

2 Variations of Model

- As per our project plan, we have **two** overall model: simple and complex.
- However, there are some sub models too:

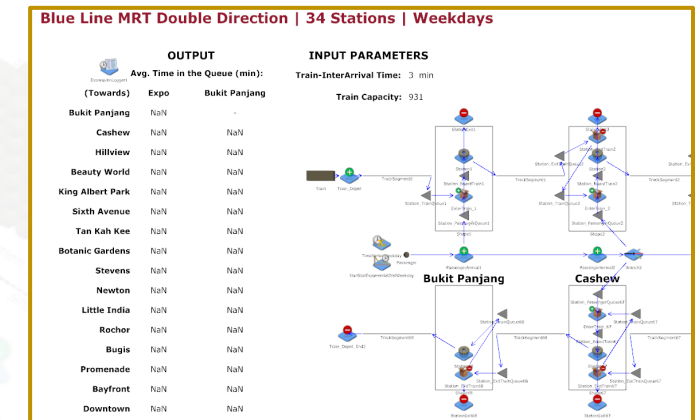
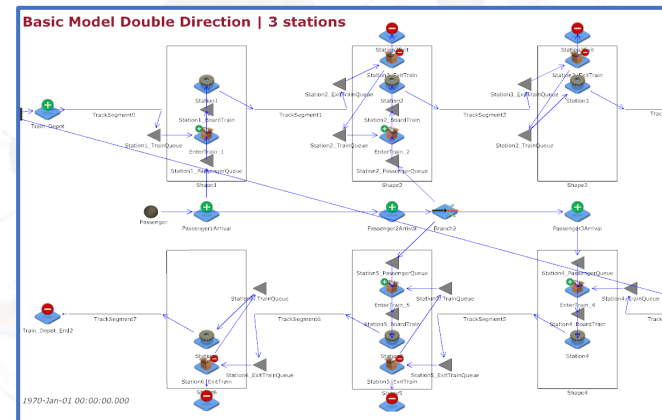
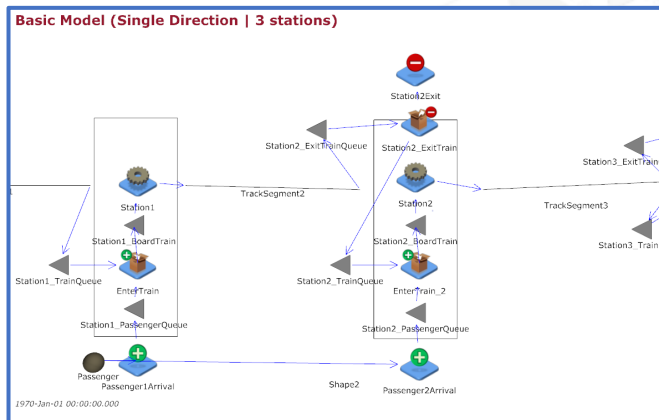
Simple Model 1: 3 Stations in 1 direction - *3_Stations_1_Direction.cfg*.

Simple Model 2: 3 Stations in 2 directions - *3_Stations_2_Direction.cfg*.

Complex Model (Weekdays) : Blue Line in 2 directions (34 Stations) on Weekdays - *Blue_Line_Weekday.cfg*.

Complex Model (Weekends) : Blue Line in 2 directions (34 Stations) on Weekends - *Blue_Line_Weekends.cfg*.

- For the subsequent slides on the Model Documentation, we will be going through the **Complex Model (Weekdays)**.



Assumptions

For our **Complex Model**, Blue Line on **Weekdays** and **Weekends** (differ only in terms of Passenger Interarrival Times).

Main Assumptions:

1. Train Interarrival times from the depots are constant parameters, subjected to user input.
2. Passenger Interarrival times at each station follow an exponential distribution whose rate varies according to the timeframe of the day (Morning Peak hours, Evening Peak hours and Non-peak hours). Different rates for weekdays and weekends too.
3. Passenger departures at each station is proportional to current train occupancy.
4. Passenger arrivals at each station alternate between opposite directions.
5. To generalize and simplify our simulation, train operations are from 0500hrs to 0000hrs for both Weekday and Weekend.

Note most of these assumptions are regarding the parameters of the Simulation model which Land Transport Authority would be able to provide better estimates.

Input Parameters

INPUT PARAMETERS

Train-InterArrival Time: 3 min

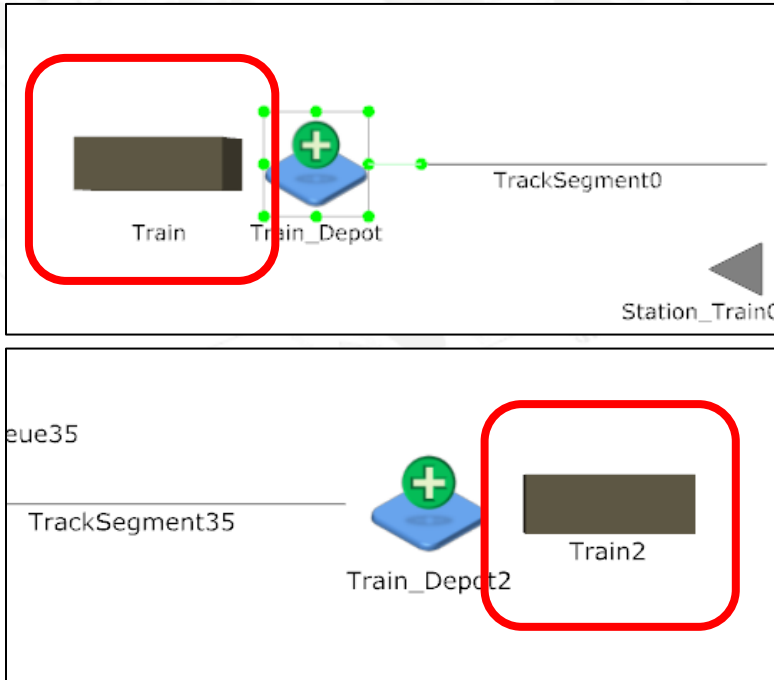
Train Capacity: 931

- The Train Interarrival time are parameters that are adjustable by the user before running the simulation using "InputValue".
- Similar for Train Capacity which is set to the current maximum capacity of a medium-capacity MRT line.

Input Editor - InputValue1		
Key Inputs	Options	Font
Format	Graphics	
Keyword	Default	Value
Description	None	
UnitType	None	TimeUnit
Value	0.0 h	3 min

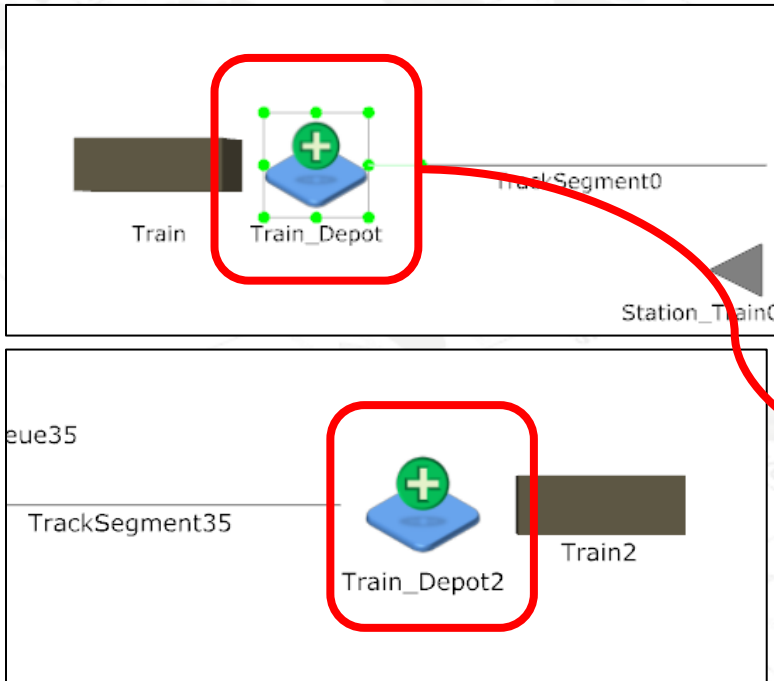
Input Editor - InputValue2		
Key Inputs	Options	Font
Format	Graphics	
Keyword	Default	Value
Description	None	
UnitType	None	DimensionlessUnit
Value	0.0	931

Model Train Arrivals



- The container trains are represented by a 3D block.

Model Train Arrivals



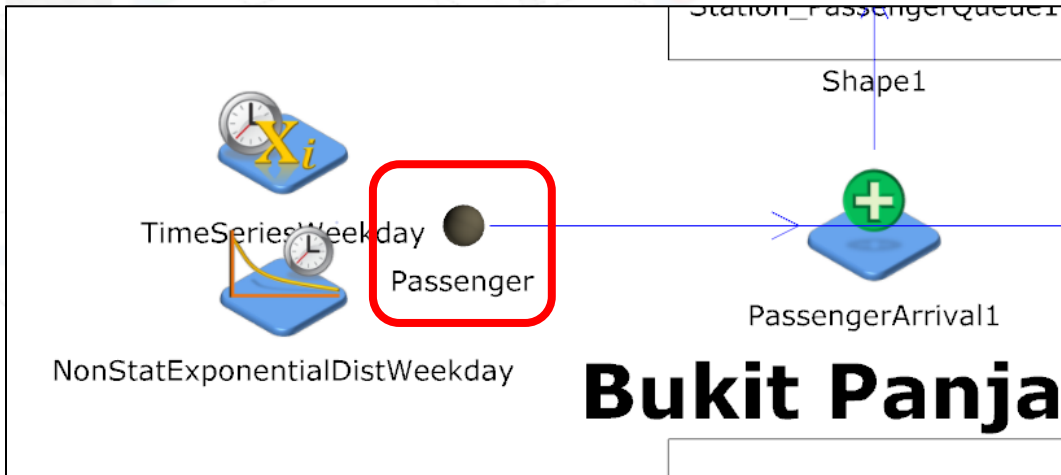
Input Editor - Train_Depot

Key InputsOptionsThresholdsMaintenanceFormatGraphics

Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment0
FirstArrivalTime	0.0 h	5 h
InterArrivalTime	2.7777777777...	InputValue1
EntitiesPerArrival	1	
PrototypeEntity	None	Train
BaseName	Generator Name	
MaxNumber	Infinity	2147483647

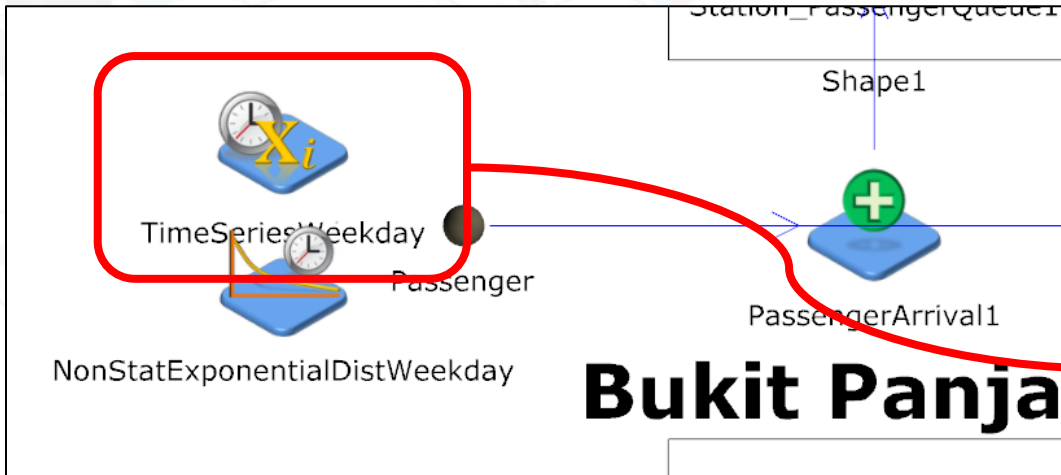
- Similar logic for the Train_Depot2.
- Note the InterarrivalTime for the Train Container follows the InputValue1 from the previous slide. First Arrival timing is set to 0500hrs as per operating hour.
- Arrivals are 1 by 1.

Passenger Arrivals



- The entity passenger is represented by a 3D sphere.
- **Note** for subsequent slides, the blue arrows represent the entities flow.

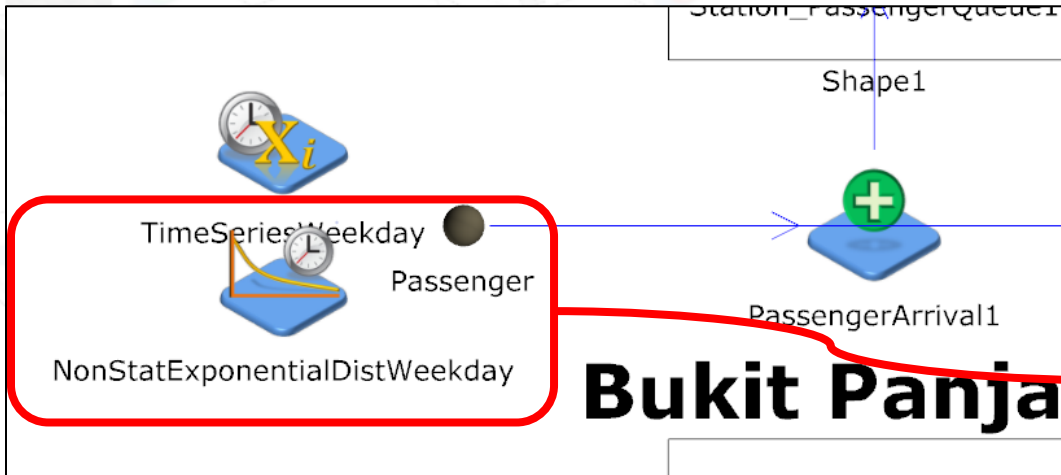
Passenger Arrivals



Input Editor - TimeSeriesWeekday		
Key Inputs Options Graphics		
Keyword	Default	Value
Description	None	
OffsetToFirst	TRUE	
UnitType	None	DimensionlessUnit
Value	None	{ 0 h 0 } { 5 h 0 } { 6 h 3480 } { 7 h 8580 } { 8 ...
CycleTime	Infinity h	24 h

- Timeseries of the expected cumulative number of passenger arrivals as a function of time over a day.
- The given example is for the **Weekday** version; hence the values will differ for the **Weekend** version.
- For example, the estimated average number of passenger arrivals per hour are as follows: 5100 (morning peak, 0600hrs – 0900hrs), 7980 (evening peak, 1900hrs – 2100hrs) and 3480 (non-peak).
- Hence the expected cumulative number of passenger arrivals would be { 0 h 0 } { 05 h 0 } { 06 h 3480 } { 07 h 3480+5100 } ...

