

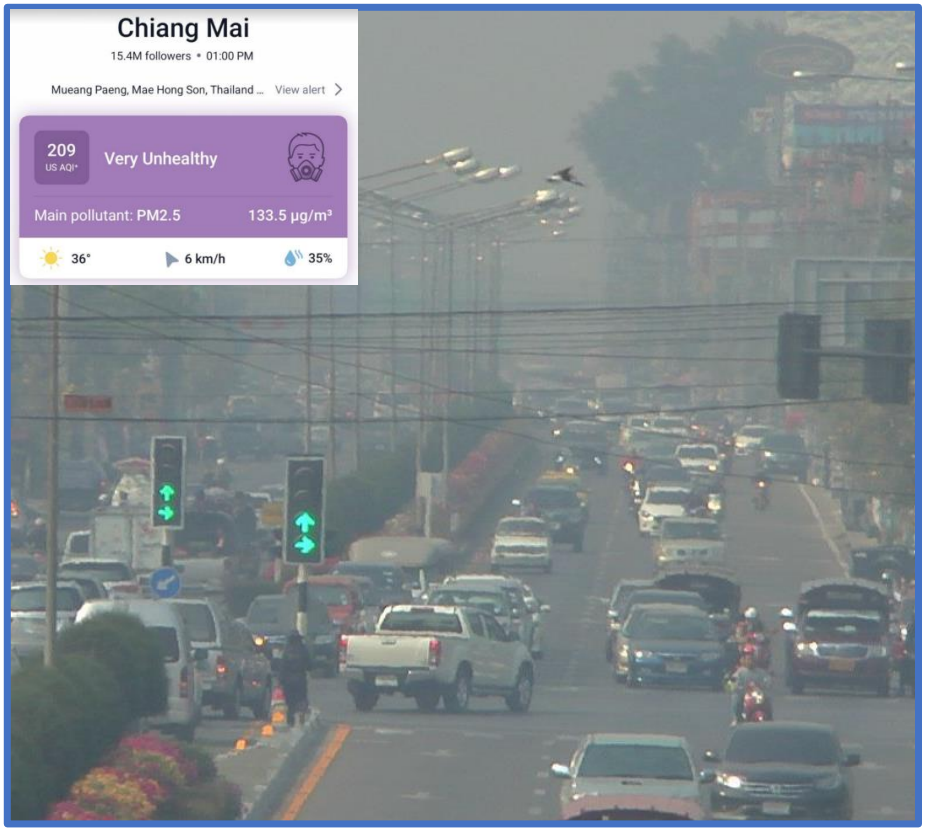
การควบคุมสัญญาณไฟจราจรเพื่อลดการปล่อยมลพิษ: มีความเหมาะสมเชิงเศรษฐศาสตร์หรือไม่?

นายพลเทพ เลิศวรวนิช

ผู้อำนวยการสำนักวิจัยและพัฒนางานทาง

๓ สิงหาคม ๒๕๖๙

Do we need an emission-based signal control? → Really?



DOH Sig. Ints ≈ 2,200

↓ Performance Gap!

Retiming Signal Control !!

↓

To reduce Green House Gases (GHGs)

↓ ✕

Global Warming + Climate Change !!!

Is it really worth (economical) implementing emission-based signal control policy?

Overview

- Emission VS Delay (congestion) Signal Controls
- Intersection Fundamental Diagram (IFD) + emission-IFD (eIFD)
- Marginal External Costs of Emission and Congestion Ratio (MECR)
- Some Observations in BKK
- Absence of economic justification!
- What-we-learn and Future research

Signal Timing Calculations

Performance Measures

- Delay per time unit
- Stop per time unit (Stop Rate)
- Emission per time unit
- Fuel consumption

Signal Timing Optimization

- Minimize ***delay*** per time unit
- Minimize ***emission*** per time unit

Different timing plans!!

Many studies on emission-based signal control algorithms!!!

→ Balance between mobility and sustainability!

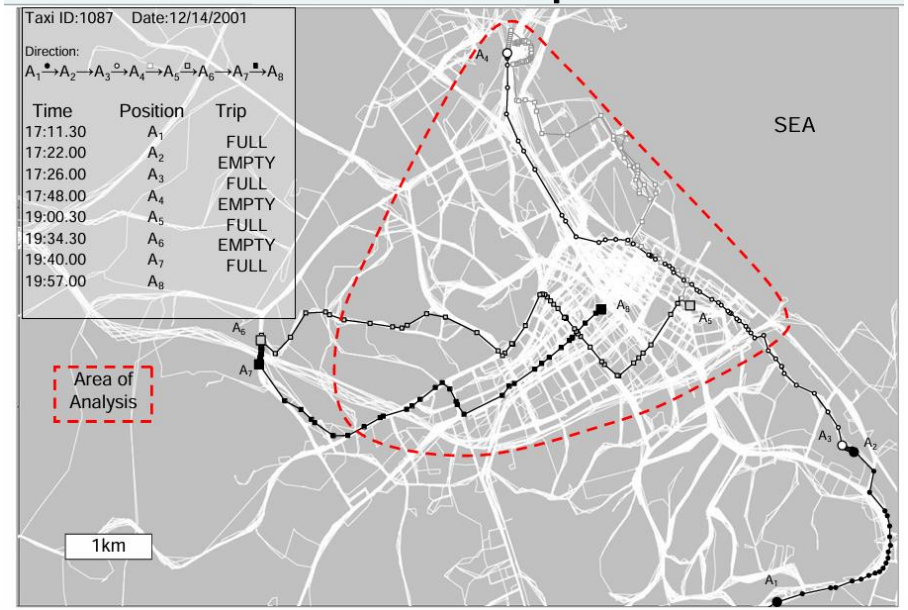


Economically?

Congestion ≠ Emission

- Is it worth implementing emission-based signal control policy?
- In what traffic conditions should emission-based signal control be implemented?

Real World Experiment: Yokohama, Japan



Hypothesis

If vehicles (i.e., congestion) are uniformly distributed in space

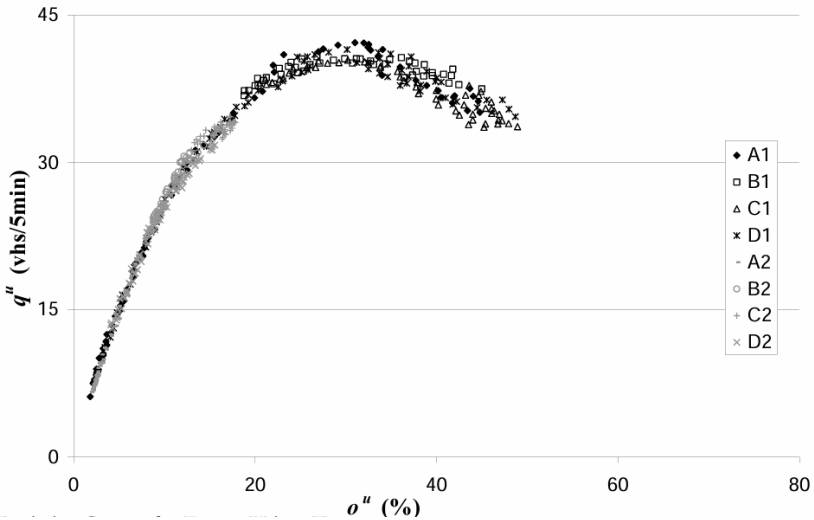
Then

(a) VKT (i.e., average network flow) and VHT (i.e., average number of vehicles in network, average density or average occupancy) are related by MFD.

