Optimalization Mass Rapid Transit (MRT) System

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General Introduction

- Paris Metropolitan is the major transport systems that serving millions of commuters everyday in metropolitan areas.

- The networks are a high frequency service established mainly in underground tunnels or on elevated tracks separated from other traffic.

PROBLEM

- One of the major problem in the subway system is the operational cost that cause by the energy consumption need to be reduce.

- The reducing of energy consumption also lead to the “green transportation” and stakeholders (major of the city) could use the budget for the transportation to another field like education, rural area development, etc.

Research Objectives

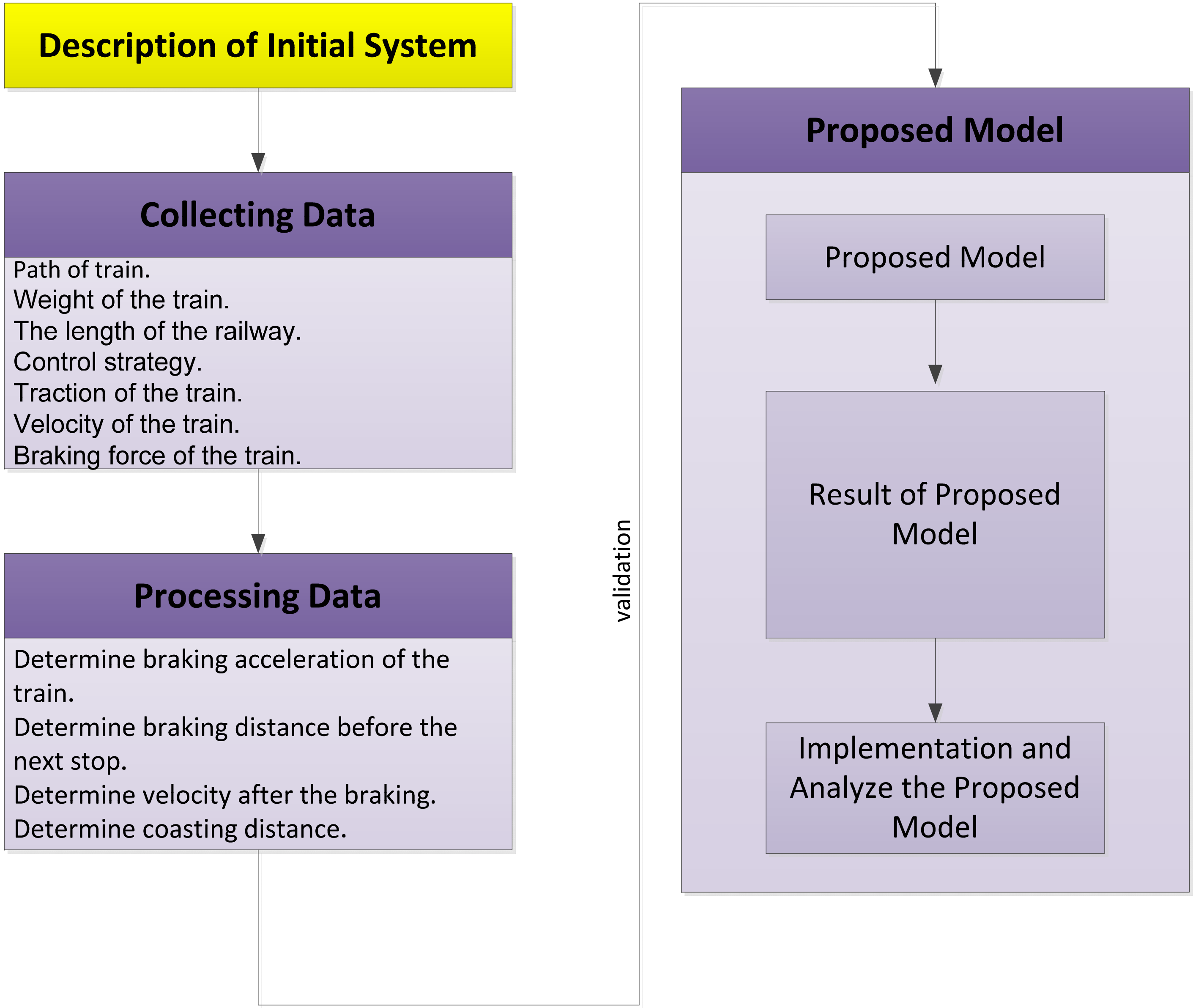
With the proposed approach :

- To know the performance and the amount of the energy that could be reduced
- To know the performance and the travelling time that could be reduced

Presentation Main Frame:

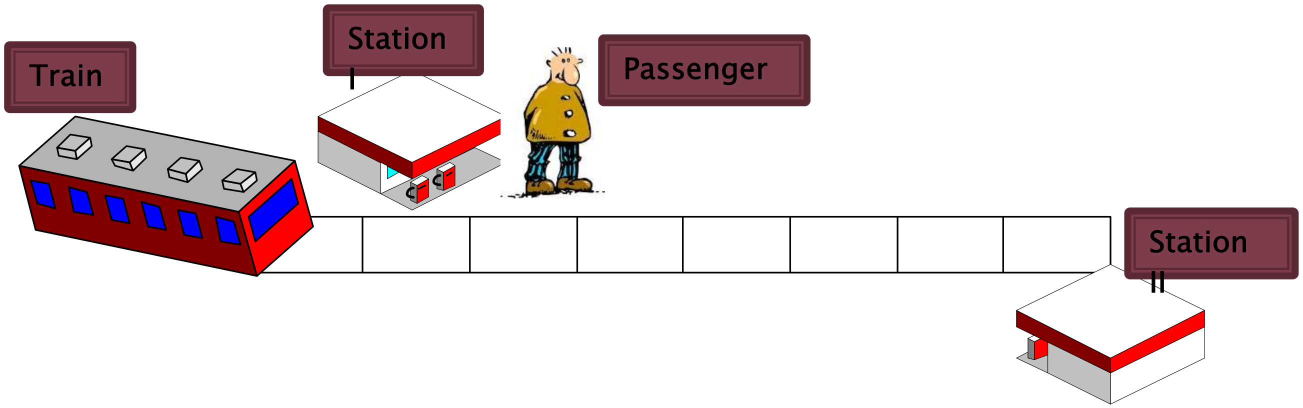
Total Energy Consumption – How to reduce?

- Literature Review
- Collecting Data
- Assumption
- Implementation and Analysis
- Limitation and Perspective

