How would delays and punctuality be affected by driverless and unattended trains?

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Background

- Railways are one of the most energy-efficient modes of transportation, however its modals share is decreasing or at best stable
- Some of the reasons the railways are not increasing the modal share:
  - Lack of capacity
  - Not flexible
  - Reliability
  - Shortage of train drivers
    - Cancelled trains
  - Not cost-efficient
- Could automation of the train operation make mainline railways more attractive?
- Urban railway systems have been automated for a long time

Automatic train operation

- Automatic train operation (ATO) has different grades of automation (GoA)
    - GoA 1 and 2 have a driver
    - GoA 3 has only train attendant
    - GoA 4 is a full automated system

- With a high grade of automation several potential benefits could be achiveied

Grade of automation	Train operation	Setting the train in motion	Driving and stopping the train	Opening and closing the doors	Operation in the event of disruptions
1	ATP with a driver	Driver	Driver	Driver	Driver
2	ATP and ATO with a driver	Driver / Automatic	Automatic	Driver	Driver
3	Driverless	Automatic	Automatic	Automatic / Attendant	Attendant
4	Unattended	Automatic	Automatic	Automatic	Automatic

ATP - Automatic Train Protection
ATO - Automatic Tran Operation
Shift2Rail

Source: Shift2Rail and IEC 62290-1

Research gap and aim

- Many studies have identified the challenges with driverless and unattended train operation but they have not been quantified
- In order to make decisions on future strategies these challenges should be quantified together with the benefits to have a complete business case
- The hypothesis is that some types of delays would be different
  - Driver-related delay causes would no longer be a factor in GoA3 and GoA4
  - With unattended train operation (GoA4) there will no longer be any personnel onboard the trains that could handle unplanned events
- This study is the first step in quantifying the challenges by transforming and simulating new delay distributions for GoA3 and GoA4 trains
- This is a KAJT project (SIMULATO) and also part of Europes Rail Motional WP8/9

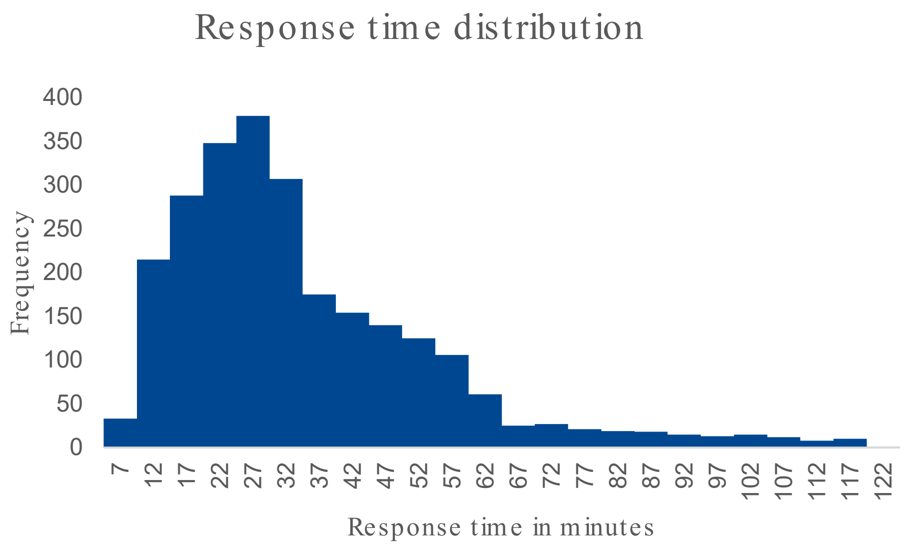
Data sources

- Response times for subcontractors in Sweden
  - One year 2019
- Delay causes from Trafikverket (LUPP)
  - One year 2019
- Vehicle failures from Skånetrafiken
  - Jan 2017 – Jun 2019

I	EA	Electrical installations
I	FK	Passability on the tracks due to the weather
I	SA	Signalling devices
I	TA	Telecommunications facilities
I	ÖA	Other facilities
J		Railway undertakings' reasons
J	AS	Deviating formation
J	DE	Late from depot
J	DM	Traction vehicle/railcar
J	FÖ	Train driver
J	JF	No information from RU
J	OM	Onboard staff
J	PR	Prioritisation
J	ST	Stationary staff
J	TP	Loading/Unloading/Platform services
J	UF	During journey
J	VA	Wagon
O		Accidents and incidents
O	BÖ	Bridge opening
O	DJ	Animals
O	MÄ	Humans

