

# TRAIN STATION SYSTEM

## Case Study

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# Purpose of this Case Study

- The Train Station case study is used as the first translation exercise to introduce people to the process of translating functional requirements into Behavior Trees.
- The exercise is also used to illustrate requirements integration

## **TRAIN-STATION PROBLEM (Sherwood Station)**

Develop a system to model the behavior of a Train-Station. You need to model a train entering the station from the north and then leaving the station to the south. A crossing with boom gates and flashing red lights is located just south of the station. There is a signal to the north of the station that only allows a train to enter when the station is not occupied, that is, when the north signal is green. There is also an exit signal light that ensures the train can only leave the station when the boom gates are down. There is also a north detector that can detect the train approaching the station region from the north. And, there is an exit detector that detects when a train leaves to the south.

1. Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north a train is detected, by the north detector, which causes the north signal to turn red.
2. When the north detector detects a train it causes the crossing lights to start flashing red. At the same time, a timer starts timing and when it times out it causes the boom gates to be lowered after which the exit light turns green.
3. After the train is detected the north detector, it subsequently arrives at the station, the doors open, the people disembark, and then the doors close.
4. After the doors close the train may leave the station only when and if the exit light is green. When the train leaves the station, heading south, it is detected by the exit detector which means the station is again not occupied. This causes the north signal to turn green and the exit light to turn red. When the exit detector detects the train leaving, it also causes the boom gates to be raised and then the crossing lights to stop flashing red.

For the purposes of the exercise ignore trains approaching the station from the south. This additional requirement can be integrated later as a separate exercise. Also ignore situations where the train does not stop at the station - this too requires some refinements to the design.

# Translation to Behavior Trees

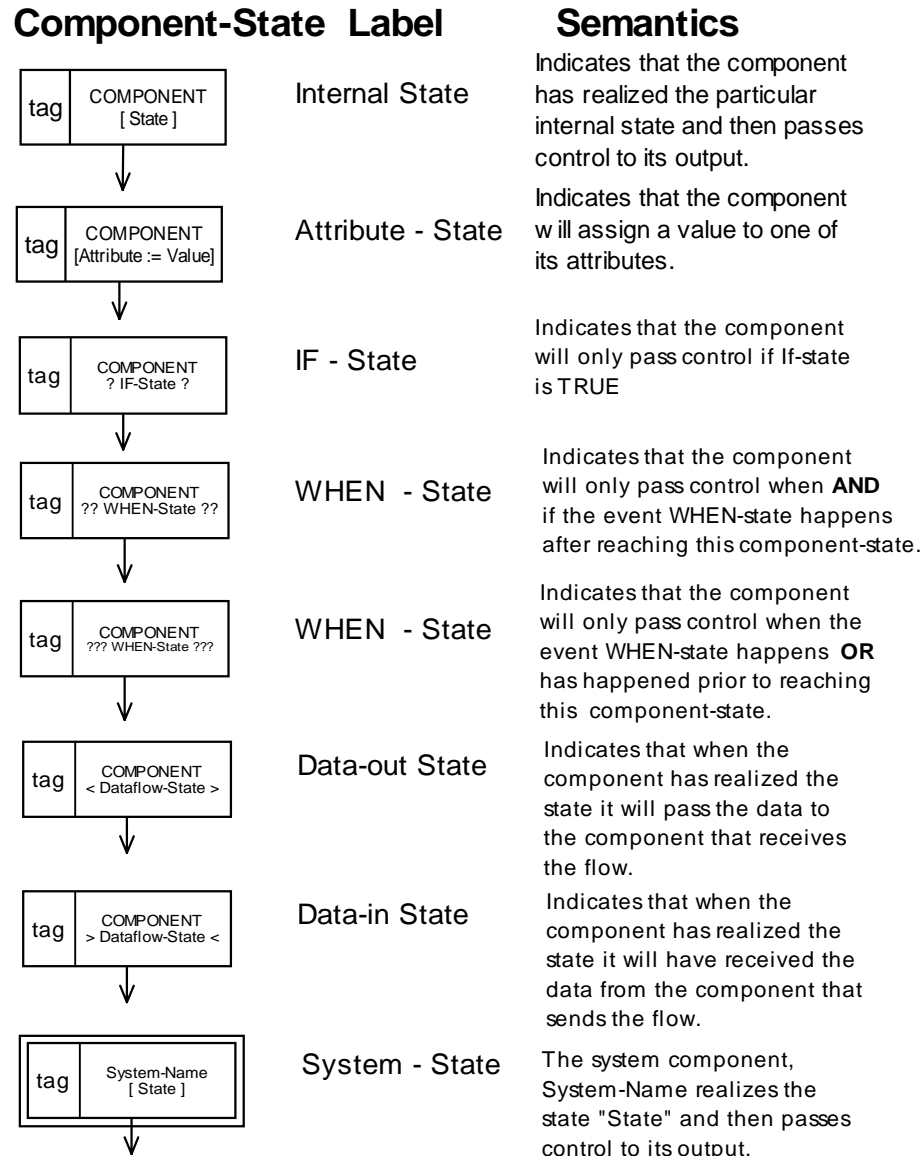
## **REQUIREMENT-R1**

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

# Translation Process (Abridged)

1. Look for Components - Nouns
2. Look for States – Verbs or Actions done to components or Events or Conditions
3. Look for indicators of flow or relative time – conjunctions, disjunctions, then, before, after
4. Account for every word and don't leave out out any words in your translation. Also do not introduce any new words.

# Behavior Tree Notation



# Translation to Behavior Trees

## First, Second and Third Sentences

### **REQUIREMENT-R1**

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

**Components ?**

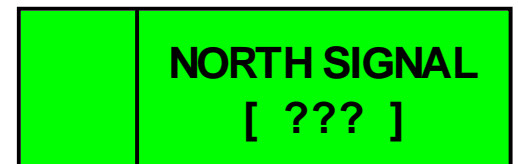
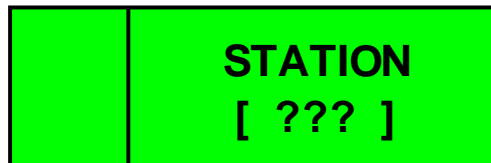
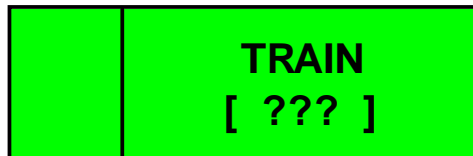
# Translation to Behavior Trees

## First, Second and Third Sentence

### REQUIREMENT-R1

Initially the **station** is not occupied. The **north signal** turns green whenever the **station** is not occupied. Whenever the **north signal** is green a **train** may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

