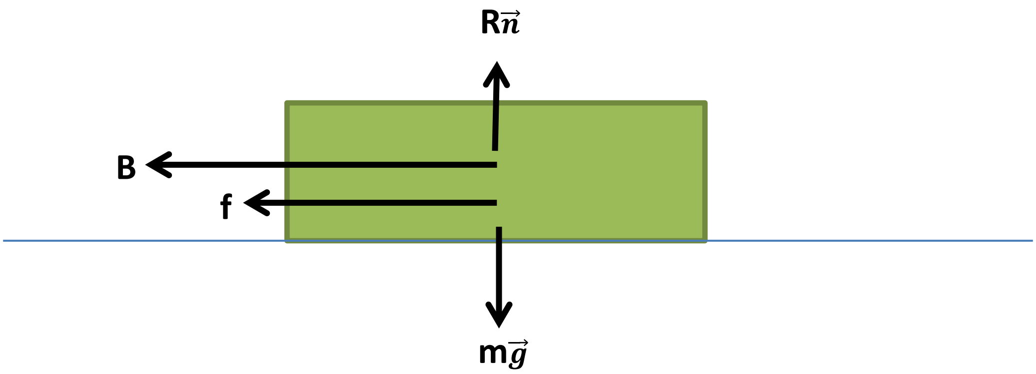
APPENDIX J

LINE 9 – PARIS METRO

J.1. Determine the braking acceleration

Determining the braking acceleration will be done by the mechanical model. The step of determining the braking acceleration will be examine by dividing the mechanical form of the train.



The equation as follow :

$-B - f + \cancel{R\vec{n}} - \cancel{m\vec{g}} = m.a$

Braking forces = 1900 N/ton

Mass train = 125.7 ton = $12.57 \cdot 10^4$ kg

B = 1900N/ton. 125.7 ton

= 238,830 N

Friction forces = 100 N/ton

f = 100 N/ton. 125.7 ton

= 12,570 N

Then :

$-B - f = m.a$

$-$ 238,830 N – 12,570 N = $12.57 \cdot 10^4$. a

a = -2 m/s^2

Result : The acceleration (negative) after the braking point is -2 m/s^2. In this research negative acceleration symbolized by –K.

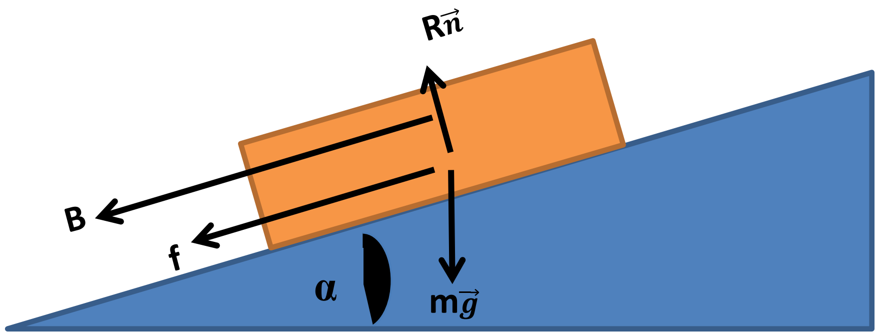
J.2. Determine braking state

The velocity after the braking is 20 km/h which is 5.56 m/s. But in this process the braking velocity will be re-determined if the braking velocity do not utilize on the maximum state.

There is 3 state of the train when the brakes applied which is (t_b, d_b, v_b) . So to determine the braking point is following the equation below :

$$d_b = \frac{V_b^2}{2\,(K + a_g)}$$

a_g = acceleration due to the gradient of the track, in this research the assumption of there is no gradient will be applied.



So, the braking point will be :

$$d_b = \frac{V_b^2}{2\,(K + a_g)}$$

$$= \frac{5.56^2}{2\,(2+0)}$$

= 7.7284 m

To recheck if the velocity of the brake is at the maximum state can use the following equation :

$$V_b = \sqrt{2\left(K + a_g\right).d_b}$$

$$= \sqrt{2\,(2+0).7.7284}$$

= 5.56 m/s

Result : The braking point before the next station is 7.7284m with braking velocity 5.56m/s.

