

# RETROSPECTIVE IMPACT OF OPERATIONS RESEARCH & OPERATIONS MANAGEMENT ON FREIGHT RAILWAY OPERATIONS

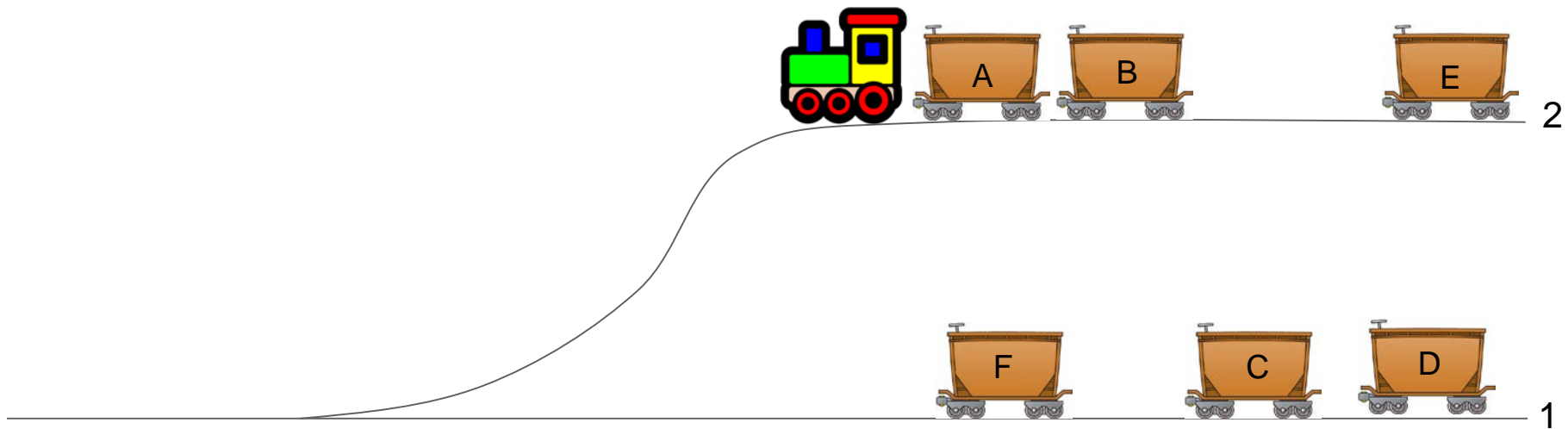
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Marc Meketon & David Hunt

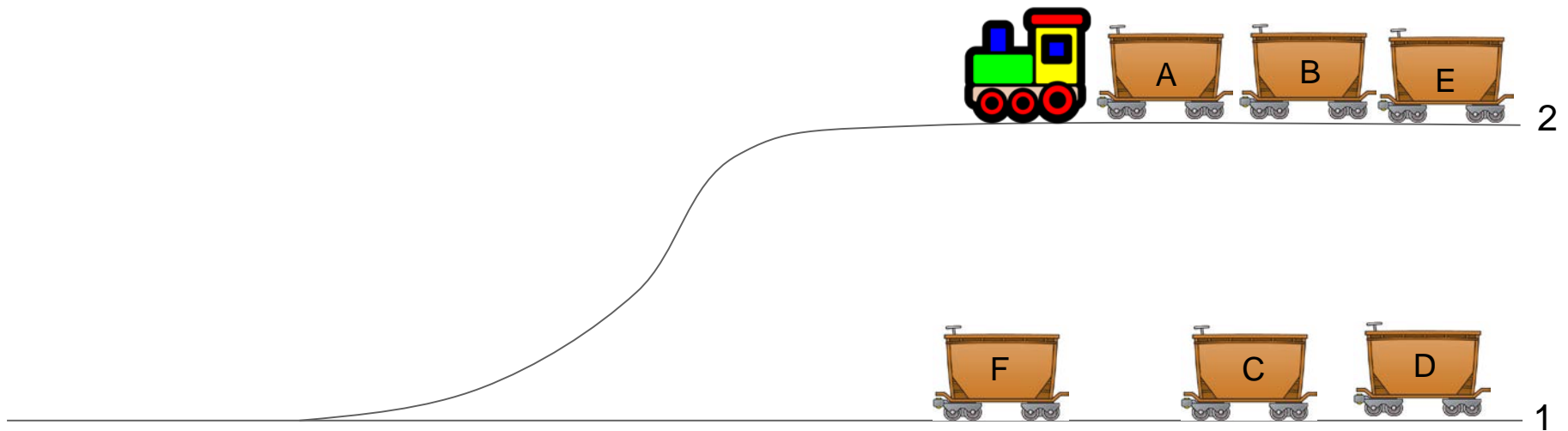
# Railways have a long history of analytical analysis

