Opus Suite Conference | STOCKHOLM

2024-04-09

CAPABILITY IMPROVEMENTS ON MALMBANAN

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by Systecon opus suite

MALMBANAN – HISTORY

- **First electrified railway in Sweden (1910)**
  - said to be the first LCC procurement
  - ASEA (ABB) and Siemens
  - delayed delivery – increased cost – ”blame game”
  - payment withheld due to:
    - supplier not being committed
    - spare parts not being delivered
    - work not being completed
  - huge success!

- **100 years later – still as important**
  - transportation of freight and passengers
  - NATO membership

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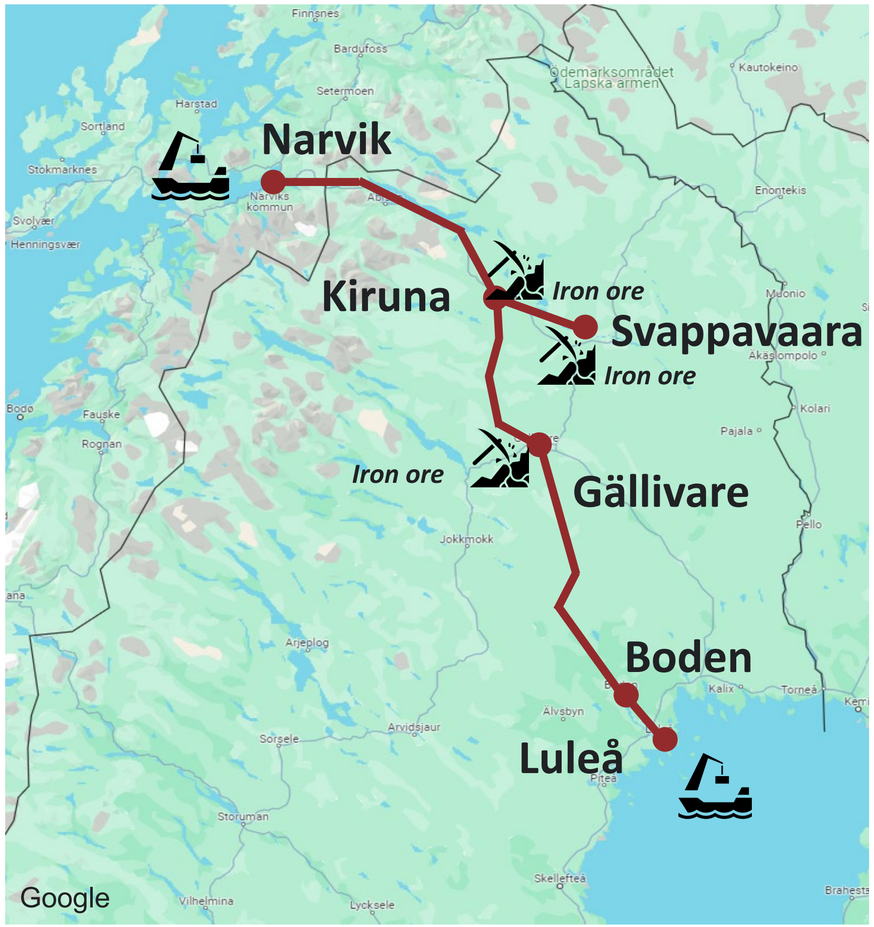
MALMBANAN – INTRODUCTION



- **Facts**
  - ≈ 500 km single track
  - ≈ 45 % of Swedish rail freight transport (weight)
- **LKAB mining**
  - transportation – only by railway
  - 135 000 tons iron ore per day
  - value ≈ 100 million SEK per day
- **Malmbanan**
  - high requirements on dependability and availability

