Tool development: automated/semi-automated

Madhu N. Belur & Narayan Rangaraj

Control & Computing, Electrical Engg
Indian Institute of Technology Bombay (IITB)

www.ee.iitb.ac.in/%7Ebelur/talks

www.ee.iitb.ac.in/%7Ebelur/railways

belur@iitb.ac.in 99 874 66 279

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Outline

- Simple software tools (not big software ‘packages’)
- Overview and significance of ‘home-grown’ tools, in FOSS
- Examples of semi-automated tools (decision support tool)
- ZBTT, section and network simulator by IITB

Tool conception/design

- CS/IT graduates won't come and conceive/design our tools.
- We need to find those opportunities: they (CS/IT) can code or advise.
- Tools
  - screw-driver made by manufacturing/metallurgy person
  - but conceived/thought/needed/used/designed by electrical engineers also.
  - screw-driver cum tester: is OUR domain (of usage/concept/design)
- Tools: spreadsheet, Python: good for quick and basic analysis: for us non-CS persons

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- Everything is not “automatable". Also ongoing process: slowly, steadily.
- Tool makes things partially automatic: allows repeated retrials

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Statistics (example)

- Quality of an allocation (crew allocation), comparison with the “best" possible (can use crude guidelines)
- Smaller searches rather than “brute-force" searches
- Searching for globally best often not practical for typical search sizes
- Introduce randomness at intermediate steps in the (local) search
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- However, spreadsheet:
  - insufficient for complex allocations/constraint validation
  - has limited ability as a 'solver'
  - no 'while' loop, no jumping from one solution to another
  - not OK for automation, nor for large data
  - semi-automatic, at best

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Constrained programming based solvers:

- Gets a good feasible solution
- Helps to have spreadsheet based validators/checkers

(Though solvers have ensured satisfaction of constraints, one can validate by introducing 'test-flaws')

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  - optimize crew allotment
  - choose start-timings to get 'better and better' grouping at congested section

ZBTT (for GQD)

- Start-timings decided by ZR, and path-charting by IITB tool
- Maintenance block: either taken from suggestion or extracted from a timetable
- Freight windows extracted from a simulation-coaching train timetable and then freight paths charted (w.r.t. a given ratio of freight characteristics)
- Shared resources across multiple routes (with an overlap of routes)

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- Thus: for about 1800 daily paths of any day (of GQD), need to simulate about 9000 daily paths: lowest priority trains of 19th May will find a path after tabulating 5-days of daily paths of higher priority trains.
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- Trains are simulated one by one and need to discard intermediate path-searches and move to the next
  (Possibly bad start-time for one or two trains).

Section simulation challenges

Section simulation tool for capacity estimation and timetabling

- One long section, with just one zero-milepost
- Trains go either start to end, or start/stop somewhere midway
- Trains need to decelerate/accelerate depending on
  - Multi-aspect signalling
  - Train-max-speed, accln/decln abilities
  - Section-speed, intermediate block signalling,
  - Automatic/absolute block working
  - Running lines in stations: max-speeds of loops (possibly lower than main-line)
  - Permanent Speed Restriction (PSR)
- Challenges: priority based overtaking rule

