Optimization of inbound Truck TAT at Mahindra & Mahindra Plants

THE ANYLOGIC CONFERENCE 2025

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ELECTRIC ORIGIN SUVs
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About the Department & Team

Auto Digital Centre – Aligned with Corporate Tech and R&D Teams across all Sectors

Auto, Farm, Truck & Bus, Electric Vehicles, Engines, Two Wheelers verticals

OUR TEAM & DEPARTMENT

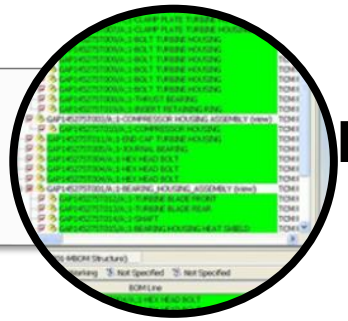
Manufacturing IT
Digital
Manufacturing
Team CoE

Presenter :
Nehanth Geetha

About the CoE

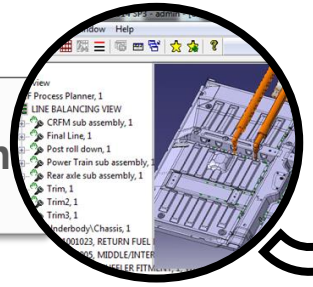
Manufacturing IT – Digital Manufacturing CoE

Manufacturing and Engineering BOM

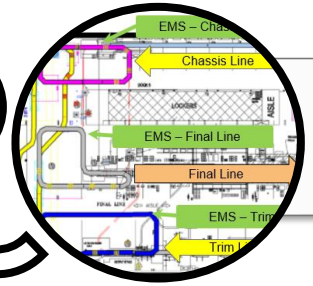


Factory Layout and Design

Process Planning Solution



Digital Manufacturing

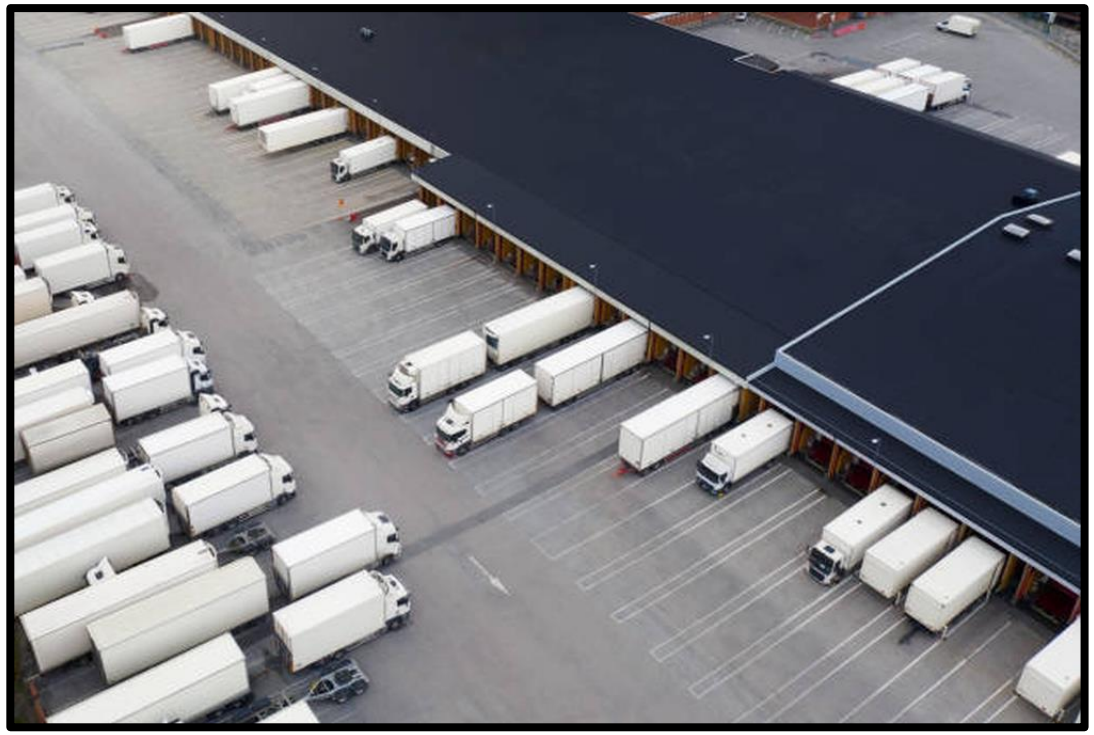


Discrete Event Simulations

Process Simulation

Virtual Reality/ Augmented Reality / Mixed Reality

Overview



With increasing production targets and fluctuating supplier schedules, Mahindra & Mahindra faced significant challenges in ensuring efficient inbound truck turnaround times (TAT) at its plants.

Concerns arose about whether the existing logistics infrastructure — including gates, docks, and internal road networks — could handle future demand.

It is important to note that M&M primarily uses **JIT (Just-in-Time)** and **JIS (Just-in-Sequence)** inventory management strategies hence there are minimal parts stored at our plants.