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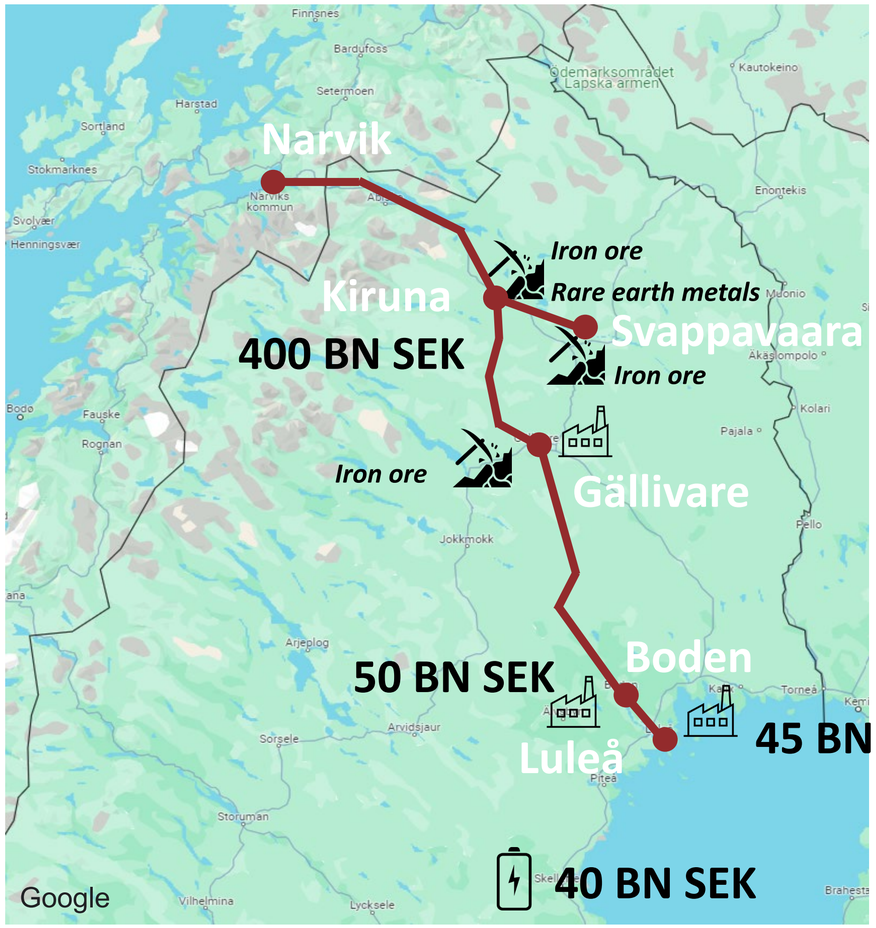
MALMBANAN – COMING DECADE



- **New investments in the region**
  - over 1000 billion SEK (2024 – 2040)
- **Mining**
  - new deposits iron ore
  - rare earth metals
- **Processing**
  - H2 Green Steel (hydrogen reduced iron)
  - Hybrit (hydrogen reduced iron)
  - SSAB (steel melting)
  - LKAB ReeMAP (rare earth metals)
- **Malmbanan**
  - increased transports
  - high requirements on dependability and availability

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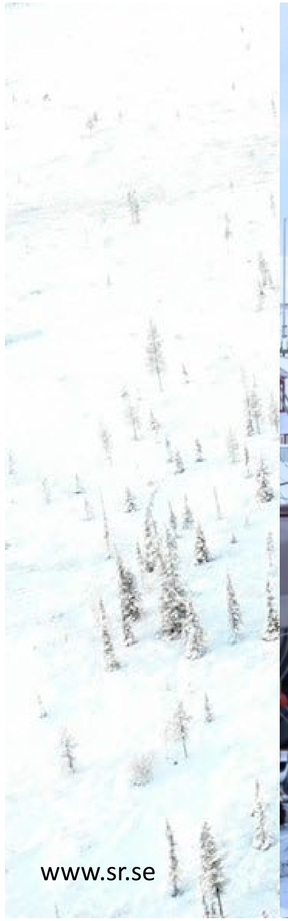
MALMBANAN – RECENT INCIDENTS/PROBLEMS


www.sr.se


www.lkab.se


www.aftonbladet.se

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MALMBANAN – INVESTMENTS

- **Trafikverket will invest several billion SEK in Malmbanan**
  - to increase capacity
  - to improve reliability and punctuality
- **Long list of desired/required actions:**
  - focusing on increasing capacity
- **What about reliability and punctuality?**
  - what actions are cost-effective – should be prioritized?
  - methodology?

