Aalto-yliopisto
Perustieteiden korkeakoulu

Dynamic Programming Approaches for the Bus Rapid Transit Investment Problem (topic presentation)

Bilqays Ayoub

12.04.2024

Supervisor: *Philine Schiewe*

Instructor: *Philine Schiewe*

Systeemianalyysin laboratorio

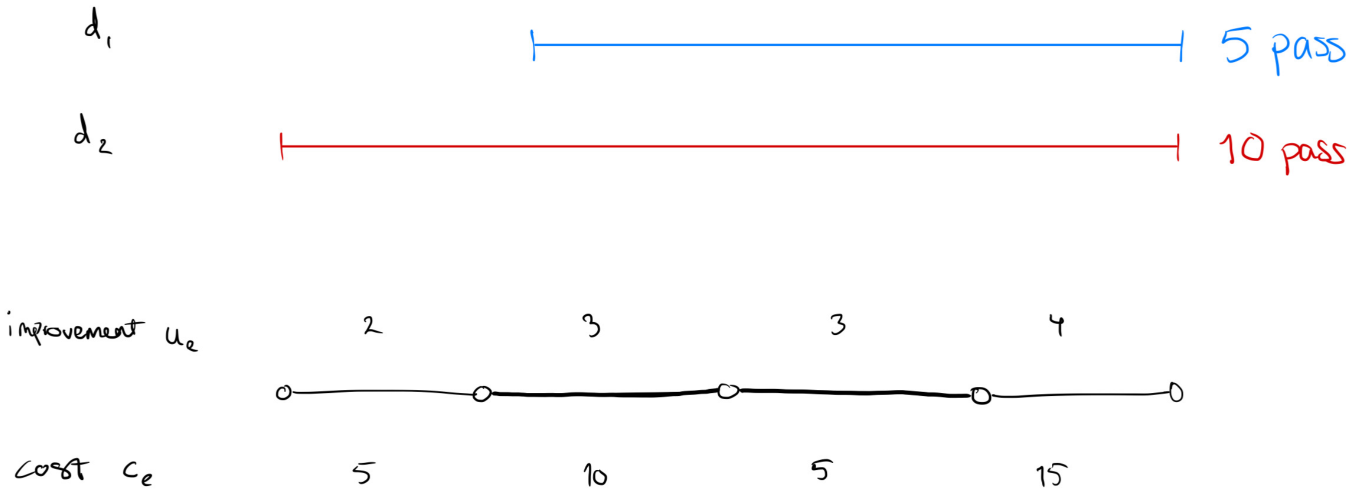
Bus Rapid Transit

- BRT is a public transportation system providing rapid and reliable bus services
- It’s more cost-effective compared to alternative transportation systems
- Attracts passengers due to its reliability and efficiency

Motivation

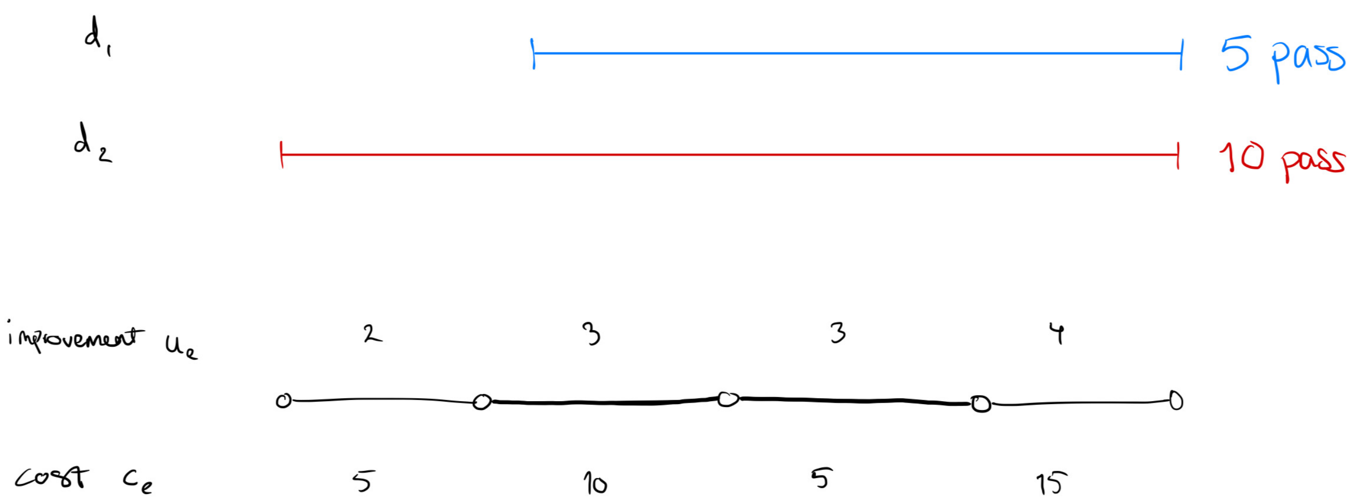
- Given bus line
- Limited budget for upgrading some segments/edges
- Goal is to attract as many passengers as possible for a given budget