**States ?**



# Translation to Behavior Trees

## First, Second and Third Sentence

**States ?**

### REQUIREMENT-R1

Initially the **station** is not occupied. The **north signal** turns green whenever the **station** is not occupied. Whenever the **north signal** is green a **train** may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

	<b>TRAIN</b> ??Approaching/??
where [from]	North

R1	<b>STATION</b> [ Not( Occupied) ]
----	--------------------------------------

R1	<b>NORTH SIGNAL</b> [ Green ]
----	----------------------------------

# Translation to Behavior Trees

## Fourth Sentence

### **REQUIREMENT-R1**

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

**Components ?**

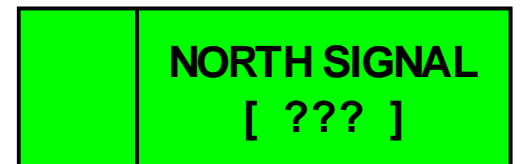
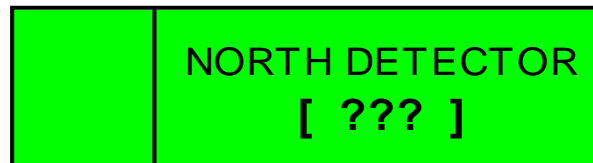
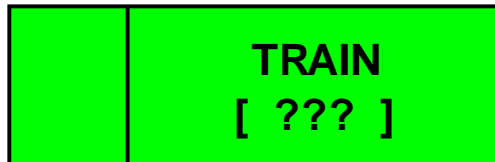
# Translation to Behavior Trees

## Fourth Sentence

**States ?**

### REQUIREMENT-R1

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a **train** is detected by the **north detector**, which causes the **north signal** to turn red.



# Translation to Behavior Trees

## Fourth Sentence

**States ?**

### REQUIREMENT-R1

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a **train** is detected by the **north detector**, which causes the **north signal** to turn red.

	<b>TRAIN</b> ?? Detected ??
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	<b>TRAIN</b> ??Approaching/??
--	----------------------------------

where [from]	
-----------------	--

	North
--	-------

	<b>NORTH DETECTOR</b> ?? Train[Detected]??
--	---

	<b>NORTH SIGNAL</b> [ Red ]
--	--------------------------------

# Translation to Behavior Trees

## REQUIREMENT-R1

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

**How to arrange component-states to specify behavior?**

	<b>STATION</b> [NOT:Occupied ]
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	<b>TRAIN</b> ??Approaching/??
where [from]	North

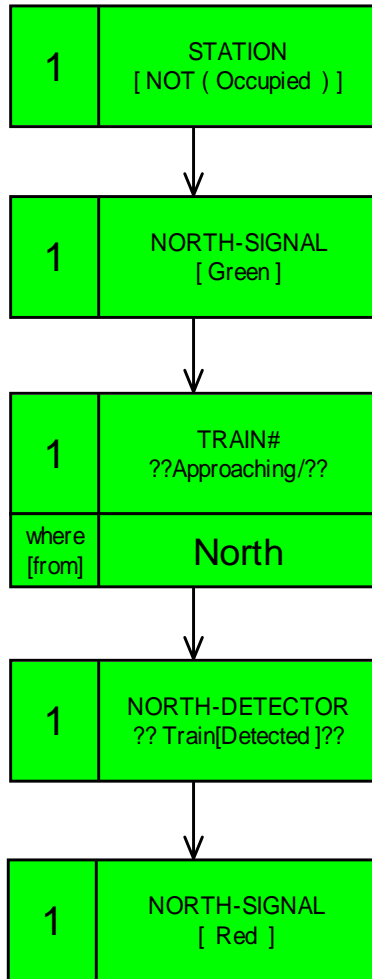
	<b>TRAIN</b> ?? Detected ??
--	--------------------------------

	<b>NORTH SIGNAL</b> [ Green ]
--	----------------------------------

	<b>NORTH DETECTOR</b> ?? Train[Detected]??
--	---

	<b>NORTH SIGNAL</b> [ Red ]
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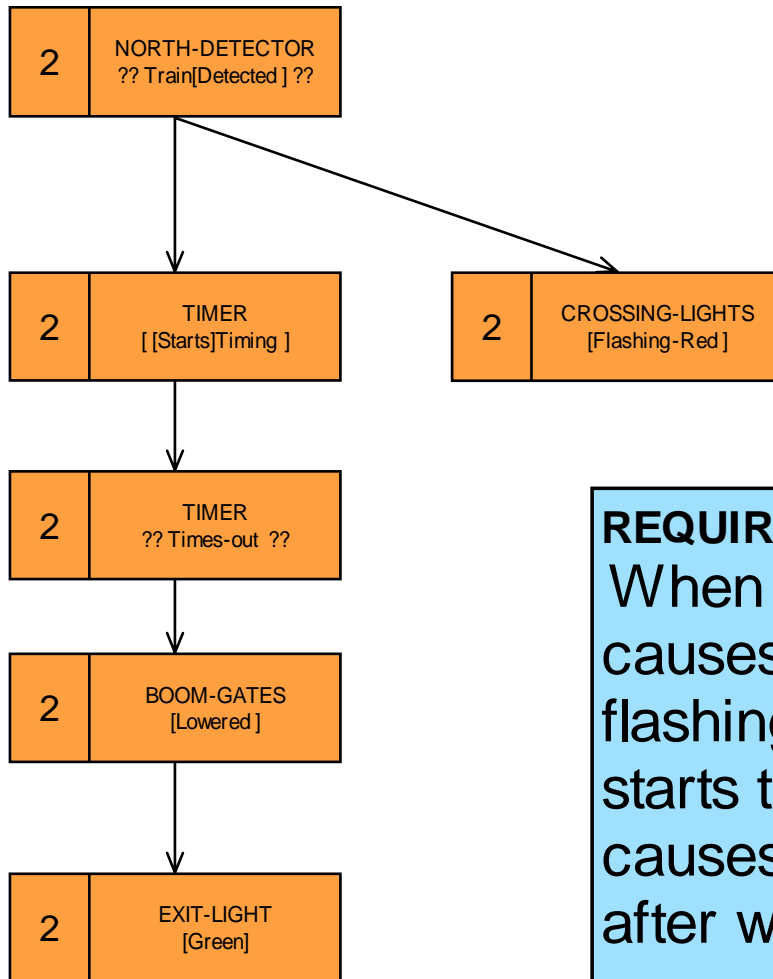
# R1 – Translated Behavior Tree



## REQUIREMENT-R1

Initially the station is not occupied. The north signal turns green whenever the station is not occupied. Whenever the north signal is green a train may approach from the north. When approaching from the north, a train is detected by the north detector, which causes the north signal to turn red.