Perhaps the earliest use of 'analytical thinking' was to minimize the switching needed to group a set of railcars in the a particular order.

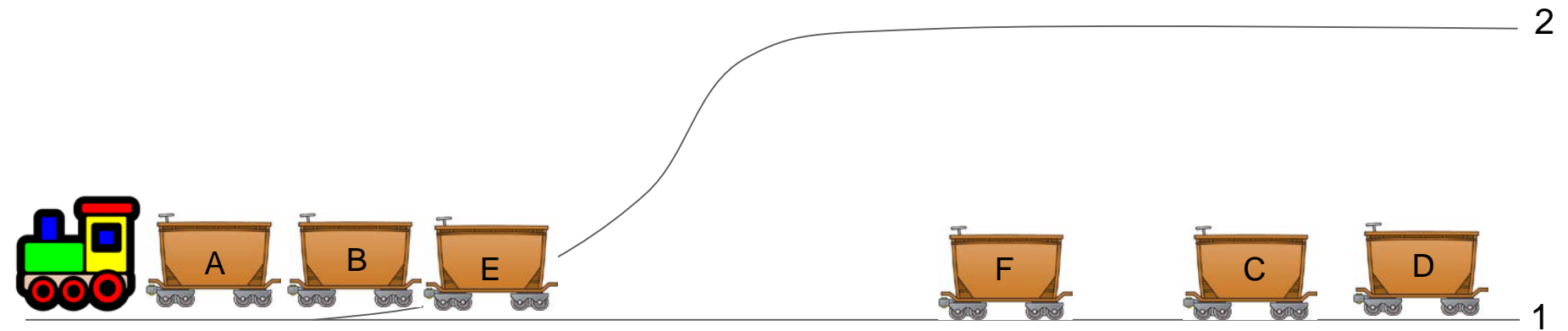
A typical railway conductor test might ask: **What is the minimum number of times a locomotive must change track to put the following cars in order A-B-C-D-E-F and onto Track 1?**



