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Human Factors, Systems and Safety

Felix Schmid, PhD, FIMechE, FIRSE
Professor of Railway Systems Engineering
University of Birmingham

Felix Schmid

Poor Management of Change Causes Accidents

Overview of Presentation

- Different views of railway systems;
- Railway subsystems, interfaces and interactions;
- Railway complexity, complication and people;
- What are human factors? What is ergonomics?
- Why do we need ergonomics?
- Ergonomics in the railway industry;
- Some railway operations examples;
- Recent major railway accidents;
- Where are the REAL failures?

Slide No: 3

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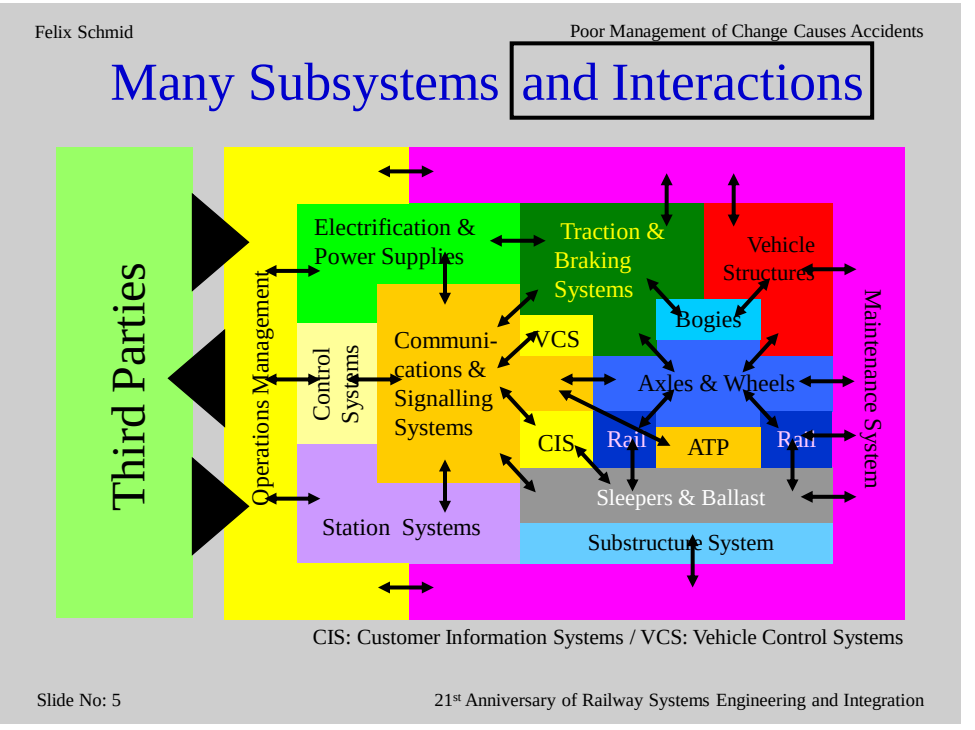
Poor Management of Change Causes Accidents

Railways involve 'Stuff'and People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Poor Management of Change Causes Accidents
Many Subsystems and Interactions
Third Parties
Operations Management
Control Systems
Electrification & Power Supplies
Traction & Braking Systems
Vehicle Structures
Bogies
Communi-cations & Signalling Systems
VCS
Axles & Wheels
CIS
Rail
ATP
Rail
Sleepers & Ballast
Station Systems
Substructure System
Maintenance System
CIS: Customer Information Systems / VCS: Vehicle Control Systems
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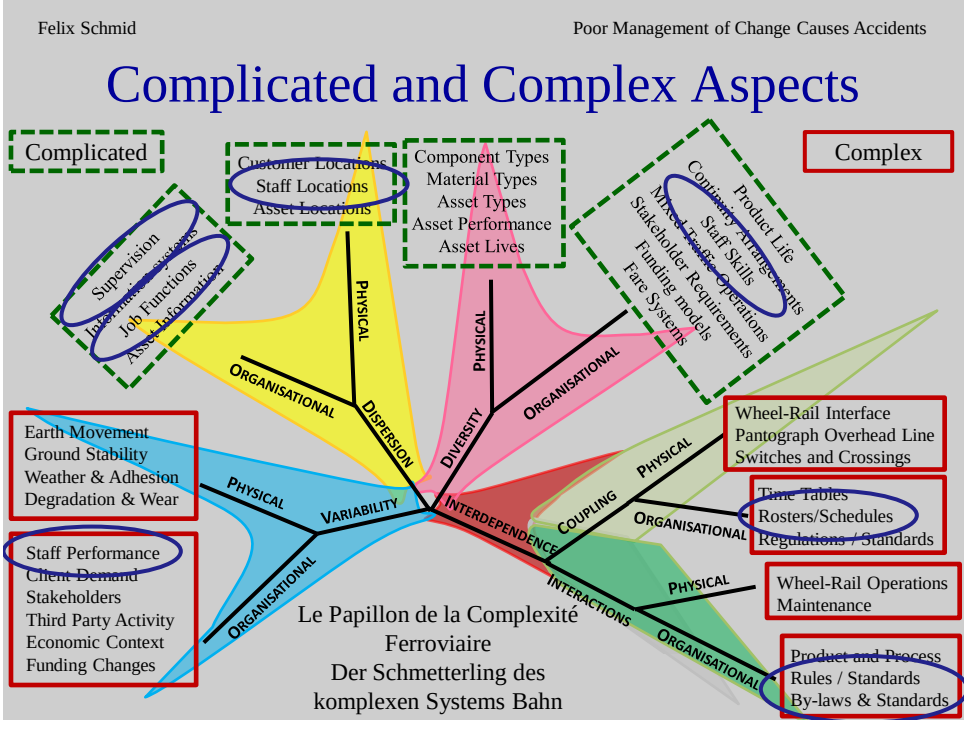
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Complicated and Complex Aspects
Complicated
Complex
Customer Locations
Staff Locations
Asset Locations
Component Types
Material Types
Asset Types
Asset Performance
Asset Lives
Supervision
Job Functions
Asset Information
Product Life
Continuity Arrangements
Staff Skills
Mixed Traffic Operations
Stakeholder Requirements
Funding models
Fare Systems
PHYSICAL
ORGANISATIONAL
DISPERSION
DIVERSITY
PHYSICAL
ORGANISATIONAL
Earth Movement
Ground Stability
Weather & Adhesion
Degradation & Wear
PHYSICAL
VARIABILITY
ORGANISATIONAL
Staff Performance
Client Demand
Stakeholders
Third Party Activity
Economic Context
Funding Changes
INTERDEPENDENCE
COUPLING
PHYSICAL
ORGANISATIONAL
INTERACTIONS
PHYSICAL
ORGANISATIONAL
Wheel-Rail Interface
Pantograph Overhead Line
Switches and Crossings
Time Tables
Rosters/Schedules
Regulations / Standards
Wheel-Rail Operations
Maintenance
Product and Process
Rules / Standards
By-laws & Standards
Le Papillon de la Complexité Ferroviaire
Der Schmetterling des komplexen Systems Bahn

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Complication and Complexity result in Railway Safety Risk

Types of Railway Risks and Parties Involved

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Types of Railway Risk

- Technical Safety Risk:
  - Train component failure;
  - Track component failure;
  - Signalling system failure.
- Operational Safety Risk:
  - Poor timetabling;
  - Human performance;
  - Maintenance quality.
- Societal Safety Risk:
  - Behavioural changes;
  - Poor change awareness.
- Financial Risk:
  - Budget overrun;
  - Compensation demand;
  - Company failure.
- Project Risk:
  - Time overrun;
  - Technology failure;
  - Performance risk.
- Security Risk:
  - Malicious acts;
  - Cyber technology issues.

