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Slab Yard Simulation Model – Steel Manufacturing

About BlueScope

BlueScope Steel is the largest steel manufacturer in Australia

Agenda :

- Problem statement
- Summary
- Process introduction
- Why simulation & AnyLogic?
- Challenges
- Model components
- Verification & Validation
- Outcomes

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High Level overview of Steel Manufacturing

Molten Iron from Blast Furnace → **Steel Converter Process** → **Continuous casting - Slabs** → **Slab yard Operations** → **Steel Rolling and Product Despatch**

- **Molten Iron from Blast Furnace**: Convert Iron ore to Pig Iron (Molten)
- **Steel Converter Process**: Improve Quality and convert to Steel (Molten)
- **Continuous casting - Slabs**: Cast Slabs of various size and quality
- **Slab yard Operations**: Receiving slabs, Cutting slabs, reheat, and rolling requirements
- **Steel Rolling and Product Despatch**: Rolled Steel Plate and Slabs

We are concerned with the slab yard operations in this project

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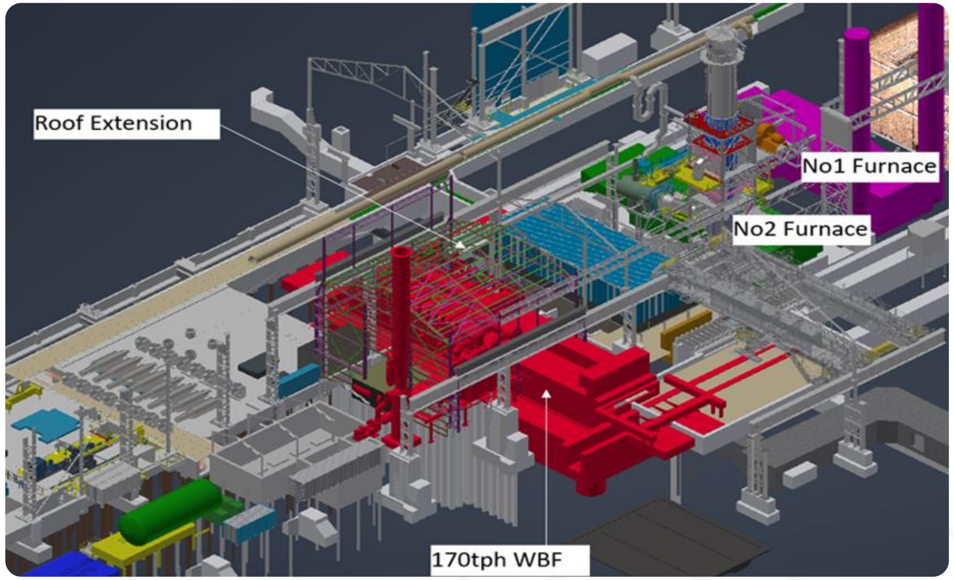
Problem Statement

- BlueScope plans to install a new Walking Beam Reheat Furnace in their site, significantly changing the aspects of Material flow within the site as well as delivering significant uplift in capacity/volume in the downstream Plate Mill.



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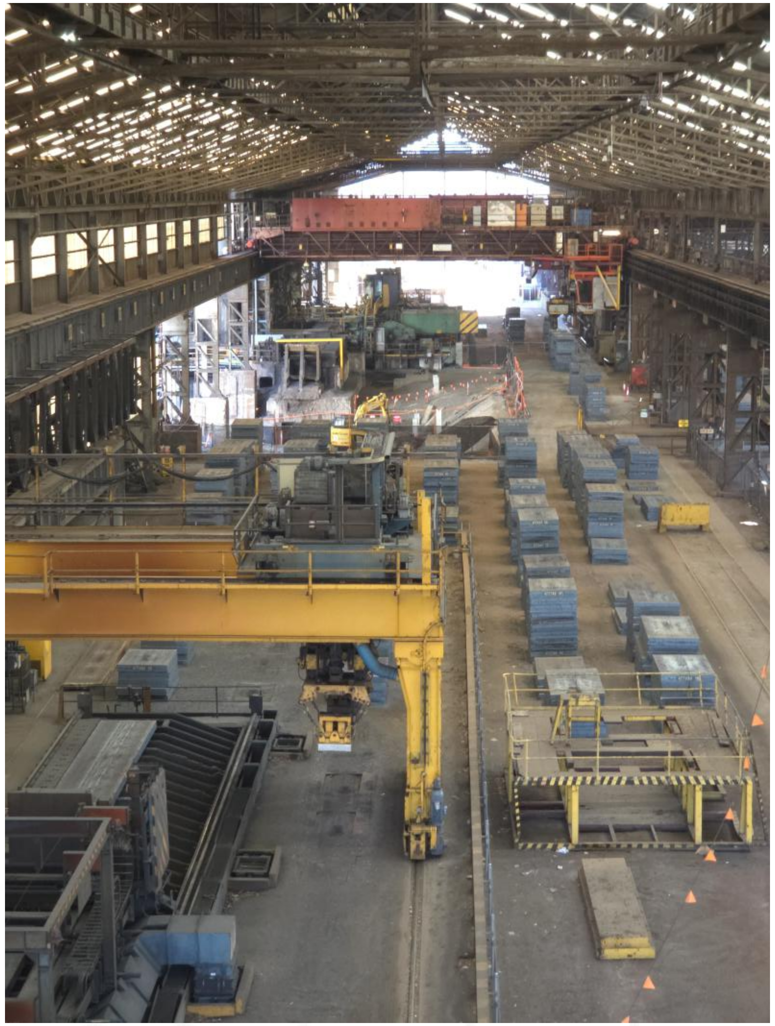
Problem Statement

- The changes in plant layout and throughput presented unknowns upstream of the proposed furnace, BlueScope Steel needed to gauge the impact on the slab yard and whether it could keep up with the increased demand.