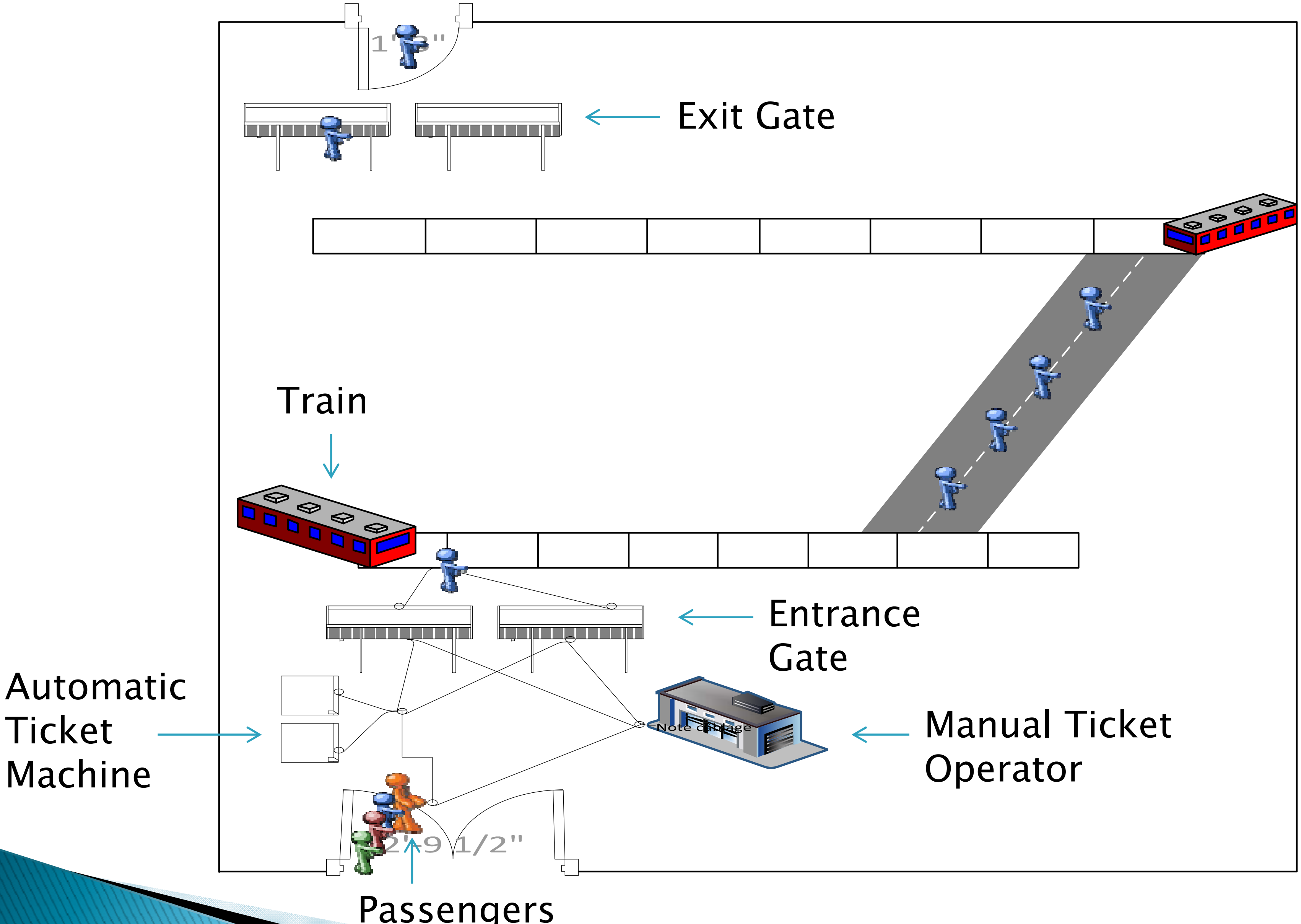


Research Logical Diagram

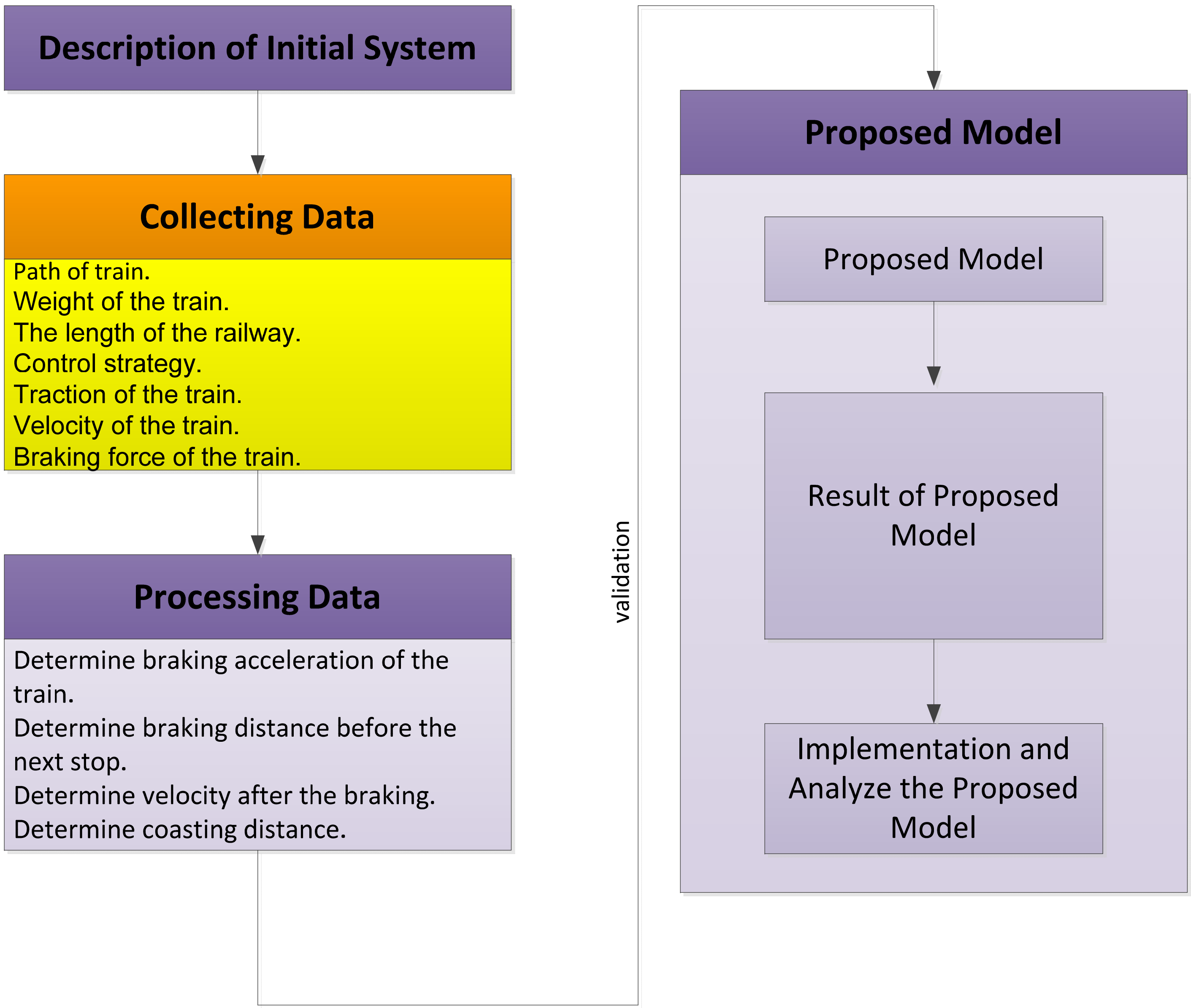
Brief Description of the Initial System



- Train
- Station
- User/ Passenger
- Railway

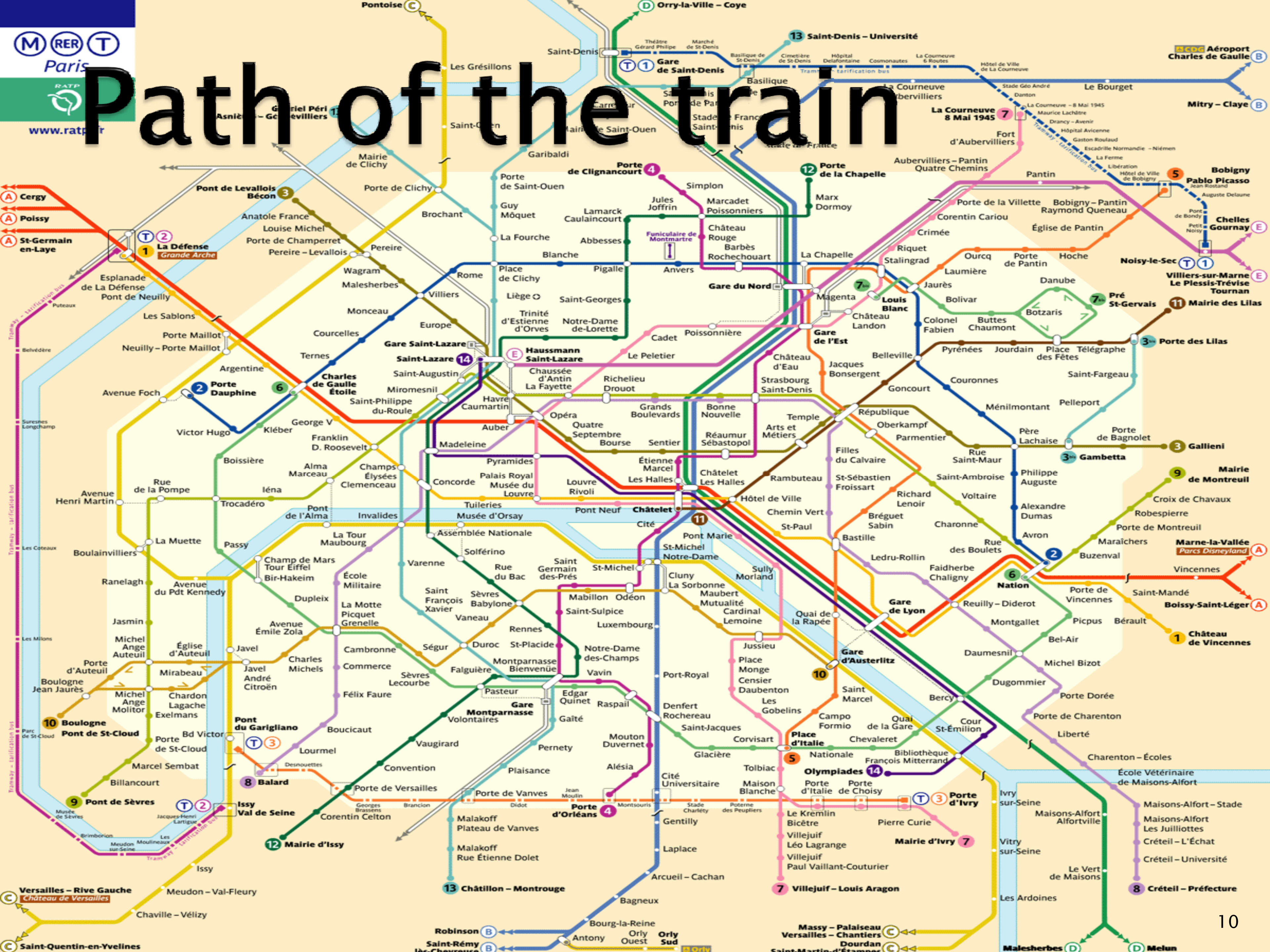


Exit Gate
Train
Entrance Gate
Automatic Ticket Machine
Manual Ticket Operator
Passengers
2'-9 1/2"

