Sweating the asset – Cases in capacity improvement

Overview

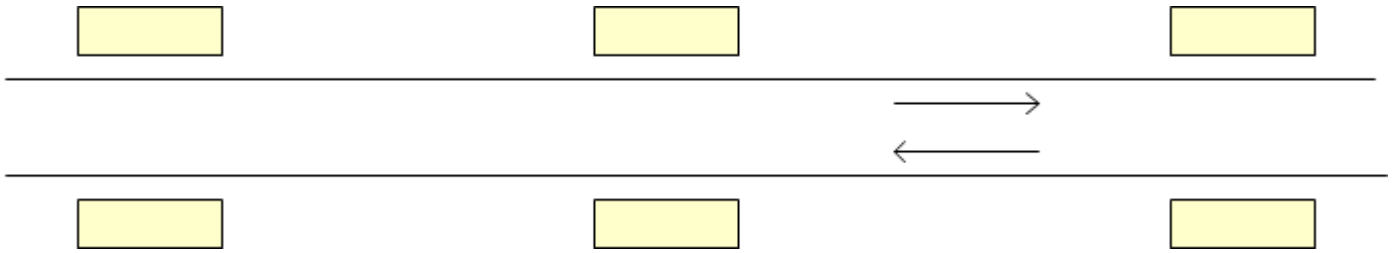
- What limits capacity in Metro style lines on conventional view?
- Look at Keikyu line in Tokyo and how it addresses those issues
- What lessons for our “toolkit”
- Safety vs Capacity

Principles on limits to capacity

- **What limits capacity on conventional view**
  - Number of tracks
  - Overlaps
  - System latencies and built-in delays
  - Station stop times
  - Line speeds
  - Crossing conflict points
  - Terminal station capacity
  - (infrastructure reliability)

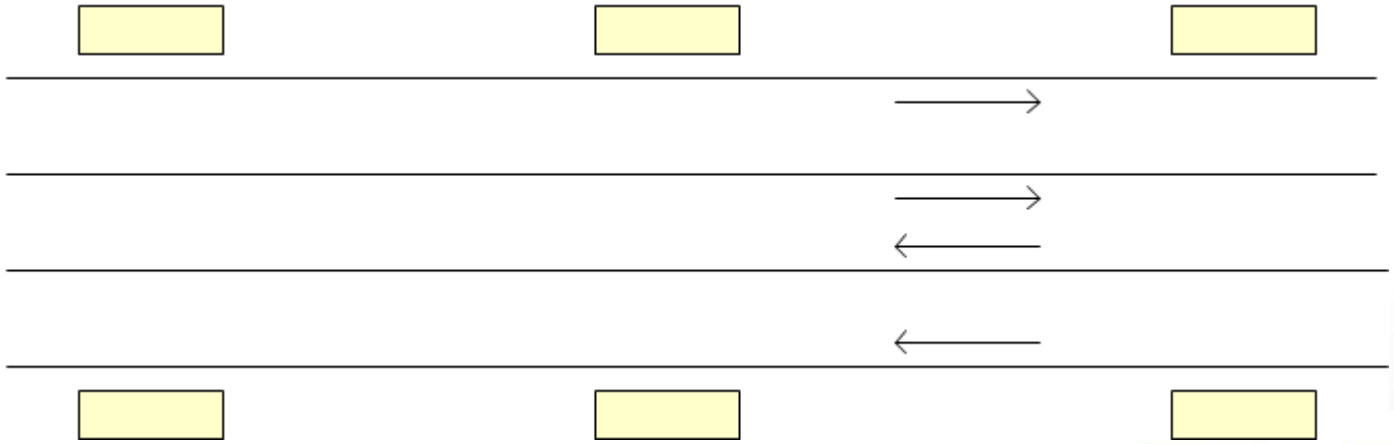
Conventional signalling limits to capacity

- **Standard 2 track Metro**
  - Simple geography
  - All trains stop all stations
  - Line speed 60 – 80 kph
  - 20s station dwell time
  - 20 trains per hour each direction with reliability (conventional signalling)