Example



- How many passengers can be attracted by an upgrade within the budget of 15?

Example



- How many passengers can be attracted by an upgrade within the budget of 15?

OD pair	$\sum_{e \in W_d} u_e$	$\sum_{e \in F \cap W_d} u_e$	a_d	$p_d(F)$
d_1	10	6	5	3
d_2	12	6	10	5

Knapsack Problem

- Given a set of items, each with weight and value
- Select items to maximize value with a bounded weight

- The 0/1 Knapsack is the decision version of the Knapsack problem
- The BRT can be formulated as Knapsack problem

0/1 Knapsack

- Maximize the total potential passengers attracted by the line impovements without exceeding its budget constraints
- Segment included (1) or not included (0)

- Dynamic programming can solve standard Knapsack in pseudo-polynomial time, which is efficient

Objective

- Adapting dynamic programming to optimize the most cost-effective upgrades within budget constraints for BRT segments
- Utilize available data on stops, connecting segments (edges) and passenger demand to inform upgrade decisions

Scope of the Thesis

- Working on a single line
- Dynamic Programming Knapsack Algorithm
- Single-objective BRT investment problem
- Modelled by implementing the algorithm on PTNs data with 10 and 25 stops, respectively

Methods

- Knapsack algorithm
  - Identifies which BRT line segments to upgrade

- Python is used for implementations

IP Formulation

$$\begin{aligned} \max \quad & \sum_{e \in E} \tilde{u}_e x_e \\ \text{s.t.} \quad & \sum_{e \in E_m} c_e x_e \leq v \\ & x_e \in \{0, 1\}, \ \forall e \in E. \end{aligned}$$

- E is the set of segments between the stations,
- e is an element in the set E,
- u_e is infrastructure improvements associated with element e,
- $\tilde{u}_e = u_e \cdot \frac{a_d}{\sum_{e' \in W_d} w_{e'}} \quad \forall e \in E$, is the number of newly attracted passengers for each OD pair $d \in D$ are based on the passenger potential a_d and the infrastructure improvement realized along the path W_d,
- x_e is a binary variable that denotes whether segment e is upgraded,
- c_e is the cost of upgrading element e,
- v is the investment budget which is fixed in one dimensional case.

Schedule

- Introduction and literature 2-3/2024
- Topic presentation 4/2024
- Implementations 3-4/2024
- Thesis writing 3-4/2024
- Thesis presentation 5/2024

Literature

- R. Hoogervorst, E. van der Hurk, P. Schiewe, A. Schöbel, and R. Urban. The Bus Rapid Transit Investment Problem. arXiv:2308.16104v3 [math.OC] 8 Feb 2024.doi:10.11583/DTU.c.6805470.v1
- Korte, B., Vygen, J. (2018). The Knapsack Problem. In: Combinatorial Optimization. Algorithms and Combinatorics, vol 21. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-56039-6_17