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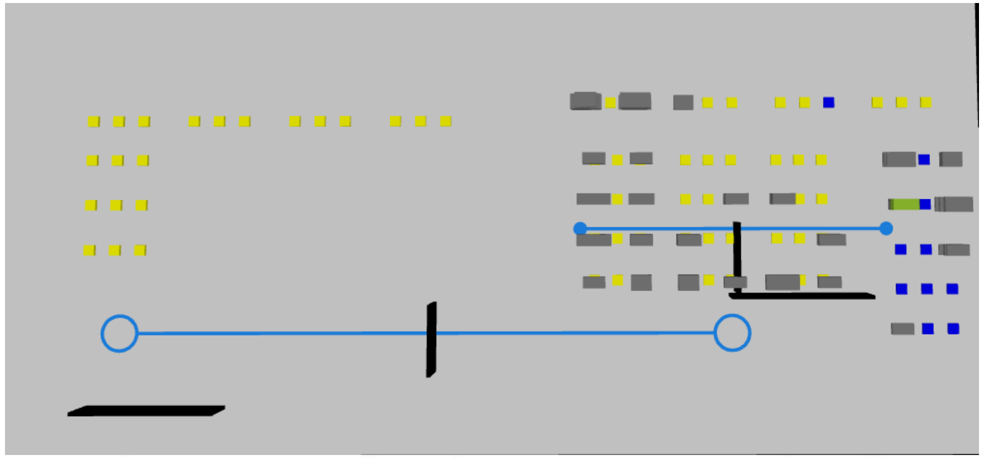
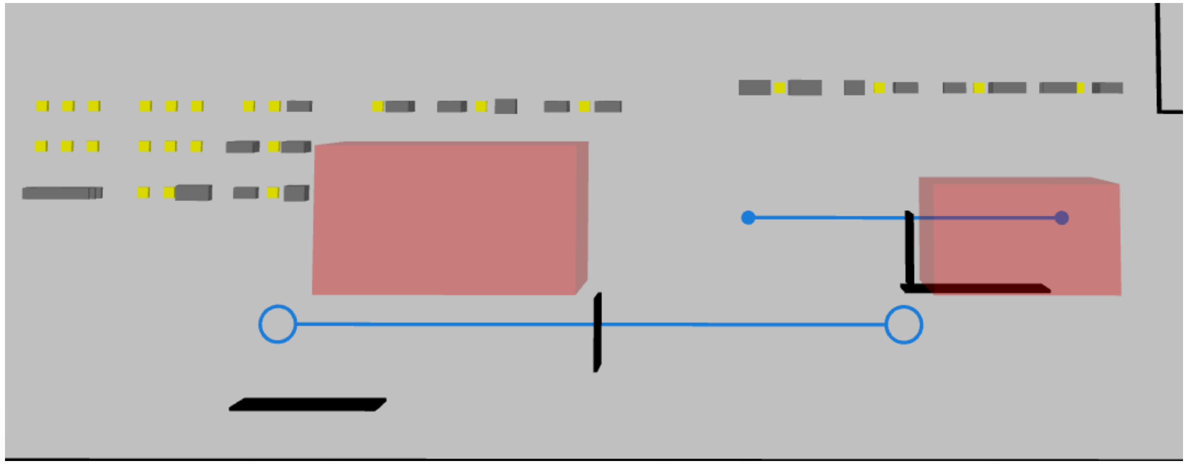
Problem Statement : Construction Phase

- During the construction of the proposed furnace, there would be a loss in storage space for the slabs and restrictions in the crane movement. It was required to gauge the impact of these construction phases on the Slab yard production.



Current State



Construction State

Problem Statement

- The problem has not been previously modelled,
- BlueScope had set up a contingency fund for the potential solutions to the problem.
- The business needed to be able to qualify and quantify the problems that would be created in the Slab yard process, to understand if it would threaten the project business case.

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Challenges the project faced:

- There was increased production ability, along with significant loss in slab storage area for preparation of slabs to go into the new furnace.
- The modelling of Crane interactions to facilitate the end goal of delivering slabs to furnace, which would have to move larger distances because of loss of storage areas.
- Priority-based task and movement management of the Cranes was necessary to prevent leaks in the system.
- Due to the restricted areas during construction phase, it was necessary to have logic for crane to avoid restricted areas during movement.
- Modelling of the Transfer Car to move slabs between yards, and management of space in the yards to always prioritise furnace and mill operation.
- Modelling of the Slab Cutting where some of the process steps are manually performed and require a separate delay scheduling.

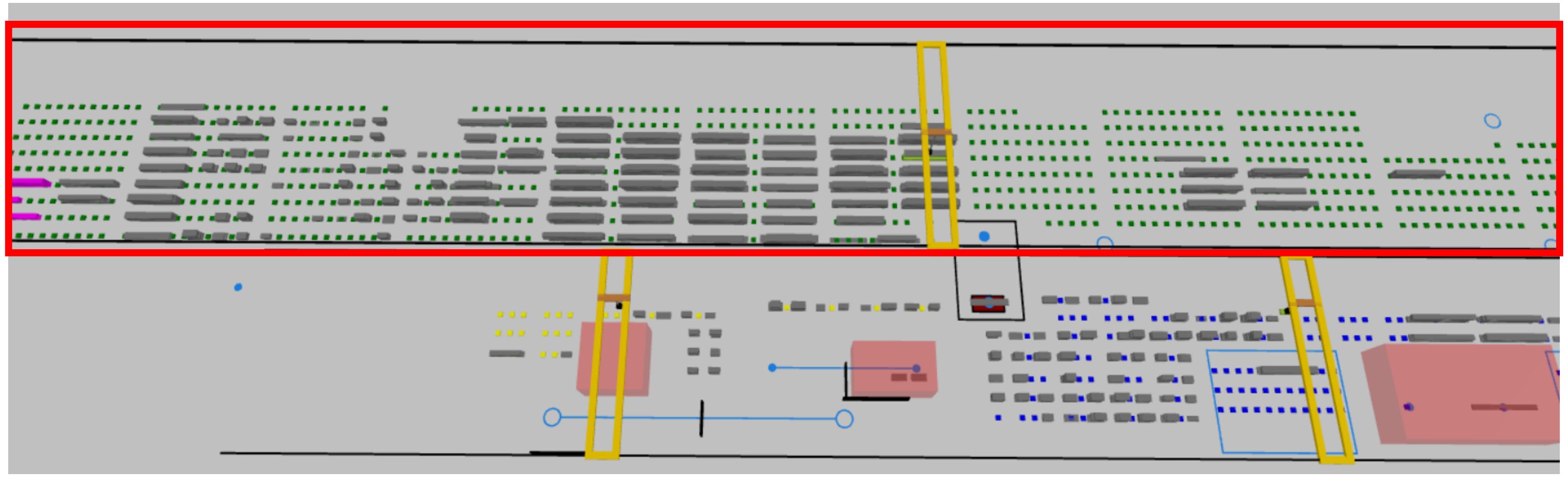
Why Simulation?

- Desktop Calculations were not enough to encompass the fidelity of the problem as :
  - Product range and associated manufacturing requirements such as throughput rates and heating durations were extremely variable and volatile.
  - Artificially creating a schedule to drive the calculations was not feasible, therefore, there was a need to use large chunk of historic real time data.
  - The real-life crane behaviors with their conflicts and interactions.
  - There was completely different complex scheduling for process further upstream impacting ability to flow material through process to Walking Beam Furnace.
  - Many different processes needed to be described, linked and balanced together for material to be able to flow material through all required steps.
- Hence an approach to find a solution through simulation was proposed as:
  - It was a time saving solution that was flexible enough to encompass all the requires calculations and interactions, while serving as a base to build further upon.