Conventional signalling limits to capacity

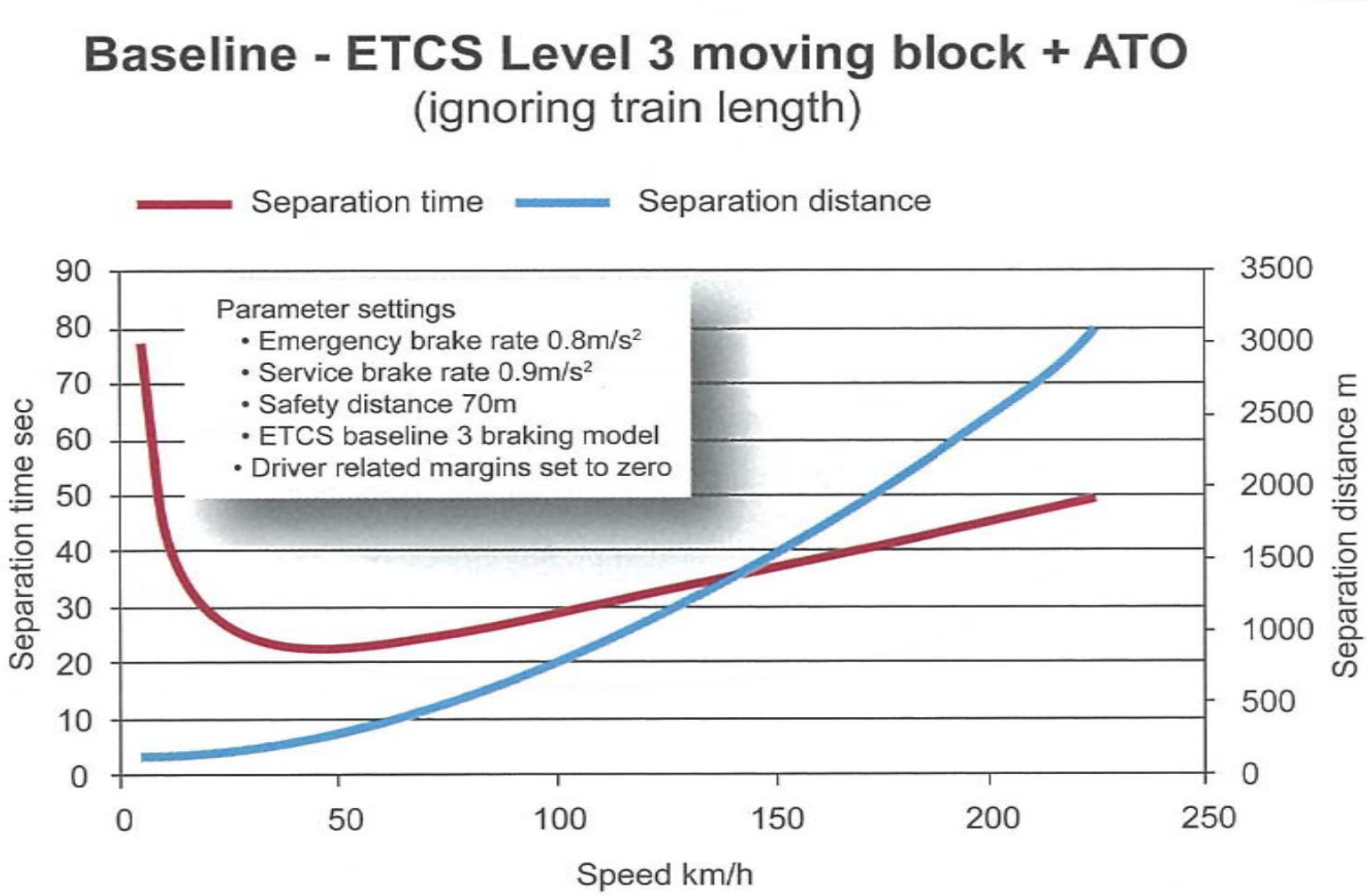
- **Standard 4 track Main Line**
  - Local (stopping) and Through (express lines)
  - Local trains stop all stations; Through trains run express
  - Line speed 80 – 100 kph
  - 20s station dwell time
  - 40 trains per hour each direction with reliability (conventional signalling)