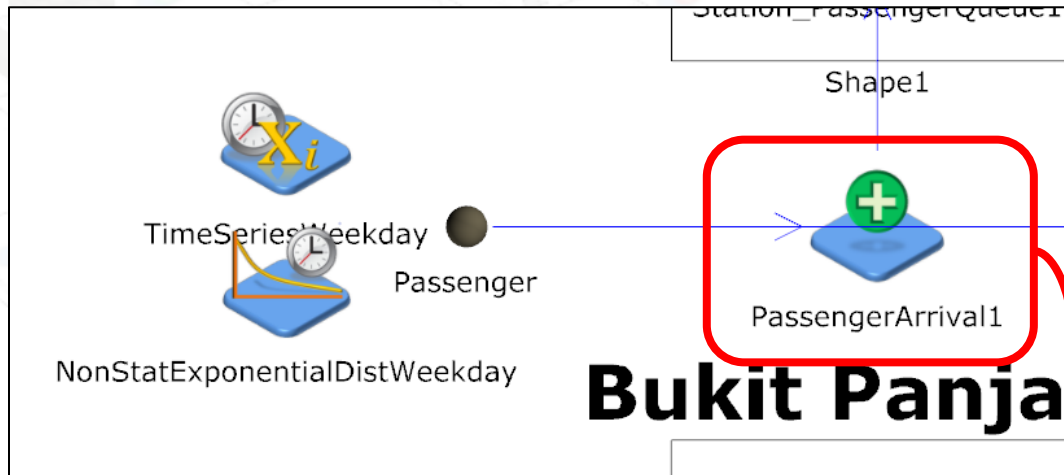
Passenger Arrivals



Input Editor - NonStatExponentialDistWeekday		
Key Inputs	Options	Graphics
Keyword	Default	Value
Description	None	
RandomSeed	None	1
MinValue	0.0 h	
MaxValue	Infinity h	
ExpectedArrivals	None	TimeSeriesWeekday
ScaleFactor	1.0	

- As mentioned, the expected arrivals for the exponential distribution takes in values from the Timeseries.

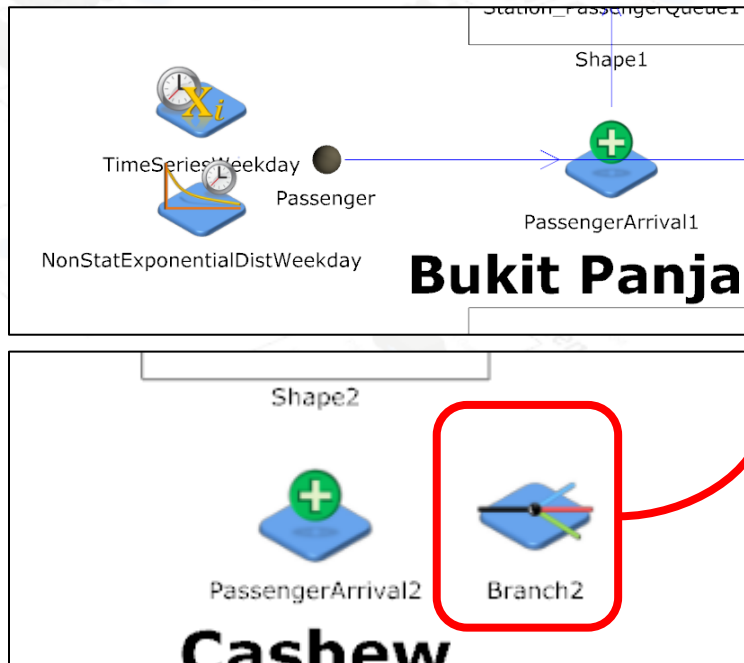
Passenger Arrivals



Input Editor - PassengerArrival1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_PassengerQueue1
FirstArrivalTime	0.0 h	5 h
InterArrivalTime	2.7777777777...	NonStatExponentialDistWeekday
EntitiesPerArrival	1	1
PrototypeEntity	None	Passenger
BaseName	Generator Name	
MaxNumber	Infinity	

- The arrivals are 1 by 1.
- Interarrival time follows the NonStatExponential Distribution.
- **Note** the First Arrival Time will be further discussed in later slides under Passenger Queues.

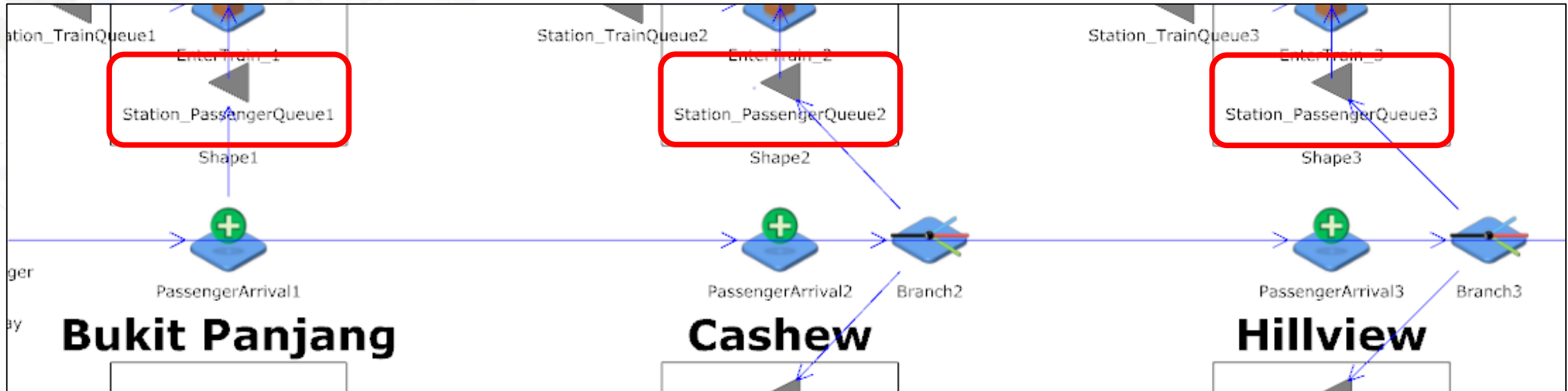
Passenger Arrivals



Input Editor - Branch2		
Key Inputs Options Graphics		
Keyword	Default	Value
Description	None	
NextComponentList	None	Station_PassengerQueue2 Station_PassengerQueue67
Choice	None	'this.NumberProcessed % 2 + 1'

- The passengers arriving at the middle stations can choose either of the two directions to travel.
 - Assumption: The arriving passengers will enter the both direction queues alternatively (1st passenger enters the queue towards Expo, then the 2nd passenger towards Bukit Panjang, 3rd passenger towards Expo, ...)
- E.g. "this.NumberProcessed % 2 + 1":
- 1 modulo 2 + 1 = 2
 - 2 modulo 2 + 1 = 1
 - 3 modulo 2 + 1 = 2
 - ...

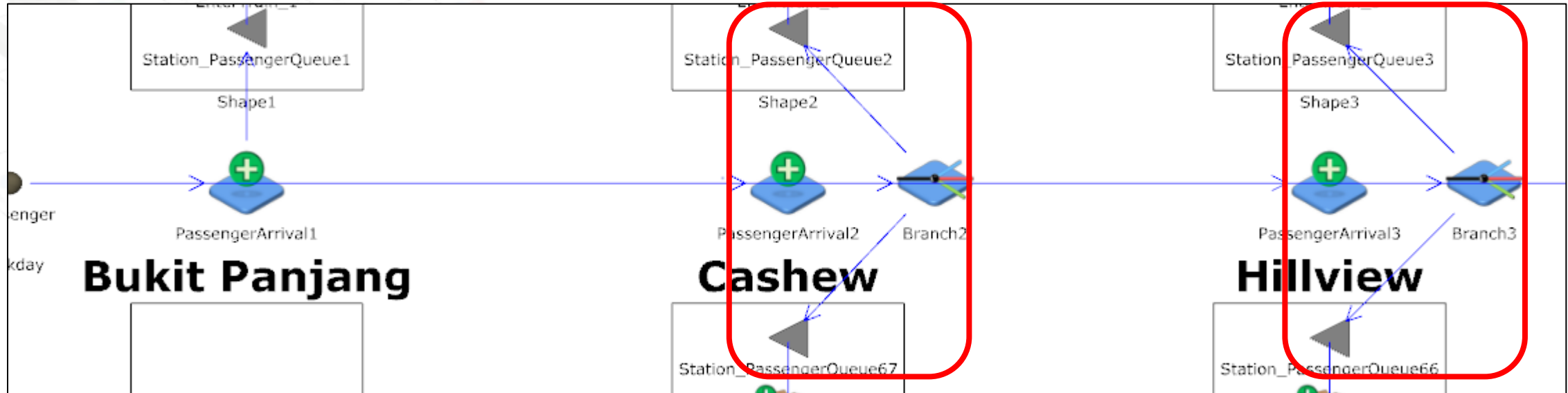
Passenger Queues



Problem 1:

- Note for **all** stations, the PassengerArrival entity generator starts from 0500hrs. However, the 1st train that leaves the depot at 0500hrs towards Expo only arrives at the 1st station (Bukit Panjang) at 0503hrs, 2nd station (Cashew) at 0504hrs, 3rd station (Hillview) at 0506hrs ...
- Hence passengers at the last few stations towards Expo will be waiting for very long since they begin queuing from 0500hrs but the 1st train only arrives around 0600hrs.

Passenger Queues



Problem 2:

- Note for **middle** stations, the PassengerArrival starts from 0500hrs. However, the 1st train that leaves the depot at 0500hrs towards Expo only arrives at the 2nd station (Cashew) at 0504hrs. At the same time, the 1st train that leaves the depot at 0500hrs towards Bukit Panjang arrives at the 2nd last station (Cashew) at 0608hrs ...
- Hence passengers generating for Cashew for example, should only enter the queue towards Expo from 0504hrs onwards and towards Bukit Panjang from 0608hrs.

Passenger Queues

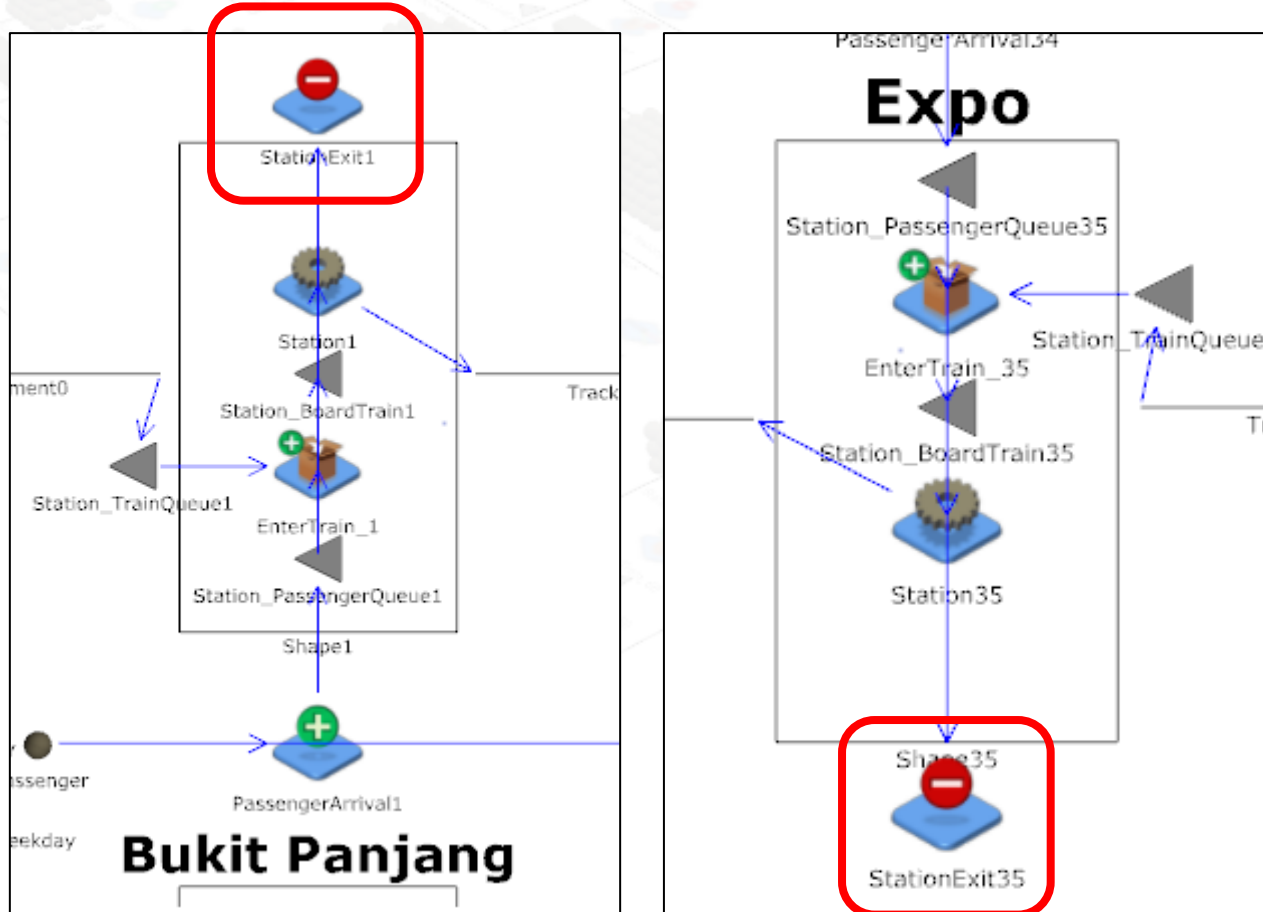
Input Editor - Station_PassengerQueue2		
Key Inputs	Options	Format Graphics
Keyword	Default	Value
Description	None	
Priority	0	
Match	None	
FIFO	TRUE	
RenegTime	None	0 h
RenegCondition	1	'this.SimTime < 5.06666666666667 [h]'
RenegDestination	None	StationExit2
MaxValidLength	10000	2147483647