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ENTER SYSTECON AND LCM ANALYTICS

FRACAS AND INFORMATION ANALYTICS

APPROACH – METHODOLOGY

FRACAS

- **good statistics/monitoring of disturbances in/on Malmbanan**
  - Ofelia, LUPP

- **central questions**
  - amount of operational down time?
  - where – on what section?
  - caused by what subsystem/component?
  - impact on traffic – resulting delay time?
  - effect of corrective action – reduced failure rates, …
  - influence from increased traffic volumes – wear, increased failure rates, …

Failure **R**eporting

Analysis and

Corrective **A**ction

System = methodology

FRACAS

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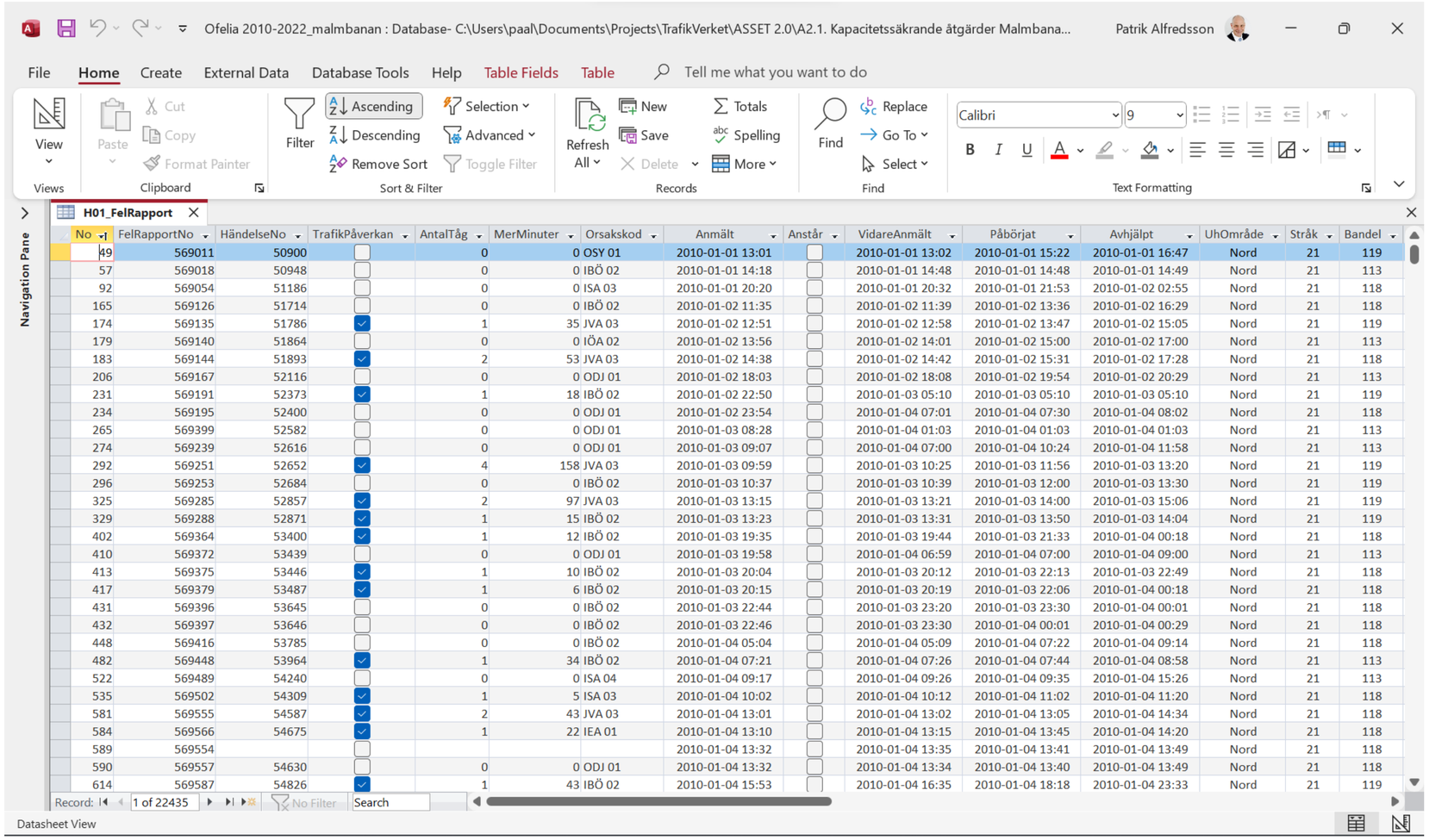
KIRUNA – LULEÅ

