Optimization of the network design of a futuristic transport system based on moving walkways

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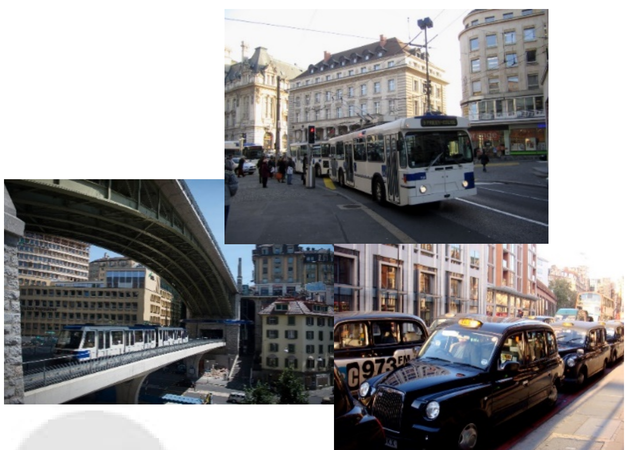
Moving walkway, Exposition Universelle, Paris 1900

Post-Car World

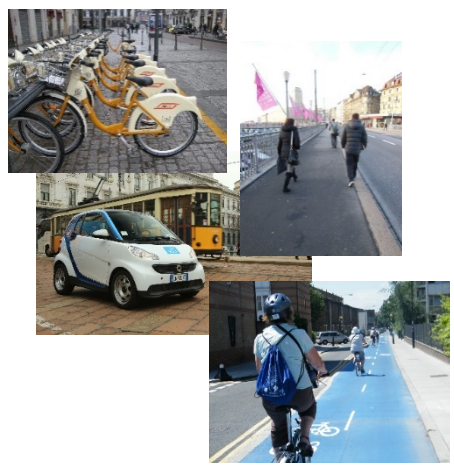
No use of private car

- Redistribute the “future” demand on a mix of transport systems

Traditional



Innovative

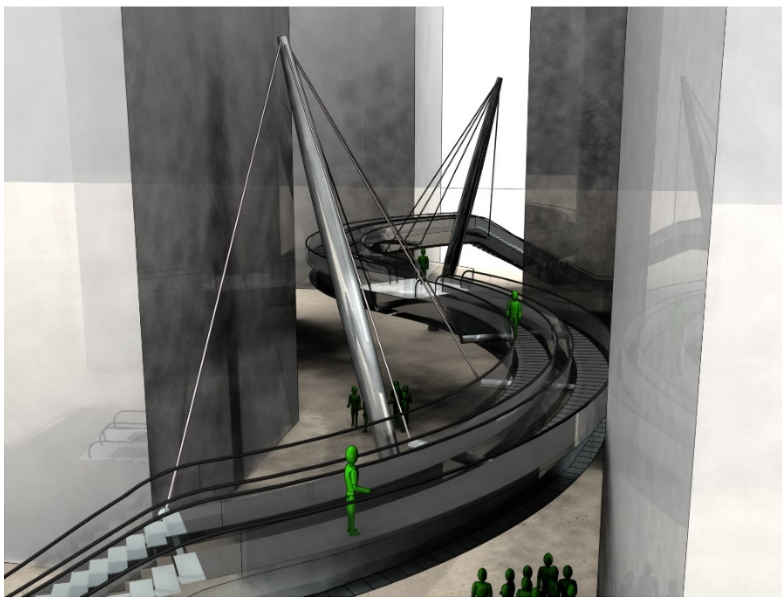