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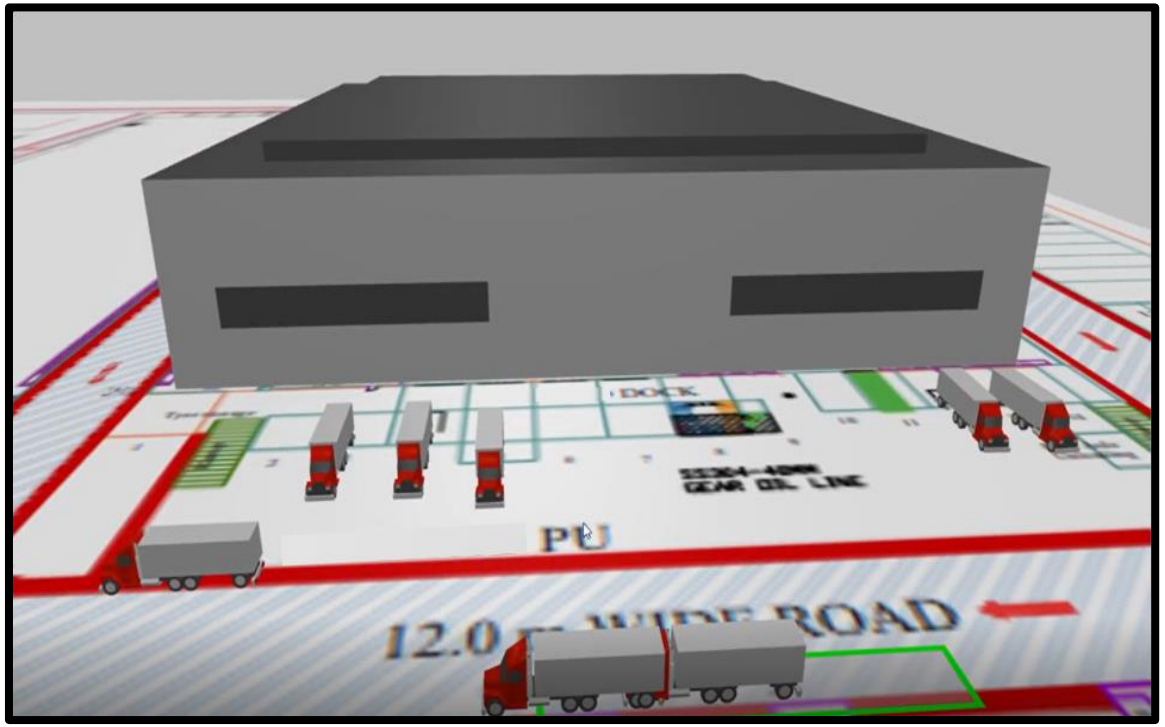
Objectives

❖ **Goal:**

To create a model that can be used to test future scenarios and identify potential bottlenecks. This should in-turn help stakeholders to take critical decisions.

❖ **Objectives:**

- ❖ To validate truck TAT and dock utilization based off current scenario
- ❖ To understand and estimate truck TAT and dock utilization for future what-if scenarios
- ❖ To identify any traffic and congestion areas



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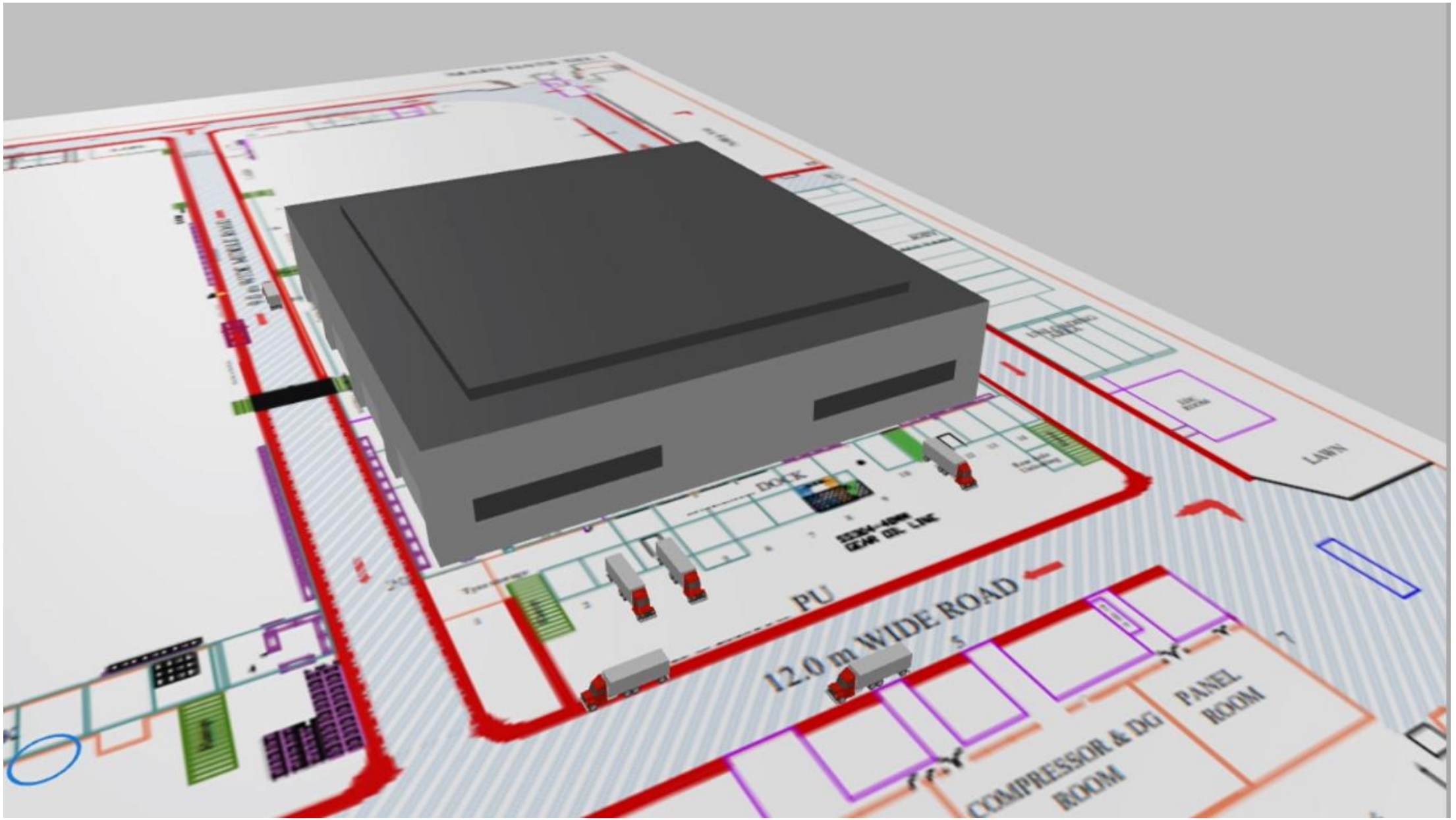

