The Rail Engineering Challenge

Specifications booklet

NEALS

NEW SOUTH WALES
DEPARTMENT
OF EDUCATION
AND TRAINING

Acknowledgements

The *Rail Engineering Challenge* was originally developed as partnership between RailCorp and the Curriculum K–12 Directorate of the NSW Department of Education and Training as the *Making Tracks* program.

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Contents

Definitions

The following definitions will help you understand the different features that are required to meet the requirements of the Engineering challenge. Once you understand the meaning of the terms used in railway technology it may be a useful activity to develop a mind map to show the interrelationship of concepts.

If you are still unsure of what the terms are referring to or you wish to know more, the online conversations with engineers will give you the opportunity to ask questions and get answers.

Note: Wikipedia has extensive information on many aspects of railways including track layout.

Words in italics are defined elsewhere in the definitions list.

Ballast

Ballast is one of the components of the railway track substructure. The substructure is comprised of ballast, sub-ballast and the sub-soil or natural ground. Ballast keeps the rail and sleepers in the required position, improves drainage and protects the sub-ballast and soil from stress. It consists of crushed rock.

Braking curves

Braking curves are graphs that show how long it takes a train to stop from different speeds. You may need to use braking information when working out where to place signals. See *Headway* and the Braking curves graph, page 15.

Bridges

Bridges may be:

(single span, single track)

(single span, double track)

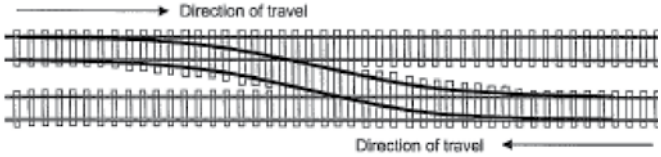
(multi-span, single track)

(multi-span, double track)

The maximum span length for a typical rail bridge is 45m. A bridge for a larger span would be classified as a 'large bridge'. More typical spans would be 20m using pre-cast deck units. 45m spans would use concrete box girder or steel girder sections. If a bridge is longer than one span, it needs a pier for each extra span. Piers less than 4m high (not including below-ground foundations) are included in the bridge cost.

Crossover

Crossovers connect two tracks and are made up of two *turnouts* on adjacent tracks, generally connected by a short section of plain track. A crossover is needed for a train to switch from an up track to a down track or vice versa.



When you are designing crossovers and other turnouts, remember that connections between tracks are best placed in a few compact locations.

Culvert

A culvert is a structure used to enclose a flowing body of water. They are used to allow water to pass underneath the railway. Culverts can be made of many different materials: steel, polyvinylchloride (PVC) and concrete are the most common.

Curves

The permissible radius of a curve in a railway track depends on how fast the trains will be going. The faster the train, the bigger the minimum radius required. A table to estimate curve radius based on train speed and *line* speed is included on page 12. If the *line* speed for a section of track is lower, then the minimum radius allowed can be smaller. Curves on railways are banked (this is called super-elevation) and have a length of track where a straight blends into a radius (this is called a transition).

Note: Super-elevations and transitions do not have to be considered in this challenge.

Cuttings

Some *formations* are dug out to reduce grade changes, i.e. the track has been cut through a hill. The maximum depth before a tunnel should be used instead of a cutting is 30m. In a city, many of the city underground tunnels are only 5 to 10m below ground (from street level to tunnel roof).

Down track

The track on which the train is heading away from Sydney.

Double lines

Double lines have two tracks, one away from Sydney and one towards Sydney. As travel on double lines is only in one direction, a train on its return journey will have to change to the other track. A *crossover* is used to move from one track to the other.

Embankments

Some formations are built up between two high points to reduce grade changes, these are embankments. Embankments can be up to 15m high before a *bridge* becomes economic. Approximate an average height for calculating your embankment costs. If you use fill from an adjacent cutting (of similar size) to build an embankment, you can take 50% off the cost of the embankment.

Fastenings

Rails are connected to *sleepers* using fastenings.

Flying junction

A flying junction is a railway junction at which one or more tracks in a multiple-track route cross other tracks on the route by bridge to avoid conflict with other train movements. Simple flying junctions may have a single track pass over or under other tracks to avoid conflict.