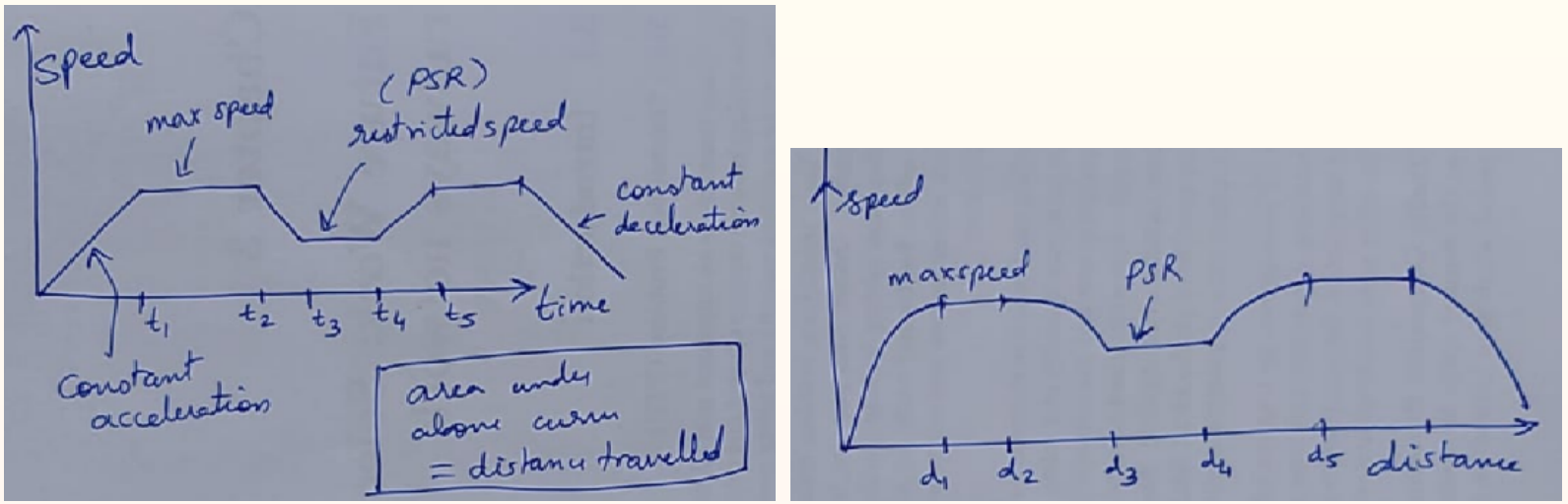
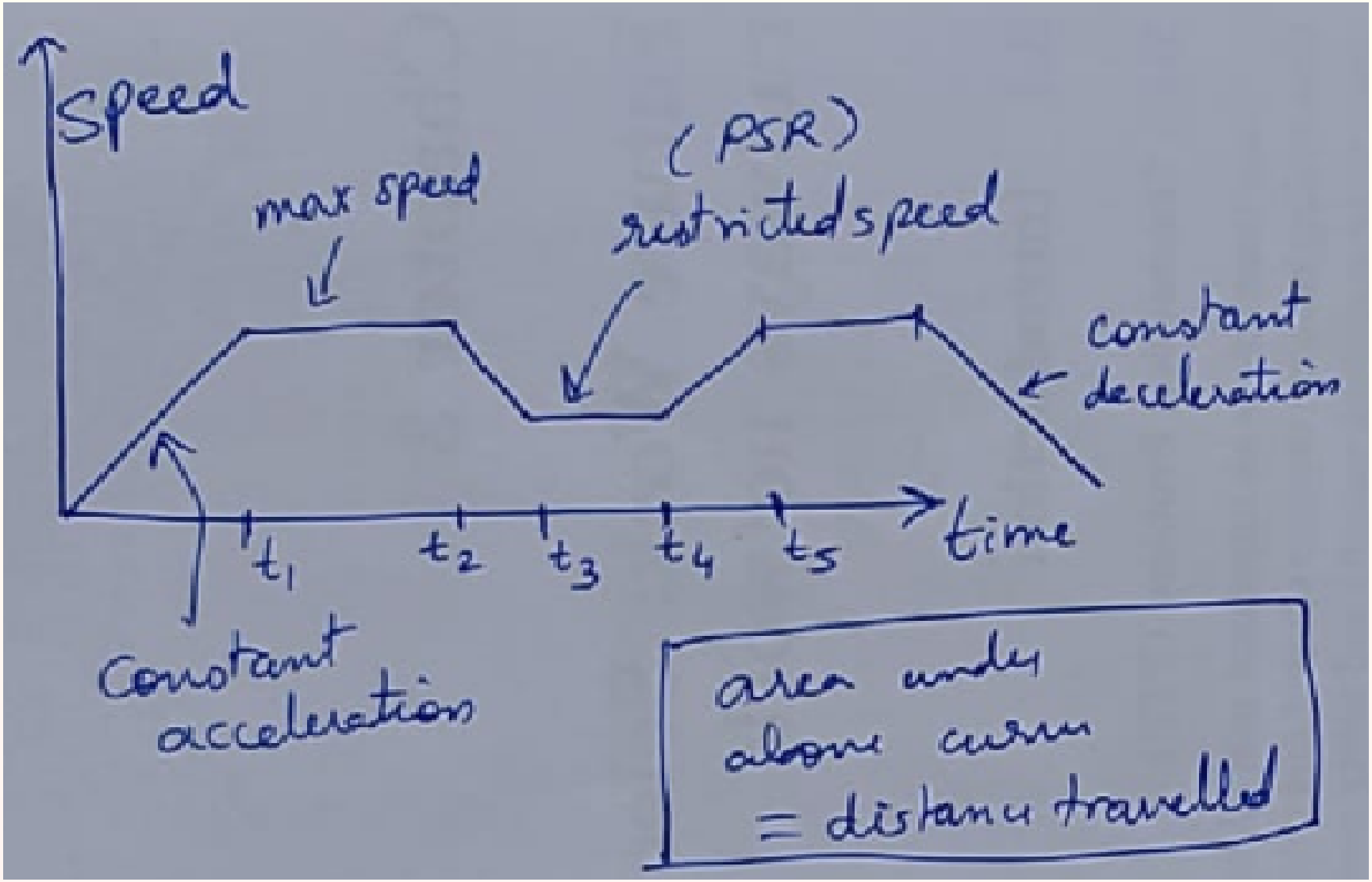