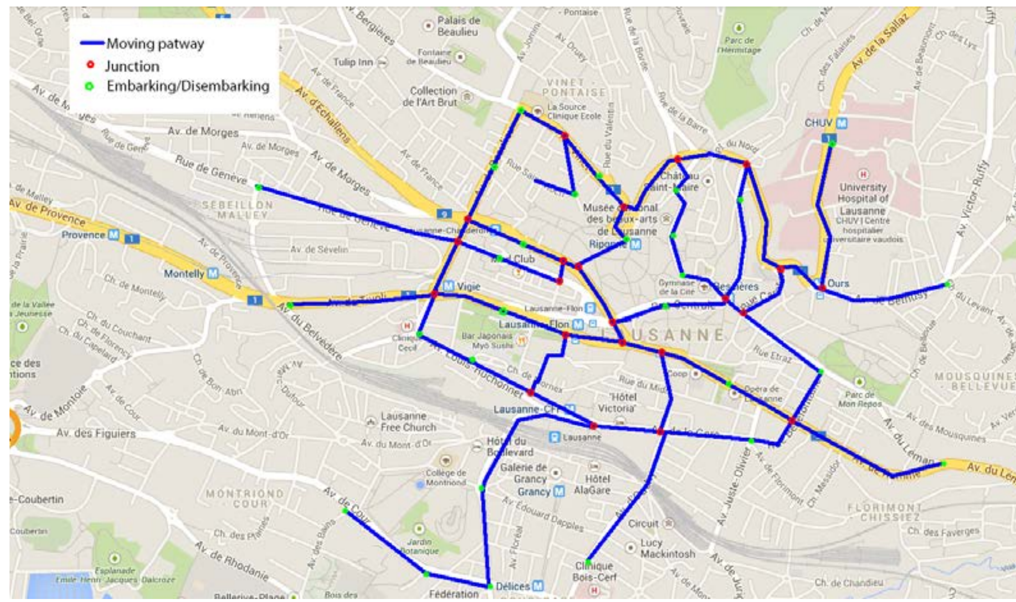
Futuristic

Research idea

Accelerated Moving Walkway (AMW)

A network of Accelerated Moving Walkway in urban area





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Accelerated Moving Walkway

Implementation examples

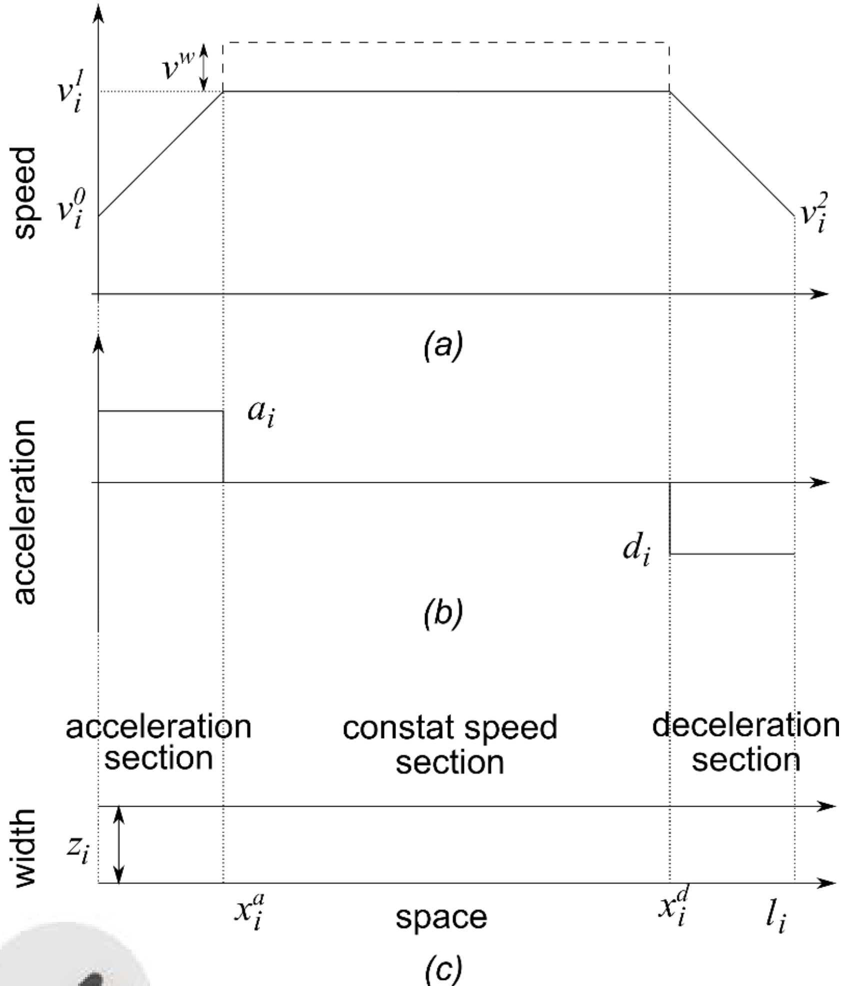
TurboTrack Toronto

- Entry speed: 0.65 m/s (2.3 km/h)
- High speed: 2 m/s (7.2 km/h)
- Length: 270 m
- Acceleration zone: ~13 m
- Acceleration: ~0.14 m/s^2
- Width: 1.2 m

