Capacity for Rail

Capacity Trade-Offs Analysis Tool

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Work Package 3.1

SEVENTH FRAMEWORK PROGRAMME

Capability Trade-Offs Analysis Tool

- Development Objectives

  - Need to cater for continued growth in rail passenger and freight traffic
    - Affordably, Sustainably, Reliably, Efficiently etc
    - Where should investment be focused?
    - Relative effectiveness of different options/solutions

  - Quick, Easy to use, High-level tool to:
    - Change current mindsets and move away from specific sub-system solutions
    - Enable a whole-systems approach that takes into account the particular characteristics of the route and their mutual inter-dependencies to identify the impacts of potential options

Capability Trade-Offs Analysis Tool

Capacity for Rail

- High level assessment of alternative options to improve capacity:

Define the analysis section / represent the capabilities of the system

- Infrastructure
- Rolling stock
- Operations

For each proposed improvement ‘option’

- Represent the effects on system capabilities

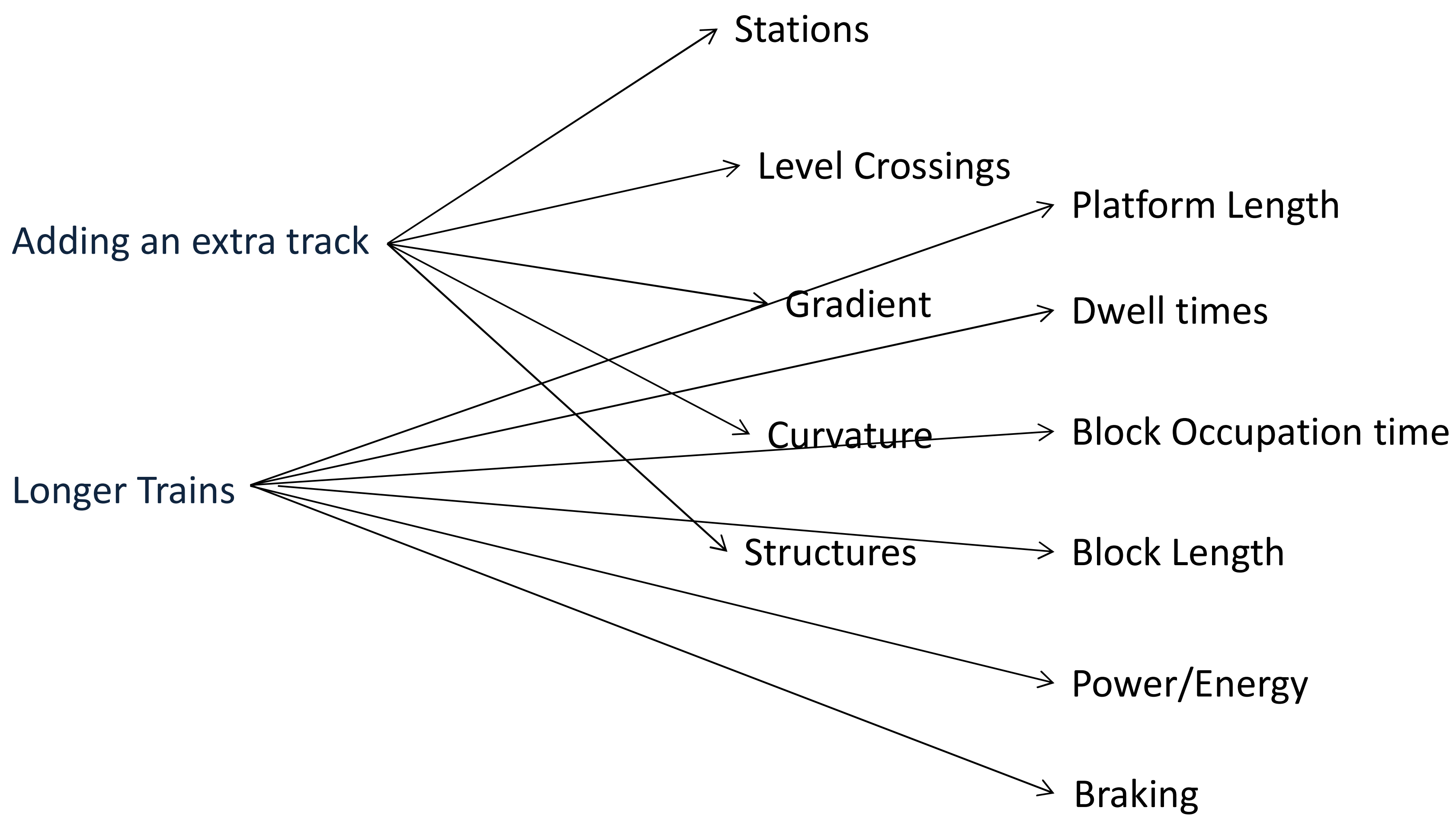
Reports on:

- Impact on the **Capacity** of the section
  - Passenger trains
  - Freight trains
- **Affordability** of the ‘option’
  - Relative costs/Life cycle costs
- Changes in the **Resilience** and **Adaptability** of the section
- Changes to **Automation** levels within the system

Whole systems approach

- Changing a capability can have **direct** or **indirect impacts** on other capabilities
- Can impact on delivering the "planned-for" capacity increases

Whole systems approach



Capability trade-offs

Capacity for Rail

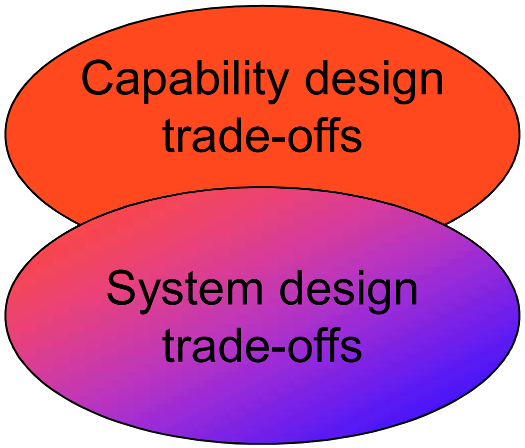
The Tool will reflect system interactions and the impacts of trade-offs to establish the relative benefits of different innovations/improvements