Footbridge

A footbridge allows people to get across the tracks safely.

Formation

The formation is the base under the track. It is made of soil that is packed firmly, or compacted in layers.

Grade

The term 'gradient' is more commonly called 'grade'. It is the rate at which the finished surface of a track rises or falls in its length. The maximum grade allowed for a finished track is 1 in 30 — the track rises or falls a maximum of 1 metre for every 30 metres of length. 1 in 100 is more common.

Headway

Headway is the minimum time between trains on a rail line. To work out the headway, you need to know the maximum number of people you need to move from your busiest station in an hour. *Signal spacing* is linked to headway. A detailed method for calculating headway is included in the *Teacher's handbook*.

Level crossings

These are where roads cross the tracks at the same level as the running surfaces of the rails. Level crossings should be placed so rail and road traffic have good visibility. They are only used in low traffic areas.

Line speed

Line speed is the maximum speed at which a train can travel on a section of track. It will depend on grades, track curve radii and train acceleration or deceleration.

Maintenance shed

A maintenance shed is usually found in a rail yard. It has a track running through it to enable trains to go in and be cleaned and maintained. You will need one maintenance shed for your new rail network. The rail yard (where trains that are not in use are kept) will need to have room to park 10 eight car trains.

Overbridge

This is where road traffic goes over the track. Any overbridge must be at least 5.5 metres above the track to allow sufficient clearance for the *overhead wiring*.

Overhead wiring

The *stanchions* carrying the overhead wiring must be designed so that the wiring is always above the track, but if the wire is always in the same place relative to the track, it will cause uneven wear on the train's *pantograph*. The top of the overhead wiring must be at least 0.5 metres above the train.

Pantograph

The pantograph is the structure on top of the train that transfers electricity from the overhead wires for use by the train's motors and electrical system.

Piers

Piers are used to support the spans of multi-span bridges. Piers into water (bridge over a river) or > 4m high cost $150,000. Piers for double track bridge cost $200,000. Piers must be costed separately.

Rail corridor

The rail corridor is the minimum area of land set aside by law for railway use. It is generally fenced and extends from either side of the track. A standard single track rail corridor is 15m wide, a double track corridor is 18m wide.

Rails

A bar or pair of parallel bars of rolled steel making the railway along which railroad cars or other vehicles can roll.

Relief lines

These are extra tracks in the form of loops to allow faster trains to overtake slower trains.

Route kilometrage

Is the length of a section of track from beginning to end in kilometres.

Sections

There are two types of sections:

- A signal section: the length of track between two adjacent *signals*.
- An electrical section: the length of track serviced by a single *substation*.

Siding

Sidings are usually connected to the main line at one end. They are used to store goods trains for loading and unloading, to store passenger trains when not in use, or to allow fast trains to pass slower trains in some areas.

Sighting distance

A train driver has to be able to see a *signal* before the train reaches it so the train can be stopped in time if necessary. The driver needs to see the *signal* 10 seconds before the train reaches it. If the train is going faster, the sighting distance needs to be greater. A graph to work out sighting distance is included on page 16. When placing signals, they have to be in a position

where the driver can see them in time, so you might need to have relatively straight track or a view down a hill before a signal if the train is moving at speed.

Signals

Signals are coloured lights placed next to the track to give train drivers instructions on when to stop and when they can travel at normal speed. They are placed on posts or attached to structures over the track.

Signal spacing

Signal spacing is the distance between signals. It is dependent on *headway*, because signals must be placed far enough apart to allow a train to stop safely and not hit the train in front. Where trains travel more slowly signals can be closer together because a train can stop in a shorter time. For the purpose of this challenge, the distance between signals must be at least the length of the train plus 2 times the braking distance calculated from the Braking Curves graph on page 15. The maximum distance allowed between signals is 4km.

Single line

Single lines have only one track. Trains travel in both up and down directions using the same track. Signals are bi-directional on single lines so they can be seen from both sides.

Sleepers

A key component of the railway track sub-structure is the railway sleeper. Its main purpose is to distribute loads from the rail to the ballast. Sleepers were made from hardwoods but can now be made from concrete, recycled plastic or steel.

Station platforms

A station platform for a single line is 10m wide. A platform between the tracks of a double line is 15m wide.

