Transport Systems and Public Health: the Case of Traffic Congestion

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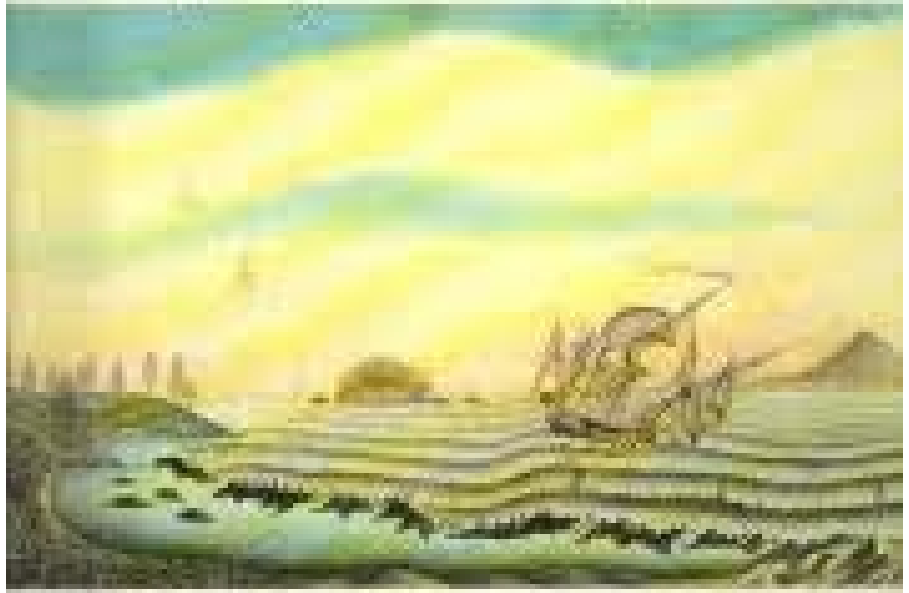
NATIONAL BESTSELLER

The FATAL SHORE

The epic of Australia's founding



ROBERT HUGHES

"One of the greatest non-fiction books I've ever read.... Hughes brings us an entire world."
— Los Angeles Times

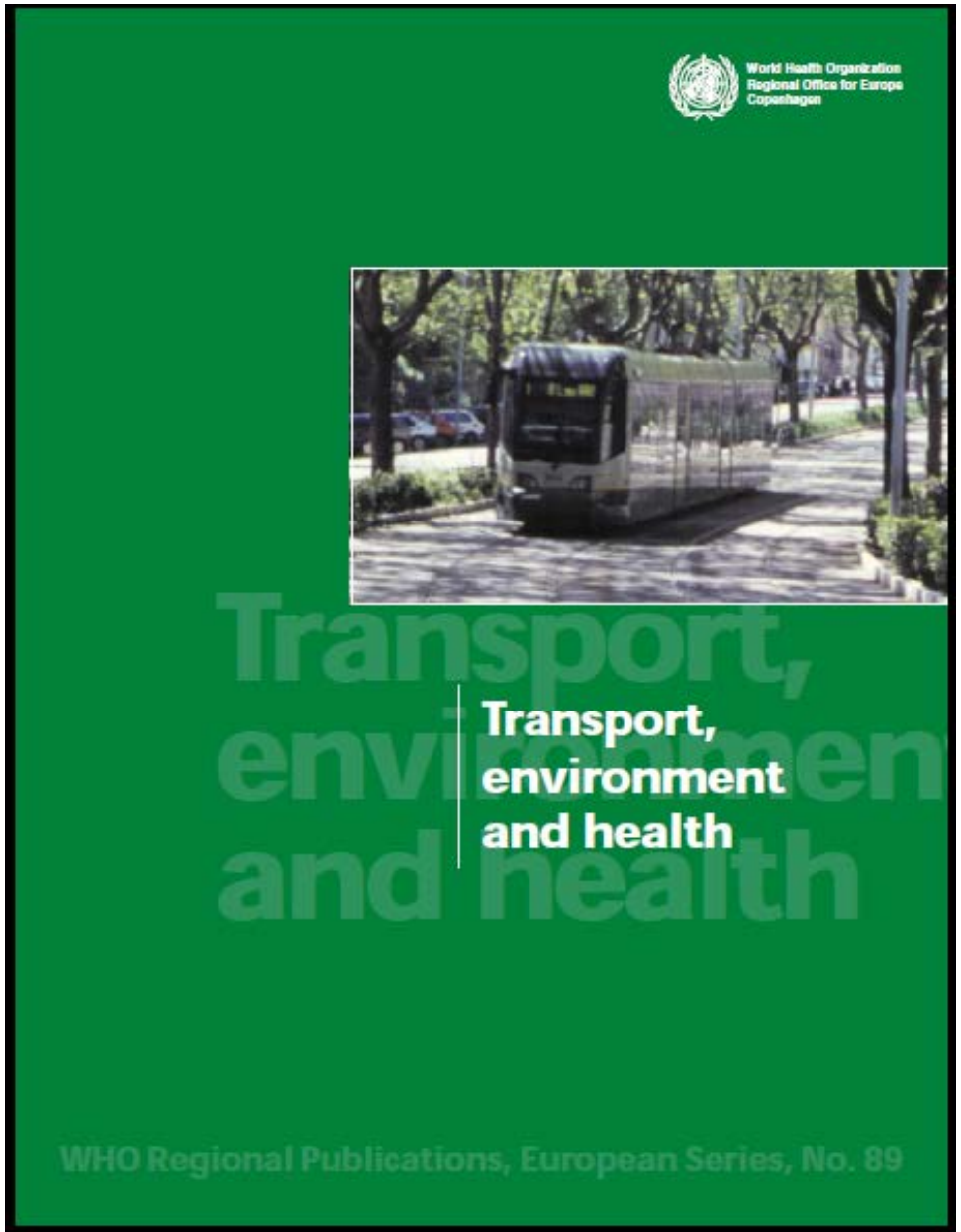
Transport Systems: the good

- Key to economic health
- Integral to social wellbeing
- Strategic/national defense
- A public health component
  - Increased physical activity
  - Improved nutrition
  - Decreased occurrence of specific health issues: diabetes, stroke, obesity, …
  - Other…

Transport Systems: the not-so-good

Report:

World Health Organization (WHO)



1. Transport noise: a pervasive and underestimated ambient stressor

2. Transport accidents and injuries

3. Serious health impact of air pollution generated from traffic

4. The effects of transport on mental health and wellbeing

What is Health?

- *“a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”*
  - World Health Organization