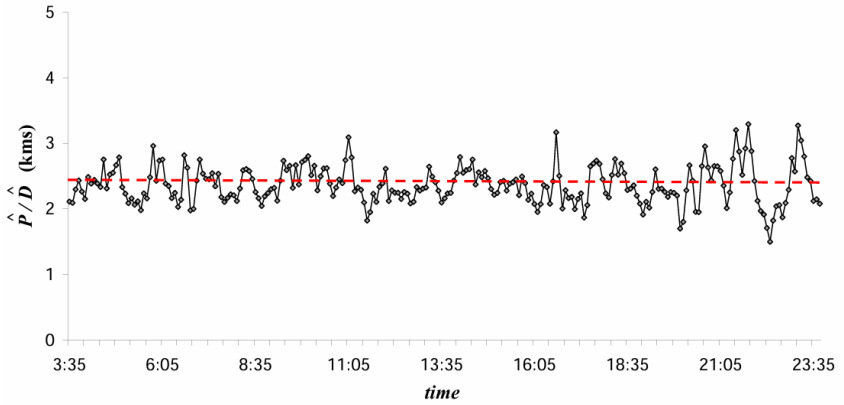
(b) Trip completion rate/network flow(or VKT) ≈ constant

From: http://faculty.ce.berkeley.edu/daganzo/Research/MacroFD/index.html

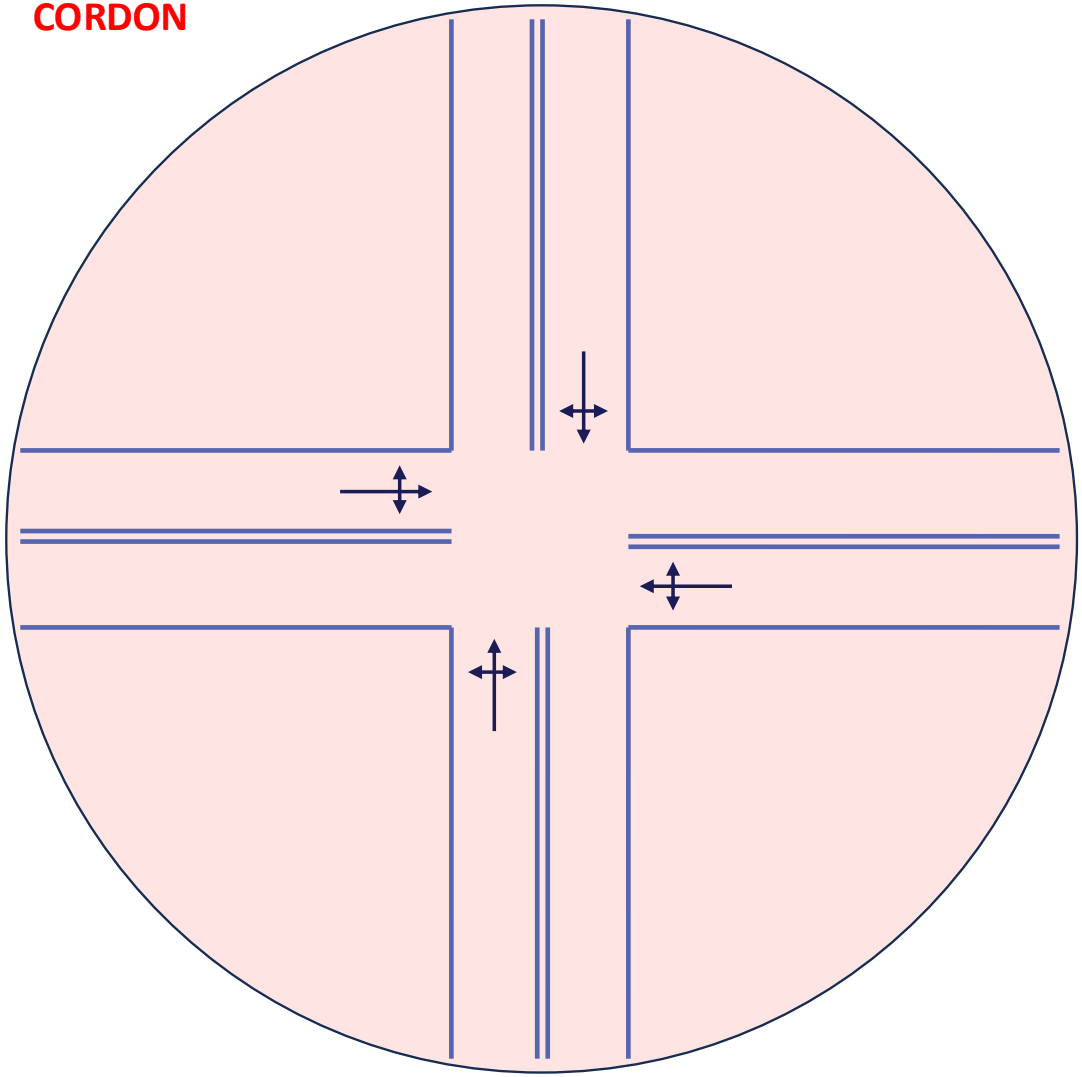
Experiment Result: Conjecture (a) MFD



Conjecture (b) Completion Rate Ratio



Intersection Fundamental Diagram (IFD)

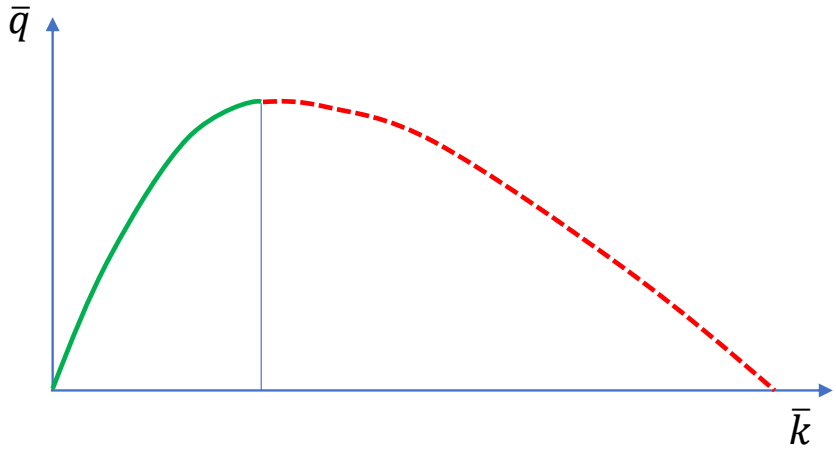


Generalized Traffic Parameters

$$\bar{q} = \frac{\sum d}{|A|} = \frac{Total\ Traveled\ Distance}{\Delta T \cdot \sum L_i}$$

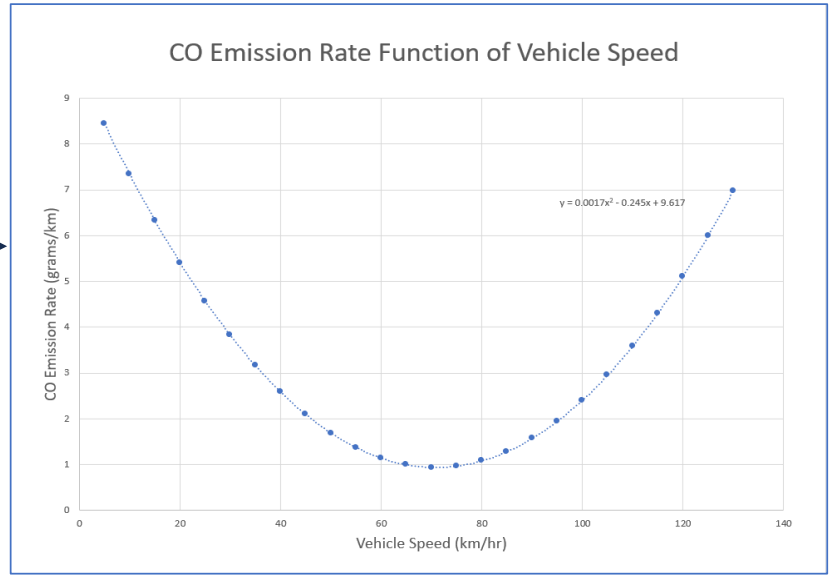
$$\bar{k} = \frac{\sum t}{|A|} = \frac{Total\ Traveled\ Time}{\Delta T \cdot \sum L_i}$$