Gateway Paris

- Entry speed: 0.62 m/s (2.2 km/h)
- High speed: 2.5 m/s (9 km/h)
- Length: 185 m
- Acceleration zone: ~10 m
- Acceleration: ~0.28 m/s^2
- Width: 1.2 m

System description

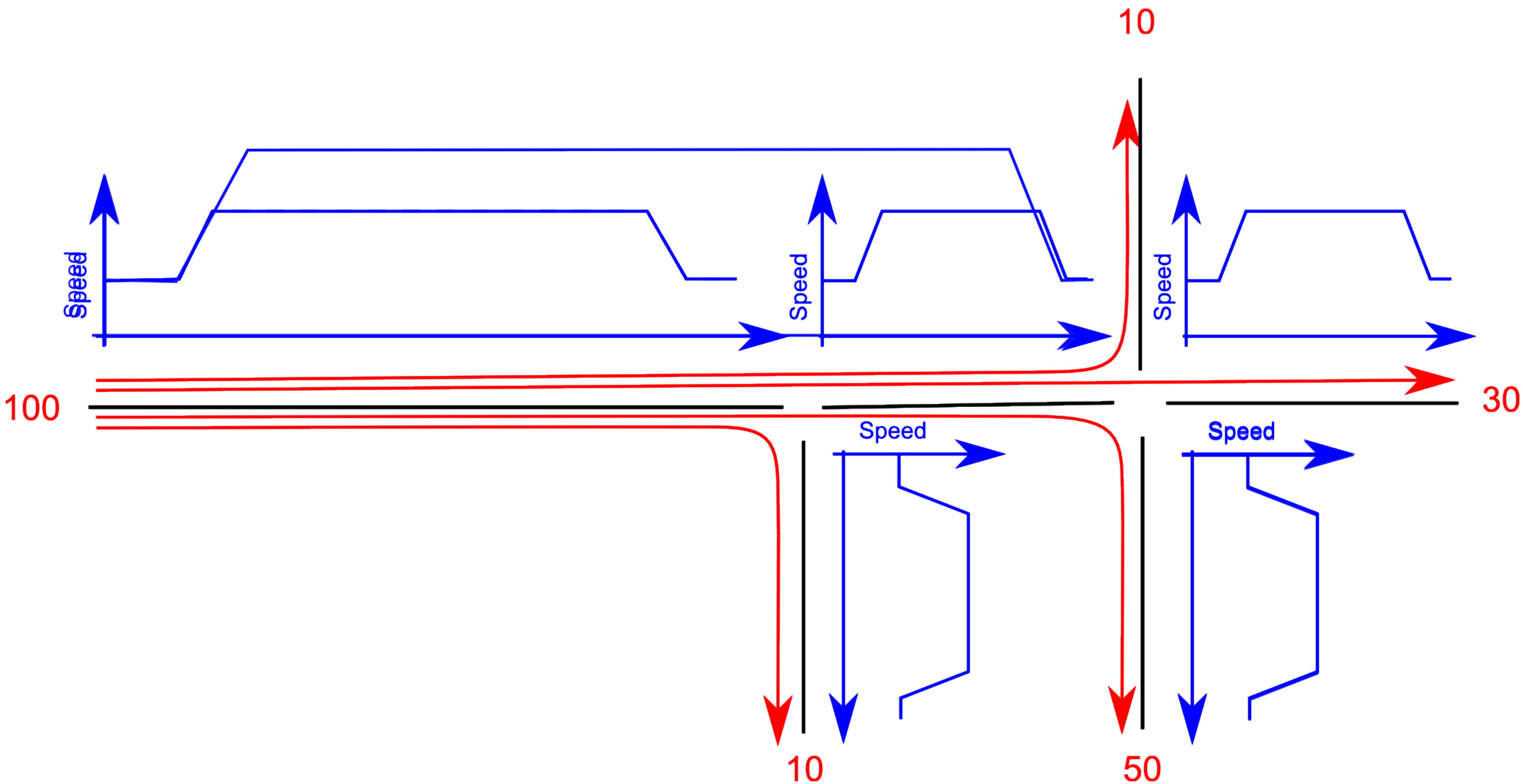


l_i	[m]	Input
x_i^a	[m]	Decision variable
z_i	[m]	Decision variable
v_i^0	[m/s]	0.65
a_i	[m/s^2]	0.50
v_i^1	[m/s]	Derived
$v^{\max}$	[m/s]	4.57
v^w	[m/s]	1.34 (1.04)