Stanchions

Stanchions are the support structure (posts and beams) that support the wiring that delivers power (1500 Volts DC) to the trains. Stanchions are placed about 50m apart, except on curves, where they will need to be closer together to keep the overhead wiring over the track.

Substations

As the rail system will be electric, you will need substations to power the train. An electric train can consume up to 30kW per hour. You will need a substation for every 5km of double track.

Throughput

How often trains run past a given point.

Track

The path that carries the trains is called the track. The track sub-structure is a combination of the *formation*, *ballast*, *drainage*, *sleepers*, *fastenings*, and *rails*.

Track kilometrage

Track kilometrage is the length of a section of track multiplied by the number of tracks. For example, a section of track is 1.5km long with 2 tracks.

Route kilometrage = 1.5km

Track kilometrage = 2 x 1.5km = 3km.

Train stops

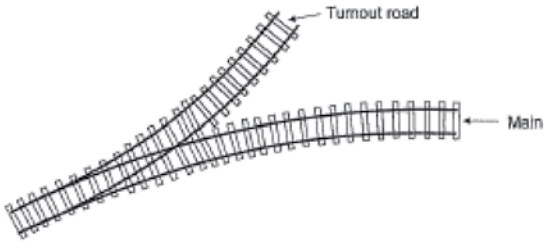
To provide a level of protection against trains travelling past a signal that is at STOP, a train stop must be placed after every signal. If a train doesn't come to a halt at a signal, the train stop automatically activates the train's braking system.

Tunnel

A tunnel is built either through a mountain or used so the railway can go underground.

Turnouts

A set of points or turnout is the part of the track that allows trains to move from one track to another. Turnouts can be either straight or curved track.



Underbridge

This is where the road traffic or waterway goes under the track.

Up track

Track on which the train is heading towards Sydney.

Rolling stock data

Use the following information to answer questions relating to rolling stock (trains).

A train is made up of two carriage units consisting of a Controller Trailer Carriage (this is powered and has a driver compartment) and a Motor Carriage. A train can consist of 2–4 of these units, that is, 4–8 carriages dependent on how many passengers you wish to move at any one time.

Trains can be single deck or double deck. Double deck carriages can hold more people, but take 40% more time to load and unload. Double deck carriages are heavier, so they are more expensive to run as they require more power.

This means that unless you need the extra passenger capacity, a single deck train is more energy efficient.

Train length

The length of the train will affect:

signal spacing: longer trains mean signals are further apart

platform design: platforms will need to be longer than the train itself.

Train capacity

Double deck

Double deck Controller Trailer Carriage (45 tonnes empty, 59 tonnes fully loaded); capacity for 210 people.

Double deck Motor Carriage (53 tonnes empty, 69 tonnes fully loaded); capacity for 250 people.

Carriage length: 20.4m; Height: 4.4m; Width: 3m.

Single deck

Single deck Controller Trailer Carriage (40 tonnes empty, 52 tonnes fully loaded); capacity for 130 people.

Single deck Motor Carriage (48 tonnes empty, 62 tonnes fully loaded) has capacity for 150 people.

Carriage Length: 20.4m; Height: 3.2; Width: 3m.

Boarding and disembarking

It takes time for one full load of passengers to disembark and another load to board.

Allow 2 minutes for a double deck train.

Allow 1 minute for a single deck train.

Track curvature

The following table is a guide to the smallest radius curves you can use when designing your track. The speed column refers to the *line speed* for a section of track between two stopping points, e.g. two stations.

Line speeds under 50km/h are still limited to a minimum of 140m radius.