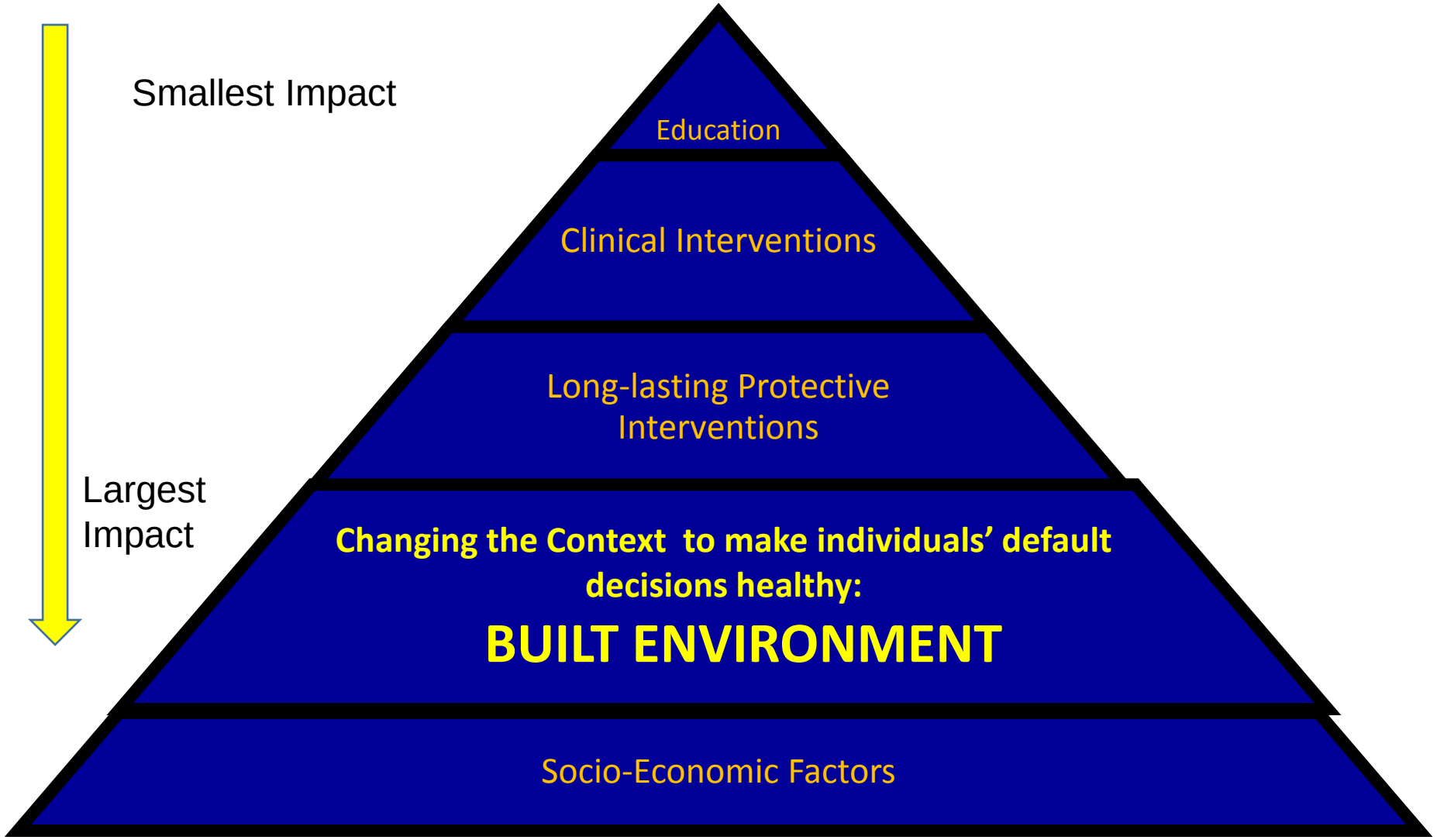
- Physical health
- Mental health
- Well-being
- Livability

QUARTIER ZUKUNFT
LABOR STADT

How Does Transportation Affect Health?

- **Physical activity and obesity**
- **Air pollution and asthma**
- **Motor vehicle crashes and pedestrian injuries**
- Other impacts
  - Water quality
  - Climate change
  - Mental health
  - Physical health
  - Noise
  - Social capital
  - Environmental justice

Factors that Affect Health



(Frieden, AJPH, 100:590, 2010)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Traffic Congestion

- Economic, productivity problem
- Environmental challenge
- A stressor
- A public health issue

Drivers happy to take long way round to avoid traffic stress

Date: June 17, 2013

Source: Fraunhofer-Gesellschaft

Summary: German motorists are willing to accept longer journey times and even detours if it means helping to ease the general traffic situation.

Traffic vs other stressors

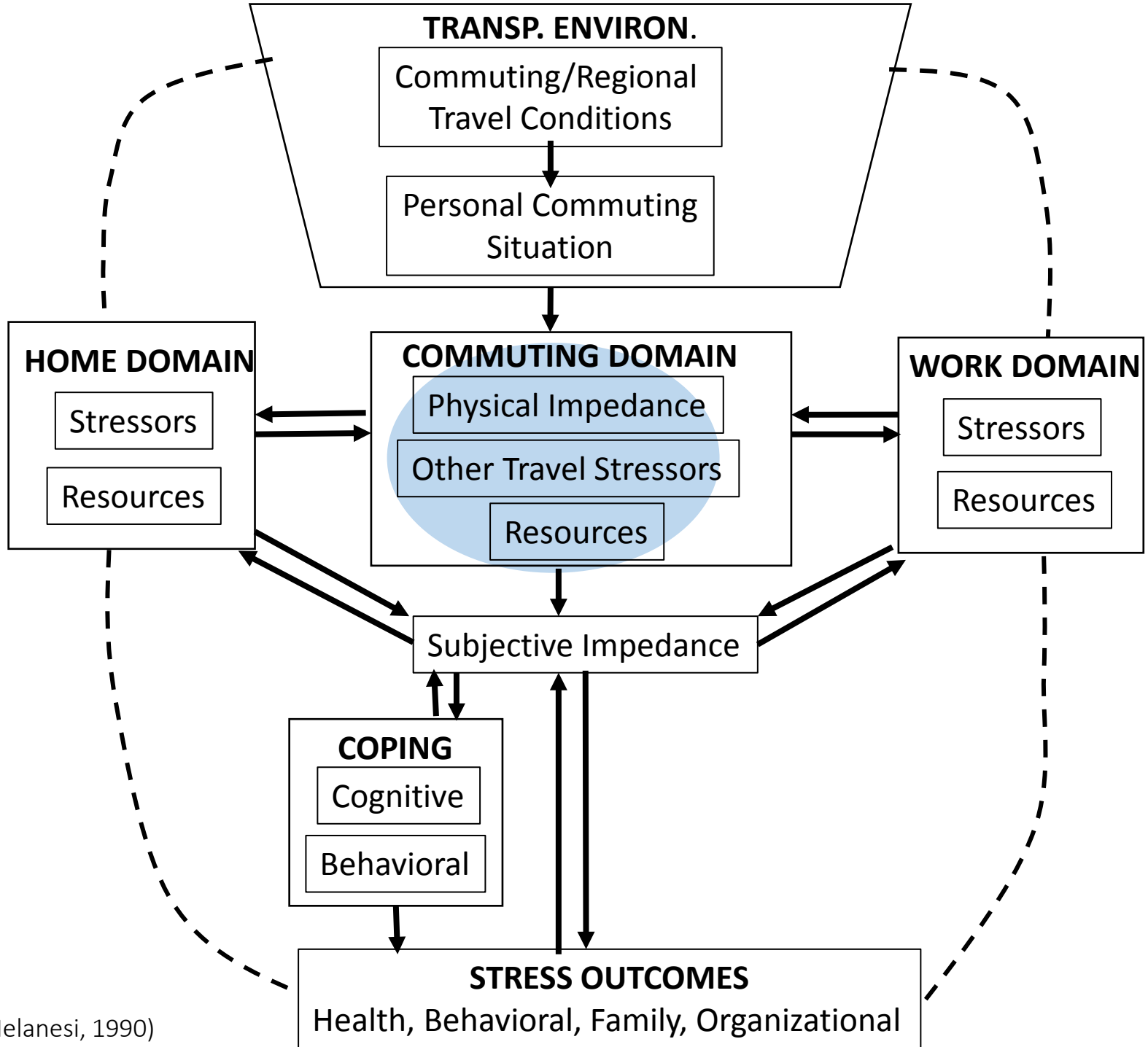
Congestion is a “stressor”

- Psychological/physiological stress
- Stressors can be health issues regardless of trigger

Effects of Congestion on Mental Health and Wellbeing

- …”regular exposure to traffic congestion impairs health, psychological adjustment, work performance and overall satisfaction with life…
- Congestion constrains movement, which increases blood pressure and frustration tolerance.” (WHO, 2000)
- Long term physiological impairment

The Ecology of Commuting Stress



(Novako, Stokols, Melanesi, 1990)

Acute vs. Chronic Stress

- Which is worse?
- Traffic stress is chronic
- It is the little thing that matters

Sources of Stress in Traffic (literature)

1. Stuck in traffic or start-stop driving associated with congestion
2. Caught in traffic flow, can only join in
3. Brake hard for various reasons
4. Intense info/maneuvers/decisions
5. Physical & perceived impedance
6. Lack of information: why; how long, how far?
7. No big picture; no “system” view
8. Unpredictability
9. Impatient/aggressive driving by others
10. Pressured to drive faster by vehicles following
11. Other ….