Why AnyLogic?

- BlueScope has familiarity with AnyLogic and has been using it for its modeling requirements in the past.
- The flexibility offered by AnyLogic in creating custom objects which were imperative to modeling a complex Slab Yard operations network.
- The ability to combine discrete event and agent-based modelling approaches in one model, which would enable the creation of custom crane objects.
- The ability to write modular code and freedom to customize, as necessary would help the model be a good foundation that can be built upon in further phases.

Upper yard



- All the slabs enter the process enter the upper yard on rail wagons, or as the customer refers to them, rakes.
- The crane in the upper yard has 3 tasks: unload rakes and stack slabs, place slabs on transfer car so that it can be accessed in lower yard, unload cut slabs from transfer car and store them in lower yard. These actions are dependent on downstream requirements and inventory levels.
- There are numerous limitations to slab stacking, such as maximum stack height, and what type of slabs can be placed on top of each other along with overhang constraints. The length of the slab determines which location is feasible for its placement.

Verification opportunity : The crane does not collide with the stacks while moving.
Validation opportunity : Crane Utilisation and Yard inventory utilisation.

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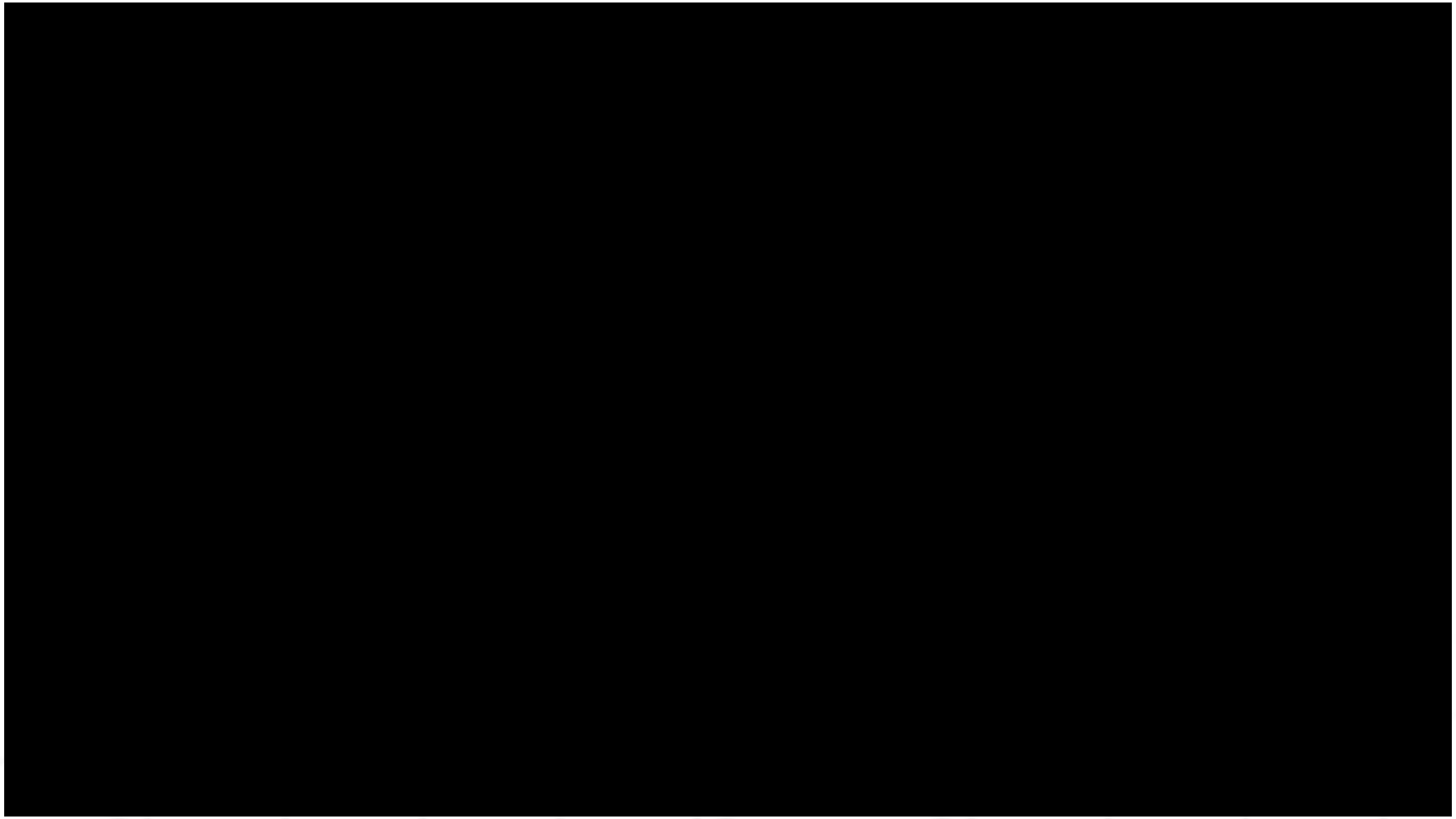
Rakes

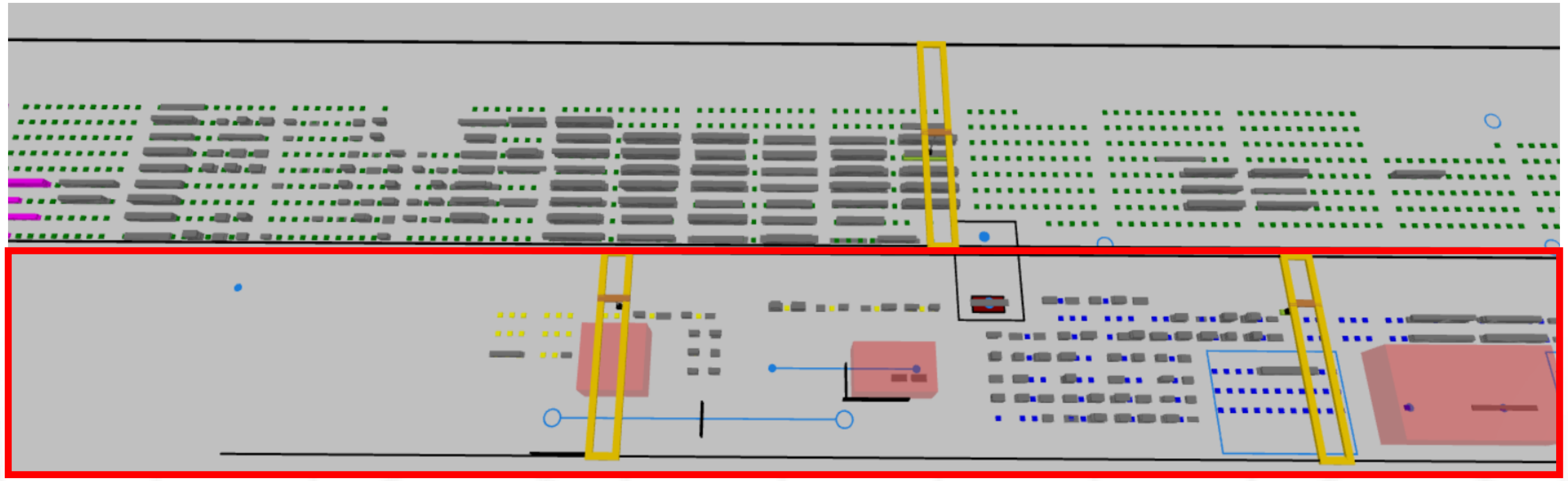
- Slabs are supplied to the upper yard via rakes
- A schedule of rakes, and the slabs they carry, is provided as input to the model.
- The crane looks for a suitable location and stacks the slabs in the yard.



