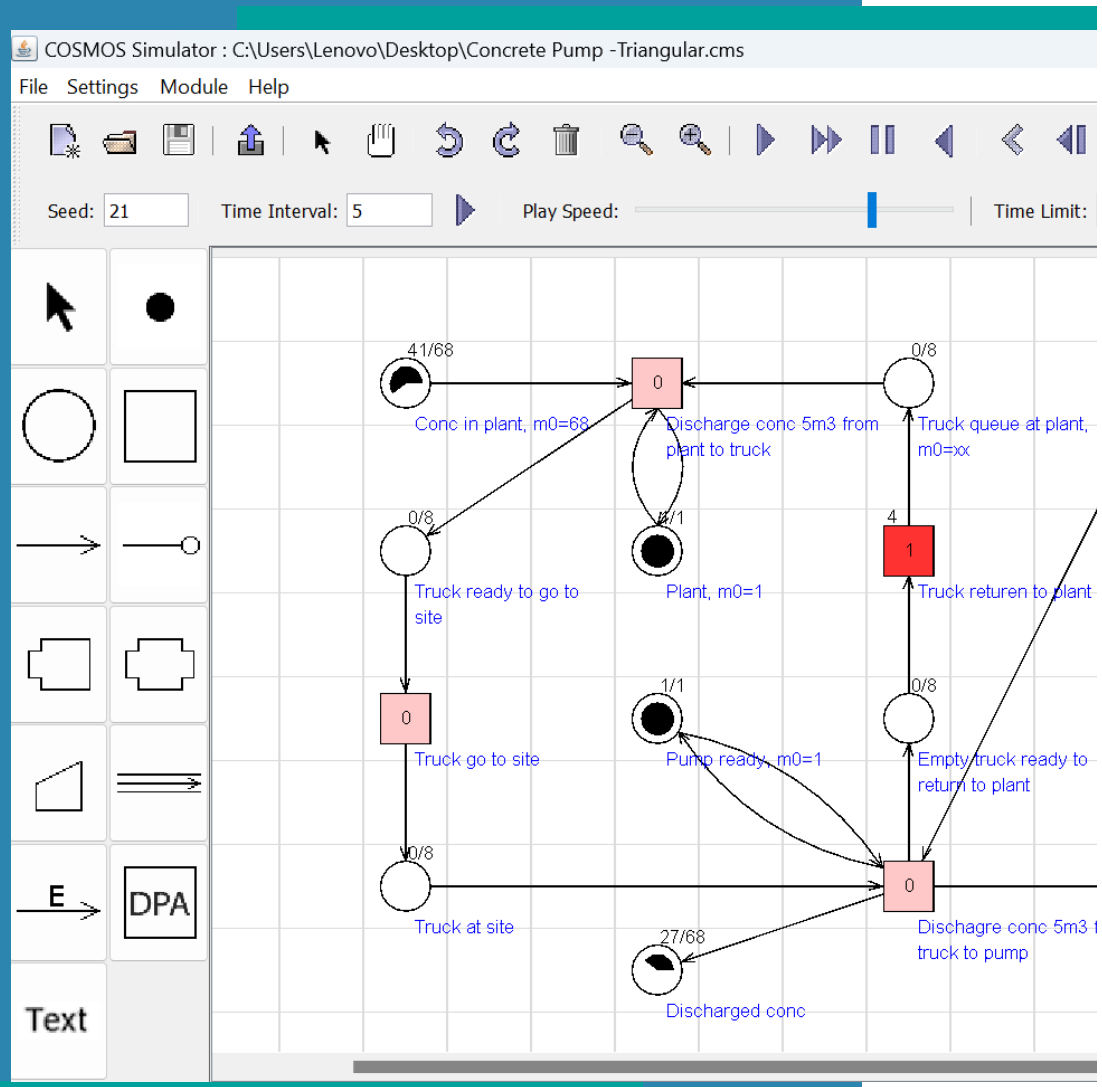
Short Resume of Presenter: Jirawat Damrianant

- Education:
  - B.Eng. (Hons) in Civil Engineering, Chiang Mai University, Thailand
  - M.Eng. in Structural Engineering and Construction, Asian Institute of Technology, Thailand
  - PhD in Civil Engineering, the University of New South Wales, Australia
- He has worked in the construction industry as a structural designer and a construction manager for several years.
- He is an associate professor in the Faculty of Engineering at Thammasat University, Thailand.
- His research interests include construction-process modelling and simulation, building information modelling, and digital twin.
- Prof. Damrianant is a registered professional civil engineer, a member of the Council of Engineers (Thailand), and a member of the Engineering Institute of Thailand under H.M. the king's patronage.

Call for Collaboration and Supports

What we are working on

- Improve the COSMOS Simulator's interface to make it more visually appealing and smoother.
- It would be great if we could display the resources used in the process, including the process itself, in some form of graphics.
- Expand COSMOS's capabilities to incorporate real-time data from construction sites.
- Add appropriate control statements to enable users to have finer control over the COSMOS models' behaviours and align them more closely with the actual behaviours of construction work in the fields.



The presentation's aim

- Provide an overview of the key features of the COSMOS Simulator.
- Highlight its applications in construction process modelling and simulation.