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Safety and Security for Travelling Public

- Concern since early days of railways;
- Travelling by train:
  - Collisions;
  - Fires and ;
  - Derailments;
  - HV AC Electrification;
  - Other passengers.
- Travelling in and through stations:
  - Slips, trips and falls;
  - Shelter and warmth.

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Safety of Operating Personnel

- Operating trains:
  - Driving activities;
  - Shunting activities;
  - Guard / conductor duties.
- Handling goods:
  - Lifting and shifting;
  - Fighting fires
  - Hazardous cargo spills.
- Dealing with incidents:
  - Derailments;
  - Animals and suicides.

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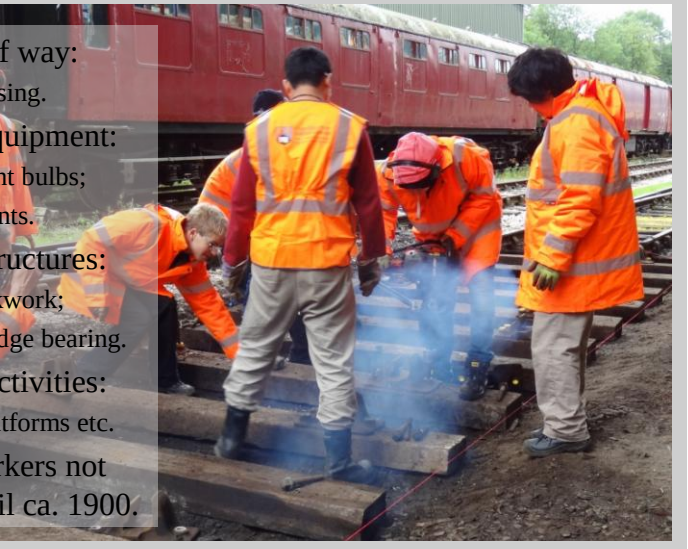
Safety of Trackside Workers

- Maintenance of way:
  - Packing, greasing.
- Maintaining equipment:
  - Replacing light bulbs;
  - Adjusting points.
- Maintaining structures:
  - Pointing brickwork;
  - Replacing bridge bearing.
- Construction activities:
  - Build new platforms etc.
- Track-side workers not considered until ca. 1900.



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Safety of Third Parties

- Level crossing accidents:
  - Vehicular interface;
  - Pedestrian interface.
- Overbridge / Underbridge:
  - Bridge-bashing;
  - Falls / drops onto railway.
- Trespass & vandalism:
  - Risks to perpetrators;
  - Risks to railway.
- Adjacent development:
  - Construction;
  - Drainage.

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Defences against Risks

- Introduction of technical assist and intervention systems:
  - Redundancy and diversity.
- Better planning and scheduling:
  - Remove in-built conflicts.
- Rules and regulations:
  - Proscribe and prescribe.
- Management;
- Supervision and control;
- Laws and deterrents;
- Training and education:
  - Competency management and assessment.
- Automation (get rid of fallible human being).

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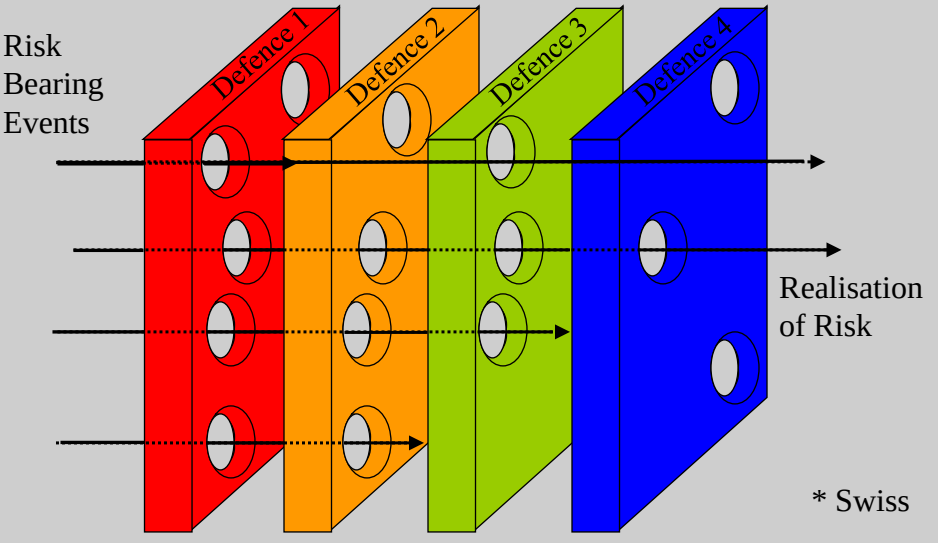
Reason's (Emmental*) Cheese Model



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People create Hazards and prevent Accidents

Human Factors / Ergonomics

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Traditional Perception of Human Error

- Negligence;
- Lack of commitment;
- Failure to follow rules or procedures.

From this perspective, people could avoid making errors by choosing to behave 'correctly'…

Too simplistic - we're only human, and we can all fail, in predictable ways!

How likely we are to fail is "shaped" by …

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Performance Shaping Factors

[HSE publication HSG 48 (Reducing Error and Influencing Behaviour)]

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Neuhausen am Rheinfall
Switzerland
2013-01-10, 07:34

Signal Passed at Danger – Human Error?

Collision on a set of Points

No Fatalities / 26 Injuries

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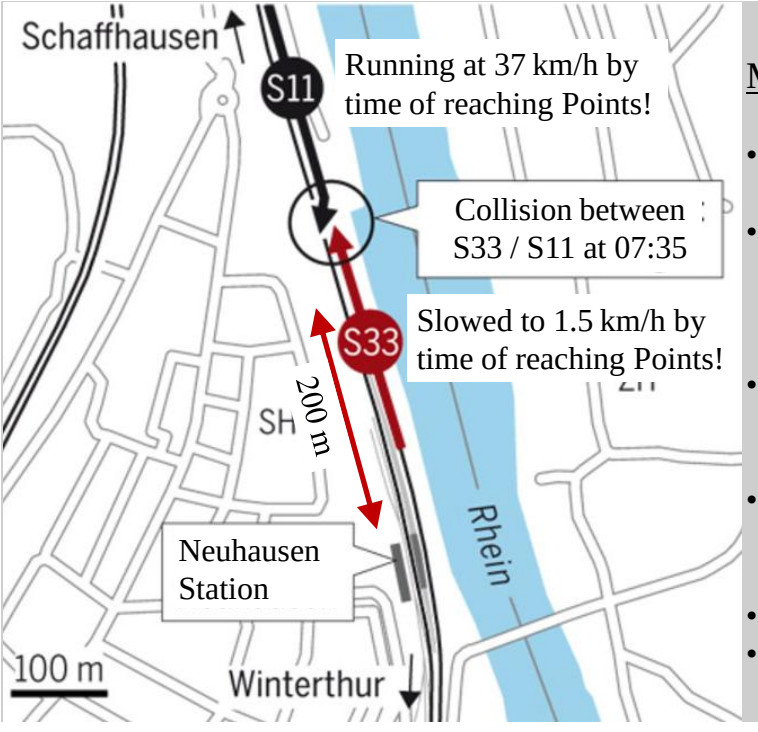
Light Weight Local Train derails Loco



Main Issues:

- 20% more services;
- Punctuality essential on single track railway line;
- Much higher performing trains;
- More ergonomic operation;
- Human error;
- Lack of ATP.