The Question…

- Can we eliminate/reduce/lessen these sources of stress through carefully designed control?
- Yes/No?

Sources of stress in traffic

1. Stuck in traffic or start-stop driving associated with congestion
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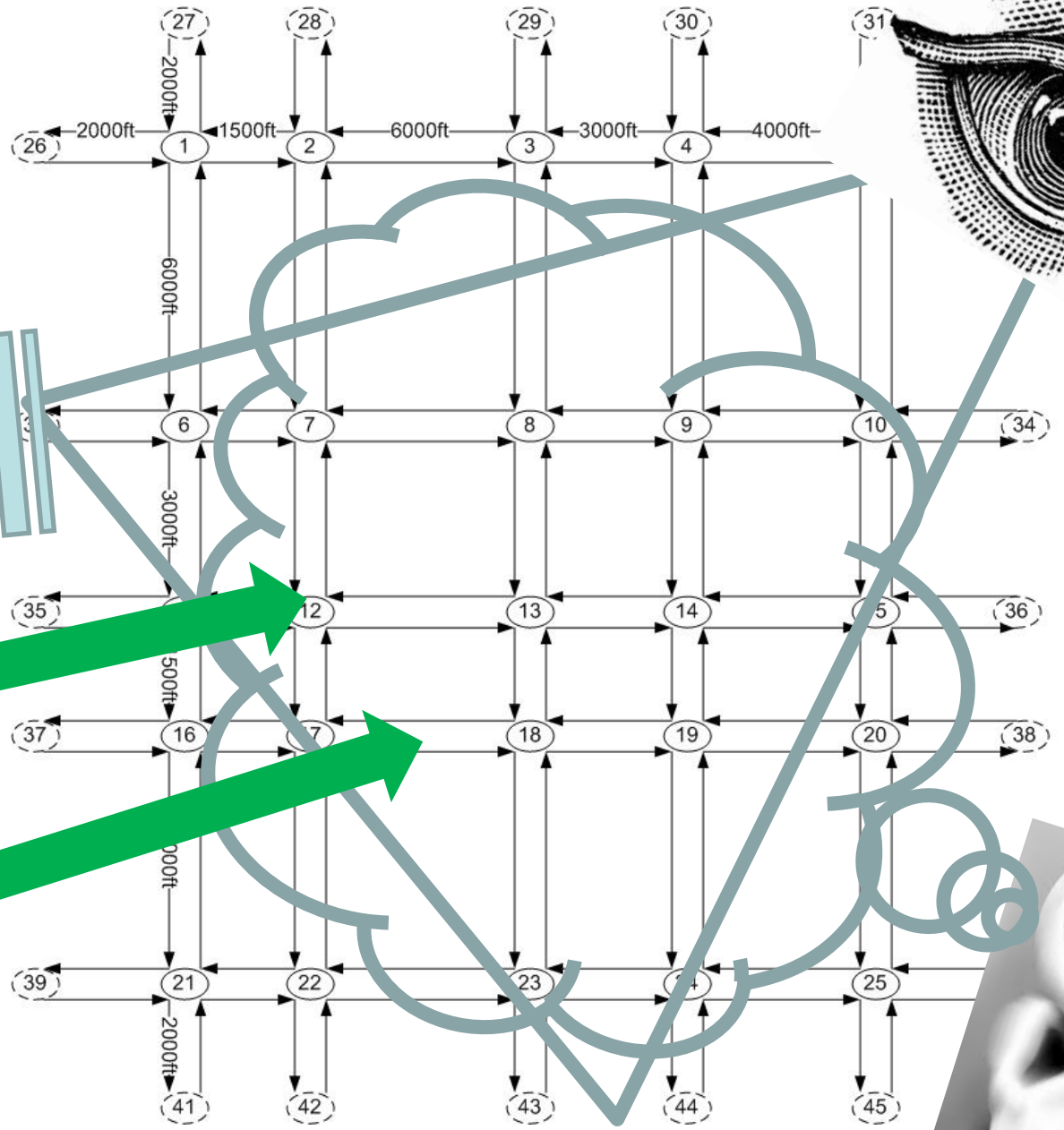
New Control

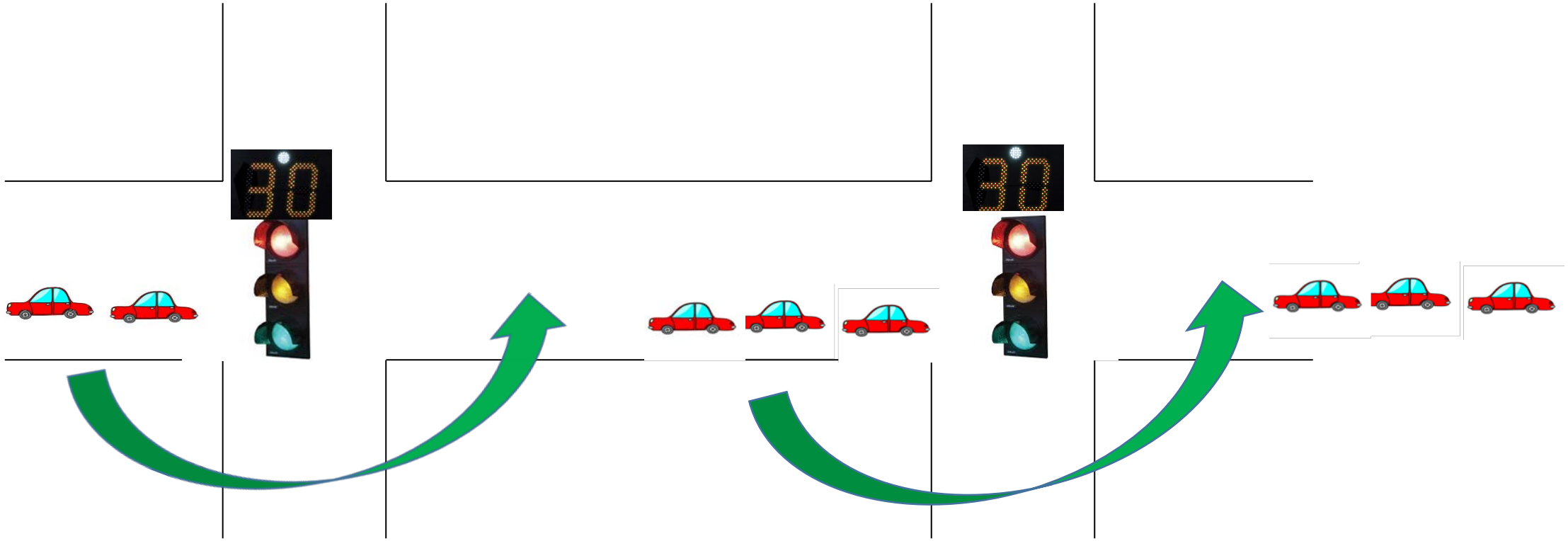
- Dynamic signal control &
- Dynamic speed control
  - Change signal control and speed dynamically
  - Communicate link speed to drivers

Control schematics



- Repeat over time

A closer look…



Objective Function

Max. $\left(throughput - \lambda * stop \right)$

Max.

