Applied Scientific Research:
From Lab to Field

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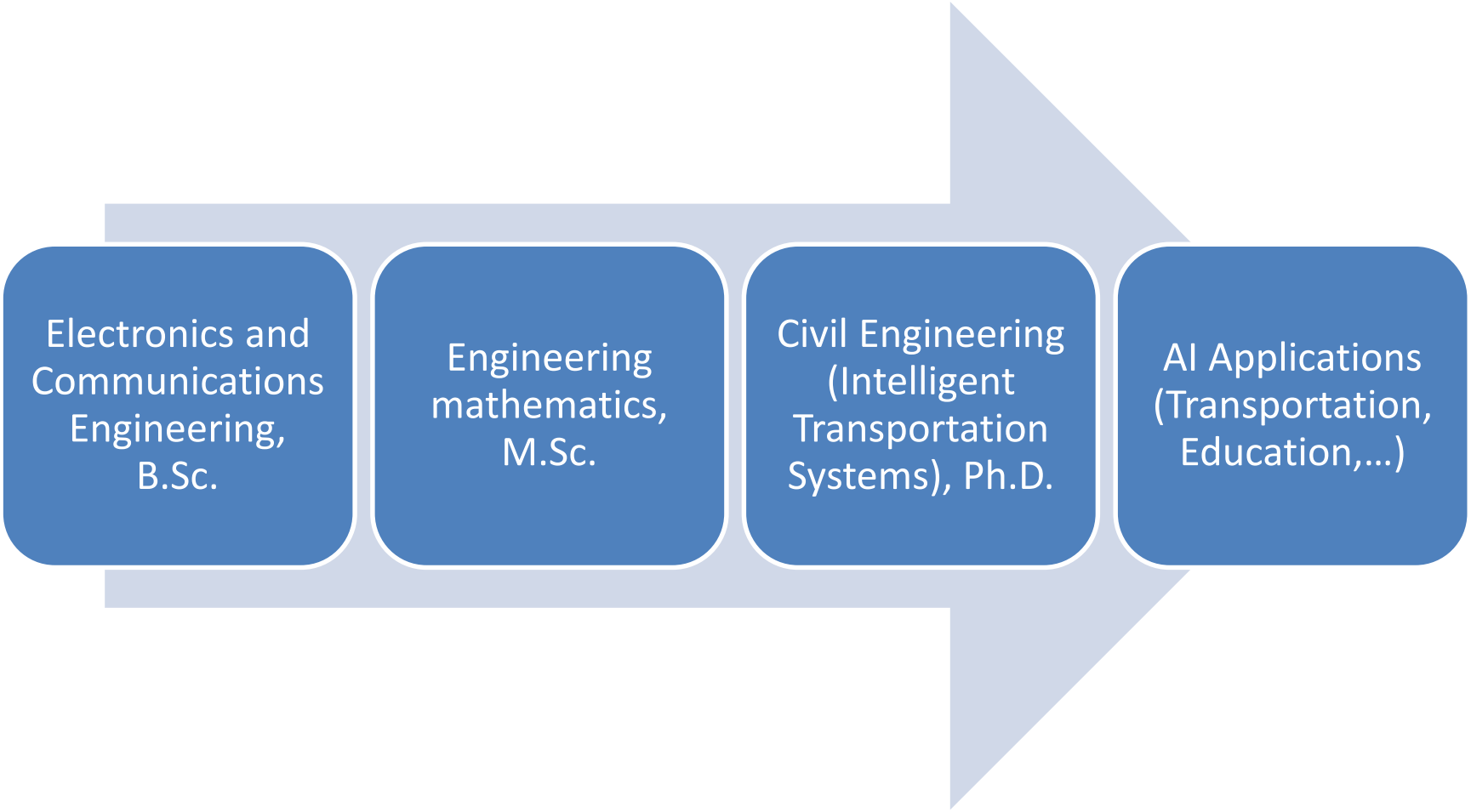
2/07/2018

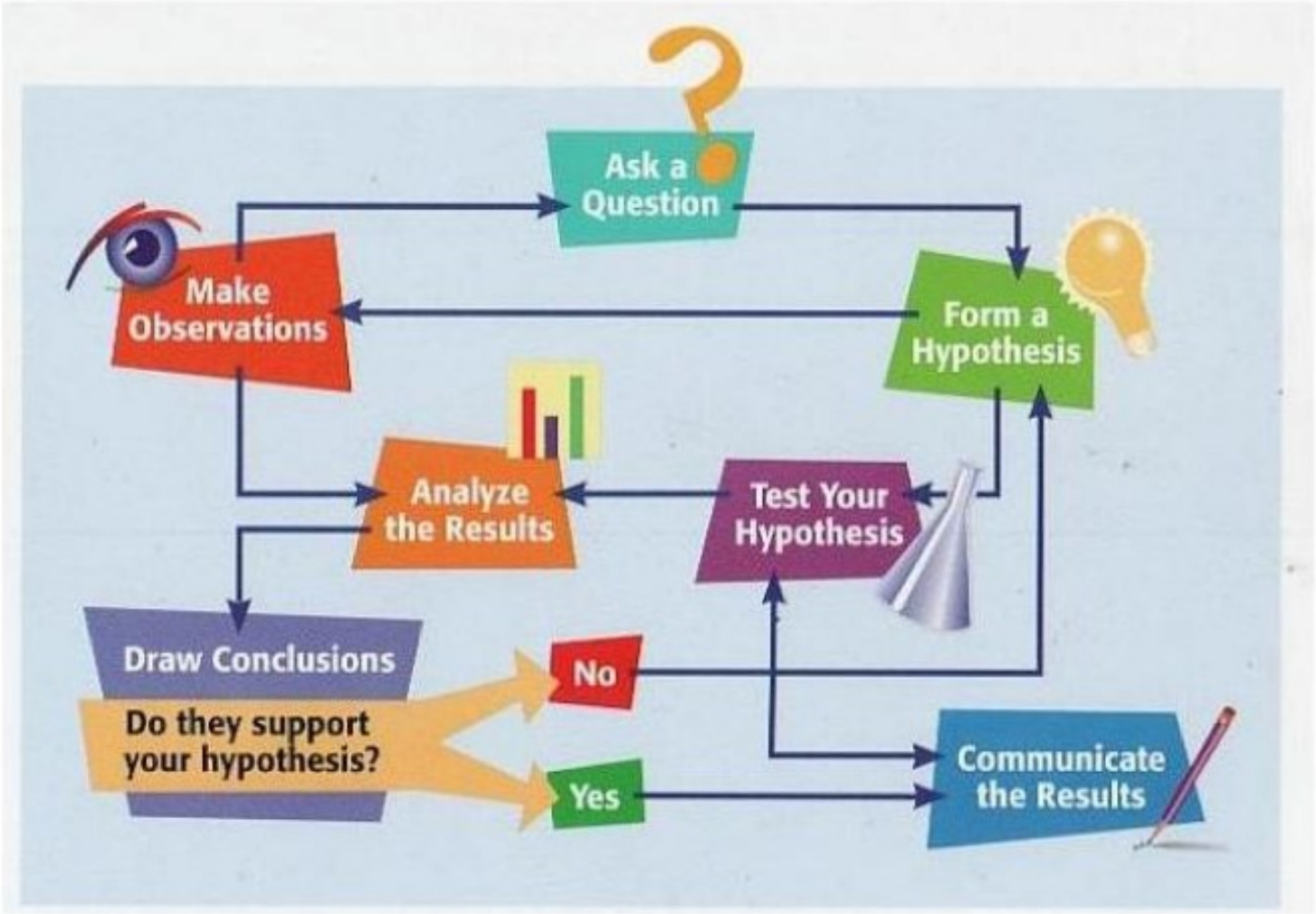
My Academic Career Journey



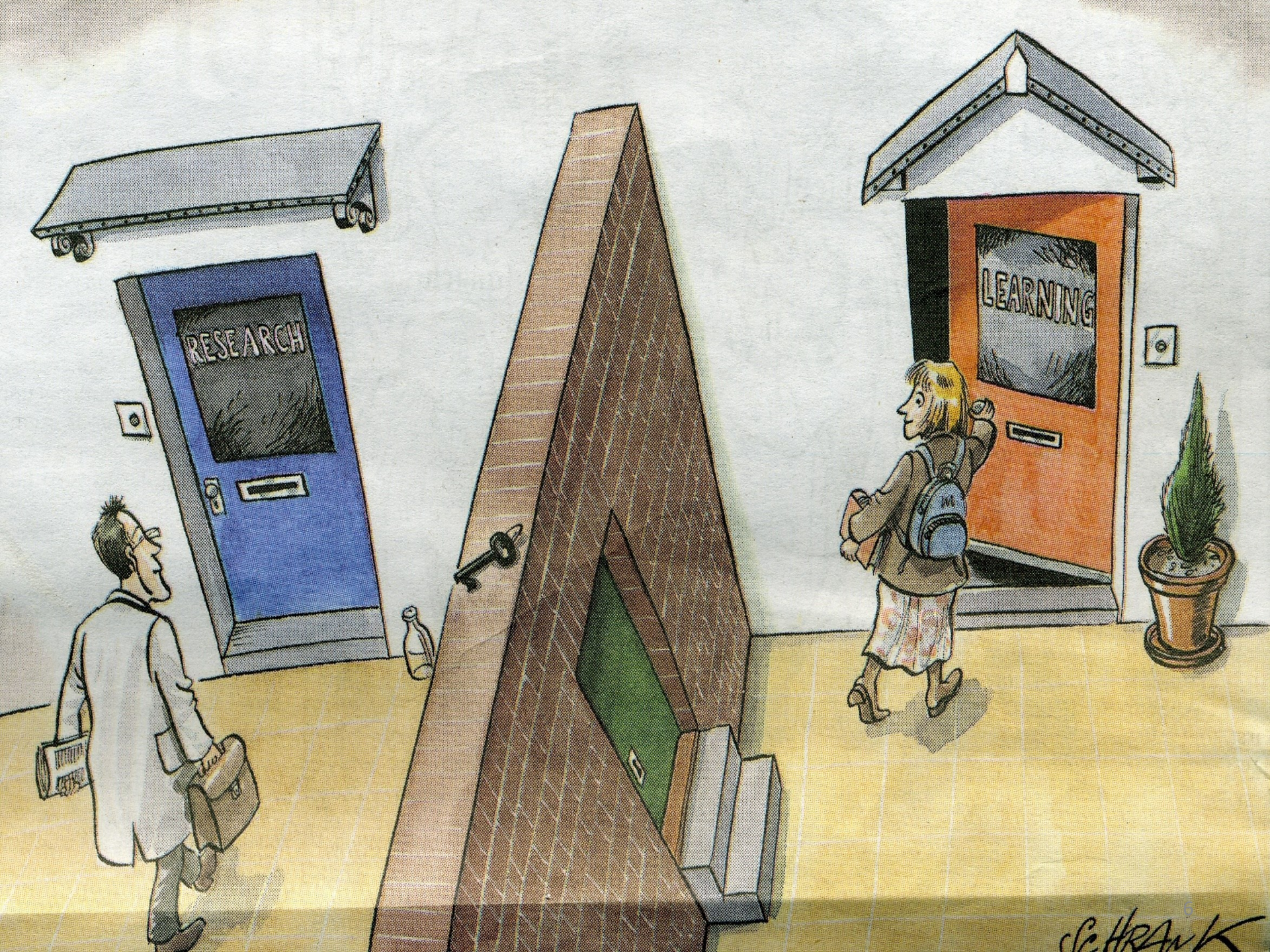
Agenda

- I: What is research? The Scientific Research Process
- II: Why is Research?
- III: A Journey of An Applied Scientific Research Example From Lab to Reality
- IV: When to Start Research?
- V: What do you need to know before starting your research?

I. Scientific Research Process



Have you conducted scientific research before?


RESEARCH
LEARNING

II. Why Do We Need to Conduct Research?

Research is a Key Driver of Innovation

"I believe in innovation and that the way you get innovation is you fund research and you learn the basic facts." – Bill Gates

Why should we conduct Research?

- *To develop knowledge for professions.*
- *To develop effective policies.*
- *To solve practical problems.*
- *To make informed decisions.*
- *To increase the knowledge base of larger society.*

Huge amounts of daily life and experience in our society are based on what we have learned using the logic and evidence involved in scientific research.

III. Taking Research From Lab to Field

Smart Traffic Lights that Learn !