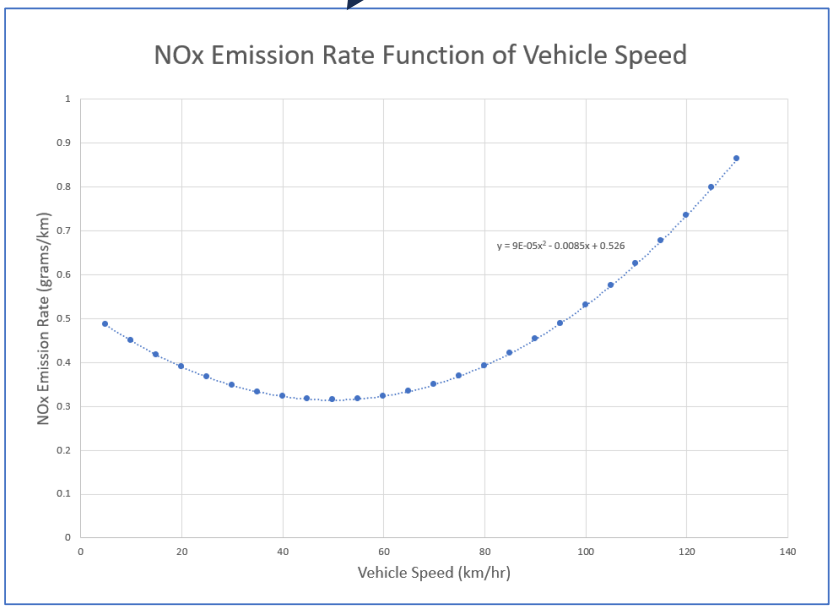
$$\bar{v} = \frac{\bar{q}}{\bar{k}} = \frac{\sum d}{\sum t} = \frac{Total\ Traveled\ Distance}{Total\ Traveled\ Time}$$