OFELIA 2010-2022



No	FelRapportNo	HändelseNo	TrafikPåverkan	AntalTåg	MerMinuter	Orsakskod	Anmält	Anstår	VidareAnmält	Påbörjat	Avhjälpt	UhOmråde	Stråk	Bandel
49	569011	50900	☐	0	0	OSY 01	2010-01-01 13:01	☐	2010-01-01 13:02	2010-01-01 15:22	2010-01-01 16:47	Nord	21	119
57	569018	50948	☐	0	0	IBÖ 02	2010-01-01 14:18	☐	2010-01-01 14:48	2010-01-01 14:48	2010-01-01 14:49	Nord	21	113
92	569054	51186	☐	0	0	ISA 03	2010-01-01 20:20	☐	2010-01-01 20:32	2010-01-01 21:53	2010-01-02 02:55	Nord	21	118
165	569126	51714	☐	0	0	IBÖ 02	2010-01-02 11:35	☐	2010-01-02 11:39	2010-01-02 13:36	2010-01-02 16:29	Nord	21	118
174	569135	51786	☑	1	35	JVA 03	2010-01-02 12:51	☐	2010-01-02 12:58	2010-01-02 13:47	2010-01-02 15:05	Nord	21	119
179	569140	51864	☐	0	0	IÖA 02	2010-01-02 13:56	☐	2010-01-02 14:01	2010-01-02 15:00	2010-01-02 17:00	Nord	21	113
183	569144	51893	☑	2	53	JVA 03	2010-01-02 14:38	☐	2010-01-02 14:42	2010-01-02 15:31	2010-01-02 17:28	Nord	21	118
206	569167	52116	☐	0	0	ODJ 01	2010-01-02 18:03	☐	2010-01-02 18:08	2010-01-02 19:54	2010-01-02 20:29	Nord	21	113
231	569191	52373	☑	1	18	IBÖ 02	2010-01-02 22:50	☐	2010-01-03 05:10	2010-01-03 05:10	2010-01-03 05:10	Nord	21	119
234	569195	52400	☐	0	0	ODJ 01	2010-01-02 23:54	☐	2010-01-04 07:01	2010-01-04 07:30	2010-01-04 08:02	Nord	21	118
265	569399	52582	☐	0	0	ODJ 01	2010-01-03 08:28	☐	2010-01-04 01:03	2010-01-04 01:03	2010-01-04 01:03	Nord	21	113
274	569239	52616	☐	0	0	ODJ 01	2010-01-03 09:07	☐	2010-01-04 07:00	2010-01-04 10:24	2010-01-04 11:58	Nord	21	113
292	569251	52652	☑	4	158	JVA 03	2010-01-03 09:59	☐	2010-01-03 10:25	2010-01-03 11:56	2010-01-03 13:20	Nord	21	119
296	569253	52684	☐	0	0	IBÖ 02	2010-01-03 10:37	☐	2010-01-03 10:39	2010-01-03 12:00	2010-01-03 13:30	Nord	21	119
325	569285	52857	☑	2	97	JVA 03	2010-01-03 13:15	☐	2010-01-03 13:21	2010-01-03 14:00	2010-01-03 15:06	Nord	21	119
329	569288	52871	☑	1	15	IBÖ 02	2010-01-03 13:23	☐	2010-01-03 13:31	2010-01-03 13:50	2010-01-03 14:04	Nord	21	119
402	569364	53400	☑	1	12	IBÖ 02	2010-01-03 19:35	☐	2010-01-03 19:44	2010-01-03 21:33	2010-01-04 00:18	Nord	21	118
410	569372	53439	☐	0	0	ODJ 01	2010-01-03 19:58	☐	2010-01-04 06:59	2010-01-04 07:00	2010-01-04 09:00	Nord	21	113
413	569375	53446	☑	1	10	IBÖ 02	2010-01-03 20:04	☐	2010-01-03 20:12	2010-01-03 22:13	2010-01-03 22:49	Nord	21	118
417	569379	53487	☑	1	6	IBÖ 02	2010-01-03 20:15	☐	2010-01-03 20:19	2010-01-03 22:06	2010-01-04 00:18	Nord	21	118
431	569396	53645	☐	0	0	IBÖ 02	2010-01-03 22:44	☐	2010-01-03 23:20	2010-01-03 23:30	2010-01-04 00:01	Nord	21	118
432	569397	53646	☐	0	0	IBÖ 02	2010-01-03 22:46	☐	2010-01-03 23:30	2010-01-04 00:01	2010-01-04 00:29	Nord	21	118
448	569416	53785	☐	0	0	IBÖ 02	2010-01-04 05:04	☐	2010-01-04 05:09	2010-01-04 07:22	2010-01-04 09:14	Nord	21	118
482	569448	53964	☑	1	34	IBÖ 02	2010-01-04 07:21	☐	2010-01-04 07:26	2010-01-04 07:44	2010-01-04 08:58	Nord	21	113
522	569489	54240	☐	0	0	ISA 04	2010-01-04 09:17	☐	2010-01-04 09:26	2010-01-04 09:35	2010-01-04 15:26	Nord	21	113
535	569502	54309	☑	1	5	ISA 03	2010-01-04 10:02	☐	2010-01-04 10:12	2010-01-04 11:02	2010-01-04 11:20	Nord	21	118
581	569555	54587	☑	2	43	JVA 03	2010-01-04 13:01	☐	2010-01-04 13:02	2010-01-04 13:05	2010-01-04 14:34	Nord	21	118
584	569566	54675	☑	1	22	IEA 01	2010-01-04 13:10	☐	2010-01-04 13:15	2010-01-04 13:45	2010-01-04 14:20	Nord	21	118
589	569554		☐				2010-01-04 13:32	☐	2010-01-04 13:35	2010-01-04 13:41	2010-01-04 13:49	Nord	21	118
590	569557	54630	☐	0	0	ODJ 01	2010-01-04 13:32	☐	2010-01-04 13:34	2010-01-04 13:40	2010-01-04 13:49	Nord	21	118
614	569587	54826	☑	1	43	IBÖ 02	2010-01-04 15:53	☐	2010-01-04 16:35	2010-01-04 18:18	2010-01-04 23:33	Nord	21	119

