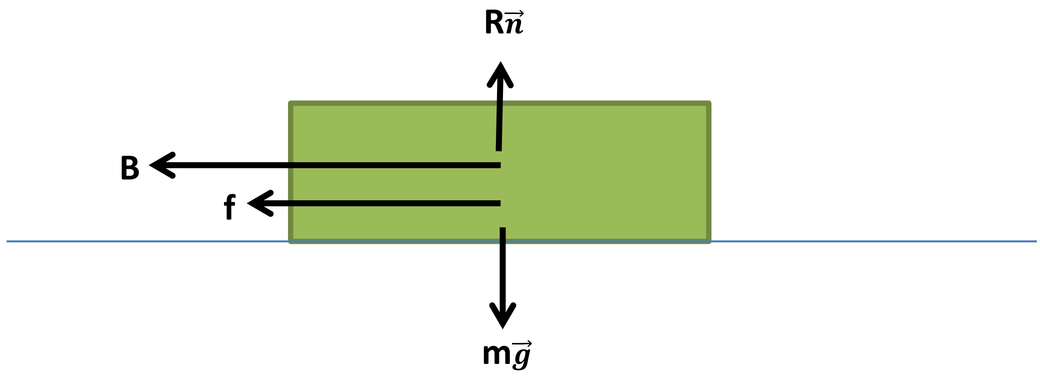
APPENDIX O

LINE 14 – PARIS METRO

O.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 = 135 ton = $13.5 \cdot 10^4$ kg

B = 1900N/ton. 135 ton

= 256,500 N

Friction forces = 100 N/ton

f = 100 N/ton. 135 ton

= 13,500 N

Then :

$-B - f = m.a$

$-256{,}500\ N - 13{,}500\ N = 13.5 \cdot 10^4 \cdot a$

$a = -2\ m/s^2$

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

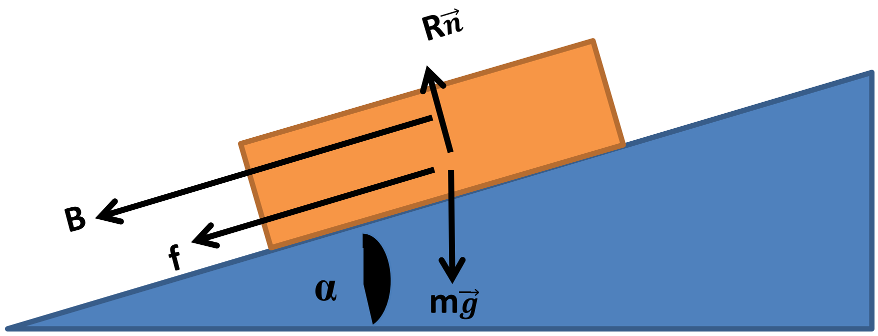
O.2. Determine braking state

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 :

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

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

= 5.56 m/s

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

O.3. Determine the coasting phase

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

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

$22.22 = 0 + 1.25 .t$

$t_{acceleration} = 17.776$ s

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

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

$= 0.\ 17.776 + 0.5\ .\ 1.25\ .\ 17.776^2$

$= 197.5$ m

The travelled distance during the coast phase as following equation :

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

S_c = 1129m – 197.5 – 7.7284m

= 923.7716 m

O.4. Determine the acceleration of the coasting phase

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

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

$$923.7716 = \frac{22.22^2 - 5.56^2}{2ac}$$

$a_c = 0.25$ m/s.

O.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 14
3. Implementation and analysis for the proposed model

O.5.1. The duration time

The duration of the brake phase is :

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

$= \frac{5.56}{2}$

$= 2.78s$

The coasting time will be

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

$923.7716 = 22.22.t + 0.5.\ 0.25.\ t^2$

$t_{coasting} = 34.77s$

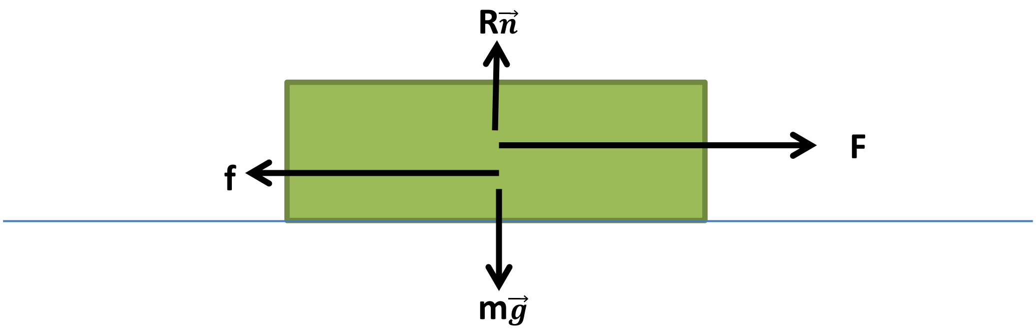
Total time for the journey = $t_{acceleration} + t_{coasting} + t_{braking}$