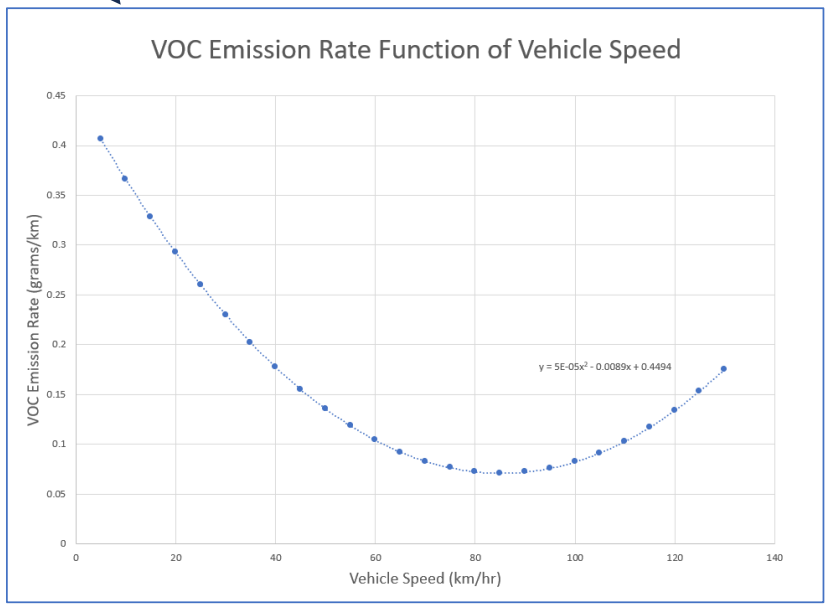


Emission Rate Functions

$ef\ (V)$

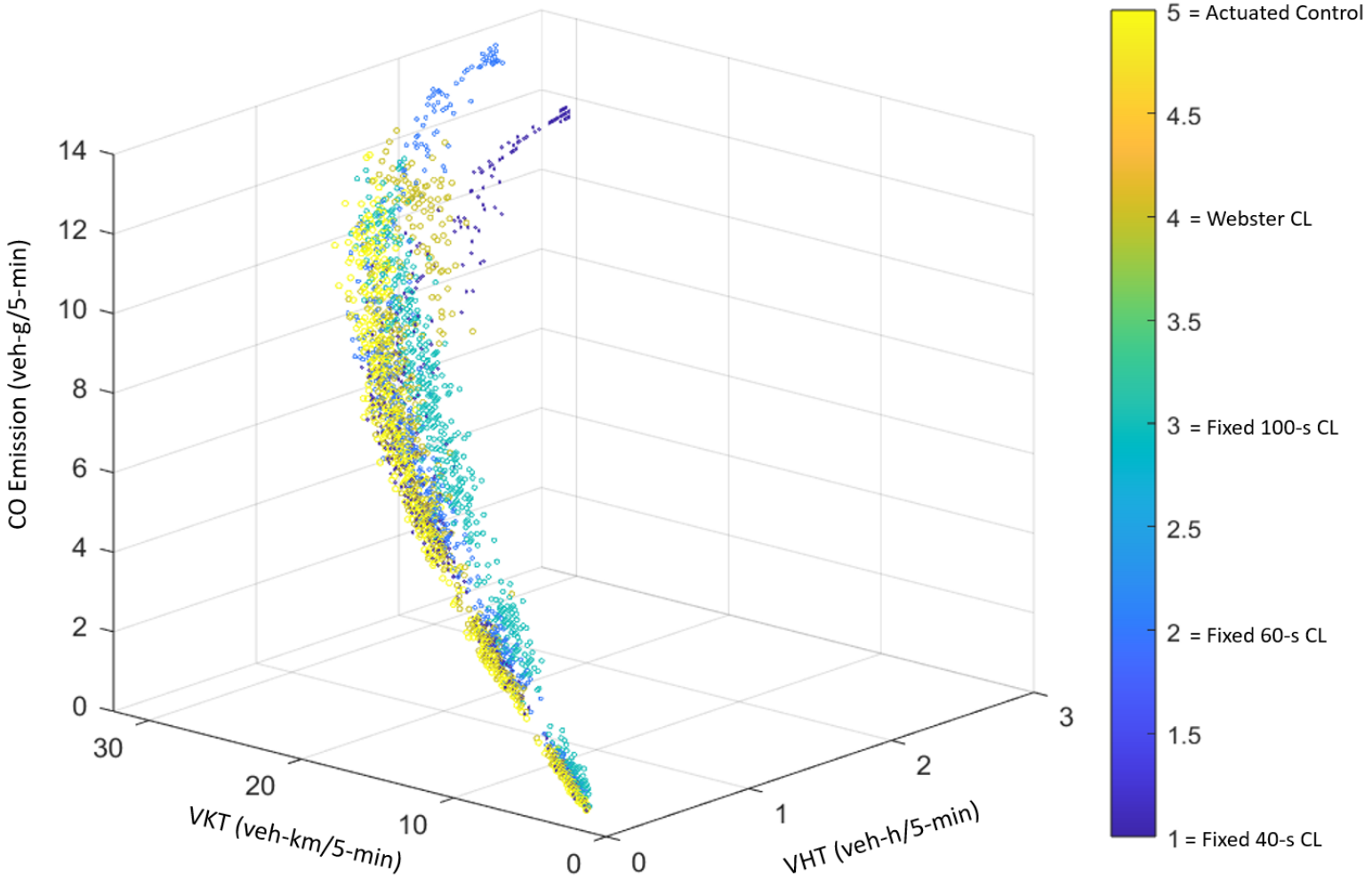






Emission Intersection Fundamental Diagram

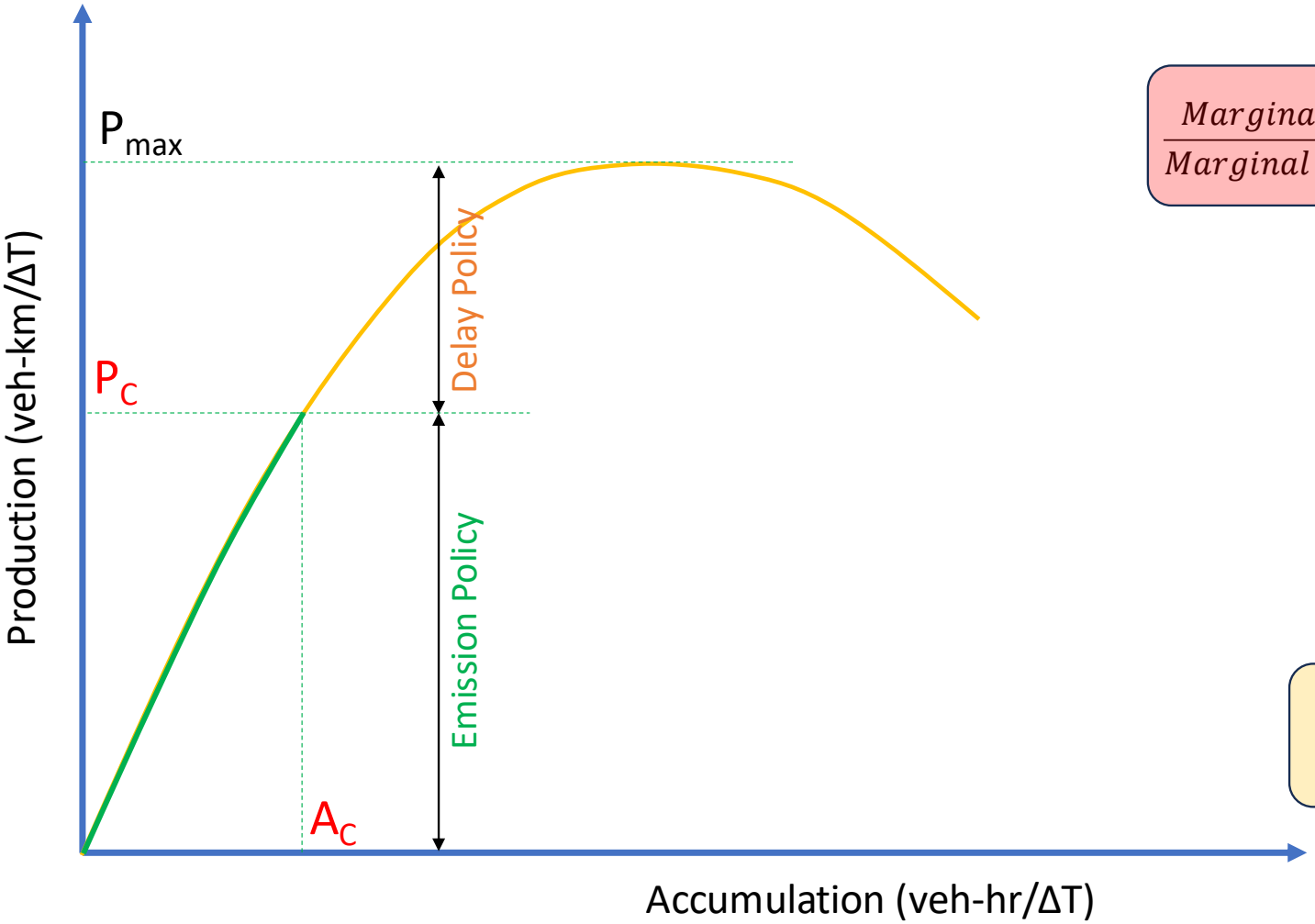
eIFD



When do emissions generate higher externality than congestion?

$$\frac{Marginal\ External\ Cost\ of\ Emission}{Marginal\ External\ Cost\ of\ Congestion} = \frac{MEC_E}{MEC_C}\ or\ MECR > 1$$

Intersection Fundamental Diagram



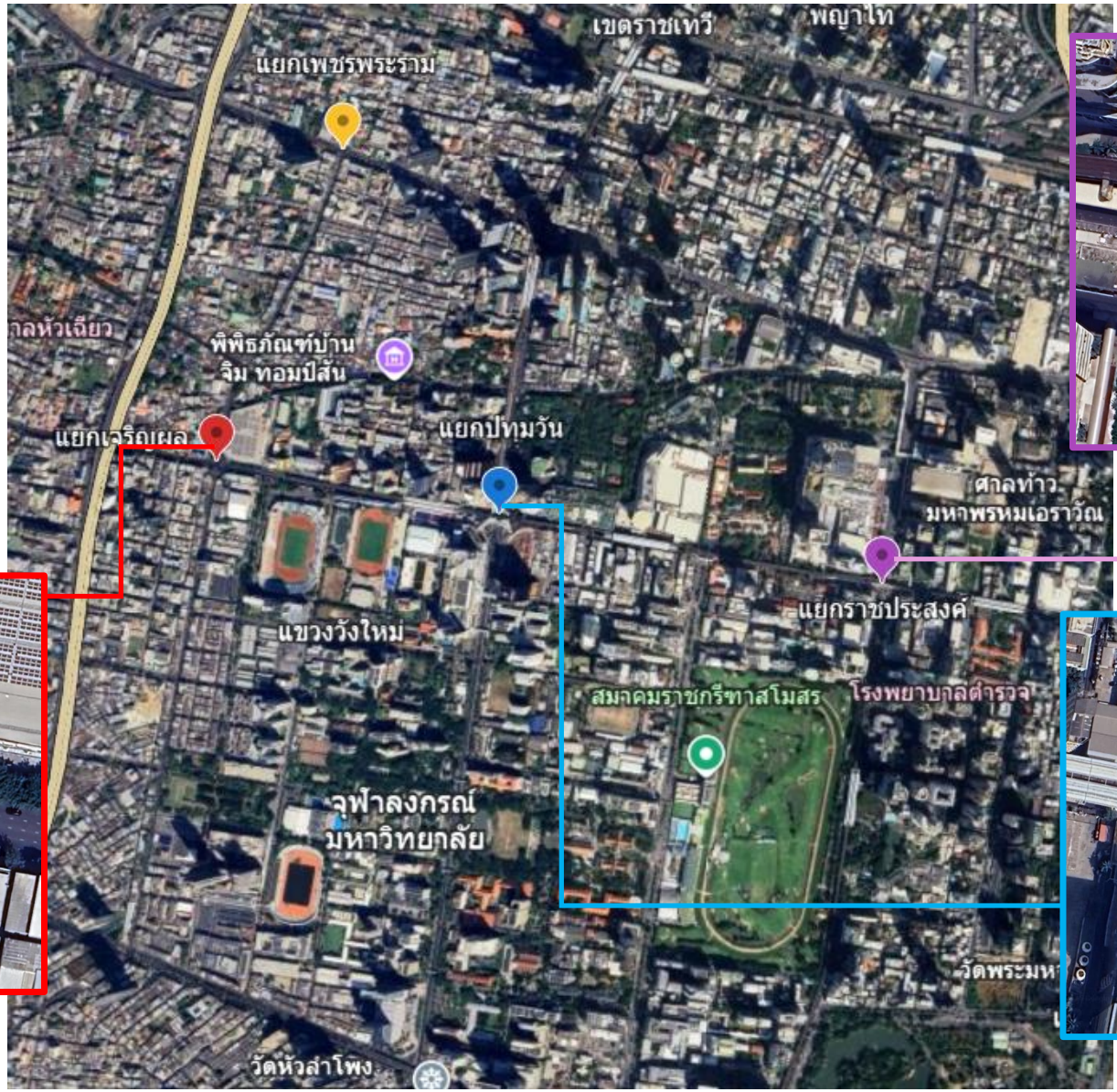
$$\frac{Marginal\ External\ Cost\ of\ Emission}{Marginal\ External\ Cost\ of\ Congestion} = \frac{MEC_E}{MEC_C} = 1$$

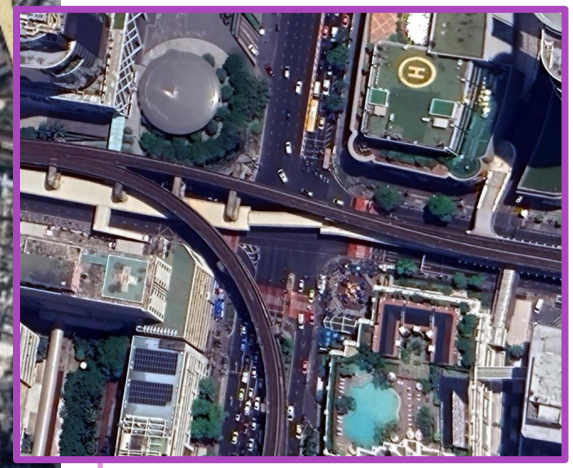
Critical Accumulation (A_C)