Multi-**A**gent **R**einforcement **L**earning for **I**ntegrated **N**etwork of Adaptive Traffic Signal Controllers

M A R L I N

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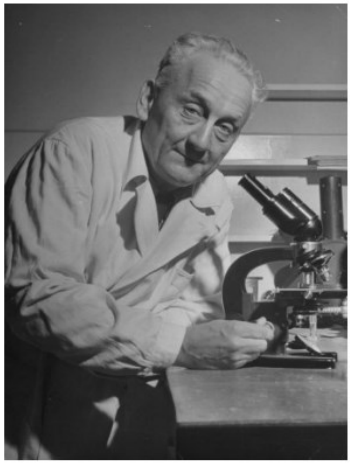
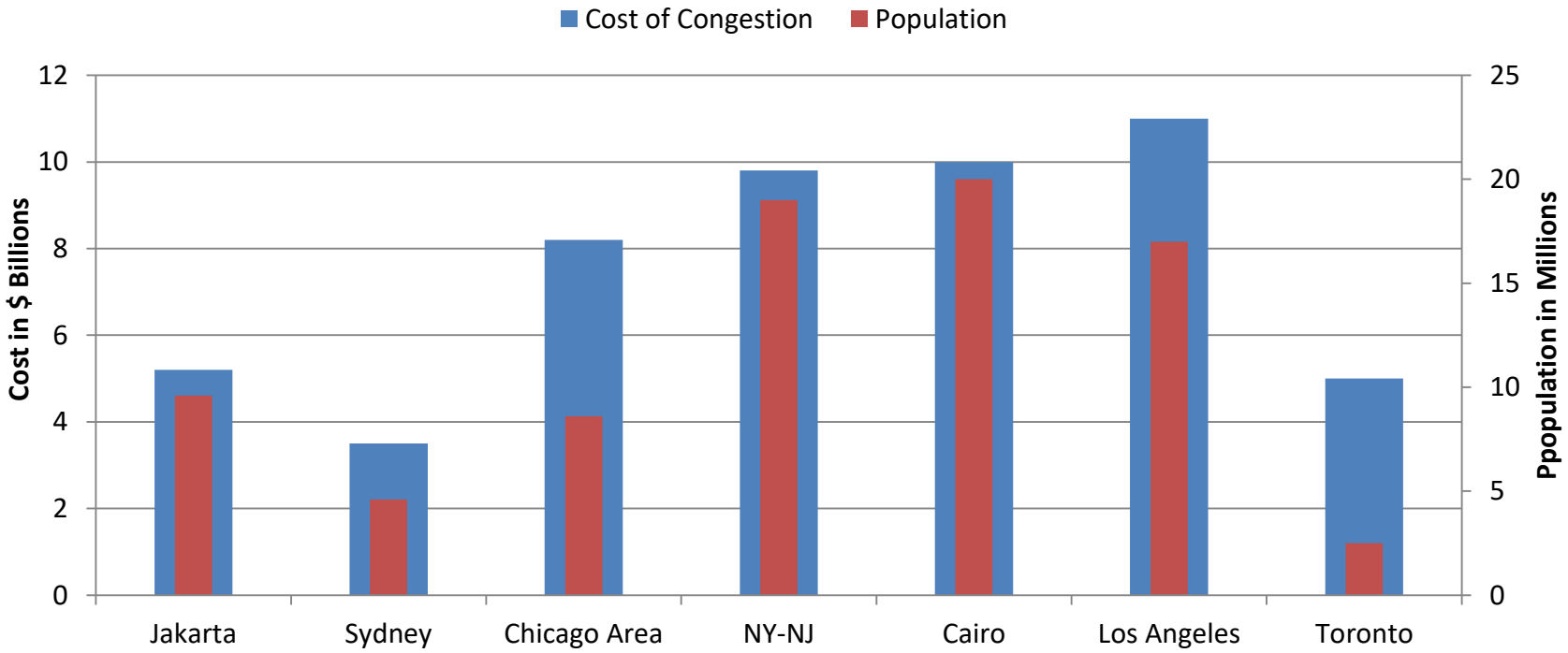
UNIVERSITY OF TORONTO

1. Make An Observation

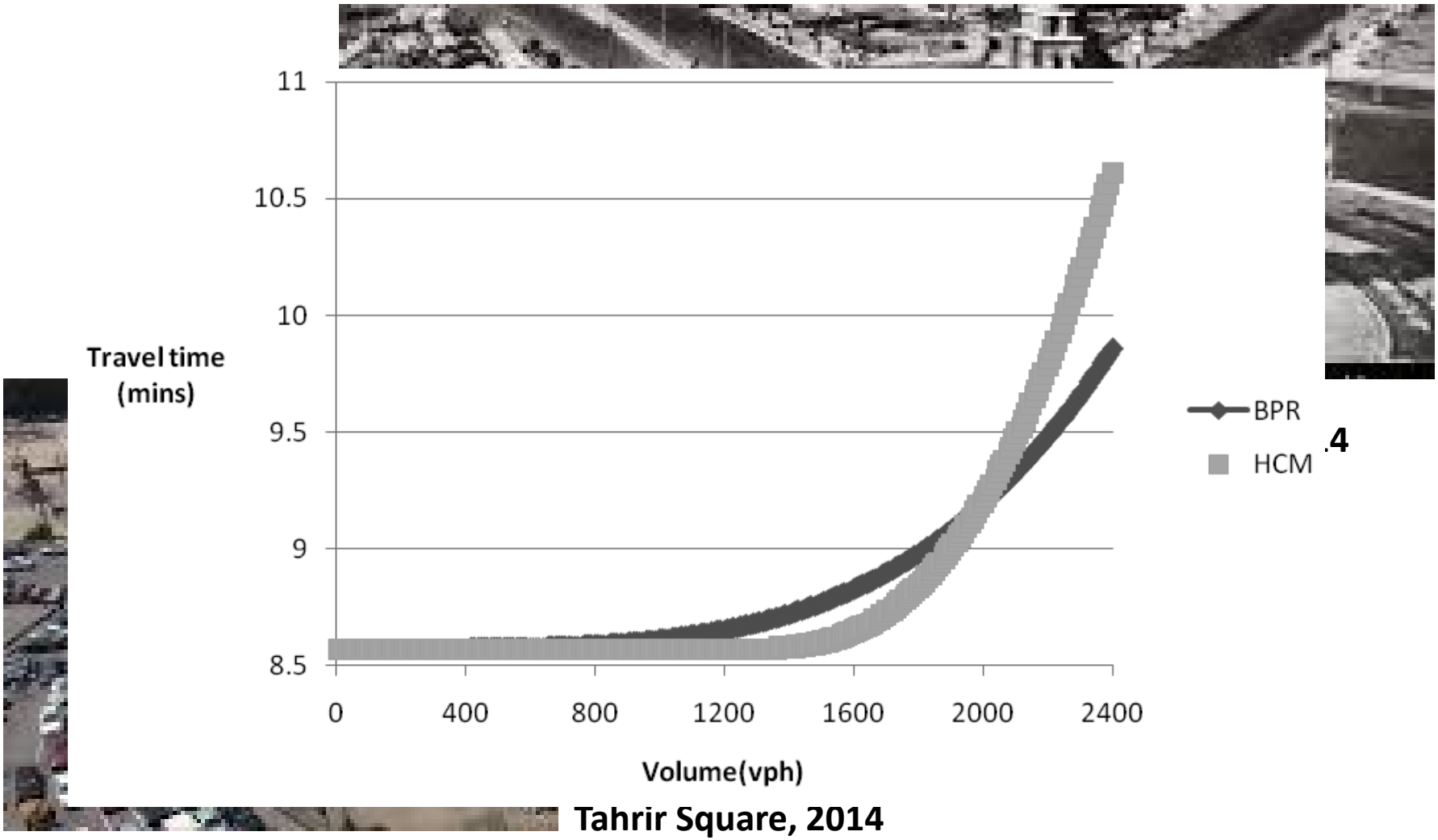
“Research is to see what everyone else has seen, but thinking what no one else has thought.”
— Albert Szent-Gyorgyi



Traffic Congestion: Urban CANCER



Traffic Congestion Problem



Tahrir Square, 2014

2. Define a Problem Statement and Formulate a Research Question

“The scientist is not a person who gives the right answers, he's one who asks the right questions.” — Claude Lévi-Strauss

What is a problem statement?

- A problem statement addresses both the "why" (the specific aim or purpose of the study) and the "what" (the central research question or a set of questions) of the research

- There are three key criteria for a good problem statement; it should be:
  a) relevant
  b) feasible
  c) interesting

Traffic Congestion Solutions

Less Dema

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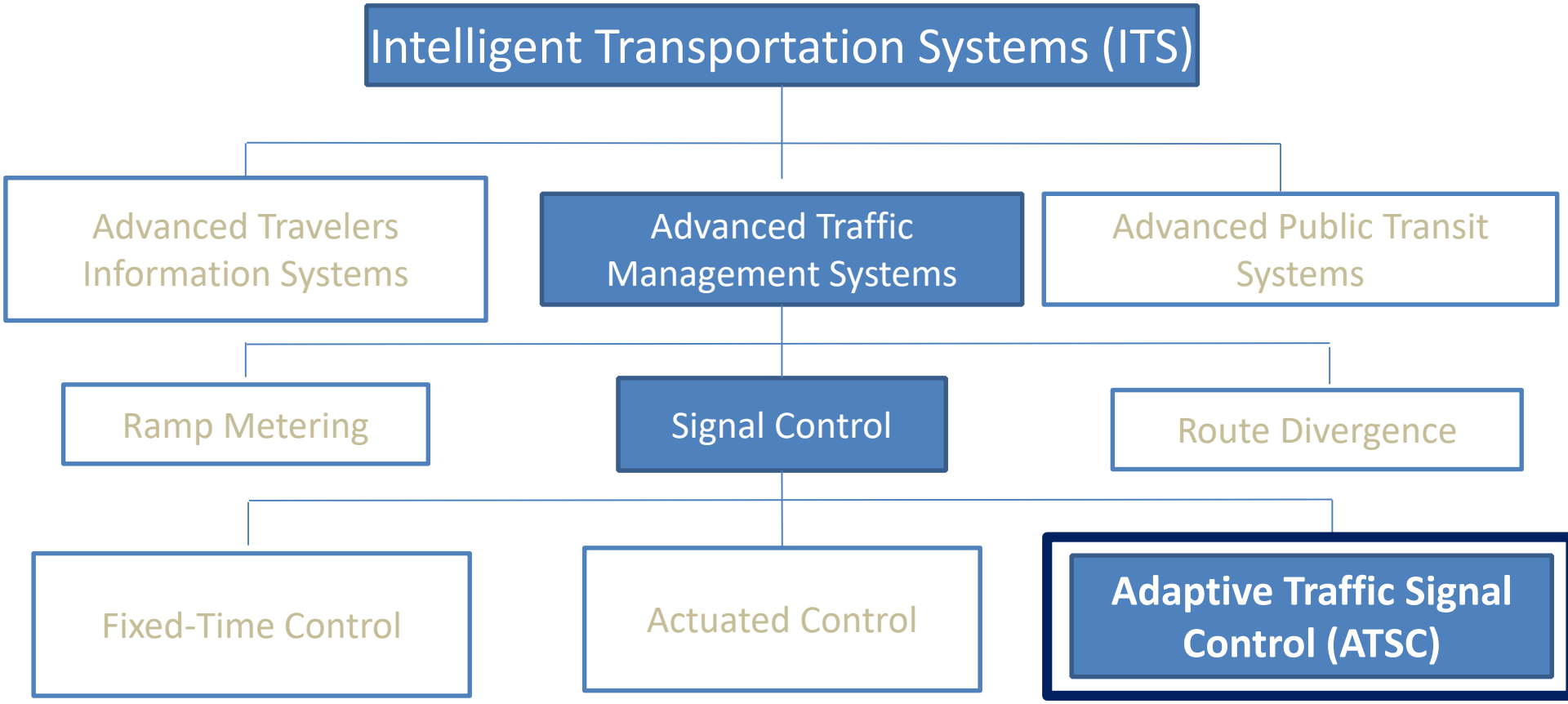
Intelligent Transportation Systems



3. Gather Information Literature Review

"إن الباحث عن الحقيقة ليس هو من يدرس كتابات القدماء، على حالتها ويضع ثقته فيها، بل هو من يُعلّق إيمانه بهم ويتساءل ما الذي جناه منهم. هو الذي يبحث عن الحجة، ولا يعتمد على أقوال إنسان طبيعته يملأها كل أنواع النقص والقصور. وبالتالي فإن من الواجب على من يحقق في كتابات العلماء، إذا كان البحث عن الحقيقة هدفه، هو أن يستنكر جميع ما يقرأه، ويستخدم عقله حتى النخاع لبحث تلك الأفكار من كل جانب. وعليه أن يتشكك في نتائج دراسته أيضًا، حتى يتجنب الوقوع في أي تحيز أو تساهل"

Ibn al-Haytham

What is literature?

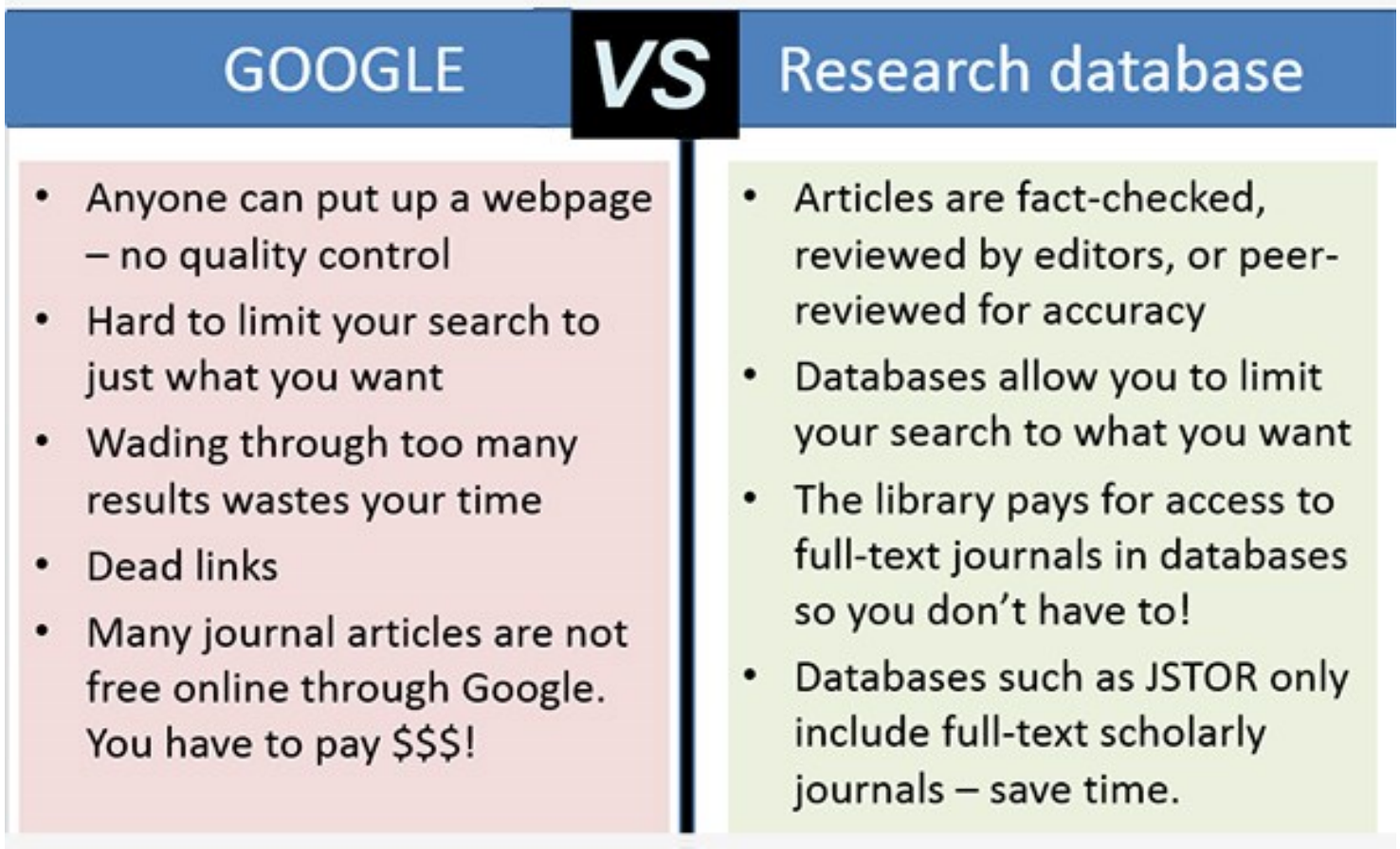
- Literature – the body of knowledge available to you or what is already known and written down that is relevant to your research project.