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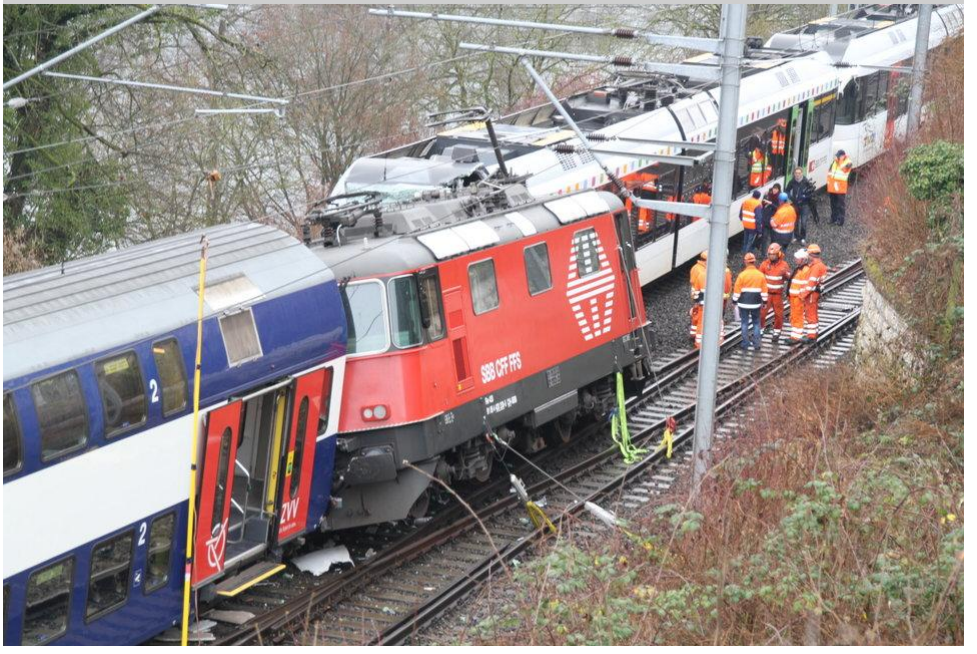

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Poor Management of Change Causes Accidents

Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Neuhausen, CH	Better Train Performance	SPAD (1.2 km/h)	No Speed Supervision	We are the best in the World
Lac Mégantic, CA				
Brétigny-sur-Orge				
Santiago de Comp				
Granges-Marnand				
New York, USA				
Casselton, USA				

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Lac Mégantic Disaster Canada 2013-07-06, 01:15

Lax Attitude to Safety – Human Error?

8 m litres of Bakken oil exploded and burnt!

Huge Fire / Town Destroyed / 45 Deaths

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Lac Mégantic Disaster, Canada

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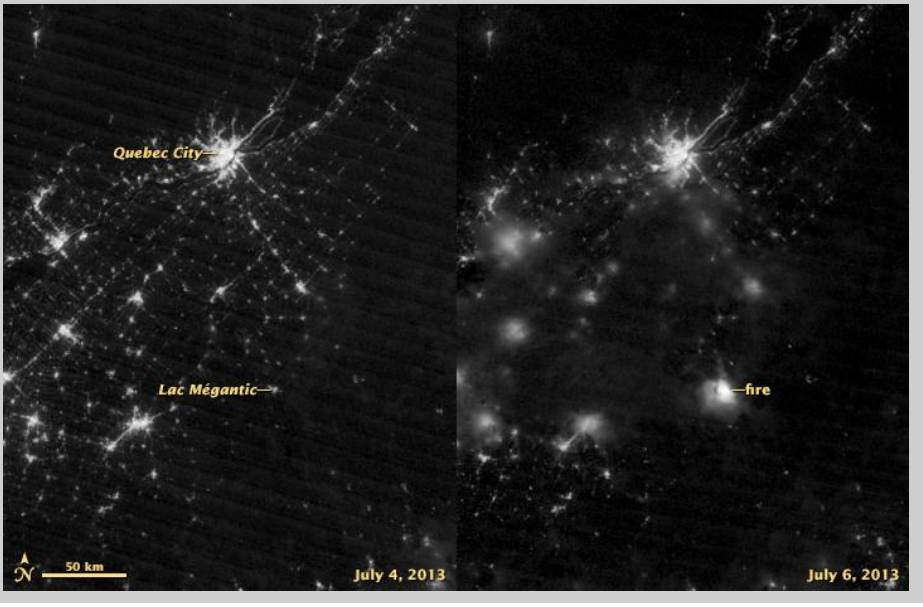
Satellite Image Normal / after Accident



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Poor Management of Change Causes Accidents

Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Neuhausen, CH	Better Train Performance	SPAD (1.5 km/h)	No Speed Supervision	We are the best of the World
Lac Mégantic, CA	New Flows of New Fuels	Train Not Secured	Poorly Main-tained Locos	Cost Cutting & Negligence
Brétigny-sur-Orge				
Santiago de Comp				
Granges-Marnand				
New York, USA				
Casselton, USA				

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Spuyten Duyvil Curve New York, USA 2013-12-01, 08:10

Microsleep by the Driver – Human Error?

Classical Overspeed Scenario on a Curve

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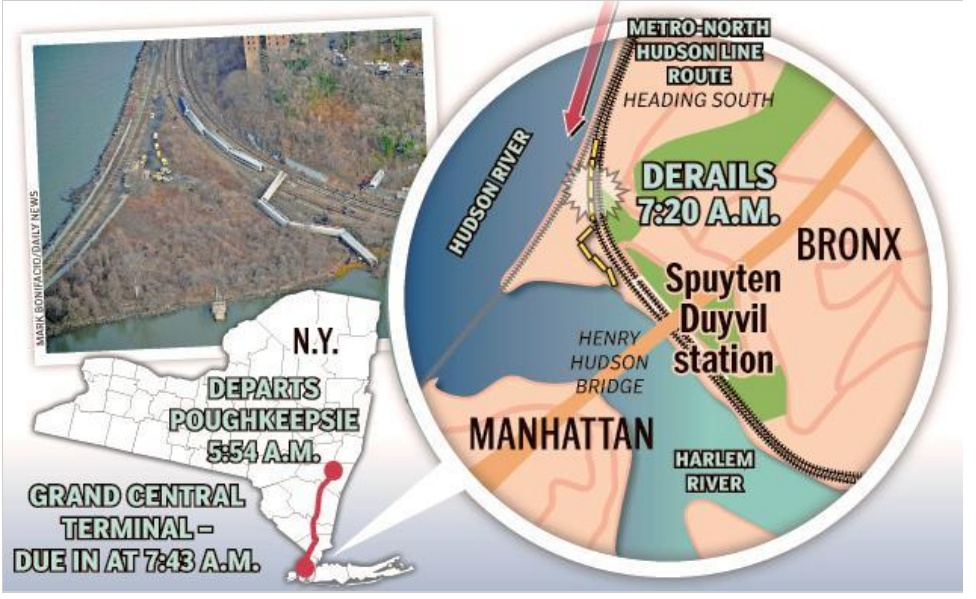
As Reported in New York Daily News