$$\left(\sum_{k=1}^{n} \left(\sum_{i=1}^{nq} edv_{(i,nx)k} + \sum_{j=1}^{nx} ndv_{(nq,j)k} \right) - \sum_{k=1}^{n} \sum_{i=1}^{nq} \sum_{j=1}^{nx} \left(\begin{bmatrix} eq_{(i,j+1)k} + (eoff_{((i,j)(i,j+1))k} - \\ c\_eoff_{((i,j)(i,j+1))k}) \cdot vu / ((vu - vt) \cdot h) \end{bmatrix} + \begin{bmatrix} nq_{(i+1,j)k} + (noff_{((i,j)(i+1,j))k} - \\ c\_noff_{((i,j)(i+1,j))k}) \cdot vu / ((vu - vt) \cdot h) \end{bmatrix} \right) \right)$$

Constraints

- $\min\ g \le g_{(i,j)k} \le \max\ g,$

  $\text{for } (i,j) \in N(ny,nx),\ k = 1,2,...n$
- $\min\ \ ds \le ds_{(i,j)k} \le \max\ \ ds,$

  $\text{for } (i,j) \in N(ny,nx),\ k = 1,2,...n$

- $q_{(i,j)1}$ are known;

  $\text{for } (i,j) \in N(ny,nx), k = 1,2,...n$
- $q_{(i,j)k} \le \max\ \ q$;

  $\text{for } (i,j) \in N(ny,nx), k = 1,2,...n$

- $av_{(l,m)k} = dv_{(i,j)k},$

  $\text{for } (i,j),(l,m) \in N(ny,nx),\ k = 1,2,...n$

  and *(i, j)* is the immediate upstream signal of *(l, m)*
- $$dv_{(i,j)k} = \begin{cases} \min(q_{(i,j)k} + av_{(i,j)k}, \dfrac{g_{(i,j)k}}{h}), \\ c\_off_{((i,j),(l,m))k} \ge off_{((i,j),(l,m))k}; \\ \min(q_{(i,j)k} + \\ av_{(i,j)k}, \dfrac{g_{(i,j)k} - (c\_off_{((i,j),(l,m))k} - off_{((i,j),(l,m))k})}{h}), \\ c\_off_{((i,j),(l,m))k} < off_{((i,j),(l,m))k} \end{cases}$$
- $dv_{(i,j)k} \le q_{(i,j)k} + av_{(i,j)k};$

  $\text{for } (i,j) \in N(ny,nx),\ k = 1,2,...n$
- $q_{(i,j)k+1} = q_{(i,j)k} - dv_{(i,j)k} + av_{(i,j)k},$

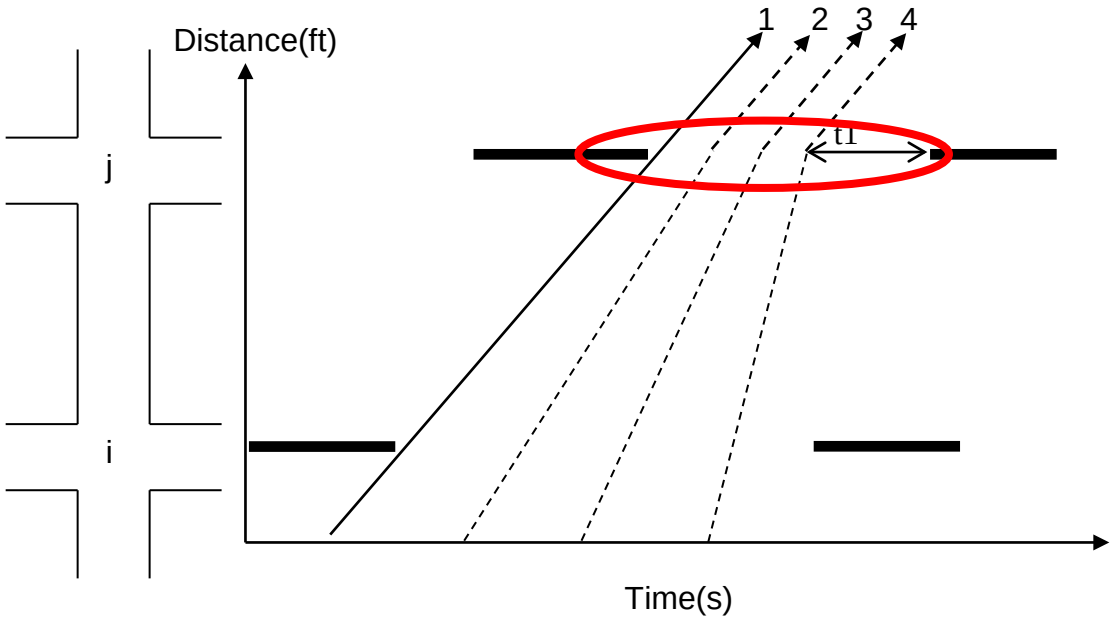
  $\text{for } (i,j) \in N(ny,nx),\ k = 1,2,...n$
- $g_{(i,j)k} \le g_{(l,m)k} + off_{((l,m),(i,j))k} + L_{(i,j),(l,m)} / vt,$

  $(i,j),(l,m) \in N(ny,nx),\ k = 1,2,...n$

  ; and *(i, j)* is the immediate upstream signal of *(l, m)*. This constraint is to prevent spillback.
- Offsets between signals along the independent arterials are set to compact values as determined by equation 3 or 4; offsets between signals along the dependent arterials are locked in offsets;
- $gc_{(l,m)k} = cycle_{(i,j)k} + off_{((l,m),(i,j))k} + off_{((l,m),(i,j))k+1} - g_{(l,m)k}$;
- $ngs_{(1,1)1} = 0;$

Some Modeling Specifics …

- Efficient use of green time



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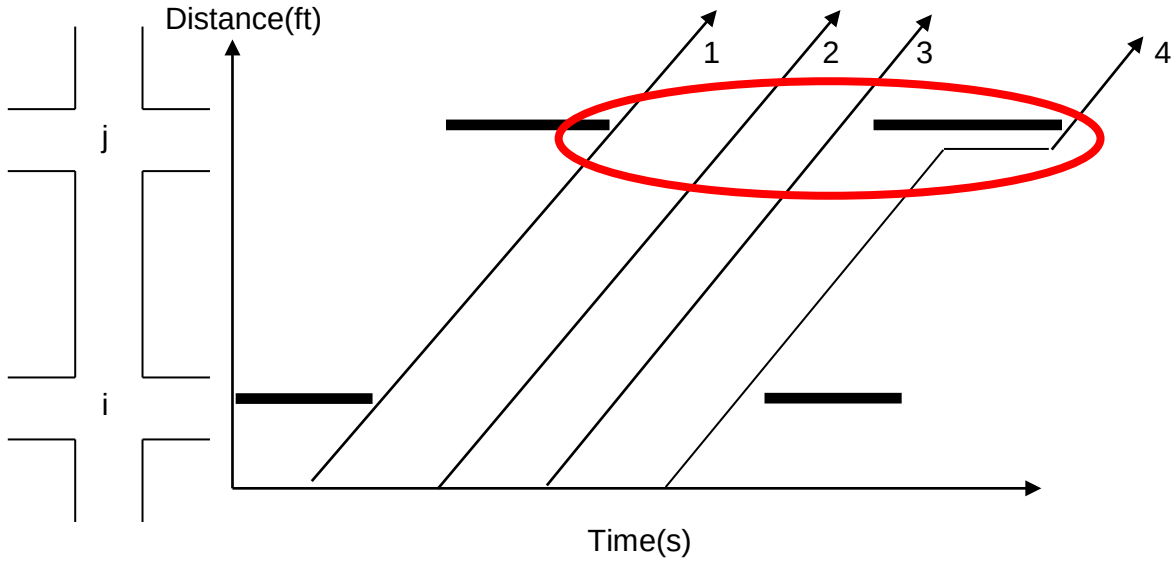