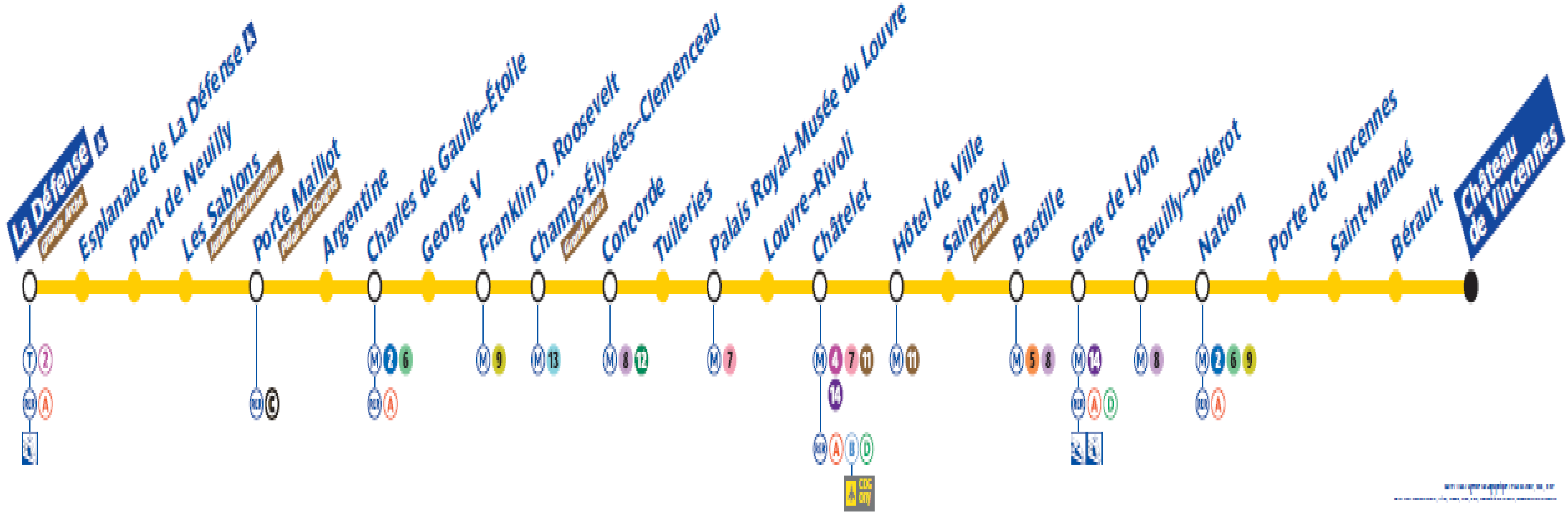


Research Logical Diagram

Path of the train



Path of the train



Geometrical characteristic of the railway – Length

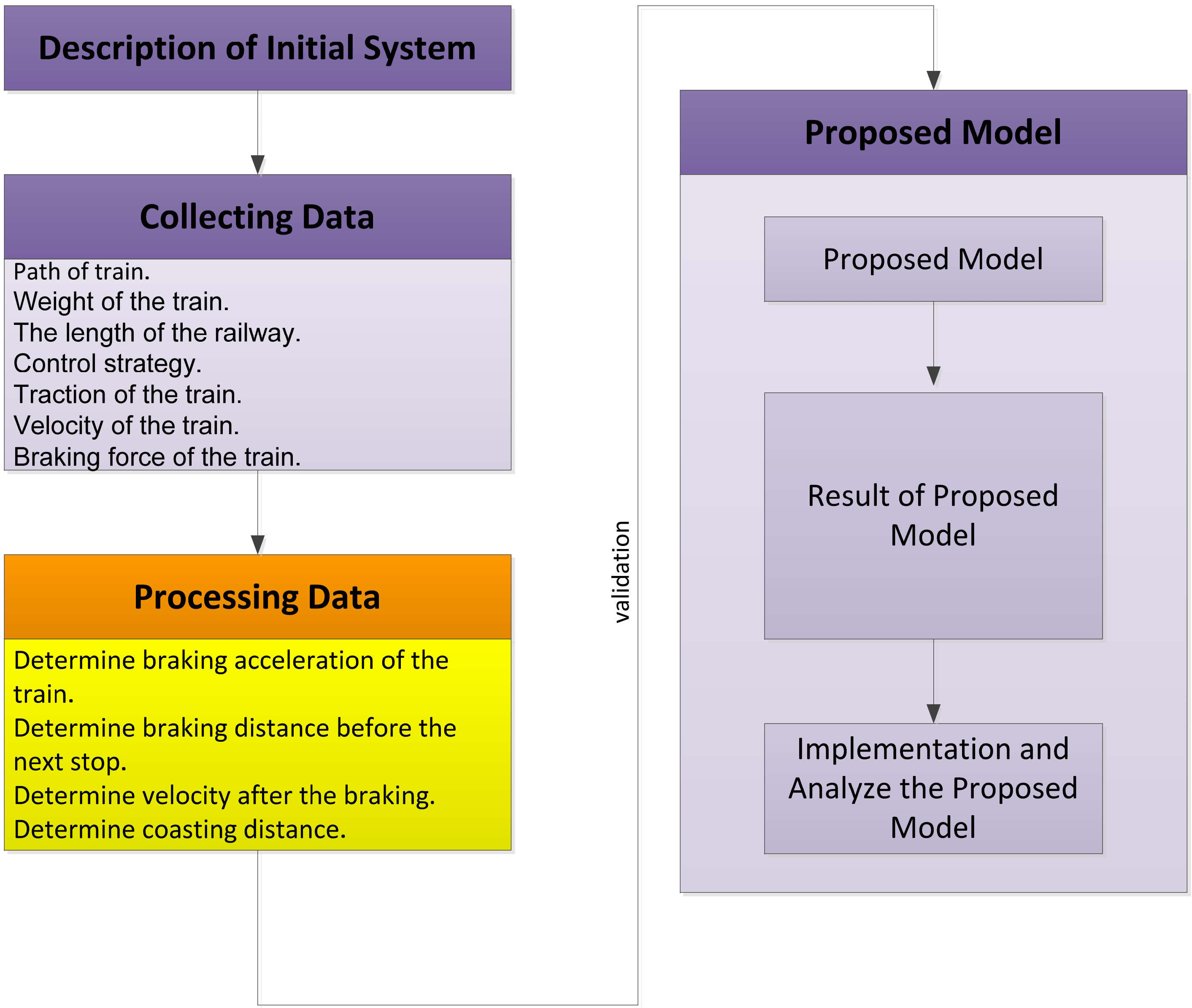
Ligne	Number of stations	Length (km)	Average interstation (m)
1	25	16,6	692
2	25	12,3	513
3	25	11,7	488
3 bis	4	1,3	433
4	26	10,6	424
5	22	14,6	695
6	28	13,6	504
7	38	22,4	605
7 bis	8	3,1	443
8	37	22,1	614
9	37	19,6	544
10	23	11,7	532
11	13	6,3	525
12	28	13,9	515
13	32	24,3	776
14	9	9	1129

Wikipedia, 2012

Train Data

Types of train	Number of train	Ligne	mass (ton)	Power Supply	Power (kW)	Acceleration at start (m/s ²)	Speed (km/h)	Maximum Speed (km/h)
MP 89-CC	52	1 and 4	144,2	3rd rail 750V DC	2800	1,25	70	80
MP 89-CA	21	14	135				80	
MP 05	49	1	140		2400	1,35	80	80
MF 01	161	2, 5 and 9	125,7		1800	0,9	70	80
MF 67	220	3, 3 bis, 5, 9, 10, and 12	106		1080	1	70	80
MF 59	56	4 and 11	126,4		1760	1,3	70	80
MP 73	46	4 and 11	132,5		1080	1,3	70	80
MF 77	66	7,8 and 13	130,8		1500	0,81	80	100
MF 88	9	7 bis	74,2		840	0,95	40	80

Wikipedia, 2012



Research Logical Diagram

Assumptions

- The railway network system are on the flat ground without deviation degree.

- There is no disruption on the MRT systems. One example for the disruption is there is no people entering the train at the time when the door will be close

Total Energy Consumption

$$E^k_{(i,j)}(X) = \mu_k \int_0^{T^k_{(i,j)}(X)} F^k_{(i,j)}(X,t) v^k_{(i,j)}(X,t)\,\mathrm{d}t + A_k T^k_{(i,j)}(X) + \xi_k \int_0^{T^k_{(i,j)}(X)} B^k_{(i,j)}(X,t) v^k_{(i,j)}(X,t)\,\mathrm{d}t\,.$$

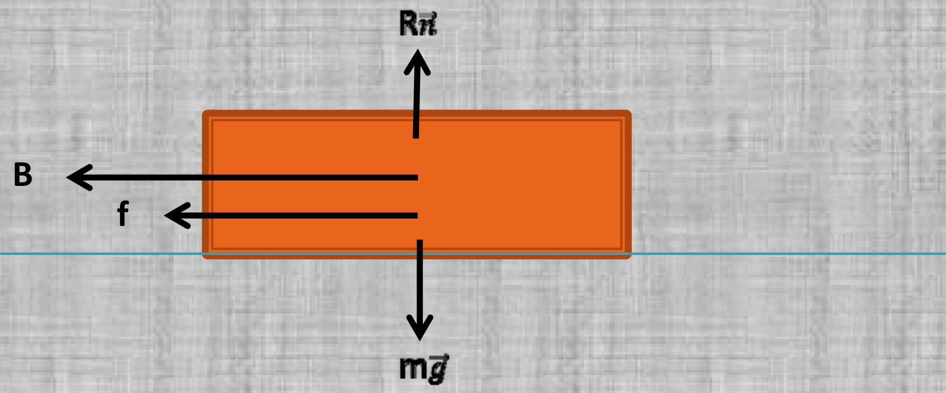
Reformulation using Weighted Deviation Degree

$$F_\alpha(X) = \alpha \cdot \max\left\{\frac{E(X)-\bar{E}}{\bar{E}}, 0\right\} + (1-\alpha)\cdot \max\left\{\frac{T(X)-\bar{T}}{\bar{T}}, 0\right\},$$

Determine Braking acceleration

The equation as follow :

$- B - f + R_n - mg = m*a$



Braking forces = 1900 N/ton

Mass train = 140 ton = $14 * 10^4$ kg

B = 1900N/ton * 140 ton

= 266 000 N

Friction forces = 100 N/ton

f = 100 N/ton * 140 ton

= 14 000 N

Then :

-B – f = m*a

$- 266{,}000\ N – 14{,}000\ N = 14 * 10^4 * a$

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

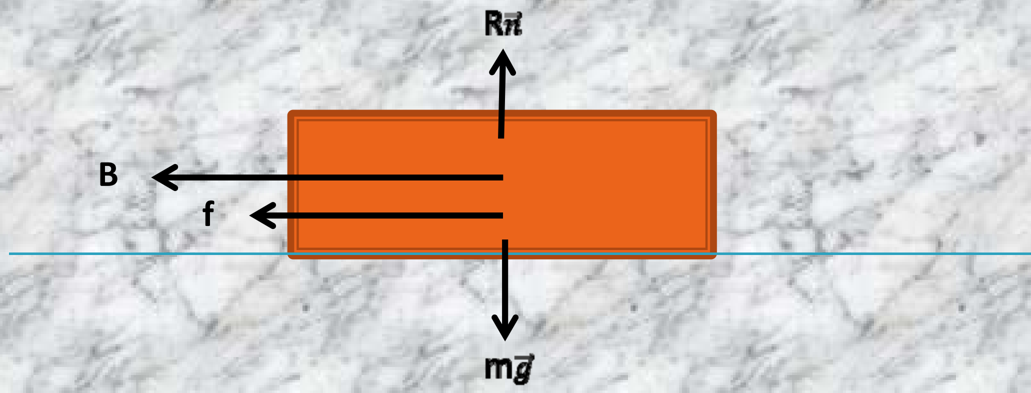
Determine braking state

So, the braking point will be :