- A literature review is a process that involves the identification of published work on the topic of interest, the evaluation of this work in relation to the problem, and the documentation of this work.

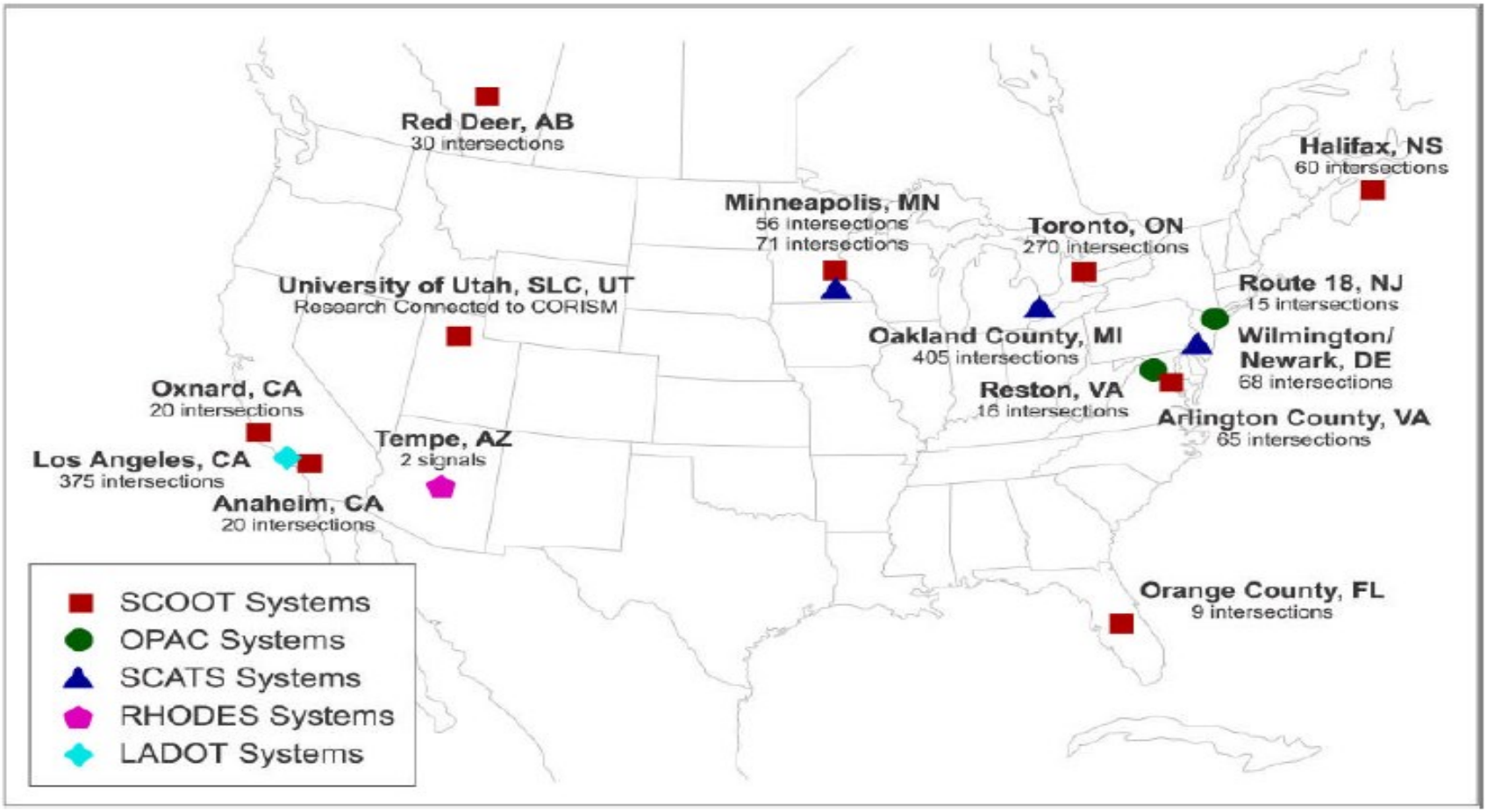
A literature review ensures that:

1. Put your research into context
2. You do not run into the risk of "reinventing the wheel"
3. You look at your problem from several angles
4. You didn't miss an important variable
5. You know the research methods

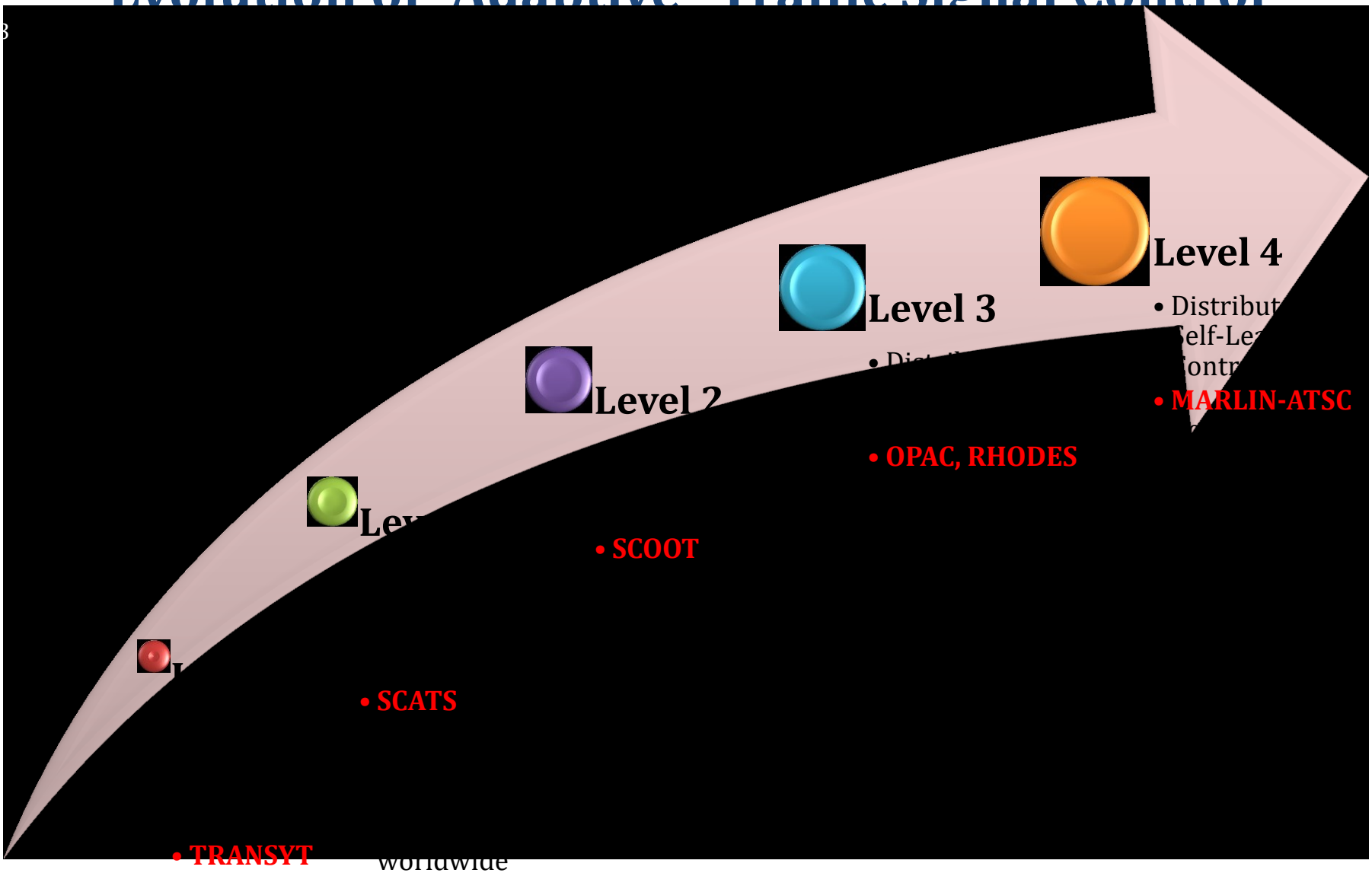
Research Database



ATSC in North America



Evolution of "Adaptive" Traffic Signal Control

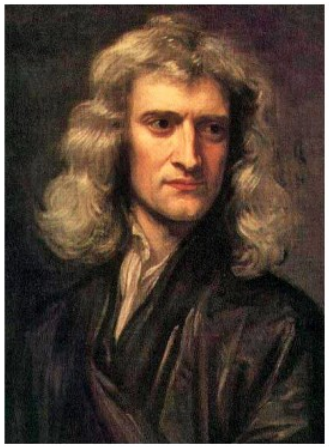


Issues with Leading ATSC Technologies

Centralized	• Expensive • Not scalable • Not robust
Model-Based	• Relying on an accurate traffic modelling framework • the accuracy of which is questionable
Curse of Dimensionality	• Increasing the complexity of the system exponentially with the increase in the number of intersections/controllers
Human Intervention Requirements	• Requiring highly skilled labour to operate due to their complexity.

4. Hypothesis Construction

“No great discovery was ever made without a bold guess.”
— Sir Isaac Newton

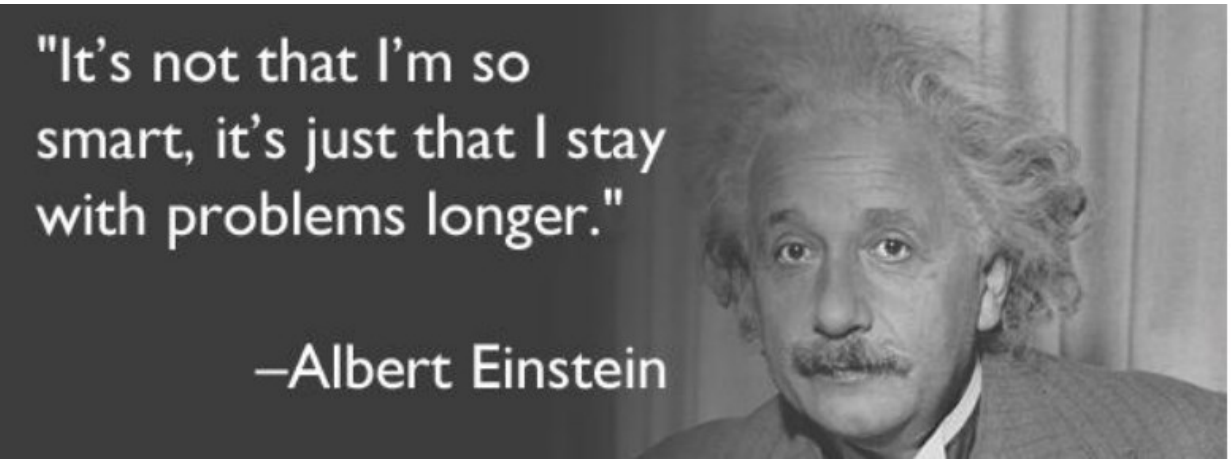


In a Nutshell

- **Grand objective**
  - Intersections "talk to each other"
  - Each is affected by what is happening upstream
  - Each affects what is happening downstream –
  - Whole network control in one shot from a grand brain is the dream
- **Issue**
  - Intractable theoretically
  - Too complex practically
  - Requires massive and very expensive communication
- **Solution??**
  - Decentralized
  - Self learning: **agents learn to control** their local intersection
  - Game theory based: **agents learn to collaborate**