- **total number events**
  - 22 435
- **traffic disturbing**
  - 5 763
- **caused by infrastructure**
  - 4 565
- **also records**
  - down times, repair times
  - traffic delay times
- **excellent statistical baseline**

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SYSTEMATIC BEHAVIOR

PER 100 KM (OR SWITCH) PER YEAR

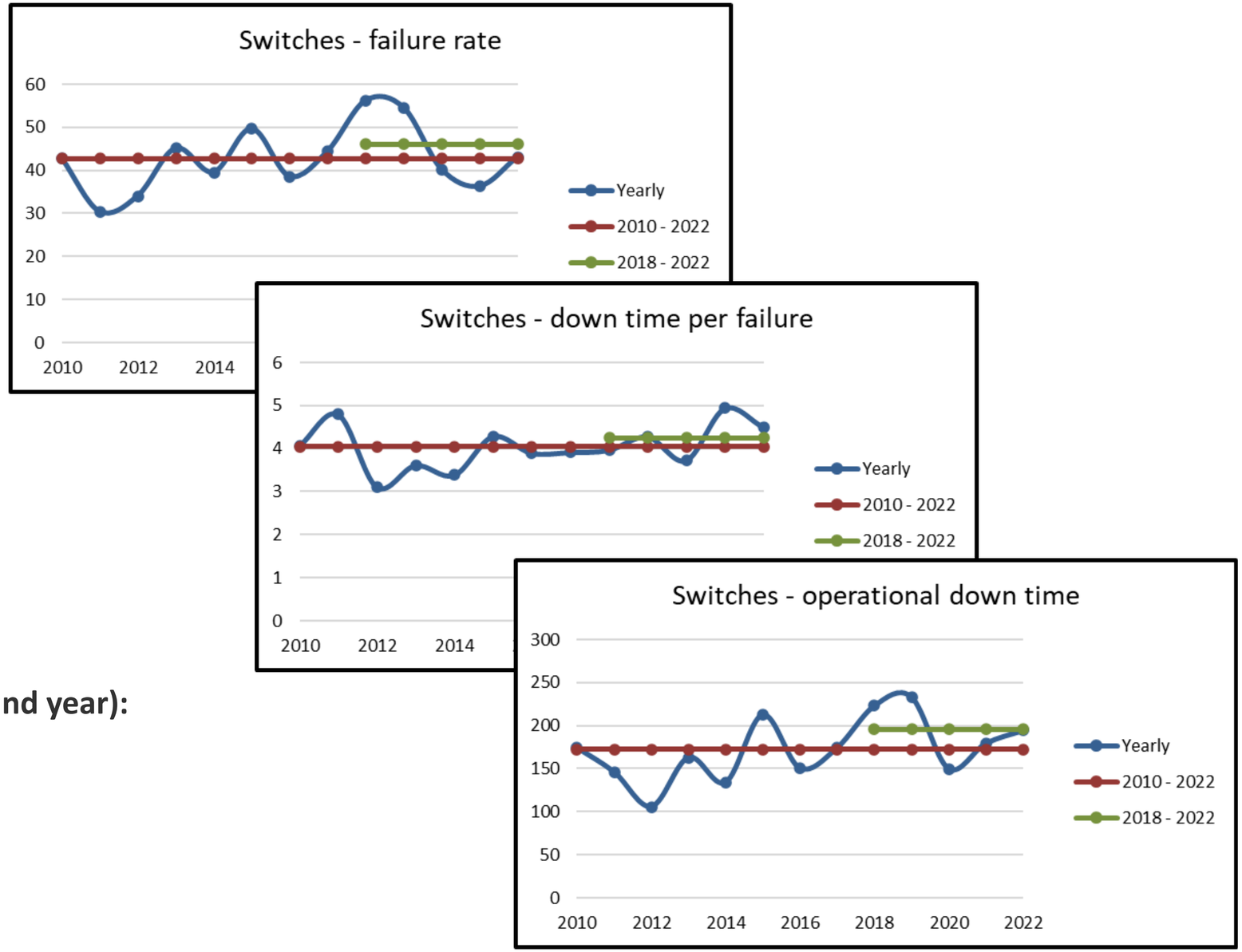
- **failure rate/frequency (traffic-disturbing):**
  - 114,8 failures per 100 km and year
  - 0,81 failures per switch and year
- **average down time per failure:**
  - 4,5 hours
  - relatively stable
- **operational down time:**
  - 520 hours per 100 km and year – ≈ 22 days
- **fraction – contribution to operational down time**
  - signaling: 43,9 %
  - switches: 33,3 %