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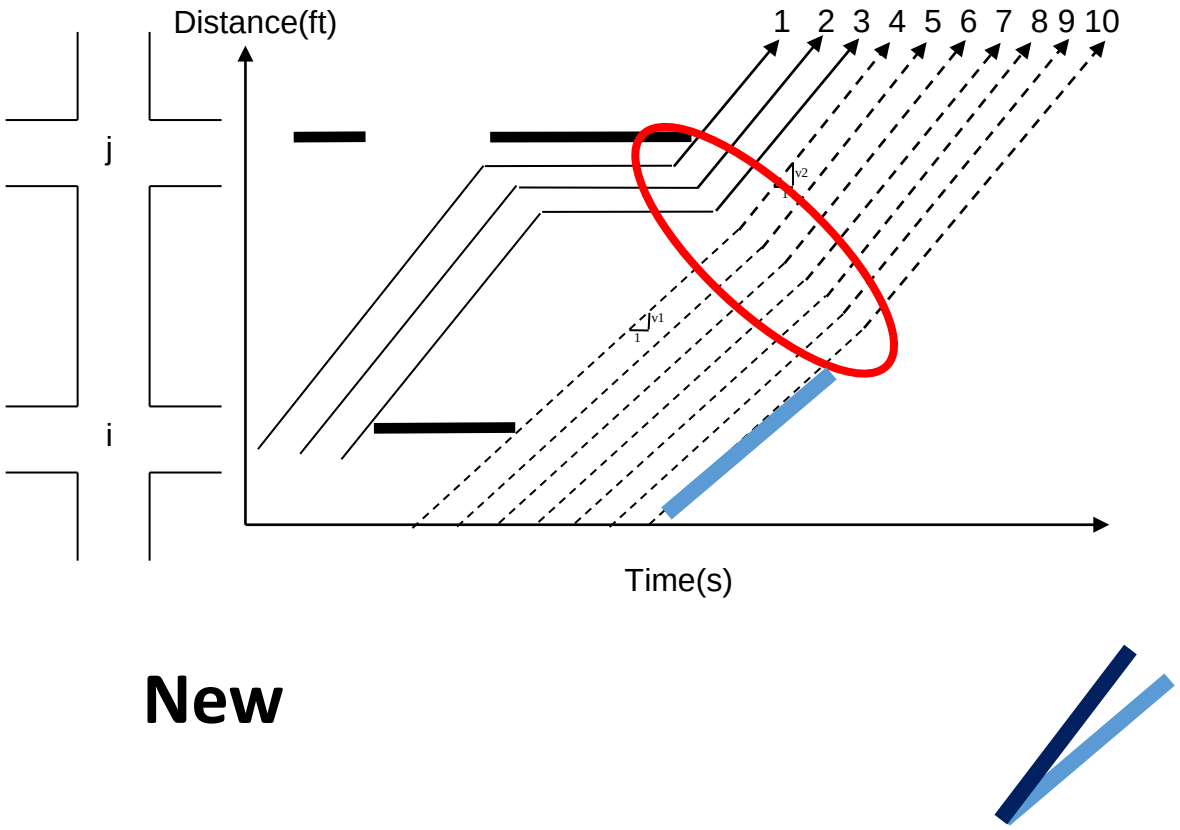
- Speed management, smoother flow



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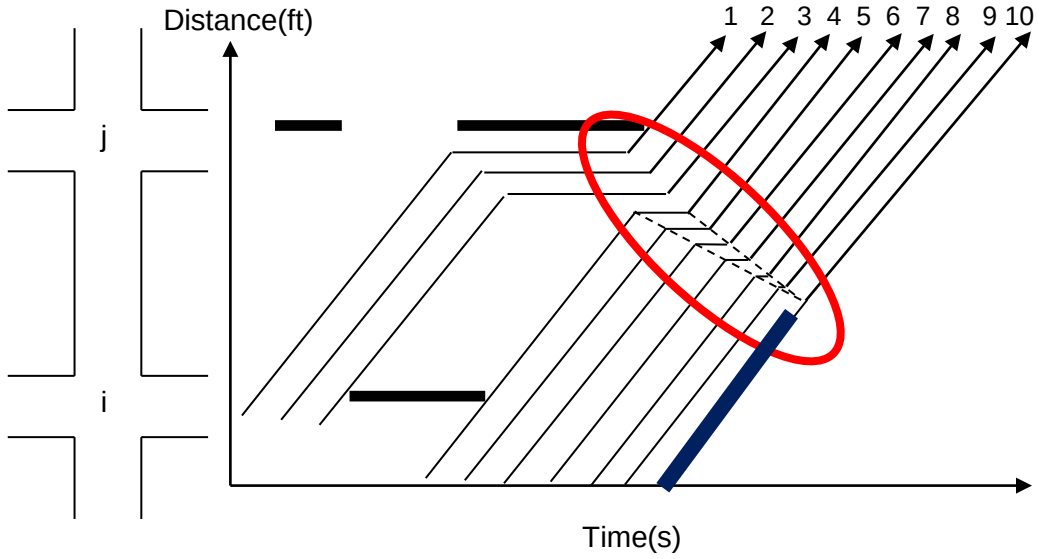