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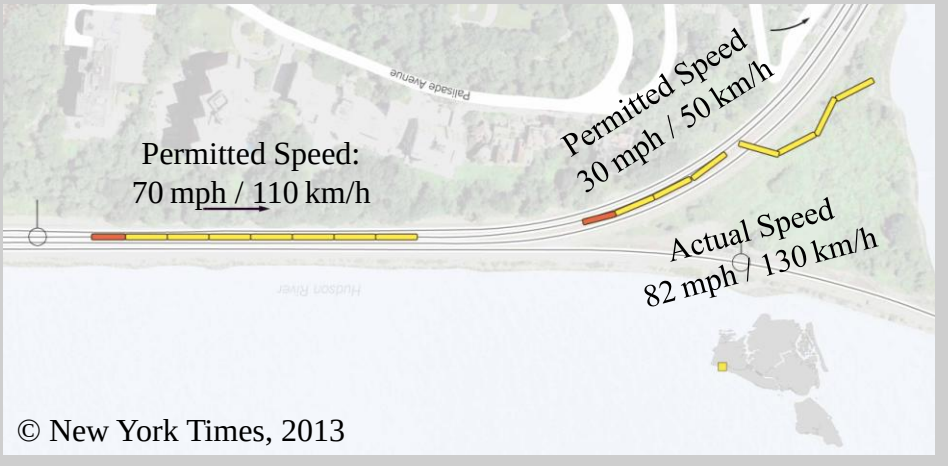
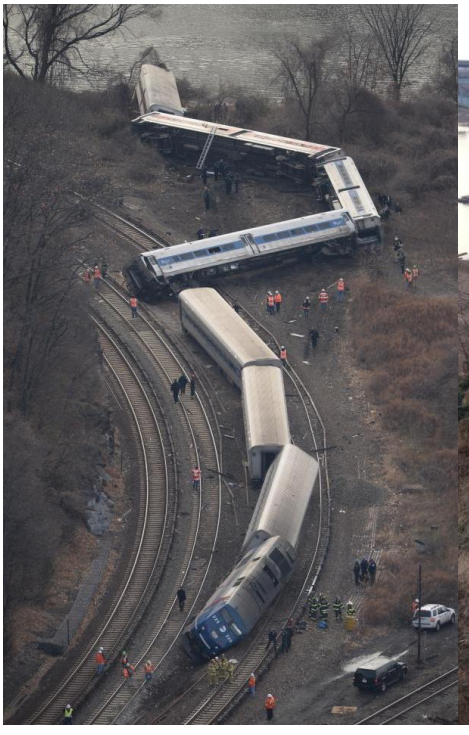
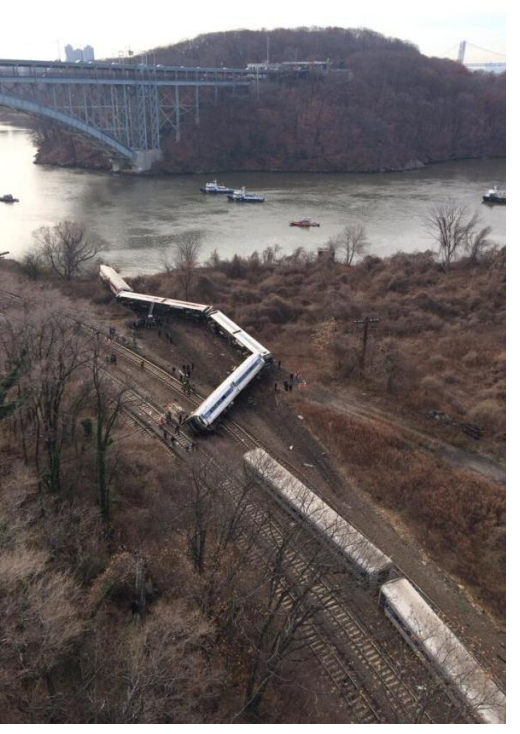
The Classical Overspeed Scenario







5 m / 100 m more: Greater Consequences

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Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Neuhausen, CH	Better Train Performance	SPAD (1.5 km/h)	No Speed Supervision	We are the best in the World
Lac Mégantic, CA	New Flows of New Fuels	Train Not Secured	Poorly Main-tained Locos	Cost Cutting & Negligence
Brétigny-sur-Orge	Focus on LGV Higher Speeds	Dislodged Fishplate	Inadequate Supervision	Lack of Interest
Santiago de Comp	ATP off, no trainstop	Driver error Overspeed	Hasty start of new services	Reliance on human beings
Granges-Marnand	New services, peak time only	SPAD (50 km/h)	No ATP, train stop site wrong	Minor routes not enhanced
New York, USA	No vigilance device in cab	Microsleep Overspeed	No ATP, no speed traps	Politically focused
Casselton, USA				

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Casselton Collision
North Dakota, USA
2013-12-30, 14:00

Derailment of 112 Wagon Soy Bean Train
106 wagon shale-oil train collides with wreckage and results in 21 wagons burning for a day.
Casselton had to be evacuated but no casualties.

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Bakken Shale-Oil is similar to Diesel

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Wagons of Crude Oil in 2008: 10,000 / in 2013: 400,000

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Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Neuhausen, CH	Better Train Performance	SPAD (1.5 km/h)	No Speed Supervision	We are the best in the World
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New York, USA	No vigilance device in cab	Microsleep Overspeed	No ATP, no speed traps	Politically focused
Casselton, USA	Huge growth in oil flows	Poor track maintenance	New type of fuel oil, wagons	Undercutting of competition

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Accident at Rafz Station in Switzerland 2015-02-20 06:41

Signal Passed at Danger – Human Error?