Figure: Speed vs time (more intuitive), and vs distance (for timetabling)



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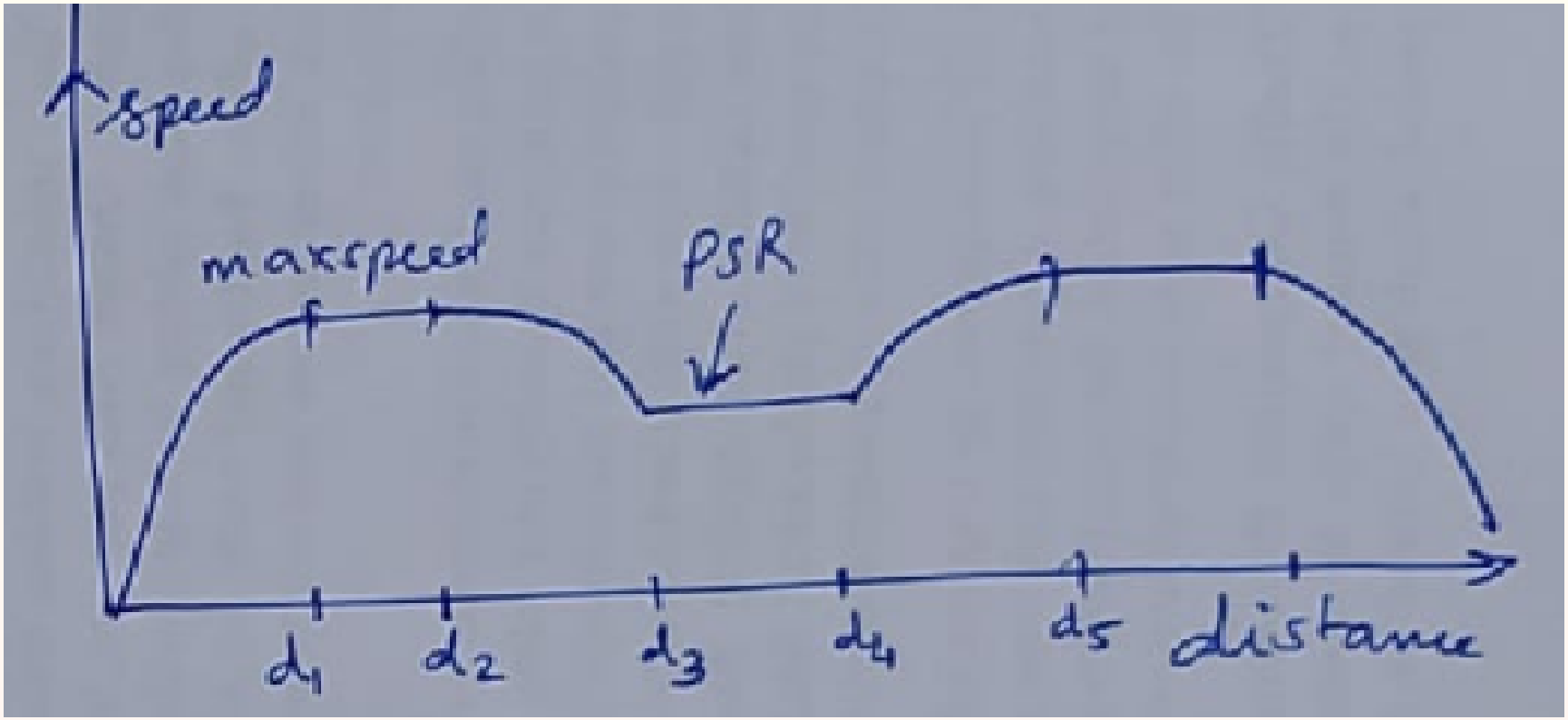
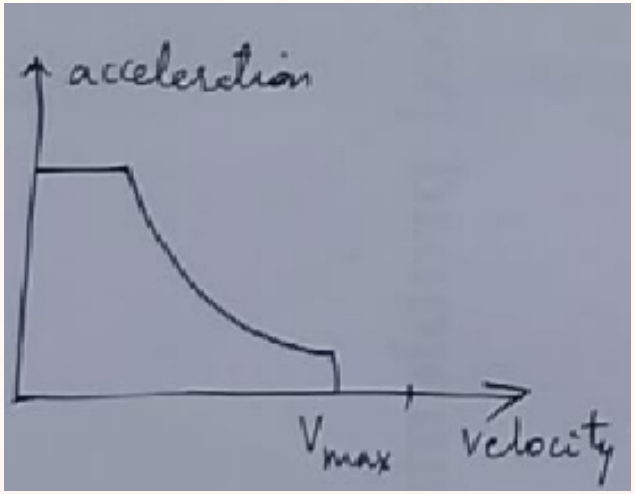