Process Simulation in Construction

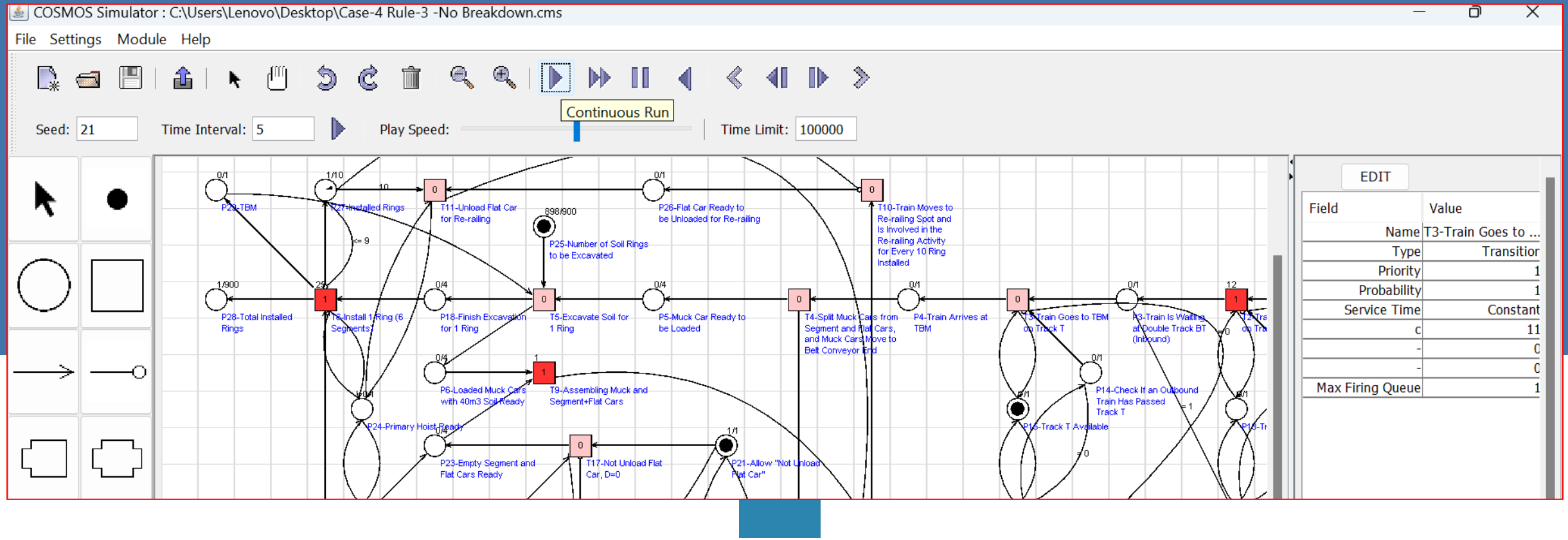
- Computer simulation software is an essential tool for efficiently simulating complex processes.
- Construction processes for large construction projects are complex.
- Early systems, like the Micro-Computerized CYCLic Operation Network (MicroCYCLONE) (early 1980s), laid the groundwork for construction modelling and simulation.
- Since then, some software tools for construction have been developed.

Why COSMOS Simulator?

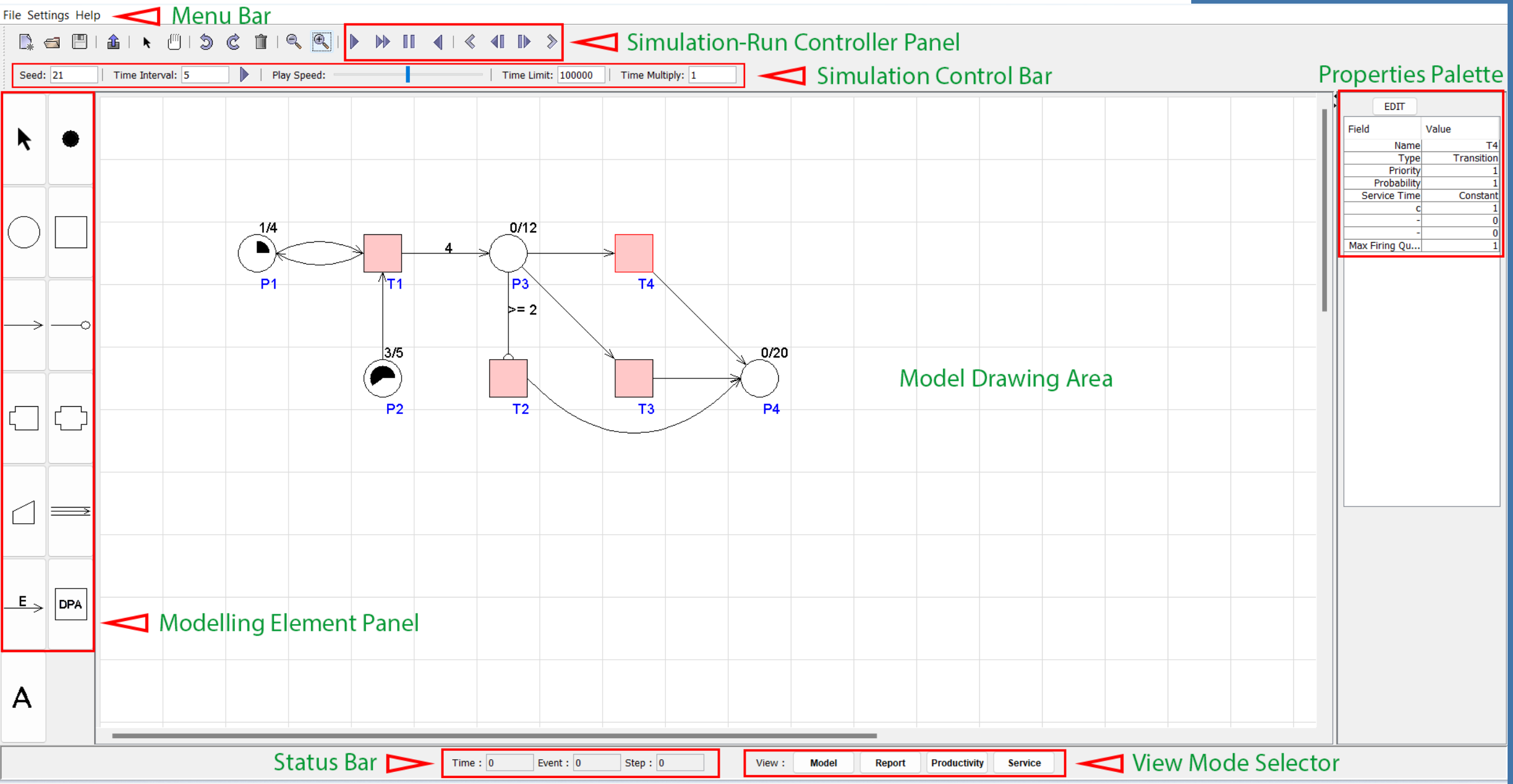
- However, the inherent uncertainties and dynamic interactions of construction operations continued to pose challenges for simulation modelling.
- The COSMOS Simulator was then developed as an alternative simulation tool for construction.
- The simulator is designed based on COSMOS methodology - a modified Petri Net.

Why COSMOS Simulator?

- What is good about Petri Nets in the construction context?
- Petri nets' basic structures are intuitive to construction personnel.
- The PN structures also align with the fundamentals of construction operations: activity and resource-based.
- However, unlike some other Petri Net-based simulators that may demand a deep understanding of Petri Net theory, the COSMOS Simulator is crafted to be easily accessible for construction professionals.