Optimization of a network of AMW

Optimization of a network of AMW

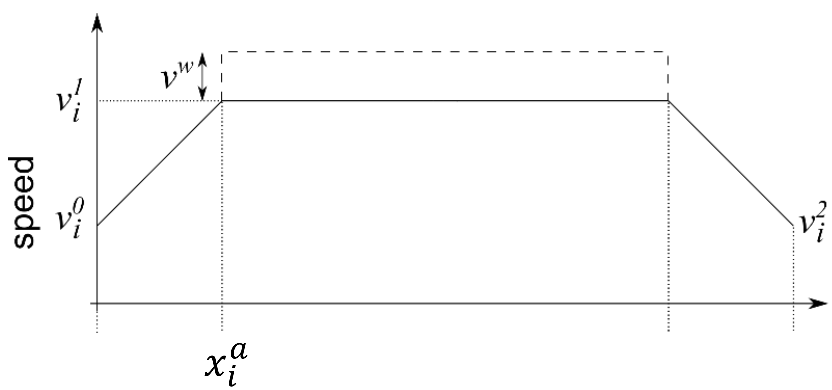
Conceptual example



Decision variables and criteria

Decision variables:

- y_i equipped or not
- x_i^a acceleration section
- z_i width of the walkway

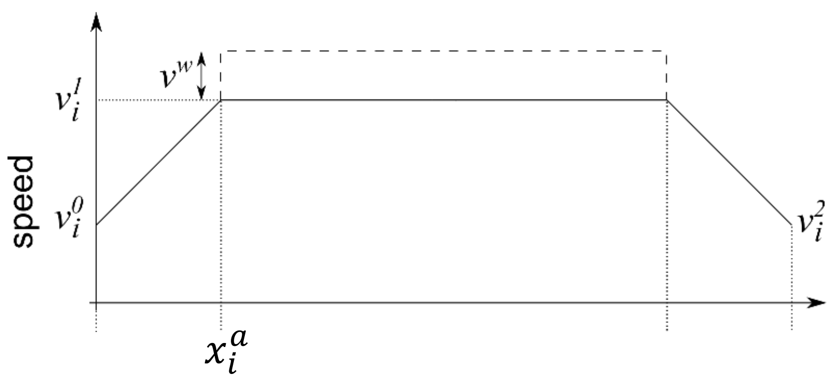


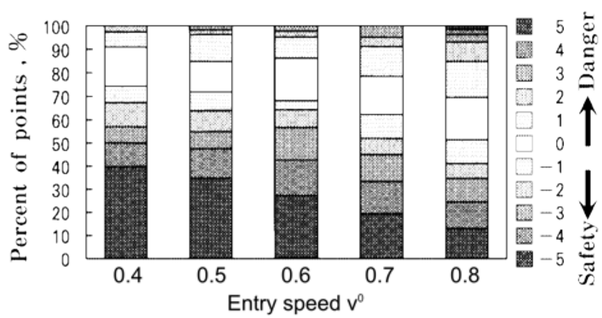
Criteria:

- Travel time
- Discomfort
- Energy consumption
- Construction cost
- Operational cost

Criteria

- Travel time $$TT_i = 2t_a + t_c = \frac{1}{a}\left(\sqrt{v_0^2 + 2ax_i^a} - v_0\right) + \frac{l_i - 2x_i^a}{\sqrt{v_0^2 + 2ax_i^a} + v^w}$$
- Discomfort $$d_i = \delta 2t_a + \gamma = \frac{2\delta}{a}\left(\sqrt{v_0^2 + 2ax_i^a} - v_0\right) + \gamma$$



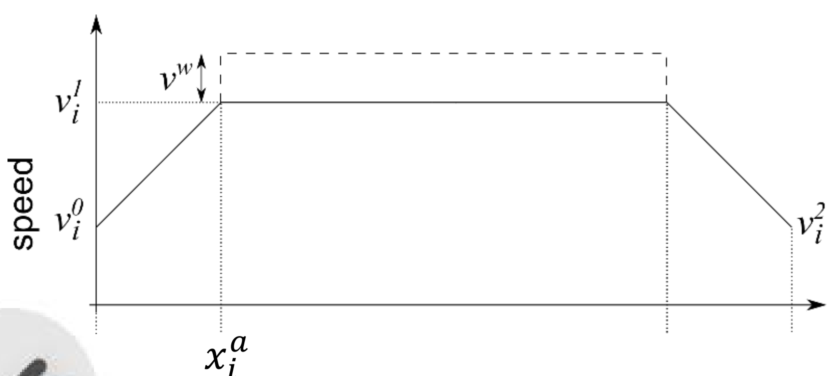


Criteria

- Energy consumption $e_i = \left(3(2x_i^a) + x_i^d - x_i^a\right) e^{\text{CMW}} = \left(3(2x_i^a) + (l_i - 2x_i^a)\right) e^{\text{CMW}}$