Input Editor - Station_PassengerQueue67		
Key Inputs	Options	Format Graphics
Keyword	Default	Value
Description	None	
Priority	0	
Match	None	
FIFO	TRUE	
RenegTime	None	0 h
RenegCondition	1	'this.SimTime < 6.13333333333333 [h]'
RenegDestination	None	StationExit67
MaxValidLength	10000	2147483647

Solution to both problems: (For example Cashew Station)

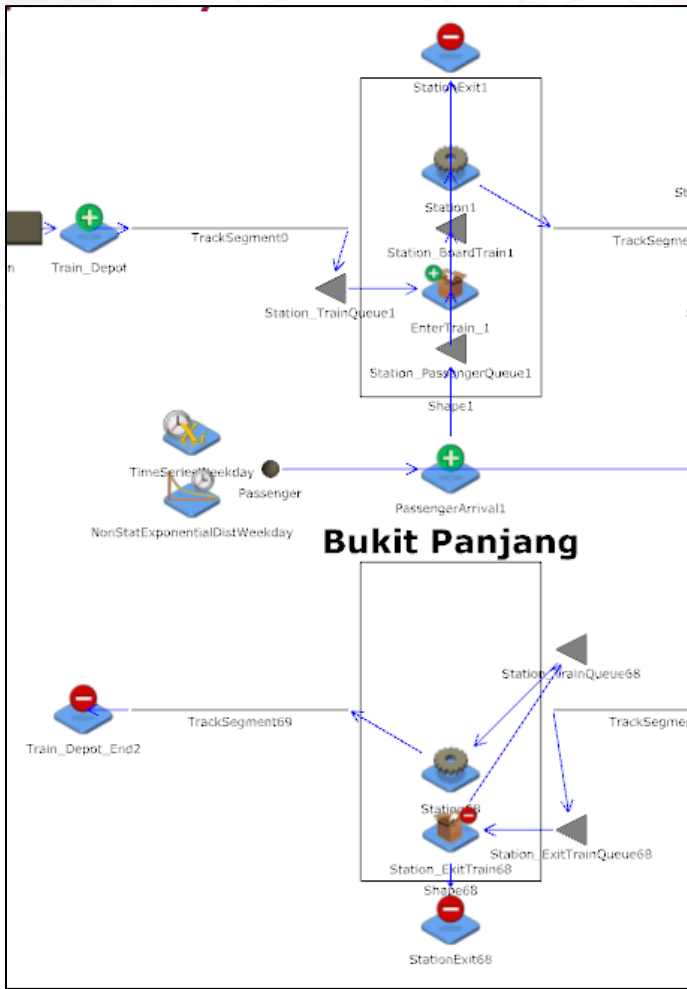
- We make use of reneging, whereby any passenger arriving before the 1st train arrives at the station in that direction will be reneged.
- The passengers who are reneged, would simply be sent to their respective station entity sinks for removal.

Passenger Queues



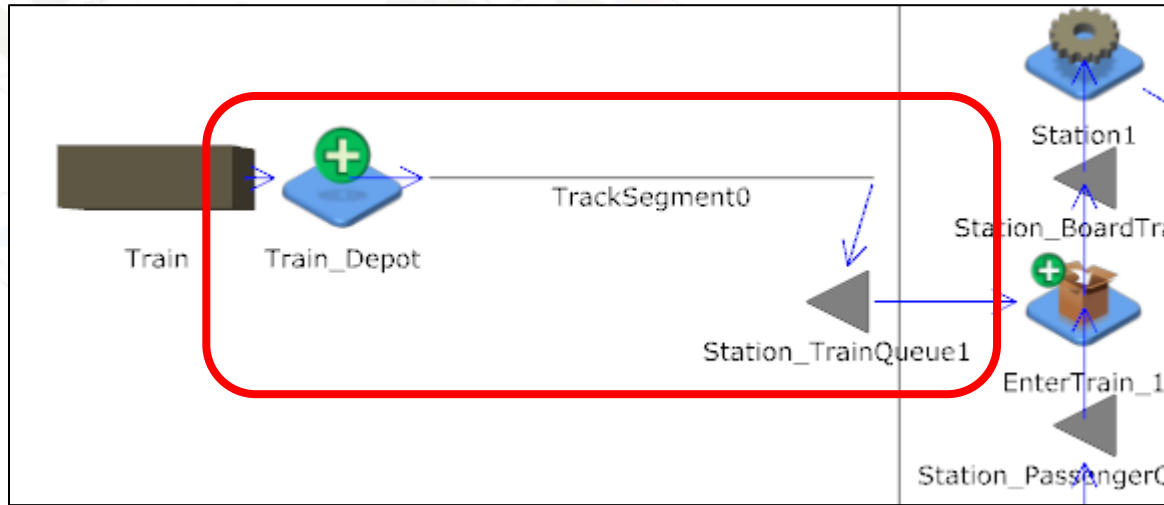
- **Note** for the 1st stations from both sides:
- Even though the passengers **only board** the train, there is an entity sink for the reneged passengers to exit.

Extreme End Stations



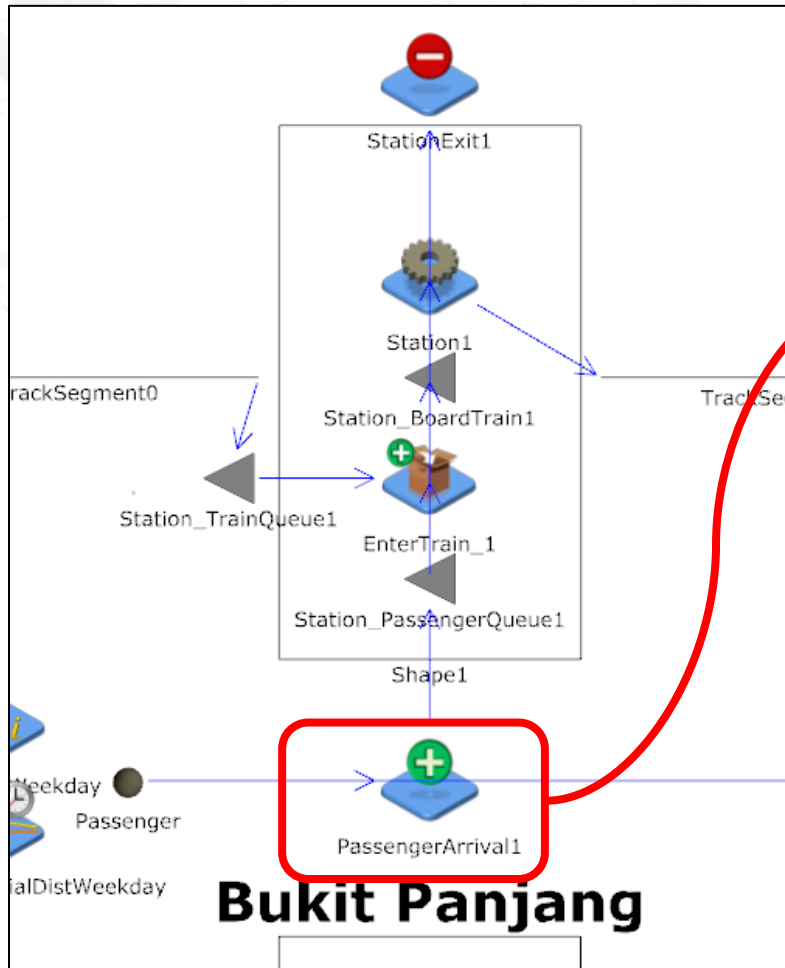
- The two stations are: **Expo** and **Bukit Panjang**. Similar logic for both stations.
- Two rectangular shapes to represent both sides of the MRT platforms going in the opposite direction. For example, Bukit Panjang: The top shape represents it as the 1st station and the bottom shape represents the last station of the line.
- The station name is in **bold**.
- **Note** the shapes are not mirror images. This is because passengers only board at the 1st station and only alight at the last station.

Extreme End Stations – 1st Station



- As the 1st station, the trains come directly from the Train_Depot.

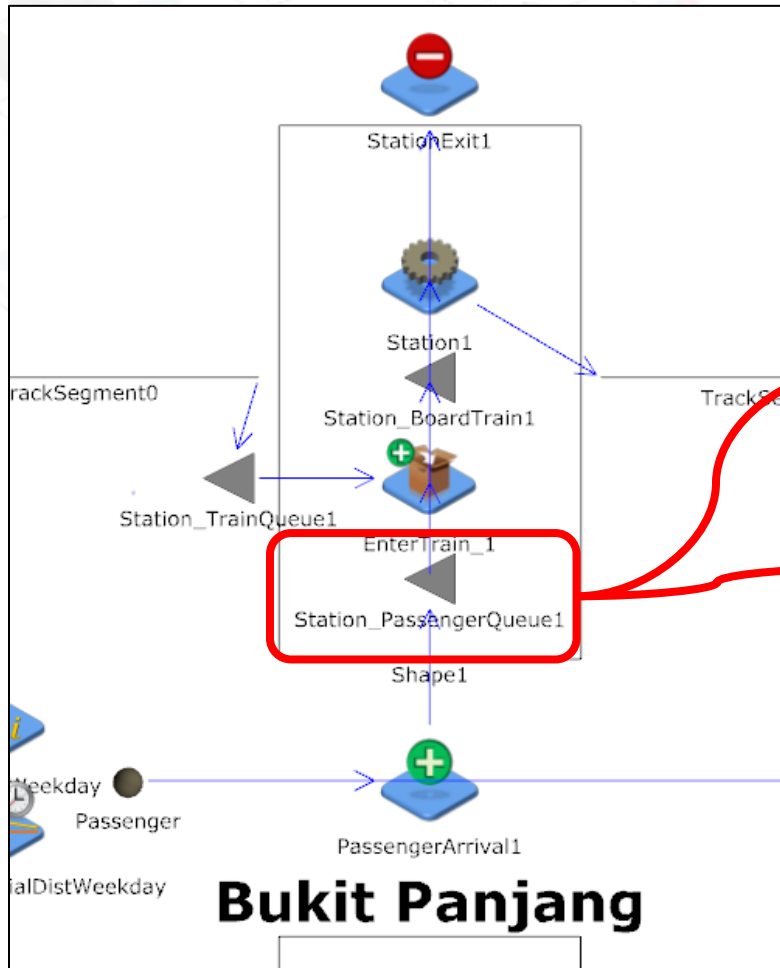
Extreme End Stations – 1st Station



Input Editor - PassengerArrival1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_PassengerQueue1
FirstArrivalTime	0.0 h	5 h
InterArrivalTime	2.777777777...	NonStatExponentialDistWeekday
EntitiesPerArrival	1	1
PrototypeEntity	None	Passenger
BaseName	Generator Name	
MaxNumber	Infinity	

- For the extreme stations, there is no branching as arriving passengers only enter 1 queue towards the other end.