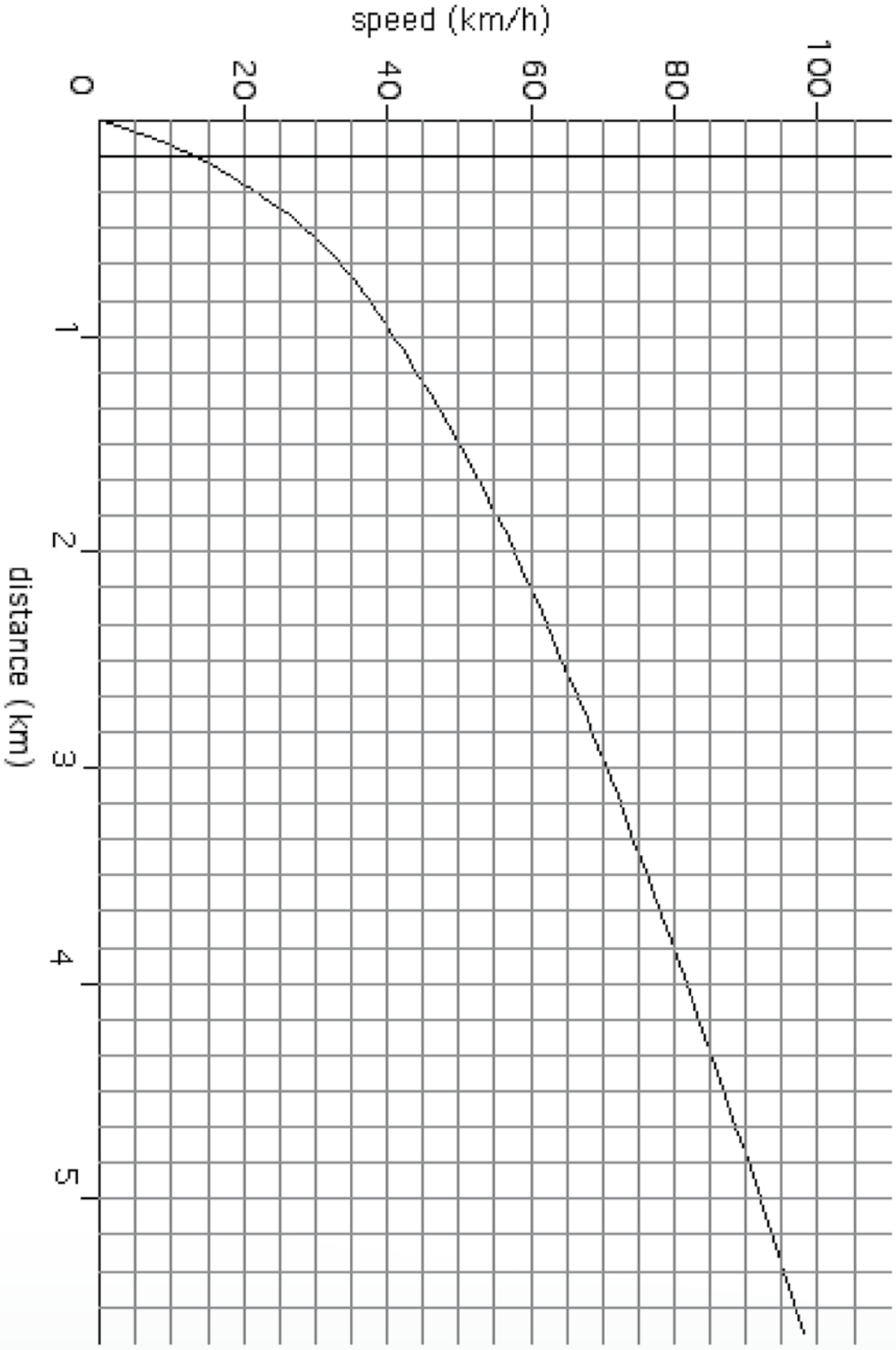
Speed [km/h]	Radius [in metres]
50	140
55	170
60	200
65	230
70	270
75	300
80	350
85	400
90	450
95	500
100	550
105	600
110	660
115	730

