Bi-Objective Staggered School Schedules Optimization for the morning commute problem

Introduction

- In most countries, the schools within an urban road network start simultaneously.
- Commuters compete for traffic space, leading to a value of demand exceeding the network capacity, causing congestion.
- This research focuses on a demand management methodology to properly **regulate** the start time of schools in the network so that congestion can be alleviated entirely.

Encapsulation of Morning Commute

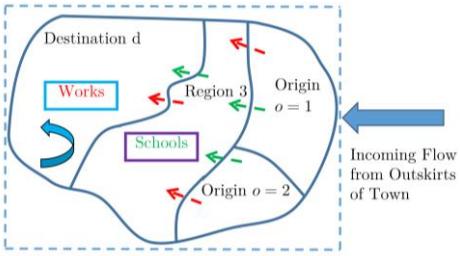


Fig. 1: Network Architecture.

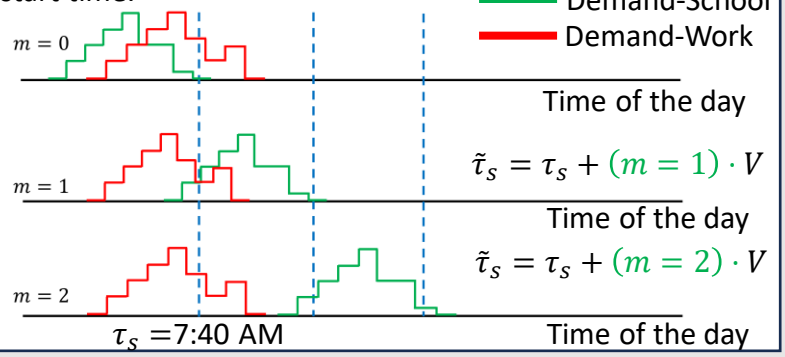
Most trips during the morning rush hour can be segmented into two classes of vehicle commuters. We utilize the notion of the *Macroscopic Fundamental Diagram*.

Why is morning commute a challenging problem?

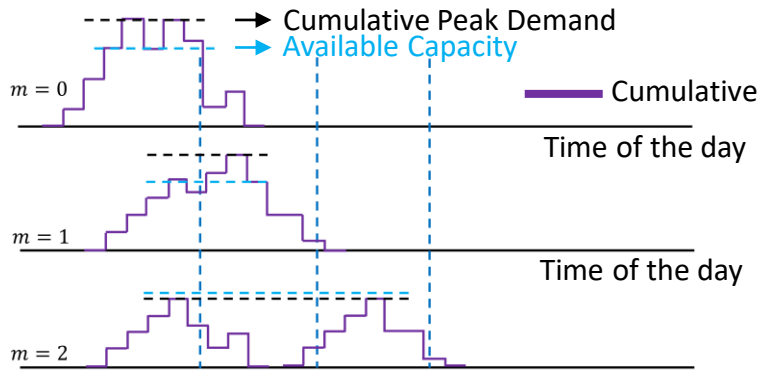
Traditionally, commuters head straight to work or stop at school before going to work. To ensure timely arrival, these commuters leave home in a synchronized fashion, leading to congestion.

Idea - School Demand Allocation Paradigm (SDAP)

V: duration of shifting interval for each *candidate* school start time.



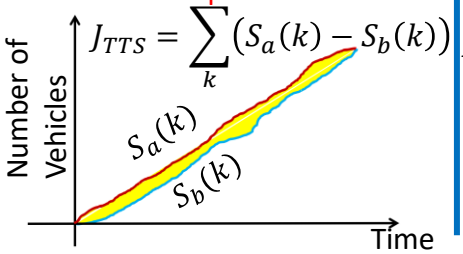
Summation of Distributions for different readings



In this example for the last reading ($m=2$) the cumulative peak demand remains constantly below the available capacity → **Congestion is eliminated.**

Multiple Objectives

1. Total Time Spent Criterion



2. Shifting Criterion

$$J_{QUO} = \sum_{s\in\mathcal{S}} \sum_{m\in\mathcal{M}} \xi_{m,s} mV$$

binary variable: school s starts at time $\tau_s + mV$

How do we select school start time?

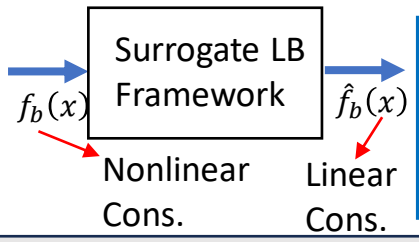
The described problem is formulated as a Bi-Objective Mixed Integer Nonlinear Program (MINLP). We construct a surrogate Lower Bound (LB) formulation, which relaxes the nonconvex and nonlinear constraints with linear ones.

Minimize $\{J_{TTS}, J_{QUO}\}$
Subject To Traffic Dynamics
SDAP

MINLP → **Intractable**. Employ ϵ-constraint scalarization technique to transform to a single objective function.

Lower-Bound (LB) Solution

The constraints associated with the SDAP and the traffic dynamics, alike that were linear in the first place are denoted with $h_j(x) \le C,\ j = 1, \dots, P, \mathrm{C} > 0, D > 0$.

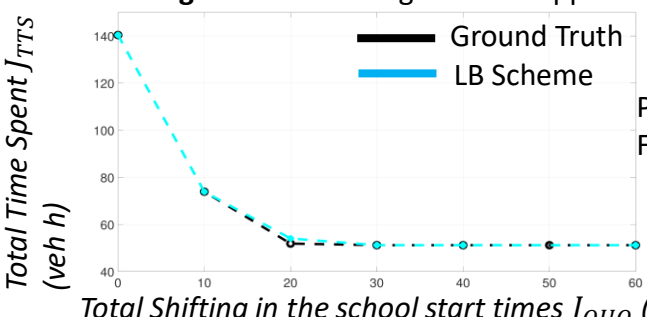


MILP

Minimize J_{TTS}
Subject To i) $h_j(x) \le C$
ii) $\hat{f}_b(x) \le D$
iii) ϵ-constraint

Results

Testbed: Fig. 1, 10 schools and 10 workplaces are incorporated. Total number of school start time combinations with 5 candidate start times, using an Exhaustive Search procedure: $5^{10} =$ **9.765.625.** The solution from MILP is compared with an ***Exhaustive Search*** procedure. **Convergence** → congestion disappears.



The approximate LB scheme can almost always retrieve the **optimal** control decision. 20-minute shift can eliminate cong.

Future Work

- Extended network architecture, in which schools and works can be scattered across the urban network.

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