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

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

$$= 7.7284 \text{ m}$$



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

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

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

$$= 5.56 \text{ m/s}$$

Determine Coasting Phase

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

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

$22.22 = 0 + 1.35.t$

$t_{acceleration} = 16.46$ s

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

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

$= 0.16.46 + 0.5 . 1.35 . 16.46^2$

$= 182.878$m

The travelled distance during the coast phase as following equation :

$S_c =$ Total length interstation – S – db

$S_c = 692$m – 182.878m – 7.7284m

= 501.3936 m

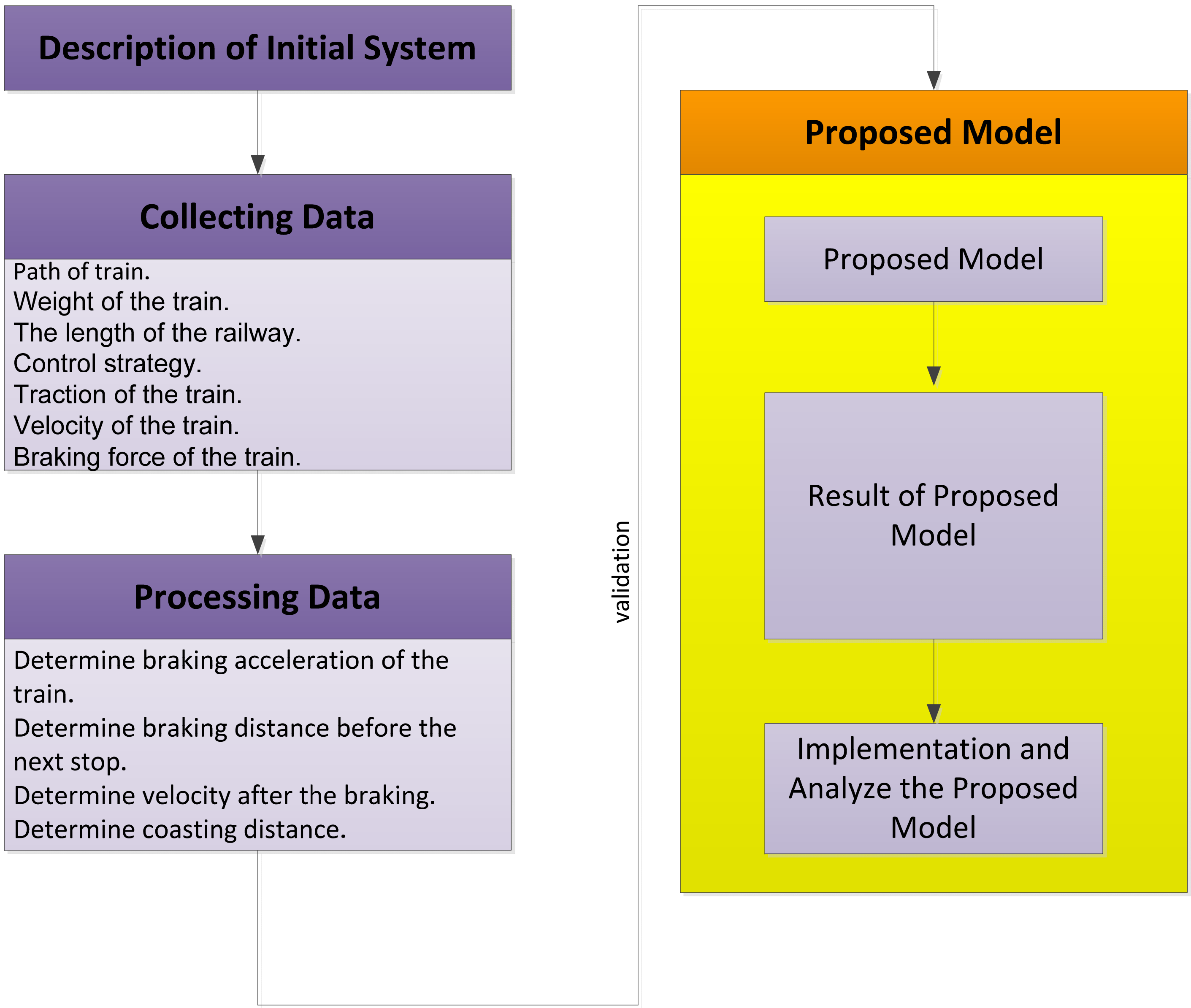
Determine the acceleration of the coasting phase

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

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

$$501.3936 = \frac{22.22^2 - 5.56^2}{2ac}$$

$$a_c = 0.461 \text{ m/s}^2.$$



Research Logical Diagram

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

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

$501.3936 = 22.22.t + 0.5.\ 0.461.\ t^2$

$t_{coasting} = 18.87s$

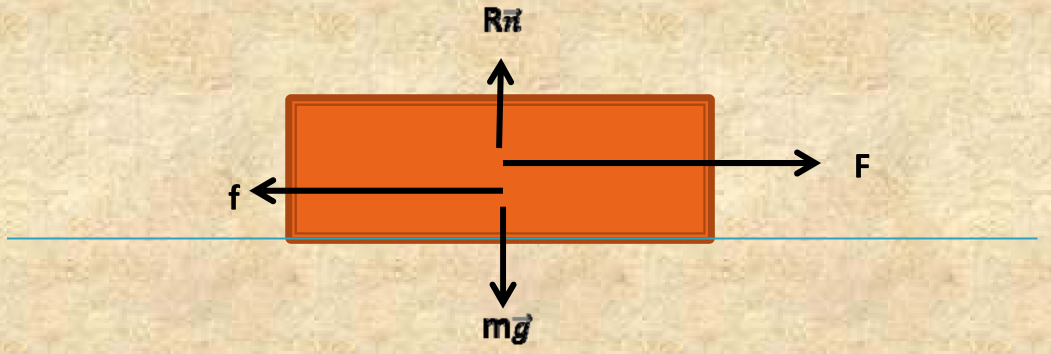
Total time for the journey = $t_{acceleration} + t_{coasting} + t_{braking}$

