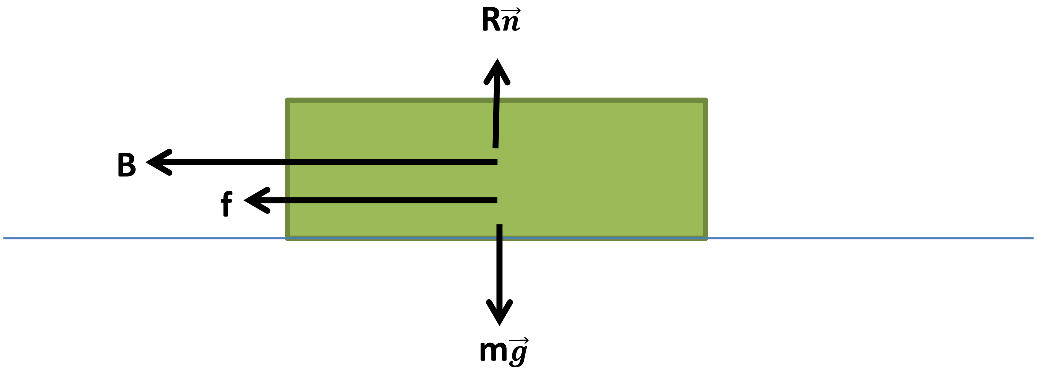
APPENDIX L

LINE 11 – PARIS METRO

L.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 :

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

Braking forces = 1900 N/ton

Mass train = 126.4 ton = 12.64 . 10^4 kg

B = 1900N/ton. 126.4 ton

= 240,160 N

Friction forces = 100 N/ton

f = 100 N/ton. 126.4 ton

= 12640 N

Then :

$-B - f = m.a$

- 240,160 N – 12,640 N = 12.64 . 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.

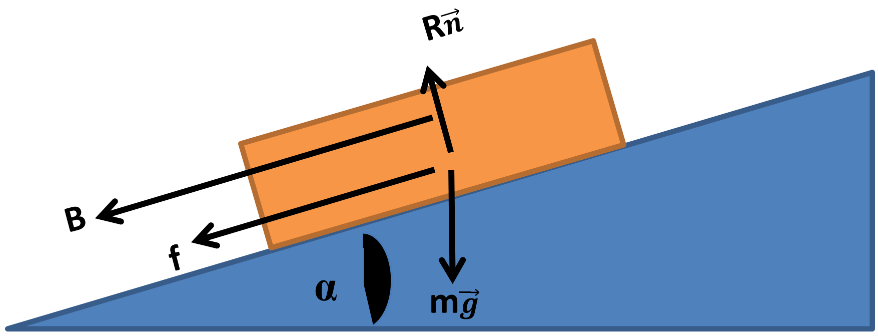
L.2. Determine braking state

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.

L.3. Determine the coasting phase

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

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

$19.44 = 0 + 1.3\ .t$

$t_{acceleration} = 14.95$ s

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

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

$= 0.\ 14.95 + 0.5\ .\ 1.3\ .\ 14.95^2$

$= 145.35$ m

The travelled distance during the coast phase as following equation :

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

S_c = 525m – 145.35m – 7.7284m

= 371.9216 m

L.4. Determine the acceleration of the coasting phase

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

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

$$371.9216 = \frac{19.44^2 - 5.56^2}{2ac}$$

$a_c = 0.47$ m/s.

L.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 11
3. Implementation and analysis for the proposed model

L.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

371.9216 = 19.44.t + 0.5. 0.47 . t^2

$t_{coasting}$ = 16.02

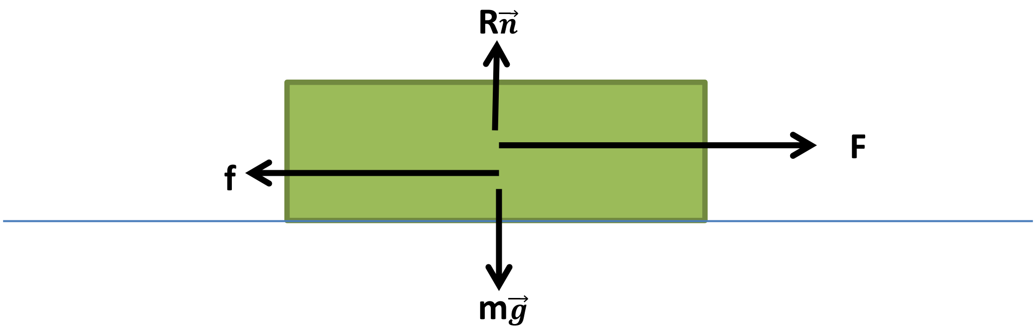
Total time for the journey = $t_{acceleration}$ + $t_{coasting}$ + $t_{braking}$