Critical Production (P_C)

$$\frac{P_C}{P_{max}} \approx Intersection\ \frac{Volume}{Capacity}$$

Some BKK Observations





Ratcha-Prasong Intersection



Charoen-Phon Intersection

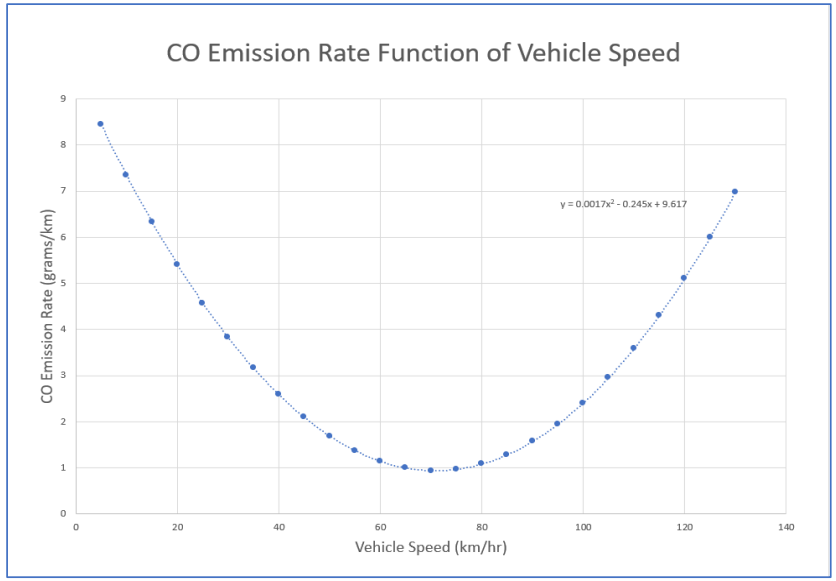


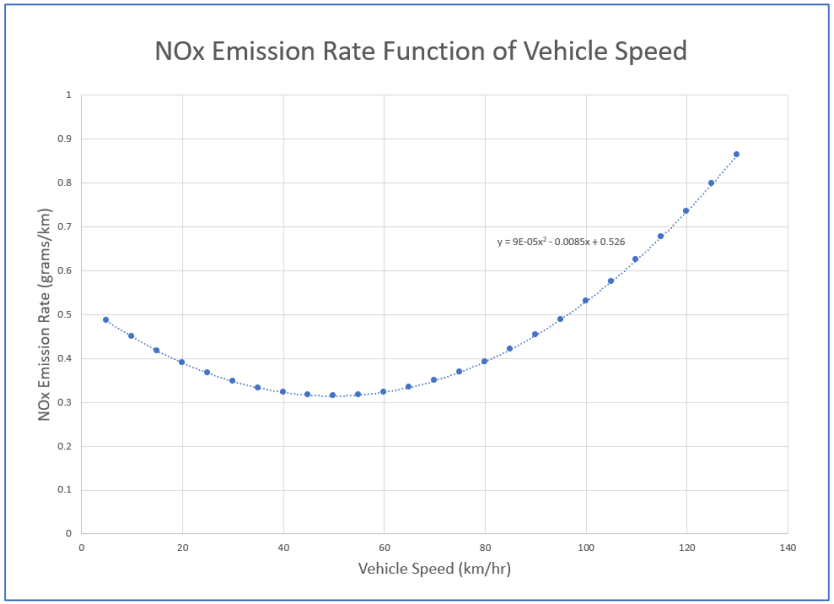
Prathumwan Intersection

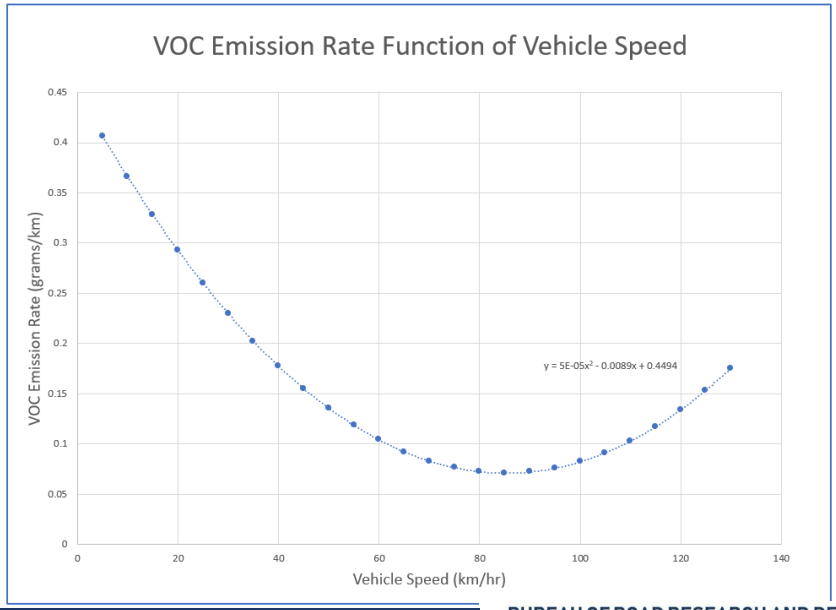
Thank Bangkok Metropolitan Administration (BMA) for data used in this research.

Assumptions:

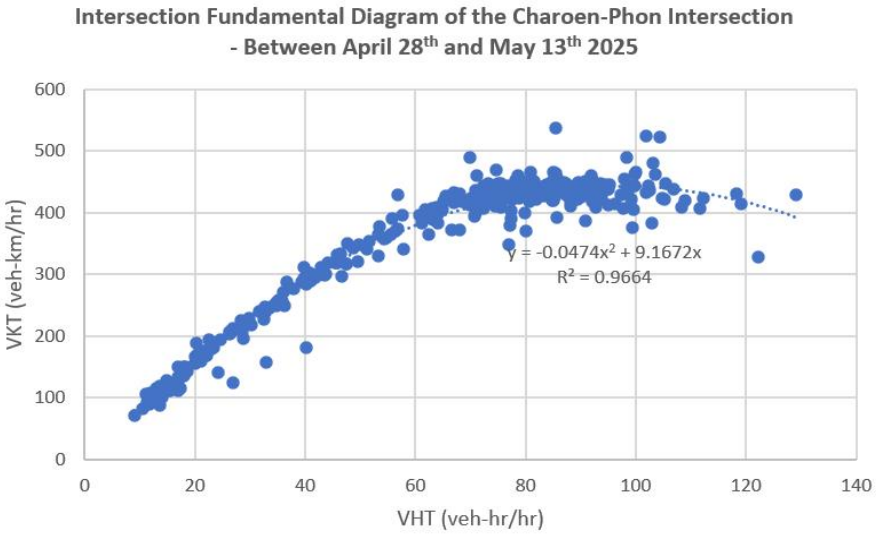
- VOT = 200 THB/veh/hr
- VOE_{CO} = 0.05 THB/gram
- VOE_{VOC} = 1.50 THB/gram
- VOE_{NOx} = 3.00 THB/gram