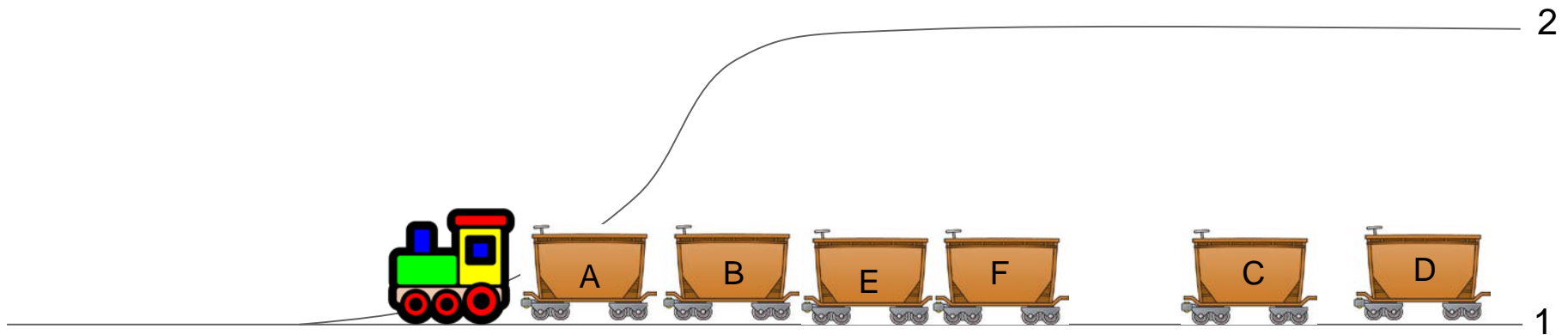
...Backup and connect to A-B to E



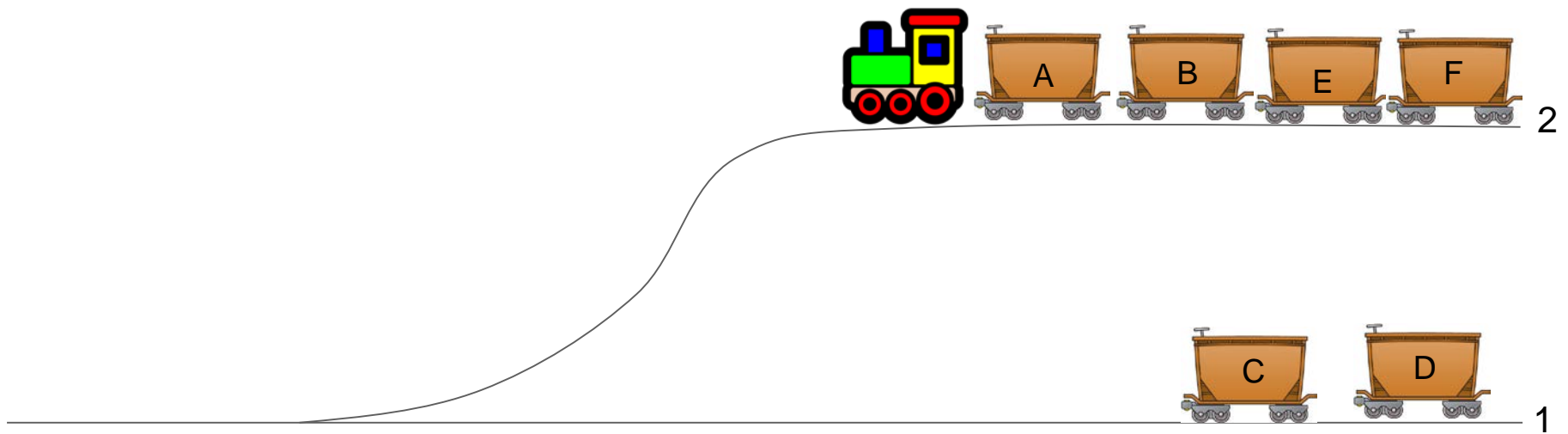
... Switch to track 1



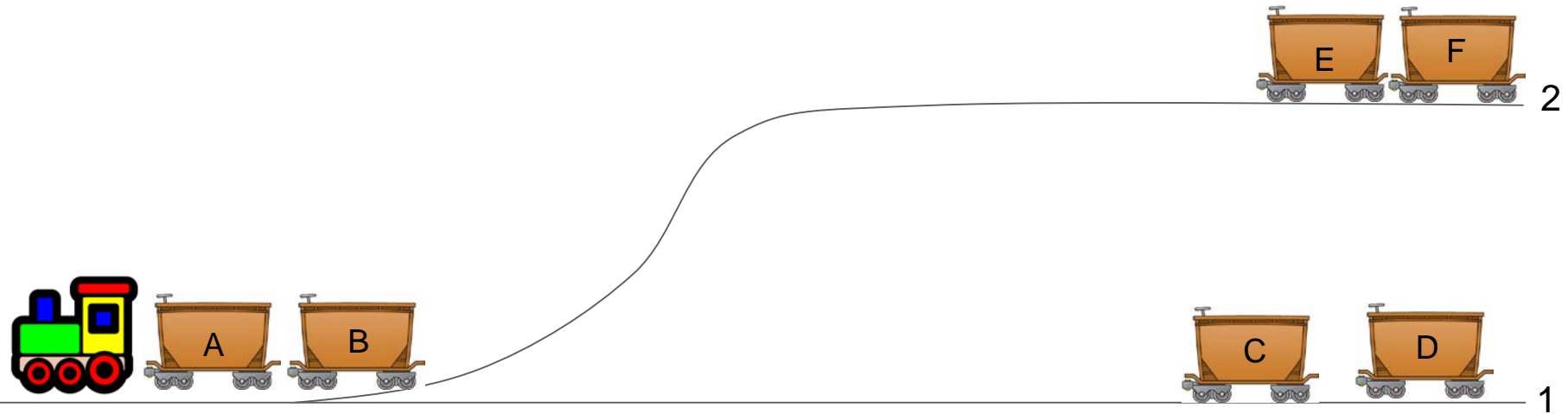
...Backup and connect A-B-E to F



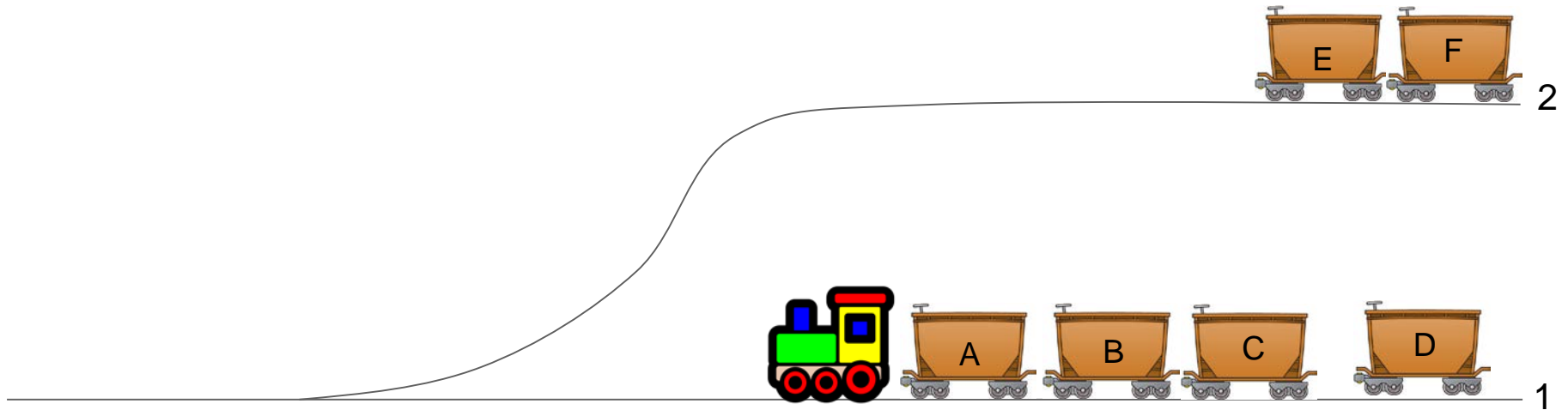
...Switch to track 2



...Leave E-F on track 2, switch to track 1 with A-B

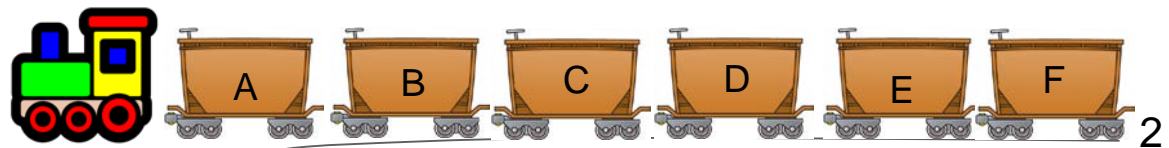


...Backup and grab C-D

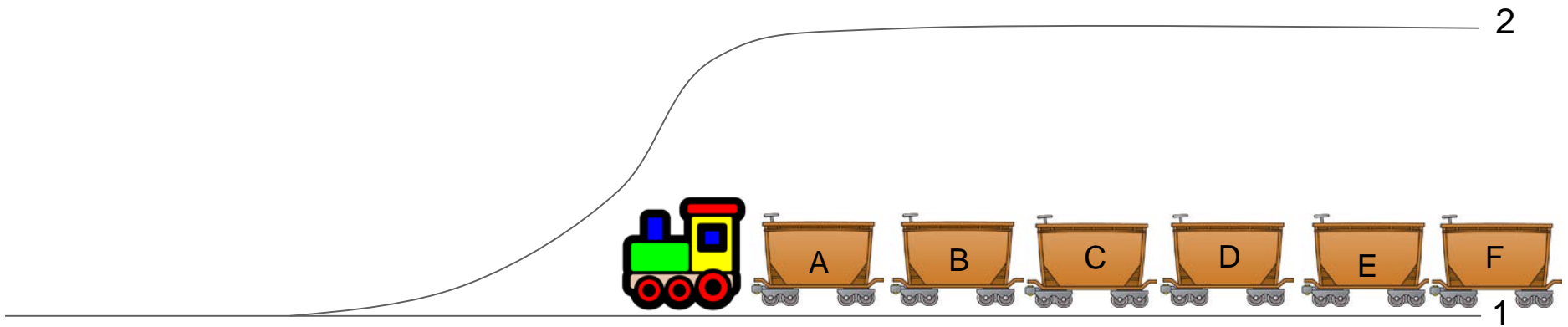




...Switch to track 2 with A-B-C-D and grab E-F



...Switch to track 1 with A-B-C-D-E-F



A total of 5 switches