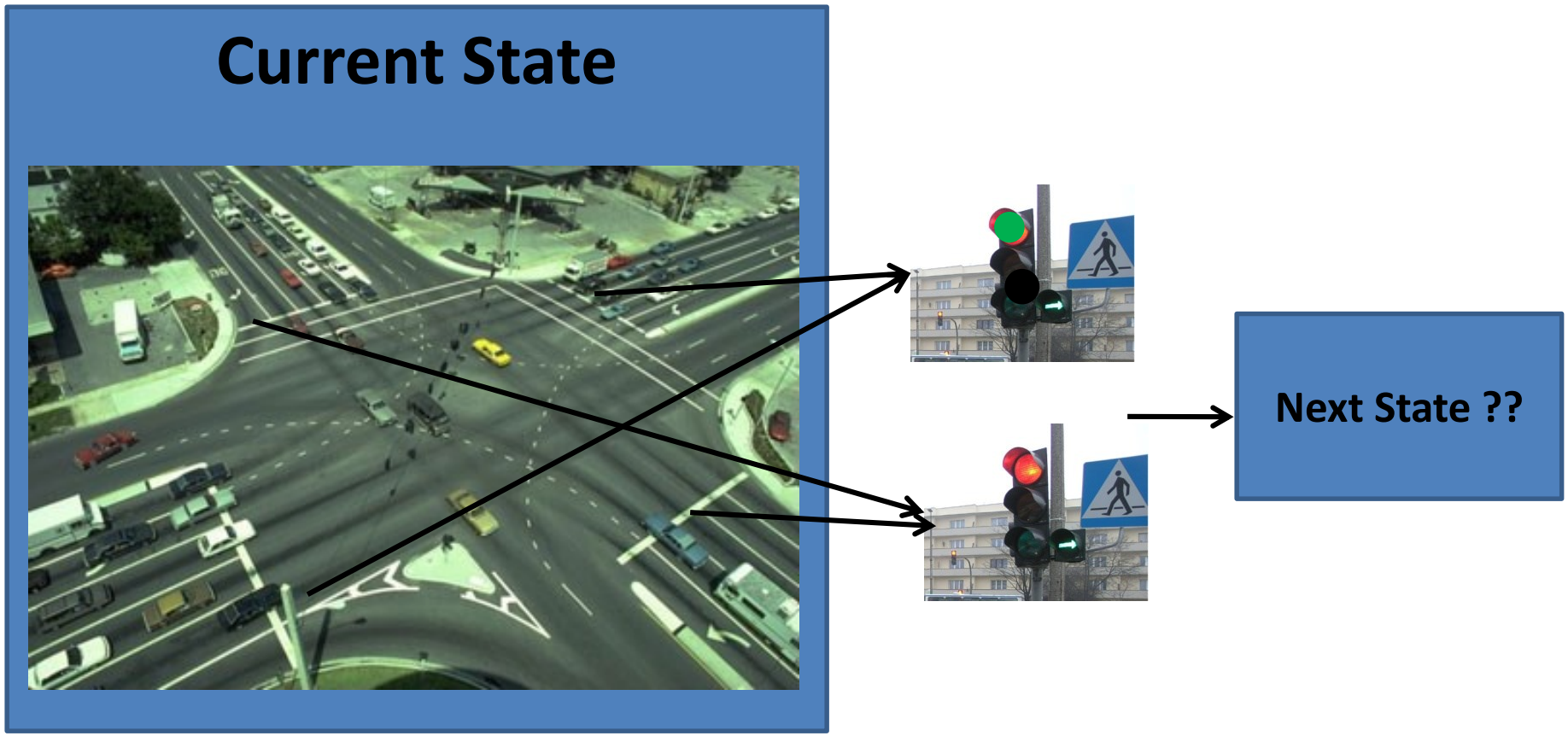
5. Define Methodology and Do Experiments

What if things go wrong ?!!



Traffic Signal Control Problem

Markov Decision Process



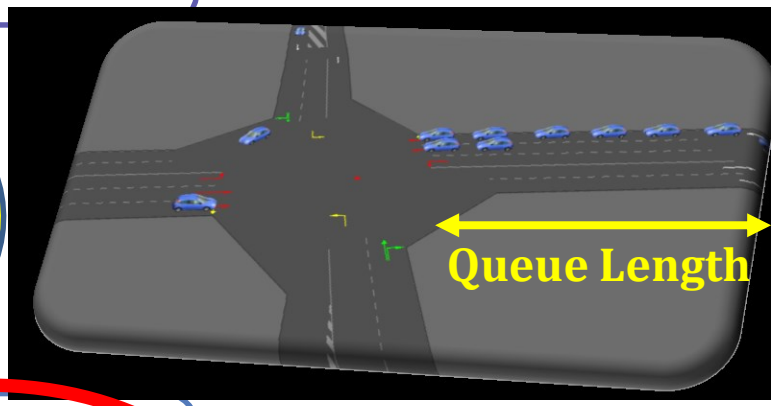
Markov Decision Process

Dynamic Programming

- Queue Length
  - Short (S1)
  - Long (S2)

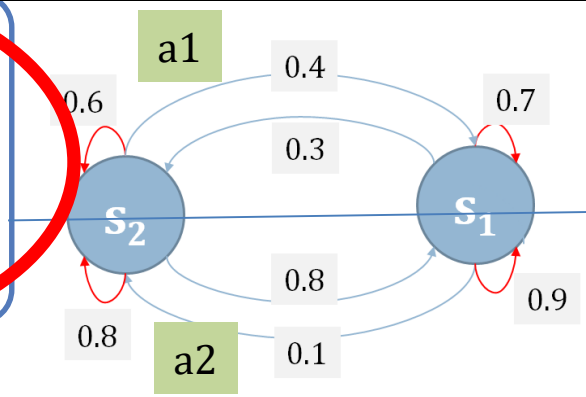
- Extend Green (a1)
- Switch to Minor Street (a2)

Optimal *Control Policy* that maximizes the expected long-term reward



- (-1)* Delay

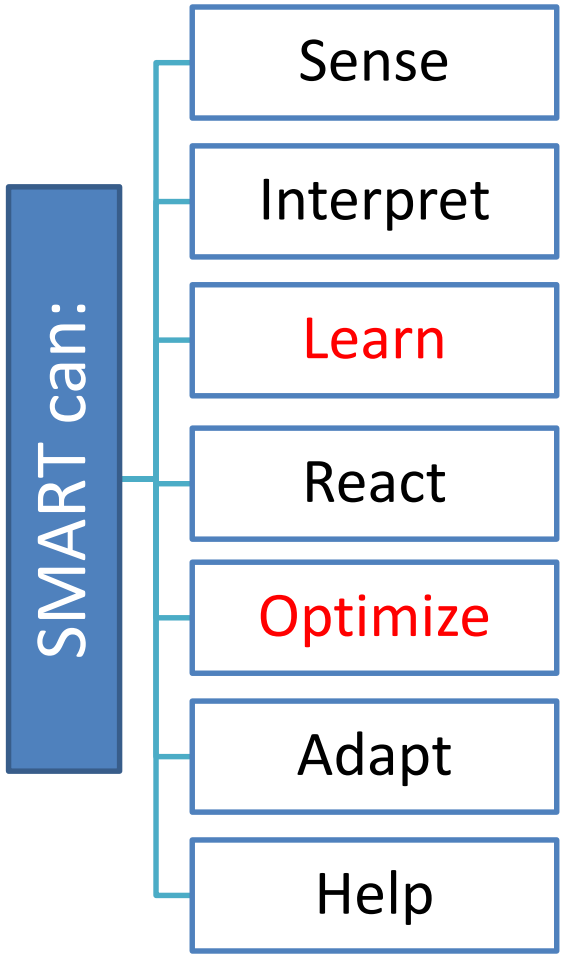
- The **T**ransition **P**robability **M**atrices (TPM)



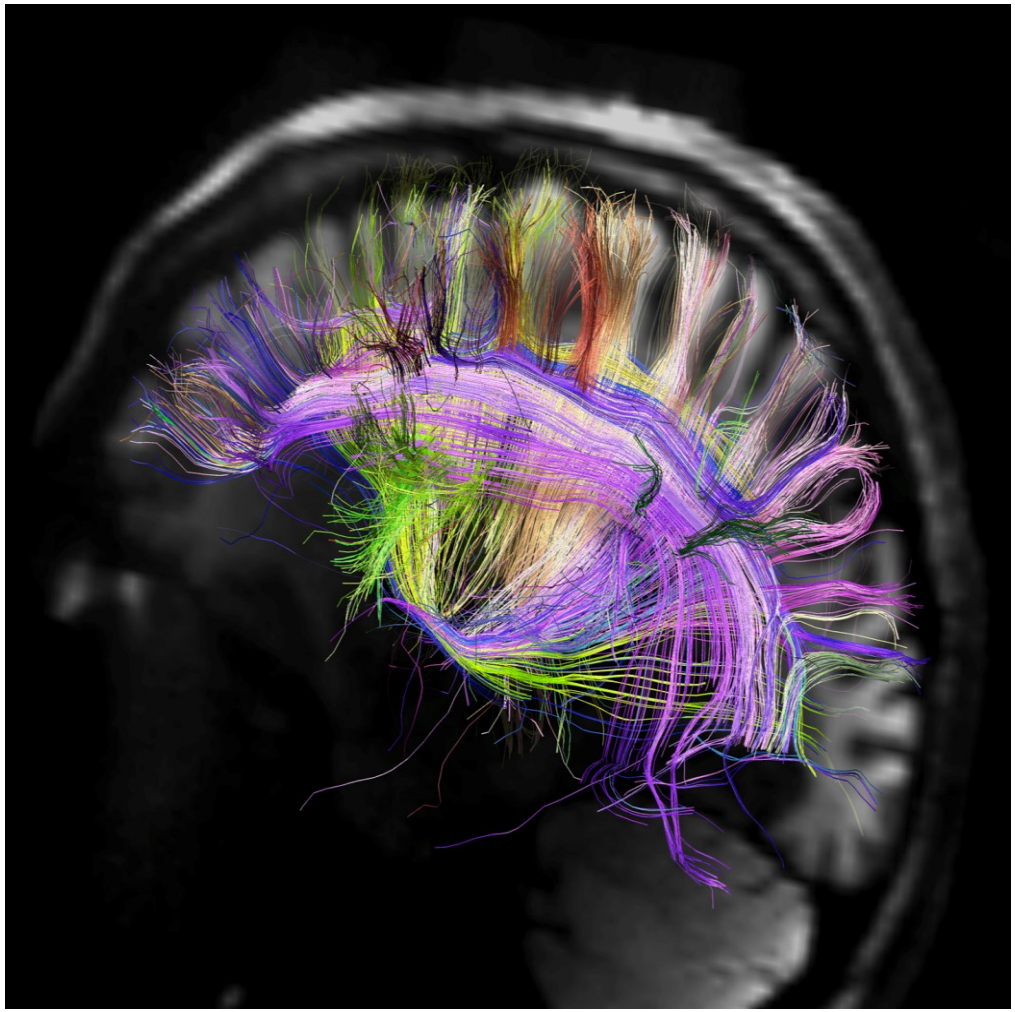
Curse of Modeling

Curse of Dimensionality

Smart / Intelligent Machine?



The Most Intelligent Machine Known to Man?

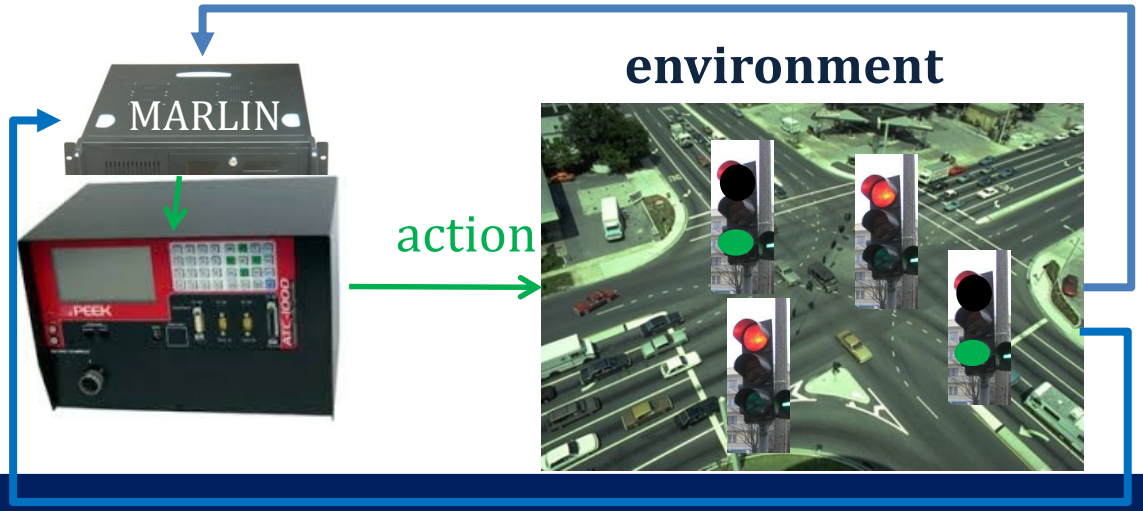


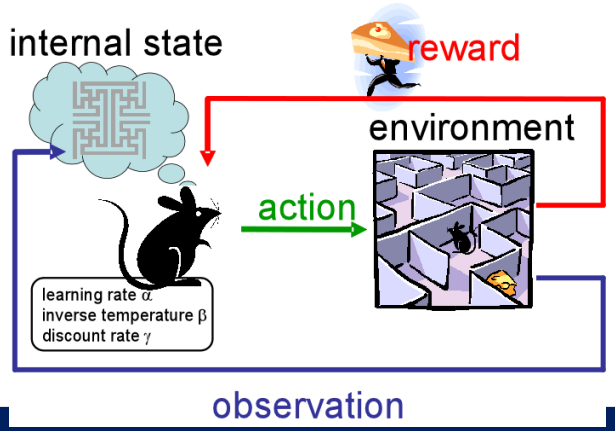
Artificial Intelligence Method
Reinforcement Learning