# R2 – Translated Behavior Tree

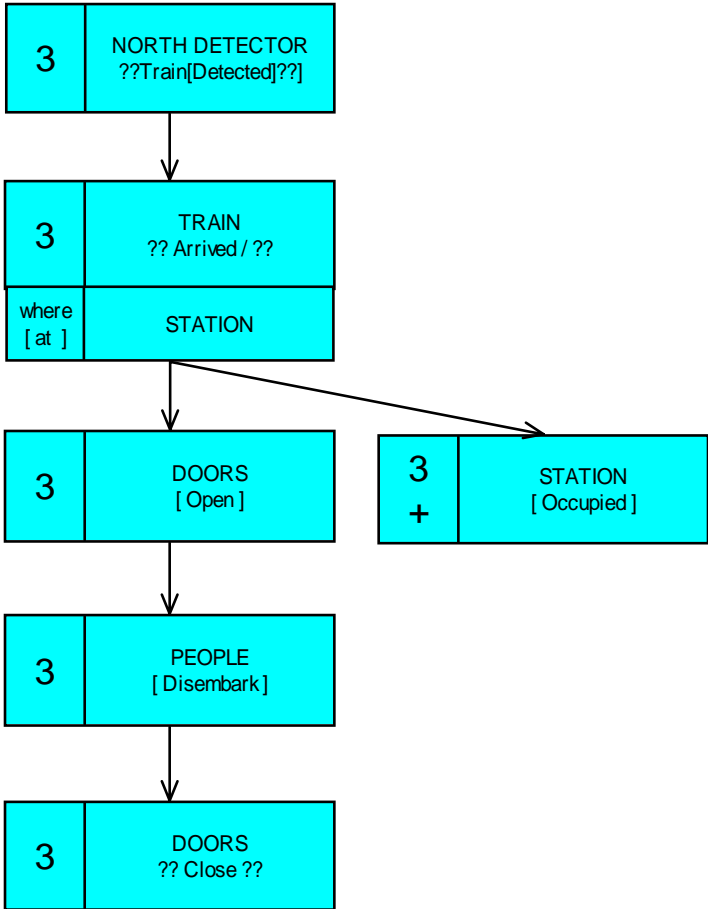


## REQUIREMENT-R2

When the north detector detects a train it causes the crossing lights to start flashing red. At the same time a timer starts timing and when it times out, it causes the boom gates to be lowered, after which the exit light turns green.

# R3 – Translated Behavior Tree

**REQUIREMENT-R3**  
After the train is detected by the north detector, it subsequently arrives at the station, the doors open, the people disembark, and then the doors close.

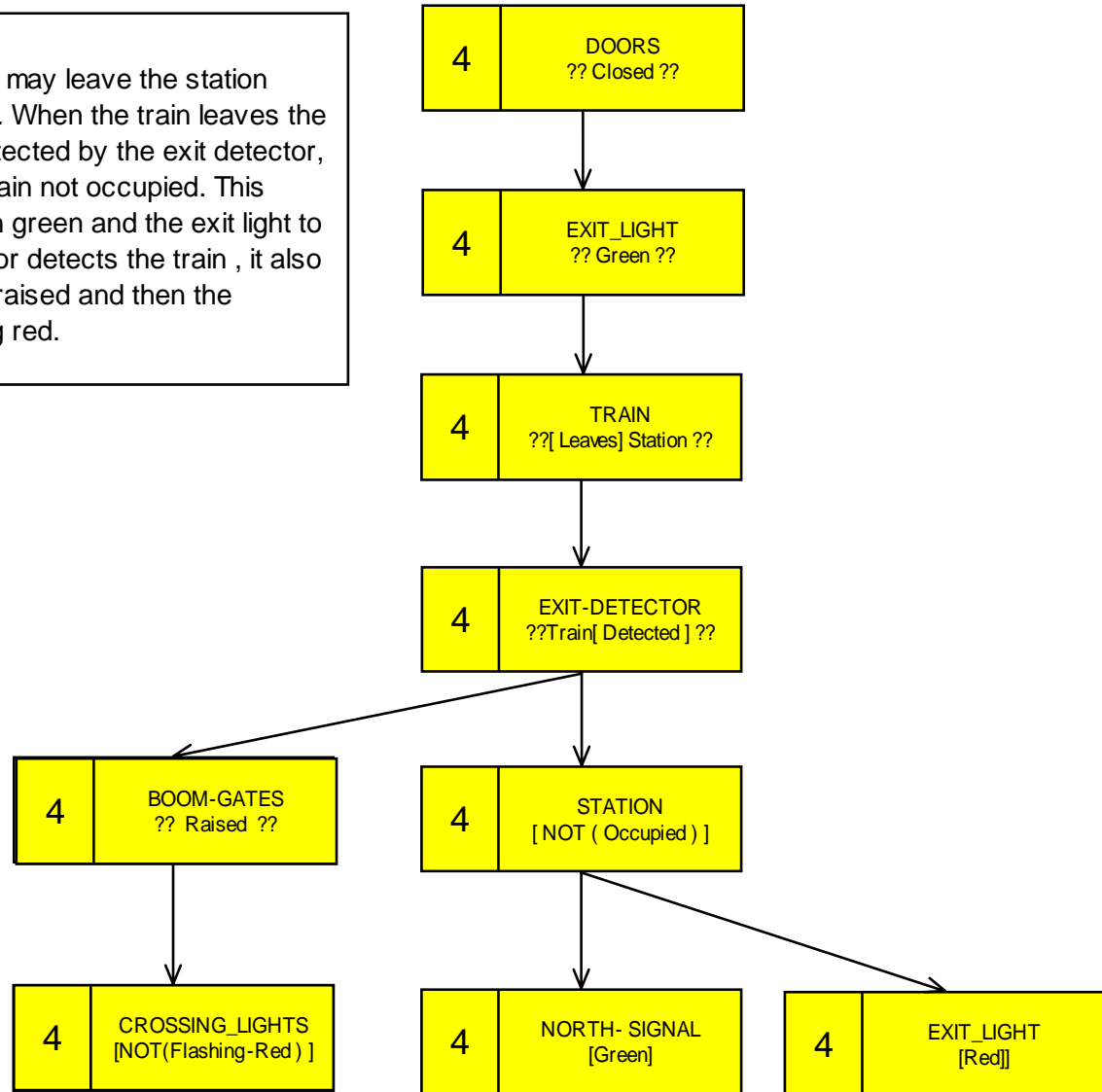


Implied (+)