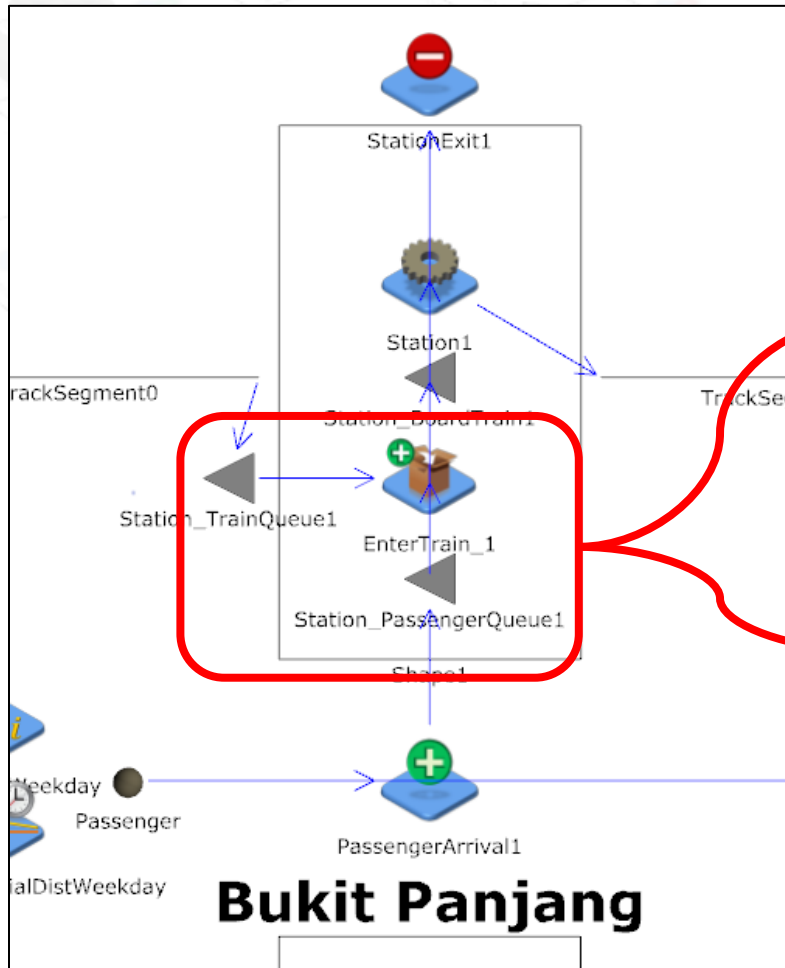
Extreme End Stations – 1st Station



Input Editor - Station_PassengerQueue1		
Key Inputs	Options	Format
Keyword	Default	Value
Description	None	
Priority	0	
Match	None	
FIFO	TRUE	
RenegTime	None	0 h
RenegCondition	1	'this.SimTime < 5.05 [h]'
RenegDestination	None	StationExit1
MaxValidLength	10000	2147483647

- The Queue is FIFO basis and the maximum number of passengers in the queue is kept to be the largest number possible. This assumes there is no limit on the number of passengers on the MRT platforms.

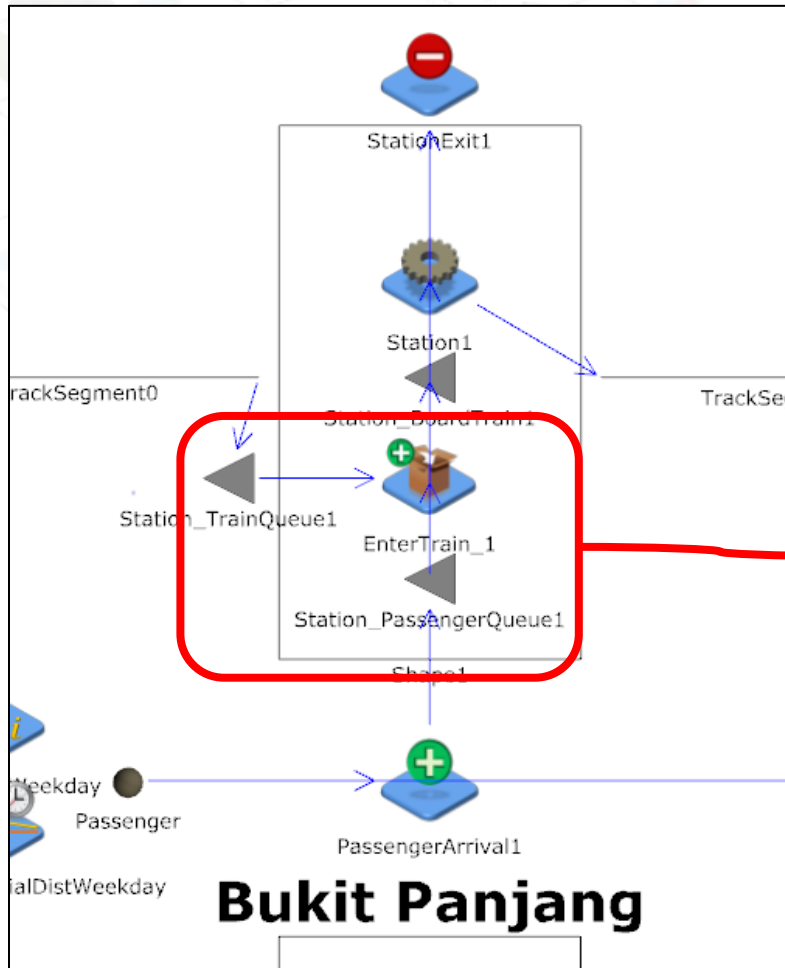
Extreme End Stations – 1st Station



Input Editor - EnterTrain_1		
Key Inputs	Options	Thresholds
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain1
WaitQueue	None	Station_PassengerQueue1
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	min([Station_PassengerQueue1].QueueLength,[InputValue2].Value)
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue1

- The Packing takes in Passenger entity from the Passenger Queue and the Container, Train is from the Train Queue.

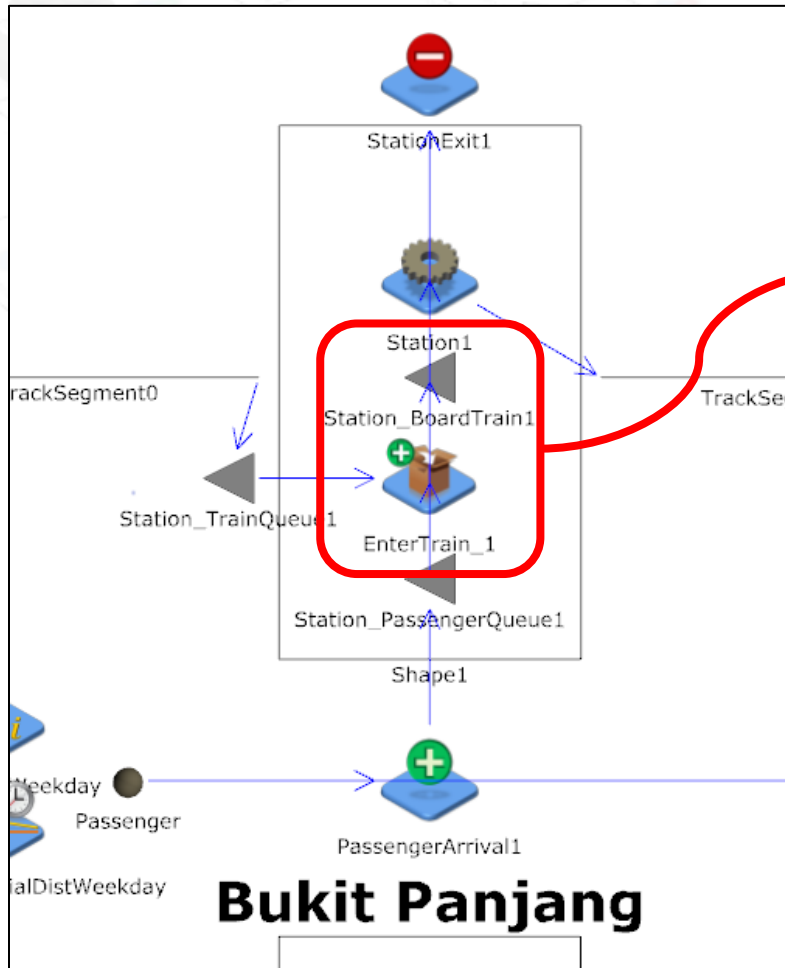
Extreme End Stations – 1st Station



Input Editor - EnterTrain_1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain1
WaitQueue	None	Station_PassengerQueue1
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	min([Station_PassengerQueue1].QueueLength,[InputValue2].Value)
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue1

- The number of Passengers to be packed into the Train is the minimum between the number of Passengers in the queue and train maximum capacity (InputValue2).
- This is to ensure that if the train is full, no passengers are allowed to board the train.

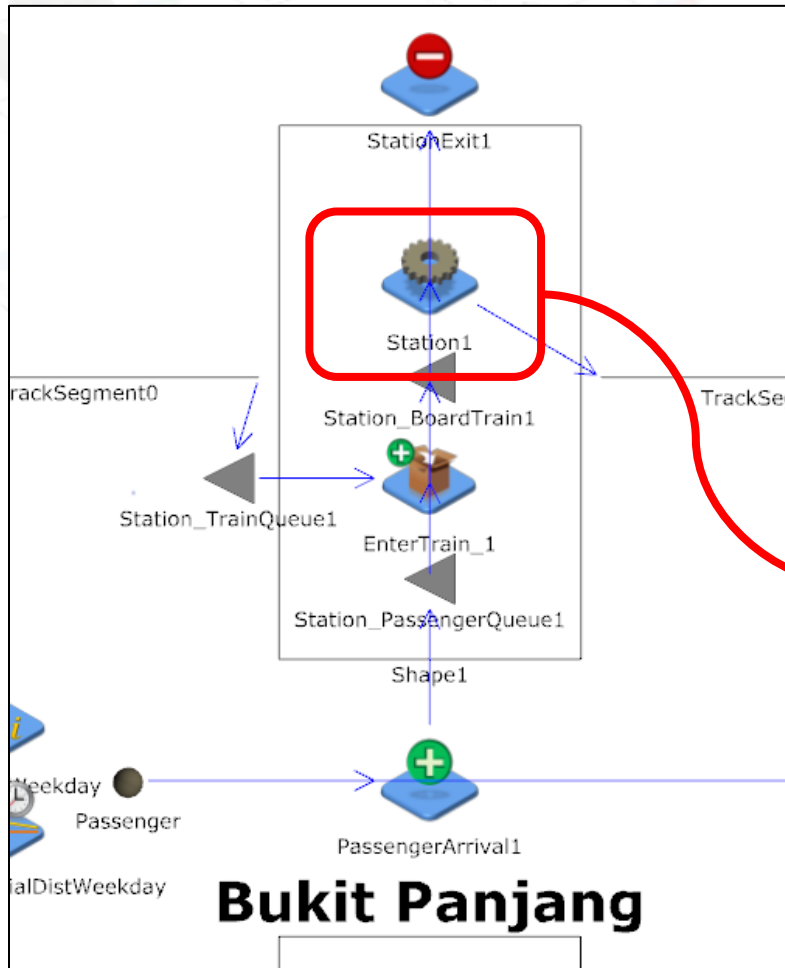
Extreme End Stations – 1st Station



Input Editor - EnterTrain_1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain1
WaitQueue	None	Station_PassengerQueue1
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	min([Station_PassengerQueue1].QueueLength,[InputValue2].Value)
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue1

- The next component for the Train filled with passengers is the boarding queue to enter the server, Station1, where we simulate the duration that the train doors are kept open.

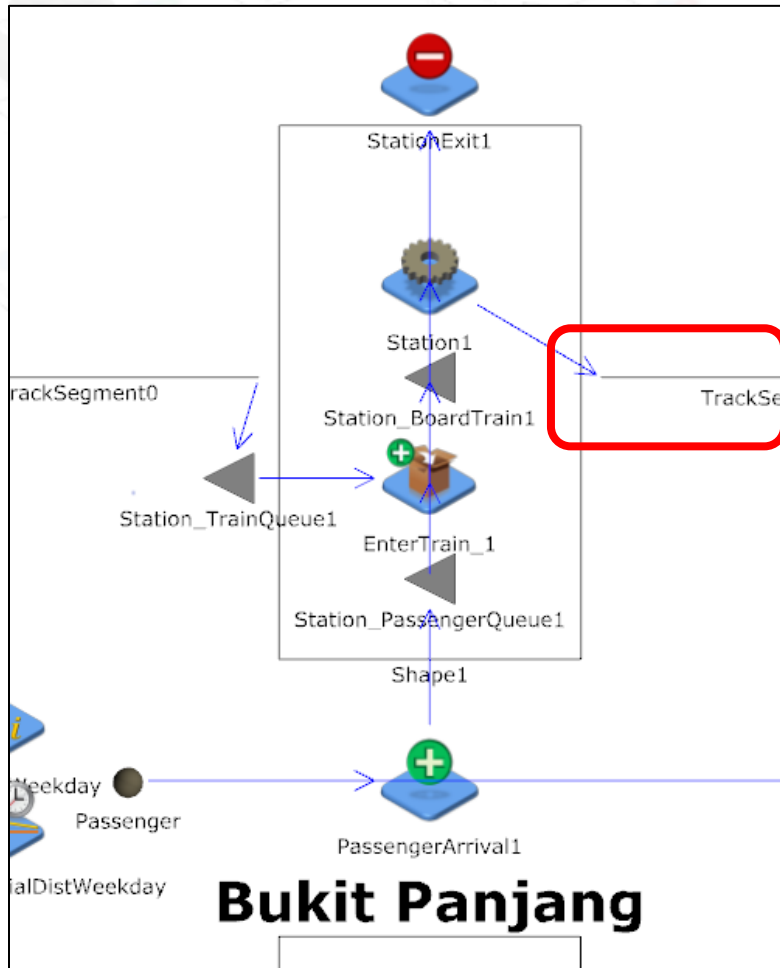
Extreme End Stations – 1st Station



Input Editor - Station1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment1
WaitQueue	None	Station_BoardTrain1
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

- As mentioned earlier, the ServiceTime of 0.33 min is to simulate the duration that the train doors are kept open.
- The ServiceTime is assumed to be 0.33 min for every station.