Q Table

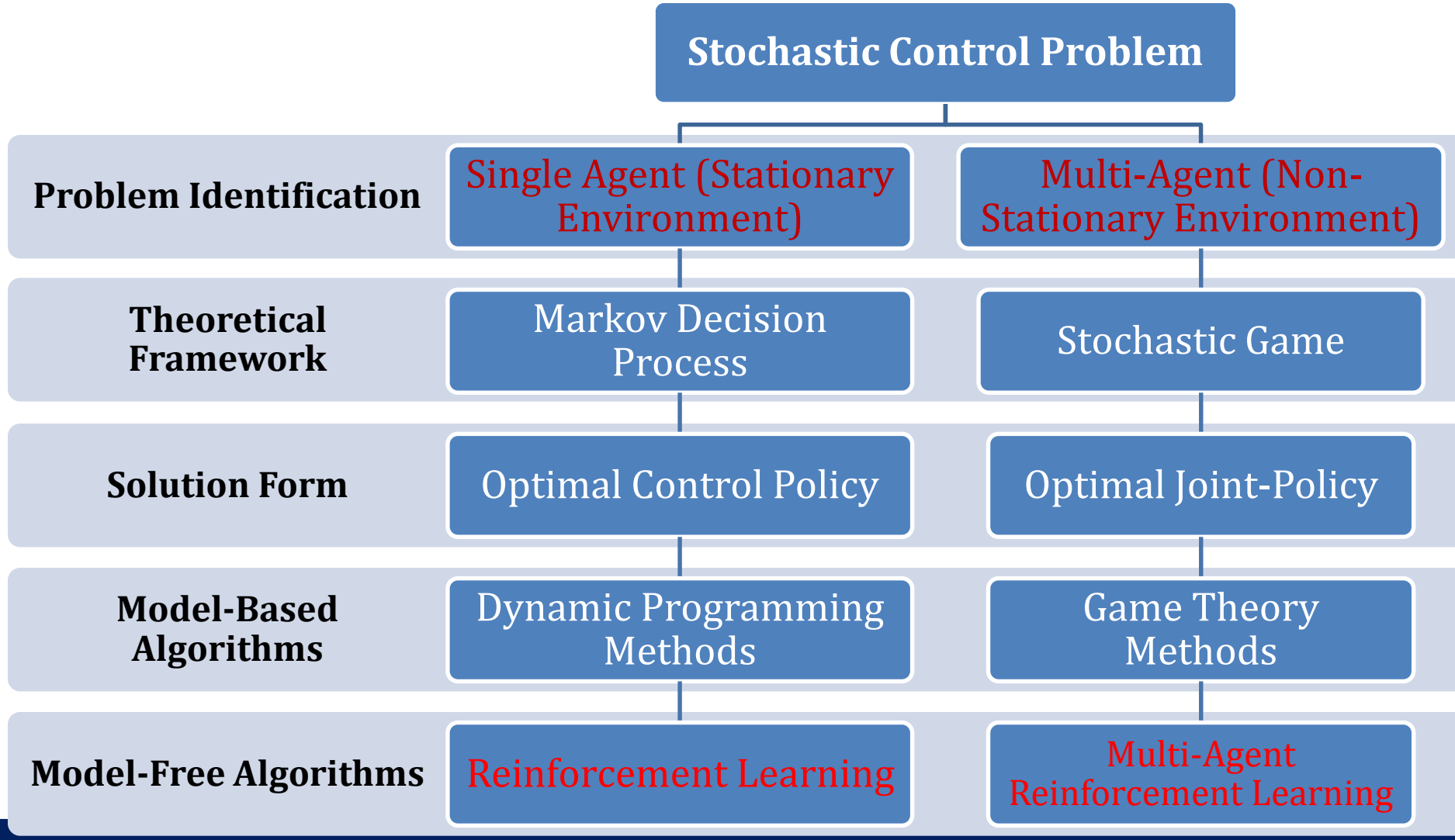
Q	a_1	a_2
s_1	-10	-5
s_2	-3	-15

Reward (savings in delay)



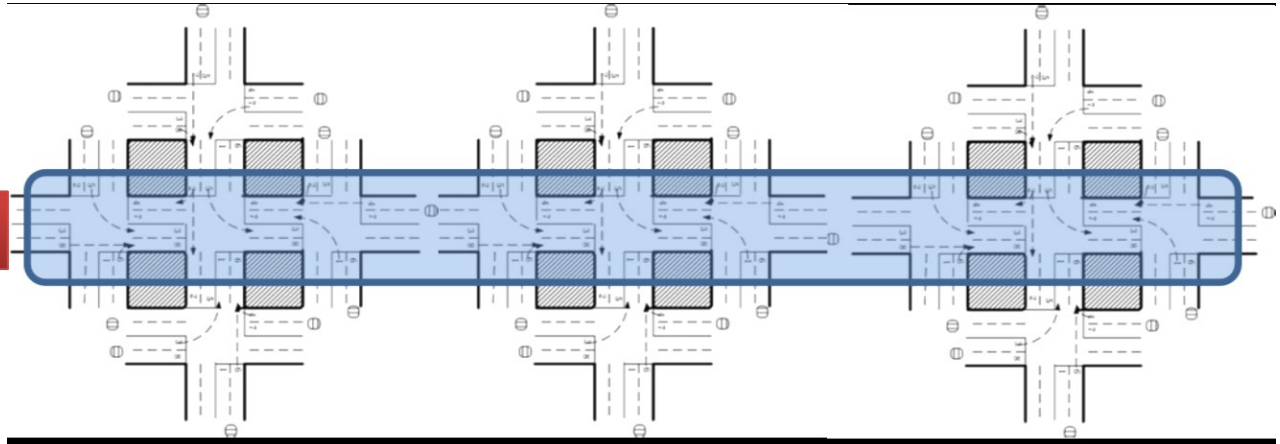


Single vs. Multiple Agents:
MARLIN Independent vs Integrated

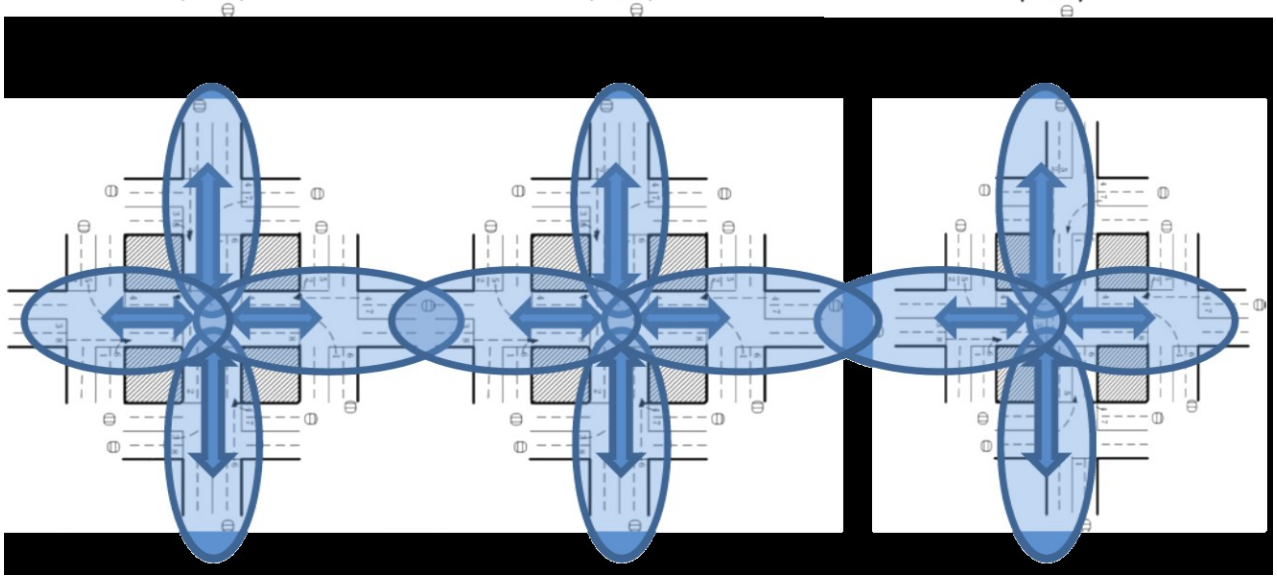


Corridor Synchronization Vs. Network-Wide Coordination

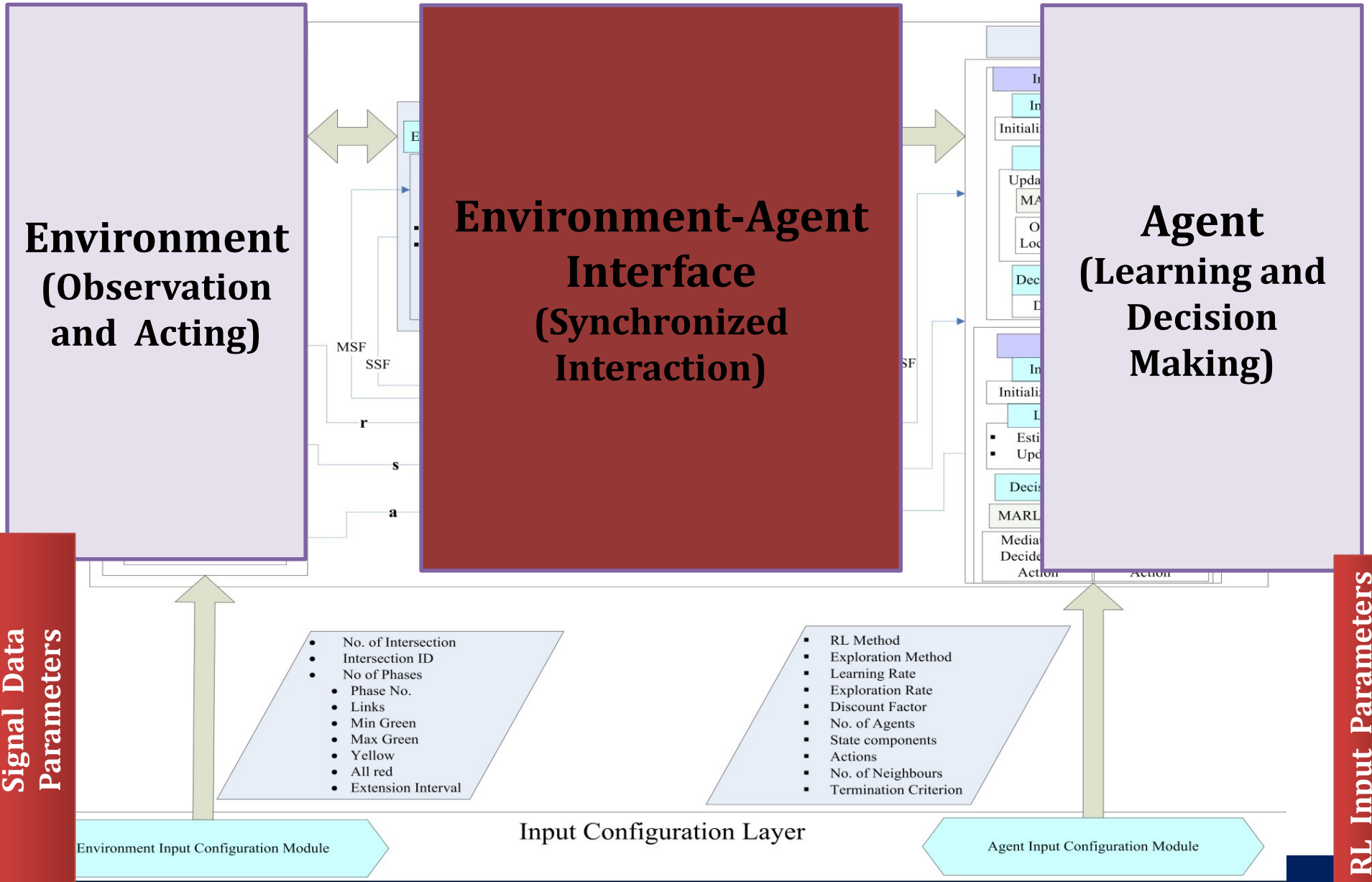
Corridor Synchronization



Collaboration with each adjacent intersection in the neighborhood



MARLIN-ATSC Framework

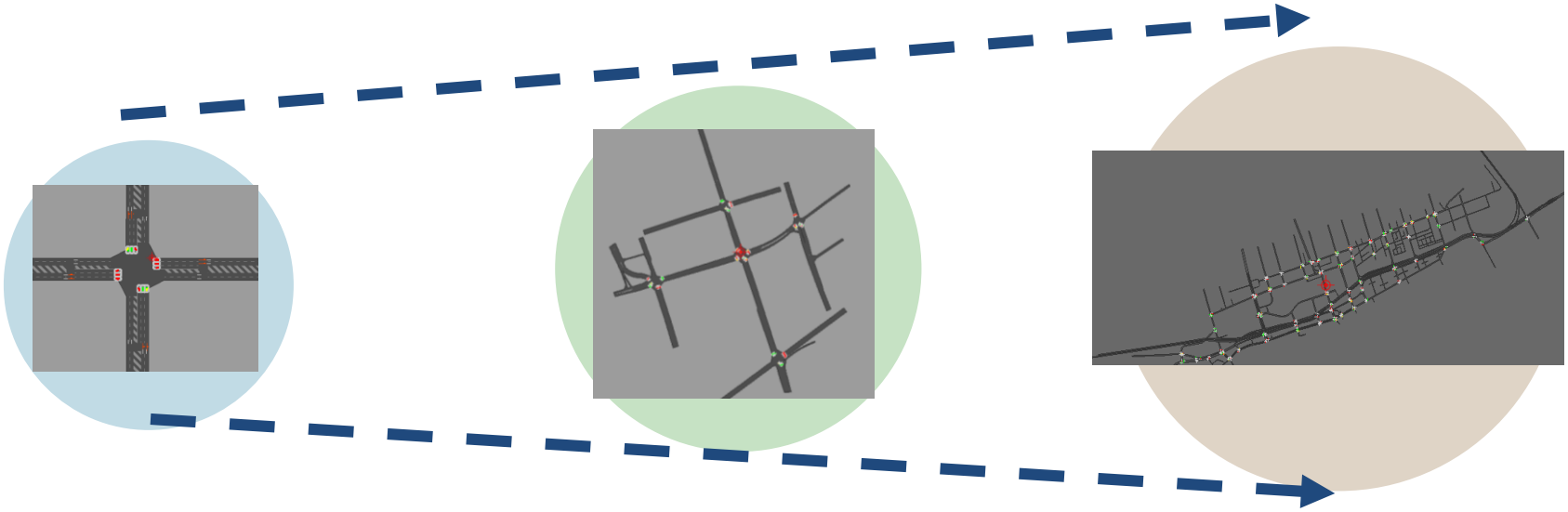


6. Data Collection and Analysis

"An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer." – Max Planck

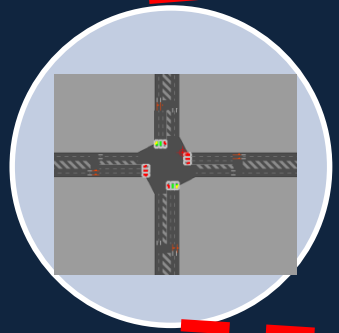
Applications

Simulation Testbeds on Toronto



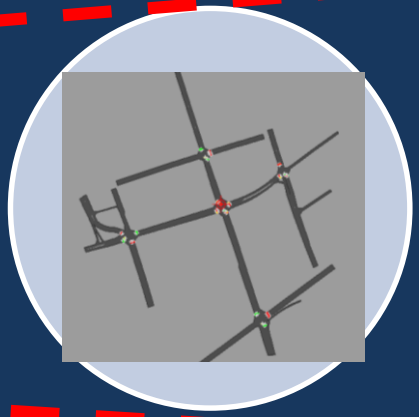
Traffic Simulator

Testbed Networks and Applications



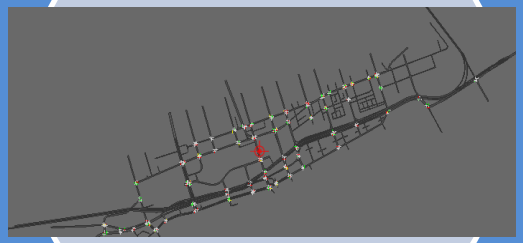
Isolated Int.