Collision on a set of Points

No Fatalities / 6 Injuries of which 1 Serious

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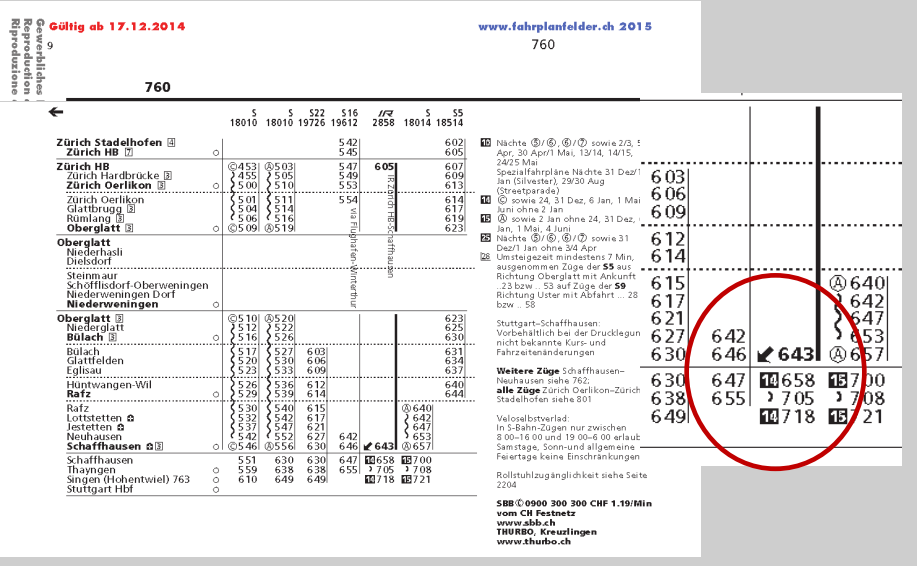
Normal Weekday Peak Timetable



Gültig ab 17.12.2014

www.fahrplanfelder.ch 2015

760

	S 18010	S 18010	S22 19726	S16 19612	2858	S 18014	S5 18514
Zürich Stadelhofen 4				542			602
Zürich HB 7 ○				545			605
Zürich HB	Ⓒ453	Ⓐ503		547	605		607
Zürich Hardbrücke 3	⟩455	⟩505		549			609
Zürich Oerlikon 3 ○	⟩500	⟩510		553			613
Zürich Oerlikon	⟨501	⟨511		554			614
Glattbrugg 3	⟨504	⟨514					617
Rümlang 3	⟨506	⟨516					619
Oberglatt 3 ○	Ⓒ509	Ⓐ519					623
Oberglatt							
Niederhasli							
Dielsdorf							
Steinmaur							
Schöfflisdorf-Oberweningen							
Niederweningen Dorf							
Niederweningen ○							
Oberglatt 3	Ⓒ510	Ⓐ520					623
Niederglatt	⟩512	⟩522					625
Bülach 3 ○	⟩516	⟩526					630
Bülach	⟨517	⟨527	603				631
Glattfelden	⟨520	⟨530	606				634
Eglisau	⟨523	⟨533	609				637
Hüntwangen-Wil	⟨526	⟨536	612				640
Rafz ○	⟨529	⟨539	614				644
Rafz	⟨530	⟨540	615			Ⓐ640	
Lottstetten ⌂	⟨532	⟨542	617			⟩642	
Jestetten ⌂	⟨537	⟨547	621			⟩647	
Neuhausen	⟨542	⟨552	627	642		⟩653	
Schaffhausen ⌂ 3 ○	Ⓒ546	Ⓐ556	630	646	↙643	Ⓐ657	
Schaffhausen	551	630	630	647	14658	15700	
Thayngen ○	559	638	638	655	⟩705	⟩708	
Singen (Hohentwiel) 763 ○	610	649	649		14718	15721	
Stuttgart Hbf ○							

Via Flughafen-Winterthur

Via Eglisau-Schaffhausen

10 Nächte Ⓢ/⑥, ⑥/⑦ sowie 2/3, 1 Apr, 30 Apr/1 Mai, 13/14, 14/15, 24/25 Mai
Spezialfahrpläne Nächte 31 Dez/1 Jan (Silvester), 29/30 Aug (Streetparade)
10 Ⓒ sowie 24, 31 Dez, 6 Jan, 1 Mai
15 Ⓐ sowie 2 Jan ohne 2 Jan
23 Nächte Ⓢ/⑥, ⑥/⑦ sowie 31 Dez/1 Jan ohne 3/4 Apr
28 Umsteigezeit mindestens 7 Min, ausgenommen Züge der **S5** aus Richtung Oberglatt mit Ankunft ..23 bzw. ..53 auf Züge der **S9** Richtung Uster mit Abfahrt ..28 bzw. ..58

Stuttgart–Schaffhausen: Vorbehältlich bei der Drucklegung nicht bekannte Kurs- und Fahrzeitenänderungen

Weitere Züge Schaffhausen–Neuhausen siehe 762;
alle Züge Zürich Oerlikon–Zürich Stadelhofen siehe 801

Veloselbstverlad:
In S-Bahn-Zügen nur zwischen 8.00–16.00 und 19.00–6.00 erlaubt. Samstags, Sonn- und allgemeine Feiertage keine Einschränkungen

Rollstuhlzugänglichkeit siehe Seite 2204

SBB 0900 300 300 CHF 1.19/Min vom CH Festnetz
www.sbb.ch
THURBO, Kreuzlingen
www.thurbo.ch

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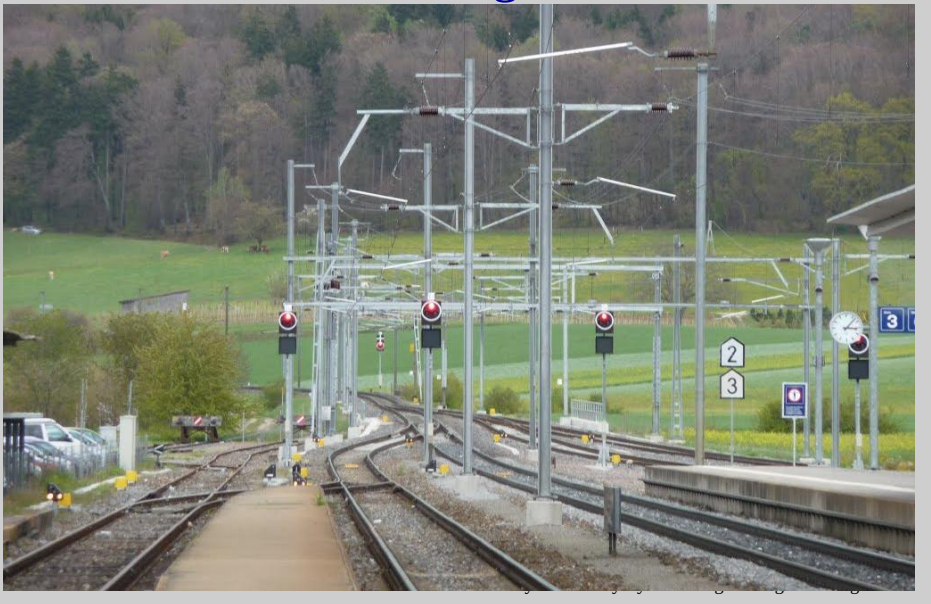
Poor Management of Change Causes Accidents

Station Throat to Single Track Section



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View from Platform 3/4

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Poor Management of Change Causes Accidents

Accident Timeline

- Line from Rafz to Neuhausen is single track;
- IR 2858 is timetabled to pass Rafz at ca. 06:31:
  - Non-stop Inter-Regional Zürich to Schaffhausen.
- S 18014 peak hours train starts day in Rafz:
  - Mo-Fr only, normal departure 06:40;
  - Arrived ECS (empty coaching stock) from North.
- IR 2858 is running 10 minutes late;
- S 18014 leaves platform on time at 06:40;
- IR 2858 hits S 18014 on points leaving station.