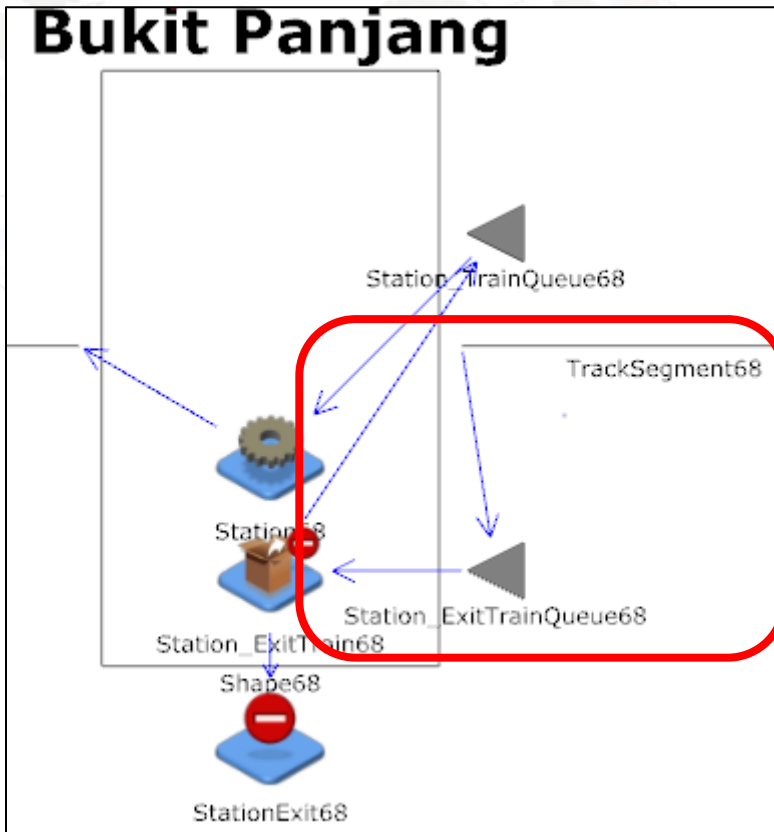
Extreme End Stations – 1st Station



Input Editor - Station1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment1
WaitQueue	None	Station_BoardTrain1
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

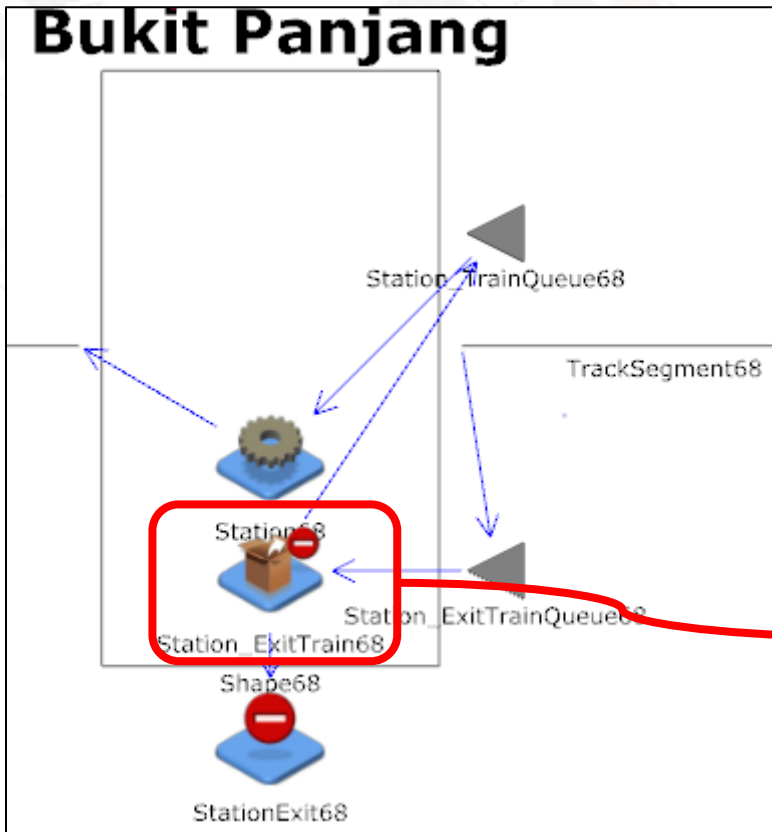
- The next component for the Train with passengers would simply be the next Station.

Extreme End Stations – Last Station



- As the last station, the trains come from the 2nd last station and enter the queue to be unpacked.

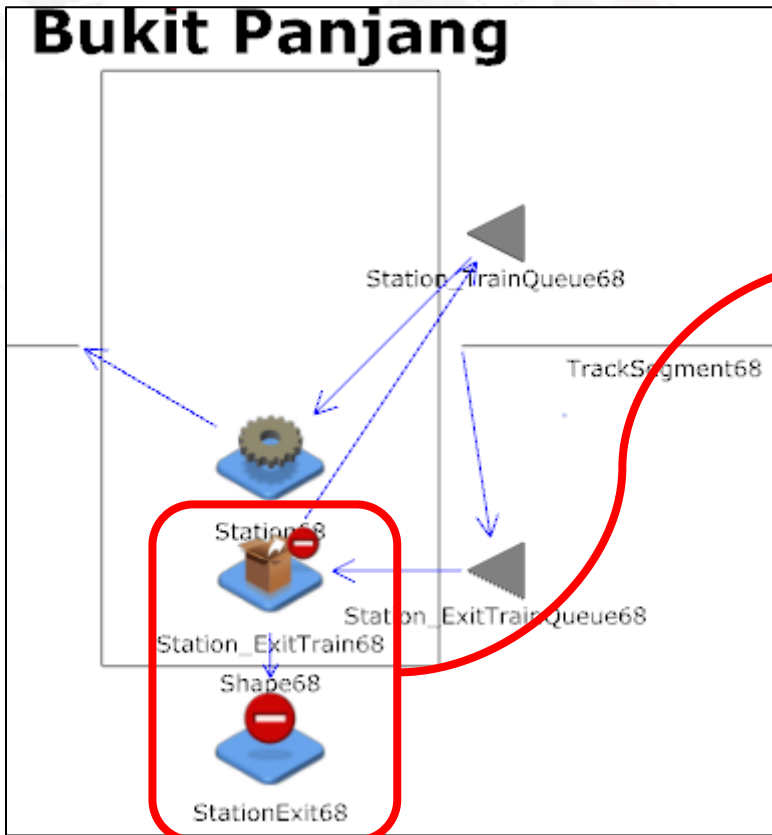
Extreme End Stations – Last Station



Input Editor - Station_ExitTrain68		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit68
WaitQueue	None	Station_ExitTrainQueue68
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	this.Container.Count
NextForContainers	None	Station_TrainQueue68

- Since this is the last station, all the passengers in the Train container should exit (unpack). Hence the maximum number of entities to be removed is set to be the number of passengers in the train.

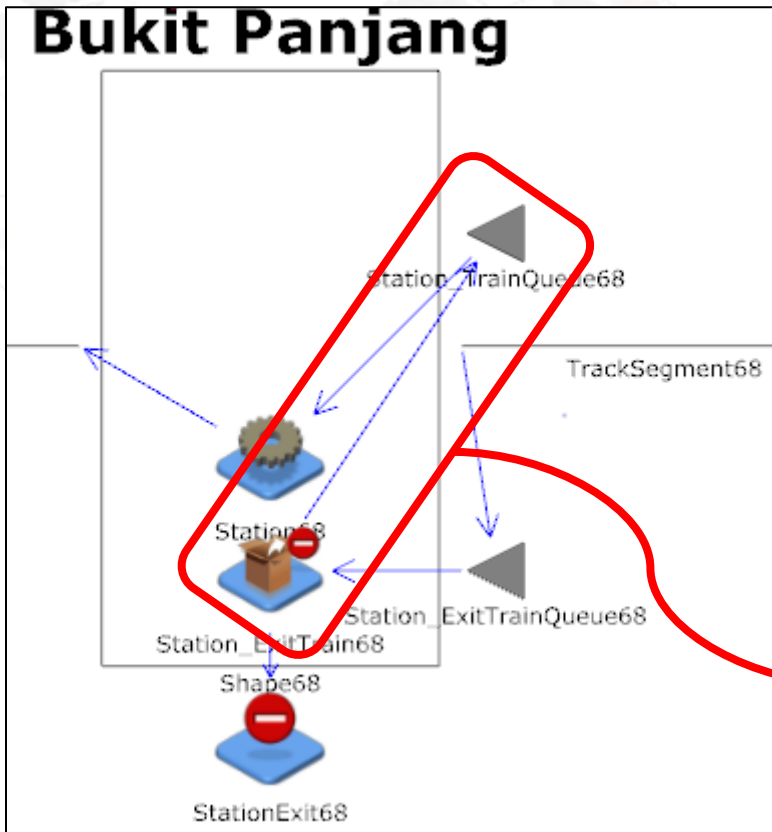
Extreme End Stations – Last Station



Input Editor - Station_ExitTrain68		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit68
WaitQueue	None	Station_ExitTrainQueue68
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	this.Container.Count
NextForContainers	None	Station_TrainQueue68

- The next component for the passenger entities who exited the train would be the StationExit entity sink.

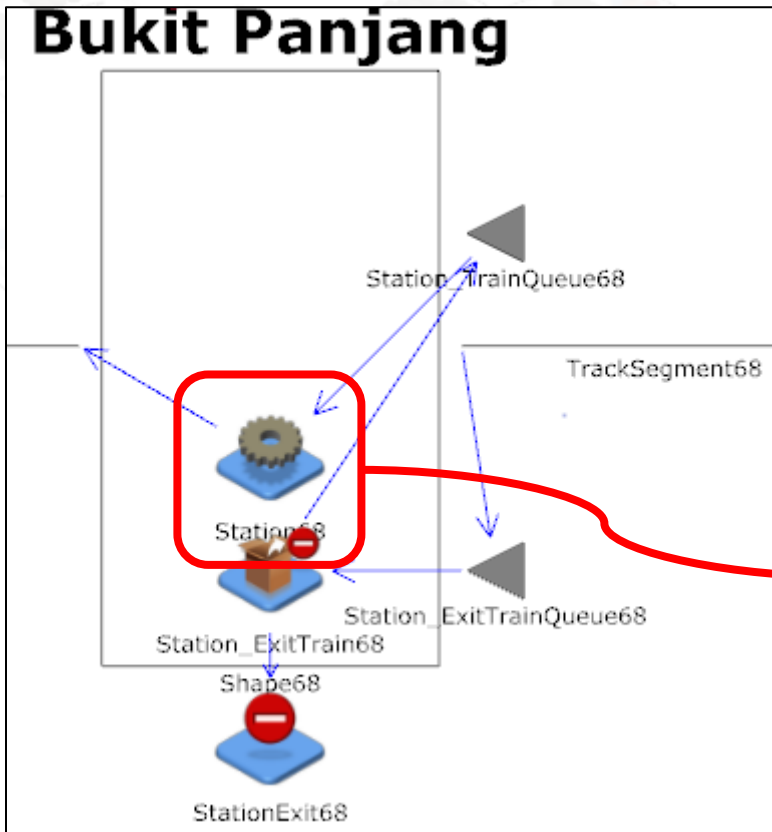
Extreme End Stations – Last Station



Input Editor - Station_ExitTrain68		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit68
WaitQueue	None	Station_ExitTrainQueue68
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	this.Container.Count
NextForContainers	None	Station_TrainQueue68

- The next component for the empty Train would be the queue to enter the Station Server where we once again simulate the duration that the doors are open.

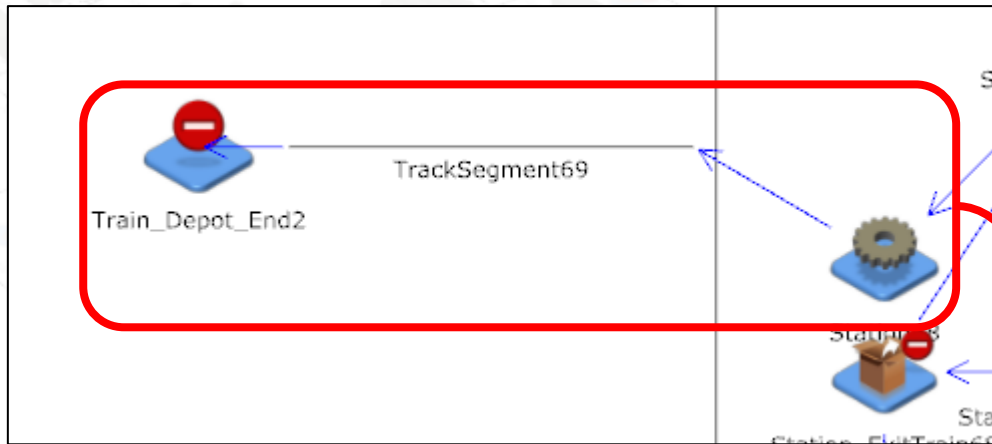
Extreme End Stations – Last Station



Input Editor - Station68		
Key Inputs Options Thresholds Maintenance Format Graphics		
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment69
WaitQueue	None	Station_TrainQueue68
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

- As assumed earlier, the ServiceTime is 0.33 min.