$= 16.46 + 18.87 + 2.78$

$= 38.11$ s

The Energy Consumption

The energy consumption for **acceleration phase** for 1 station



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

$F = f + m.a$

$= 100 . 140 + 140000 . 1,35$

$= 203000$ N

Energy = F.S

$= 203000 . 182,878$

$= 37,124,234$ J

The Energy Consumption

The energy consumption for **coasting phase** for 1 station

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

$F = f + m.a$

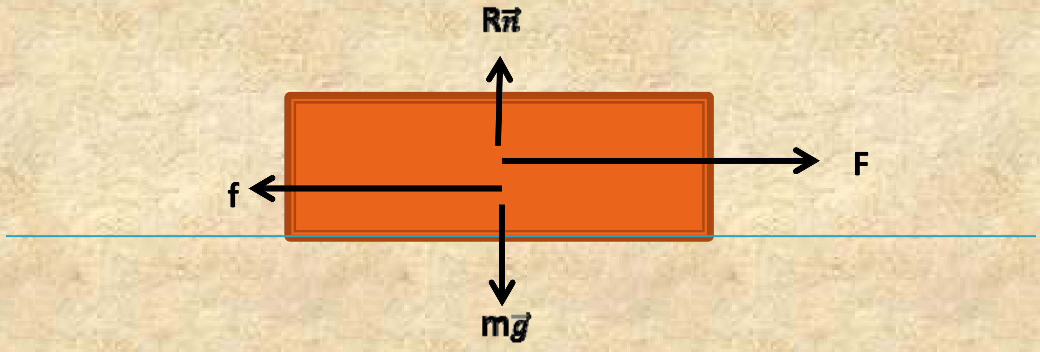
$= 100 . 140 + 140000 . 0.461$

$= 78,540$ N

Energy = F.S

$= 78,540 . 501,396$

$= 39,379,453.34$ J



The energy consumption for **braking phase** for 1 station

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

$-B = m.a + f$

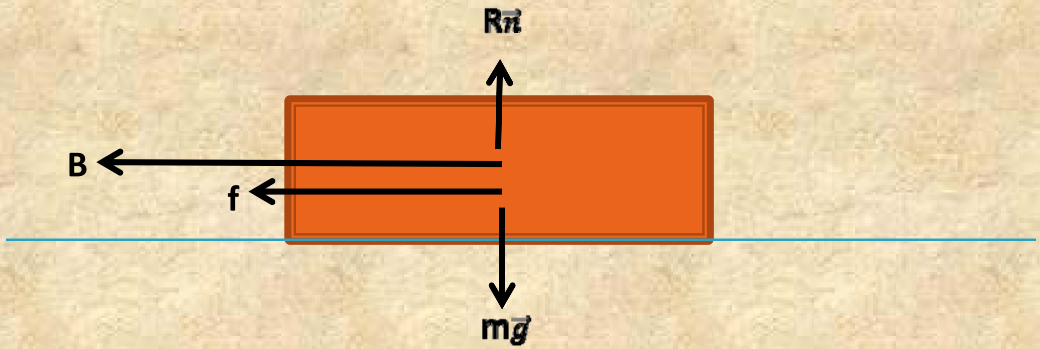
$= 140,000 . 2 + 1,900 . 140$

$= 546,000$ N

Energy $= |B|. d$

$= 546,000 . 7.7284$

$= 4,219,706.4$



The Energy Consumption

Total energy using between 2 stations

Energy Total = $Energy_{acceleration} + Energy_{coasting} + Energy_{braking}$
= 37,124,234 J + 39,379,453.34 J + 4,219,706.4 J
= 80,723,393 J

Total energy consumption for line 1

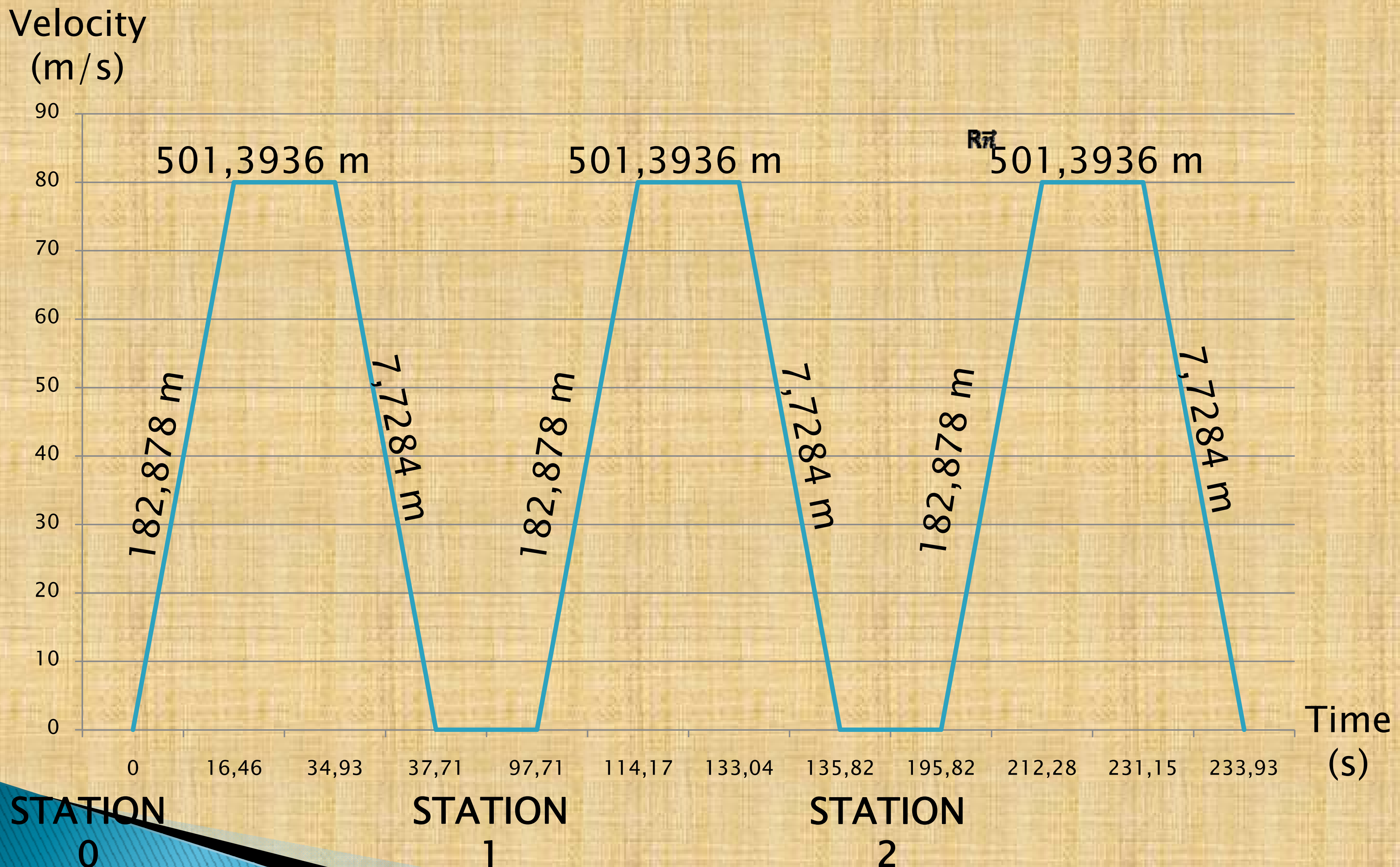
Total energy consumption = 25 station . Energy Total
= 25. 80,723,393
= 2 018 084 825 J ~ $2 * 10^9$ J