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Assumptions (Trucks)

- VTS (Vehicle tracking System) data provided by Logistics team
  - Unique ID of truck
  - Plant IN time
  - Dock Number
  - Dock IN time
  - Dock OUT time
- Trucks are scheduled based on their Plant IN time and spawn outside the IN gate.
- If dock is free, truck proceeds directly to the dock otherwise they **wait outside the plant** (Plant IN time tells the time it should get generated and not the time it enters the Plant). Exceptions are there for certain docks as they have parking buffers inside the Plant.
- Trucks begin the loading/unloading process upon reaching the dock. TAT at Dock is derived from the recorded Dock IN and Dock OUT times.
- Average speed: 5 kmph on straights, 2 kmph on curves.

Assumptions (Trolleys)

- Following trolley data were provided by the Logistics team
  - Destination
  - Number of trolleys
  - Start Time
  - Per Trolley Length (mm)
  - Trip repeat interval (minutes)
- Trolleys use a **separate gate** for entry and exit.
- The **end** time for all trolley movements are **5:05PM**
- Trolleys are to be given priority to pass if in case there is an **obstruction** (by a truck)
- 4 different kind of trolley movement flows are present depending on the destination. **Trolleys are the main cause for congestion in the plant**, as there are multiple of them and they are much more frequent than trucks.
- Average speed: 4 kmph on straights, 2 kmph on curves.

Input Data

- Input Data gets collected from excel at model initialization. Which is then used to create a schedule for generating trucks.
- The trolley information is also read and stored in AnyLogic at initialization
- Dock out times were also collected from VTS to get Unloading / Loading times.

Unique ID	Dock Number	IN Time	Dept IN Time	Dept OUT Time
250601686	12	06:29	08:34	10:03
250602009	4	08:14	08:41	09:55
250602030	2	08:28	08:37	09:29
250601675	16	08:52	09:58	11:21
250601682	16	09:01	09:19	09:57

Sample VTS data

			mm	Minutes
Part carried	No. of Trolleys	Start Time	Per Trolley Length	Trip Repeat
4W Body	4	08:38	5580	8
Chassis	4	09:05	5320	35
Bumper	4	09:35	1650	65
CCB	3	09:42	1500	72
S1T Body	5	10:00	2800	12

Trolley types

(Each color represents a different destination)