Figure: Speed vs distance (less intuitive, for timetabling)

In practice: acceleration is not constant (w.r.t. speed)

- Accln is lower at higher speeds (due to constant power reasons)
- Slope of speed vs time: decreases as speed increases



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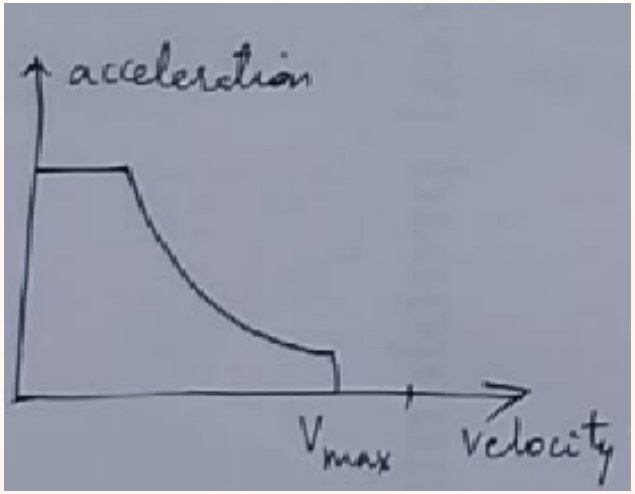

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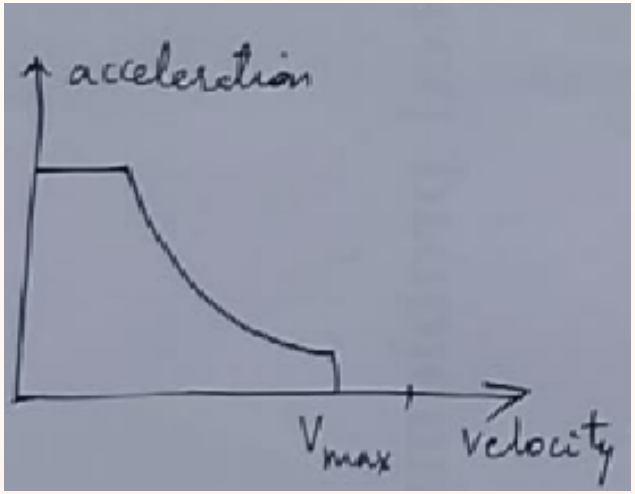