Lower yard

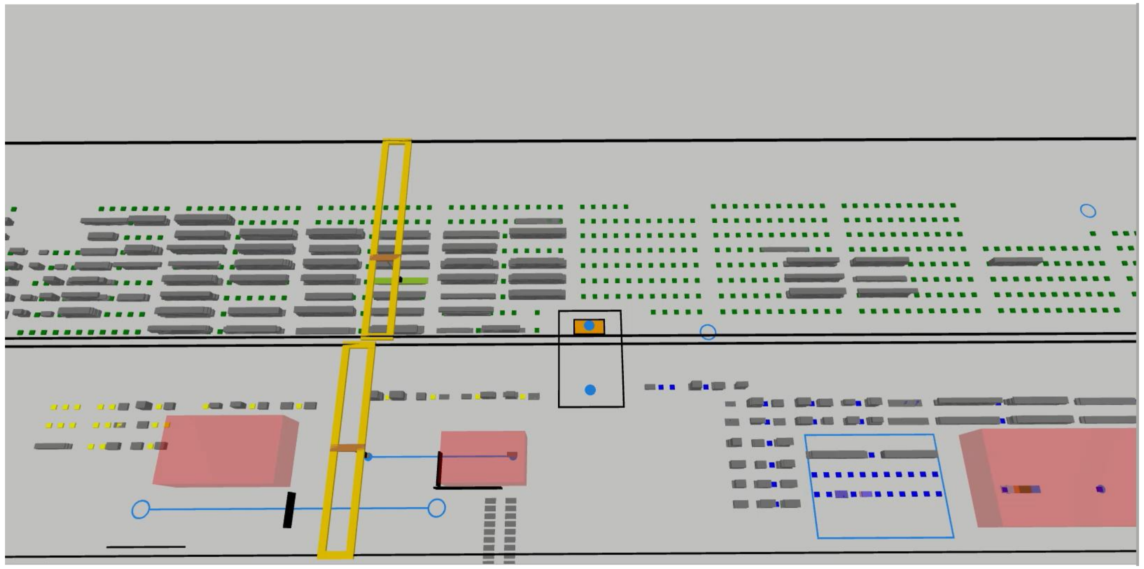
- This yard has the bulk of the operations such as slab cutting, furnace and rolling mill
- It also has 2 overhead cranes for slab movement. These cranes are on same rails and hence crane interaction needs to be considered
- The left crane is a magnet crane and can only lift 1 slab at a time. Its main task is to load the slabs on Furnace feed table based on a sequence provided as input
- The crane on right can lift multiple slabs at a time and is restricted by total weight as well as stack height
- There are multiple tasks for the right-side crane: unloading from transfer car, supplying slab to slab cutter, moving cut slabs from slab cutter compound, sending cut slabs not required soon back to transfer car (upper yard) and moving the cut slab stacks to charging area for left crane to use them

Verification opportunity : The cranes do not crash with each other.
Validation opportunity : Crane Lift statistics and Utilisation and Yard inventory utilisation, and the transfer car utilisation.



Transfer Car

- Transfer car is a single shared resource that transfer slabs between the two yards.
- The transfer car operates based on requests from each yard. This request is prioritised based on the task type. A queue based on priority is used.
- Whenever Transfer Car is requested, The yard where the transfer car is travelling to prioritises the transfer car task.



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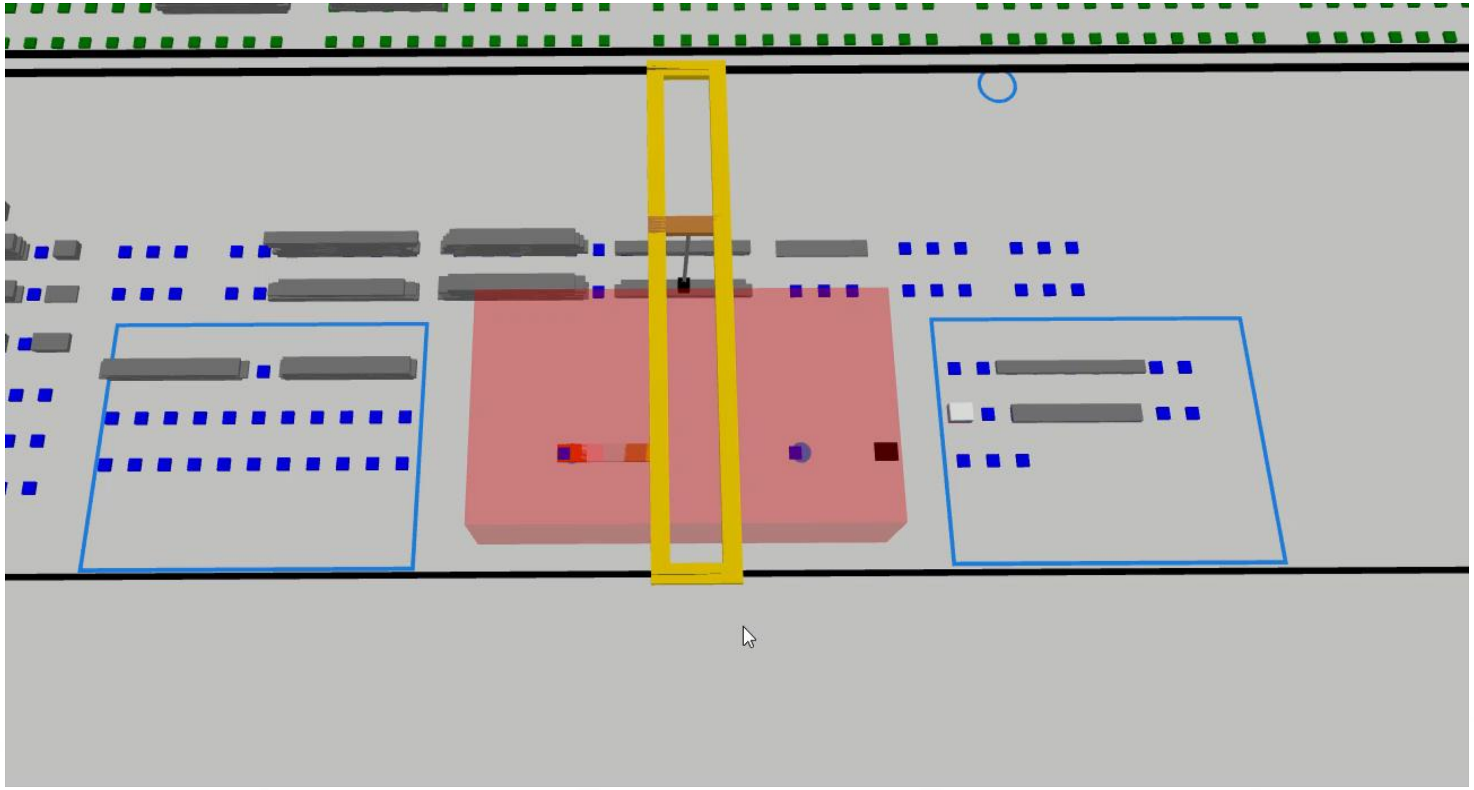
Slab cutter