Response times

- The distributions of response times for southern Sweden year 2019
- The time from an event has been reported to a person is at the location, usually contractors
- Upper and lower bound based on the response time for ”person hit by train” (should be prioritised)
  - 7 min – 118minutes in southern Sweden
    - 2515 of total 2954 response times (only train disturbances)
    - Median 27 minutes
    - Average 32.7 minutes
    - Standard deviation 20.1 minutes



Vehicle failure logs

- Vehicle failure logs from the onboard system
- A total of 451 unique failures of which 109 a driver is needed today
- They amount of 6.3% of a total of 668,000 failures during Jan 2017 – Jun 2019

Delay causes

- Delay causes are used in other countries such as Germany and Norway, however on a less detailed level than in Sweden
- Each delay that is 3 minutes or longer should be given a cause

2.4 Railway undertakings' reasons (J)

Railway undertakings' reasons			
Code level 1	Code level 2	Code level 3	Description of code level 3
J	**AS**		**Deviating formation**
J	AS	1	Excess load profile/Exceptional transport
J	AS	2	Unplanned train length
J	AS	3	Unplanned train weight
J	AS	6	Unplanned/deviating HPS
J	AS	7	Dangerous goods
J	**DM**		**Traction vehicle/railcar[1)]**
J	DM	1	ATC/ETCS error
J	DM	3	Pantograph
J	DM	4	Wheel damage alarm
J	DM	5	Brake error/Brake system/Unintentional brake alarm
J	DM	6	Rebooting of the system/System recovery
J	DM	9	Door malfunction
J	DM	10	Typhoon

Delay causes

- Together with experts from the industry delay causes that the train drivers could handle have been identified

Code	Level	Description	GoA3	GoA4
FOI 03	3	Turnaround train staff		Removed
JDE 25	3	Late from depot - Driver is late or missing	Removed	Removed
JDM	2	Traction vehicle/railcar		Response time
JFÖ	2	Train driver	Removed	Removed
JOM	2	Onboard staff		Removed
JVA	2	Wagon		Response time
OSY	2	Inspection of track/vehicle		Response time
OTÅ 04	3	Unauthorised stop passage	Removed	Removed