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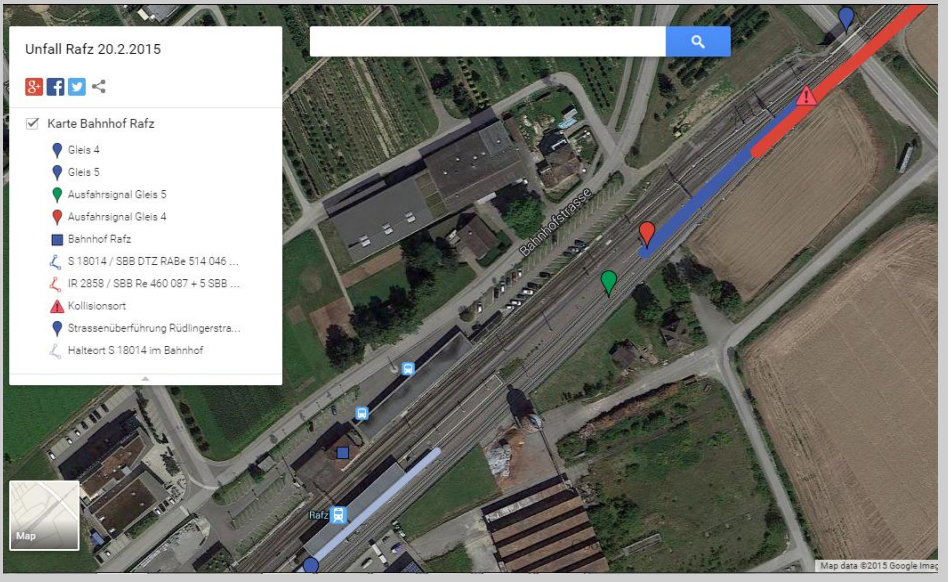
Layout and Accident Scenario



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Electronic Timetable as a Factor?

	km	-	+	S		AE	Bern	R150	An	Ab
	16.1	3	8		1302		**Killwangen-S.**	140	(20:13)	
							WE - BDO / BG - AA			
	17.4						Langacher ▲ P17 / Q17			
	18.6						Rüsler P19 / Q19			
	19.9						Hiltiberg P20 / Q20			
	21.1						Rückerfeld P21 / Q21			
	21.5						km 21.500 F			
	22.2	3	8				*Mellingen Heitersberg*	140	(20:16)	
	22.8	0	10				**Mellingen**	140	(20:16)	
	23.5						Block P24/Q24			
	25.9	0	3				**Mägenwil**	140	(20:17)	
	27.1						*Kurve* 130			
	27.7	10	10		1304		**Othmarsingen** 130	130	(20:18)	
	30.2 [63.9]	10	0				**Gexi**	130	(20:20)	
	31.9	10	0				**Lenzburg** 125 140	140	(20:21)	
							Rothrist via Suhr			
	33.7						Stockhard 34P/Q			
	35.6	3	6				**Rupperswil** 140	160	(20:22)	

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Poor Management of Change Causes Accidents

Observations about Rafz Accident

- Both trains had two drivers:
  - Instructor plus trainee;
  - Instructor and trainee discussion may have diverted attention.
- Only one train a day starts journey in Rafz;
- Block entry signal (beyond last point) may show green, even though starter is red;
- Electronic timetable may have led drivers to start 'on-time':
  - Is there a live update about delays?

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Poor Management of Change Causes Accidents

Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Bintaro Level X	Overall Traffic Growth	Truck on Level Crossing	No CCTV LC Supervision	People are unimportant
Collision at Rafz	Train Power Increases	SPAD by Trainee Driver	Difference in Timetable	We are still best in World

Slide No: 48

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Halifax, North Carolina 2015-03-09

Collision of Amtrak North East Corridor Train with Truck on Level Crossing

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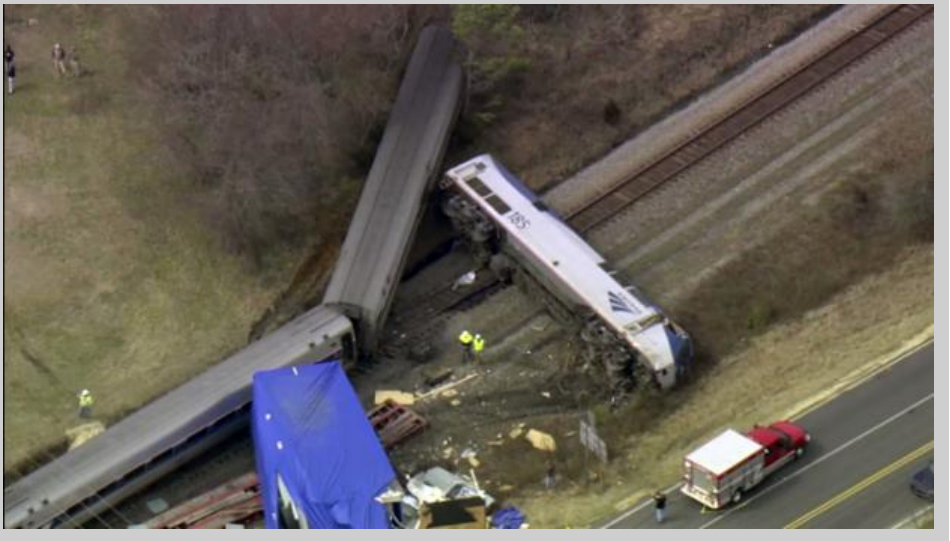
Poor Management of Change Causes Accidents

LC Collision between Train and Truck



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Poor Management of Change Causes Accidents

Level Crossing Incidents are High Risk

- 55 people injured but no fatalities;
- Truck carried mobile equipment building;
- Truck was accompanied by state trooper to deal with highway / road traffic issues;
- Difficult turn into main road – truck stalled on level crossing for 20 minutes before crash;
- Poor instructions for level crossing users;
- Similar incident with a bacon truck on 5 June 2015 near Wilmington, no casualties.

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Poor Management of Change Causes Accidents

Situation and Aftermath

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Poor Management of Change Causes Accidents

Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Bintaro Level X	Overall Traffic Growth	Truck on Level Crossing	No CCTV LC Supervision	People are unimportant
Collision at Rafz	Train Power Increases	SPAD by Driver	Difference in Timetable	We are still best in World
West Virginia Train Derailment	Huge growth in oil flows	Poor track maintenance	Out of date wagons in use	Undercutting of competition
Halifax Level Crossing Collision	Growing Road Vehicle size	Truck on Level Crossing 20'	No CCTV LC Supervision	Instructions for police incorrect

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Frankfort Junction, Port Richmond, Philadelphia 2015-05-15

Derailment of Amtrak North East Corridor Train due to Overspeed on Curve

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Immediate Aftermath of Derailment

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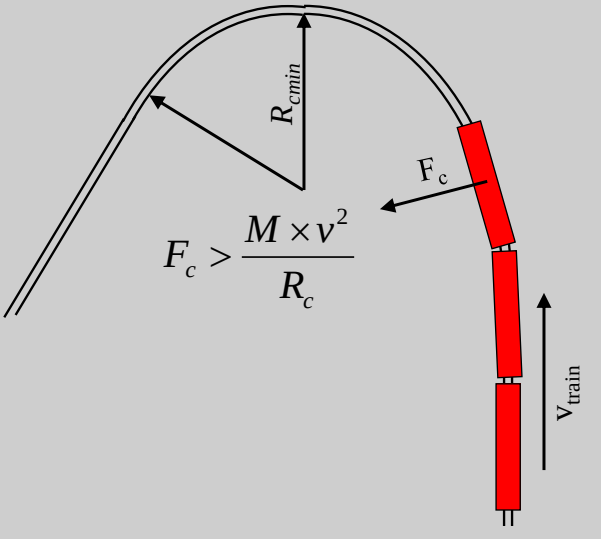
Safely Travelling on Curves