Category	Number failures 2010 – 2022	Failure Rate [# per 100 km and year]	Failure Rate [# per switch and year]	Down Time [hours per failure]	Repair Time [hours per failure]	Operational Down Time [hours per 100 km and year]	Fraction
Track	433	10,88		5,56	4,03	60,5	11,5%
Switches	1698	42,68	0,81	4,07	2,43	173,6	33,3%
Power	291	7,32		5,48	3,82	40,1	7,7%
Signaling	2048	51,48		4,41	2,67	227,2	43,9%
Communication	91	2,29		7,73	5,07	17,7	3,5%
Track substructure	4	0,10		4,07	0,77	0,4	0,1%
Total	**4565**	**114,8**		**4,53**	**2,83**	**519,5**	**100,0%**

TRENDS

EX: SWITCHES

- **failure rate (100 km and year):**
  - slightly higher 2018 – 2022
  - +8,0 %
- **ageing effects?**
  - not necessarily
- **down time per failure:**
  - somewhat higher 2018 – 2022
  - +5,1 %
- **operational down time (100 km and year):**
  - higher 2018 – 2022
  - +13,4 %



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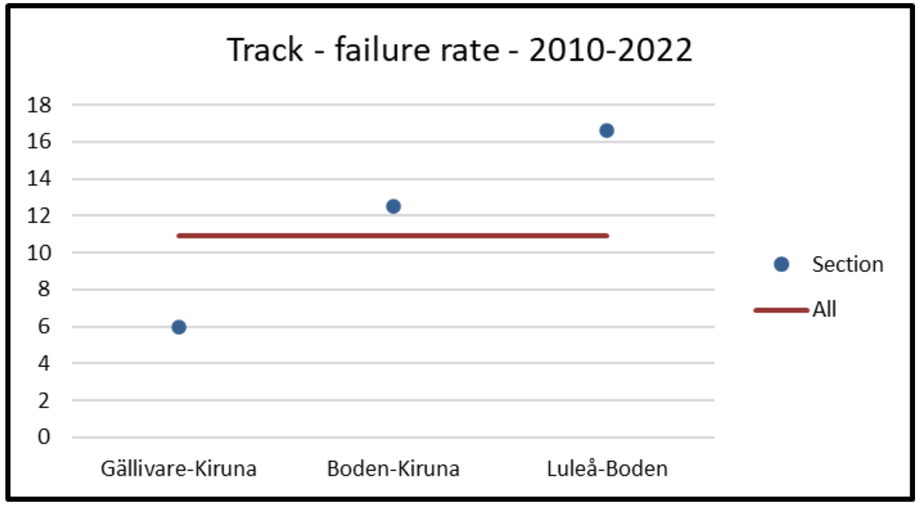
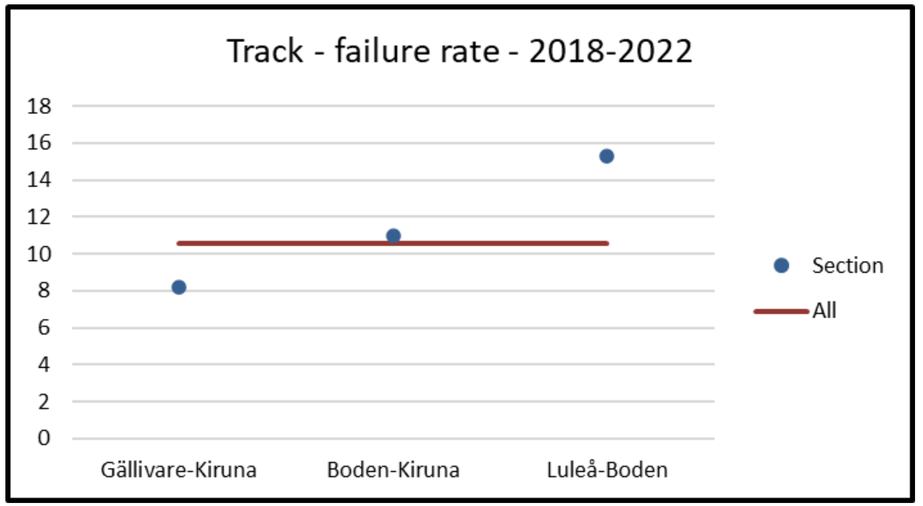
SYSTEMATIC SECTION-DEPENDENT BEHAVIOR

