Potential Health Implications of New Mobility

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Part I
Transportation and Health: The 14 Pathways and Technology Implications

Part II
Case Studies on Impacts of Pathways
Part I: Transportation and Health

14 PATHWAYS TO HEALTH

BENEFICIAL

DETRIMENTAL

[Diagram showing icons for beneficial and detrimental pathways to health]
Each year > 1.5 million deaths and 79 million injuries warranting medical care

- Low and middle-income countries account for >90% of road fatalities despite having 48% of world’s registered vehicles

- Ambient air pollution and physical inactivity – 4.2 and 3.2 million annual global deaths
“Less Recognized Linkages”

EQUITY

Land Use and the Built Environment
Urban design, development decisions, density, diversity, distance to public transportation, destination accessibility, distribution centers, other

Transportation Infrastructure
Construction, maintenance, and rehabilitation of roads, parking spaces, cycling and pedestrian lanes, public transportation hubs, freight hubs, railways, electric grids, electricity generation stations, other

Transportation Mode Choice
Car, public transportation, walking, cycling, freight, other

Transportation Technologies and Disruptors
Connected, autonomous, shared, zero and near-zero emissions passenger and freight vehicles; 3-D printing; other

TRANSPORTATION
<table>
<thead>
<tr>
<th>Transportation point of impact</th>
<th>Link number</th>
<th>Health pathway</th>
<th>Potential direction of impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation jobs</td>
<td>1</td>
<td>Social exclusion</td>
<td>Adverse</td>
</tr>
<tr>
<td>Transportation equity</td>
<td>2</td>
<td>Access</td>
<td>Positive</td>
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<td></td>
<td>3</td>
<td>Mobility independence</td>
<td>Positive</td>
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<tr>
<td></td>
<td>4</td>
<td>Social exclusion</td>
<td>Positive</td>
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<tr>
<td>Land use and built environment</td>
<td>5</td>
<td>Access</td>
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<tr>
<td></td>
<td>6</td>
<td>Social exclusion</td>
<td>Adverse</td>
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<td>7</td>
<td>Contamination</td>
<td>Adverse</td>
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<td>8</td>
<td>Greenhouse gases</td>
<td>Adverse</td>
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<td>9</td>
<td>Community severance</td>
<td>Adverse</td>
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<td>10</td>
<td>Heat</td>
<td>Adverse</td>
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<td>11</td>
<td>Noise</td>
<td>Adverse</td>
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<td>12</td>
<td>Air pollution</td>
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<td>13</td>
<td>Green spaces</td>
<td>Uncertain</td>
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<td></td>
<td>14</td>
<td>Physical activity</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Traffic flow</td>
<td>15</td>
<td>Contamination</td>
<td>Positive</td>
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<tr>
<td></td>
<td>16</td>
<td>Greenhouse gases</td>
<td>Positive</td>
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<tr>
<td></td>
<td>17</td>
<td>Heat</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Noise</td>
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<tr>
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<td>19</td>
<td>Air pollution</td>
<td>Positive</td>
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<td></td>
<td>20</td>
<td>Stress</td>
<td>Positive</td>
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<td>Trip, mode and route choice</td>
<td>21</td>
<td>Contamination</td>
<td>Adverse</td>
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<td>22</td>
<td>Greenhouse gases</td>
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<td>27</td>
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<td>Transportation infrastructure</td>
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<td>29</td>
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<td>30</td>
<td>Green spaces</td>
<td>Uncertain</td>
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<td></td>
<td>31</td>
<td>Electromagnetic fields</td>
<td>Adverse</td>
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<tr>
<td>Traffic safety</td>
<td>32</td>
<td>Road crashes</td>
<td>Positive</td>
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</table>

AVs' implementation is linked to public health through 32 linkages. AVs may adversely impact health through 16 linkages.
For beneficial implementation of AVs, supporting policies are required to govern:

✓ Urban sprawl (TDM, urban boundaries)
✓ CAVs ownership (shared ownership)
✓ Ridesharing and public transit
✓ Job loss (smoother transition)
✓ AVs infrastructure and limiting EMF
✓ Electrification of AVs (given electricity is clean)
✓ Monitor and limit non-tailpipe emissions

Research Needs:
Quantifying and monitoring the burden of disease of AVs implementation (19 papers)