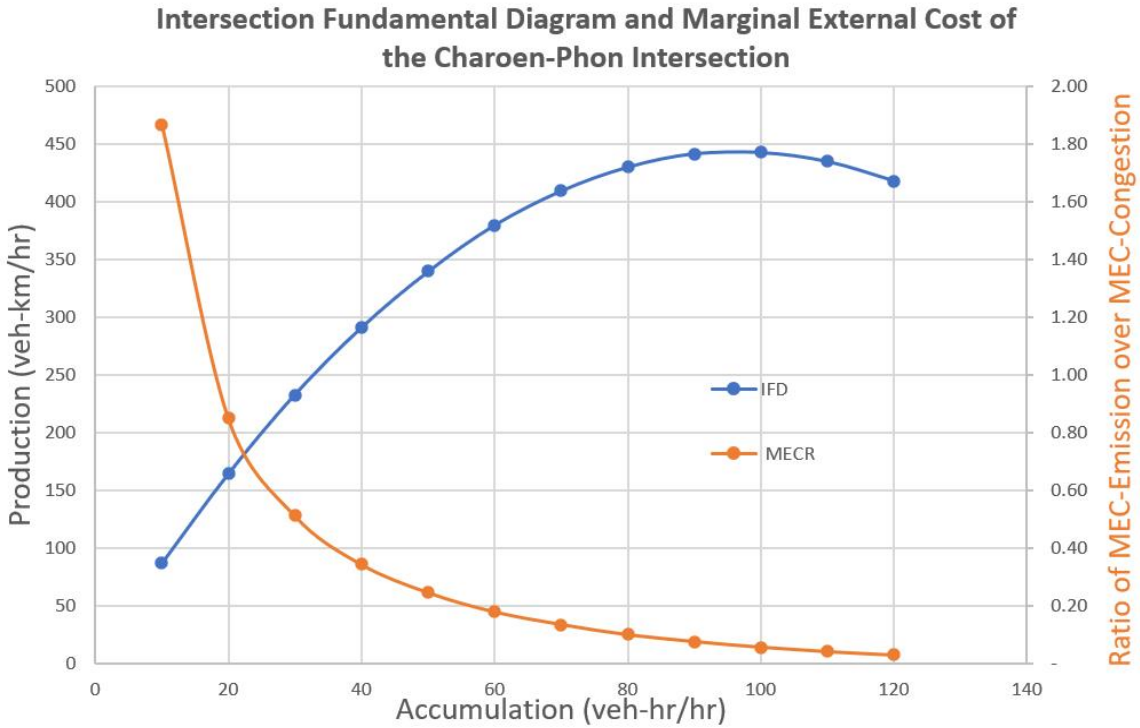


Charoen-Phon Intersection

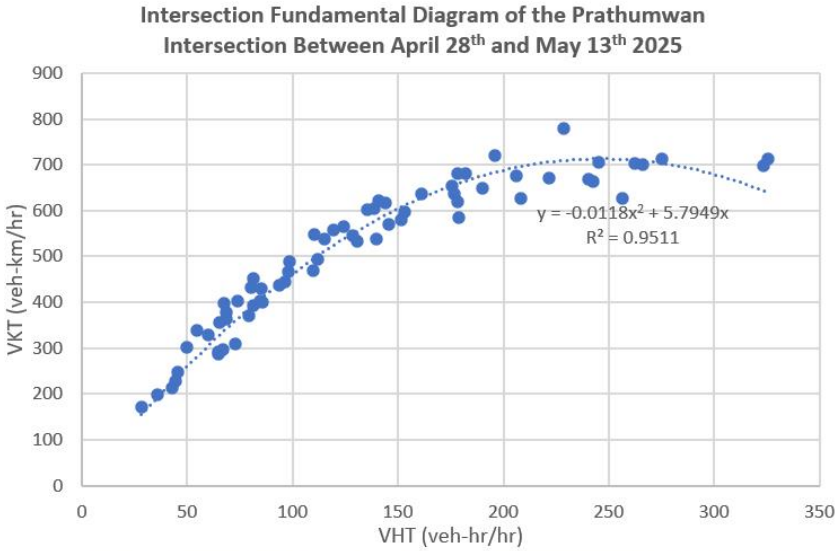


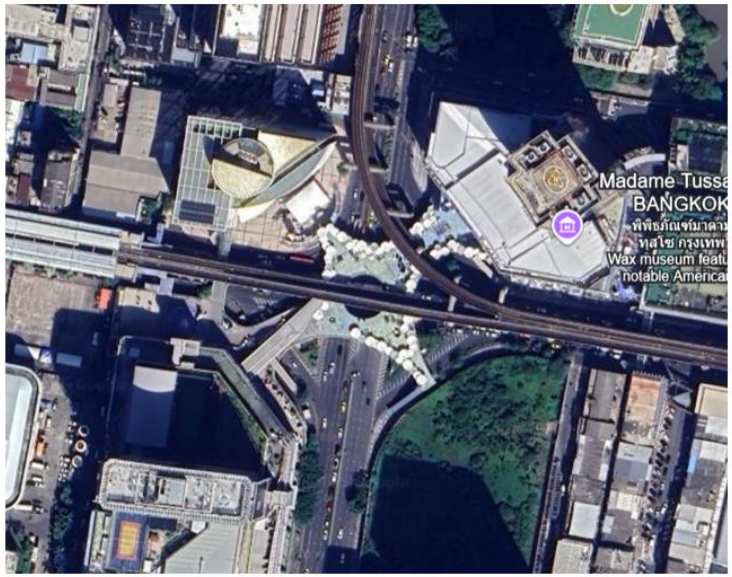


$$\frac{MEC_E}{MEC_C} \geq 1 \; when \; DS_C \leq 0.33$$



Thank Bangkok Metropolitan Administration (BMA) for data used in this research.