Determine best way to …

Get 50000 people an hour through Route A

Get 300 people off the train every 3 minutes

… by doing …



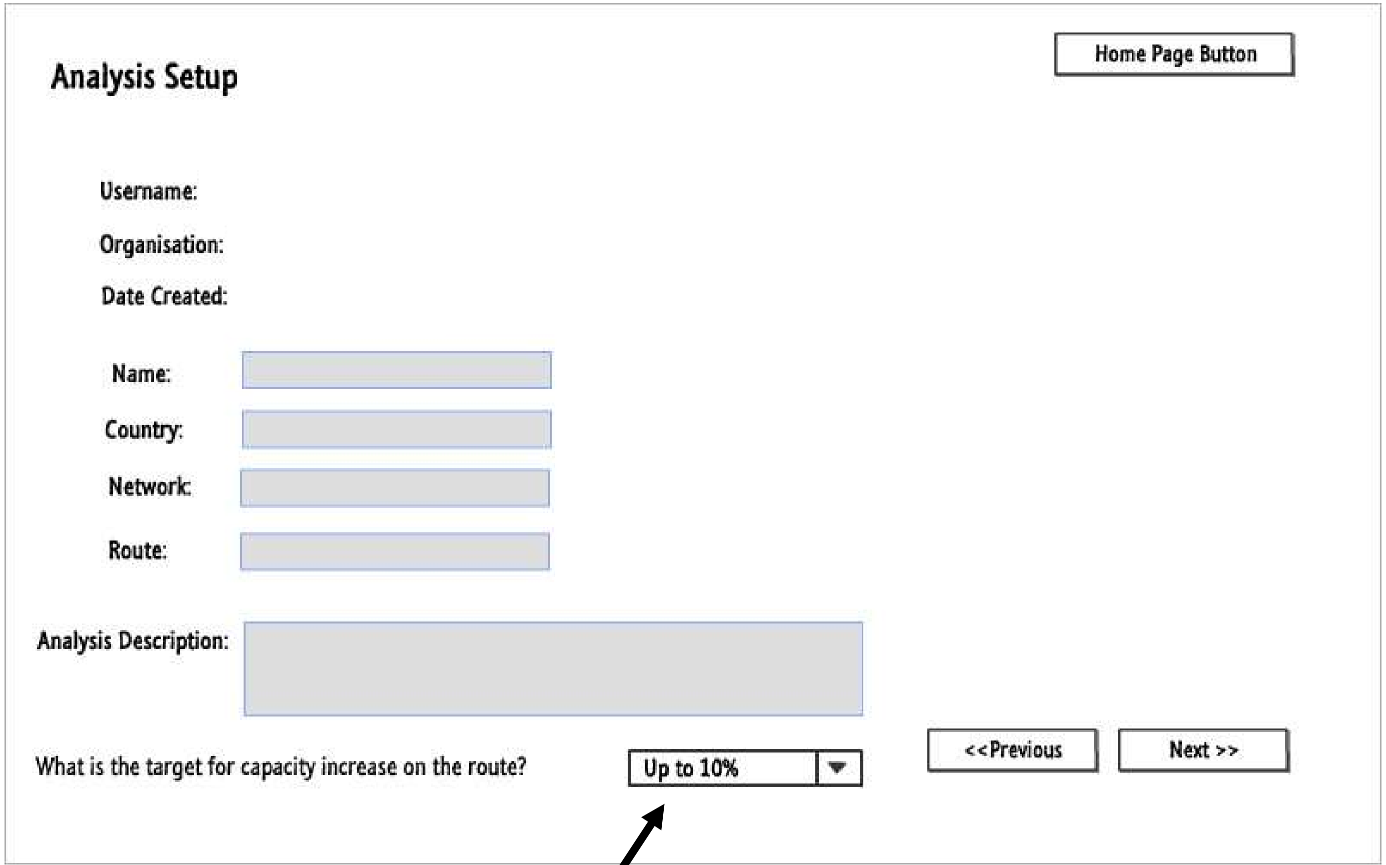
… by comparing …

High performance low capacity trains vs low performance high capacity trains

Acceleration/braking vs number/size of doors

The C4R Tool for capability trade-offs

Capability Trade-Offs Analysis Tool