Limits to capacity with CBTC

- **IRSE News February 2016**
  - February 2016 International Technical Committee reported on ERTMS Level 4 (Train convoys or Virtual Coupling) and commented:
  - "The experience of metros that have adopted moving block CBTC signalling is that the achievable capacity depends largely on station dwell times for passengers to board and alight at the busiest stations, and on turnaround arrangements at termini. If this is the case, abandoning the principle of absolute braking distances for the train convoy concept will not deliver any further improvement."
  - September 2016 followup by David Fenner: "UK Railway Safety & Standards Board research into Closer Running" revealed the size of the prize involved in breaking the nexus between station stop times and capacity.
  - Diagram (p 13 in article) revealed that headways of 22s were possible at 50 kph, 30s at 100 kph and 60s at 200 kph with the station stop affect removed.

Materials on limits to capacity

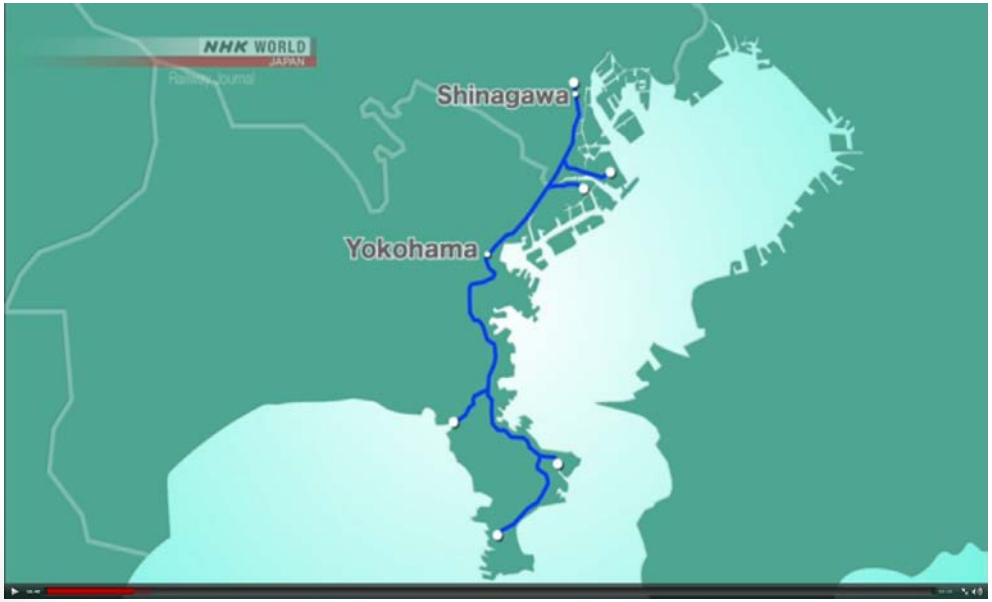


The importance of station stops

- **Headway is limited by the need to follow a stopping train**
- **What drives capacity on conventional view**
  - Station stops can be 1 minute on busy lines (27s Paris *line 14* off peak)
  - Headway is station stop + allowance + express headway
  - Station stop can dominate in moving block applications
  - Moving block has limited benefit