# R4 – Translated Behavior Tree

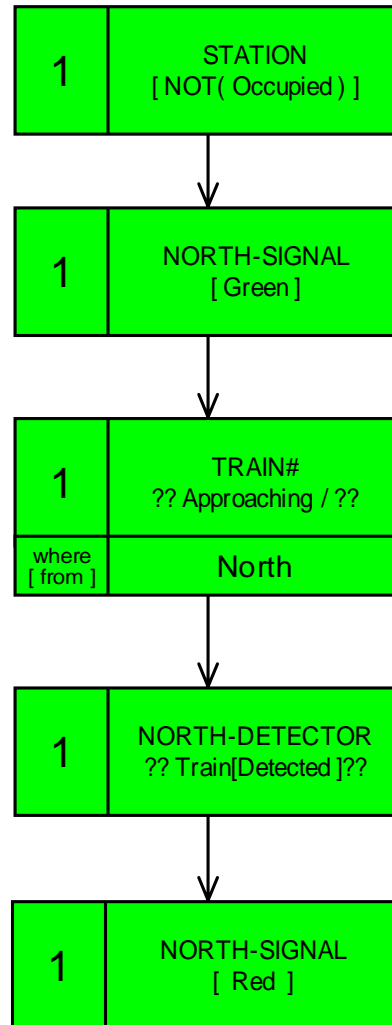
## REQUIREMENT-R4

After the doors close the train may leave the station provided the exit light is green. When the train leaves the station, heading south, it is detected by the exit detector, which means the station is again not occupied. This causes the north signal to turn green and the exit light to turn red. When the exit detector detects the train, it also causes the boom gates to be raised and then the crossing lights to stop flashing red.