User Interface and Distinctive Features of COSMOS Simulator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Menu Bar
Simulation-Run Controller Panel
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Time Interval: 5
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Time Limit: 100000
Time Multiply: 1
Simulation Control Bar
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1
1/4
P1
T1
4
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P3
>= 2
T4
3/5
P2
T2
T3
0/20
P4
Model Drawing Area
E
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Status Bar
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Report
Productivity
Service
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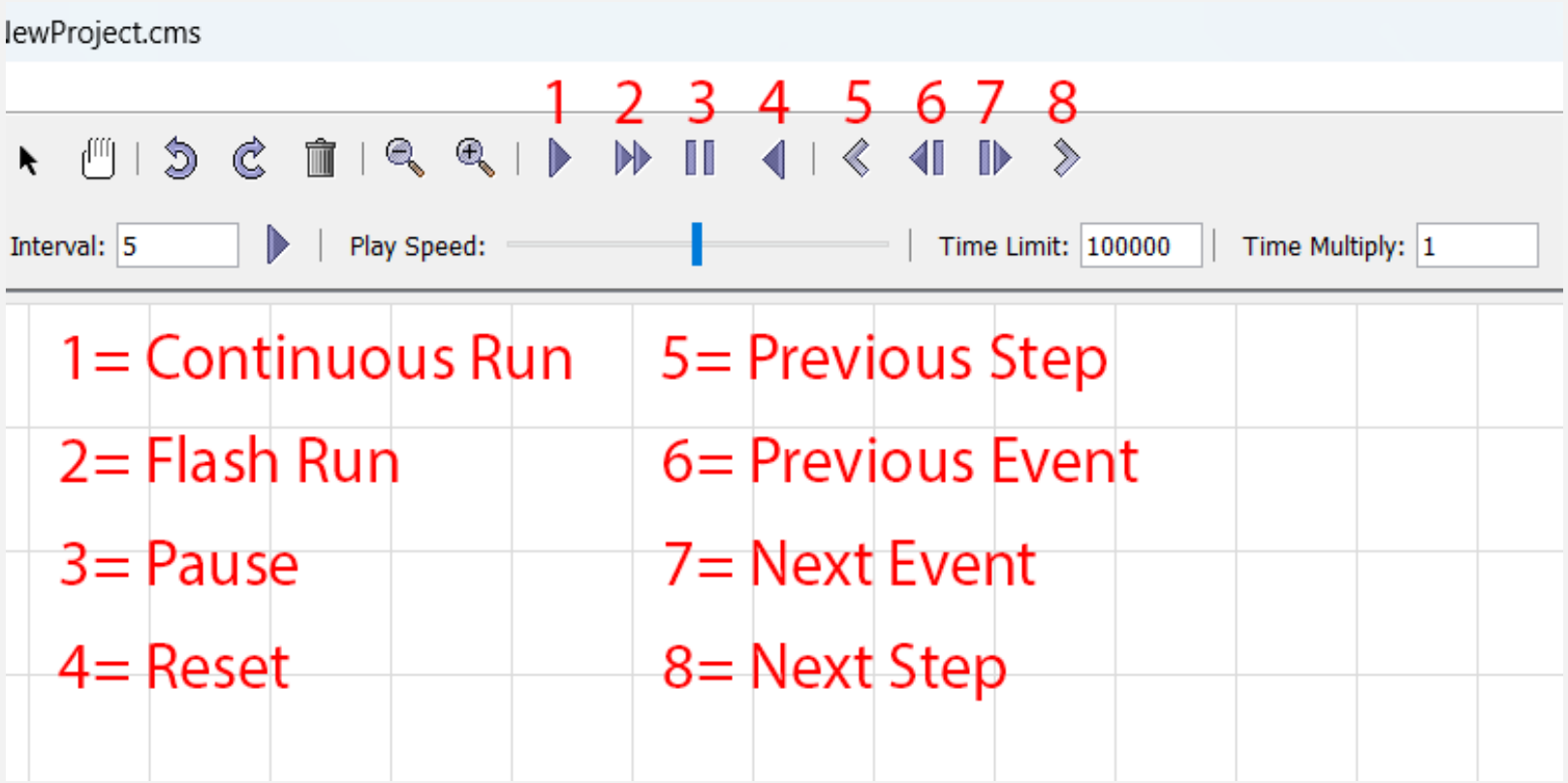
lewProject.cms
1 2 3 4 5 6 7 8
Interval: 5
Play Speed:
Time Limit: 100000
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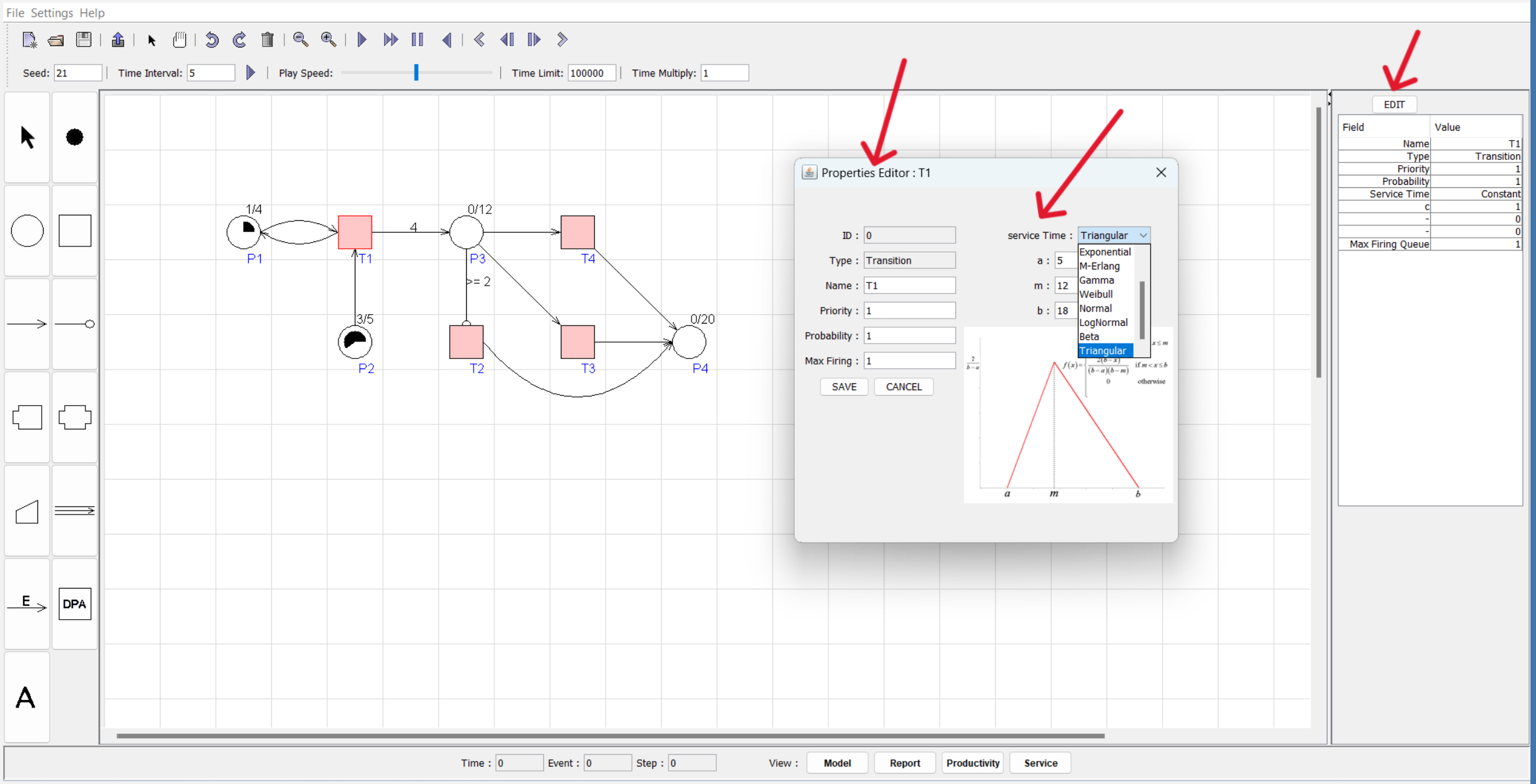
1= Continuous Run
2= Flash Run
3= Pause
4= Reset
5= Previous Step
6= Previous Event
7= Next Event
8= Next Step