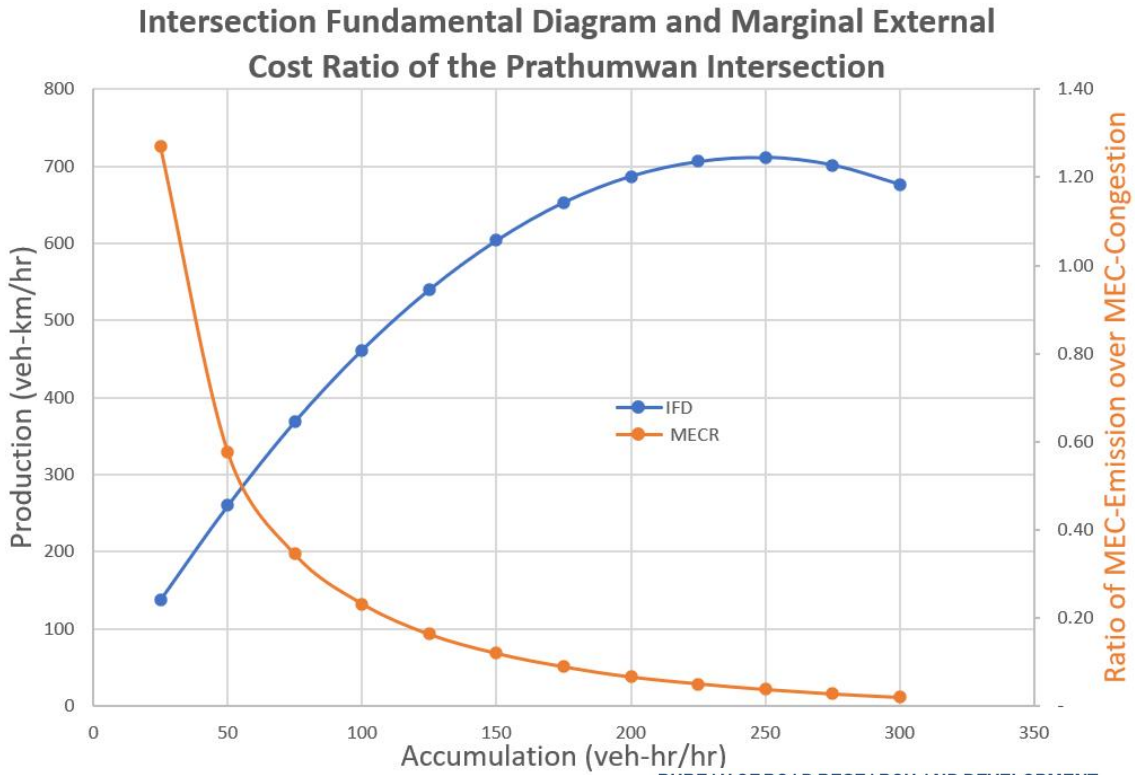




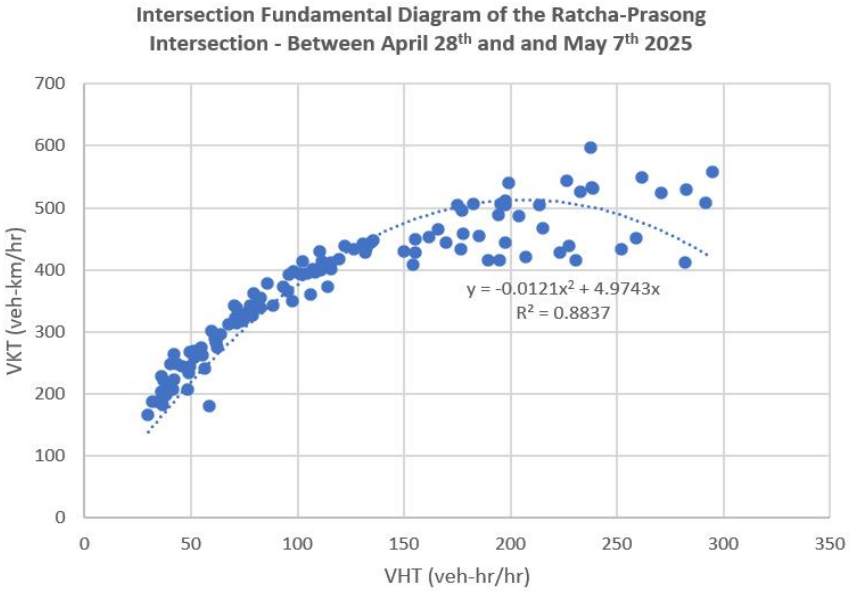
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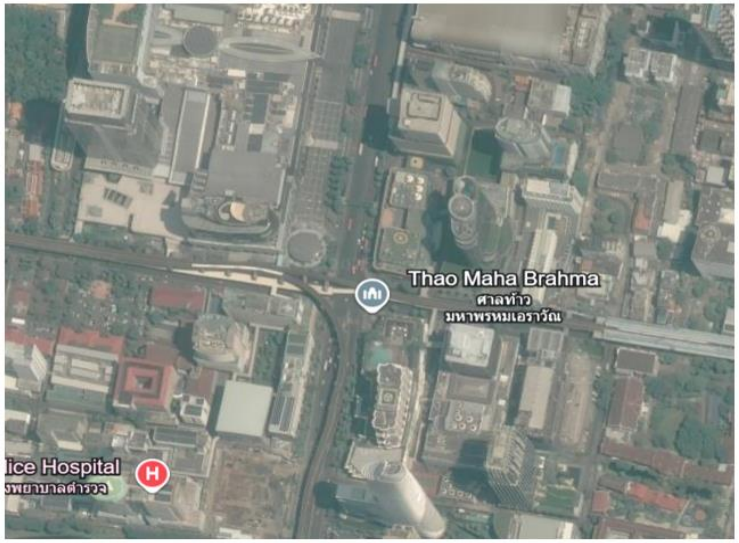
Prathumwan Intersection

$$\frac{MEC_E}{MEC_C} \geq 1 \; when \; DS_C \leq 0.24$$

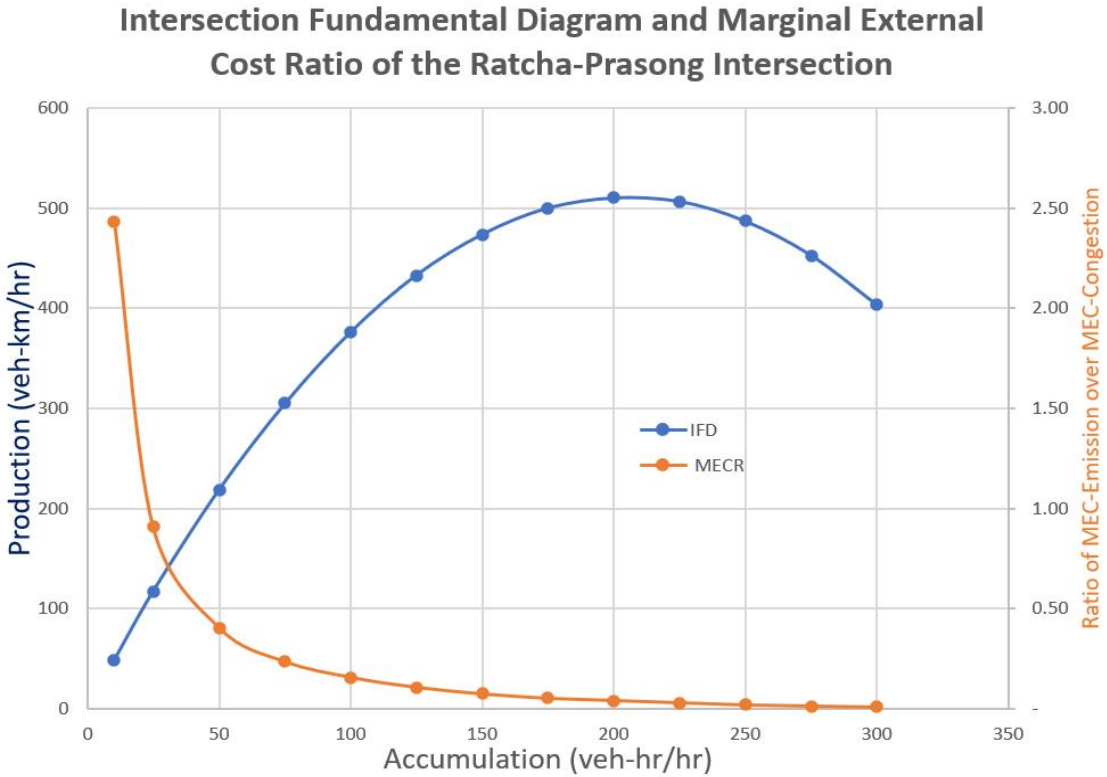


Ratcha-Prasong Intersection





$$\frac{MEC_E}{MEC_C} \geq 1 \; when \; DS_c \leq 0.21$$



Thank Bangkok Metropolitan Administration (BMA) for data used in this research.

Behavior of the MECR (= MEC-E/MEC-C)

As accumulation increases:

- **Numerator (MEC-Emission)** grows slowly.
- **Denominator (MEC-Congestion)** grows quickly.

Therefore:

- At very low accumulation: MECR may be **close to or** above 1, justifying emission-based control.
- At moderate to high accumulation: $\mathrm{MECR} \ll 1$,making delay-based control more economically efficient.

Absence of Economic Justification of emission-based signal control policy?

- At moderate to high accumulation → ***Absence of economic justification***!
- What does it mean? (Policy Implications)
  - Attempting to implement ***emission-based*** signal control - when ***MEC-E << MEC-C*** - risks misallocating resources (***risk public dissatisfaction***) and ***reducing operational efficiency***.
  - This ***absence of economic justification*** (of emission-based signal control policy) is itself ***a valuable policy insight***. It highlights ***the need for complementary approaches***:
    - Electric Vehicle (EV) Adoption
    - Fleet Modernization (cleaner technologies)
    - Low-emission zone