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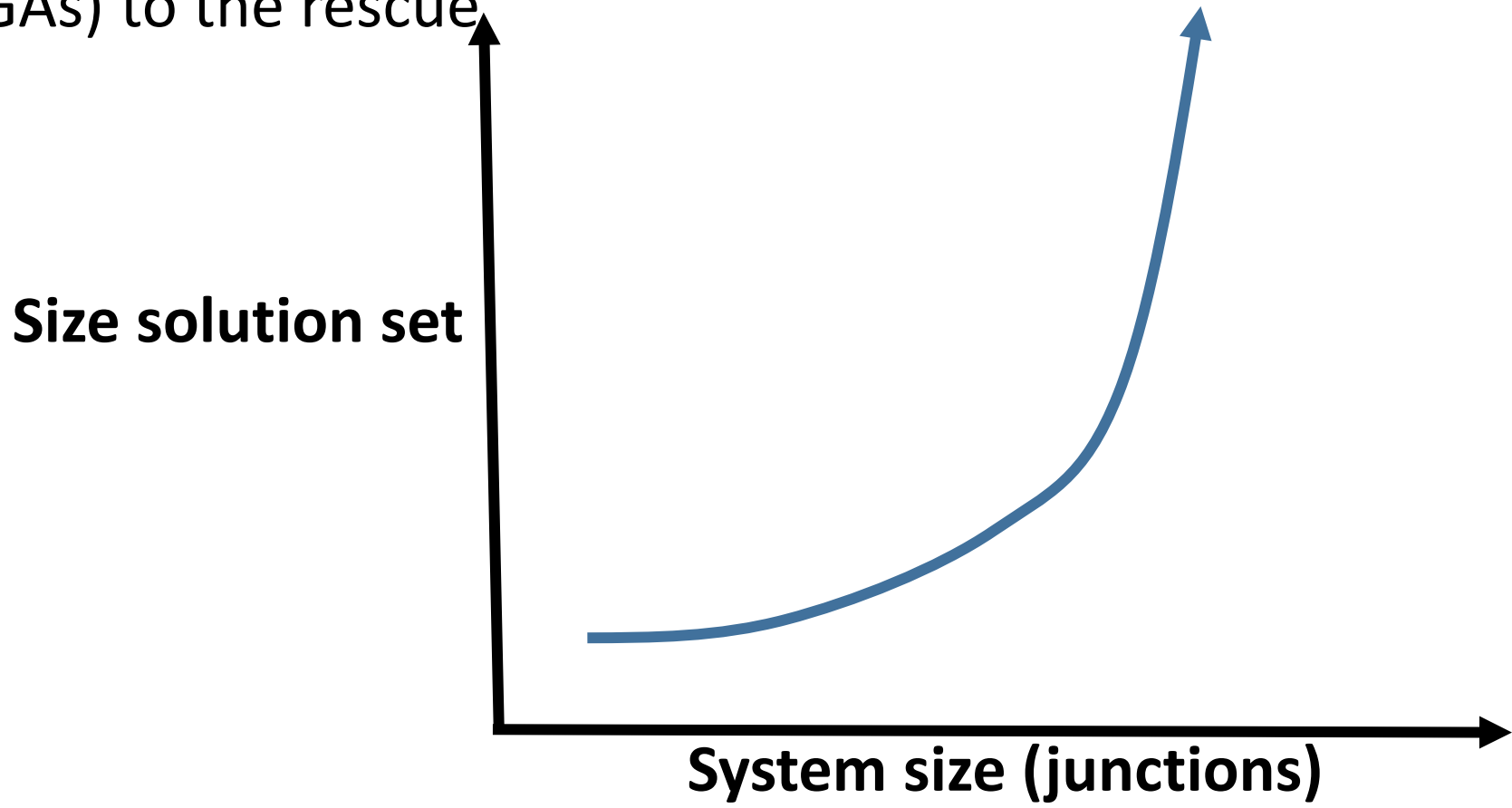
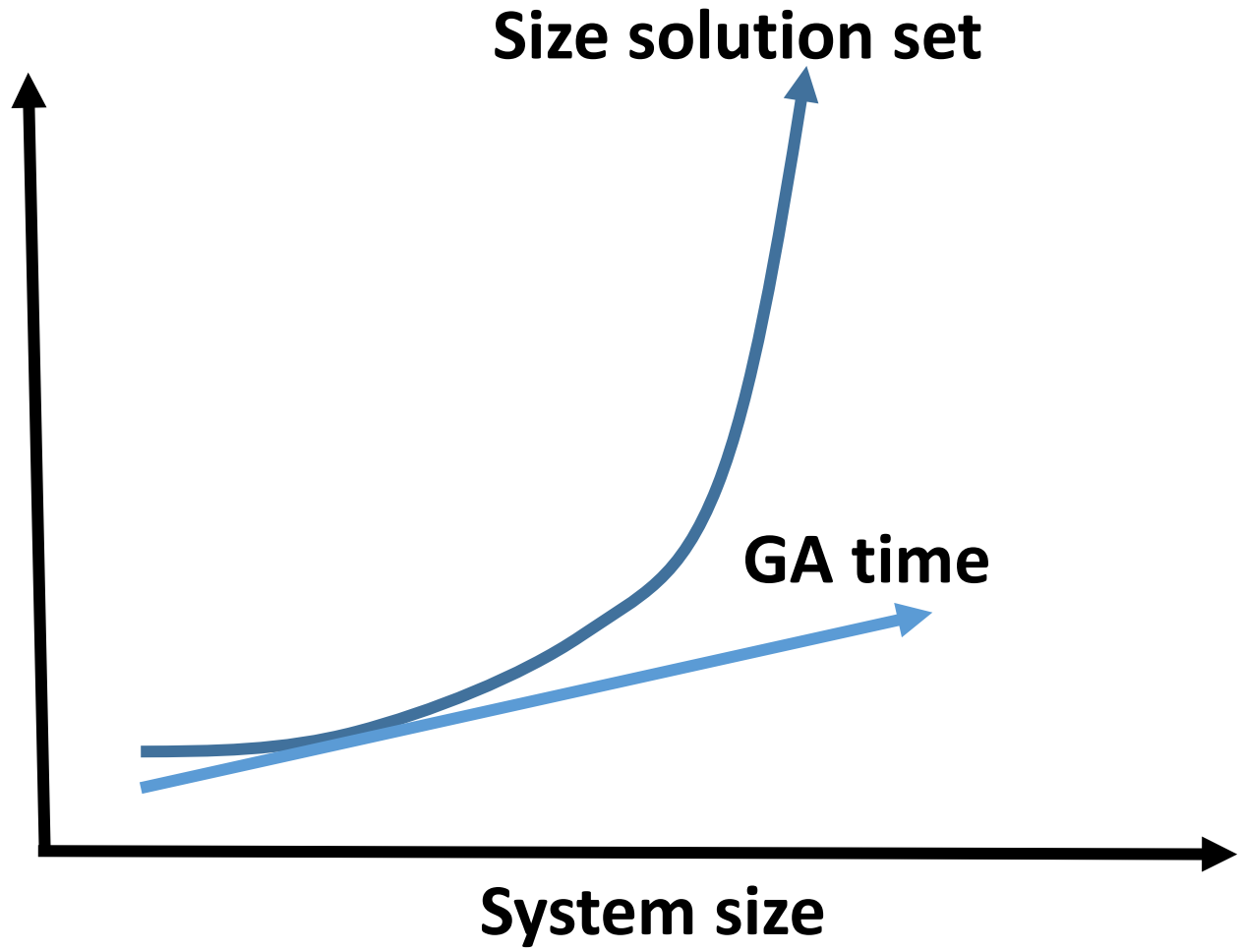
The Control Problem

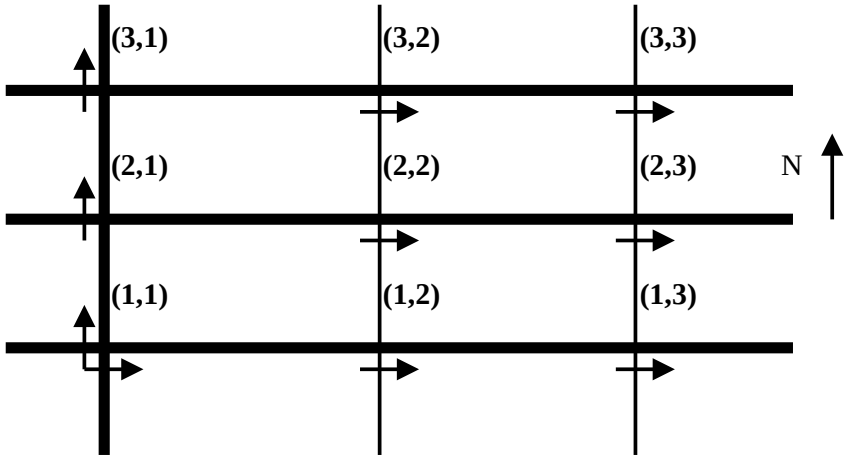
- A combinatorial problem
- Genetic Algorithms (GAs) to the rescue