= 14.95 + 16.02 + 2.78

= 33.75 s

L.5.2. The energy consumption

- The energy consumption for acceleration phase for 1 station



F –f + $R\vec{n}$ - $m\vec{g}$ = m.a

F = f + m.a

= 100 . 126.4 + 126,400 . 1

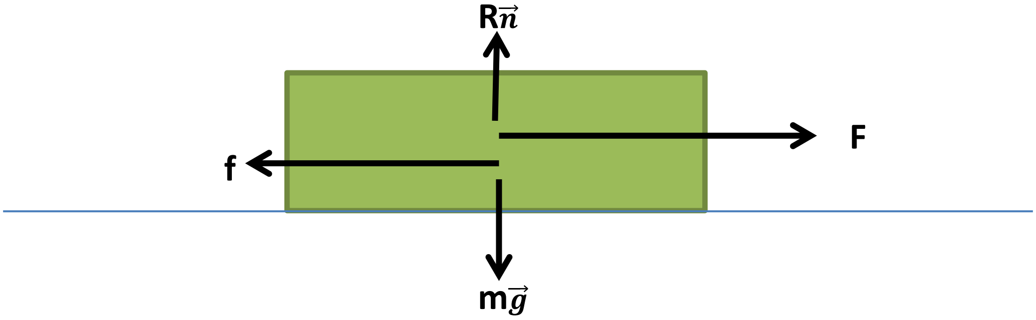
= 139,040 N

Energy = F.S

= 139,040 . 145.35

= 20,209,464 J

- The energy consumption for coasting phase for 1 station



F –f + R$\vec{n}$ - m$\vec{g}$ = m.a

F = f + m.a

= 100 . 126.4 + 126,400 . 0.47

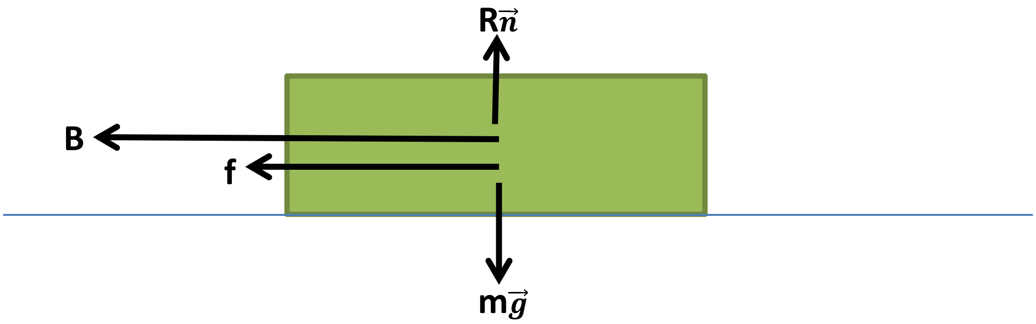
= 72,048 N

Energy = F.S

= 72,048 . 371.9216

= 26,796,207.44 J

- The energy consumption for braking phase for 1 station



-B –f + R$\vec{n}$ - m$\vec{g}$ = m.a

-B = m.a +f

= 126,400 . 2 + 1,900 . 126.4

= 492,960 N

Energy = $|B|$. d

= 492,960 . 7.7284

= 3,809,792.064 J

- Total energy using for 1 station

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

= 20,209,464 J + 26,796,207.44 J + 3,809,792.064 J

= 50,815,463.5 J

- Total energy consumption for line 11

Total energy consumption = 13 station . Energy Total

= 13. 50,815,463.5 J

= 660,601,025.6 J

L.5.3. Implementation and Analysis

The power consumption for the initial system is 1760KW. So the energy consumption for the line 1 with 4 station is 1760 kW x 13 menit = 381.33 kWh = 1,372,788,000 Joule. With the proposed model, we can save the energy up to 712,186,974.4 J or 197.83 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 L.1

Table L.1 Carbon and CO_2 emission

Fuel		Line 11	
		kg C	kg Co2
Grid electricity	Delivered	23,14611	85,0669
	Primary	206,7917	32,85956
Natural gas		10,24759	37,5877
Coal		16,16271	59,349
Coke		19,98083	73,1971
Petroleum Coke		18,33884	67,2622
Gas / diesel oil		13,45244	49,4575
Heavy fuel oil		14,02615	51,4358
Petrol		12,95787	47,4792
LPG		11,33566	41,5443
Jet Kerosene		12,95787	47,4792
Ethane		10,78174	39,566
Naphtha		14,02615	51,4358
Refinery gas		10,78174	39,566