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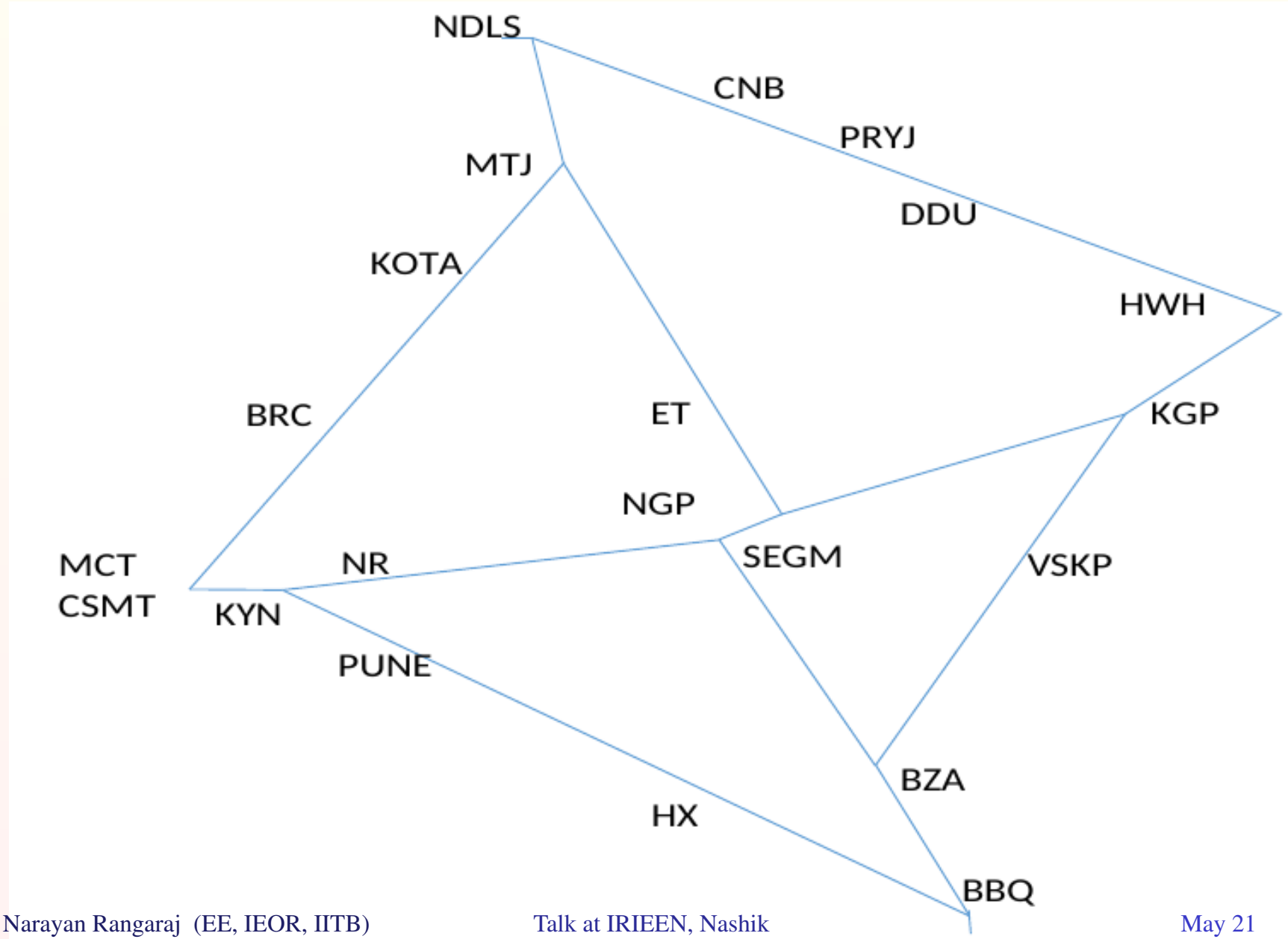
But need to start with simple tools/approximations, and (at least) for 'decision support' (semi-automation)

Network simulation tool

- Infrastructure up/down convention CANNOT be uniform in a network
- Multiple zero-mileposts since routes could overlap: much/little/none
- Possibly need to jump milepost distances (at junctions)
- Reversals are typical
- Break long train journey into parts, and simulate one by one (Navjeevan Exp)

GQD network: schematic (thanks to NR)



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‘Software package’: more complete, integrated, stand-alone, with-GUI, etc.