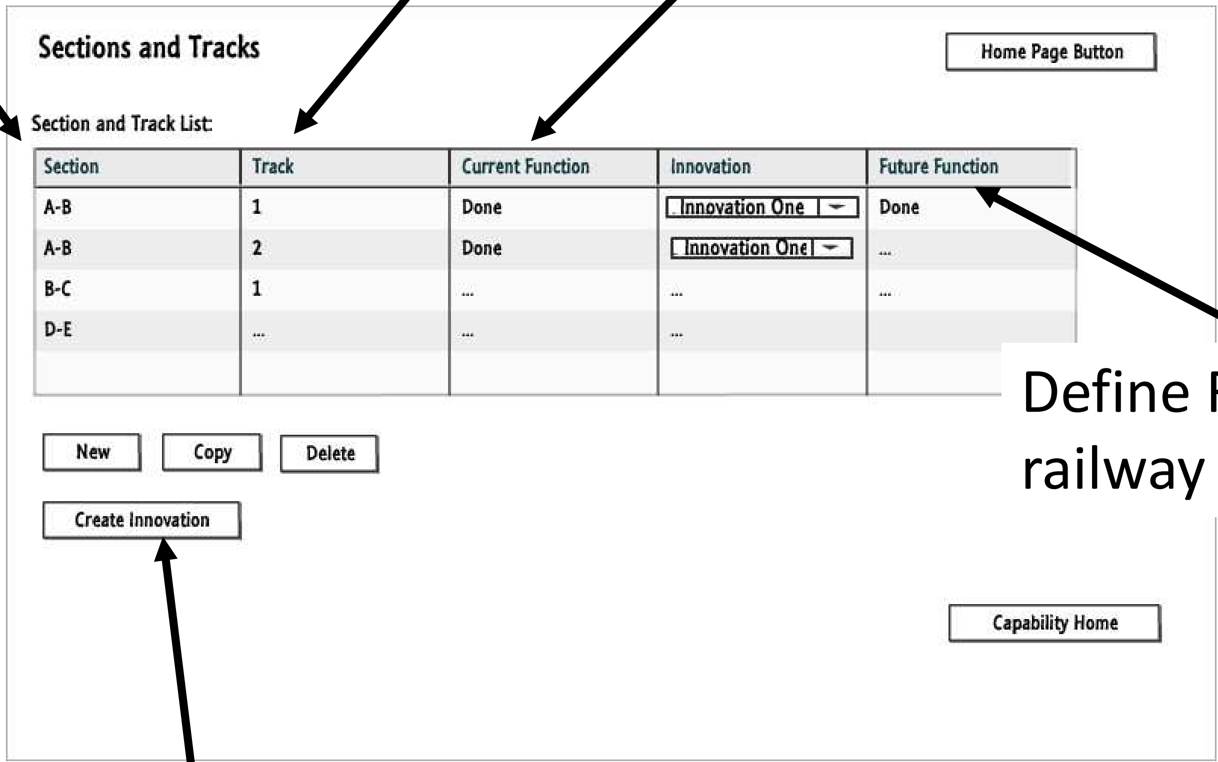
Increase of capacity target

Capability Trade-Offs Analysis Tool

Define the Section

Define the Track

Define Current railway **Functions**

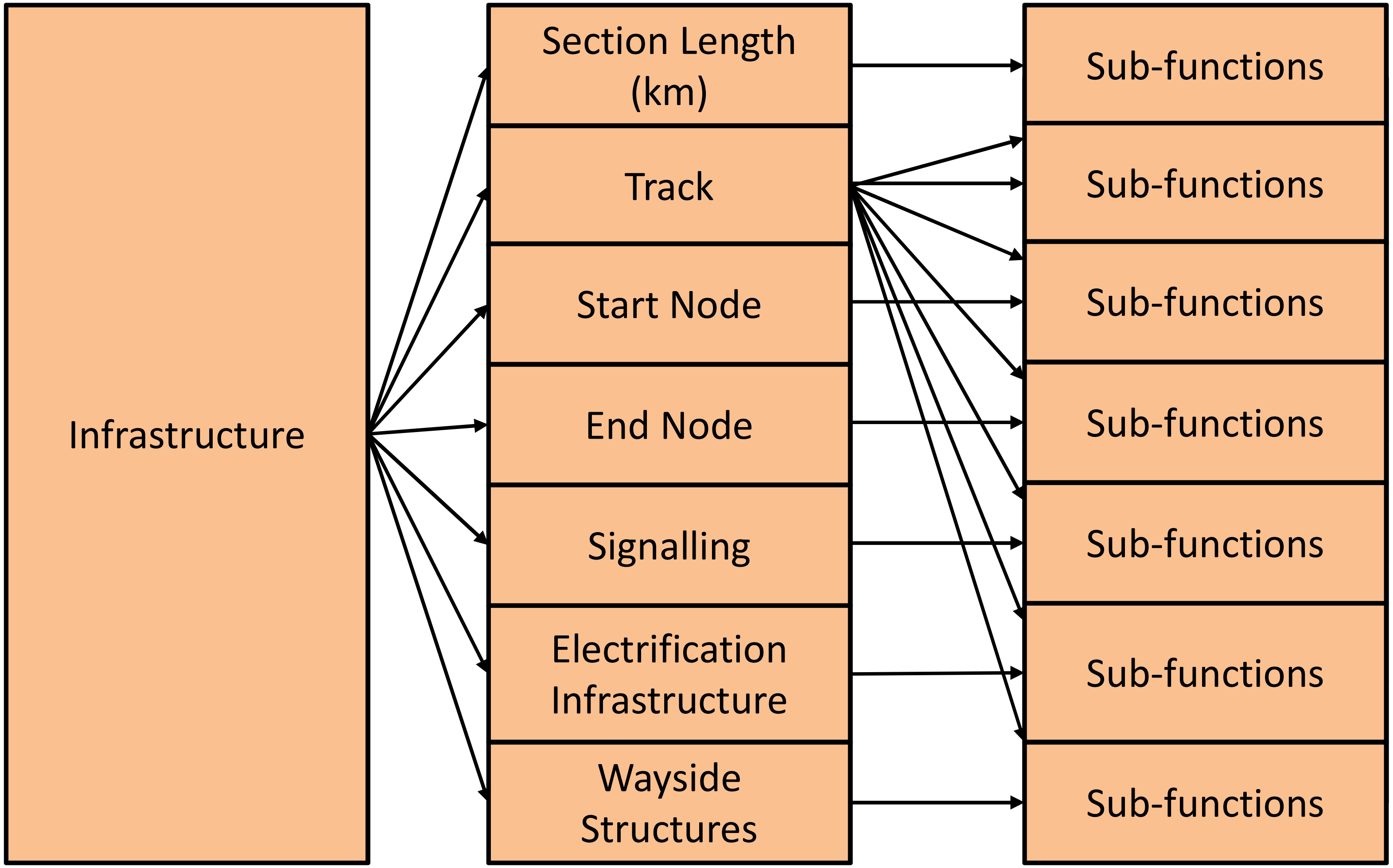


Section	Track	Current Function	Innovation	Future Function
A-B	1	Done	Innovation One	Done
A-B	2	Done	Innovation One	...
B-C	1	...	...	...
D-E	...	...	...	