Implementation and Analysis

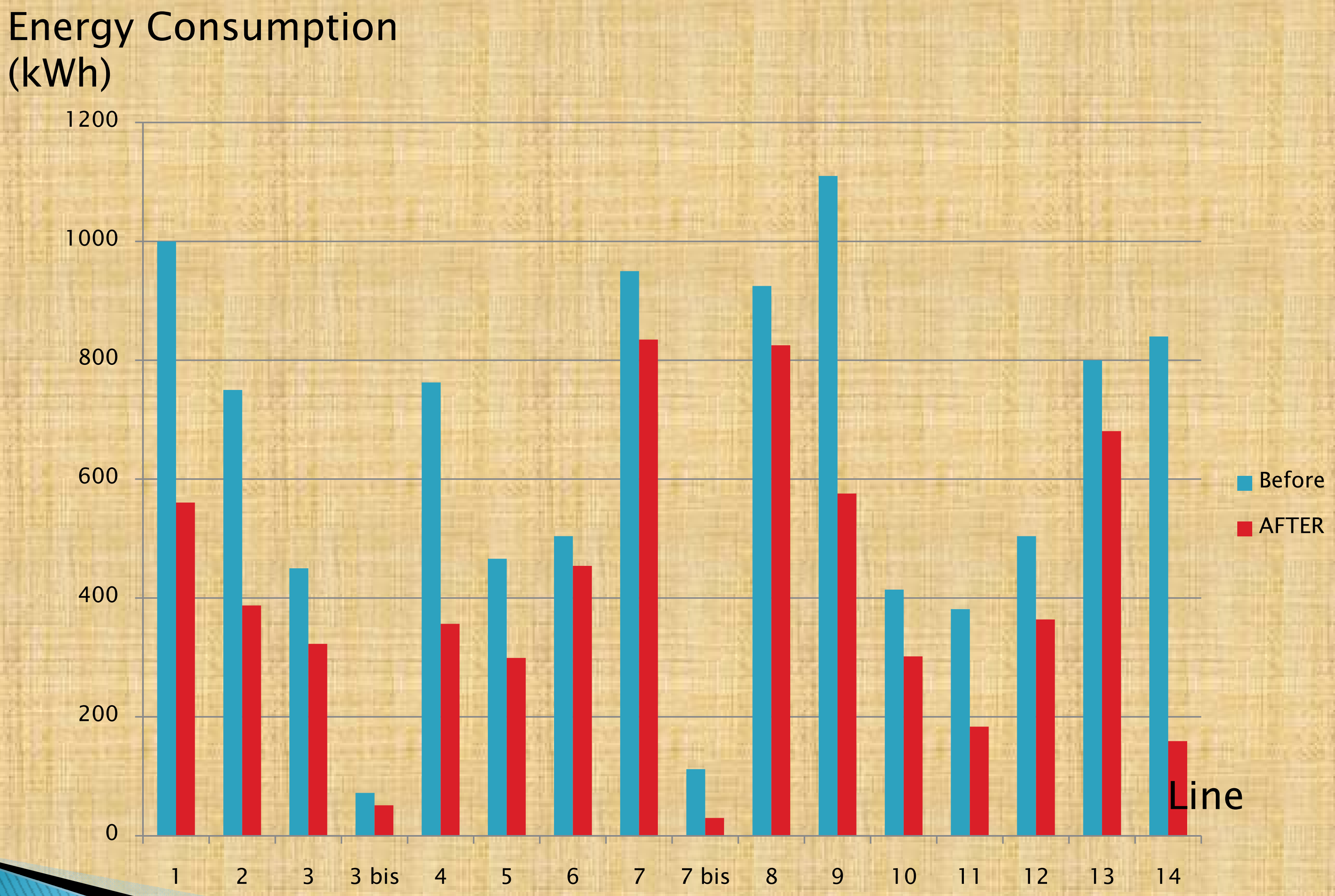
- Energy Consumption

Ligne	Initial Energy Consumption (kWh)	Proposed Energy Consumption (kWh)
1	1000	560,58
2	750	387,46
3	450	322,92
3 bis	72	51,11
4	762,66	356,49
5	466	299,1
6	504	454,08
7	950	834,85
7 bis	112	29,95
8	925	825,17
9	1110	575,78
10	414	301,72
11	381,33	183,5
12	504	363,88
13	800	680,82
14	840	159,28