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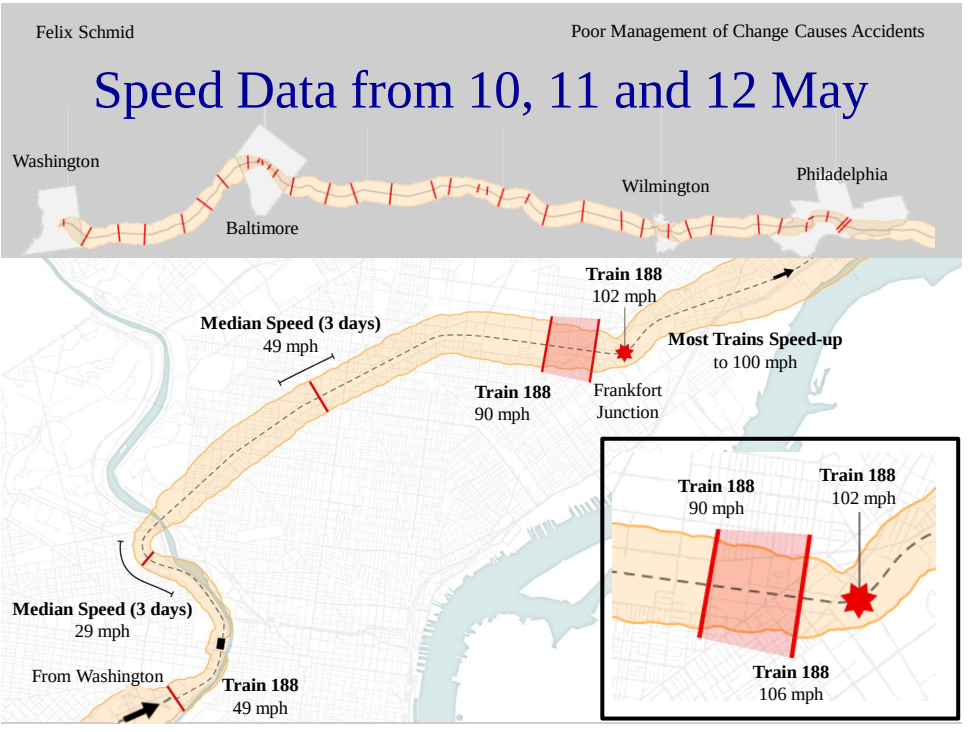
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Speed Data from 10, 11 and 12 May
Washington
Baltimore
Wilmington
Philadelphia
Train 188
102 mph
Median Speed (3 days)
49 mph
Most Trains Speed-up
to 100 mph
Train 188
90 mph
Frankfort
Junction
Train 188
90 mph
Train 188
102 mph
Median Speed (3 days)
29 mph
From Washington
Train 188
49 mph
Train 188
106 mph


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Trajectories of Loco and Carriages
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Beginning of Recovery Operation

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Roof Removal from first Carriage

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Poor Management of Change Causes Accidents

Consequences and Theories

- 238 staff and 5 crew on board;
- Locomotive stayed upright;
- 8 deaths and 200 injured, of which 11 seriously;
- Driver behaviour normal before accident:
- Report of damage to locomotive windscreen;
- Mobile phone records of driver being investigated;
- PTC installed on track and train but not in use;
- Legacy ATC (=ATP) system allowed overspeed;
- FRA now actively reviewing PTC implementation.

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Poor Management of Change Causes Accidents

Causal Analysis of recent Accidents

Accident	Change not understood?	Immediate Cause(s)	Contributory Cause(s)	Management Failure(s)
Bintaro Level X	Overall Traffic Growth	Truck on Level Crossing	No CCTV LC Supervision	People are unimportant
Collision at Rafz nr. Zürich, CH	Train Power Increases	SPAD by Driver	Difference in Timetable	We are still best in World
West Virginia Train Derailment	Huge growth in oil flows	Poor track maintenance	Out of date wagons in use	Undercutting of competition
Halifax Level Crossing Collision	Growing road vehicle size	Truck on Level Crossing 20'	No CCTV LC Supervision	Instructions for police incorrect
Philadelphia High Speed Derailment	Complexity of Driving Task	Driver Mistake	PTC not yet Operational	Budget cuts & radio spectrum

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Eckwersheim, High Speed Train Derailment 2015-11-14, 15:10

Derailment of LGV-Est Test Train due to Overspeed on Curve

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Derailment due to Overspeed

- Test train on the Ligne à Grande Vitesse (LGV) Est from Beaudrecourt to Vendenheim derails on curve that connects phase 2 of LGV-Est to classic network;
- Last of 200 test runs at a 10% over-speed to assess ride quality and stability;
- 53 people were on board, 49 test personnel and colleagues as well as 4 children;
- 11 people are killed and 42 injured, of which 4 in a life threatening state;
- 7 people were in the cab at the time of the accident: driver, second driver, traction inspector, engineer from SYSTRA and 3 others;
- Traction inspector took a mobile phone call at time where braking was due to start;
- Statement from SNCF: We shall punish responsible people!

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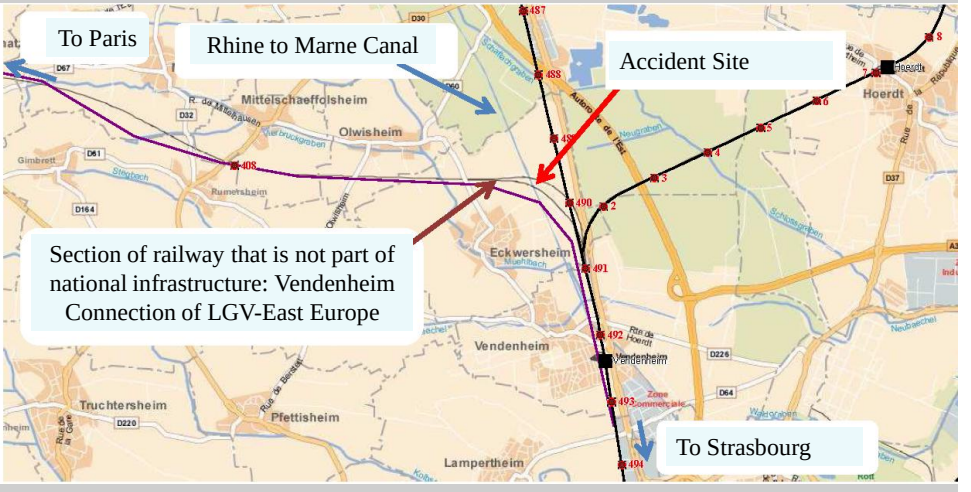
Geographic Context of Derailment



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Aerial View of Results of Derailment