File Settings Help
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Time Interval: 5
Play Speed:
Time Limit: 100000
Time Multiply: 1
1/4
P1
T1
4
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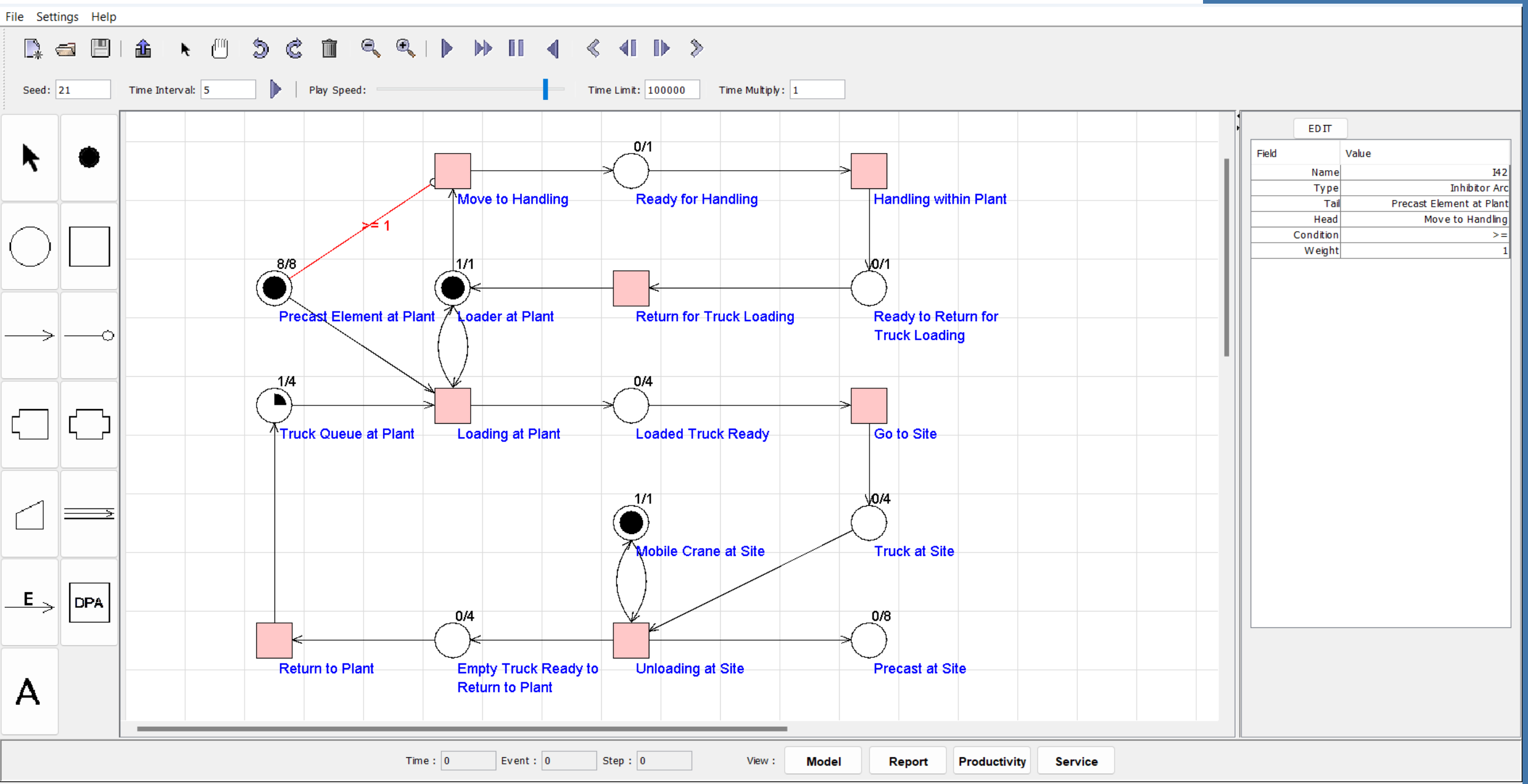
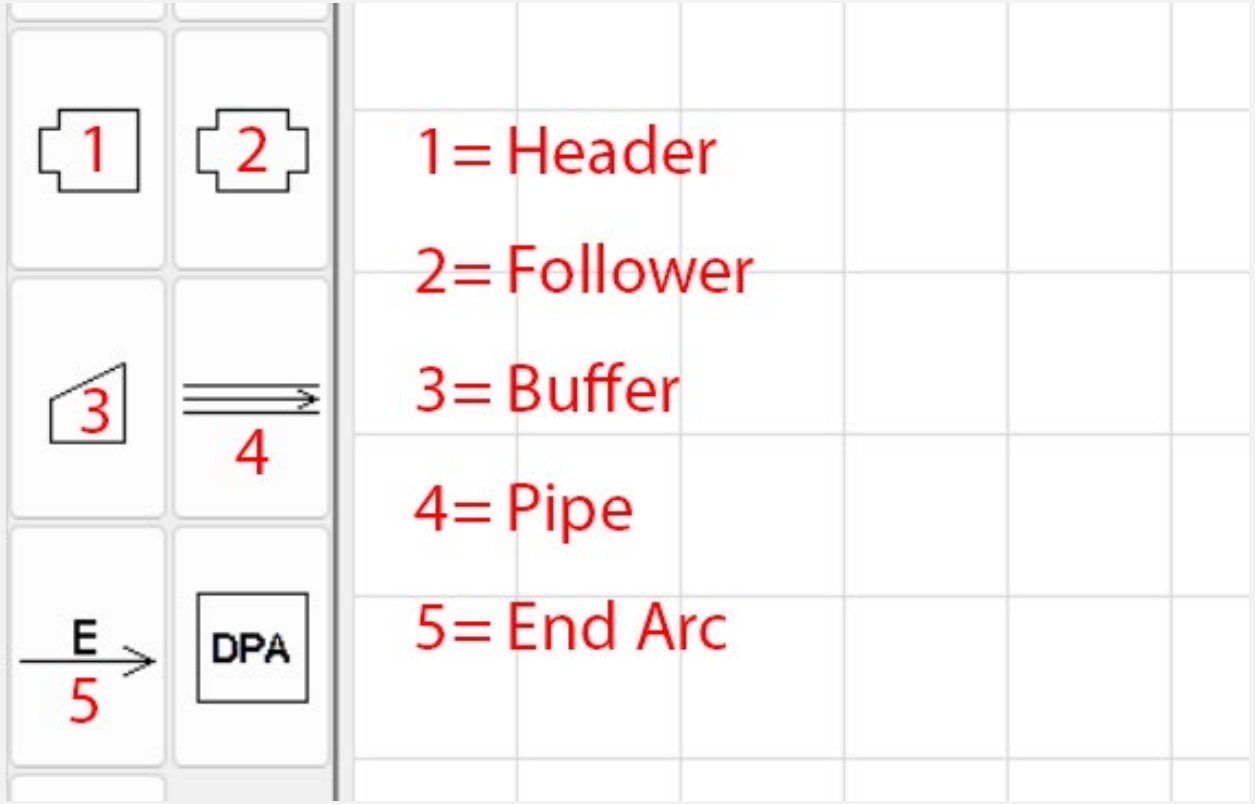
>= 2
T4
3/5
P2
T2
T3
0/20
P4
E
DPA
A
Properties Editor : T1
ID : 0
Type : Transition
Name : T1
Priority : 1
Probability : 1
Max Firing : 1
SAVE
CANCEL
service Time : Triangular
a : 5
m : 12
b : 18
Exponential
M-Erlang
Gamma
Weibull
Normal
LogNormal
Beta
Triangular
EDIT
Field
Value
Name T1
Type Transition
Priority 1
Probability 1
Service Time Constant
c 1
- 0
- 0
Max Firing Queue 1
Time : 0
Event : 0
Step : 0
View :
Model
Report
Productivity
Service