AVs = autonomous vehicles
TDM = transportation demand management
EMF = electromagnetic field
Part II: Case Studies on Impacts of Pathways
Quantitative Health Impact Assessment

Crashes Mortality/Morbidity Data
Air Pollution Exposure
Noise Exposure
Green Space
Physical Activity (Average MET)

Exposure Response Function (ERF)
Relative Risk (RR) for Exposure (Difference)
Population Attributable Fraction (PAF)
Model

Attributable Mortality/Morbidity

Baseline Mortality/Morbidity Rate

$ Value of Statistical Life
$ Cost of Illness
Case Study 1 → Changing the Urban Design of Cities for Health: The Barcelona Superblock Model
Rationale

• Barcelona has 1.6 million people on only 100 km²
• Highest traffic density in Europe → 6,000 vehicles circulating/km²
• High air and noise pollution levels
• Little green/open space → amplifying anthropogenic heat (city center 8°C > than surrounding areas)
• 503 super-blocks are proposed → a land-use intervention to reclaim space for people
Road hierarchy in a Superblock model

**CURRENT SITUATION**

- Segregated bus, cycling and pedestrian lanes on basic network
- Bus stops at each superblock intersection
- Buses at high frequency
- Development of public open and green space

**SUPERBLOCK**

- Basic network: 50 km/h
- Local network: 10 km/h
- Highest aim: pedestrian
- Exercise of all the rights that the city offers. Highest aim: citizen.
Aim and Study Setting

• Estimate preventable premature mortality attributable to Superblocks:
  • Physical activity (PA)
  • Air pollution (NO$_2$)
  • Noise
  • Access to green space
  • Mitigation of urban heat island

• Barcelona residents ≥ 20 years (N=1,301,827) on the projected superblock census area level (N=503)
The natural-cause mortality rate was 1,144 deaths/100,000 persons in Barcelona in 2015

### Methods – Exposure-Response Functions

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Risk estimate</th>
<th>Exposure</th>
<th>Health effect</th>
<th>Study design</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical activity</td>
<td>RR = 0.81</td>
<td>11 versus 0 MET h/week</td>
<td>All-cause mortality</td>
<td>Meta-analysis</td>
<td>Woodcock et al. 2011</td>
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<tr>
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<td>(95% CI: 0.76, 0.85)</td>
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<tr>
<td>NO₂</td>
<td>RR = 1.02</td>
<td>per 10 μg/m³</td>
<td>All-cause mortality</td>
<td>Meta-analysis</td>
<td>Atkinson et al. 2018</td>
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<tr>
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<td>(P₁: 0.99, 1.06)</td>
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<tr>
<td>Noise</td>
<td>HR = 1.038</td>
<td>per 10 dB L_{den}(Road)</td>
<td>CVD mortality</td>
<td>Cohort study</td>
<td>Héritier et al. 2017</td>
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<tr>
<td></td>
<td>(95% CI: 1.019, 1.058)</td>
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<tr>
<td>Green space</td>
<td>RR = 0.99</td>
<td>per 10% increase in greenness</td>
<td>All-cause mortality</td>
<td>Meta-analysis</td>
<td>Gascon et al. 2015</td>
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<tr>
<td></td>
<td>(95% CI: 0.98, 1.01)</td>
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<tr>
<td>Heat</td>
<td>RR = 1.19</td>
<td>99th versus 74th temperature percentile</td>
<td>All-cause mortality</td>
<td>Time-series study</td>
<td>Guo et al. 2014</td>
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<tr>
<td></td>
<td>(95% CI: 1.16-1.23)</td>
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</table>

CVD = cardiovascular disease; HR = hazard rate; L_{den} = EU day-evening-night noise indicator with 5 dB and 10 dB weights for the evening and night time, respectively; MET = metabolic equivalent of task (1 MET = 1 kcal/kg/h); PI = prediction interval; RR = relative risk; 95% CI = 95% confidence interval
Methods – Exposure Changes