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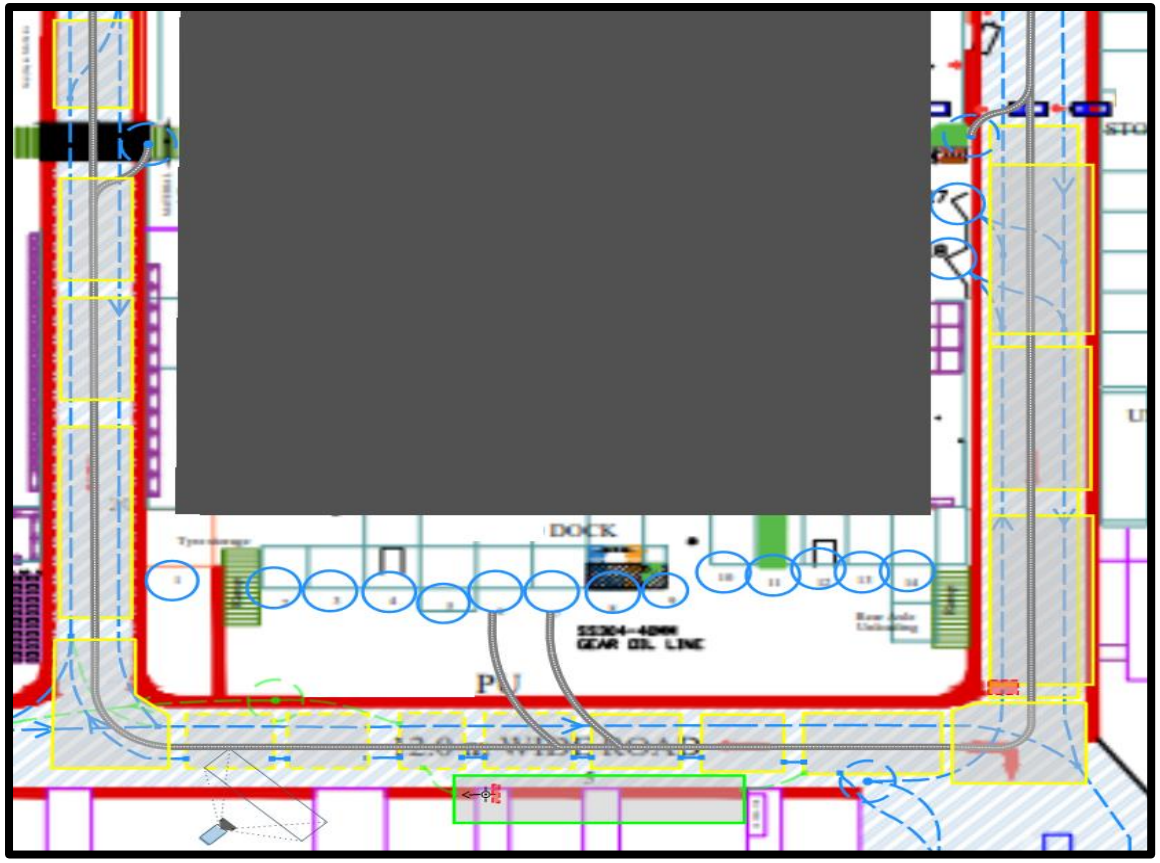
Approach in AnyLogic

- The model was made primarily using the **Material Handling Library**.
- Trucks and Trolleys were made as **transporters** (for easier routing, collision detection, access restrictions etc.)
- Several **Rectangular node-based access zones** were created
- Restrictions were created in these nodes to allow **only a certain number** of transporters to enter
- Virtual Gates were added when restrictions had to be applied to only **one transporter type** but still required to process **all types**
- Exact process flow of the truck's & trolley's path was made to get accurate results.



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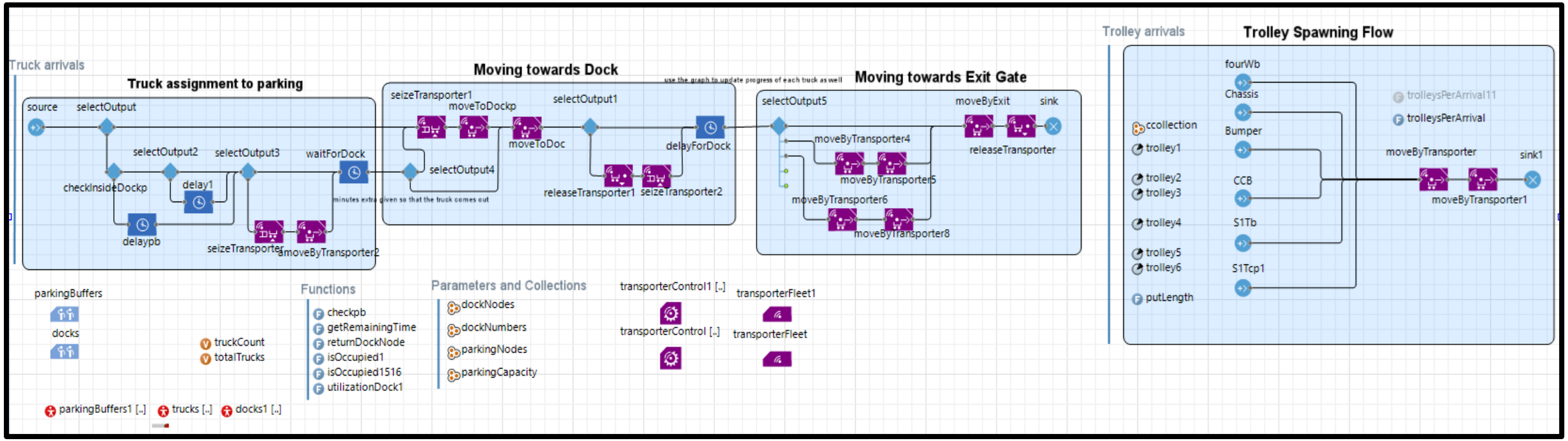
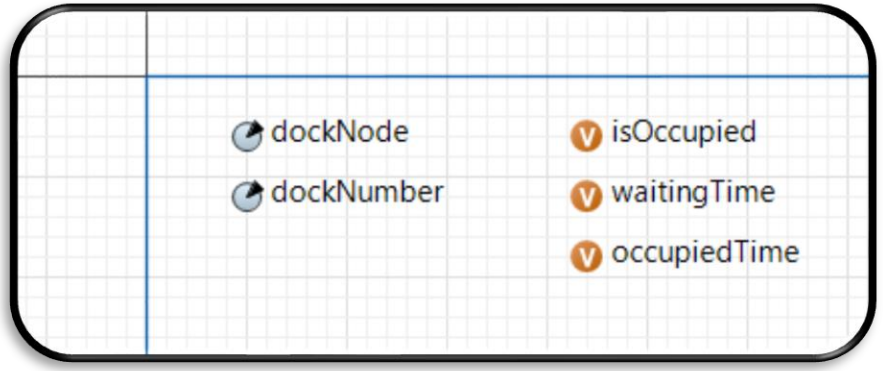
Model Logic