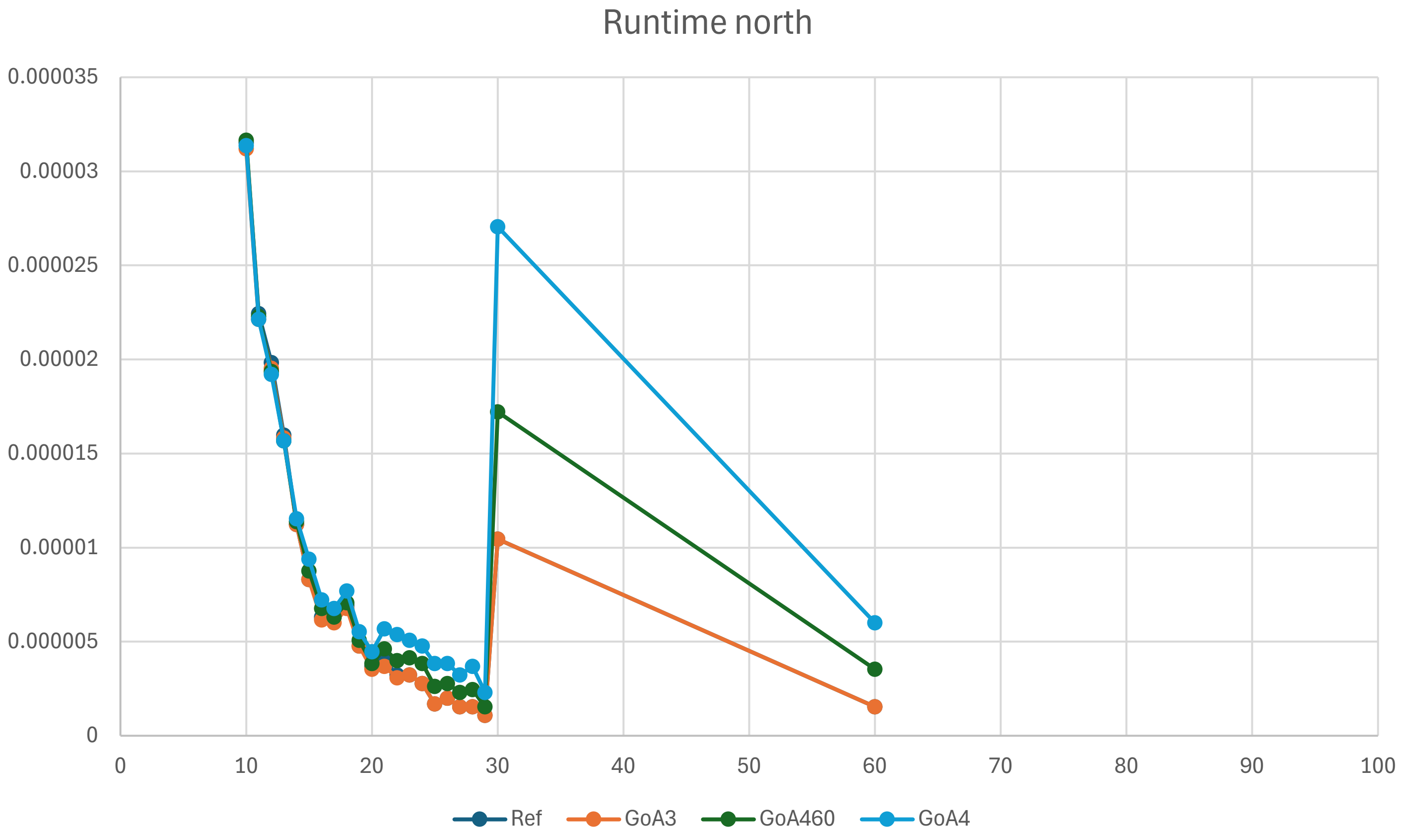
New delay distributions

- The delay distributions was based on a previous study in Skåne (Palmqvist et al., 2023)
- Based on the identified causes and the response times a new delay distributions was introduced
- The delays (n=307) that should be removed (train driver and onboard staff) were removed and replaced with a timestamp of 0-minute value
- The delays (n=599) that would need a physical person in GoA4 were given an additional delay drawn from the response times
    - The original delay was removed and replaced with the original delay + response time
- Due to the uncertainties of new technological developments and new work processes with GoA4 trains a sensitivity analysis is added.
    - 60% of the vehicle failures are supposed be handled without a physical person

Palmqvist, C.W., Johansson, I., Sipilä, H., 2023. A method to separate primary and secondary train delays in past and future tim etables using macroscopic simulation. Transportation Research Interdisciplinary Perspectives 17, 100747. URL: https://linkinghub.elsevier.com/retrieve/pii/S259019822200207X, doi:10.1016/j.trip.2022.100747.

New delay distributions

- The distributions are very similar even after the transformation, the differences can be seen at higher delay values for the scenarios with GoA4



Preliminary results – Punctuality and delays

- The simulation results show small differences between the scenarios

- The differences in average delay time, even though very small, show expected tendencies
  - GoA3 scenario should be better than the reference scenario
  - GoA4 scenario should be worse than the reference scenario

Commuter trains

	RT+5	RT+15	Average (s)	Std (s)
Ref	91.9	98.6	109.1	226.2
GoA3	91.9	98.6	108.9	227.1
GoA4	91.8	98.4	112.6	256.9
GoA4 60%	92.0	98.5	110.6	245.1

All trains

	RT+5	RT+15	Average (s)	Std (s)
Ref	90.0	97.9	77.8	692.5
GoA3	90.1	97.9	77.0	692.8
GoA4	90.0	97.8	79.2	699.3
GoA4 60%	90.1	97.9	77.3	695.0

Difference in total delay time (over 300 cycles) with reference scenario for commuter trains

Scenario	Difference (h)
GoA3	-10
GoA4	145
GoA4 60%	62

Limitation

- In this study no consideration to other aspects of ATO such as run times and headway
  - This will be covered in the upcoming simulations in Europes Rail during spring 2025
- The simulations are only done with a macroscopic tool, PROTON
  - But the delay distributions could be used in any simulation tool
- Only dwell and run-time delays were transformed
- Trains are not connected at the end stations

Discussion

- A first glimpse of the negative effects of GoA4 trains on a mainline system
  - The results show small negative effects for the GoA4 trains
  - The number of events are small compared to the number of departures of a commuter train system
- Another type of train system with fewer departures could be more affected by GoA4
  - Such as long-distance trains or freight trains
- The delay causes for animal (ODJ) and humans (OMÄ) have been discussed a lot in the project and this will be further discussed in the project

Discussion

- But there also other aspects
- Thanks to an observant driver last year a potential disaster was prevented in northern Sweden
- The preceding driver alerted the traffic control about damage to embankment and eventually the traffic controller reduced the speed from 160 km/h to 40 km/h

Source: Statens Haverikommission , 2024 (SHK 2024:14)

Future work

- In Europe's Rail a simulation with GoA4 will be performed on the Iron Ore Line with a similar setup

- In Europe's Rail simulation of GoA2 will be performed on Citybanan, Citytunneln and Norrköping-Mjölby

Thanks for listening !

Questions or suggestions?