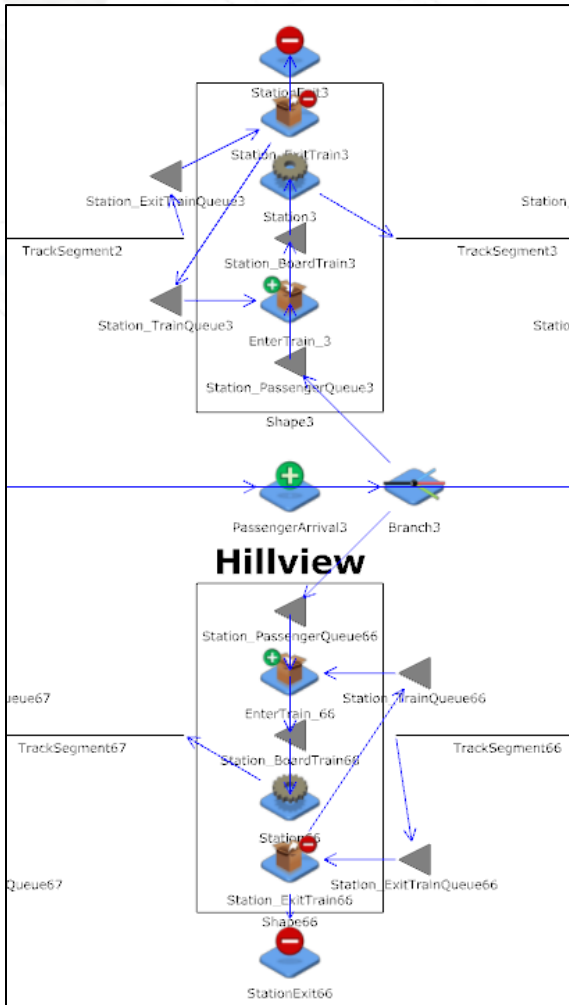
Extreme End Stations – Last Station



Input Editor - Station68		
Key Inputs Options Thresholds Maintenance Format Graphics		
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment69
WaitQueue	None	Station_TrainQueue68
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

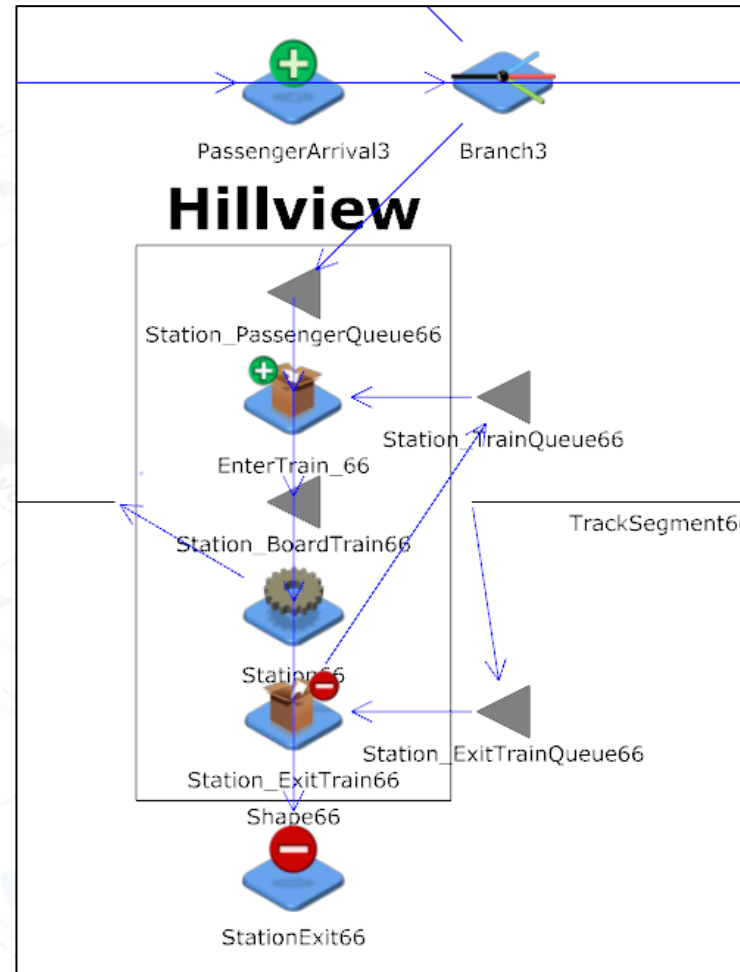
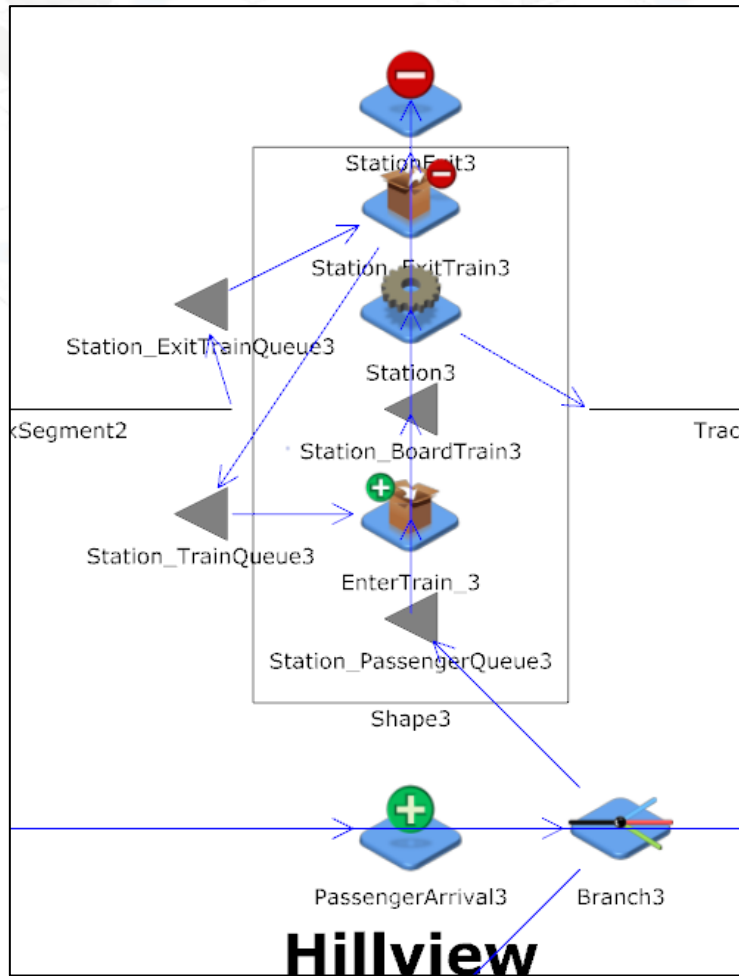
- The next component for the empty Train would simply be the Train_Depot_End2 sink.

Middle Stations



- The remaining middle stations have similar logic and hence are repetitive.
- Two rectangular shapes to represent both sides of the MRT platforms going in the opposite directions.
- The station name is in **bold**.
- **Note** the middle stations' shapes are mirror images. The reason is that unlike the Extreme End Stations, the passengers can choose to exit or board the trains for either direction.
- **Note** due to the limitations of JaamSim in copying and pasting multiple objects, we edited the model config file directly in Visual Code Studio with the help of R programming language instead.

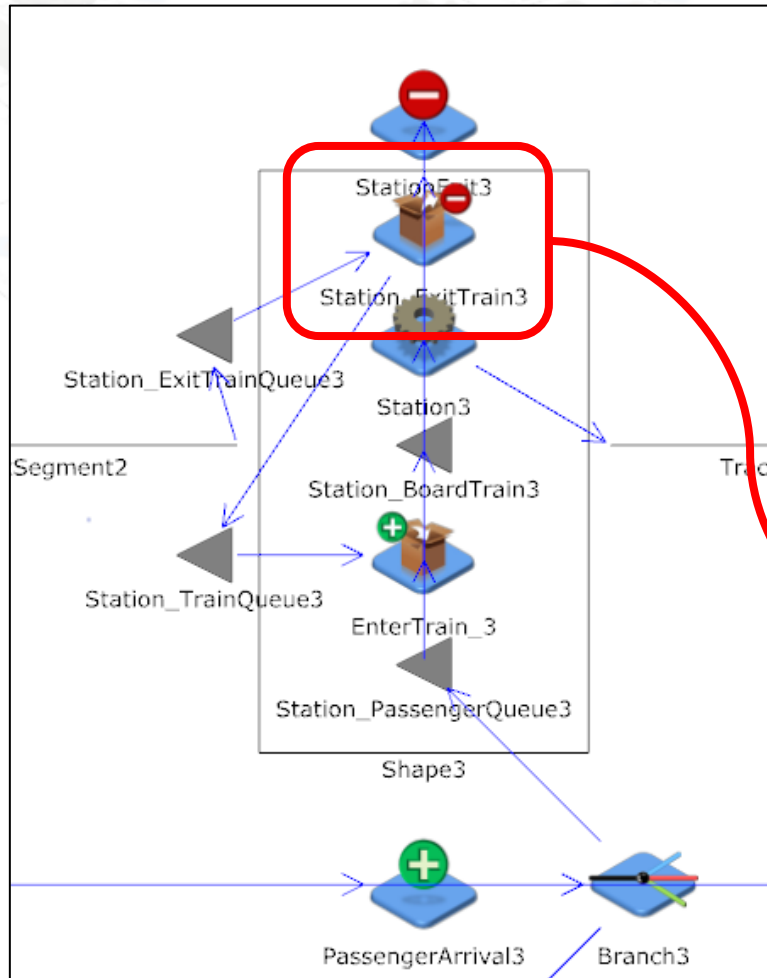
Middle Stations



- For every middle station, both shapes are a mirror image of the other, both pointing in opposite direction of travel.

- unpacking.
- 
-
- Modeling and Analysis | Mass Rapid Transit System Line Simulation

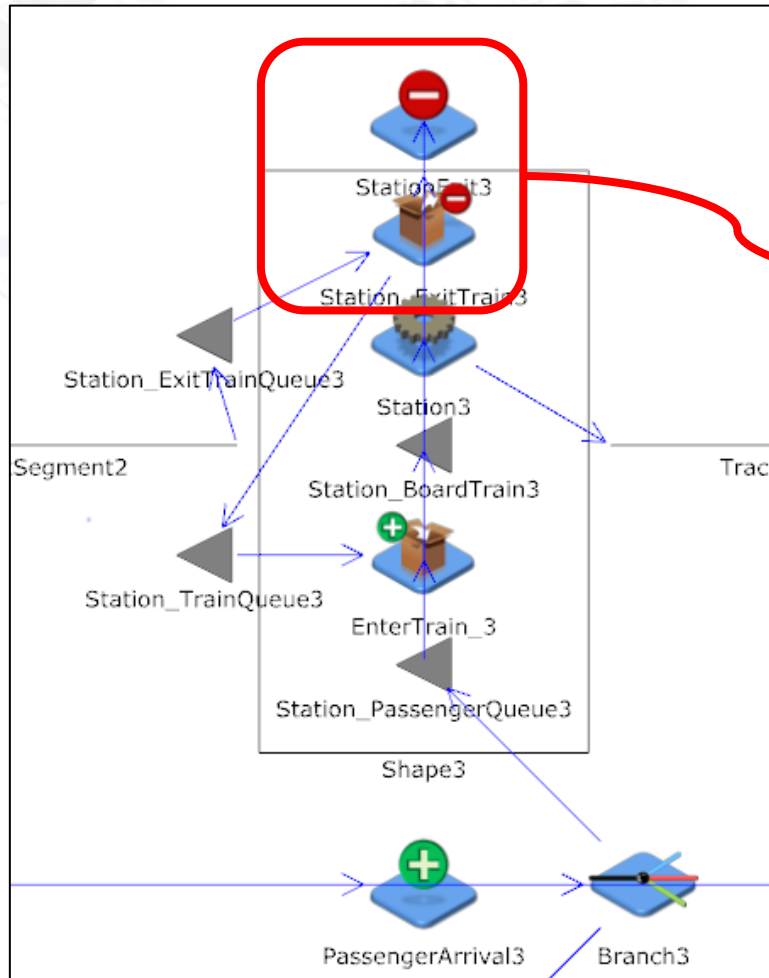
Middle Stations



Input Editor - Station_ExitTrain3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit3
WaitQueue	None	Station_ExitTrainQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	0.4*this.Container.Count
NextForContainers	None	Station_TrainQueue3

- For this unpacking, only some of the passengers in the Train will exit (unpack).
- Assumption is that 40% of the passengers will leave the train, which can be changed too.

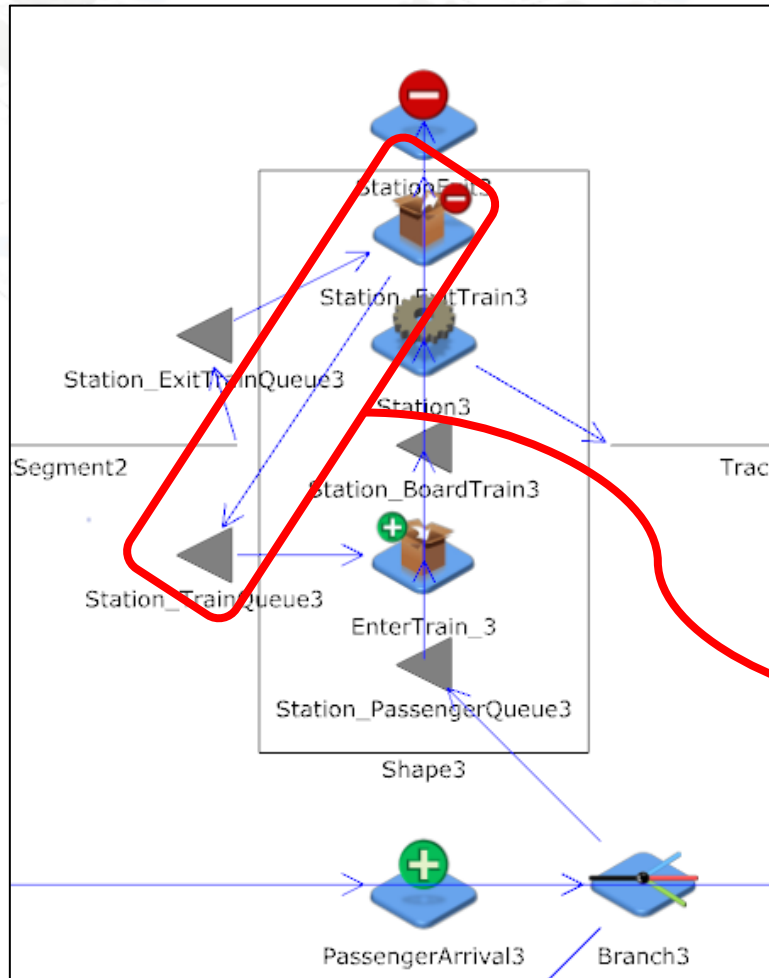
Middle Stations



Input Editor - Station_ExitTrain3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit3
WaitQueue	None	Station_ExitTrainQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	0.4*this.Container.Count
NextForContainers	None	Station_TrainQueue3

- The next component for the passenger entities who exit the train would be the StationExit3 entity sink.