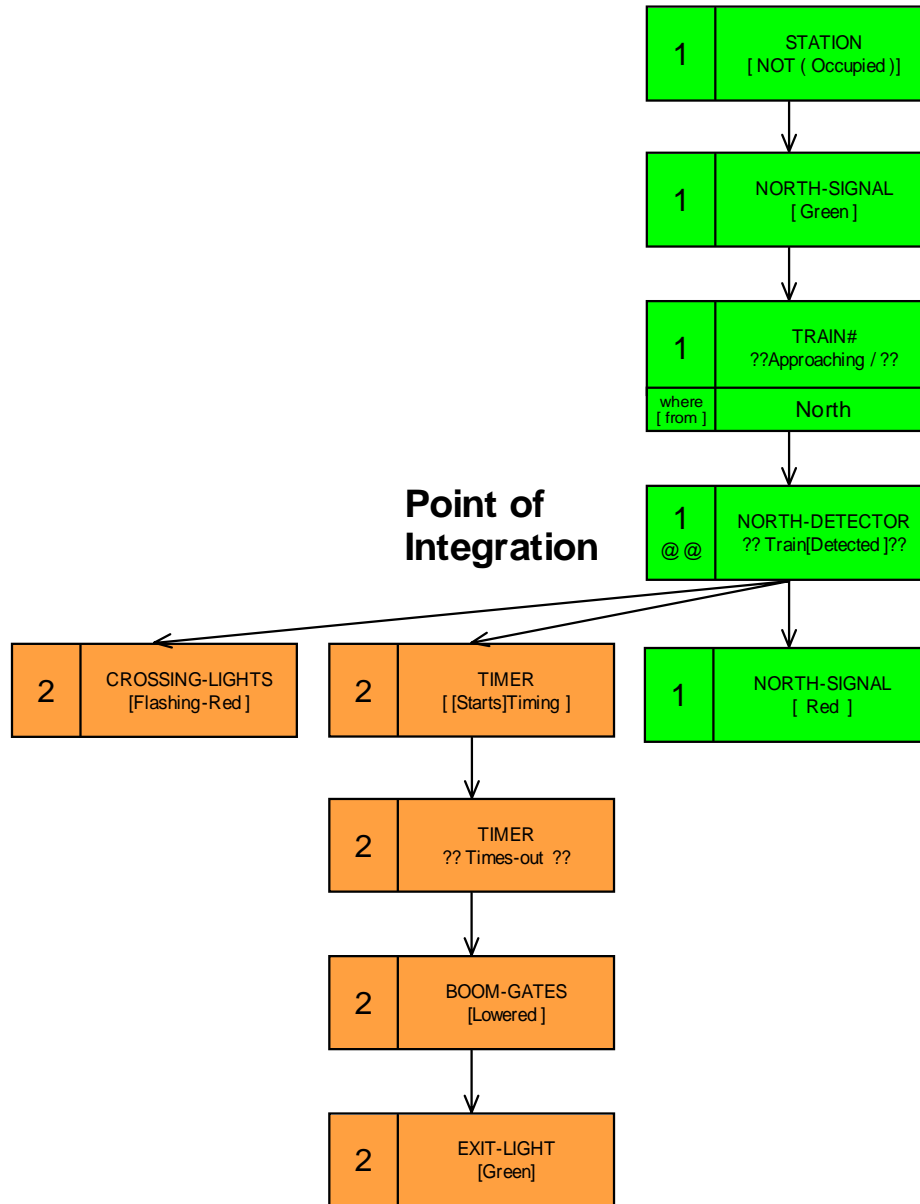


# **Integrating the Requirements Behavior Trees**

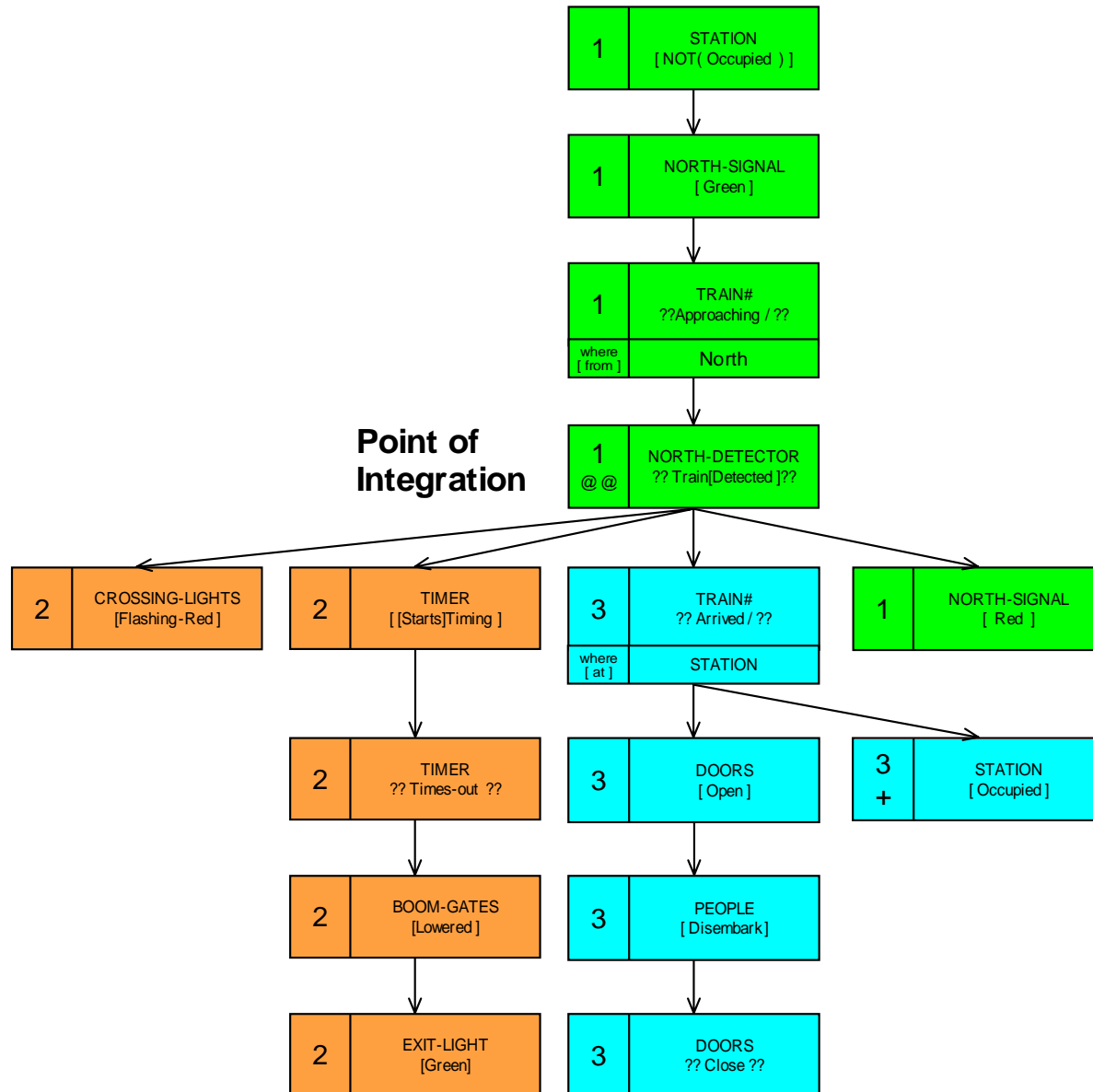
# Integration – Base Case



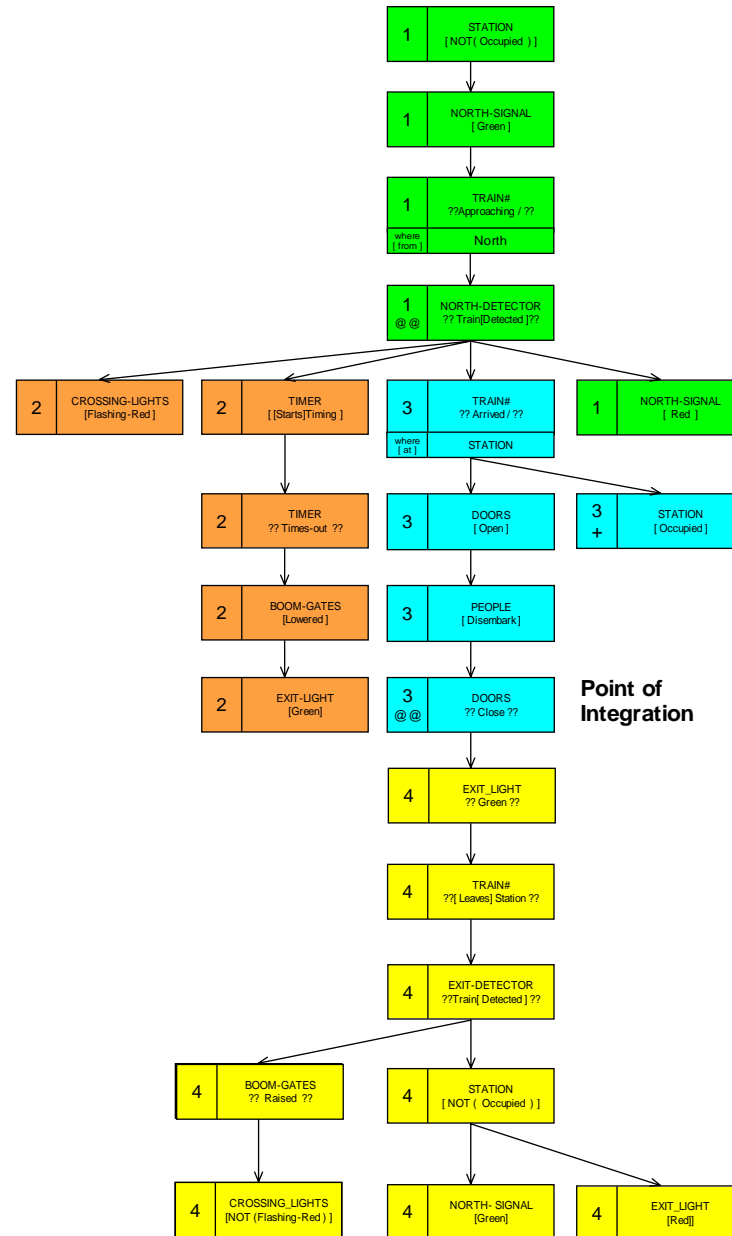
# Integration of R2 with R1



# Integration of R3 into IBT

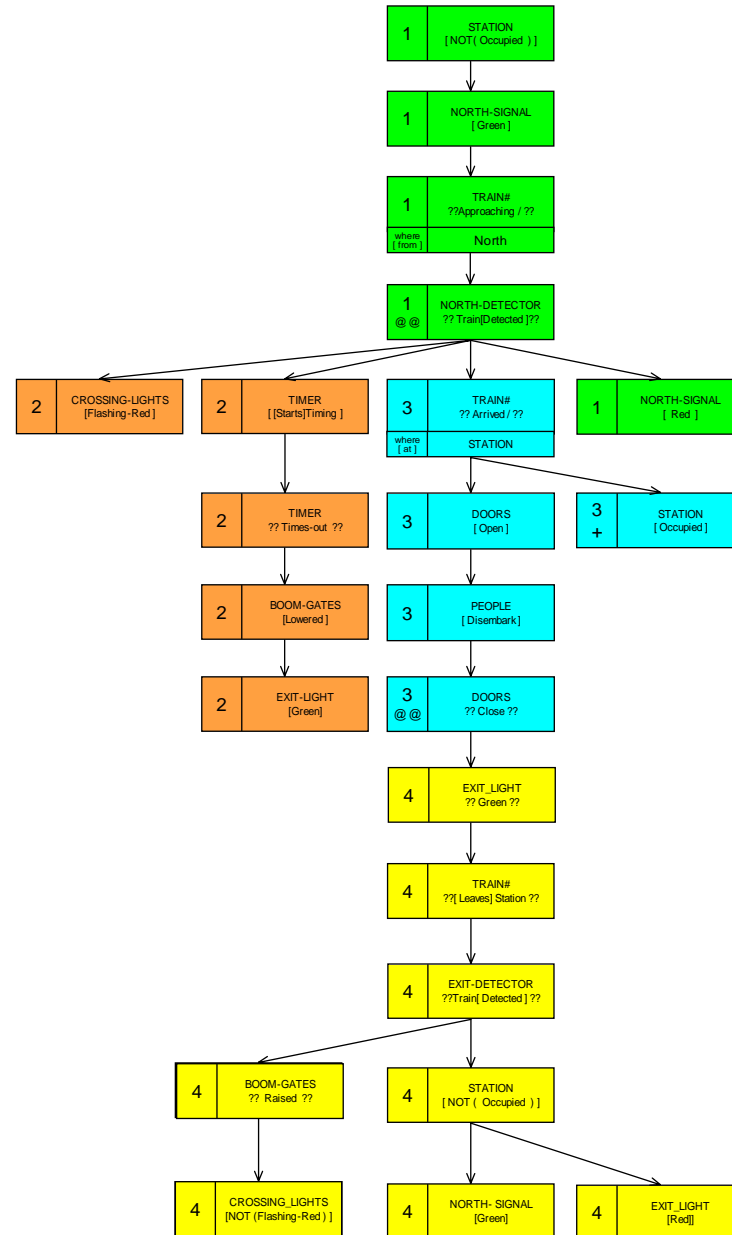