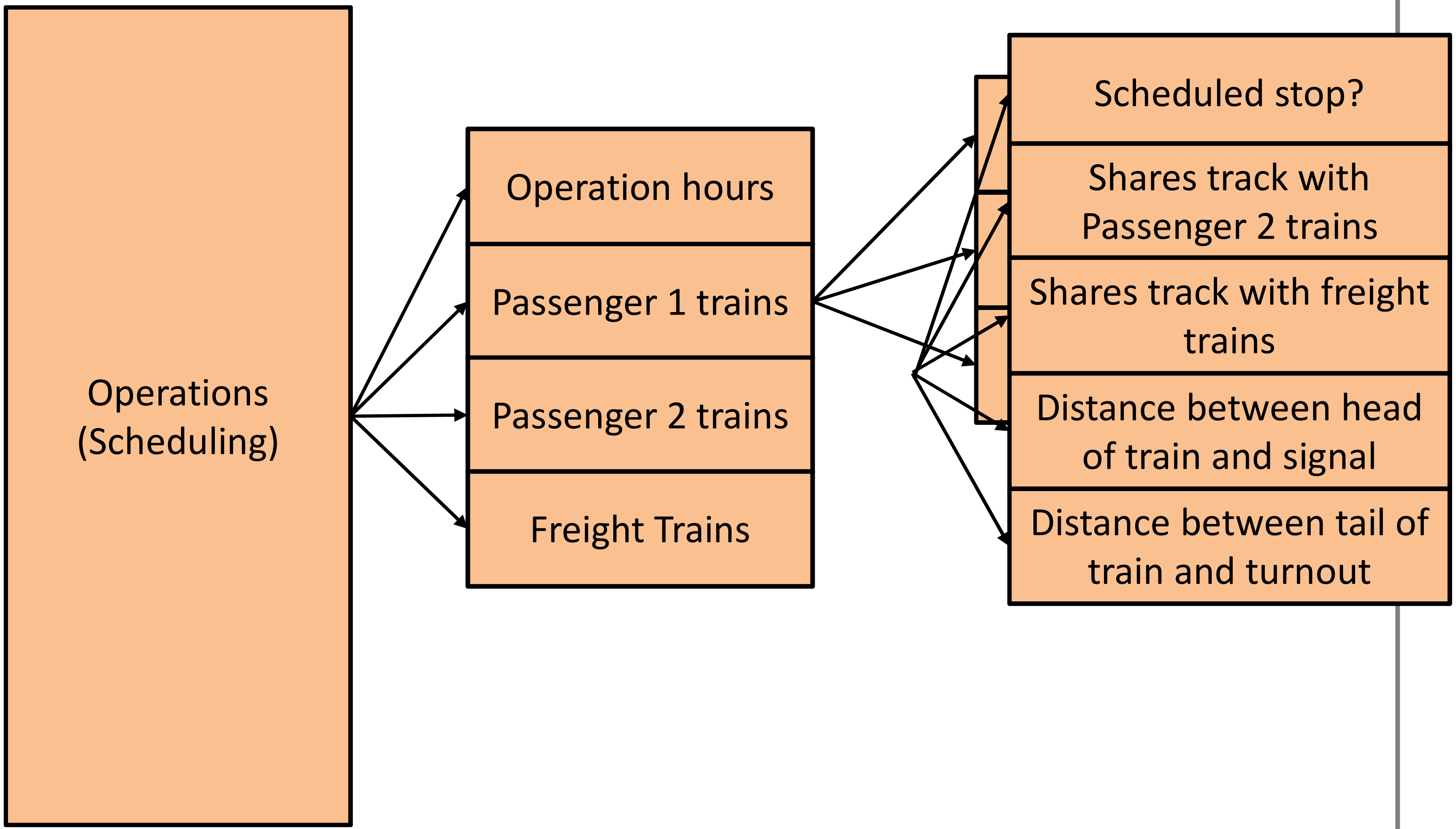
Define Future railway **Functions.**

Define **innovation/improvement**

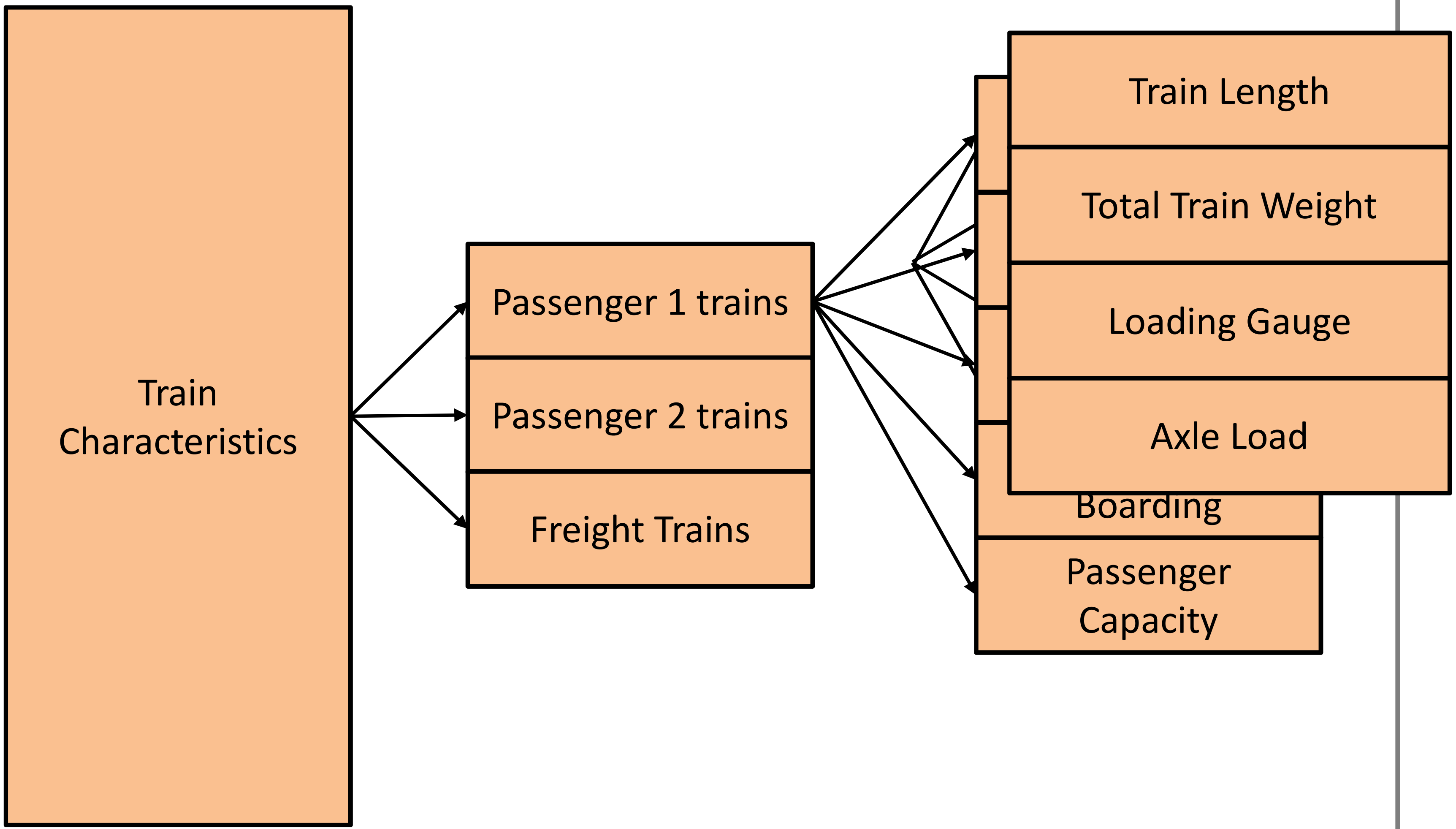
Railway Capability



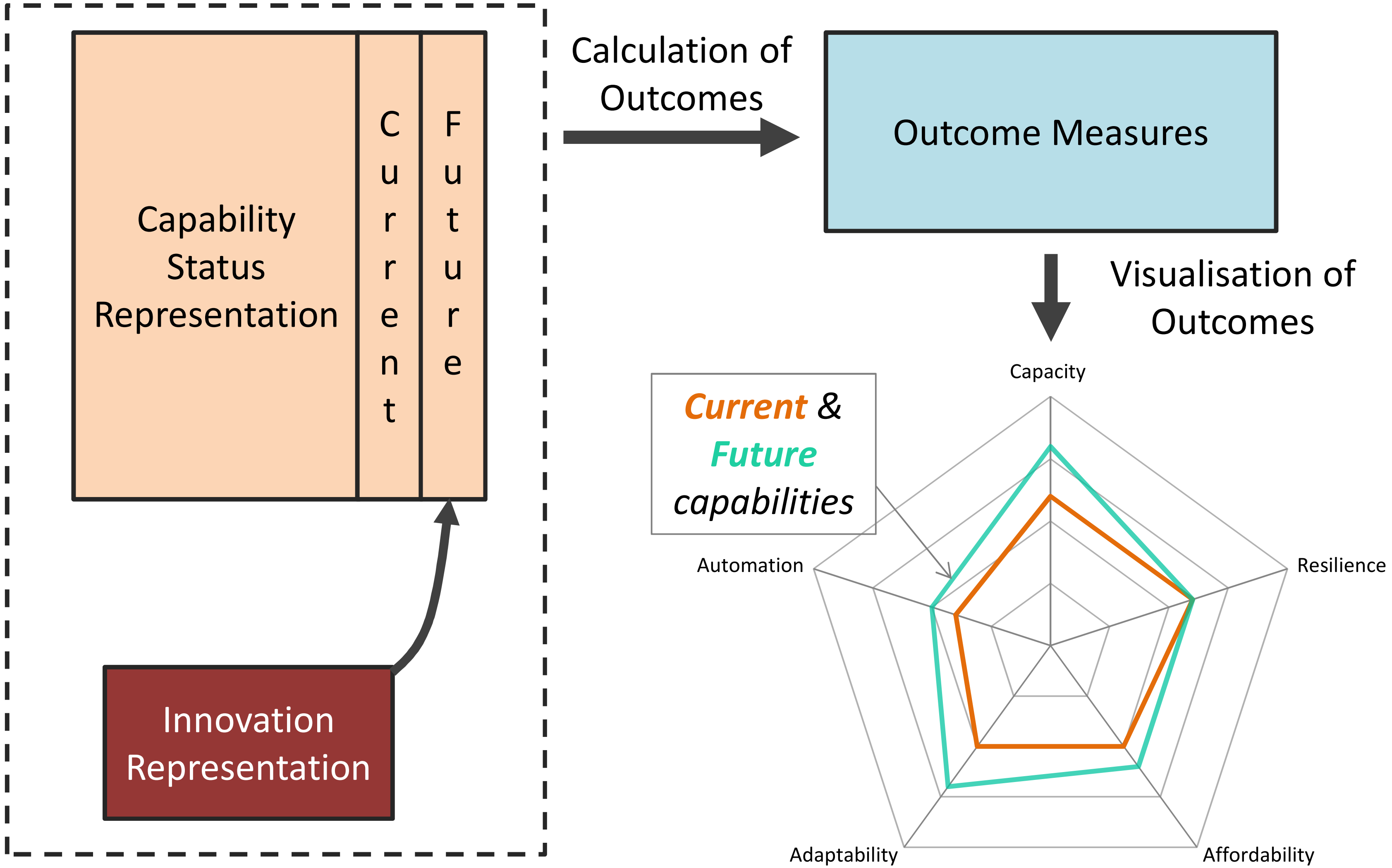
Railway Capability



Railway Capability



Capability Trade-Off Analysis Tool



Capacity for Rail

Capacity

Capacity estimation model overview

Capacity for Rail

- The model allows the estimation of a line's capacity in terms of
  - trains per hour per direction
  - carrying capacity (passengers / cargo)
- The capacity estimation component uses an **analytical model**
- It is applicable at the **network-wide** level
- The model is suitable for use on **conventional networks with mixed traffic**
- The model requires only a **modest amount of input data** and set-up time:
  - infrastructure properties
  - operational parameters