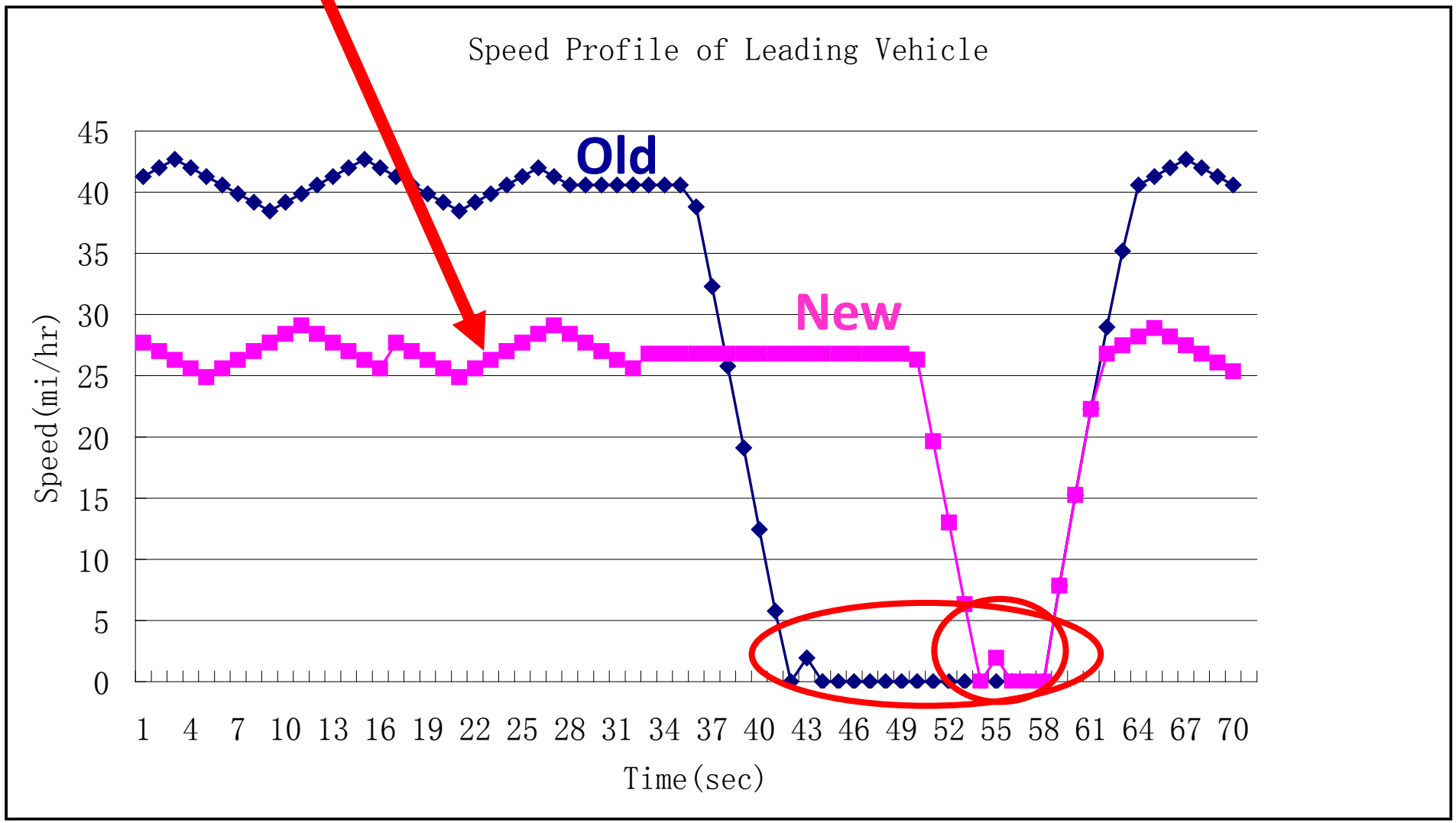
Why GAs?



Test Network



Shorter stops n lower speed



Verification with microscopic simulation

- Less disturbance, fewer decisions/actions

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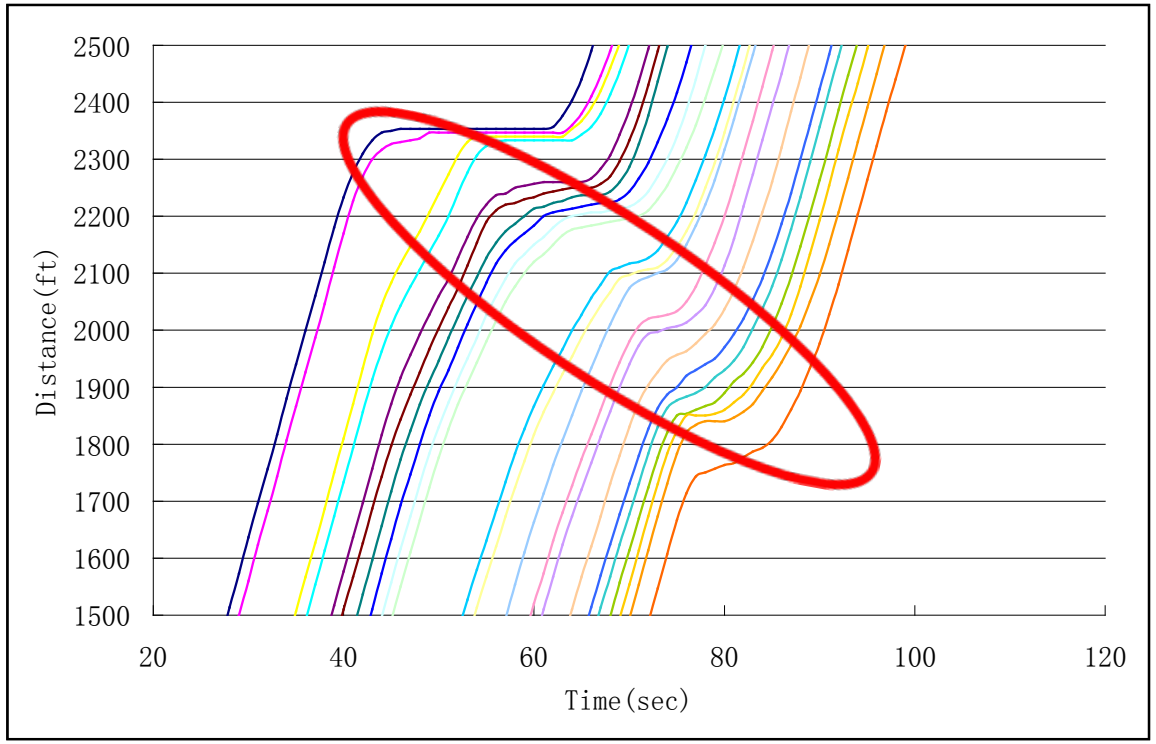

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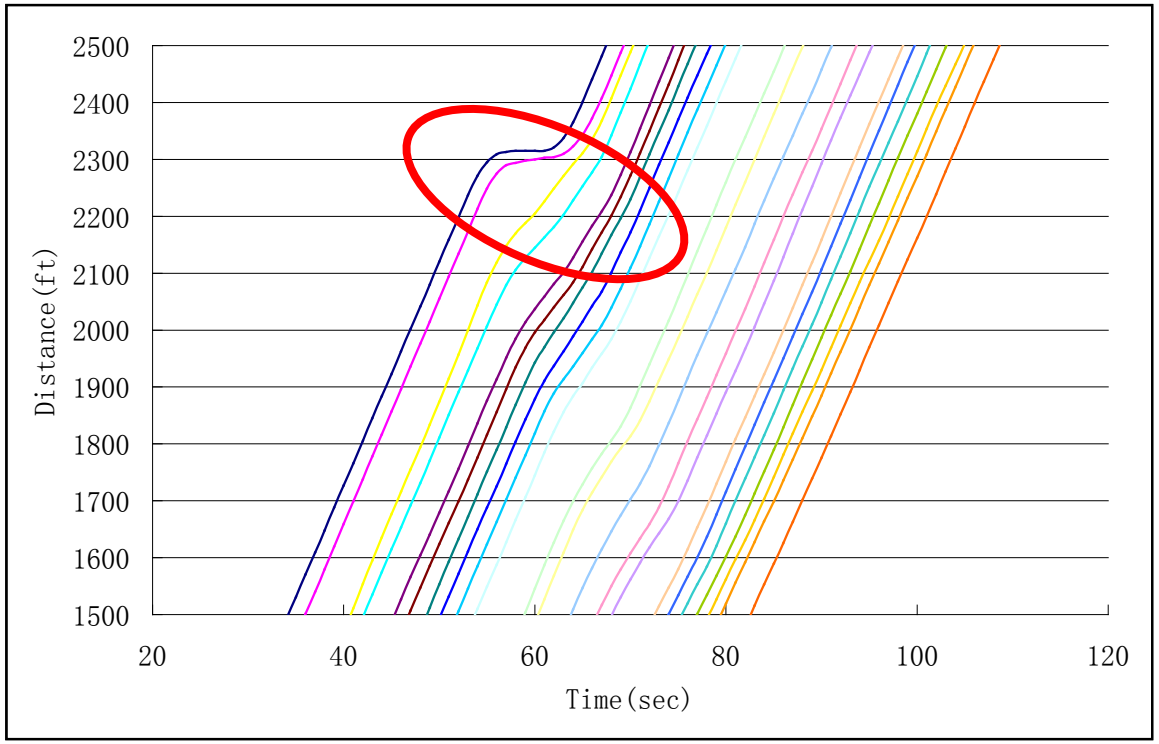