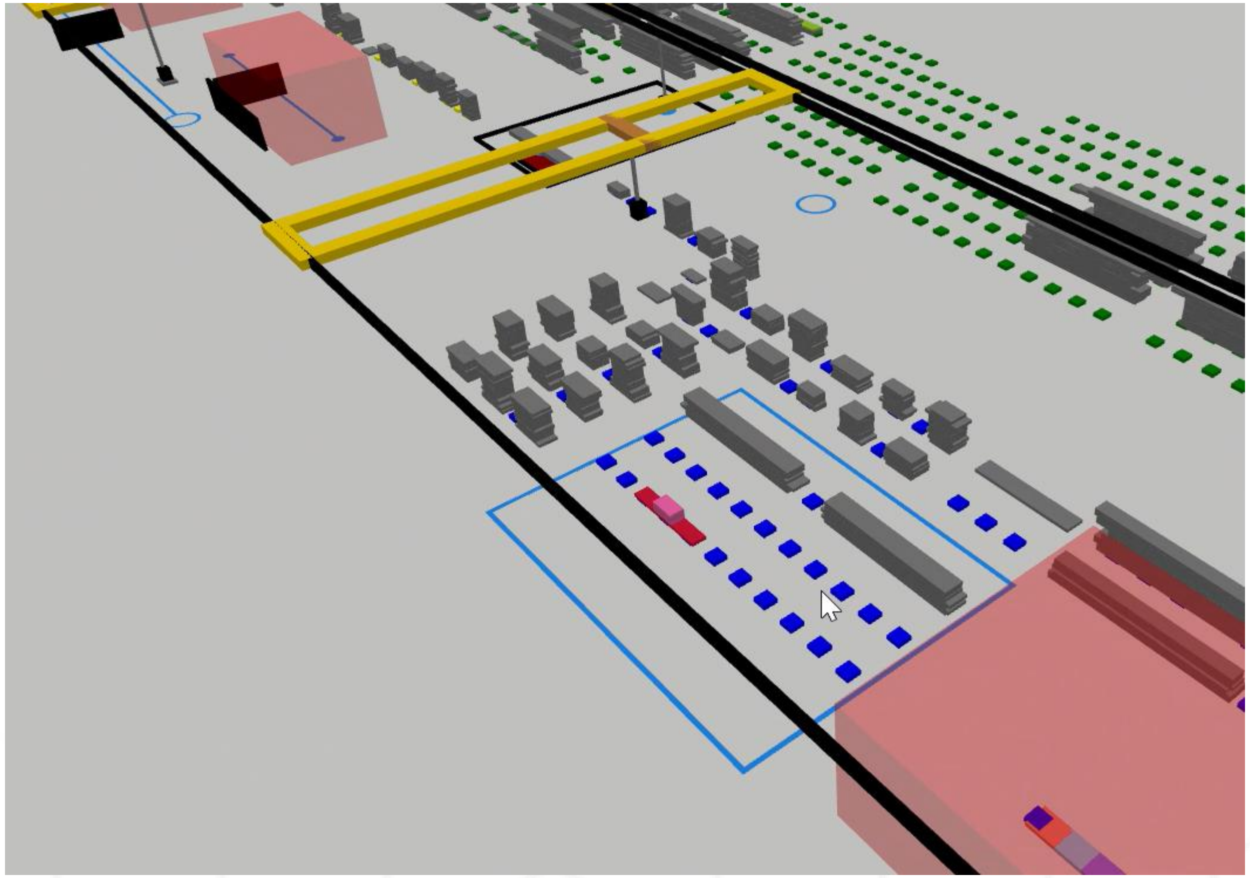
- Slab cutter has 2 cutting beds and will cut slabs into smaller sizes
- It has multiple process steps and cutting happens only on one bed at a time
- Loading slabs on cutting bed and moving cut slabs from cutting bed is done by another smaller crane (which was not modelled explicitly), but the process has been replicated using a time-based delay.
- The slab cutter operates on a need basis, where it asks for slabs from Upper yard as needed to maintain a lead in front of rolling demands.
- Downtime events are modelled on a planned and unplanned basis on this Cutter.



Verification opportunity : The Slabs are being cut in the required Order.
Validation opportunity : Cutter utilisation and the number of slabs cut per day. Downtime verification.