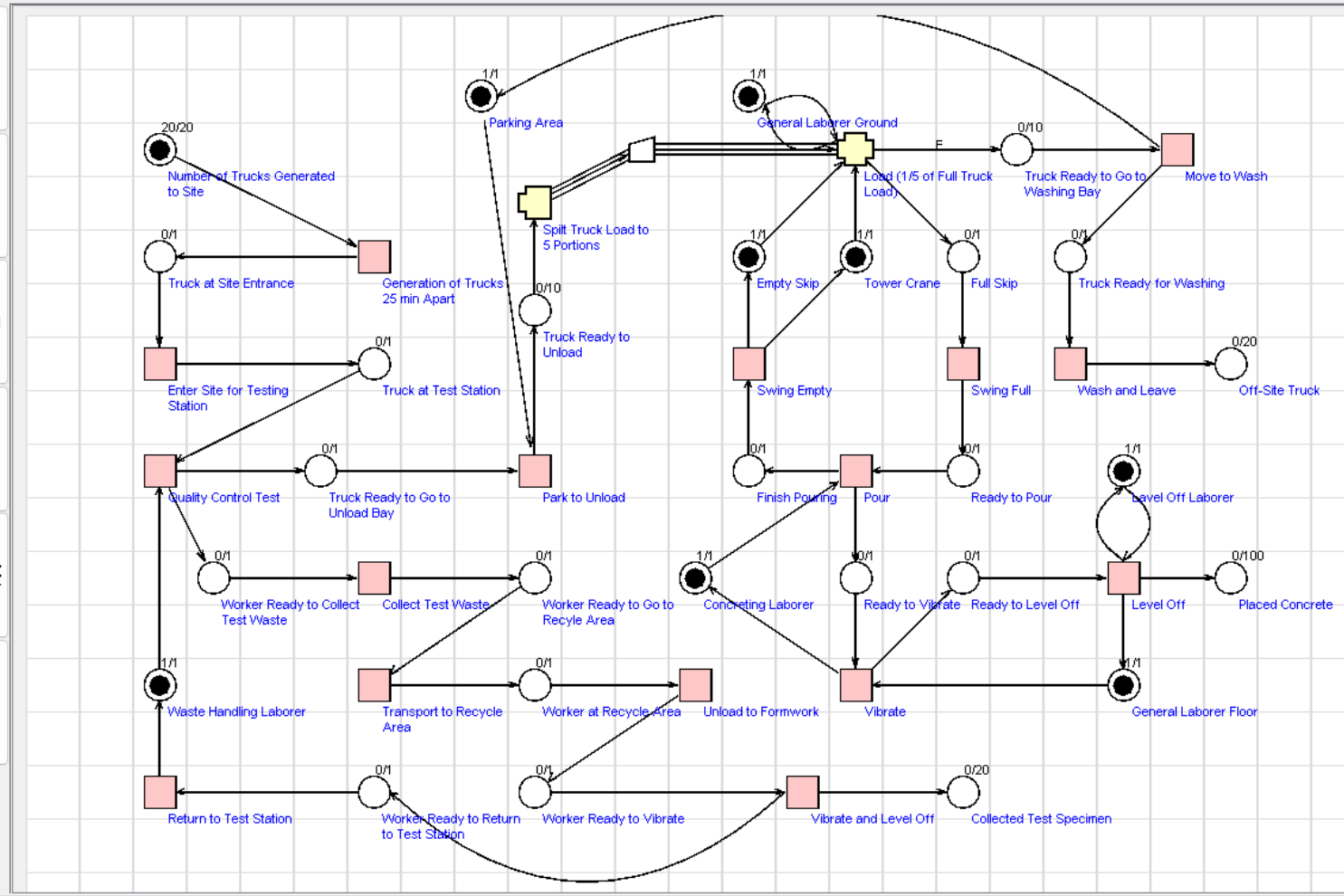

File
Settings
Help
Seed: 21
Time Interval: 5
Play Speed:
Time Limit: 100000
Time Multiply: 1
Move to Handling
0/1
Ready for Handling
Handling within Plant
>= 1
8/8
Precast Element at Plant
1/1
Loader at Plant
Return for Truck Loading
0/1
Ready to Return for Truck Loading
1/4
Truck Queue at Plant
Loading at Plant
0/4
Loaded Truck Ready
Go to Site
1/1
Mobile Crane at Site
0/4
Truck at Site
0/4
Empty Truck Ready to Return to Plant
Unloading at Site
0/8
Precast at Site
Return to Plant
E
DPA
A
EDIT
Field
Value
Name I42