$= 17.776 + 34.77 + 2.78$

$= 55.326\ s$

O.5.2. The energy consumption

- The energy consumption for acceleration phase for 1 station



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

$F = f + m.a$

$= 100\ .\ 135 + 135{,}000\ .\ 1.25$

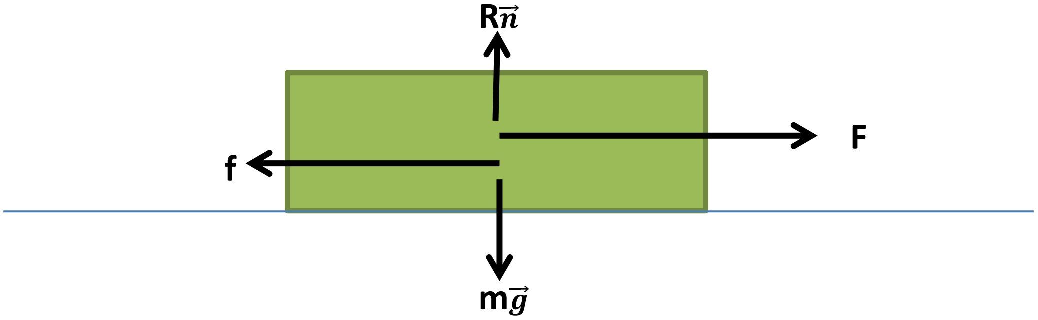
$= 182{,}250\ N$

Energy = F.S

$= 182{,}250\ .\ 197.5$

$= 35{,}994{,}375\ J$

- 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 . 135 + 135,000 . 0.25

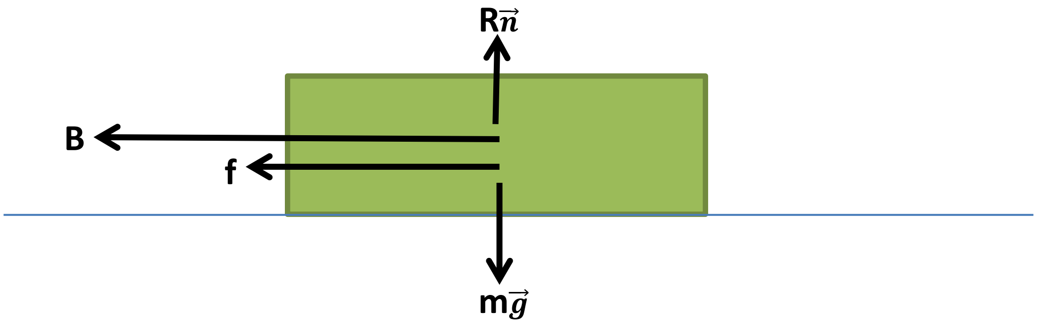
=47,250 N

Energy = F.S

= 47,250 . 923.7716

= 43,648,208.1 J

- The energy consumption for braking phase for 1 station



-B –f + R$\vec{n}$ - m$\vec{g}$ = m.a

-B = m.a +f

= 135,000 . 2 + 1,900 . 135

= 526,500 N

Energy = $|B|$. d

= 526,500 . 7.7284

= 4,069,002.6 J

- Total energy using for 1 station

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

  = 35,994,375 J + 43,648,208.1 J + 4,069,002.6 J

  = 83,711,585.7 J

- Total energy consumption for line 14

  Total energy consumption = 9 station . Energy Total

  = 9. 83,711,585.7 J

  = 753,404,271.3 J

O.5.3. Implementation and Analysis

The power consumption for the initial system is 2800 KW. So the energy consumption for the line 1 with 9 station is 2800 kW x 18 menit = 840 kWh = 3,024,000,000 Joule. With the proposed model, we can save the energy up to 2,450,595,729 J or 680.72 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 O.1

Table O.1 Carbon and CO_2 emission

Fuel		Line 14	
		kg C	kg Co2
Grid electricity	Delivered	79,64424	292,7096
	Primary	711,556616	113,0676
Natural gas		35,261296	129,3368
Coal		55,614824	204,216
Coke		68,75272	251,8664
Petroleum Coke		63,102744	231,4448
Gas / diesel oil		46,28896	170,18
Heavy fuel oil		48,263048	176,9872
Petrol		44,58716	163,3728
LPG		39,005256	142,9512
Jet Kerosene		44,58716	163,3728
Ethane		37,09924	136,144
Naphtha		48,263048	176,9872
Refinery gas		37,09924	136,144