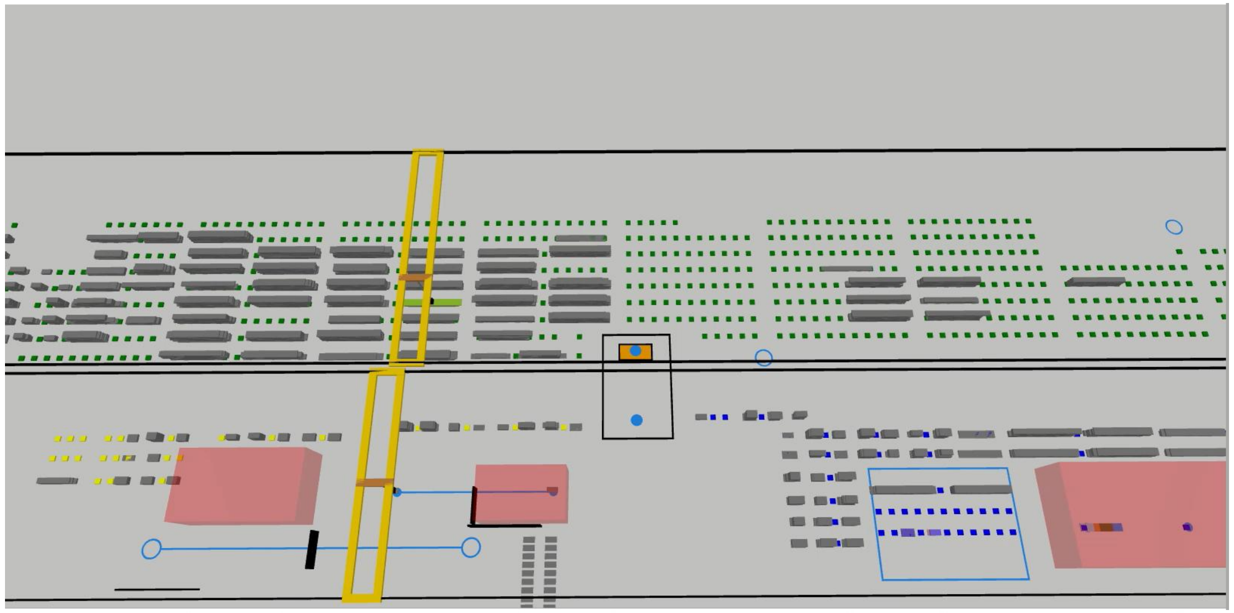
Crane Agents

- Crane agent has been modelled on top of a base crane components agent that has the architecture for movement from a point in space to another.
- Crane has been divided into three agents:
  - Crane Bridge: Moves in the horizontal x axis, houses crane Trolley agent
  - Crane Trolley: Moves in the y-axis, houses crane hoist agent
  - Crane Hoist: Moves in the vertical Z axis, houses the slab agents that need to be picked up
- Using an Agent based modelling approach, the two crane agents can communicate with each other.



Crane decision table: Data driven decision making

- Each crane can have multiple types of tasks, each task type can be at 3 importance levels:
  - 0: Cannot do this task currently
  - 1: Can do this task
  - 2: Should do this task (urgent)
- Based on the state of the system, crane will decide which task takes precedence
- All the possible states considering the importance levels are defined exhaustively in input table and is configurable by user based on preference.
- Cranes have been created as custom objects using ABM
- Cranes post request to other crane if they are in the way and then wait for access, Once crane completes any task, they check if other crane has requested for access and responds by giving way and communicating this to other crane



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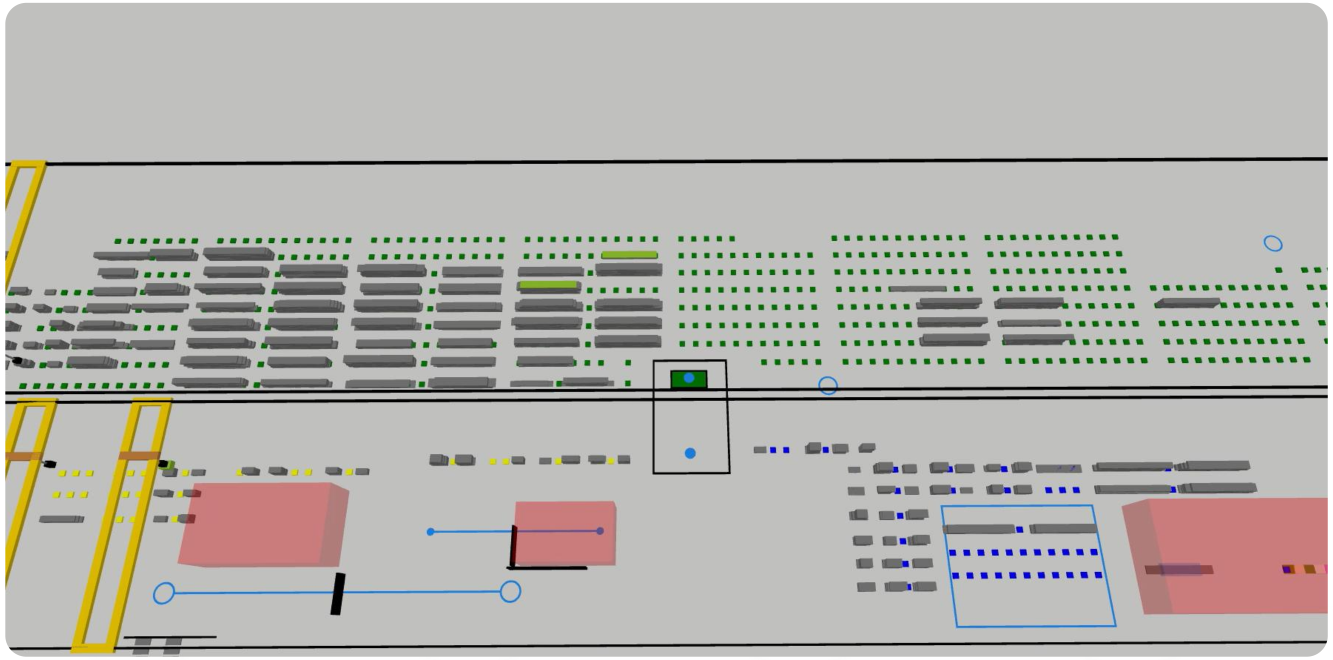
Crane restricted area movement:

- When Crane has to travel through a restricted space, The crane performs a series of intermediate steps to avoid moving through the restricted area:
    - First it moves to safe height in the vertical axis to avoid collision while movement
    - Then it moves out to a clear line to perform the horizontal movement to its destination.
- These restricted areas are configurable based on the scenario that is being run.