Type Inhibitor Arc
Tail Precast Element at Plant
Head Move to Handling
Condition >=
Weight 1
Time : 0
Event : 0
Step : 0
View :
Model
Report
Productivity
Service


1
2
3
4
E
5
DPA
1= Header
2= Follower
3= Buffer
4= Pipe
5= End Arc

COSMOS Simulator : C:\Users\Lenovo\Desktop\Model Final Version -With Header.cms

File Settings Module Help

Seed: 21 Time Interval: 5 Play Speed: Time Limit: 100000



EDIT

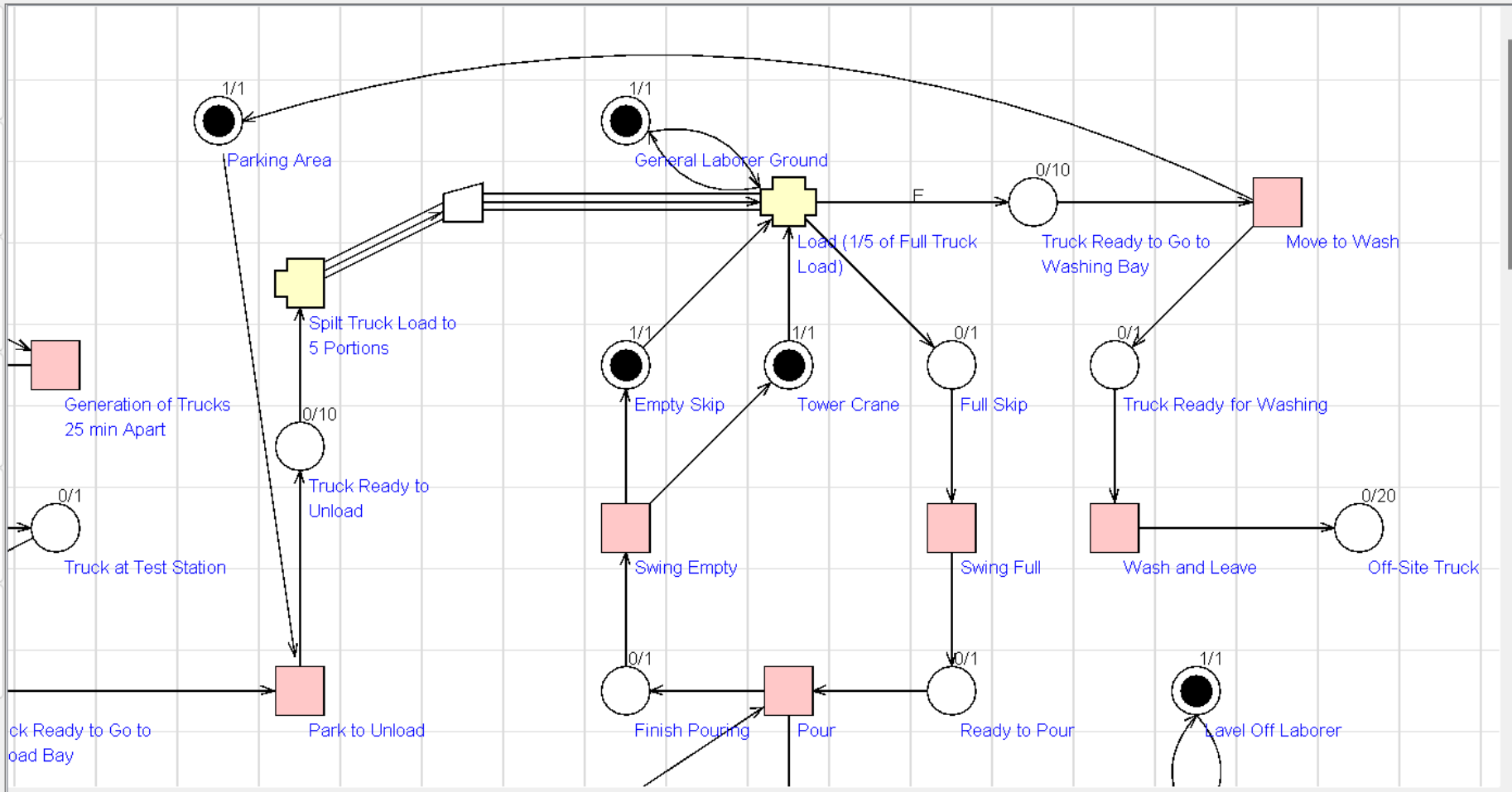
Field	Value
Name	E149
Type	EndArc
Tail	Load (1/5 of Full ...
Head	Truck Ready to G...
Priority	1
Probability	1
Weight	1