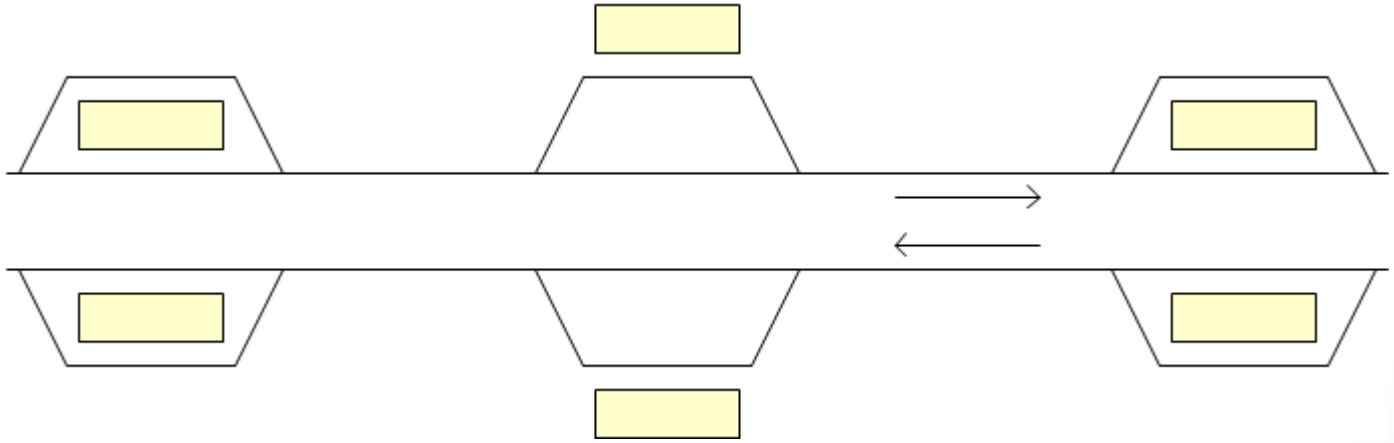
Introducing Keikyu line

- **Look at Keikyu line in Tokyo**
  - 2 tracks, 55km, 120kph line speed
  - More than 2.4 million passengers per day (1.2 million with split in middle)
  - Metro environment
  - Need to run express (for travel time) and stopping trains on corridor

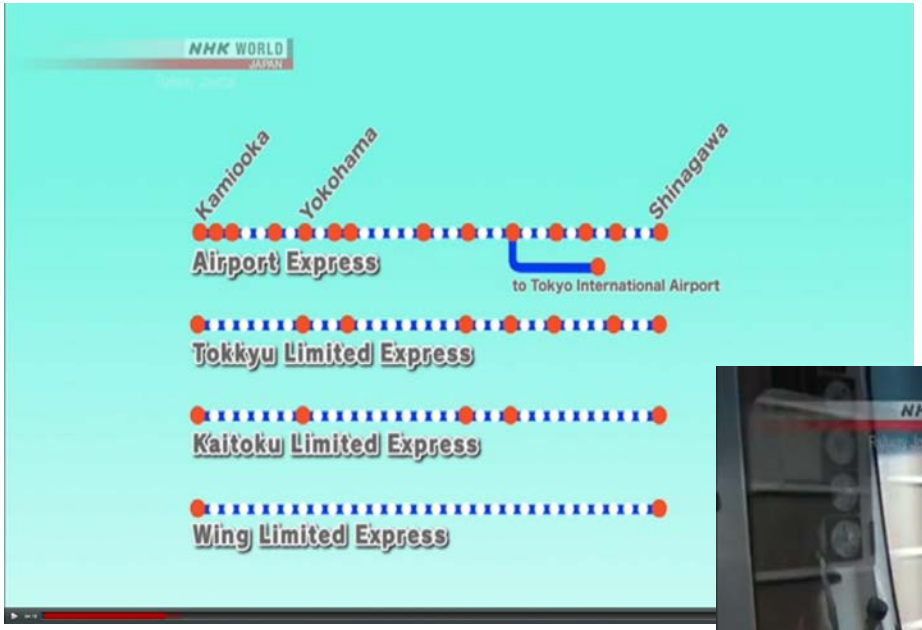


Introducing Keikyu line

- **How does it addresses capacity and mixed running issues**
  - 2 platform faces with following trains alternating between each
  - Nexus between station stop and headway is broken
  - Following train can enter station while previous train is still there
  - 27 trains each direction per hour run reliably (per timetable)



Train running patterns on line



Limits to capacity with platform splitting

- **Latency in Electronic Interlocking and Train Control Systems**
  - Track picks 4s after train clear of points
  - TFM to central interlocking 3s (+ 2s software slug)
  - Control centre telemetry cycle 5s to see track clear, 1s to issue point control
  - Interlocking receives after 5s, 1s to issue point command
  - TFM receives in 3s, points take 5s to operate, 1s for detection in TFM
  - Telemetry 3s, interlocking 1s, Control Telemetry 5s, Process Signal 1s
  - Same back to clear signal + 6s cycle on mechanical trainstop
  - **Up to 60s latency in signalling for following train**