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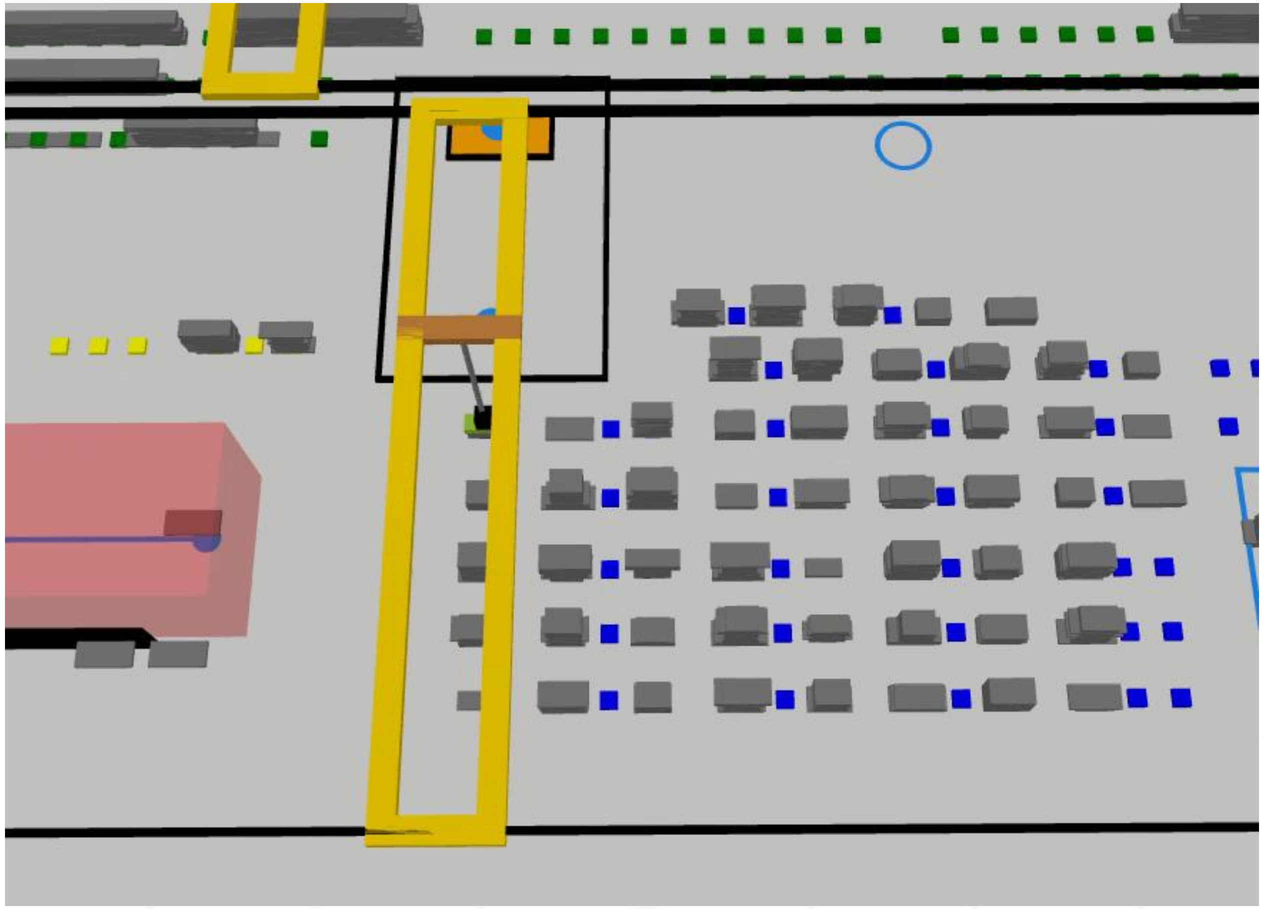
Digging of Slabs

- Slabs need to be delivered to the furnace in a particular sequence
- Crane gets instructions to pick a particular slab and move it to stack location near furnace
- The required slab maybe covered by other slabs. Hence Crane will have to move slabs above it to other locations before getting access to required slabs.
- The “digging logic” determines all these moves. It will also try to move more than 1 slab at a time (next few required slabs) to optimize lifts



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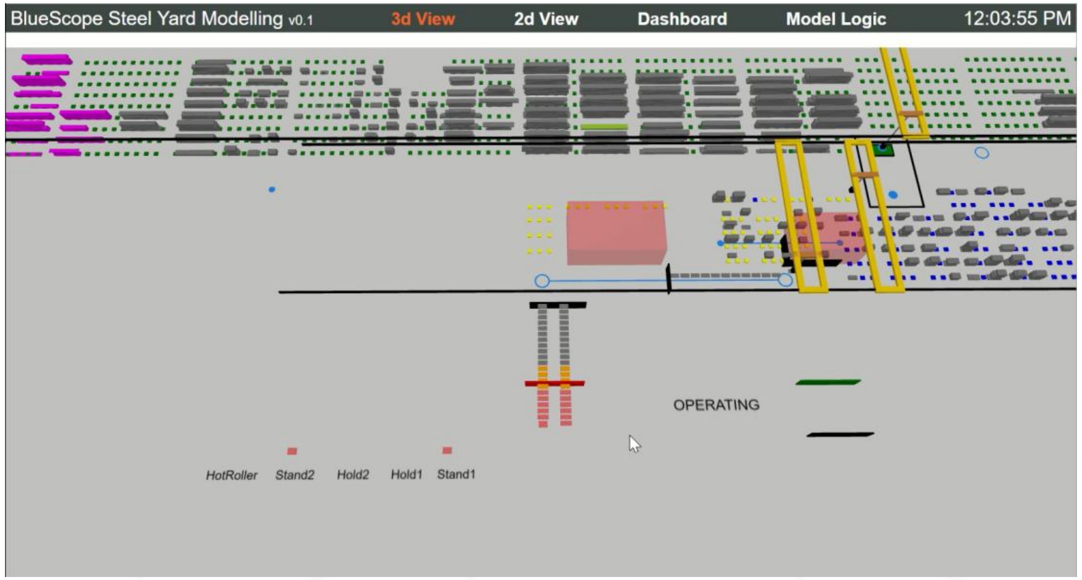
Furnace and Rolling Mill

- We modelled 3 modes of furnace operation:
  - Existing Operation : Single Pusher Furnace
  - Existing Operation : Dual pusher furnace
  - Future Operation : Walking beam furnace
- Based on Slab characteristics, they need to spend a minimum time inside the furnace
- Rolling is a multiple step process
  - Based on the Slab characteristics the processing time for each of the steps vary
  - There is no buffer in between so once slabs are pulled out of furnace, they cannot wait, they need to move from one process to another
  - A pacing logic was developed which makes sure of this.
- Downtime events are implemented on Planned and unplanned basis.