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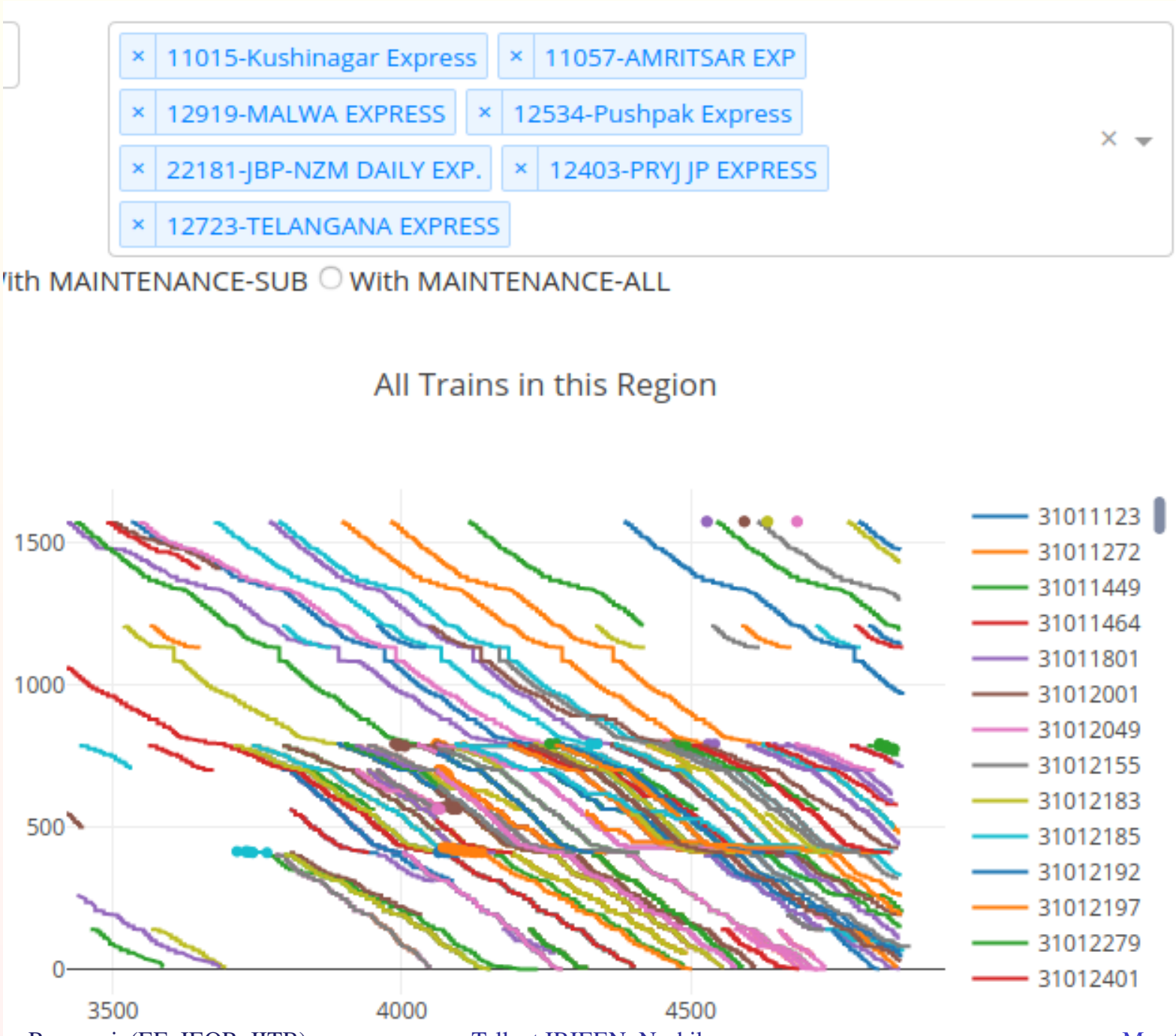
- Good design principle:
  “each tool does one small thing: and does it well"
- Integrate these smaller tools to achieve a larger goal
- This is easier for debugging and for correction
- One improvement/change/correction won’t affect many other things.
- Additional features can be incorporated as extra options