Keikyu line – manual signal control

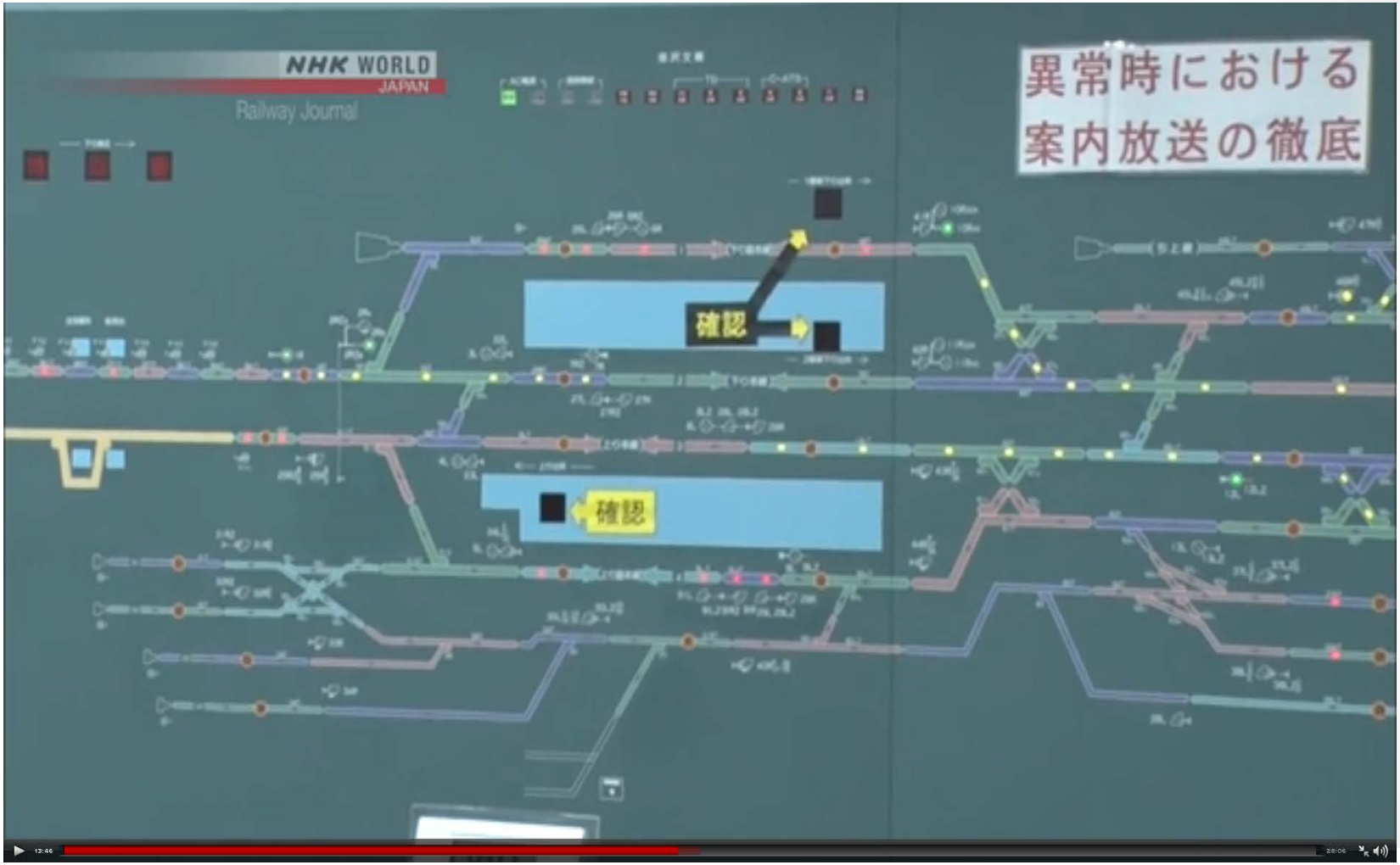
- **How does Keikyu line deal with latency?**
  - Relay based (?) interlocking with minimal latency (0.3s per direction)
  - Direct manual signal control with minimal added latency (0.3s per direction)
  - Route levers
  - Fast acting points and no mechanical trainstops (5s perhaps)
  - Latency between following diverging moves around 10s
- **Timetabled running 27 trains per direction per hour (outer stn)**