→ Different RL Design Parameters



5- Int. Network

→ Transferability and Different Coordination Approaches

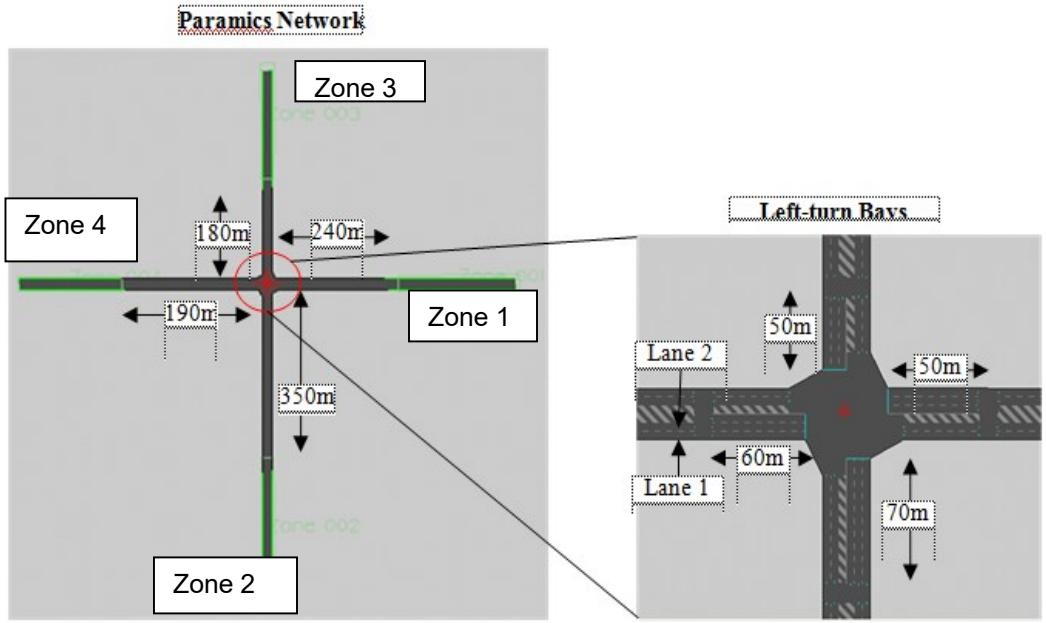


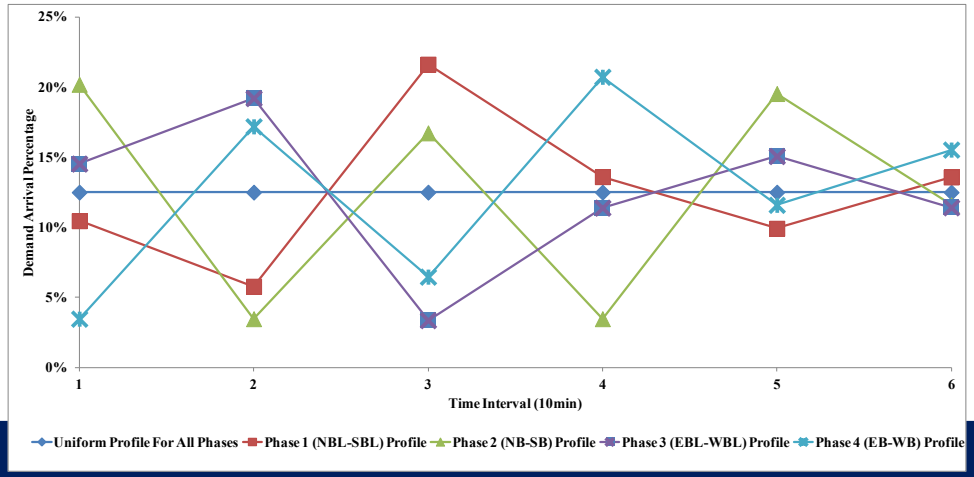
Large-Scale

→ Scalability and Network-wide Coordination Effect

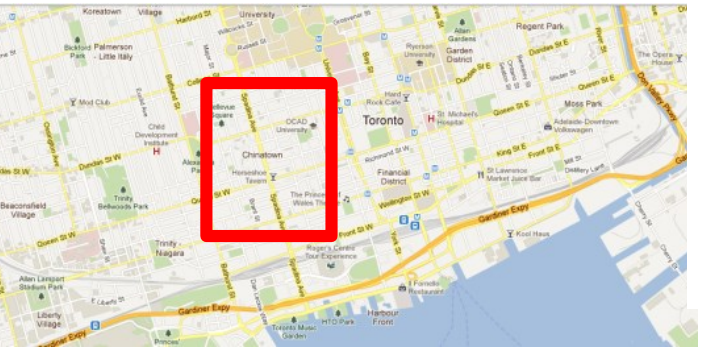
Isolated Intersection

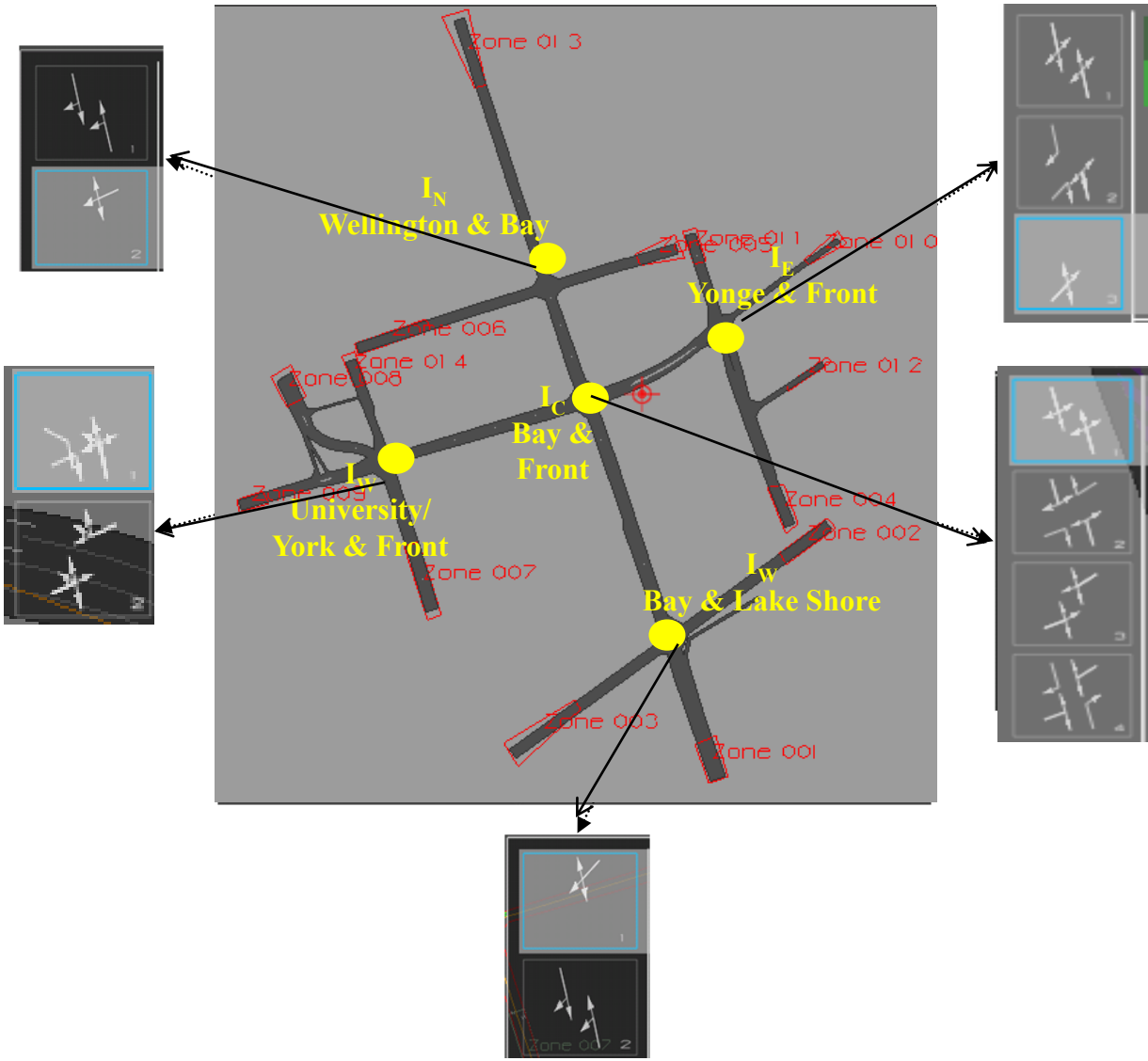
Bay and Front (Downtown Toronto)