Shorter stops, fewer vehicles

- Fewer n shorter stops, less frustration

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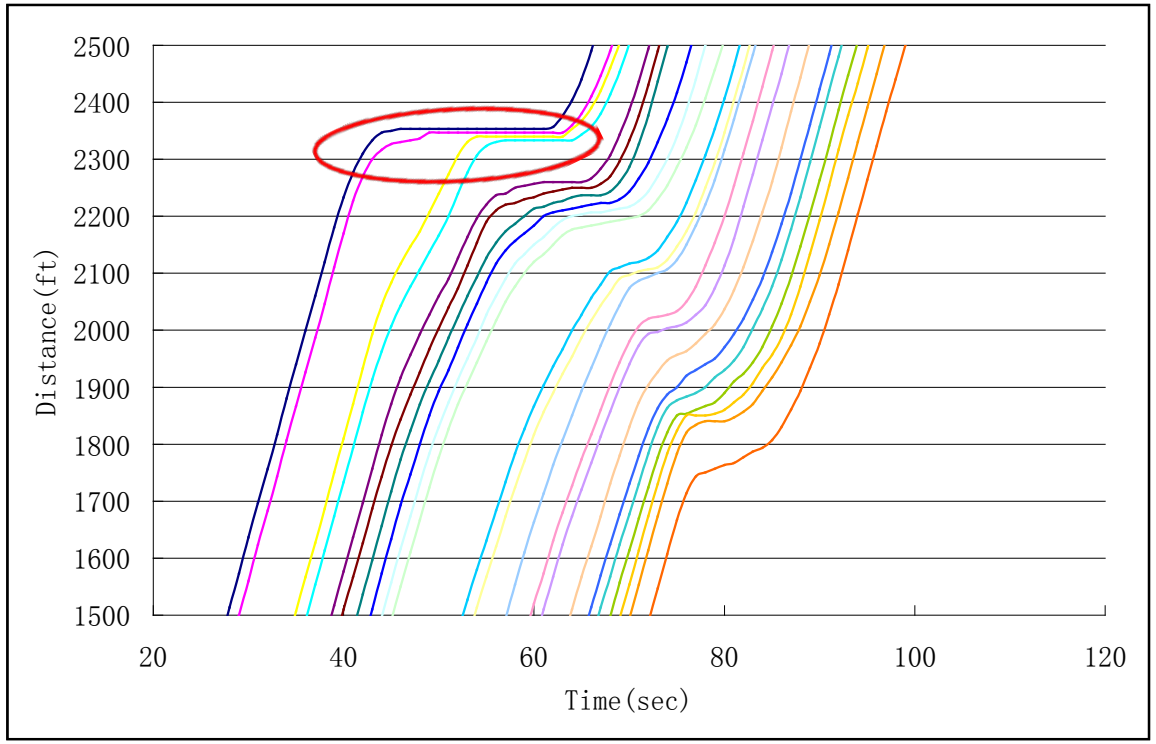

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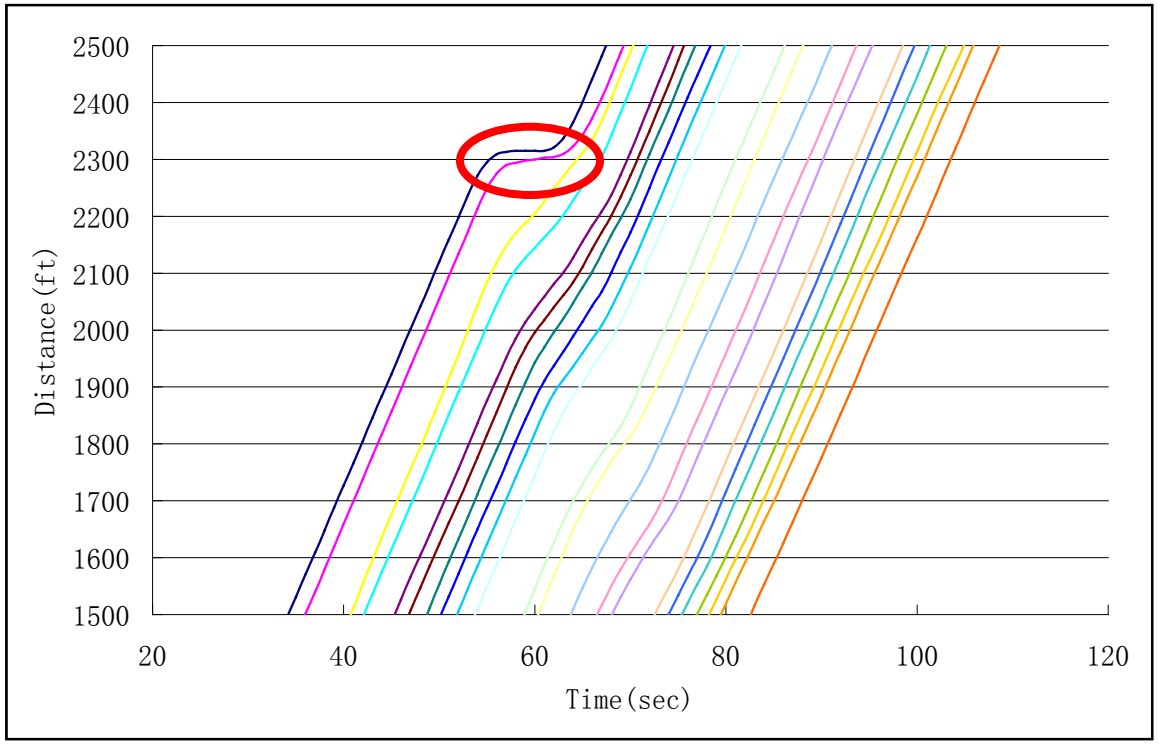

Results: traffic-wise

- Throughput at capacity, maximum
- Fewer stops
- Shorter stops
- Shorter stopping delay
- Travel time within system not shorter
- Lower average speed
- Possibly less energy consumption
- Possibly less emissions

Results: stress/health-wise

- Fewer driver decisions per unit distance/time
- More movement, less impedance (real & perceived)
- More information, less uncertainty, less anxiety
- Fewer sources of stress

Recall the sources of stress…

1. Stuck in traffic or start-stop driving associated with congestion
2. Caught in traffic flow, can only join in
3. Brake hard for various reasons
4. Intense info/maneuvers/decisions
5. Physical & perceived impedance
6. Lack of information: why; how long, how far?
7. No big picture; no “system” view
8. Unpredictability

- **Less,**
- **Far less**
- **Improved**
- **Not important**

Summary

- Traffic operations & public health tightly linked
- Traffic congestion serious stressor, a public health issue
- Can be mediated (partially) through proper “healthier” control
- Health-sensitive traffic control is possible/feasible
  - Fewer stops
  - Fewer decisions by drivers
  - More movement, slower
  - More predictability
  - (May be) Less chance of crashes
- Less congestion iduced stress

Summary (cont.)

- Implication to how we do business
- Multi-faceted solution is necessary, traffic control is only one component
- Users education, enforcement, communication, all necessary
- Research needed