## Switching planning - epilogue

- Roger Baugher reports that there is still active work being done on switching planning/optimization.
- So this previous, little example is relevant!

# Shout outs

- This presentation was developed by interviewing several pioneers of using Operations Research in the railway industry:
  - Roger Baugher
  - Larry Ratcliffe
  - Carl Van Dyke
  - Dharma Acharya
  - Kamalesh Somani
  - Carl Martland
- Switch to Jeopardy:  
<file:///C:/DocumentsOther/INFORMS/2019%20INFORMS%20Seattle/Retropective%20OR%20in%20Railways4.html>

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# Retrospective OR in Railways\_all\_answers\_and\_questions

1960's

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How did they do yard simulations in the 60's?

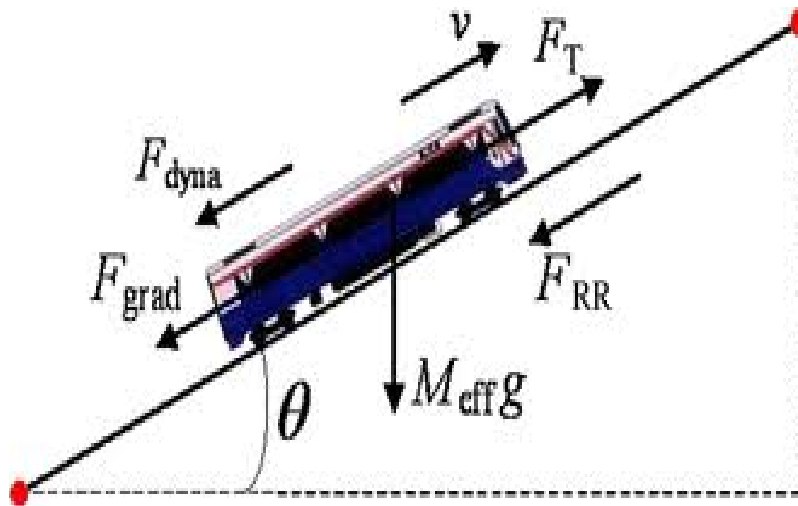
A large table was used, and pieces of paper moved to represent cars/trains/shunters. Various scenarios were examined. A simulated day might take a week to do. Mostly used for determining yard design



It was done on large tables and moving pieces of paper around

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How was train performance calculations solved?