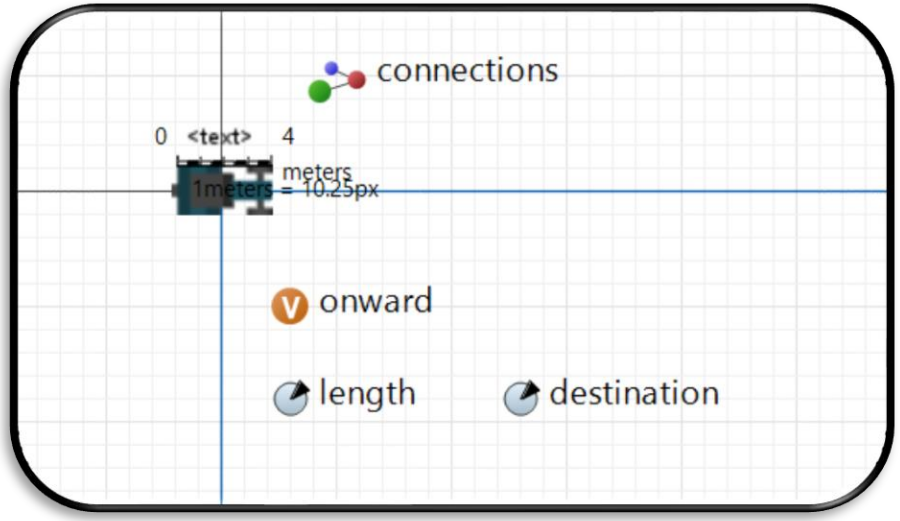
- If the Dock is occupied, the truck gets assigned its parking buffer depending on which dock it's destined to. Parking buffers are there both inside and outside the plant.
- The time it should wait gets calculated based on the U/L time remaining at the dock and the number of trucks waiting in line for that dock. **Delays** are used for this purpose
- Once delay waiting time is over, it heads towards the dock where they are again given a delay simulating the U/L process.
- Trolleys also spawn simultaneously creating a dynamic environment