EX: TRACK

- **failure rate (100 km and year)**
- **traffic-dependent?**
  - yes
  - 6 on Gällivare – Kiruna
  - 16 on Luleå – Boden
- **age-dependent?**
  - if so, mildly
- **recent incidents?**





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SYSTEMATIC SECTION-DEPENDENT BEHAVIOR

DOWN-TIME BASED RANKING/PRIORITIZATION

- **statistics 2018 – 2022**

- **based on impact on operational down time (per 100 km and year):**
  1. signaling – ERMTS 233 hours (389 hours on 119)
  2. switches on Luleå-Boden 341 hours
  3. switches on remaining sections 175 hours
  4. track on Luleå-Boden 92 hours

- **impact on delay time?**
  - ”traffic ratio” – delay time per down time

- **”traffic ratio” influenced by**
  - traffic volume – traffic intensity
  - functional impact – to what extent can effect of down time be moderated

- **system effectiveness vs. availability**
  - system ineffectiveness vs. system unavailability

Category	Section	Failure Rate [# per 100 km and year]	Down Time [hours per failure]	Operational Down Time [hours per 100 km and year]
Signaling	Le-Bdn	117,89	3,30	388,8
Switches	**Le-Bdn**	**88,95**	**3,84**	**341,5**
Signaling	Bdn-Gv	47,62	4,87	232,0
Switches	**Bdn-Gv**	**40,24**	**4,38**	**176,3**
Switches	**Gv-Kra**	**39,60**	**4,40**	**174,4**
Signaling	Gv-Kra	43,40	4,02	174,4
Track	**Le-Bdn**	**15,26**	**5,99**	**91,5**
Track	Bdn-Gv	10,95	6,74	73,8
Track	Gv-Kra	8,20	6,20	50,9
Power	Gv-Kra	9,00	5,20	46,8
Power	Le-Bdn	10,53	4,19	44,1
Power	Bdn-Gv	5,36	6,35	34,0

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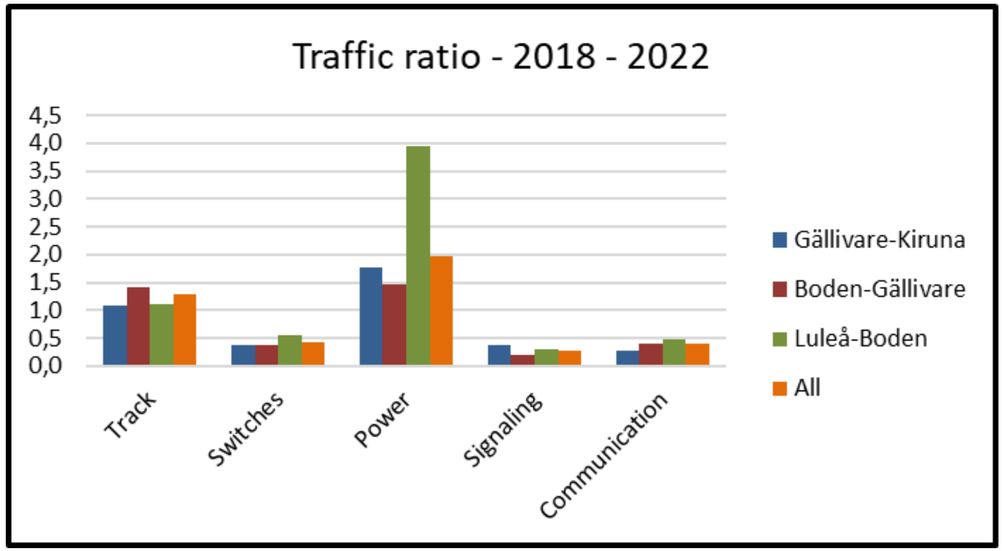
“TRAFFIC RATIO”