  - traffic characteristics

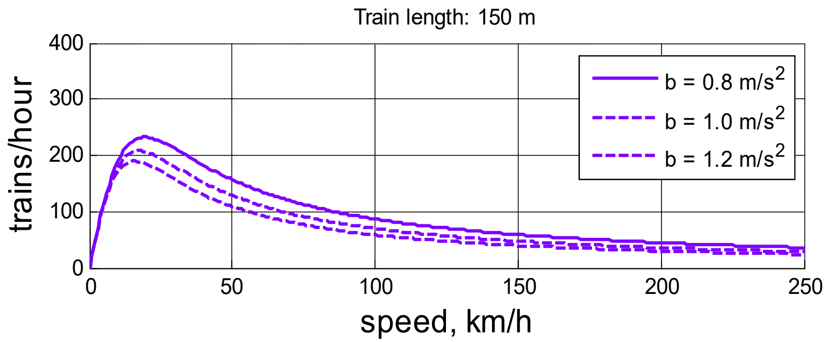
SEVENTH FRAMEWORK PROGRAMME

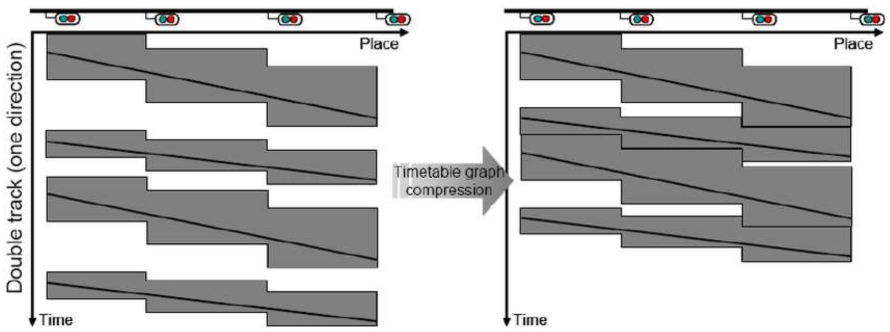
Level of detail

- **No simulation is required** in the C4R capacity calculation process

- The model's level of detail can be classified as moderate

- There is more detail than simple theoretical throughput models which can give inaccurate (optimistic) results



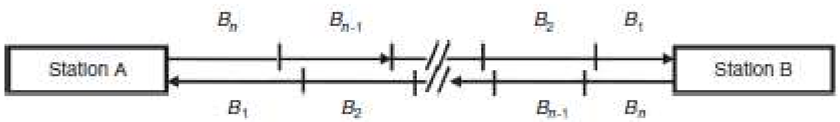


- The model does not go as far as compressing blocking time staircases (c.f. UIC 406 method) which are time-intensive, sensitive to incorrect splitting of the lines and require precise timetable information

Level of detail

Capacity for Rail

- The model differentiates
  - signalling system
  - block size (incl. moving block)
  - station layout
  - dwell time
  - rolling stock types
  - service specifications (simplified)