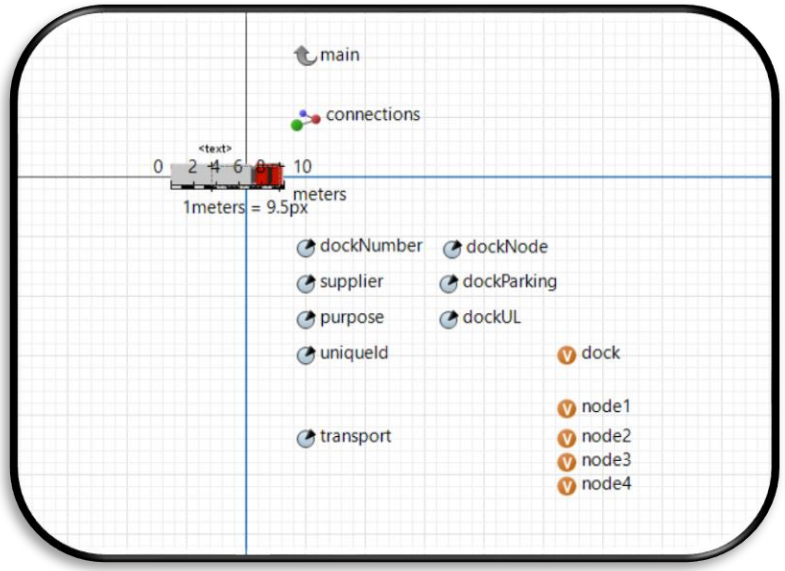
Model Logic



Dock Agent



Trolley Agent



Truck Agent

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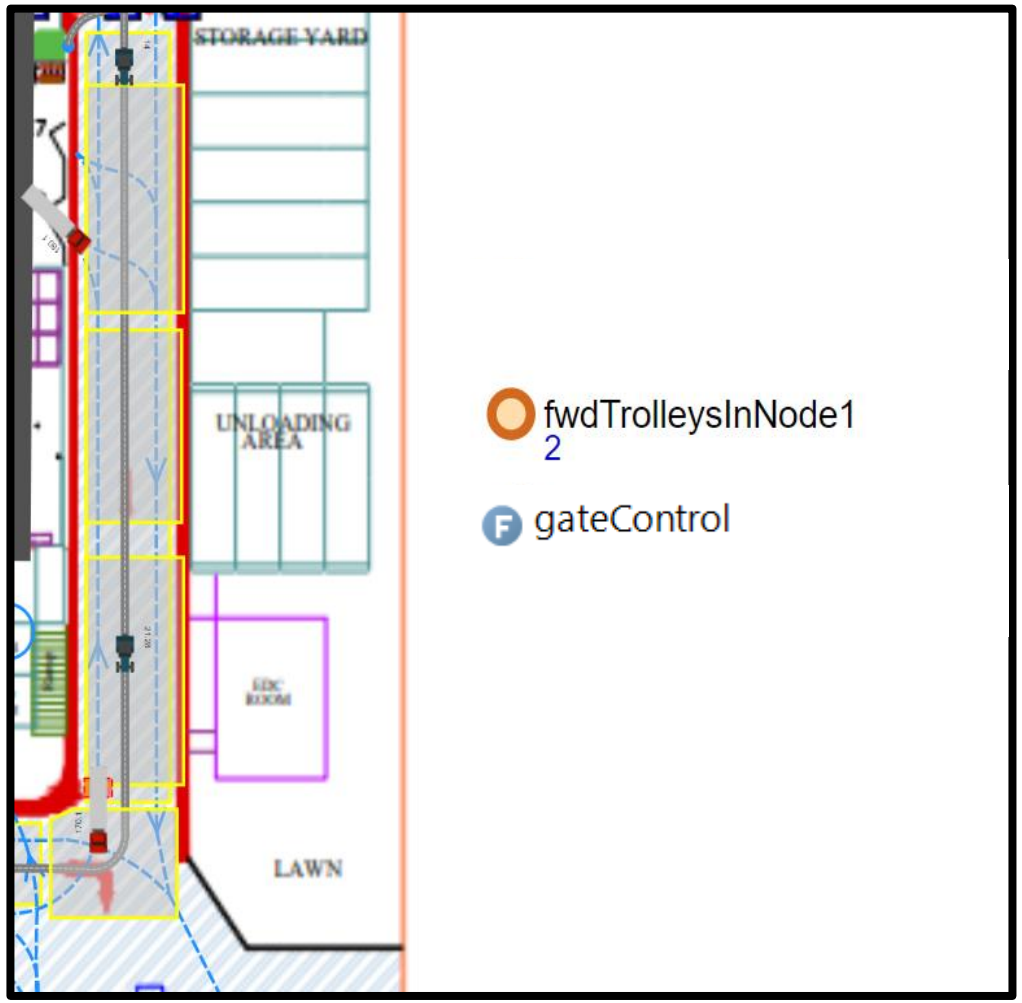
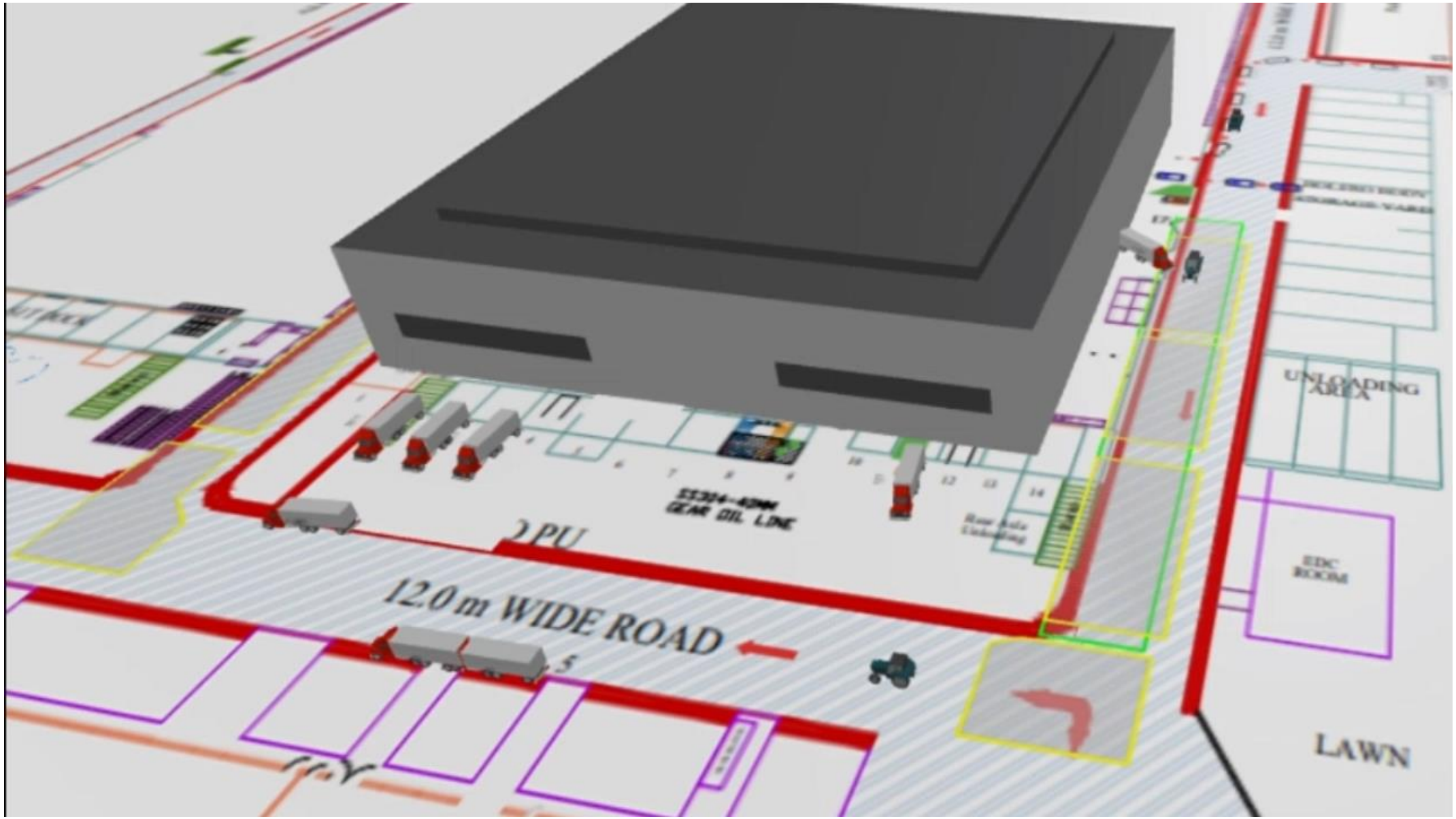
Example Scenario