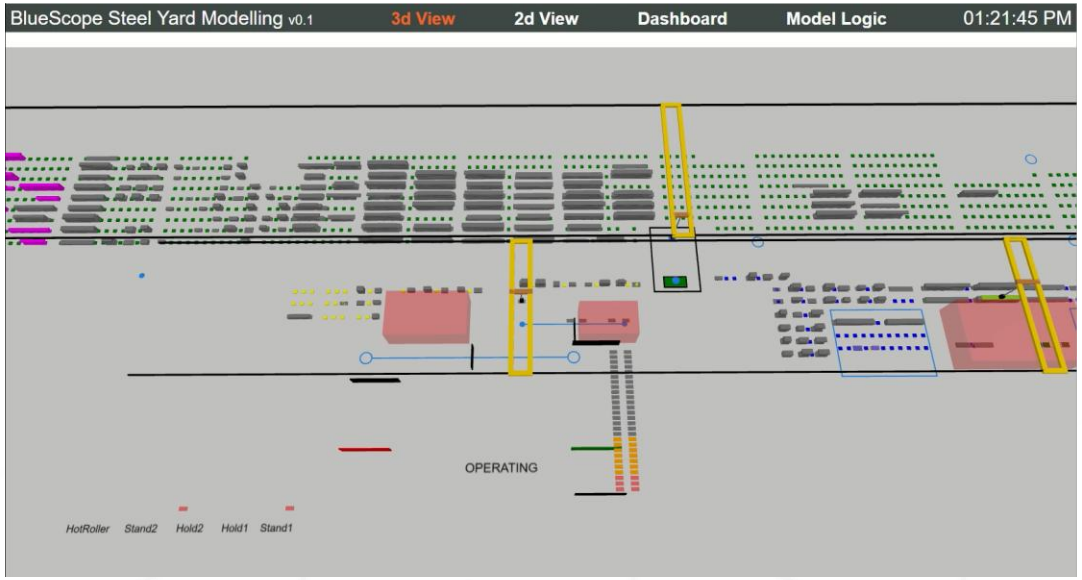
Verification opportunity : No slabs are sent to the furnace out of schedule.
Validation opportunity : Cycle time of slabs out of furnace, Downtime validation. Throughput in tons per hour.

Furnace Configurations

Single Pusher Furnace



Walking Beam Furnace



Model Verification & Validation

Model verification:

- Model verification was done via developer testing as well as independent testing by another developer
- Model animation was used to aid in verification
- Extensive reports were generated from model and analysed for verification

Metric	Method	Verdict
Slab Stacking	Checks in the model to recheck if the stacks fit the constraints.	✓
Crane collision with Stacks	The crane is ensured to move to a safe height before commencing the movement in any direction.	✓
Crane crashing with other crane.	A report was generated for the live position of the cranes on the bridge and checked for overlaps.	✓
Cut Slabs in required order	A report of the slabs cut was generated and verified.	✓
Slabs being sent to the furnace in correct order	A check has been built in the model to check the sequence of incoming slabs, along with reports	✓

Model Verification & Validation

Model Validation:

Model was validated on past 60 days of historical performance on following criteria

Metric	Method	Remarks	Verdict
Crane Utilisation	The model outputs the utilisation metrics which were compared with historical metrics.	Within 2 % for upper yard crane and lower yard left crane. Within 10% for lower yard right crane, which was agreed to be within consideration as the crane movements were modelled to be conservative.	✓
Mill Cycle Times and Throughput	The outputs were used to create trends and summary analysis of the slabs coming out of the mill and furnace.	Within 1 % for summary metrics and a similar trend was observed for the model cycle time.	✓
Slab Cutter throughput	Output metrics and charts were created and compared with anecdotal information	The comparison showed results that were as per expectations.	✓
Asset downtimes	Planned and unplanned downtimes were output and compared with historical available data	Exact match for Planned downtimes and within 5% deviation was observed for unplanned downtimes.	✓

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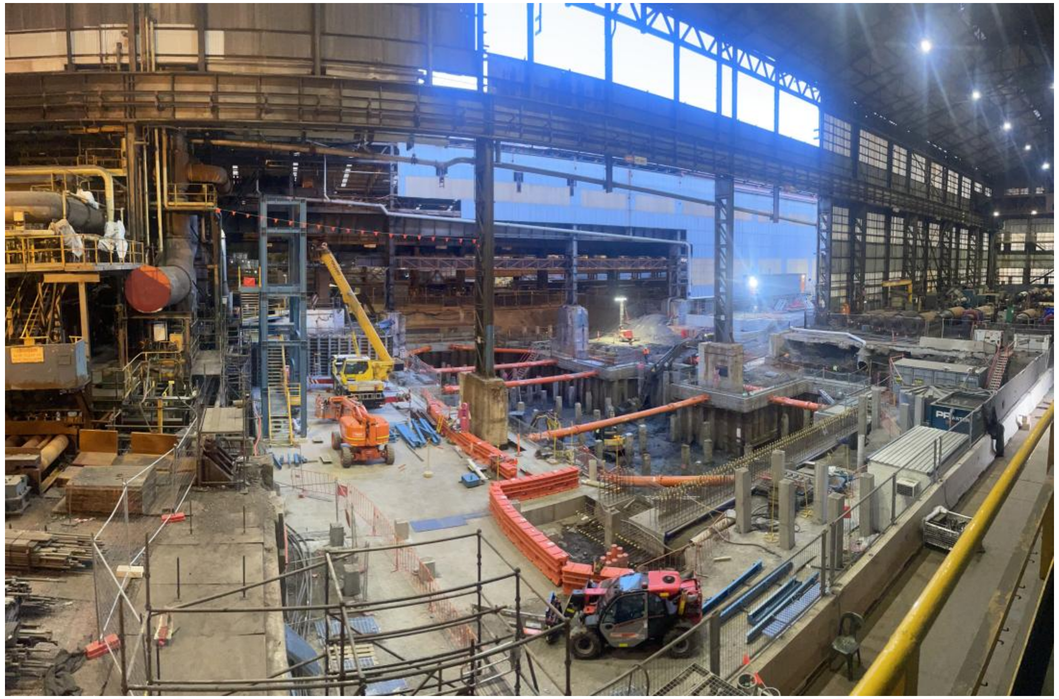
Outcome for Construction Phase

- During construction Phase,
  - Simwell's advice was that slabyard process would not inhibit mill production with delays to charging when operating in Single furnace mode.
  - Modeling indicated that the slabyard process would not be able to keep pace with Dual furnace operation.
  - The business has chosen to adopt that advice and chosen to operate in Single furnace operation without experiencing any challenges.



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Outcome for Future State

- BlueScope Steel was able to use the SimWell simulation to assess future state operations with the new walking beam furnace.
- BlueScope Steel gained confidence from the model outcomes that the upstream operations (the Slab Yard) had the capacity to meet future throughput without the need for additional large capital investments.

- Additionally:
  - BlueScope was able to identify and quantify the impact of some strategies which will help achieve target throughput levels. For example: move cut slabs to the upper yard more frequently and then move them back to lower yard when required, add more resources to bottleneck operation by doing hot seat shift changes
  - BlueScope was able to predict the magnitude of the increase in crane utilization in future state and potential actions to reduce this.

Thank you

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