J.3. Determine the coasting phase

To determine the coasting point we can use the following equation :

$V_{t} = V_0 + a.t$

$19.44 = 0 + 0.9 .t$

$t_{acceleration} = 21.6$ s

So the distance that has been travelled during the acceleration phase is :

$S = V_{o.}t + 0.5.a.t^2$

$= 0.21.6 + 0.5 . 0.9 . 21.6^2$

$= 209.952$ m

The travelled distance during the coast phase as following equation :

$S_{c} =$ Total length interstation – S – db

S_c = 544m – 209.952m – 7.7284m

= 326.3196 m

J.4. Determine the acceleration of the coasting phase

The acceleration of the coasting during the coasting phase will be varies as the following equation

$$S_{c} = \frac{V^2 - V_b^2}{2ac}$$

$$326.3196 = \frac{19.44^2 - 5.56^2}{2ac}$$

$a_c = 0.53$ m/s.

J.5. Proposed Model

There are several point on this proposed model which is :

1. The duration time
2. The energy consumption
   - Energy using during the acceleration phase for 1 station
   - Energy using during the coasting phase for 1 station
   - Energy using during the braking phase for 1 station
   - Total energy using for 1 station
   - Total energy using for 1 line which is LINE 9
3. Implementation and analysis for the proposed model

A.5.1. The duration time

The duration of the brake phase is :

$\tau_b = \frac{V_b}{K+a_g}$

$= \frac{5.56}{2}$

$= 2.78s$

The coasting time will be

$S = Vot + 0.5.\ a.\ t^2$

$326.3196 = 19.44.t + 0.5.\ 0.53.\ t^2$

$t_{coasting} = 14.08s$

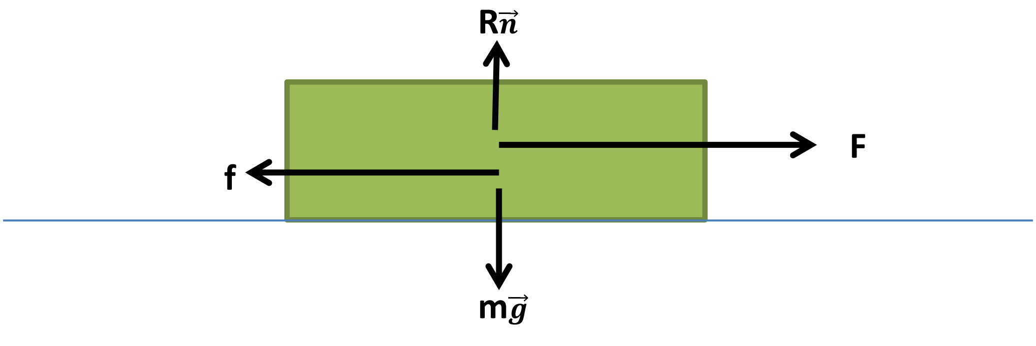
Total time for the journey = $t_{acceleration} + t_{coasting} + t_{braking}$