- In this scenario, the truck (bottom left) needs to reverse a long way into its unloading dock.
- Since there is a trolley oncoming (top left) from the opposite direction, the truck must wait for it to cross as there could be a risk of collision.
- A **rectangular node** is used to keep track of the trolleys in this node moving in the **'forward'** direction.
- If **'fwdTrolleysInNode1'** variable is non-zero then the virtual gate at the entrance of the node is **closed**, preventing the trucks from reversing
- This behaviour along with other such behaviours were added to enhance the **dynamic nature** of this model





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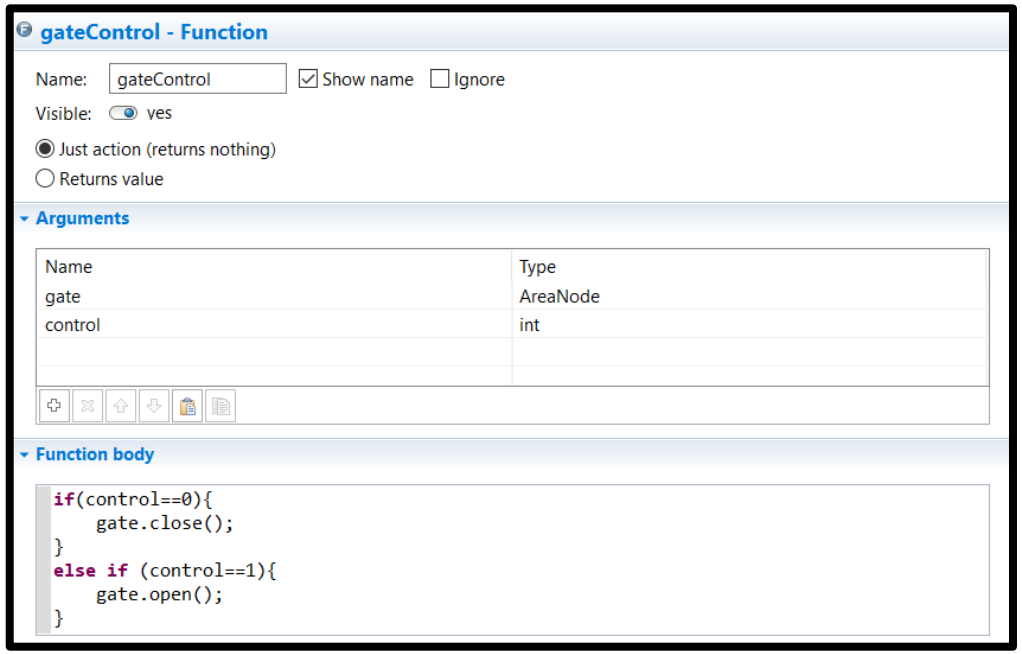
Example Scenario



gateControl ()

rectangular Node properties

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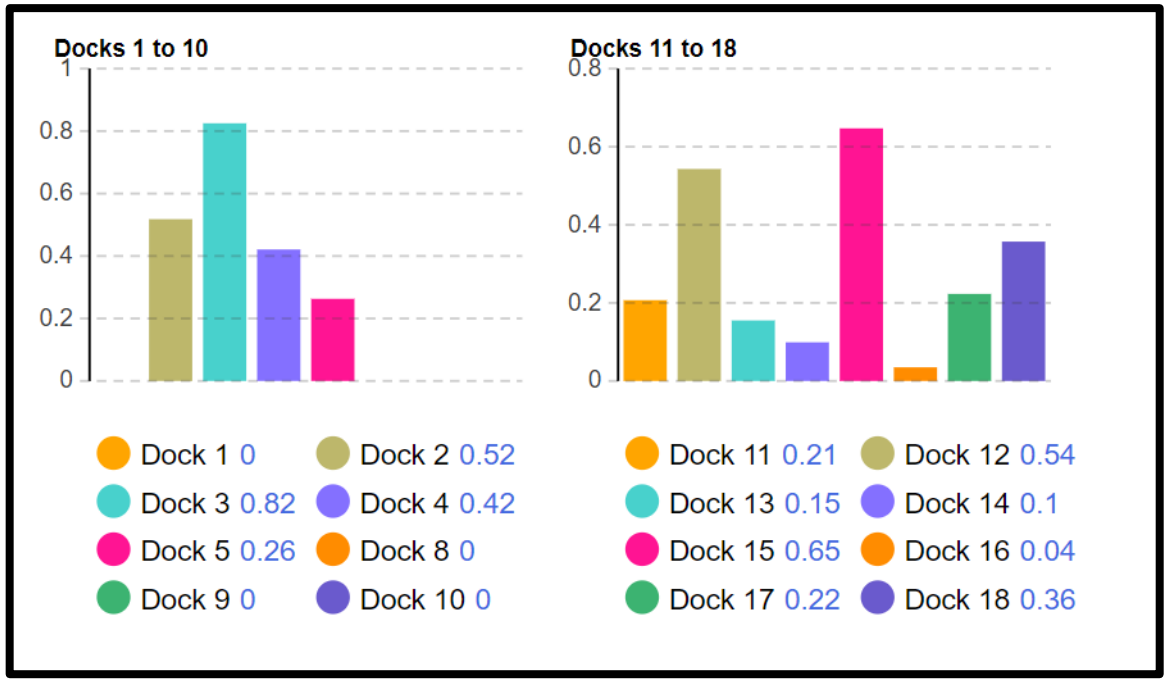
Output