Implementation and Analysis



Implementation and Analysis

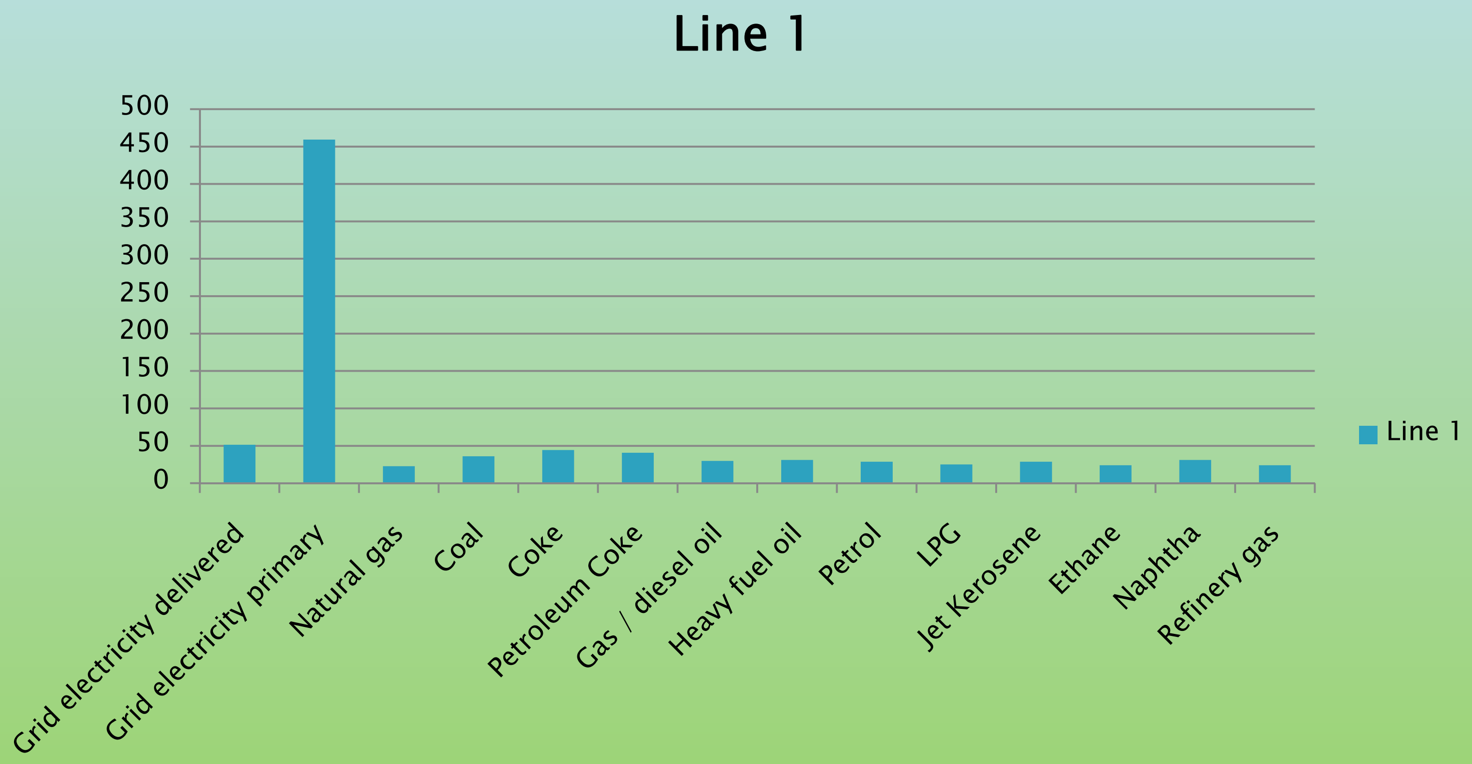


Implementation and Analysis

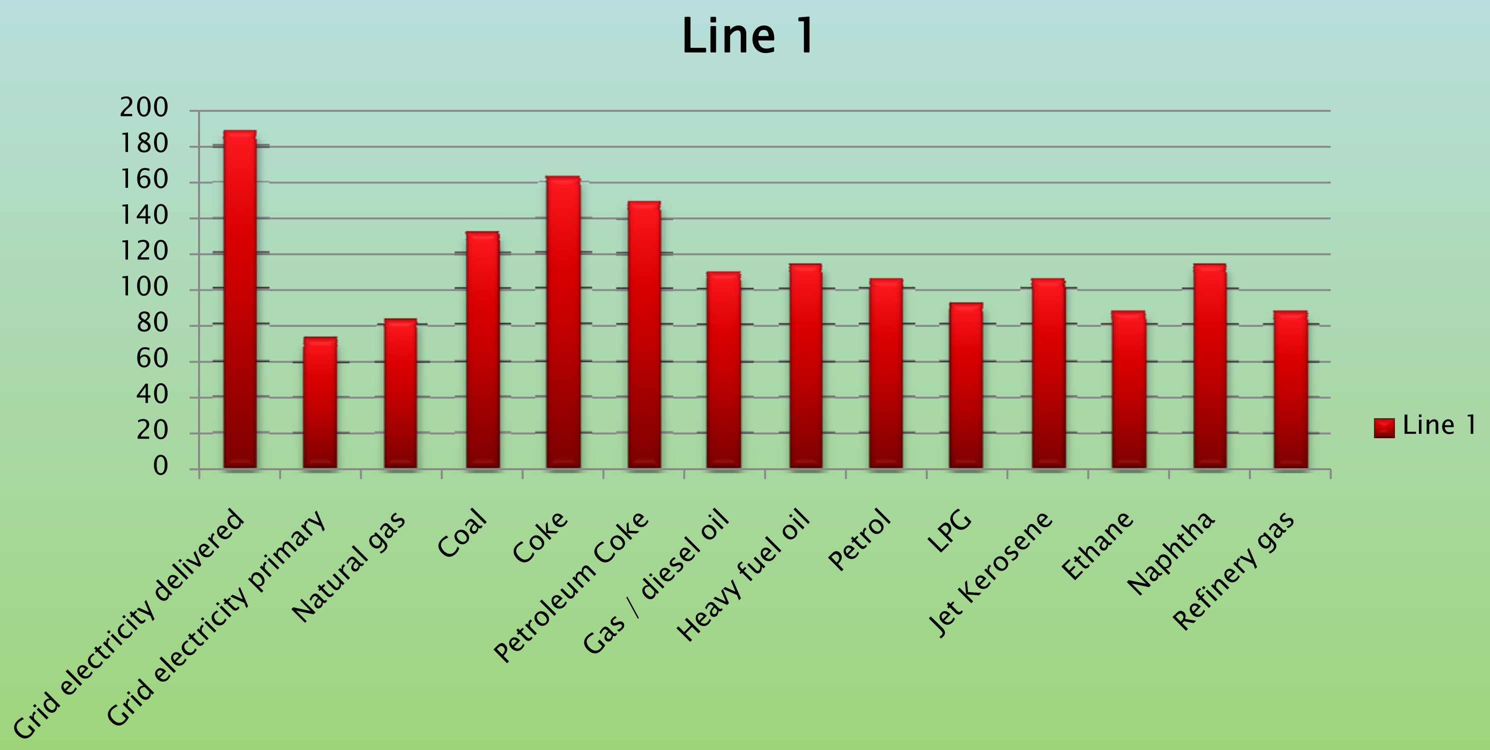
- The power consumption for the initial system is 2400KW. So the energy consumption for the line 1 with 25 station is 2400 kW x 25 = 1000kWh = 3,600,000,000 Joule.
- With the proposed model, we can save the energy up to 1,581,915,175 J or 439.42 kWh.
- www.carbontrust.co.uk/energy

Fuel	Line 1	
	kg C	kg Co2
Grid electricity delivered	51,41214	188,9506
Grid electricity primary	459,3257	72,98766
Natural gas	22,76196	83,4898
Coal	35,90061	131,826
Coke	44,38142	162,5854
Petroleum Coke	40,73423	149,4028
Gas / diesel oil	29,88056	109,855