Costing structure

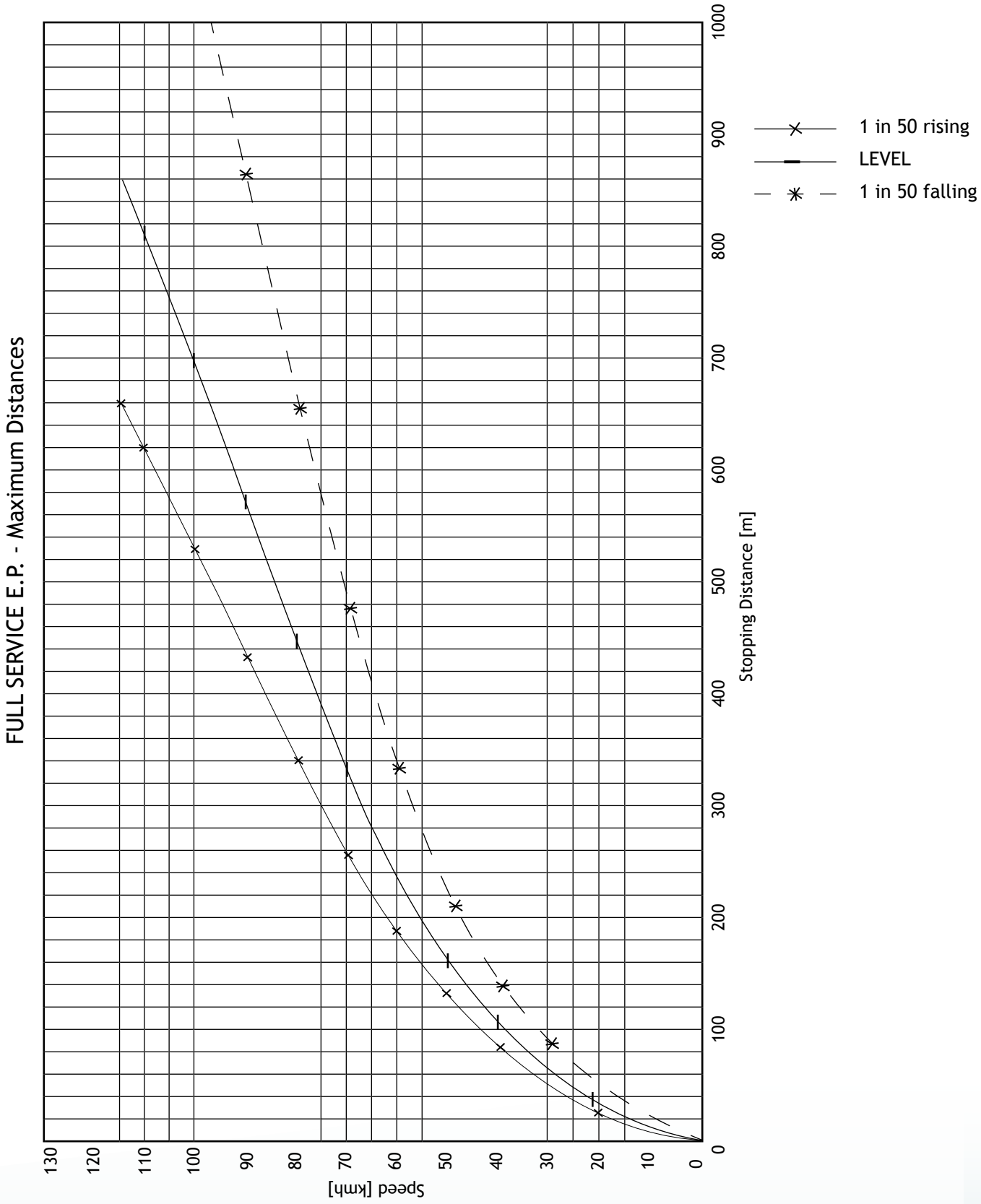
Use the table below to determine the cost of your new railway. The table outlines the cost of the structures (in Fauxton dollars) that you will need to consider when completing your railway.

Infrastructure	Cost
Bridge: 20m span single track/double tracks	$400,000/$700,000 per span (see *Definitions*)
Bridge: 40m span single track/double tracks	$1.2M/$1.8M per span (M = million) (see *Definitions*)
Bridge piers	Piers for a multi-span bridge (single track) over water or > 4m high cost $150,000. Piers for double track bridge cost $200,000.
Cross over	$100,000 per crossover
Culvert	$20,000 per culvert
Cutting	$1.2M per kilometre for each metre of height (see *Definitions*)
Embankment	$1M per kilometre for each metre of height (see *Definitions*)
Footbridge	$100,000 per footbridge
Level crossing	$70,000 per level crossing
Road overbridge	$24,000 per metre
Overhead wiring	$10,000 per kilometre
Siding	$80,000 per siding
Signals	$30,000 per signal
Single line track (x 2 for double line track)	$100,000 per kilometre
Single station platform (see *Definitions*)	$10,000 per metre
Substation	$1,500,000 per substation
Train stop	$10,000 per train stop
Tunnel single/double	$30M/$60M per kilometre
Turnout (points)	$50,000 per turnout

