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

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Global project

Post-Car World

No use of private car

• Redistribute the “future” demand on a mix of transport systems
Research idea

Accelerated Moving Walkway (AMW)

A network of Accelerated Moving Walkway in urban area
Contents

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Accelerated Moving Walkway
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/s²
- 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/s²
- Width: 1.2 m
Accelerated Moving Walkway

System description

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

Conceptual example
Optimization of a network of AMW

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
Optimization of a network of AMW

Criteria

- **Travel time**
  \[ TT_i = 2t_a + t_c = \frac{1}{a} \left( \frac{1}{2} \sqrt{v_0^2 + 2ax_i^q - v_0} \right) + \frac{l_i - 2x_i^q}{\sqrt{v_0^2 + 2ax_i^q + v^w}} \]

- **Discomfort**
  \[ d_i = \delta 2t_a + \gamma = \frac{2\delta}{a} \left( \frac{1}{2} \sqrt{v_0^2 + 2ax_i^q - v_0} \right) + \gamma \]
Optimization of a network of AMW

Criteria

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

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

- Operational cost
  \[ c_i^o = 0.25l_iq + 0.15v_0 \]

Energy consumption costs are approximately $0.02-0.05 \text{MJ/passenger-km}$, construction costs are about $30,000 \$/150m or $200,000 \$/km, operational costs range from $0.08-0.42 \$/passenger-km, and maintenance costs are approximately $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

$$k_i = 2250v_i^0(5z_i - 1)$$
Optimization of a network of AMW

Objective function

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

\[ f_i = y_i(w_1 T T_i + w_2 d_i + w_3 e_i + w_4 c^{	ext{e}}_i + w_5 c^{	ext{o}}_i) + (1 - y_i)w_6 l_i/v^w \]

Subject to constraints:

• Maximum acceleration length
  \[ x^a_i \leq l_i/2 \]

• Maximum speed
  \[ v^1_i \leq v^\text{max} ; \ \sqrt{v^2_0 + 2ax^a_i} \leq v^\text{max} \]

• Maximum width
  \[ z_i \leq z_i^\text{max} \]
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 $v_{max}$

**Graphs:**

- (a) TT on 200m link in function of $x^a$ (TT = 36.2s)
- (c) TT on 200m link in function of $x^a$ (TT = 35.9s)
- (e) TT on 200m link in function of $x^a$ (TT = 40.1s)

**Link speed profile:**

- (b) Walkways speed
- (d) Walkways speed
- (f) Walkways speed
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)
Conclusions

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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