Heavy fuel oil	31,15488	114,2492
Petrol	28,78201	105,4608
LPG	25,17877	92,2782
Jet Kerosene	28,78201	105,4608
Ethane	23,94839	87,884
Naphtha	31,15488	114,2492
Refinery gas	23,94839	87,884

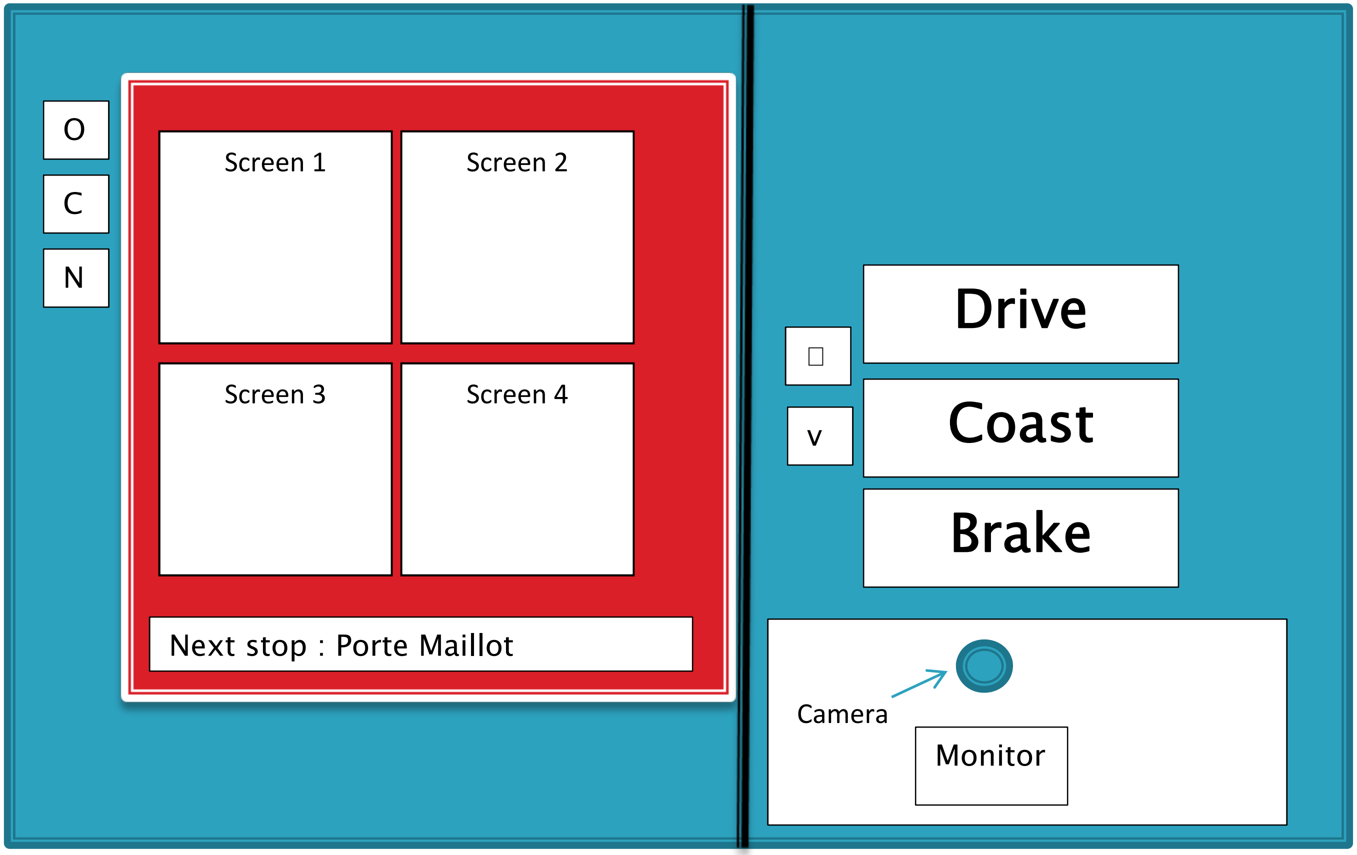
Carbon emission reduced



CO_2 emission reduced



Recommendation : Proposed Monitor Layout



Limitation

- There are not enough time to study the correlation between the tunnel systems with the energy that being used for the air-conditioning system.
- This proposed approach of this research is only focus on the control strategy while in the planning systems, we can try to simulate and decide where is the best stop for the metro so that the persons can easily access to this transportation.