- Construction cost $c_i^c = \left(1.2(2x_i^a) + x_i^d - x_i^a\right) c^{\text{CMW}} = \left(1.2(2x_i^a) + (l_i - 2x_i^a)\right) c^{\text{CMW}}$

- Operational cost $c_i^o = 0.25 l_i q + 0.15 v_0$



e^{CMW} ~ 0.02-0.05 MJ/passenger-km
c^{CMW} ~ 30,000 \$/150m ~ 200,000 \$/km
c_i^o ~ 0.08-0.42 \$/passenger-km
Maintenance cost ~ 0.13-0.17 \$/km

Optimization of a network of AMW

Capacity

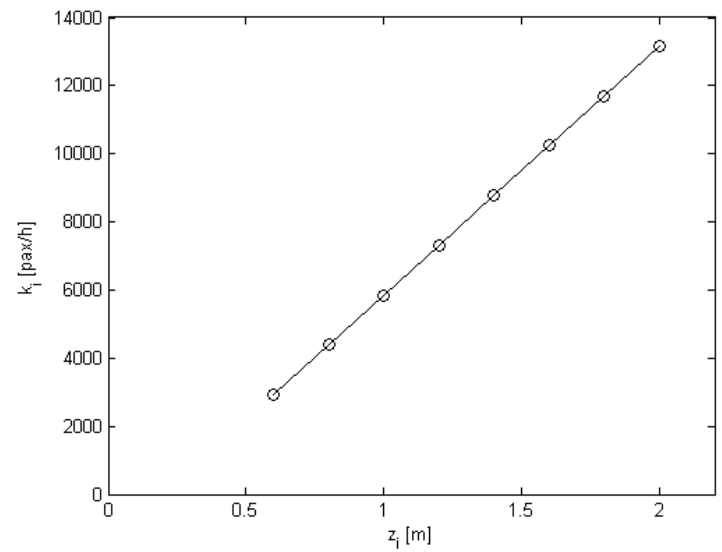
Function of z_i width of the walkway

Typically between 0.8-1.6 m large

Minimum of 1.2 m to allow two “columns” of passenger

Optimal width will be function of the passenger demand

$$k_i = 2250 v_i^0 (5 z_i - 1)$$



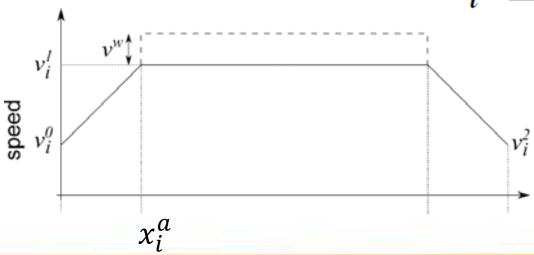
Objective function

The resulting optimization problem is defined by an weighted multi-objective mixed integer nonlinear objective function

$$f_i = y_i(w_1 TT_i + w_2 d_i + w_3 e_i + w_4 c_i^c + w_5 c_i^o) + (1 - y_i) w_6 l_i / v^w$$

Subject to constraints:

- Maximum acceleration length $x_i^a \leq l_i/2$
- Maximum speed $v_i^1 \leq v^{\max}$; $\sqrt{v_0^2 + 2a x_i^a} \leq v^{\max}$
- Maximum width $z_i \leq z_i^{\max}$