# Integration of R4 into IBT



**Now inspect IBT  
for Defects  
and Refine**

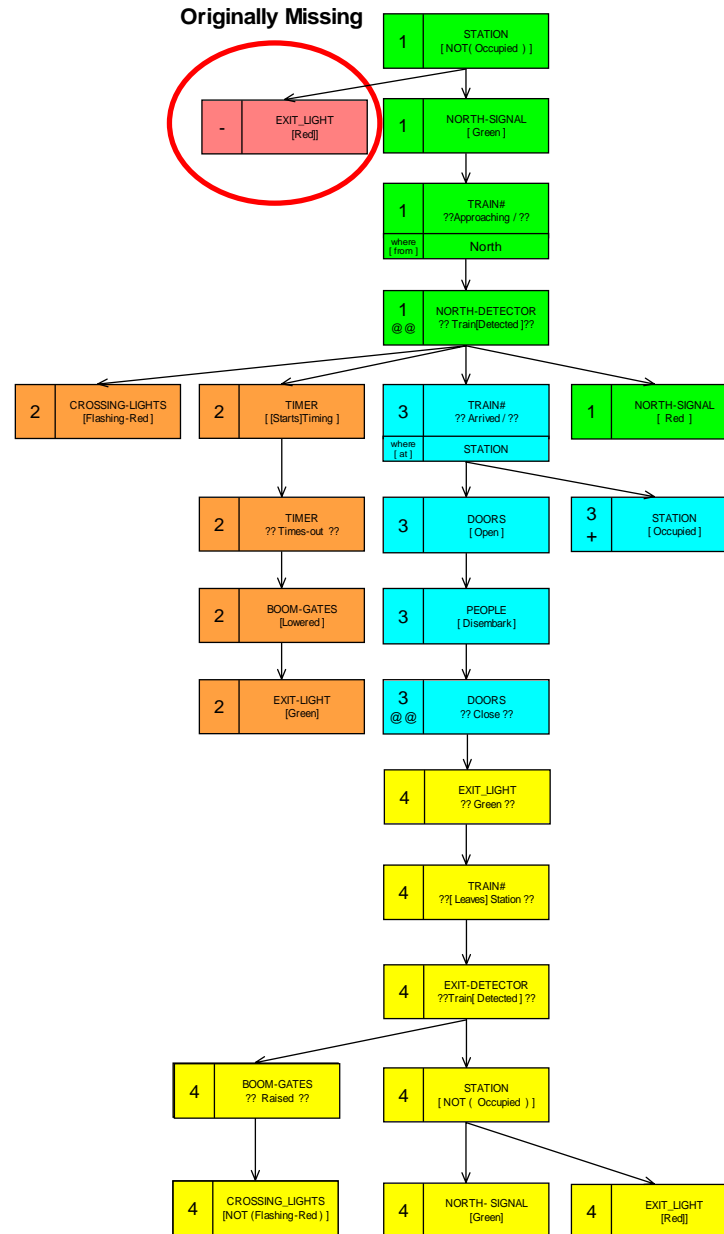
# Integrated Behavior Tree - IBT



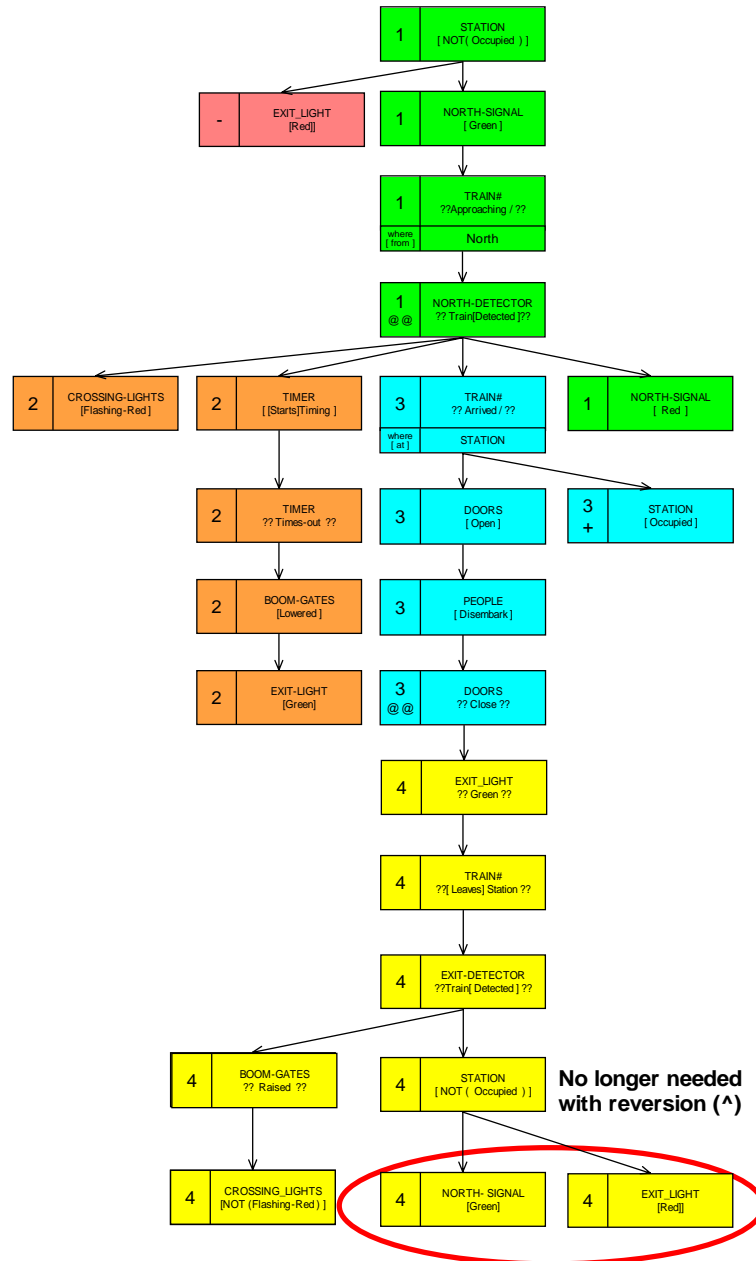
**There is something important  
Missing from these requirements  
– what is it?**