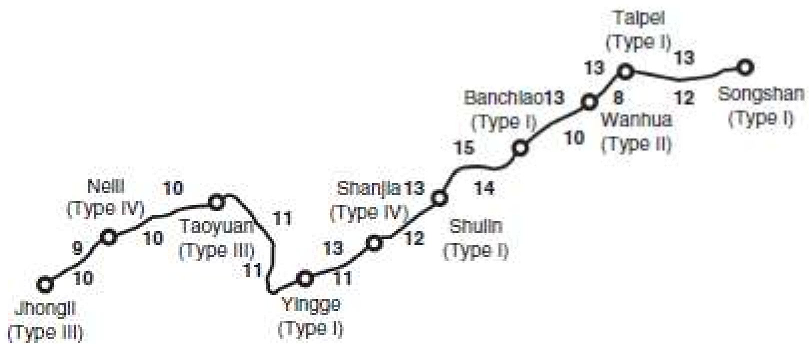


- The calculation uses the fact that stations (and junctions) are usually the bottlenecks on predominantly passenger carrying lines

TRA capacity model

- The C4R model is heavily based on a model developed for the **Taiwan Railway Administration** (TRA) [1, 2]

- The TRA model has been validated using TRA case studies (e.g. Jhongli – Songshan)
    - to verify its capacity estimates against current conditions
    - in the selection of optimal upgrades w.r.t. cost and capacity trade-offs

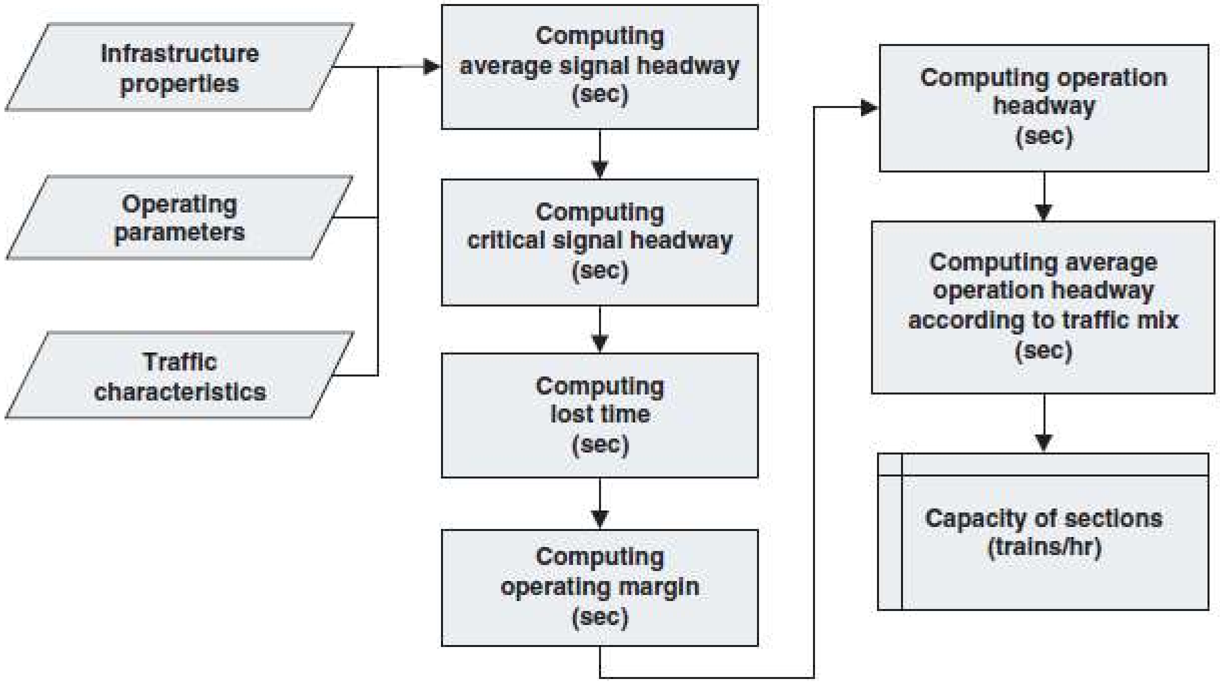


TRA case study verification area (from [1])

[1] Y-C Lai, M-C Shih. J-C Jong, Railway capacity model and decision support process for strategic capacity planning. Transportation Research Record 2197, Transportation Research Board, Washington, DC, 19-28

[2] Y-C Lai, S-H Wang. Development of analytical capacity models for conventional railways with advanced signalling systems. J. Transp. Eng. 2012. 138:961-974

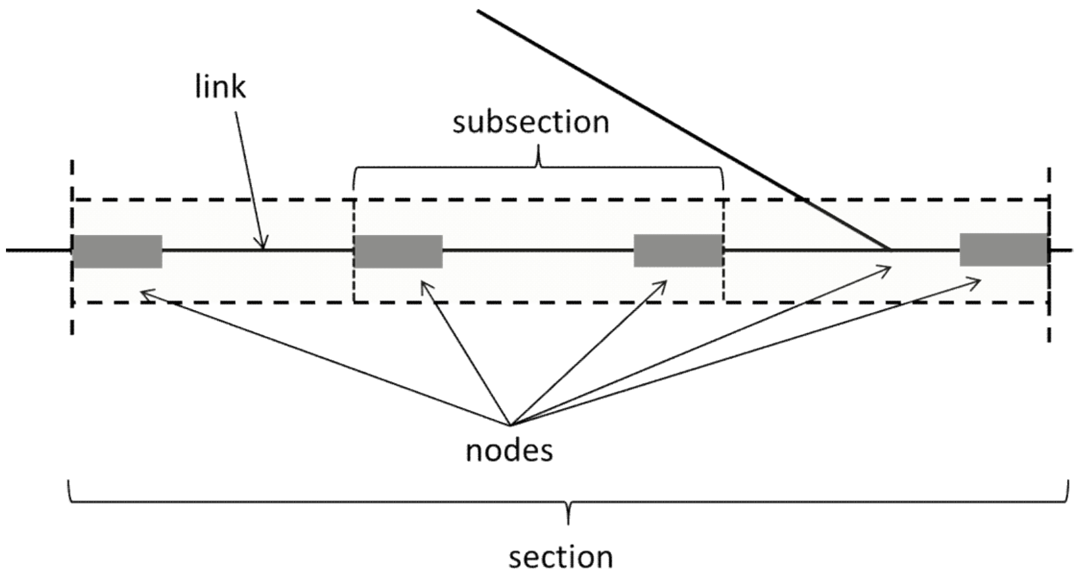
Capacity calculation framework



Infrastructure division

- The network is subdivided into **subsections**
  - Stations and junctions are termed **nodes**
  - Each track between the nodes is a **link**