‘Software package’: more complete, integrated, stand-alone, with-GUI, etc.
Usually, software company develops, owns and releases newer version


× 11015-Kushinagar Express
× 11057-AMRITSAR EXP
× 12919-MALWA EXPRESS
× 12534-Pushpak Express
× 22181-JBP-NZM DAILY EXP.
× 12403-PRYJ JP EXPRESS
× 12723-TELANGANA EXPRESS
ith MAINTENANCE-SUB
With MAINTENANCE-ALL
All Trains in this Region
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31012279
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Trade-off between accuracy and elaborate details

Realistic-outcome, accuracy, elaborate-details vs quick-outcomes

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- Often, indepth study difficult due to the need for data
- Realistic studies would inevitably require elaborate details
- No shortcuts or 'low-hanging-fruits' remaining
- A continuous/long-term engagement needed for any fruitful outcome
- IR too complex for ready-made off-the-shelf solutions

Recent railway projects completed/ongoing

- ZBTT: only GQD routes: daily coaching-train paths and daily freight paths
- Ahmedabad junction: simulation based congestion study: 2019
- RDSO: section simulator: 2018
- Use of section simulator for Niti-Aayog: short study: 2017
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- Software made in FOSS can be modified to yield valuable statistics for analysis

Ready-made/proprietary vs 'home-grown' software

- IR: complex and unique challenges
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- Each software needs significant local customization
- For complex requirements: prudent to have our own slowly-grown 'home-grown' software
- Problem specifications: from our own 'shop-floor': for example, operations personnel
- Railways/Academia/Software-agency: combination inevitable

Zero-base TT efforts elsewhere: example

The New Dutch Timetable: The OR Revolution, 2009 paper in *Interfaces*

Paper abstract

In December 2006, Netherlands Railways introduced a completely new timetable. Its objective was to facilitate the growth of passenger and freight transport on a highly utilized railway network, and improve the robustness of the timetable resulting in less train delays in the operation. Further adjusting the existing timetable constructed in 1970 was not option anymore, because further growth would then require significant investments in the rail infrastructure.

Constructing a railway timetable from scratch for about 5,500 daily trains was a complex problem. To support this process, we generated several timetables using sophisticated operations research techniques, and finally selected and implemented one of these timetables. Furthermore, because rolling-stock and crew costs are principal components of the cost of a passenger railway operator, we used innovative operations research tools to devise efficient schedules for these two resources.

The new resource schedules and the increased number of passengers resulted

Authors/affiliations (of the famous paper in Interfaces)

The New Dutch Timetable: The OR Revolution, 2009 paper in *Interfaces*
Authors: Kroon, Huisman, Abbink, Fioole, Ybema, Maroti, Schrijver, Steenbeek, Fischetti
Affiliations: railway personnel/software-firm/academia

- Department of Logistics, Netherlands Railways: Kroon, Huisman, Abbink, Fioole, Ybema
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Similar efforts in Germany: Narayan Rangaraj's collaborators

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  after showing statistics, awaits further inputs: 'decision support tools'
- Operations persons are able to specify/describe the problem where automation is possible
- With a tool, one can then dwell on complex decision making
  (since routine-calculation is now automated/semi-automated)

Summary: need to shift to automated/semi-automated tools

- Need to shift to modern tools for
  - self-growth (for ourselves remaining relevant over next few decades)
  - system productivity/efficiency
- Tools that are 'home-grown' and in FOSS allow complete flexibility/independence and customization
- Describing/formulating the specs of the tool:
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  - from anybody interested in the area

Questions, contact details

Questions ?

Thank you

Contact details (Madhu Belur):

99874 66 279, belur@iitb.ac.in

This talk currently at
www.ee.iitb.ac.in/%7Ebelur/talks

Suburban (WR) crew-allotment conference paper
http://www.ee.iitb.ac.in/%7Ebelur/pdfs/c19or-dresden.pdf
See also slides by many other speakers also:
Workshop was about suburban-railways/metro operations planning (June 2019 workshop)
www.ee.iitb.ac.in/%7Ebelur/railways/workshop