**The exit detector should initially be red.**

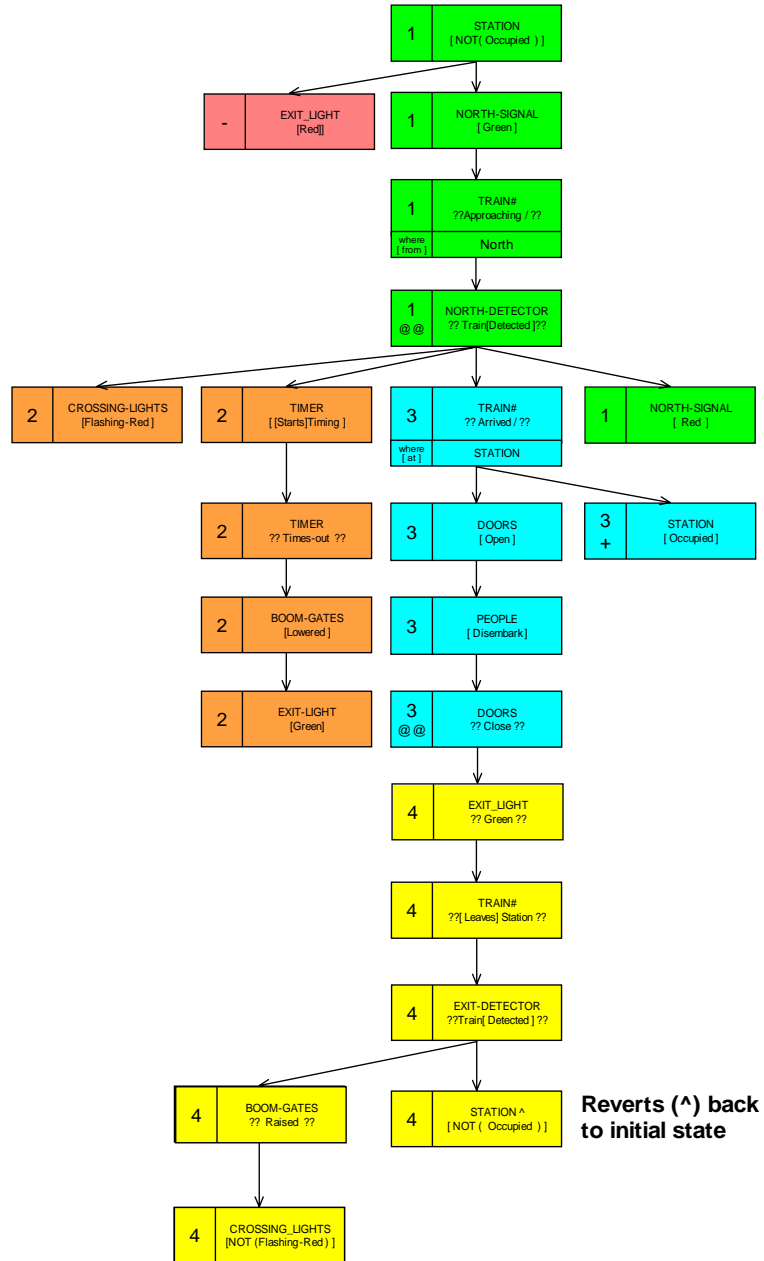
# Fully Integrated IBT – With Correction