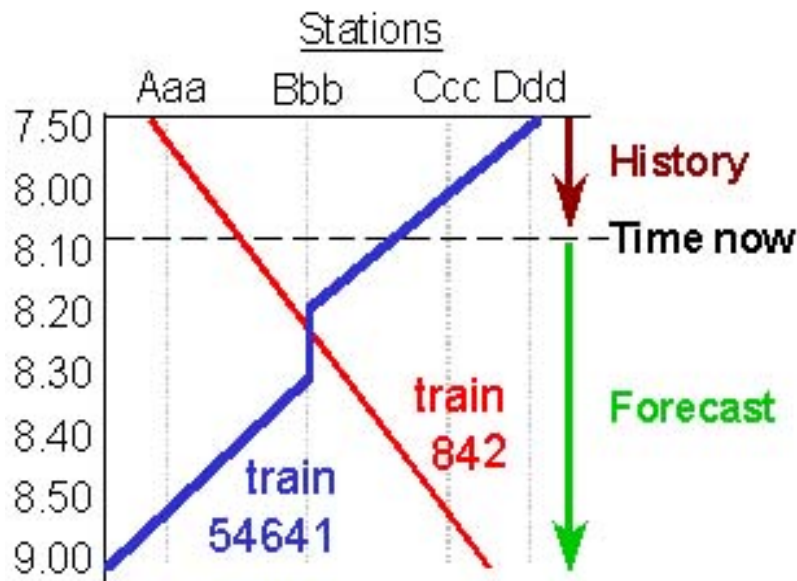


The differential equations were manually computed, one small increment at a time.

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How was meet-pass planning done?

They manually created string lines using ruler, graph paper, pencils



Rulers and graph paper were used to solve this problem.

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What was the beginning of modern-day car scheduling systems?

Southern Pacific, with the development of TOP, issued a new world of computerized tracking of railcars and developing a blocking plan for car-to-block assignments.

This was eventually adopted by BN, CN and MP (Missouri Pacific)

Southern Pacific led the way, with important improvements by Missouri Pacific

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What LTL deliver service performed a lot of (manual) optimization of their train schedule to reduce connection times.

Railway Express Agency was the LTL service

1970's

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How did they do yard simulations in the 70's?

There were quite a few attempts at yard simulations using computers. For the most part, they did not do well.

Simulations used GPSS and Simscript.

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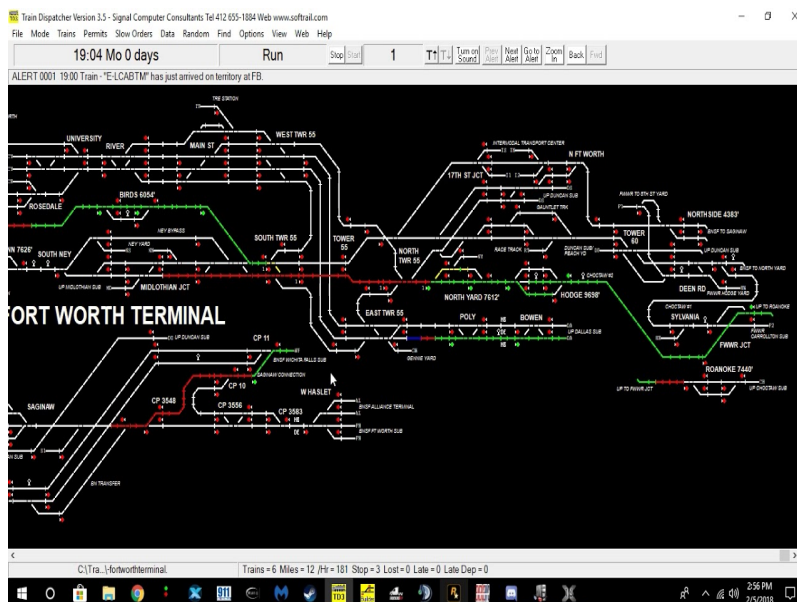
What was the USRA/SRI model used for?

The 1970's was the beginning of various network simulation models. One of them, from USRA and SRI was used for a variety of projects including the initial formation of Conrail. These models were also used in Australia, South Africa and other places to support studies by firms such as Booz Hamilton and Temple Barker Sloane (a predecessor of Oliver Wyman)

Network model used to help form Conrail

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What was the first example of Computer Aided Dispatching?



The Southern Railway was the first to developing this control system.

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What is PMake?

In the 1970's and 1980's, connections within yards were difficult. So instead of modeling trip plans with connection standards (as the Missouri Pacific pioneered in the late 70's), PMake allowed a probability distribution of whether a connection would be made or not. For that era, it was a success and implemented as part of the Service Planning Module in the early 1980's and was used for 17 years

The probability of making a connection

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What was TCS developed by the Missouri Pacific?