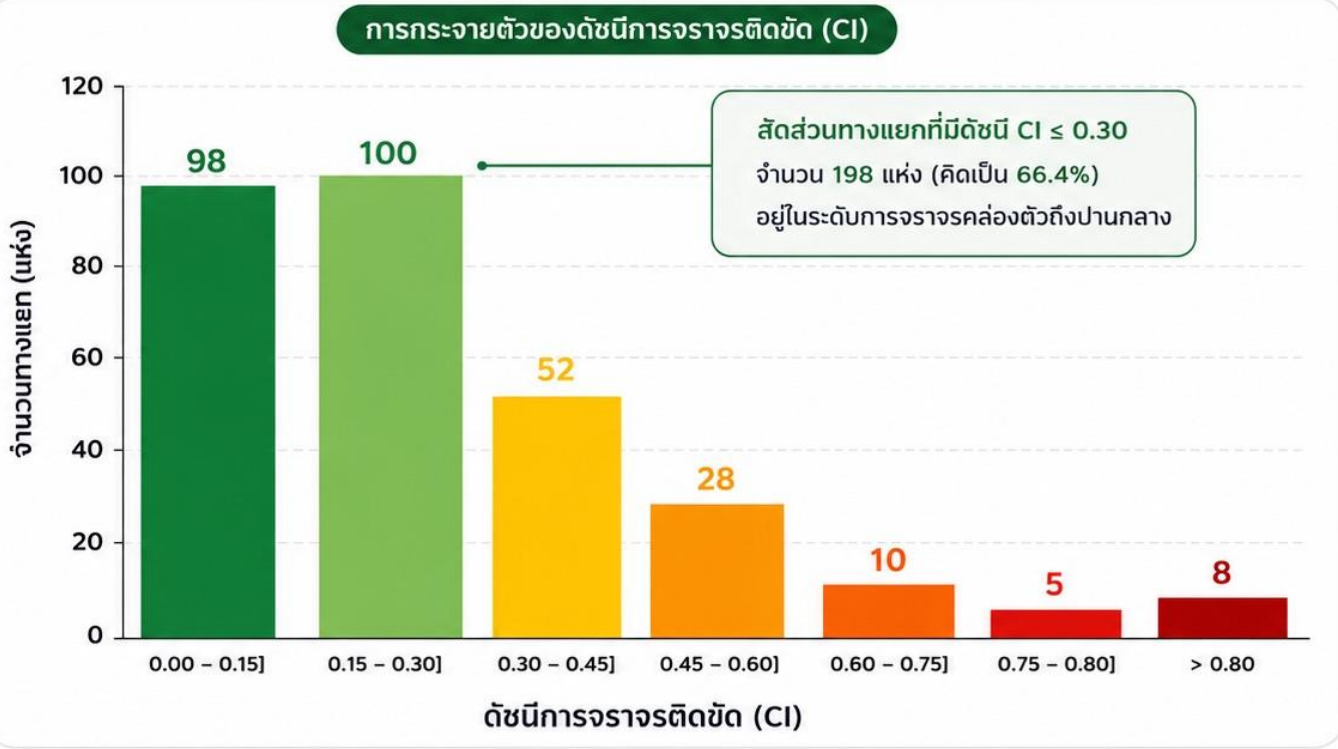
ดัชนีการจราจรติดขัดของทางแยกกรมทางหลวง

หมายเหตุ : ใช้ข้อมูลจากทางแยกที่รู้ปริมาณจราจร

ความหมาย

ดัชนีการจราจรติดขัด (CI)
คือ สัดส่วนระหว่างปริมาณจราจรกับความจุของทางแยก
ค่าเข้าใกล้ 1 แสดงว่าการจราจรหนาแน่น มีแนวโน้มติดขัดสูง

ระดับความหมายของดัชนี (CI)		
	0.00 – 0.15	การจราจรคล่องตัว
	0.15 – 0.30	การจราจรคล่องตัวถึงปานกลาง
	0.30 – 0.45	การจราจรปานกลาง
	0.45 – 0.60	การจราจรค่อนข้างหนาแน่น
	0.60 – 0.75	การจราจรหนาแน่น
	0.75 – 0.80	การจราจรหนาแน่นมาก
	> 0.80	การจราจรติดขัดมาก



ทางแยกส่วนใหญ่มีดัชนีการจราจรติดขัดไม่เกิน 0.30 ➡ จำนวน 198 แห่ง (66.4%)

ที่มา : โครงการศึกษาและพัฒนาวิธีการคำนวณสัญญาณไฟจราจรแบบตั้งเวลาเพื่อลดมลพิษทางอากาศ กรมทางหลวง พ.ศ. 2568

What we learn?

- Emission-based control is not universally justified.
- Economic hierarchy of externalities (congestion VS emissions).
- Complementary strategies are needed? (e.g. EVs, Low-emission zones).
- Control-policy design must be adaptive.

Future Research

- Integrate MECR into real-time adaptive signal control systems.
- Evaluate EV penetration's impact on MECR thresholds.
- Broader discussions on externalities and social goals of traffic management!



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Emission-based signal control policy: is there economic justification?

Ponlathep Lertworawanich

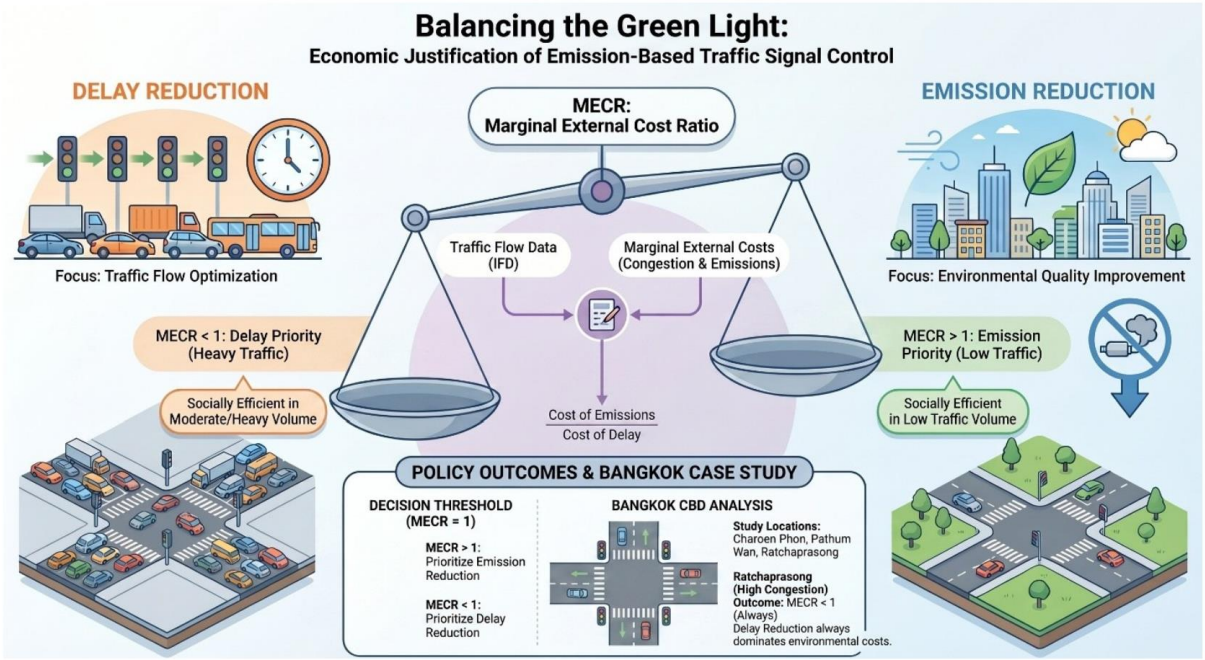
Department of Highways, 2/486 Sri-Ayudhaya Road, Ratchatevi, Bangkok, Thailand

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Economic justification

ABSTRACT

Urban traffic signal control has traditionally focused on reducing delay, often without accounting for the environmental externalities associated with vehicle emissions. This study introduces the Marginal External Cost Ratio (MECR) as an economic screening metric to assess when emission-oriented signal control is justified at urban intersections. Using operational data from three locations in Bangkok's central business district, MECR is computed from Intersection Fundamental Diagram (IFD) variables to compare the marginal external costs of congestion and emissions under different traffic states. The results show that emission-focused control is economically justified only under low traffic accumulation, whereas delay-minimizing control becomes preferable once accumulation reaches moderate or high levels due to the rapid growth of congestion externalities. A sensitivity analysis further demonstrates that lower emission-rate functions—a reasonable proxy for higher electric-vehicle penetration or cleaner fleet composition—reduce the range of traffic conditions under which emission-priority would be warranted, thereby strengthening the predominance of delay-oriented strategies. The MECR framework provides a transparent, data-driven basis for evaluating the external-cost implications of signal-control policies and supports the development of context-sensitive approaches for sustainable urban traffic management.



Lertworawanich, P. (2026). Emission-based signal control policy: Is there economic justification? *Transport Policy*, 184, 104195. https://doi.org/10.1016/j.tranpol.2026.104195

THANK YOU