Results under review – contact Haneen for more information

Mueller, Natalie; Rojas-Rueda, David; Khreis, Haneen; Cirach, Marta; Ballester, Joan; Bartoll, Xavier; Daher, Carolyn; Deluca, Anna; Echave, Cynthia; Milà, Carles; Marquéz, Sandra; Palou, Joan; Pérez, Catherine; Tonne, Cathryn; Rueda, Salvador; Nieuwenhuijsen, Mark on behalf of the Superblock evaluation team (2019). “Changing the Urban Design of Cities for Health: The Barcelona Superblock Model. Under review."
Results - Attributable Premature Mortality

Results under review – contact Haneen for more information

Mueller, Natalie; Rojas-Rueda, David; Khreis, Haneen; Cirach, Marta; Ballester, Joan; Bartoll, Xavier; Daher, Carolyn; Deluca, Anna; Echave, Cynthia; Milà, Carles; Marquéz, Sandra; Palou, Joan; Pérez, Catherine; Tonne, Cathryn; Rueda, Salvador; Nieuwenhuijsen, Mark on behalf of the Superblock evaluation team (2019). “Changing the Urban Design of Cities for Health: The Barcelona Superblock Model. Under review.
Case Study 2 ➔ Transportation and Health: Burden of Disease Analysis of Traffic Noise and Vehicle Crashes in Houston, Texas
Aim and Study Setting

• Estimate preventable premature mortality in Houston attributable to:
  • Noise levels > 30 dB Lden
  • Motor vehicle crashes
• Houston area residents (30 to 75 years old) (N=2,045,368) on the projected census tract level (N=592)
Method

- Roadway crash fatalities in Houston extracted from the National Highway Traffic Safety Administration dataset (2016)
- Noise exposures extracted from the national transportation noise maps from US Department of Transportation (Lden) (2014)
  - Road noise
  - Aviation noise

Figure. The methodological framework

Figure. Road noise levels in Houston
Method

• ERF extracted from Héritier et al. (2017)
  • HR (95% CI) for all CVD causes of death (ICD-10 = I00-I99) per 10 dB increase in \textit{Lden Road} = 1.025 (1.018–1.032)
  • HR (95% CI) for Myocardial Infarction (ICD-10 = I21-I22) per 10 dB increase in \textit{Lden Aviation} = 1.027 (1.006–1.049)
  • HR (95% CI) for Heart Failure (ICD-10 = I50) per 10 dB increase in \textit{Lden Aviation} = 1.056 (1.028–1.085)
• Adjusted for sex, neighborhood index of SES, civil status, education level, mother tongue, nationality and annual NO\textsubscript{2} exposure

\textbf{Figure.} The methodological framework

\textit{CI} = Confidence Interval
\textit{CVD} = Cardiovascular disease
\textit{NO\textsubscript{2}} = Nitrogen Dioxide
\textit{SES} = Socioeconomic Status
Method

- ERF extracted from Héritier et al. (2017)
  - HR (95% CI) for all CVD causes of death (ICD-10 = I00-I99) per 10 dB increase in $L_{den \text{ Road}} = 1.025$ (1.018–1.032)
  - HR (95% CI) for Myocardial Infarction (ICD-10 = I21-I22) per 10 dB increase in $L_{den \text{ Aviation}} = 1.027$ (1.006–1.049)
  - HR (95% CI) for Heart Failure (ICD-10 = I50) per 10 dB increase in $L_{den \text{ Aviation}} = 1.056$ (1.028–1.085)
- Adjusted for sex, neighborhood index of SES, civil status, education level, mother tongue, nationality and annual NO2 exposure
- Mortality data extracted from the Centers for Disease Control (CDC) at the county matched to outcomes by ICD-10 codes, and restricted to >30 and <= 75 years old (2016)
- There is no risk of premature mortality for noise levels below 30 dB

**Figure.** The methodological framework
Results
Results under review – contact Haneen for more information

Conclusions

14 pathways that link mobility to health

Differing levels of evidence for the different pathways

Pathways will be impacted by the introduction of AVs or similar technologies

The health impacts of the pathways are very context, population and policy specific

Transferability of policy and technology is complex and needs careful consideration

There is no research quantifying the burden of disease of AVs implementation

AVs = Autonomous vehicles
BACK-UP SLIDES
375 annual premature deaths (95% CI: 276 - 474) could be preventable by compliance with international recommendations:

- Physical activity → 327 deaths
- Air pollution → 17 deaths
- Green space → 16 deaths
- Noise → 15 deaths

Bradford Case Study

BY ETHNICITY