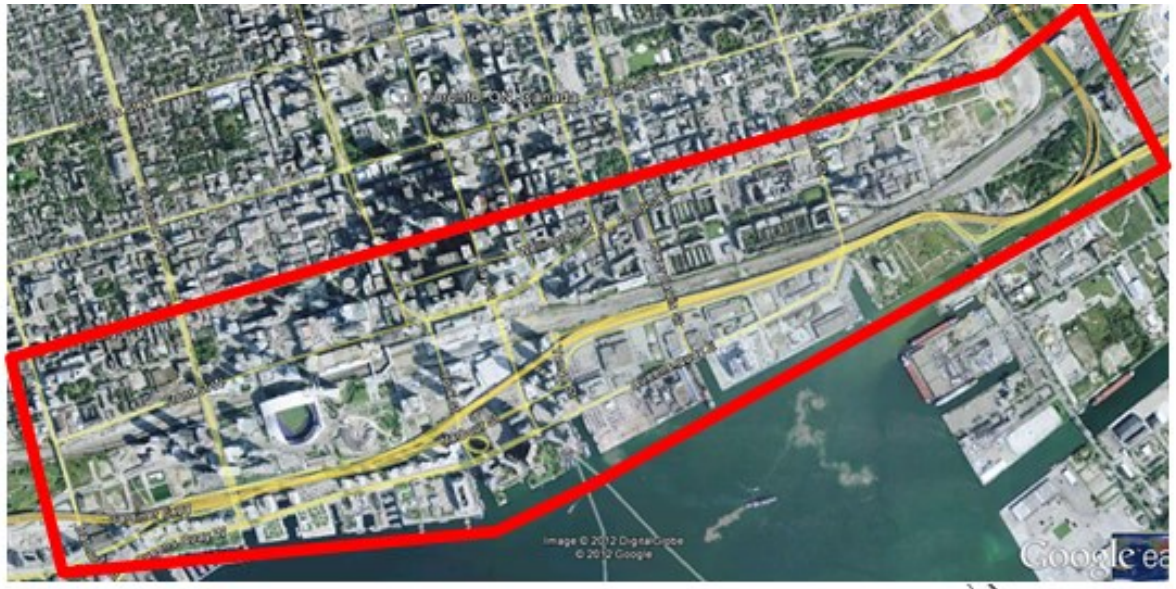


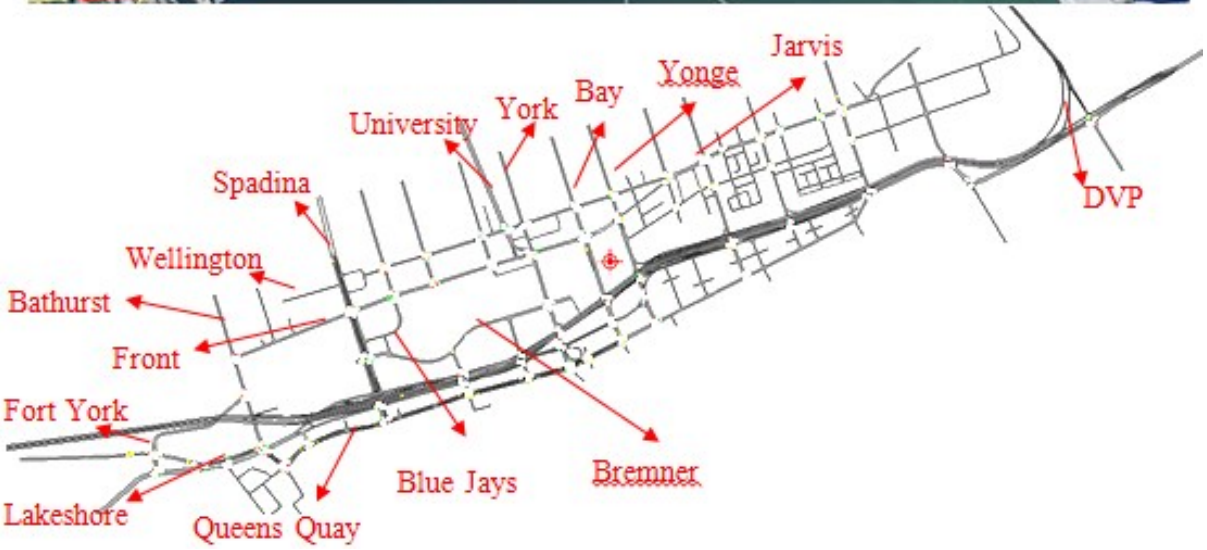
5-Intersections Network



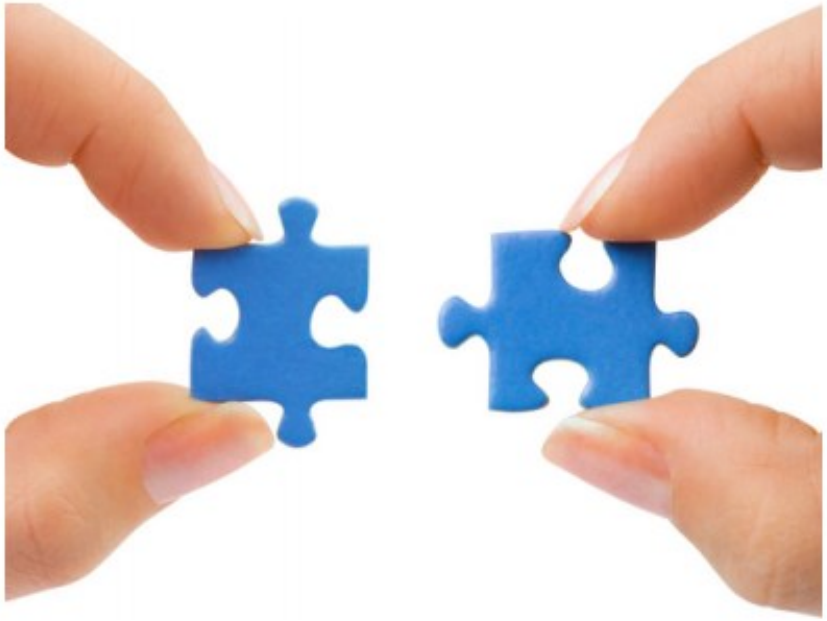


Large-Scale Application in Toronto





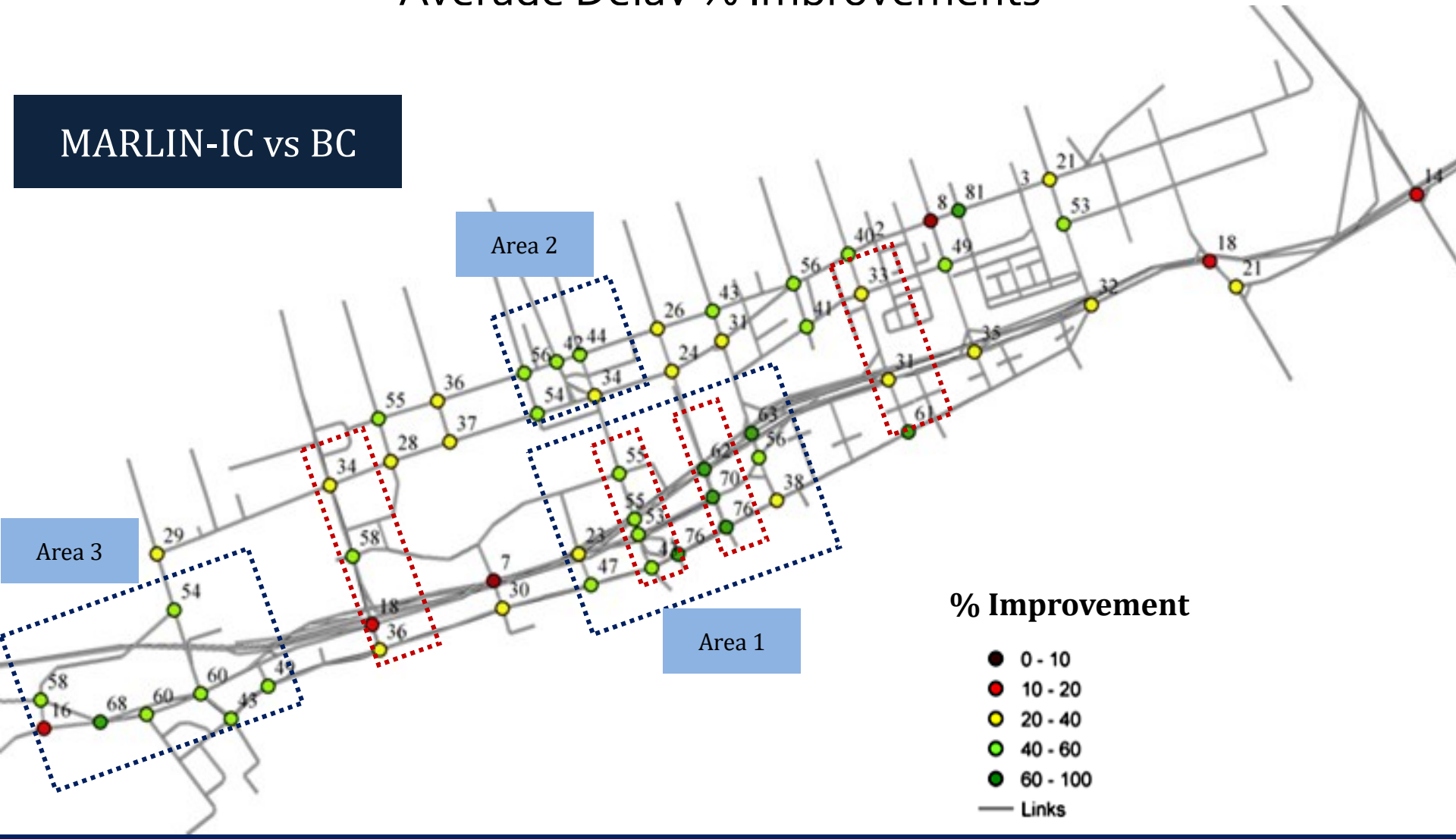
7. Make Conclusions



Large-Scale Application

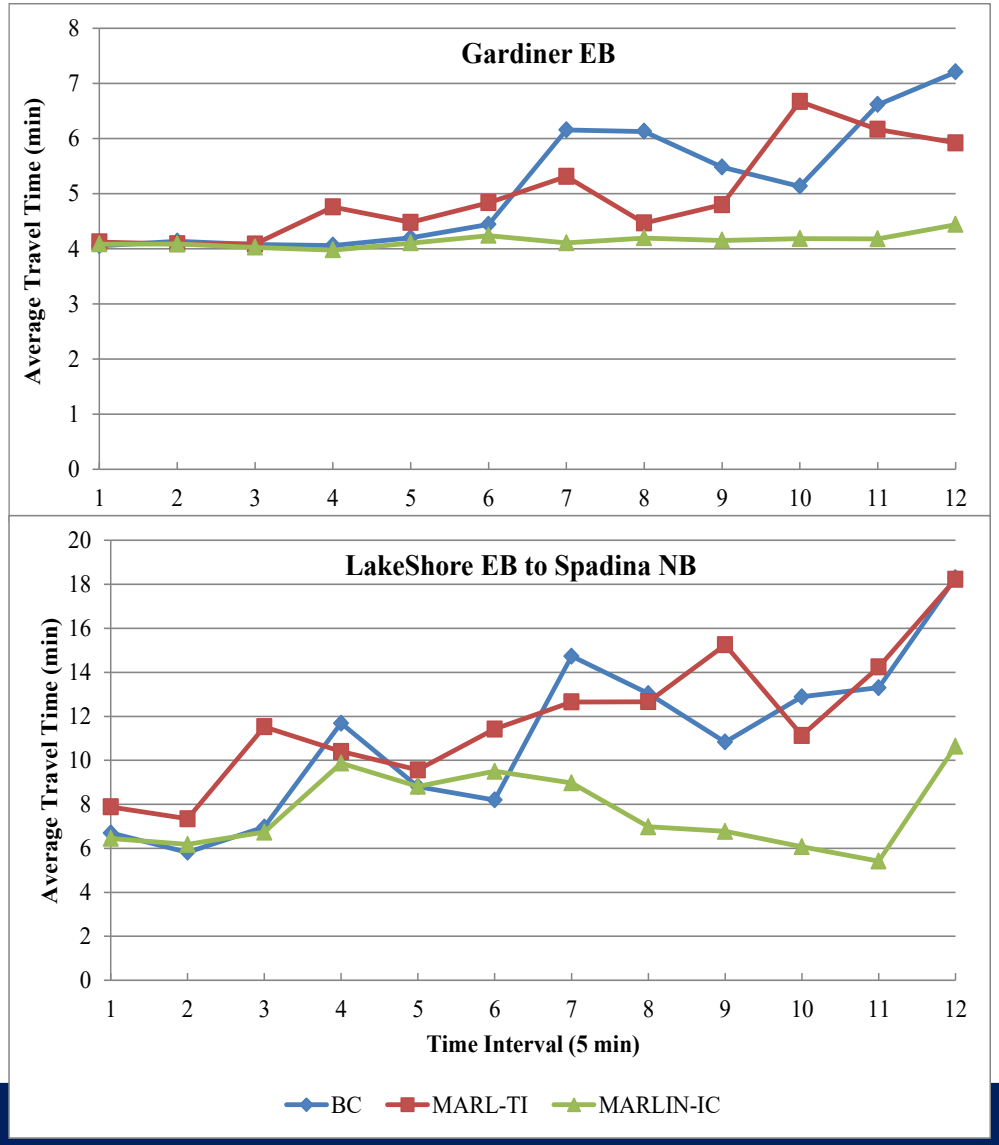
Average Delay % Improvements

MARLIN-IC vs BC



Large-Scale Application

Average Route Travel Time for Selected Routes

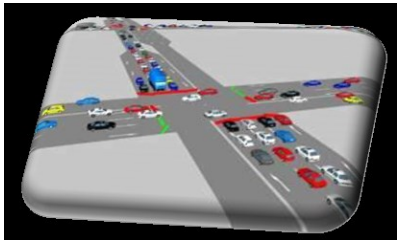


BC

MARL-TI

MARLIN-IC

Hardware-in-the-Loop Simulation (HILS)



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UNIVERSITY OF TORONTO

MARLIN-HILS Architecture

Traffic Signal Controller

Controller Interface Device(CID)
RS485 to USB

RS485 -
SDLC protocol

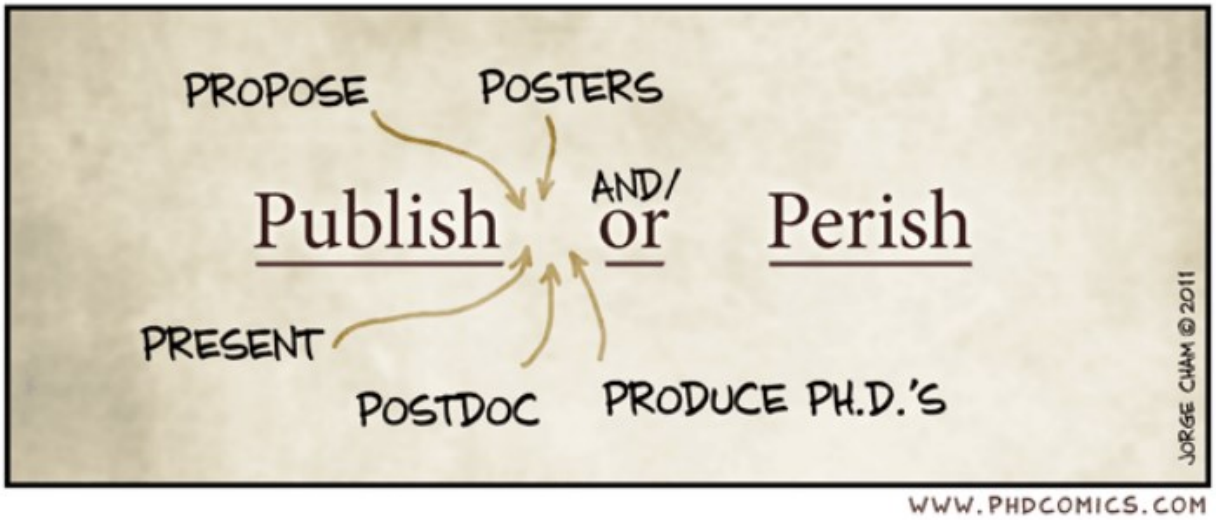
USB -
SDLC protocol

Ethernet -
NTCIP protocol

Paramics
Modeller

Industrial Computer

8. Communicate Results



Writing a Research Proposal/ Publishing a Paper

1. A working title
2. Background of the study
3. The problem statement:
   a) The purpose of the study
   b) Research questions
4. The scope of the study
5. The relevance of the study
6. The research design:
   a) Type of study – exploratory or descriptive
   b) Data collection methods
   c) The sampling design
   d) Data analysis
7. Time frame of the study
8. The budget
9. References

When to publish?

What to publish?