# Fully Integrated IBT – With Redundancy

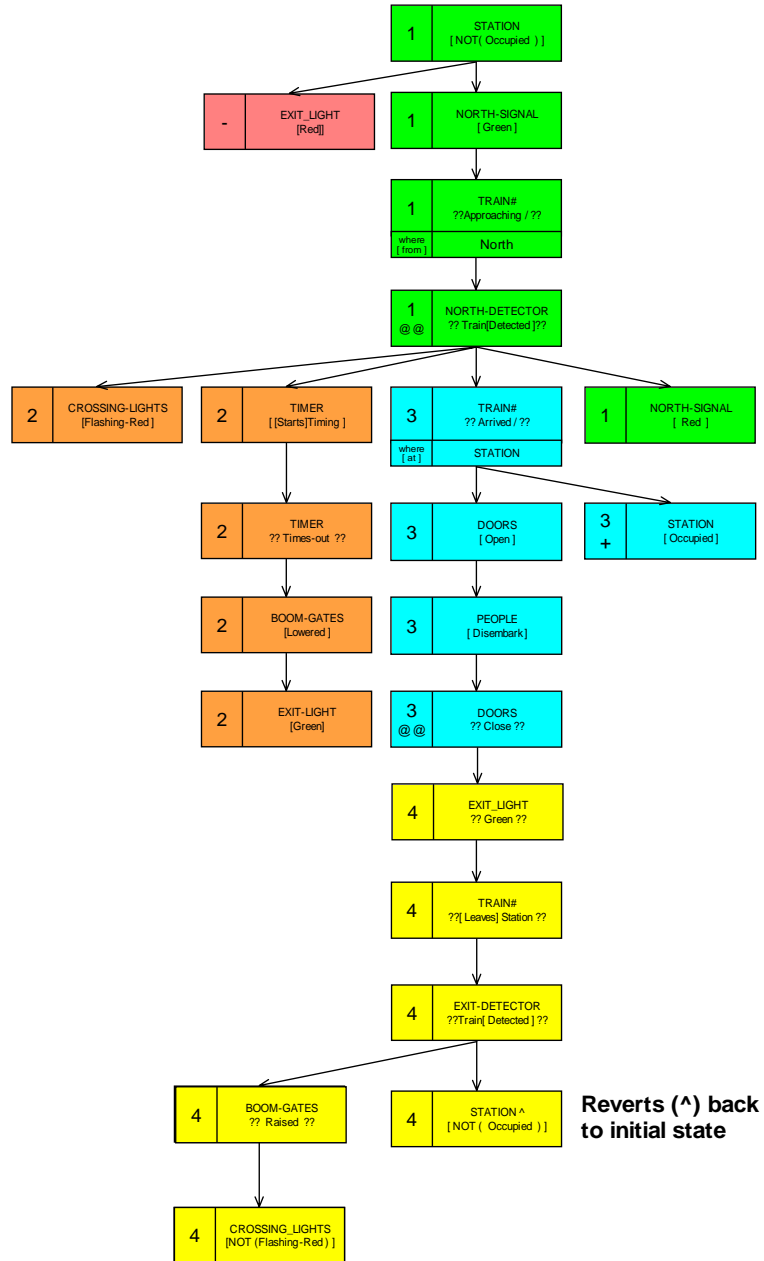


# Refined Fully Integrated IBT → DBT

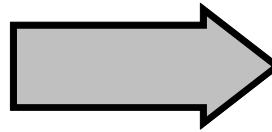
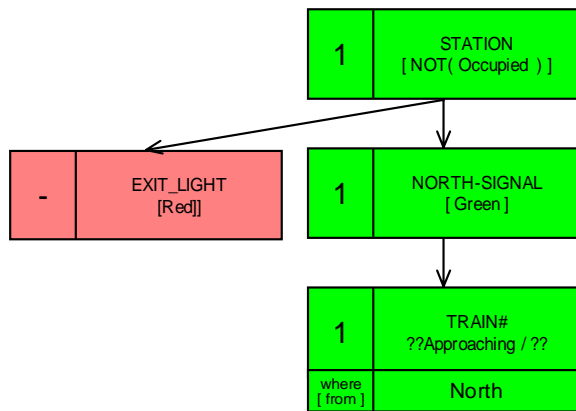


**Now derive**  
**Component Interaction Network**  
**( CIN )**

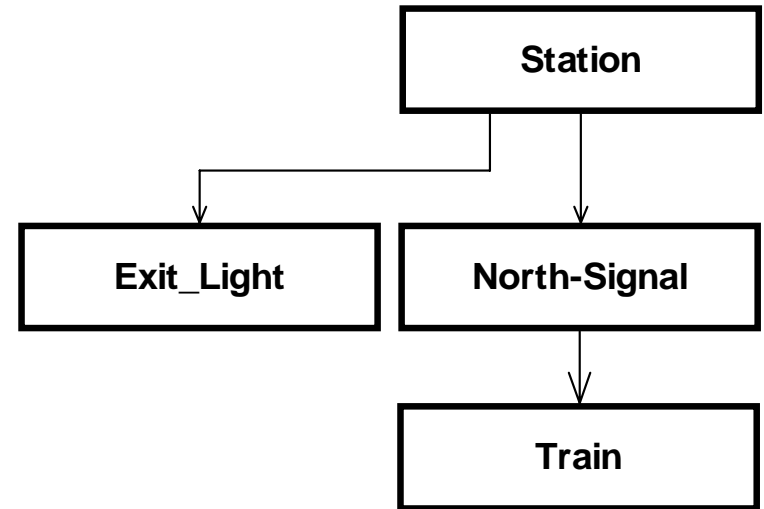
# Refined Fully Integrated IBT → DBT



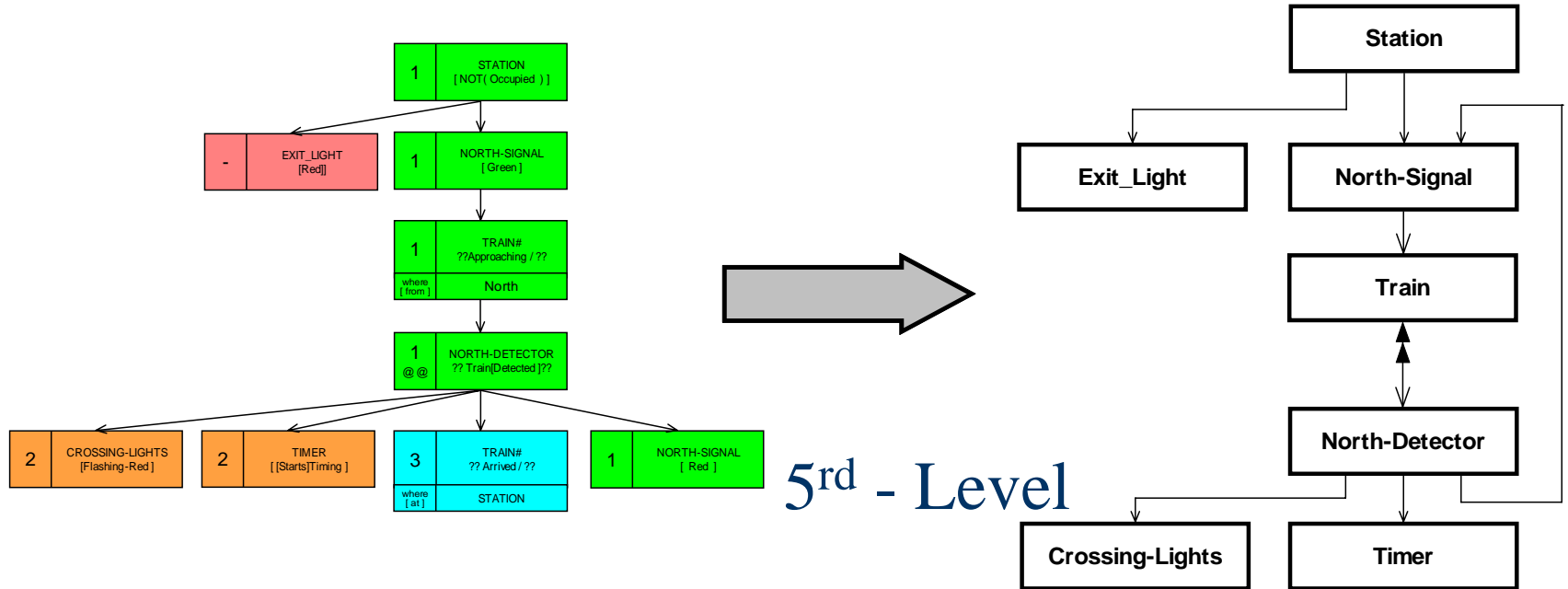
# DBT → Architecture (Level 3)



3<sup>rd</sup> - Level



# DBT → Architecture (step 5)



# Complete Component Interaction Network - CIN