$= 21.6 + 14.08 + 2.78$

$= 38.46$ s

A.5.2. The energy consumption

- The energy consumption for acceleration phase for 1 station



$F - f + \cancel{R\vec{n}} - \cancel{m\vec{g}} = m.a$

$F = f + m.a$

$= 100\ .\ 125.7 + 125700\ .\ 0.9$

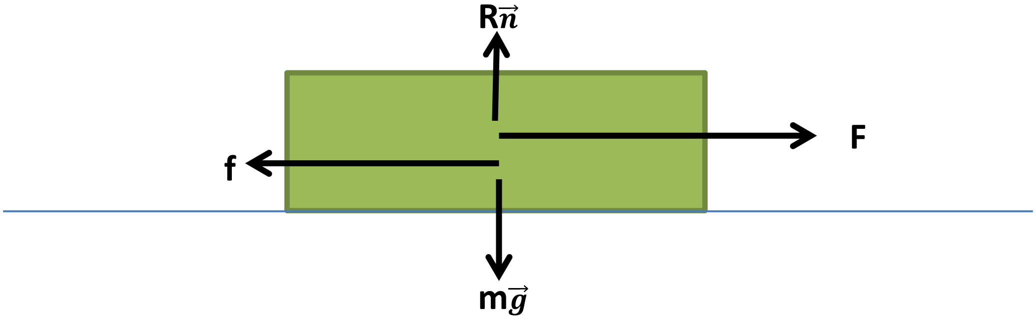
$= 125{,}700$ N

Energy = F.S

$= 125{,}700\ .\ 209.952$

$= 26{,}390{,}966$ J

- The energy consumption for coasting phase for 1 station



F –f + $\cancel{R\vec{n}}$ - $\cancel{m\vec{g}}$ = m.a

F = f + m.a

= 100 . 125.7 + 125,700 . 0.53

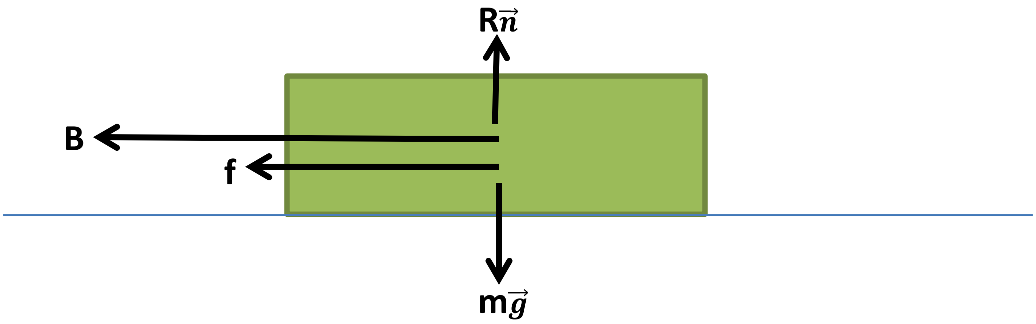
= 79,191 N

Energy = F.S

= 79,191 . 326,3196

= 25,841,575.44 J

- The energy consumption for braking phase for 1 station



-B –f + R$\vec{n}$ - m$\vec{g}$ = m.a

-B = m.a +f

= 125,700 . 2 + 1,900 . 125,7

= 490,230 N

Energy = $|B|$. d

= 490,230 . 7.7284

= 3,788,693.532 J

- Total energy using for 1 station

Energy Total = $Energy_{acceleration} + Energy_{coasting} + Energy_{braking}$

= 26,390,966 J + 25,841,575.44 J + 3,788,693.532 J

= 56,021,234.98 J

- Total energy consumption for line 9

Total energy consumption = 37 station . Energy Total

= 37. 56,021,234.98 J

= 2,072,785,694 J

A.5.3. Implementation and Analysis

The power consumption for the initial system is 1800KW. So the energy consumption for the line 1 with 25 station is 1800 kW x 37 menit = 1110kWh = 3,996,000,000 Joule. With the proposed model, we can save the energy up to 1,923,214,306 J or 534.22 kWh.

From the www.carbontrust.co.uk/energy , we can convert the energy into Carbon and CO_2 emission. The carbon and CO_2 emission saving can be seen in Table J.1

Table J.1 Carbon and CO_2 emission

Fuel		Line 9	
		kg C	kg Co2
Grid electricity	Delivered	62,50374	229,7146
	Primary	558,4202	88,73394
Natural gas		27,6726	101,5018
Coal		43,64577	160,266
Coke		53,95622	197,6614
Petroleum Coke		49,52219	181,6348
Gas / diesel oil		36,32696	133,555
Heavy fuel oil		37,8762	138,8972
Petrol		34,99141	128,2128
LPG		30,61081	112,1862
Jet Kerosene		34,99141	128,2128
Ethane		29,11499	106,844
Naphtha		37,8762	138,8972
Refinery gas		29,11499	106,844