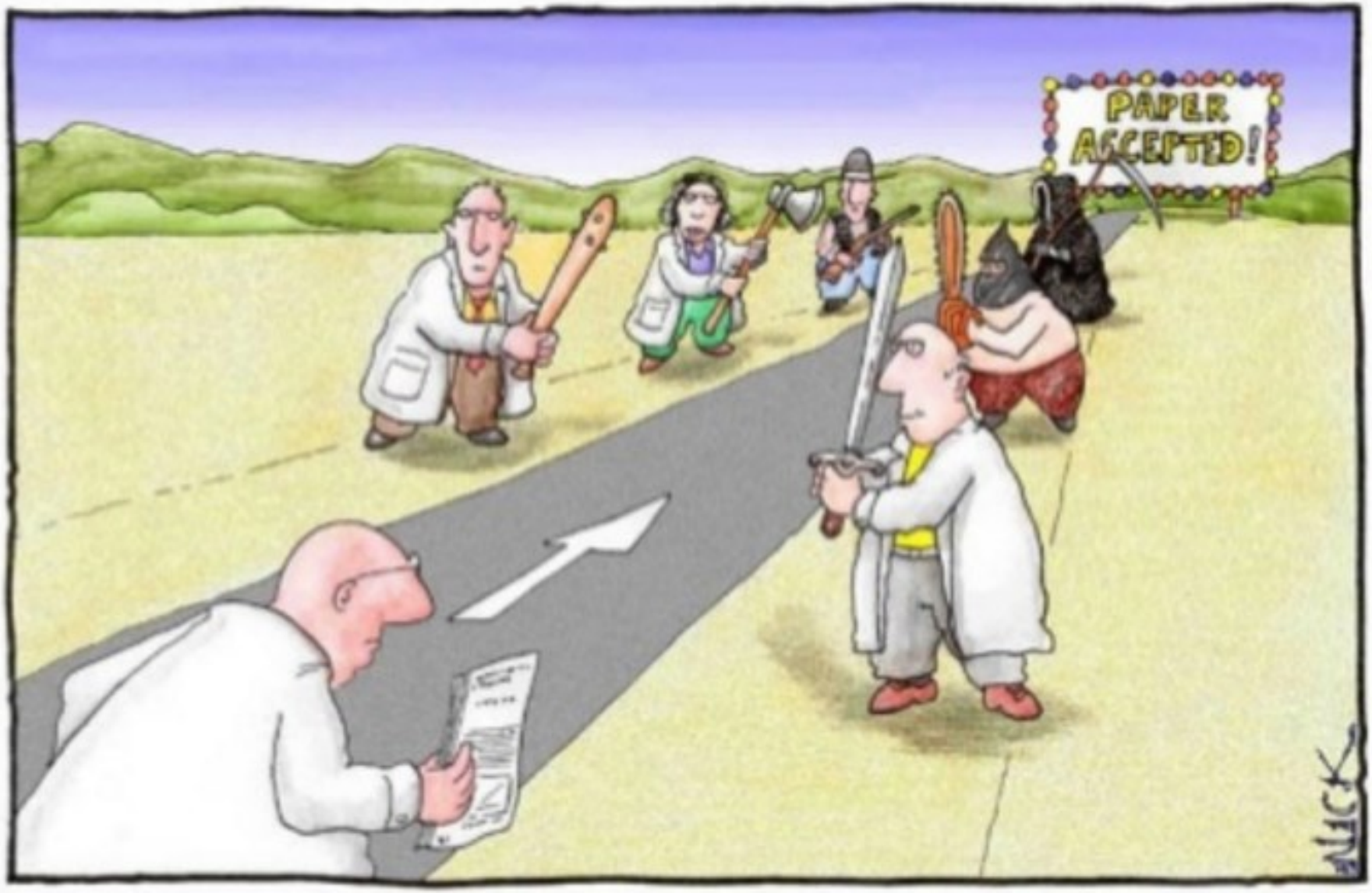
Type of publications

When to start writing?

Getting your paper noticed

Dealing with rejections

What to do to enhance your writing skills?


PAPER ACCEPTED!

MARLIN Recognition

IEEE ITSS Best Ph.D. Dissertation Award, 2013

Canadian Institute of Transportation Engineers Scholarship, 2010

INFORMS George B. Dantzig Dissertation Award, 2013

ITS Canada Scholarship, 2011

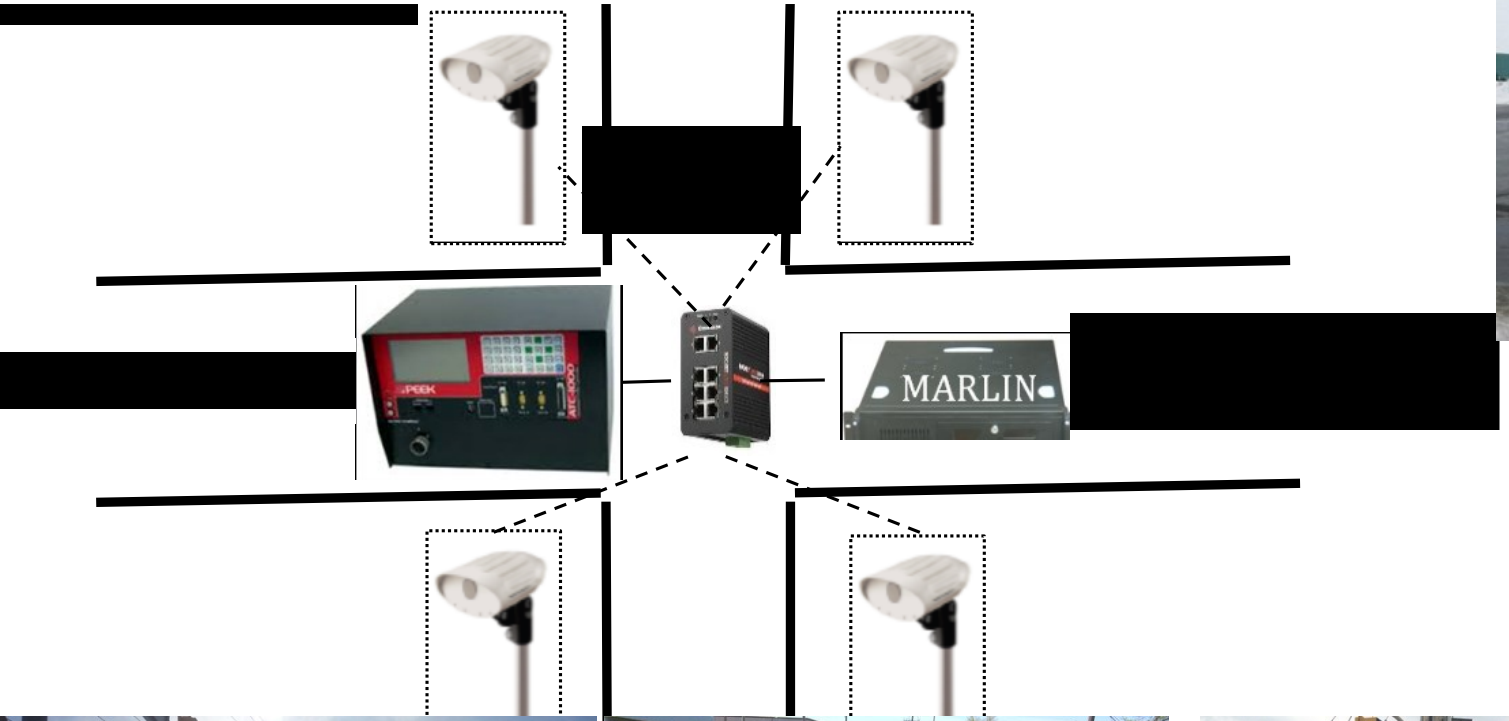
MARLIN Featured in Media!

Towards System Implementation

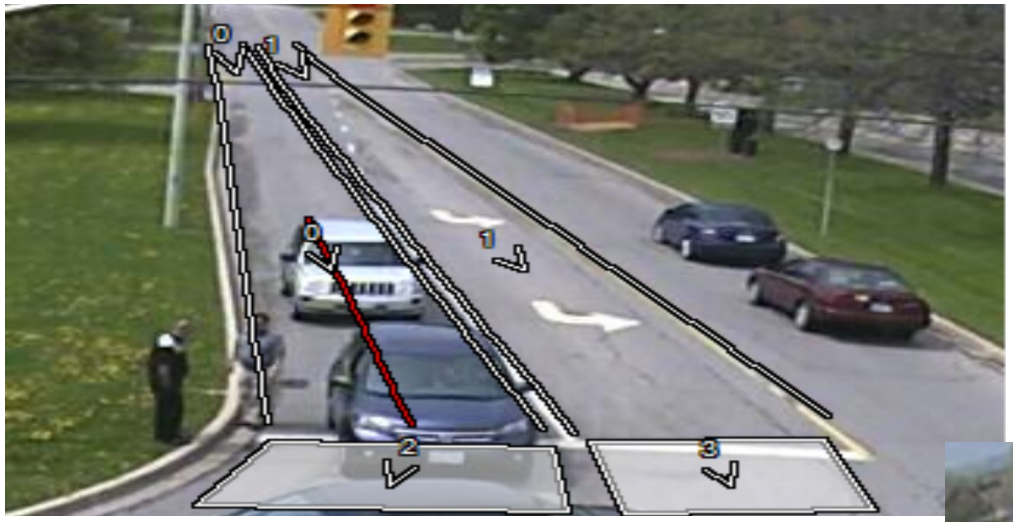
UNIVERSITY OF TORONTO

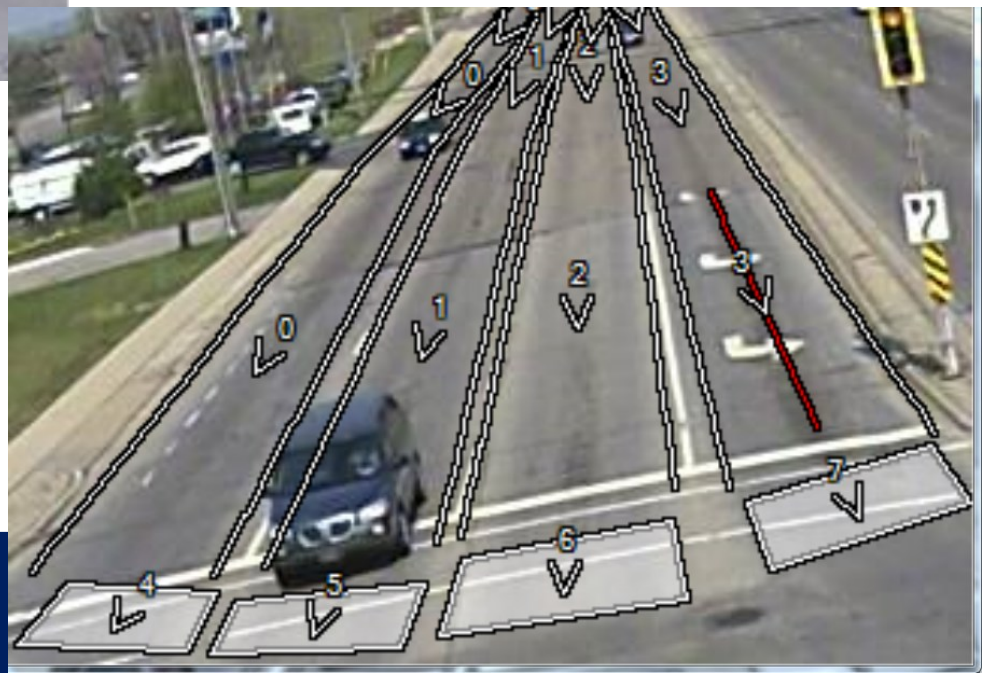
PEEK

MARLIN Field Implementation



Lessons Learned for Future Consideration






MARLIN

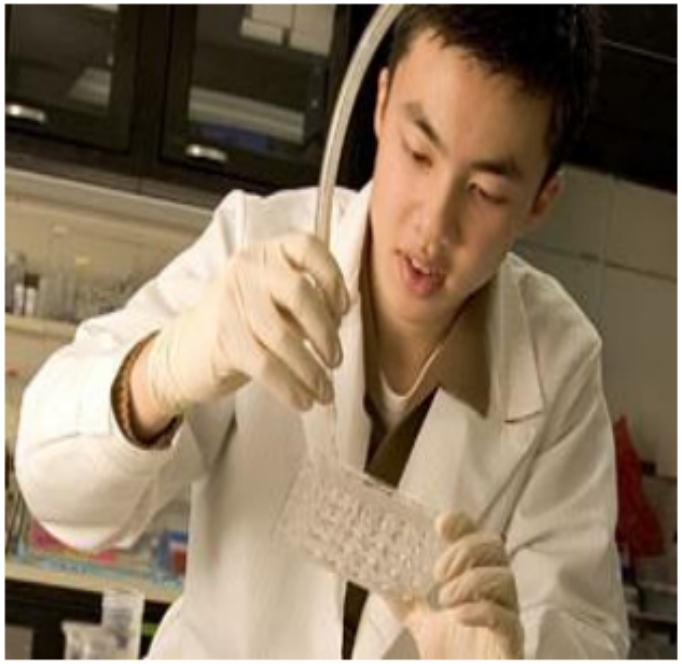
IV. When to Start?

Start as early as possible!

It's not too early or too late to get hands on a research project that inspires you.

Research for UG

1. Establish yourself in the scientific community .
2. Make connections with faculty and staff.
3. Develop valuable skills.
4. Apply the techniques and concepts you learn in class.
5. Build a well- rounded resume.
6. Be prepared for graduate school.
7. Give you a taste of what a career in science.
8. Help you in your future career.



IV. What do you need to know before starting your research?

Plagiarism

- This is the worst thing that can happen to a researcher!
- Deliberate plagiarism is a crime!

Quote or paraphrase

- You can use the exact words if you are making a quote (between quotation marks), otherwise you must summarize/ paraphrase only after those words have filtered through your own understanding of them, then cite the source
- **Quote when:** the specific words of your source matter
- **Paraphrase when:** you are more interested in the findings/data than in how your source expressed them

Lessons Learned

- Research Never Ends
  - Stay on Top of the Literature
- Passion and Handwork are the Keys
- Adapting to Your Audience
  - Academia Vs. Industry Vs. Government
- "If Opportunity Doesn't Knock, Build A Door" Milton Berle
- Being Out of Your Comfort Zone
- MARLIN is One Piece of the Puzzle

Thank You

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27/07/2017