The MP was the first to develop the concept of connection standards in yards and to develop trip plans. This eventually was used for network simulation, and now all railways have this capability. Obtaining accurate trip plans is considered essential, especially in today's PSR world.

TCS was used as a base of the car scheduling systems still being used by CN, UP, BNSF, FMX.

Fun fact: they built their own programming language and one-off database structure for TCS.

The work was partially funded by the FRA.

It became the first car-scheduling/trip planning system

**1980's**

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What were the first computerized meet/pass planning models?

Actually starting in the 1970's there were the beginnings of using computers to perform meet/pass planning. The earliest example was a model developed by Peat Marwick Mitchell. This model found its way into CN, and at least influence ITS.

The roots of RTC could be also be traced back to the 80's

RAILS, RDCAM, LCAS, CANAC were examples

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What was the first empty repositioning system in use for autoracks?

The AAR developed an Autorack Reload program, starting development in 1979 and having the first implementation finished by 1982. It used the 'principles of triangulation' to increase the asset utilization. Not known is whether this actually used shortest paths or transportation algorithms or (most likely) was developed by business rules and heuristics.

In 1995, this was brought to TTX, who currently manages the reload program (which is also used for intermodal railcar management). In the mid-2000's Princeton Consultants started to rewrite it as the Unified Fleet Distribution system.

In 2013, TTX estimates that this program saves 1.2% of the assets it manages, about \$42M/year  
Centralized management/pooling of Multilevel (Autorack) railcars

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What group did many railway studies, both for economics and operations, in the 1970's and 1980's.

The MIT group, funded from the AAR, the FRA and railways, were significant players in the development of:

- OCM (Operations Cost Model)
- Freight Car Utilization Program
- Intermodal terminal task force
- Heavy Axle Load Economic Analysis

MIT Mafia

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What was the most widely used network simulation tool of the 80's?

SPM, previously mentioned as part of PMake, was used for 17 years. Besides network simulation, its data structures and reporting was also used for the base of the first attempts at block optimization ("Automated Blocking Model") and train scheduling.

The Service Planning Model

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What Princeton company, founded in 1979, became a premier railway consultancy?

ALK Technologies, founded by Alain Kornhauser - a professor at Princeton University - became a leader in railway consultancy and contributing to many technologies such as ABC at NS, various graphing programs, locomotive models, diversion models and more.

ALK Technologies

1990's

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What systems did American Airlines Decision Technology build for Conrail?

AADT was hired to build 4 systems. Two of them found use at Conrail (up to the split-up in 1999):

- **CNAM:** Conrail Network Analysis Model. This was a network simulation model. Among items, it had an 'empty car' forecasting unit that combined business rules and network flow optimization to predict empty car movements.
- **UTSS:** Unit Train Scheduling System. An IT and OR system designed to help plan when unit trains should be scheduled and how empty cars should be organized to be loaded.

The other two systems that were not completed included a forecasting system (they achieved a 70% accuracy for daily volume at a yard), and a general merchandise train scheduling system.

CNAM and UTSS are two examples of systems

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What does the Intelligent Train Scheduler do?

Many railways, for the past 20 years or more, have used the Intelligent Train Scheduler from IRRS to estimate reasonable train delay and train timings. It is not a sophisticated meet/pass planner (and has far less data needs), but it runs quick and is perceived as being an accurate indication of train delays and capacity issues.

Not quite a meet/planner, it is used to develop train schedules/timings in the presence of probable meet/pass delays

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What organizations began in the 1990's to optimize the assignment of locomotives?

Three Princeton based organization started with some form of locomotive assignment optimization. ALK built the first set for BN and UP, and it lasted in UP for many years to suggest locomotive assignments.

Castle Lab, working with Norfolk Southern, also began to build a highly sophisticated model, although it took perhaps 15-18 years between the beginning work and it's use as a strategic model.