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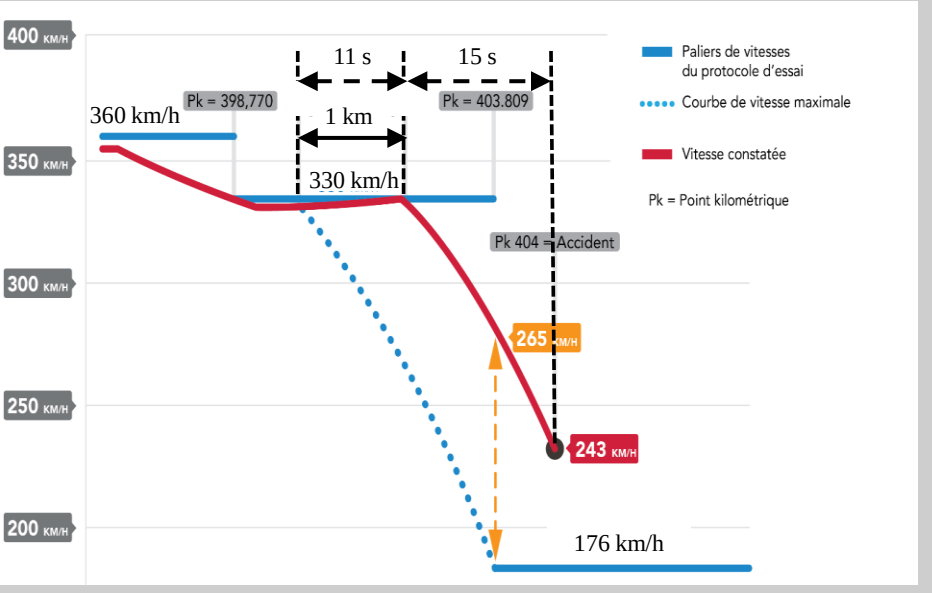
Train Speed Pattern Leading to Accident



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Bridge hit by Front Power Car

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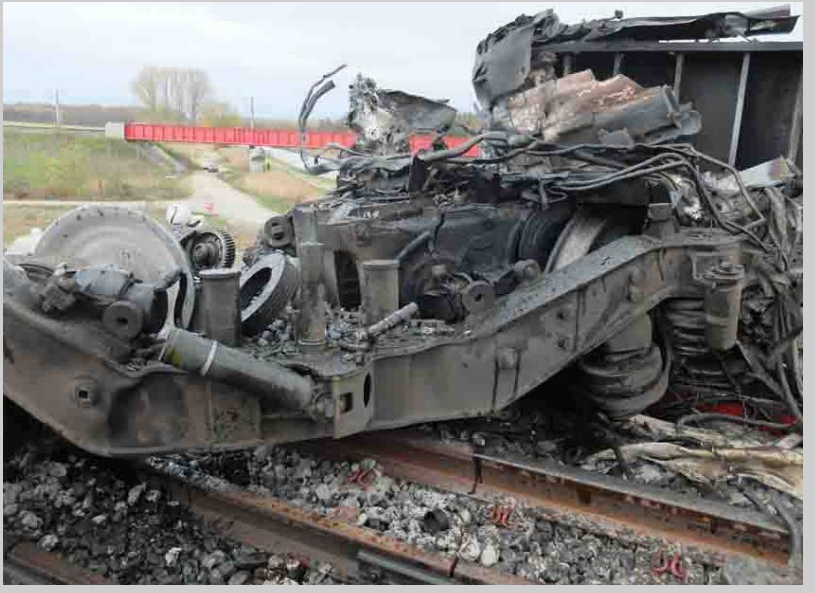
Rear Bogie of Front Power Car



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Eckwersheim, Train Derailment	Increased speed of Tests	Driver Mistake	ATP not Operational	Complacency, we are the best.

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Poor Management of Change Causes Accidents

Overall Causal Analysis of Accidents

Accident	Human Error	Regulatory Failure	Finance Issue	Automation Issue
Neuhausen, CH	X		X	X
Lac Mégantic, CA	X	X	X	
Brétigny-sur-Orge	X		X	
Santiago de Comp	X		X	X
Granges-Marnand	X	X		X
New York, USA	X	X		X
Casselton, USA		X	X	
Bintaro LC	X	X		
Collision at Rafz	X	X	X	X
West Virginia		X	X	
Halifax Collision	X	X	X	X
Philadelphia	X	X	X	X
Eckwersheim	X	X		

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General Lessons from Railway Accidents

Human beings at all levels are fallible;
Accidents are rarely caused by a single mistake;
Alignment of errors and failures creates precondition;
Early risk assessment can mitigate outcome.

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Railway Transport is a total 'System'

- System includes both people and machines;
  - People in the system include users and staff;
  - Machines in the system include amplifiers of human strength and information handling.
- Machines are often software based:
  - Can change behaviour quickly.
- Railways are joint cognitive systems:
  - Systems that require much Human-Machine interactions so as to produce a coherent product. (Erik Hollnagel et al., 2005)
- The railway is a socio-technical system.
  - (Wilson et al., 2007)

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Socio-Technical Systems Thinking

- Cherns (1976, 1987) principles of socio-technical design, e.g.:
  - Compatibility;
  - Information flow;
  - Power and authority.
- Social factors, e.g.:
  - Personnel;
  - Interactions;
  - Training.
- Technical factors, e.g.:
  - Technologies;
  - Materials;
  - Standardisations.
- Automation to manage growing complication & complexity.

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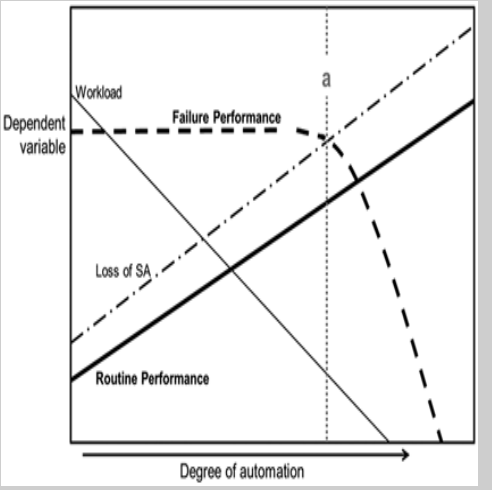
Poor Management of Change Causes Accidents

Automation and System Performance

- Onnasch et al. (2014) propose a 'degree of automation' variable to explain trade-offs in human-machine relationships;
- With any increase in degree of automation:
  - Routine performance improves;
  - Performance in failure scenarios declines;
  - Workload from automated task reduces progressively;
  - Loss of Situational Awareness (SA) grows steadily: as automation is doing more cognitive / physical work, the human is doing less.



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Ergonomics in Railway Operations

- Increasing emphasis on improving rail safety, but with pressure to improve business performance:
  - Higher speeds and higher performance trains;
  - Increasing traffic reduces time / space between trains;
  - Tilting trains and other advanced systems.
- New human interface and performance issues arise from new systems:
  - Human aspects of train control & signalling systems, Automatic Train Protection systems etc. need to be assessed.
- Increasing traffic levels and need for reliability.

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Railway Human Factors are Challenging

- Large numbers of very distributed staff;
- Complex and legally binding hierarchies;
- Many monotonous jobs;
- Antisocial hours work;
- Dangerous work places;
- High levels of responsibility, little authority;
- Need for high reliability organisations;
- Regulatory influences must be managed.

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