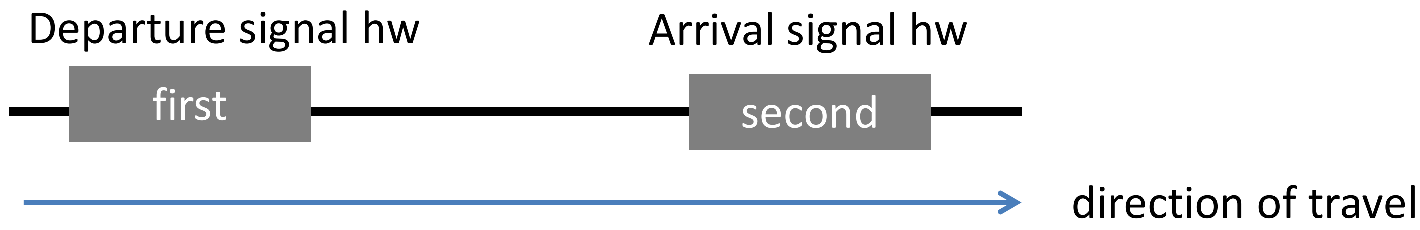
- Every subsection contains a link and the two adjacent nodes at each of its ends



Headway calculation

- Capacity analysis is conducted for **each subsection**
- The model considers the line and adjacent station characteristics at the same time
- Capacity is estimated via a series of appropriate headway calculations
- For every subsection the model determines the **subsection's critical signal headway** via a number of steps:

1a. Departure headway calculation from subsection's first station
1b. Arrival headway calculation at subsection's second station



2. Determination of **critical headway** (of arrival and departure headways)

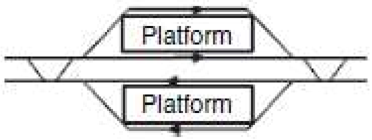
Station layout

- Station track layout has a large impact on capacity

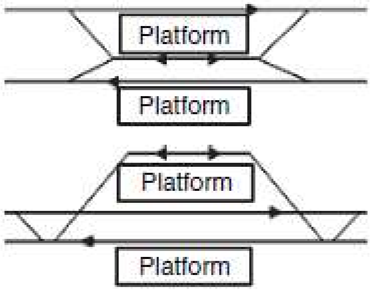
- The exact equations used for the departure and arrival signal headway calculations depend on
  - the station layout (track layout)
  - the rolling stock characteristics (performance)
  - signalling system

- For a given subsection the equations to use are defined depending on the station layouts
  - same track

  - different tracks



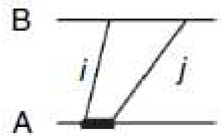
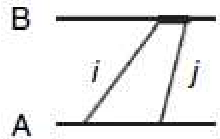
  - shared tracks



Critical headway

- Select the critical signal headway of the headways at the first and second stations in the subsection

- It depends on
  - rolling stock: relative speeds, stopping patterns,
  - stations: track layout / usage

Condition	Position of Critical Station	Critical Signal Headway
$t_i = t_j$		$T_s = \max(T^A_{s,D}, T^B_{s,A})$
$t_i < t_j$		$T_s = \max(T^A_{s,D}, T^B_{s,A} - (t_j - t_i))$
$t_i > t_j$		$T_s = \max(T^A_{s,D} - (t_i - t_j), T^B_{s,A})$

Operational headway

- The operational headway consists of a sum of
    - critical signal headway
    - buffer time between paths
    - time lost due to rolling stock speed differences

- The operational headway (tph) on subsections is an intermediate capacity output

BUT the traffic mix needs to be considered too!

Traffic mix

- Depending on the number of train groups, with the same
  - rolling stock
  - service pattern

the process is repeated for all train pair combinations

- e.g. for train group G = {A, B}:
  - A-A, A-B, B-A, B-B
  - 4 combinations

- or train group G = {A, B, C}):
  - A-A, A-B, A-C, B-A, B-B, B-C, C-A, C-B, C-C
  - 9 combinations

- For the specified proportional mix of these train groups (e.g. 7 x group A, 4 x group B, 2 x group C), the **average operational headway** is calculated per subsection

Capacity KPI outputs

- Capacity of the line
  - the minimum capacity (tph) of any of the subsections
- Carrying capacity
  - the number of passenger spaces
  - or freight carrying capacity

Affordability, Resilience, Adaptability & Automation

Affordability

Capacity for Rail

Topic 1: Infrastructure Costs

Topic 2: Rolling Stock Costs

Topic 3: Barriers to Entry

Topic 4: Infrastructure Environmental Costs

Topic 5: Operation Environmental costs

Resilience

Capacity for Rail

Topic 1: Performance (related to punctuality)

Topic 2: Train delays due to weather events

Topic 3: Train delays due to infrastructure failures and maintenance

Topic 4: Train delays due to rolling stock/train operational failures

Topic 5: Speed of recovery from timetable perturbation

Topic 6: Accessibility to network during disruptions

SEVENTH FRAMEWORK PROGRAMME

Adaptability

Topic 1 Seamless Train Movement

Topic 2: Interoperability

Topic 3: Adaptable infrastructure capability

Topic 4: Legalities when implementing change

Automation

Topic 1: Operations

Topic 2: Operations-related Communications

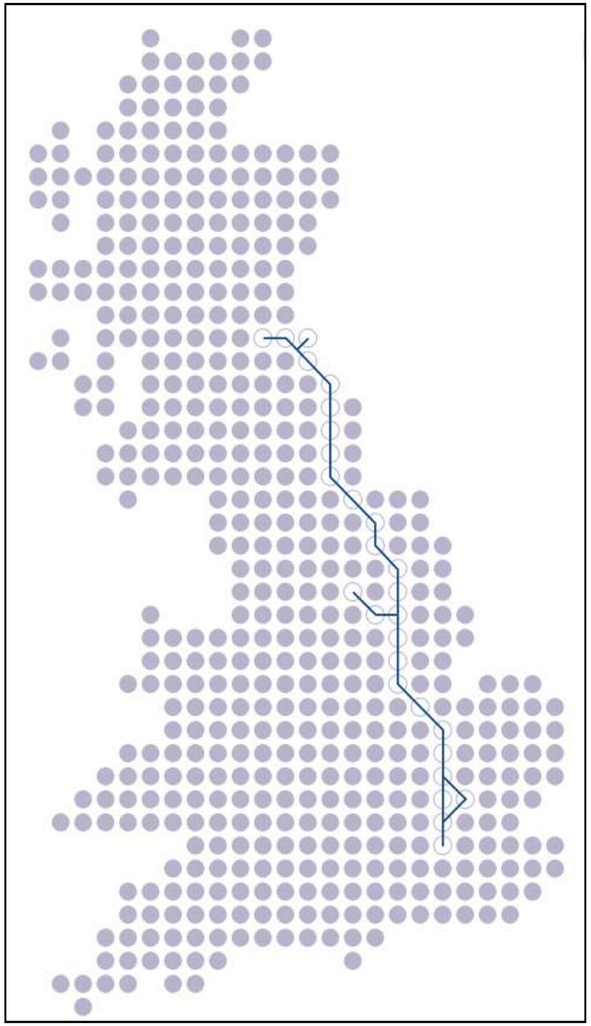
Topic 3: Monitoring and Maintenance

Topic 4: Automation for Passengers

Improving East Coast Mainline (ECML) capacity

Problem

Future demand exceeding available capacity



Geographic Scope, ***East Coast Main Line Route Utilisation Strategy, Network Rail, 2008***