Time : 0 Event : 0 Step : 0 View : Model Report Productivity Service

COSMOS Simulator : C:\Users\Lenovo\Desktop\Model Final Version -With Header.cms

File Settings Module Help

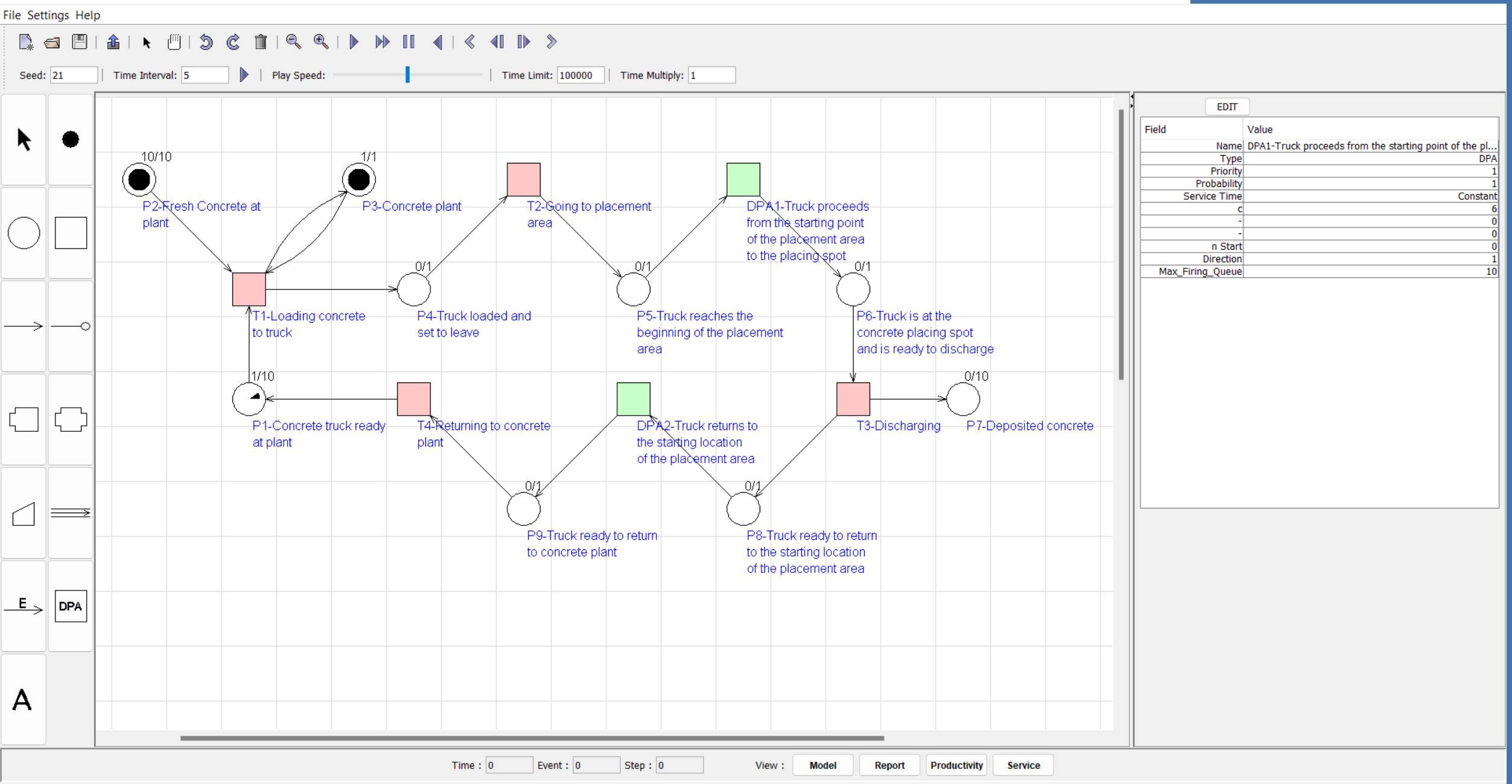
Seed: 21 Time Interval: 5 Play Speed: Time Limit: 100000



EDIT

Field	Value
Name	E149
Type	EndArc
Tail	Load (1/5 of Full ...
Head	Truck Ready to G...
Priority	1
Probability	1
Weight	1

Time : 0 Event : 0 Step : 0 View : Model Report Productivity Service


File Settings Help
Seed: 21
Time Interval: 5
Play Speed:
Time Limit: 100000
Time Multiply: 1
10/10
P2-Fresh Concrete at plant
1/1
P3-Concrete plant
T2-Going to placement area
DPA1-Truck proceeds from the starting point of the placement area to the placing spot
0/1
T1-Loading concrete to truck
P4-Truck loaded and set to leave
P5-Truck reaches the beginning of the placement area
P6-Truck is at the concrete placing spot and is ready to discharge
1/10
P1-Concrete truck ready at plant
T4-Returning to concrete plant
DPA2-Truck returns to the starting location of the placement area
T3-Discharging
0/10
P7-Deposited concrete
P9-Truck ready to return to concrete plant
P8-Truck ready to return to the starting location of the placement area
E
DPA
A
EDIT
Field
Value
Name
DPA1-Truck proceeds from the starting point of the pl...
Type
DPA
Priority
1
Probability
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Max_Firing_Queue
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Time :
Event :
Step :
View :
Model
Report
Productivity
Service

Example Previous Applications of COSMOS Simulator

Various Construction-Process Cases

Case#1:
Energy Reduction in Road Construction

Reference:

S. Meklersuewong and J. Damrianant, "Energy Reduction in Road Construction," The Third International Symposium on Engineering, Energy and Environments (ISEEE-3), Bangkok, 2013, pp. 523-532.

- This research presents an application of the COSMOS simulation system for analysing equipment fleet utilisation in an asphaltic-concrete road construction project.
- Through analysis, we optimised energy usage and lowered the power consumption of the operation's equipment fleet.
- The results showed that using the COSMOS modelling and simulation approach, 26.8% of the energy consumption could be lessened by the proper arrangement of the heavy construction equipment fleet.

Case#2:
Optimisation of Supply Trains in Tunnel Boring Operation Using Tunnel Boring Machines

Reference:

J. Damrianant, "Optimization of Supply Trains in Tunnel Boring Operation Using Tunnel Boring Machines," The Sixth International Conference on Advances in Civil, Structural and Mechanical Engineering (CSM-18) Zurich, 2018, pp. 8-12. doi:10.15224/978-1-63248-150-4-23.

- The paper presents an optimisation of the number of supply trains so that the operation of the train fleet will be well synchronised with that of the tunnel boring machines (TBM).
- The project involved building a large drainage tunnel with an inside diameter of 5 m.
- The COSMOS simulator was instrumental in conducting the simulation for this project.
- The simulation results were used successfully in the actual operation.

Case#3:
Optimising Resource Allocation Through COSMOS-Based Modelling and Simulation

Reference:

J. Damrianant and T. Panrangsri, "Resource Management Using COSMOS Modeling and Simulation System to Lessen Concrete-Placing Duration," (in Thai) Thai J. Sci. Tech., vol. 7(5), pp. 553-566, Aug. 2018, doi:10.14456/tjst.2018.50.

- This case involves a practical application of the COSMOS simulator in a process analysis and resource management for a concrete-placing operation.
- A comprehensive study was conducted on the concrete placement of a gas separation unit in Rayong Province.
- The optimum quantity of concrete to be placed daily and the optimum number of ready-mixed concrete trucks to be employed in the operation were determined.
- The results were then implemented in the actual operation of the project and found to be appropriate.