- **average traffic ratio 2010 – 2022**
  - 0,52 hours delay time per hour of operational down time
- **differs significantly between categories**
  - 1,89 for power
  - 1,14 for track
  - ≈ 0,3 for switches, signaling and communication
  - similar but slightly higher 2018 – 2022
- **differs significantly between sections**
  - power in particular
  - traffic-volume dependence

Category	Number failures 2010 – 2022	Operational Down Time [hours per 100 km and year]	Operational Down Time [hours per 100 km and year]	Traffic Ratio 2010 – 2022		Traffic Ratio 2018 – 2022
Track	433	67,87	59,78	1,14		1,28
Switches	1 698	57,81	172,62	0,33		0,42
Power	291	75,12	39,82	1,89		1,96
Signaling	2 048	63,95	227,57	0,28		0,27
Communication	91	5,60	18,02	0,31		0,40
Total	**4 561**	**270,3**	**517,8**	**0,52**		**0,57**



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SYSTEMATIC SECTION-DEPENDENT BEHAVIOR

DELAY-TIME BASED RANKING/PRIORITIZATION

- **statistics 2018 – 2022**
- **“traffic ratio” influences priority**
- **Luleå – Boden rises**
  - Power in particular – high “traffic ratio”
- **Signaling drops**
  - low “traffic ratio”
- **all based on today’s traffic**
  - scale, interpolate, extrapolate
- **input for reasonable assumptions**

Category	Section	Failure Rate [# per 100 km and year]	Down Time [hours per failure]	Operational Down Time [hours per 100 km and year]
Signaling	Le-Bdn	117,89	3,30	388,8
Switches	**Le-Bdn**	88,95	3,84	341,5
Signaling	Bdn-Gv	47,62	4,87	232,0
Switches	**Bdn-Gv**	**40,24**	**4,38**	**176,3**
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Track	**Le-Bdn**	**15,26**	**5,99**	**91,5**
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Track	Gv-Kra	8,20	6,20	50,9
Power	Gv-Kra	9,00	5,20	46,8
Power	Le-Bdn	10,53	4,19	44,1
Power	Bdn-Gv	5,36	6,35	34,0

Category	Section	Operational Down Time [hours per 100 km and year]	Delay Time [hours per 100 km and year]	Traffic Ratio
Switches	**Le-Bdn**	**341,5**	**188,0**	**0,55**
Power	**Le-Bdn**	**44,1**	**174,1**	**3,94**
Signaling	Le-Bdn	388,8	114,6	0,29
Track	**Bdn-Gv**	**73,8**	**103,6**	**1,40**
Track	**Le-Bdn**	**91,5**	**102,8**	**1,12**
Power	Gv-Kra	46,8	83,2	1,78
Switches	Bdn-Gv	176,3	68,3	0,39
Signaling	Gv-Kra	174,4	67,7	0,39
Switches	Gv-Kra	174,4	64,7	0,37
Track	Gv-Kra	50,9	54,9	1,08
Power	Bdn-Gv	34,0	50,1	1,47
Signaling	Bdn-Gv	232,0	48,7	0,21

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SUMMARY

- **we end here**
  - there is of course more – e.g., taking future predicted traffic volumes into account
  - but this is what the time allows

- **illustrate the power on LCM analytics on a solid information baseline**
  - transform data (22 435 records) into knowledge and insights

- **use this knowledge and these insights to guide decisions**
  - establish value-adding corrective actions
  - objectively

- **methodology applicable to entire railway network in Sweden**
  - “FRACAS in practice”

Thank you.

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