After running the model for a **month's** data from VTS, it was observed that a certain number of docks (**3, 15, 12, 2**) were being highly utilized whereas some others (**16, 14, 13, 11**) weren't being utilized as much.

The end user gets a report containing model data:

- IN Time
- Dock IN Time
- Dock OUT Time
- OUT Time
- Waiting (True/False)
- Waiting_Time
- Plant Truck TAT



Dock Utilization charts

Unique ID	IN Time	Model IN Time	Model Dept IN Time	Model Dept OUT Time	Model OUT Time	Dock Number	waiting	waiting_time	Model Plant TTAT
250600333	04-06-2025 7:02:05	04-06-2025 7:02:05	04-06-2025 7:09:36	04-06-2025 8:34:36	04-06-2025 8:39:00	17	FALSE	0	96
250600360	04-06-2025 7:03:43	04-06-2025 7:03:43	04-06-2025 7:09:21	04-06-2025 8:13:21	04-06-2025 8:17:24	12	FALSE	0	73
250600440	04-06-2025 7:04:11	04-06-2025 8:18:21	04-06-2025 8:23:23	04-06-2025 12:36:23	04-06-2025 12:40:26	12	TRUE	64	336
250600552	04-06-2025 8:20:25	04-06-2025 8:20:25	04-06-2025 8:27:20	04-06-2025 8:33:20	04-06-2025 8:38:42	4	FALSE	0	18

Model output to excel (yellow headers)

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Results

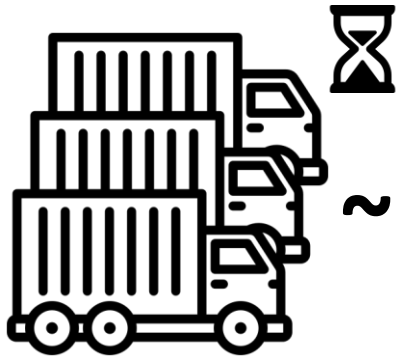
The output helped the Logistics team to plan out future truck schedules and to distribute the load evenly (no pun intended)

This helped them achieve **better material availability** and even out dock utilization. This indirectly led to lesser material shortages on the TCF line of our test Plant. The parking buffers were also utilized properly as they were able to **better plan out the schedule of trucks** from suppliers. This indirectly led to a **considerable decrease in average wait times**.

It also helped them to plan for future scenarios. The model also allows for quickly scaling up docks with the help of AnyLogic's Agent based modelling, adding model mix as well as integration with private cloud thereby widening the scope of possible improvements.

~10%

Better Material Availability



~30%

Lesser Wait Times

~20%

Reduction in the std deviation of utilization between all docks

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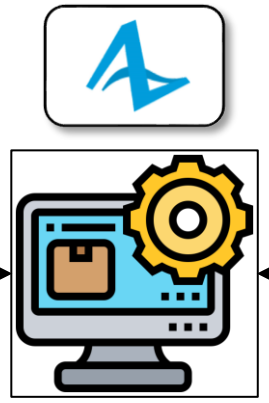
Future Scope

Live VTS Data

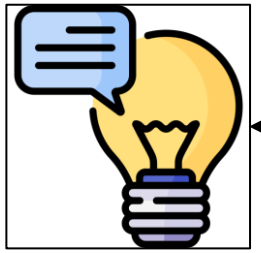


AnyLogic Digital Twin

(Simulates multiple scenarios and chooses the most optimal one)

Dock Number	06:00:00-07:00:00	07:00:00-08:00:00	08:00:00-09:00:00	09:00:00-10:00:00	10:00:00-11:00:00	11:00:00-12:00:00
2	4	1	6	7	4	9
3	8	3	4	3	6	1
4	2	5	5	6	3	7
5	3	6	6	7	5	0

Manual simulation with custom plan



Suggests plan based on forecast

(Web Interface)

Reports with insights

3D

(Visualisation in 3D along with VR using AnyLogic's Omniverse connector)

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THANK YOU !!

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