Case#4:
Concrete Slab Placement using a Concrete Pump

Reference:

N. Suri and J. Damrianant, "Comparing Construction Process Simulation between the Arena and COSMOS Programs," (in Thai). Eng. J. Research Development, vol. 30(4), pp. 89-104, Oct. 2019, ISSN: 2730-2733.

- This case compares the COSMOS Simulator to Arena simulation software, using a concrete slab placement and a concrete pump as a case study.
- Arena is a well-known software for the simulation of industrial productions.
- The productivity rate of the process, including the waiting time and the queue length of the primary resources employed in the operation, were compared.
- The comparison showed that ARENA and the COSMOS Simulator gave the same or statistically not different results depending on whether the situation was deterministic or stochastic.

Case#5:
Auger Horizontal Earth-Boring Process

Reference:

S. Meklersuewong and J. Damrianant, "Evaluating the COSMOS Software Ecosystem for Domain-Specific Construction Process Simulation," Int. Rev. Model. Simul., vol.15(3), pp. 179-188, Jun. 2022, doi:10.15866/iremos.v15i3.20268..

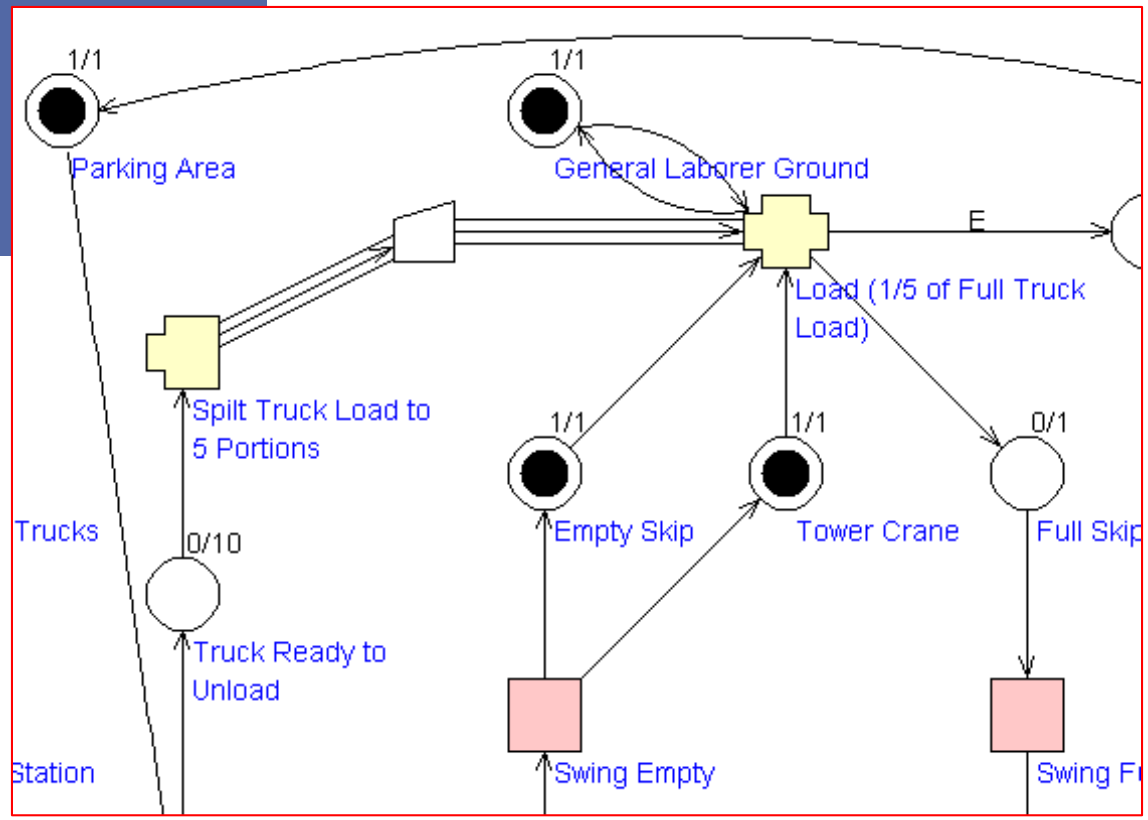
- An auger horizontal earth-boring method was used as a case for comparing the COSMOS Simulator to MicroCYCLONE.
- MicroCYCLONE is a DOS-based simulation language designed to model cyclical construction processes.
- Despite its age as a DOS-based program, MicroCYCLONE's simulation results have been widely accepted by construction researchers.
- The results from the two simulators were compared statistically.
- After a hypothesis test, it was concluded that neither simulator produces statistically different results.

Case#6:
Concreting and Waste-Handling Operation

Reference:

S. Meklersuewong and J. Damrianant, "Evaluating the COSMOS Software Ecosystem for Domain-Specific Construction Process Simulation," Int. Rev. Model. Simul., vol.15(3), pp. 179-188, Jun. 2022, doi:10.15866/iremos.v15i3.20268..

- This study compares the COSMOS Simulator to PROMODEL.
- PROMODEL is a widely used discrete event simulation (DES) software that provides a platform for modelling systems like manufacturing.
- The comparisons were in terms of resource utilisation percentage.
- It was found that COSMOS gave almost the same results as those of PROMODEL.
- The deviation from PROMODEL is only 0.6% on average due to the random mechanism of the triangular distributions used for the activity durations in the models.



The COSMOS Simulator's ability to model overlapping activities, dynamically progressive activities, and resource constraints sets it apart from other tools.

Discussion

The COSMOS Simulator provides a simulation environment tailored to the construction industry's needs.

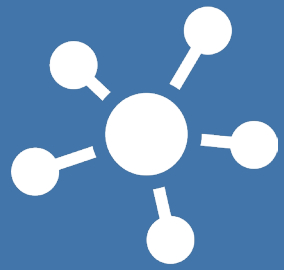
Impact and Improvements

- COSMOS brings construction-specific simulation to a broader audience.
- The COSMOS Simulator is an alternative tool for efficiently simulating construction operations.
- Areas for improvement:
  - Real-time data integration.
  - Addition of control statements, making the simulation of complex processes more convenient.

Summary

The COSMOS Simulator is a computer program designed to simulate construction processes.

COSMOS's unique modelling elements enable the simulation of specific behaviours found in construction.



The COSMOS's unique elements are not available in other simulation tools.

This paper offered a resource for researchers and practitioners interested in leveraging COSMOS for their construction modelling and simulation needs.

"Trying to understand complicated processes without **modelling and simulation** is challenging, if not impossible."

JIRAWAT DAMRIANANT

THANK YOU