Case Study – Peterborough to Doncaster

Capacity for Rail

Sub-section on the major railway link between London and Edinburgh

Traffic
- 6 High Speed Intercity Passenger Services (201 kmh)
- 2 Regional Passenger Services (120 kmh)
- 1 Freight (100 kmh)

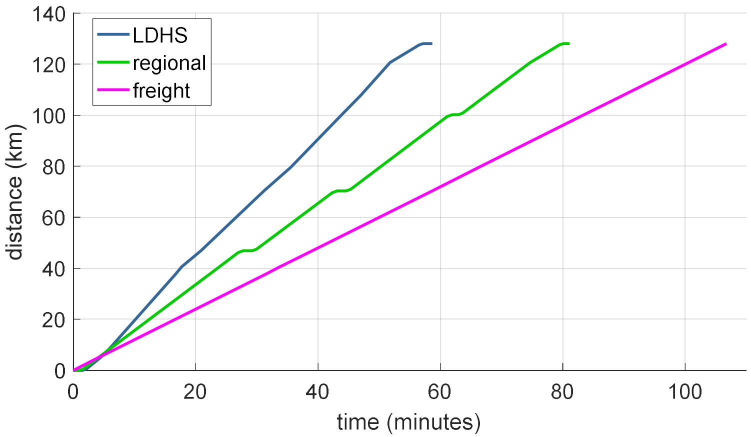
Signalling
- 4-aspect

Tracks per direction
- 1 (Doncaster to Stoke Tunnel)
- 2 (Stoke Tunnel to Peterborough)

Structures
- > 30 Level Crossings
- > 100 bridges & 4 tunnels

Case Study – Peterborough to Doncaster

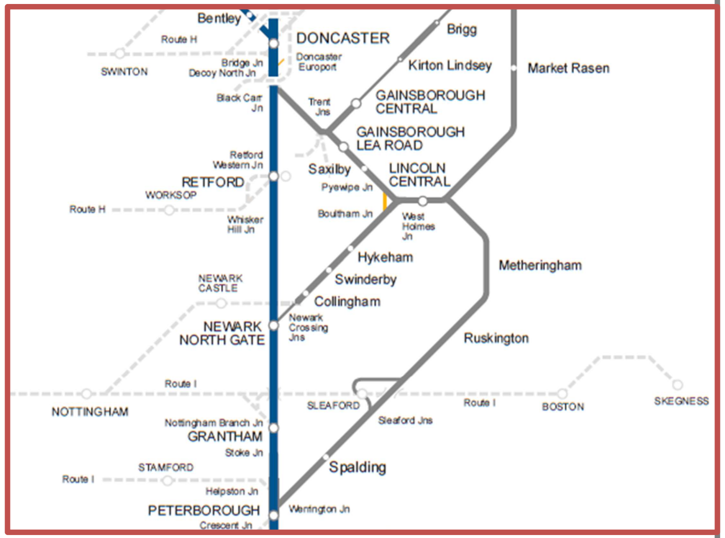
- **Scenario 1**: current conditions



- **Scenario 2**: Upgrade rolling stock

- **Scenario 3**: Sc 2 + remove freight from ECML

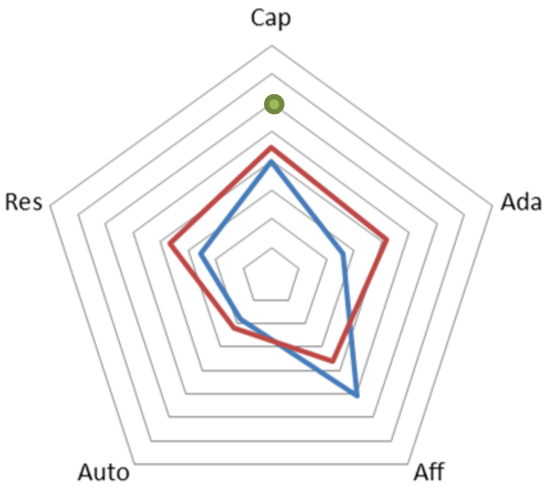
- **Scenario 4**: Sc 3 + upgrade to ETCS L2, optimised block sections



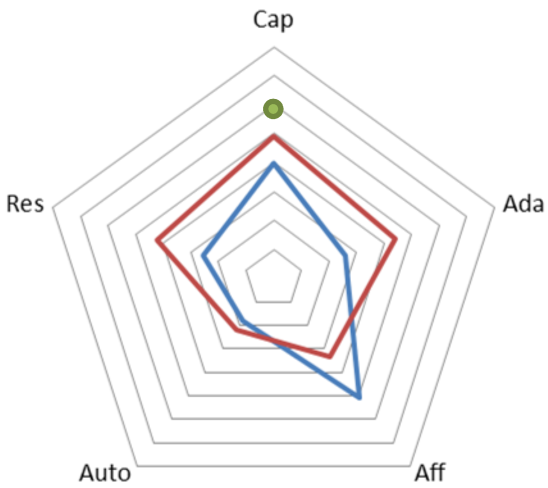
Target: Double Capacity

Capacity for Rail

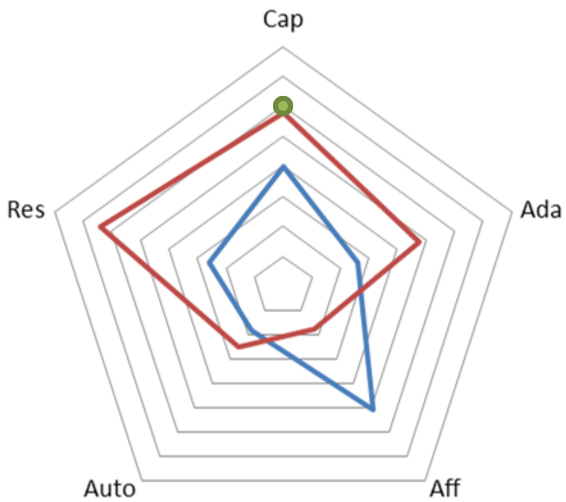
Reporting Outcomes



Current vs **Upgraded Rolling Stock**



Current vs **Upgraded Rolling Stock & Removal of freight**



Current vs **Upgraded Rolling Stock, Removal of freight & ETCS L2 (w/ Optimised Blocks)**

Capacity for Rail