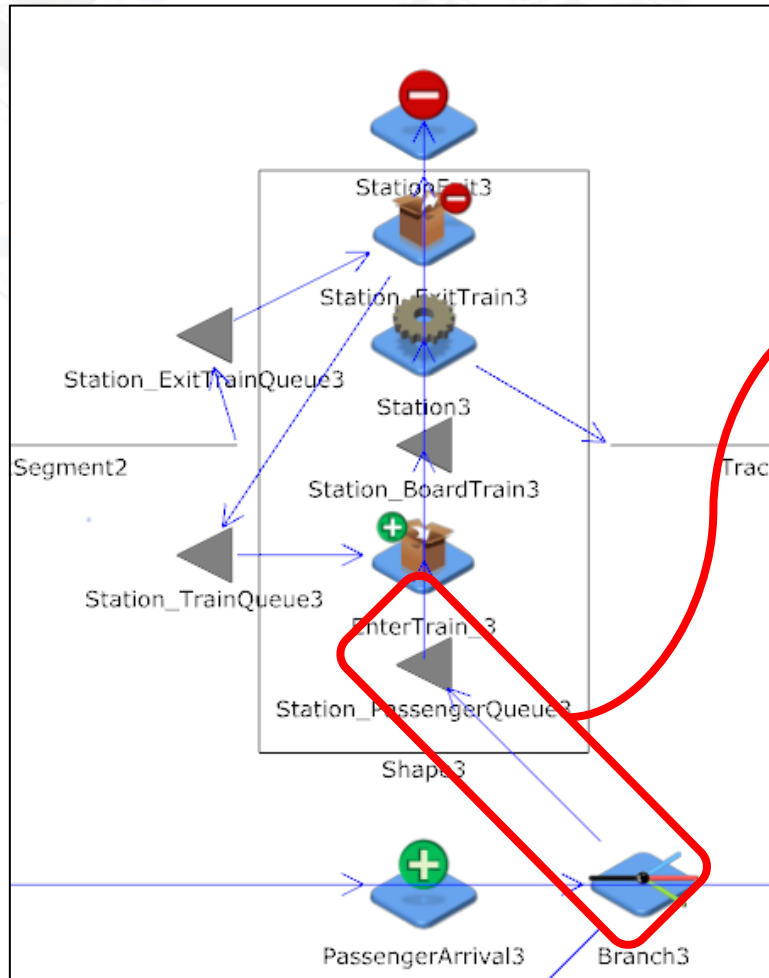
Middle Stations



Input Editor - Station_ExitTrain3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	StationExit3
WaitQueue	None	Station_ExitTrainQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
MatchForEntities	None	
ServiceTime	0.0 h	
NumberOfEntities	1	0.4*this.Container.Count
NextForContainers	None	Station_TrainQueue3

- The next component for the Train with the remaining passengers would be the Station_TrainQueue3, the queue for passengers to enter (packing).

Middle Stations



Input Editor - Branch3		
Key Inputs Options Graphics		
Keyword	Default	Value
Description	None	
NextComponentList	None	Station_PassengerQueue3 Station_PassengerQueue66
Choice	None	'this.NumberProcessed % 2 + 1'

- As mentioned under Slide Passenger Arrivals, the passengers arriving at the middle stations will alternatively branch to both directions.
- Assumption : The arriving passengers will enter the both direction queues alternatively (1st passenger enters the queue towards Expo, then the 2nd passenger towards Bukit Panjang, 3rd passenger towards Expo,...)

E.g. "this.NumberProcessed % 2 + 1":

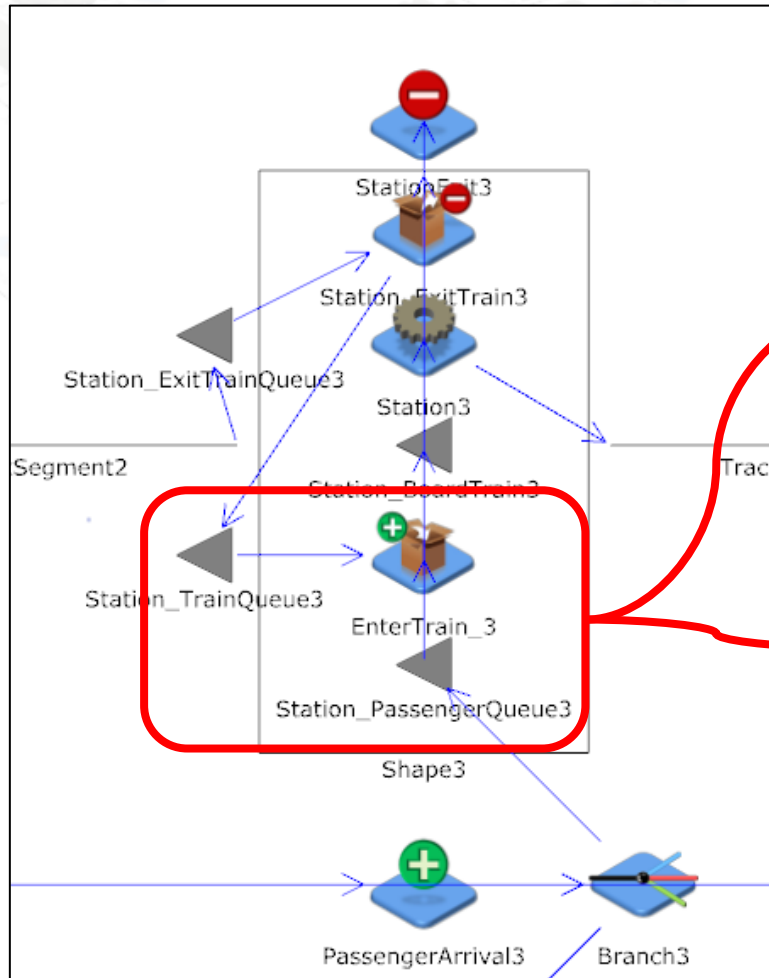
1 modulo 2 + 1 = 2

2 modulo 2 + 1 = 1

3 modulo 2 + 1 = 2

...

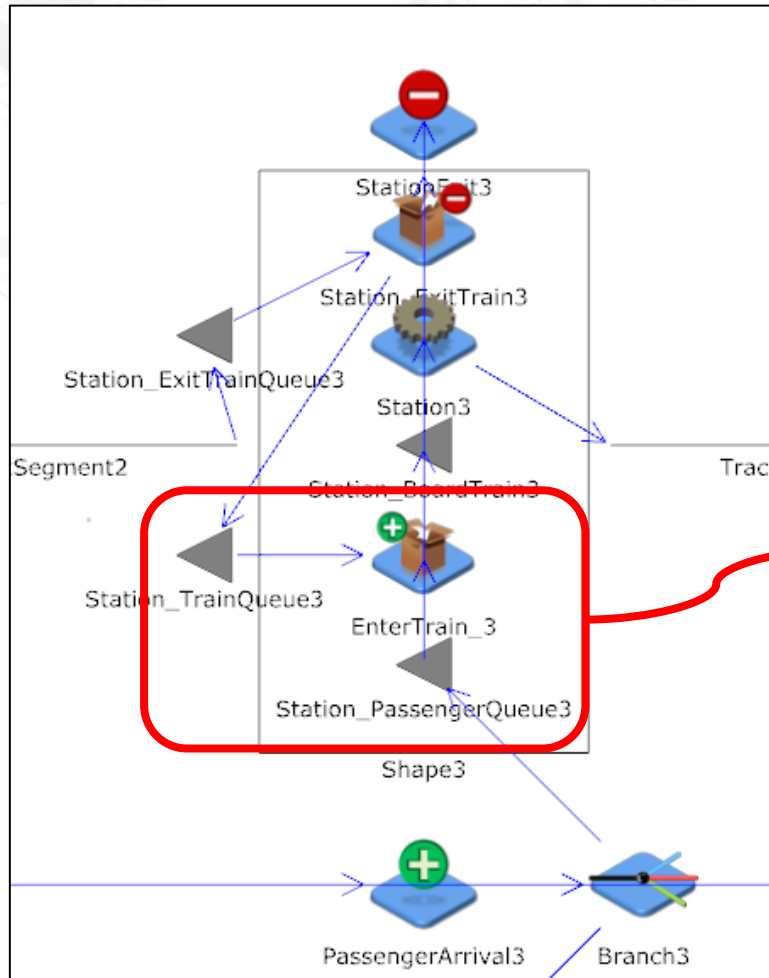
Middle Stations



Input Editor - EnterTrain_3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain3
WaitQueue	None	Station_PassengerQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	min([Station_PassengerQueue3].QueueLength,[InputValue2].Value)
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue3

- The Packing takes in Passenger entity from the Passenger Queue and the Container, Train is from the Train Queue which has the remaining on-board passengers.

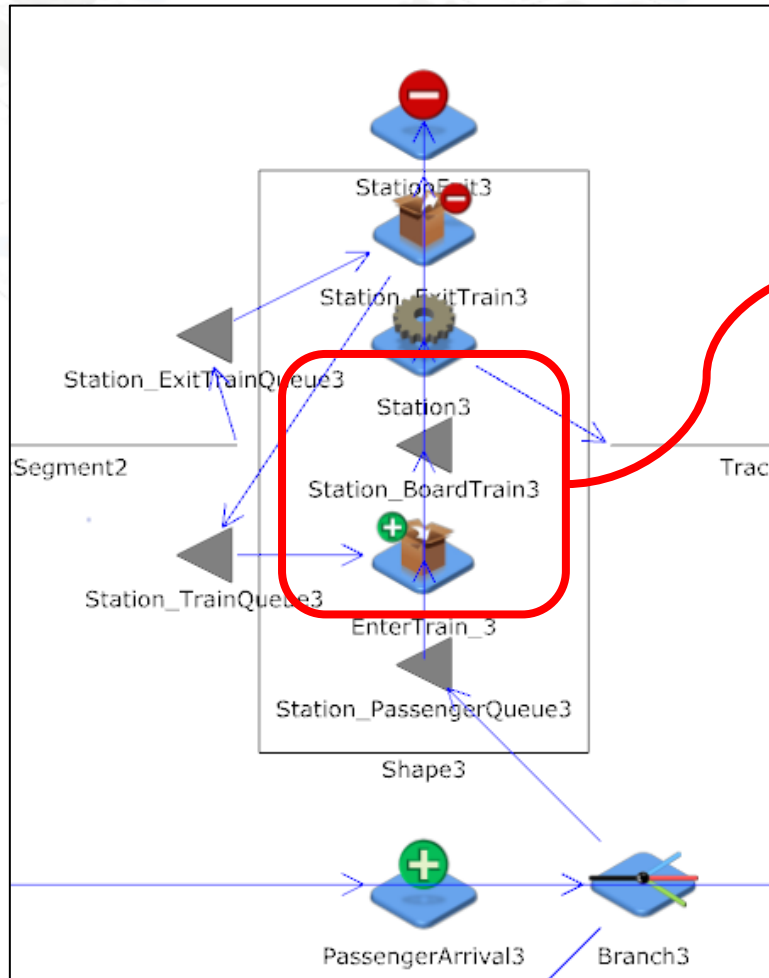
Middle Stations



Input Editor - EnterTrain_3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain3
WaitQueue	None	Station_PassengerQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	$\min([\text{Station_PassengerQueue3}].\text{QueueLength}, [\text{InputValue2}].\text{Value})$
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue3

- As before, the number of Passengers to be packed into the Train is the minimum between the number of Passengers in the queue and train maximum capacity (InputValue2).
- This is to ensure that if the train is full, no passengers are allowed to board the train.