Another Princeton group (but not affiliated with the University), MultiModal, built a 'single-fleet' locomotive model that was used for special studies. At some point, it was re-written for CP (in the early 2000's) and used to help create planned re-balancing movements, as well as to suggest schedule timing changes to improve utilization. Earliest models for single-fleet locomotive optimization came from IBM in the late 1980's.

Conrail also developed a locomotive model to study the impact of reducing locomotive dwell by re-timing train schedules.

Sante Fe was the first railway that created a locomotive shop routing model. It did not survive the merger with BN. In the 2000's Innovative Scheduling (now Optym) and CSX developed a locomotive shop routing model, although it did not become mainstream for CSX. But building on this work, CSX now has a Dead Locomotive Routing model, and NS has used a variant of their Locomotive model (derived from the Castle Lab work) to routinely route locomotives to the shop efficiently.

Sante Fe, ALK and Castle Lab were three examples of entities that built assignment optimization systems for this.

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What system planned empty car movements?

CSX, actually starting around 1998, developed the Dynamic Car Planner. This planned how empty railcars should move to customers that request them. In their Franz Edelman finalist statement, they felt that over 10 years it saved CSX around \$2.5B (yes - that's a 'B') from reduced need for railcars, fuel, manpower.

Dynamic Car Planner

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What is the TLA for NS's Algorithmic Blocking System

In the early 1990's, Norfolk Southern, with help from ALK, proposed building an Algorithmic Blocking System that developed block sequences based on an economic shortest path. The system was operational by 1998, and was a major change from the existing classification tables that CSX, UP, BN and all others used.

Over the next 20 years, several other railways would switch over to algorithmic blocking (for example, CP and CSX) due to the efficiency of developing the plan and making adjustments.

ABC

## 2000's

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What is an example of a traffic forecasting system built using a combination of expert opinion and statistical methods?

While traffic forecasting dates back for decades, the first systems built started in the 1990's and were accepted in the 2000's. The Union Pacific Prophecy system may have been the first of these completed. It used a combination of expert opinion and statistical methods. Most forecasting was only for revenue traffic. Non-revenue traffic (usually empties) were not forecasted at first.

By the late 2000's, a number of railways have implemented forecasting systems, sometimes with two additional parts:

- Operations Research models to find empty car moves to match the revenue movement forecast in a consistent way, while maintaining key metrics of load/empty ratios
- A process to 'clean up' historical data, so (e.g.) hurricanes or floods that necessitate a redirection of traffic for a period of time does not affect the forecasts.

Prophecy at the UP was one example of this system.

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What did the system Oasis originally do?

Oasis from Optimization Alternatives started out in the 1990's as a ramp optimization and intermodal train loading optimization. It quickly evolved over time to do complete work planning, gate checking and other intermodal terminal controls. This is now part of GE-Transportation/Wabtec.

Should have gone into the 1990's column... but no room was left.

In the 1990's, this was for intermodal terminal optimization

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What organization was the first to consider a large suite of operations research models to cover

- Network
- Terminal
- Track
- Crew
- Locomotive
- Railcar

Norfolk Southern Operations Research group was the first to build this.

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What was the primary tool used to study the network congestion in Chicago as part of a joint railway effort?

In the early 2000's, the FRA funded a effort to de-congest Chicago - where the four large Class 1's meet and interchange. The newest incarnation of the meet/pass tool by Berkeley Systems, called RTC, was used.

Over the years, RTC has become the main tool used by North American railways to study network congestion and evaluate changes to track, signalling, and train schedules. Most (all??) railways have groups dedicated to the care and feeding of this model.

RTC was used for the Chicago study

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What is the name of the exercise to produce an operating plan for their general merchandise network (the blocking and train plan) based on traffic and network?

Zerobased planning, usually supported by MultiRail, analyzed block sequences using algorithmic blocking, produced trip plans and performed network simulations. These tools helped to create initial plans and suggest improvements.

In the mid-2000's, new tools arrived -- especially the automated block optimizers from Innovative Scheduling.

This effort straddled two decades - Canadian Pacific started in 1997, Canadian National in 1998 during their merger with the Illinios Central, BNSF started their zero-based planning in 1999. NS followed in 2000, then CSX and UP.

It is called various names such as Cleansheet, Zerobased, Greenfield planning