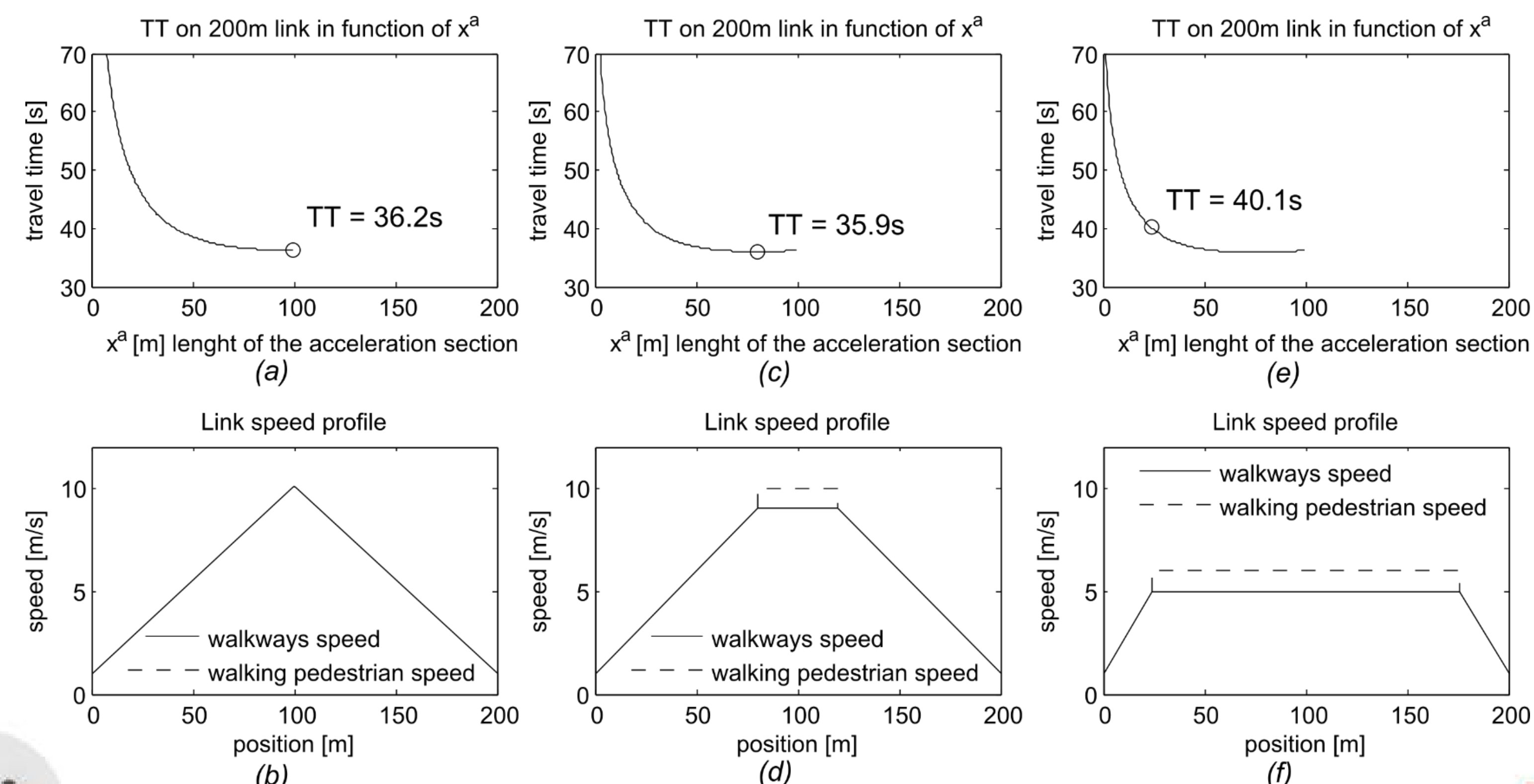


Results for a single link

Results for a single link

Objective function and resulting speed profile:

no walking and no constraint v^{max} | walking and no constraint v^{max} | walking and constraint v^{max}



Conclusions

Conclusions

- Review of Accelerated Moving Walkway (AMW)
- Definition of the optimization problem, decision variables, system parameters, objective function and constraints
- Preliminary results for a single link

Assumption: a world without private cars

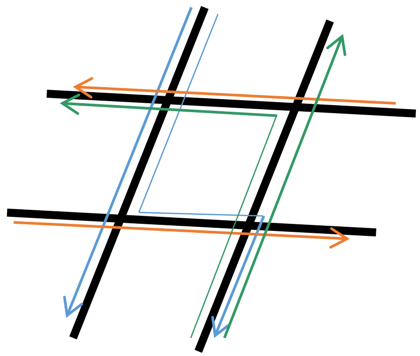
free to investigate innovative mean of transport as part of the future modal mix (reusing urban space)

- AMW could be competitive with urban public transport and private cars (average speed of 15 km/h)

Further works

- Network optimization considering route choice and demand

$$f = \sum_{i=1}^{N} f_i$$



- Intersection design
- Embarking/disembarking
- Safety and comfort
- Active Management, e.g. dynamic speed, dynamic lane direction

Thank you for your attention

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