Keikyu line – adding cars during journey

- **Option to join trains in running at junctions**
  - Train can commence at multiple start stations
  - Train merges to single train at junction station
- **Option to add extra carriages in running in journey**
  - Empty carriages added mid journey
  - Boarding at empty carriage is quicker
  - Disembarking with less boarding conflict is quicker
  - Need to allow cost of attaching empty carriages

Adding empty carriages in running

Materials re Keikyu line



Materials re Keikyu line

Reference for video sequence

- **NHK (English Language program)**
- **“Japan Rail Journal”**
  - http://www3.nhk.or.jp/nhkworld/en/tv/japanrailway/
  - https://www.youtube.com/watch?v=5kjy1YsCAbA

Keikyu line – safety vs capacity?

- On 7 April 1997, at about 2:47 pm, the first three cars of a four-car train derailed after colliding with a mudslide, resulting in 22 people injured. The accident occurred between Keikyū Taura and Anjinzuka stations, with approximately 60 people on board. Heavy rains caused the mudslide, 7 months after a report by the train company to the Transportation Minister that there was little probability of such an occurrence in that area. 500 workers were mobilized as the train service was temporarily suspended between Kanazawa-Hakkei and Horinouchi stations.[5]

- On 24 November 2000, at about 5:20 am, the front car of a four-car train derailed after a truck collided with the first car of the train at a level crossing, resulting in injuries to three passengers. The accident occurred in Yokosuka, and the approximately 100 commuters on board later walked about 200 m to the nearest station to continue their journeys via bus. The driver of the truck reported his foot became stuck between the accelerator and brake pedals, sending him through the crossing bar and into the crossing. Normal operations continued about 4 hours later that morning.[6]

- On 24 September 2012, at about 11:58 pm, the first three cars of an eight-car train derailed after colliding with a mudslide, resulting in injuries to 28 people including the train driver. Seven men and women were seriously injured, including fractures, broken ribs and pelvises. The accident occurred between Oppama and Keikyū Taura stations, between Yokohama and Yokosuka, with approximately 700 passengers on board. Heavy rains caused the mudslide, sweeping away safety nets that had been installed in 1998, the year after a similar mudslide in the area.[7] An area of soil about 12 metres high and 15 metres wide fell onto the tracks, bring trees and fencing structures with it. The train was travelling at 75 km/h before the driver applied the brakes, 30 to 40 metres before the mudslide.[8] Train services were temporarily suspended between Kanazawa-Hakkei and Hemi stations and temporary bus services were provided by the train company until normal operations resumed approximately 55 hours later after the assessment and clean-up process.[9]

- On 18 April 2013, at about 4:30 pm, two window panes shattered in the front car of a commuter train while passing an express train going the opposite direction, resulting in minor lacerations to two high school students sitting with their backs to the windows. One window pane was also cracked on the passing train with no injuries. The accident occurred between Keikyu Taura and Anjinzuka stations, with approximately 30 people in the car at the time of the accident.

Conclusion

- **Blockers to metro capacity "inside the square thinking"**
  - 22s CBTC theoretical headway cannot be exploited
  - Capacity limited by busiest station stop (40 – 60 seconds typical)
  - Capacity limited by interlocking and control latencies
  - Express and stopper services cannot mix on 2 track corridor
  - Real estate for 4 track railway is expensive
- **Keikyu railway (outside the square?)**
  - Dual platform face breaks station stop nexus in 2 track corridor
  - Focus on minimising interlocking and control latencies
  - Focus on infrastructure reliability (points never fail)
  - Focus on getting trains to run on time
- **Safety dividend for most reliable, fastest railway in Tokyo**