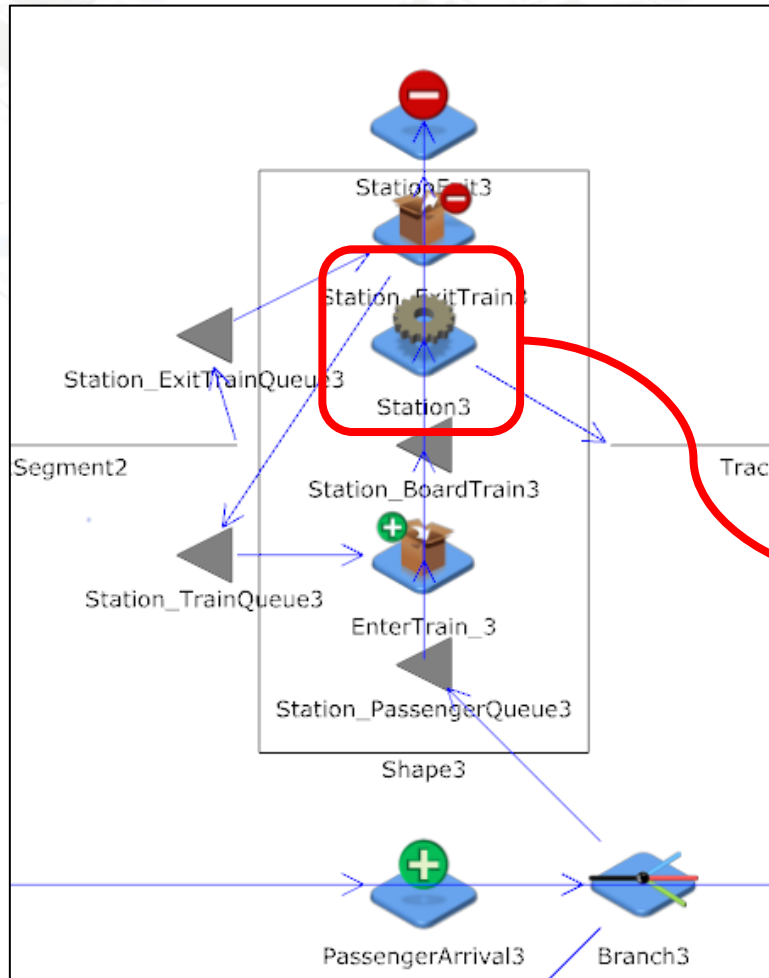
Middle Stations



Input Editor - EnterTrain_3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_BoardTrain3
WaitQueue	None	Station_PassengerQueue3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
NumberOfEntities	1	min([Station_PassengerQueue3].QueueLength,[InputValue2].Value)
ServiceTime	0.0 h	
ContainerQueue	None	Station_TrainQueue3

- The next component for the Train filled with passengers is the boarding queue to enter the server, Station3, where we simulate the duration that the doors of the train are kept open.

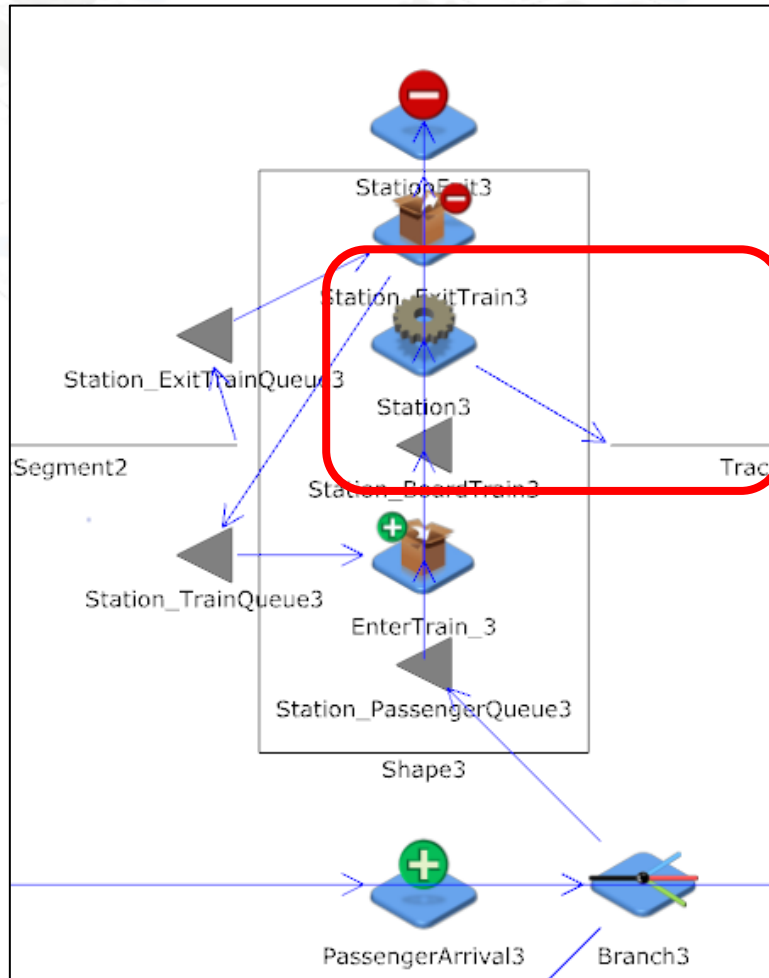
Middle Stations



Input Editor - Station3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment3
WaitQueue	None	Station_BoardTrain3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

- As mentioned earlier, the ServiceTime is 0.33 min.

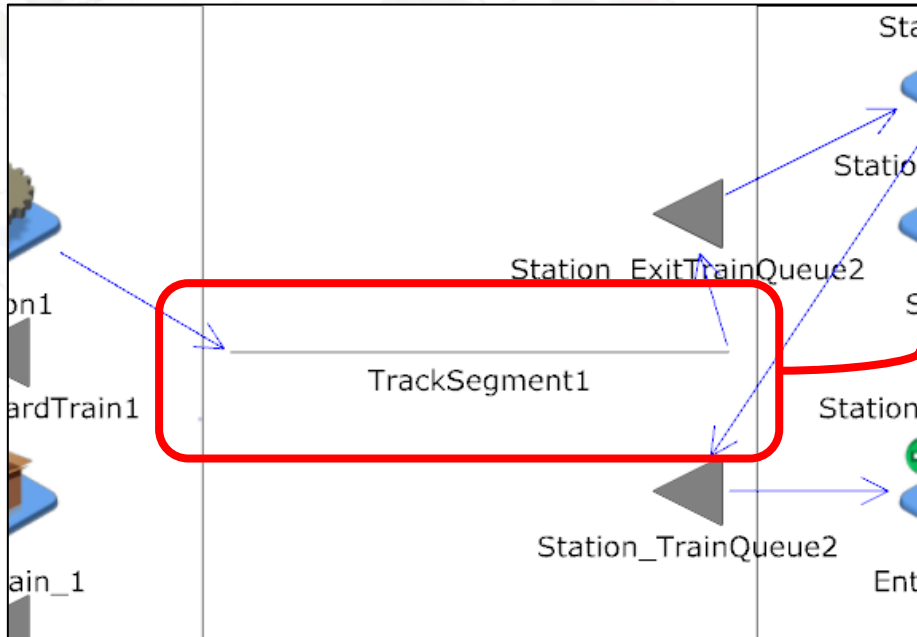
Middle Stations



Input Editor - Station3		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	TrackSegment3
WaitQueue	None	Station_BoardTrain3
Match	None	
SelectionCondition	None	
NextEntity	None	
WatchList	None	
ServiceTime	0.0 h	0.33 min

- The next component for the Train with passengers would simply be the next Station.

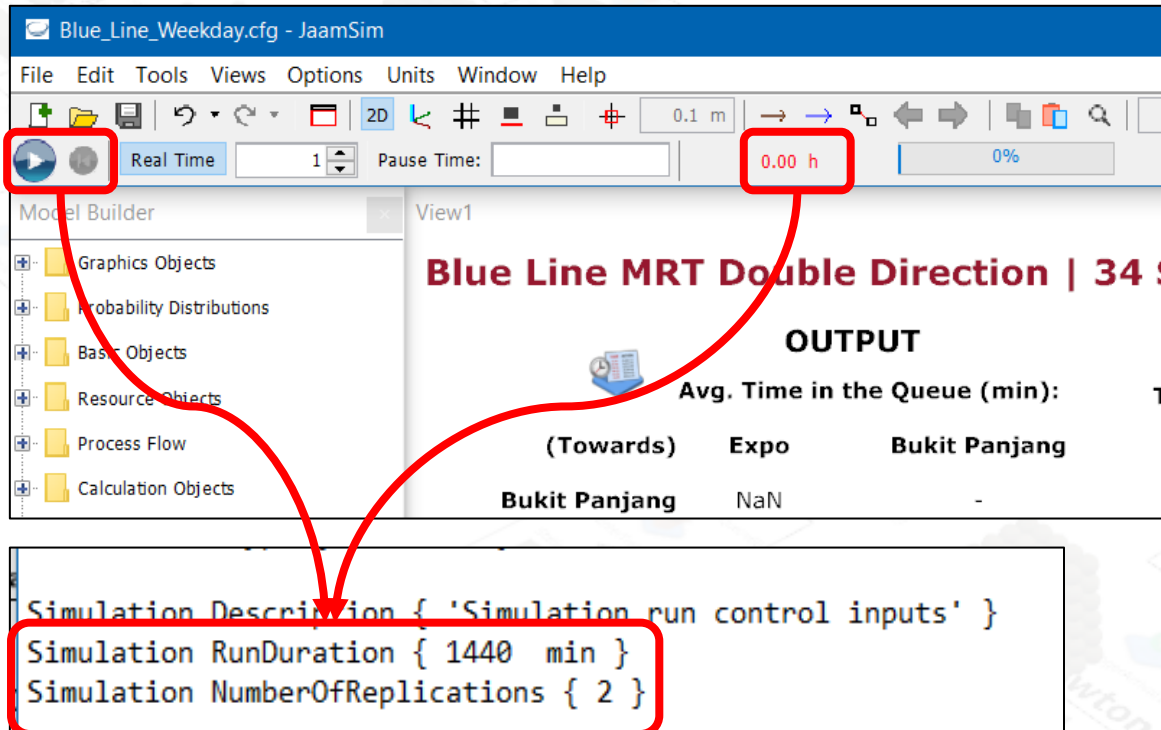
Train Tracks Timings



Input Editor - TrackSegment1		
Key Inputs	Options	Thresholds
Maintenance	Format	Graphics
Keyword	Default	Value
Description	None	
NextComponent	None	Station_ExitTrainQueue2
TravelTime	0.0 h	1 min

- TrackSegment entity conveyers simulate the travelling between the stations, the travel times are taken from the travel timing boards at the MRT Stations.

Simulation Run



- We declared the following attributes for the Simulation Object in the configuration file of the blue line models.
- Therefore, the simulation run time will be a day (1440 min) as forementioned.
- In addition, the number of replications is currently set to 2. Hence after pressing the “Run” button, the simulation will run once first and then reset automatically and run again for a second time.
- For **Output Analysis** we will be increasing the number of repetitions to 100 to provide a better overall estimate after averaging.

Interface

Blue Line MRT Double Direction | 34 Stations | Weekdays

OUTPUT



Avg. Time in the Queue (min):

(Towards)	Expo	Bukit Panjang
Bukit Panjang	1.479069	-
Cashew	1.470724	1.298578
Hillview	1.463509	1.408669
Beauty World	1.430012	1.441610
King Albert Park	1.422166	1.349901
Sixth Avenue	1.410068	1.412509
Tan Kah Kee	1.388776	1.292277
Botanic Gardens	1.372247	1.302309
Stevens	1.364922	1.289761
Newton	1.361379	1.271937
Little India	1.347352	1.307248

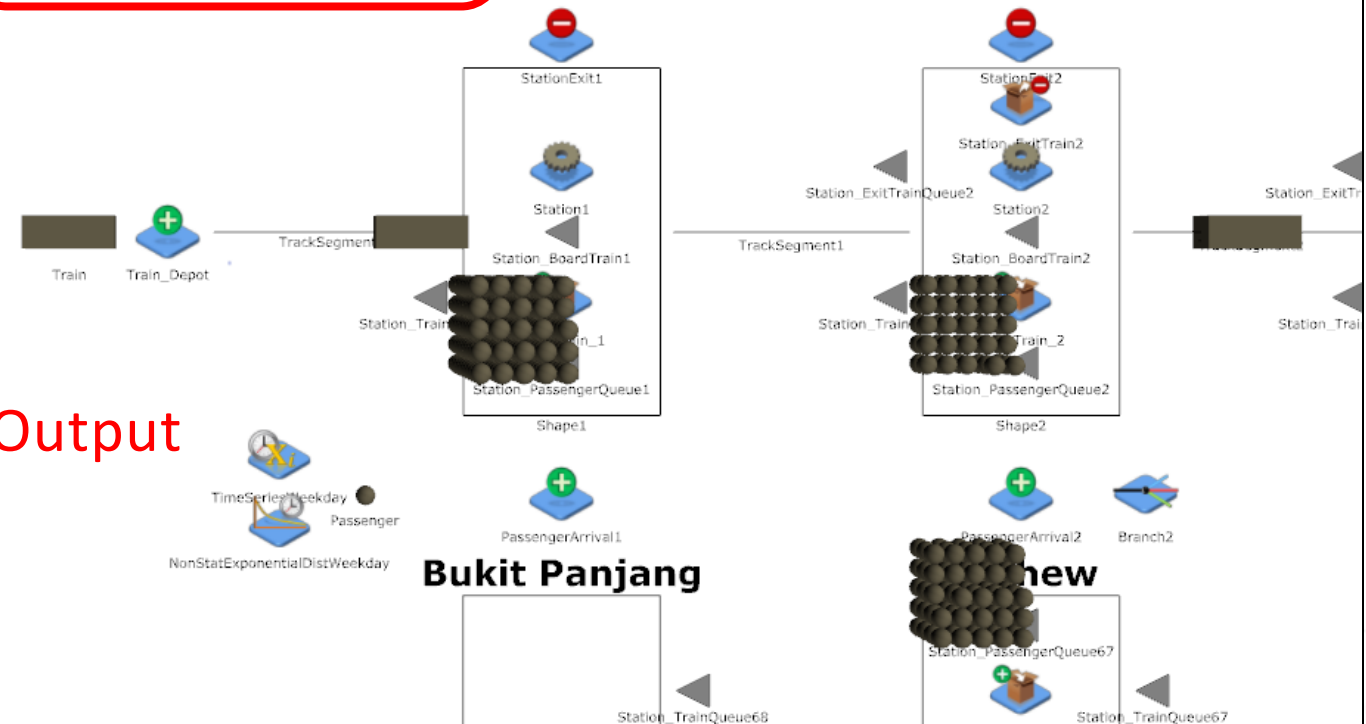
INPUT PARAMETERS

Train-InterArrival Time: 3 min

Train Capacity: 931

Input

Output



Run the Model