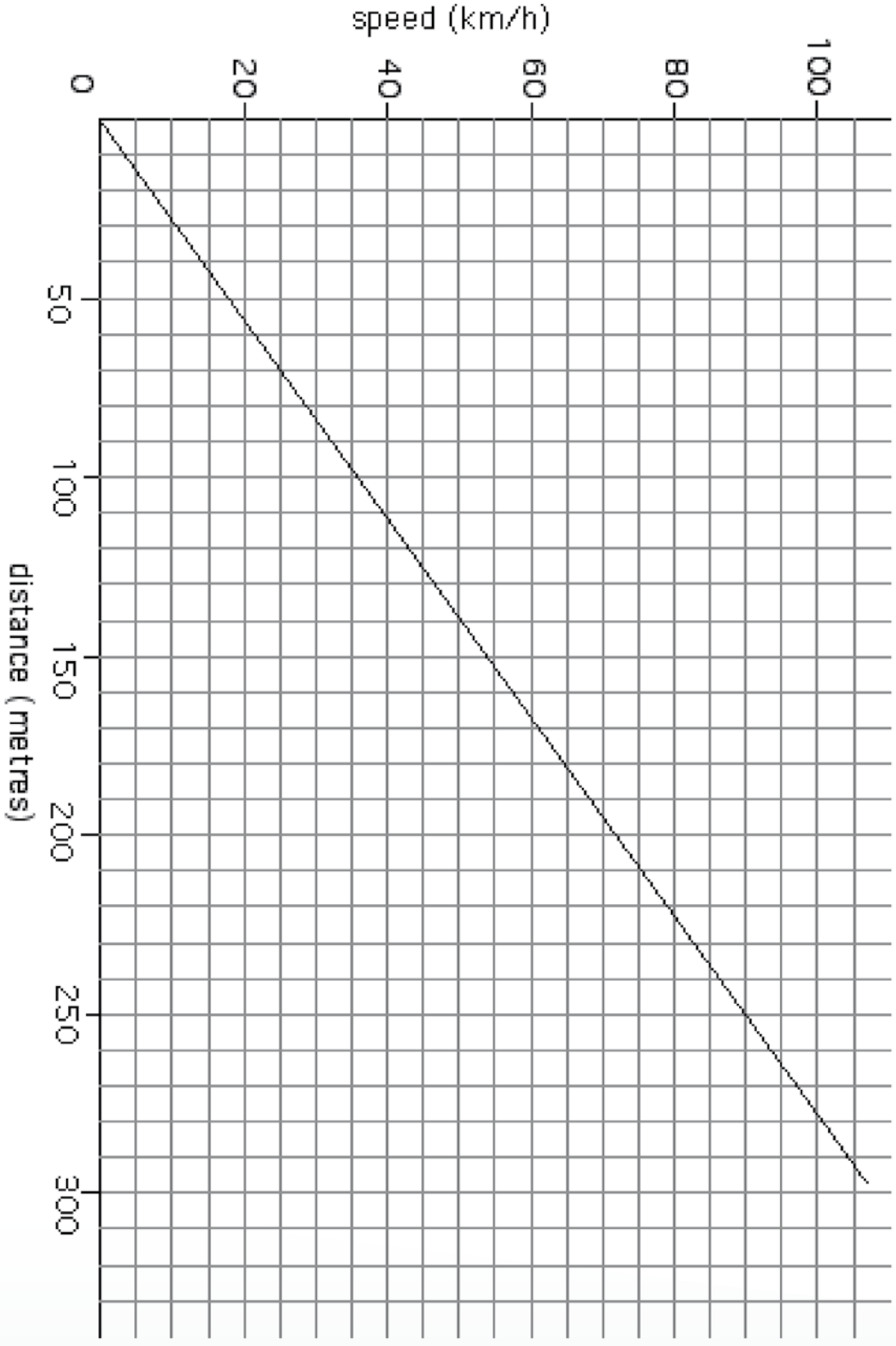
Acceleration curve



Braking curves



Signal sighting distances



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