Short-turn decision in metro-timetabling

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Problem description :

- With the increase in the use of transit services, the current public transportation services are having a hard time satisfying the growing demand.
- Many megacities across the world like New York, London, Tokyo, Shanghai and so on, many megacities in India such as Delhi, Mumbai, Chennai, Bangalore etc use Urban metro system to provide efficient and convenient means of transportation. Overcrowding is becoming a growing concern in almost all of these Metro services.
- Though the simple solution for this problem would be to expand the stations and increase the number of rakes, it takes a huge amount of operational cost to achieve such a stunt. Also, due to uneven spatial and temporal distribution of the flow of passengers, when there are some rakes which are overly crowded some of them are not crowded at all. Additionally many passengers wait for long amount of times as a consequence of this overcrowding

Some studies show that overcrowdedness to this level has affected the comfort of passengers, and even influenced their working efficiency and quality of lives. There are potential safety problems, such as trampling, falling onto the tracks, or entrapment by train doors due to this increase in the overcrowding

Solutions to this problem : SHORT TURNING FACILITY

- Short turning is a commonly used strategy in metro systems that involves terminating a train before it reaches its final destination, and then reversing its direction to head back in the opposite direction.
- Although it may seem counterintuitive to stop a train before it reaches its intended destination, short turning has several benefits that can greatly improve the overall efficiency and reliability of metro systems.

- By reducing congestion and delays, short turning can help to minimize travel times and improve the overall passenger experience.
- Additionally, short turning can also reduce operating costs by allowing metro operators to use fewer trains during off-peak periods.
- Overall, short turning is a valuable tool for metro systems that can help to improve performance, reduce costs, and enhance the overall passenger experience.

The train timetable problem under the short-turning pattern has emerged as another intriguing research area for academics due to the growth in long-distance subway lines and the geographical imbalance of passenger demands.

Some useful ideas can be adapted from the literature in the implementation of short turning

Short turning pattern for relieving metro congestion during peak hours: the substance coherence of Shanghai, China(2018) :

What is the paper about ?

- Short turning pattern has been proved to be an efficient way to solve the issue, which had been mainly used in urban ground public transport systems. This paper applied short turning pattern to urban metro system and relaxed constraints of the turning-back facility.

- A mathematical model is proposed to determine the short turning parameters, during which a load factor ‘**η**’ was introduced as a measurement of overcrowding condition. An empirical case from Shanghai Metro Line 2 was incorporated to demonstrate the effectiveness of the proposed model.

Definitions

Some technical terms :

- OD-matrix (The Origin- Destination matrix) : Gives the information about the Number of passengers travelling from one station to another(from origin to the destination). The OD-matrix data is practically useful in calculating other useful parameters like the Service matrix, passenger inflows and outflows.
- Lines : The path in a public transportation network. It consists of the list of stations that the rake is travelling to.

  Eg :- Red line, Yellow line, Blue line in Delhi Metro System.

- Frequency(of a line) : The no of times a service is offered along the line in some specified time interval(like an hour, a day or a month)

Where to perform Short turning ?

As, there is imbalance in the temporal and spatial passenger flows, performing short turning at every station and at every time would be redundant. So, to improve the frequency during the peak times ‘short turning zones’ are introduced. One of the major objectives of this paper hence is ‘zone selection’

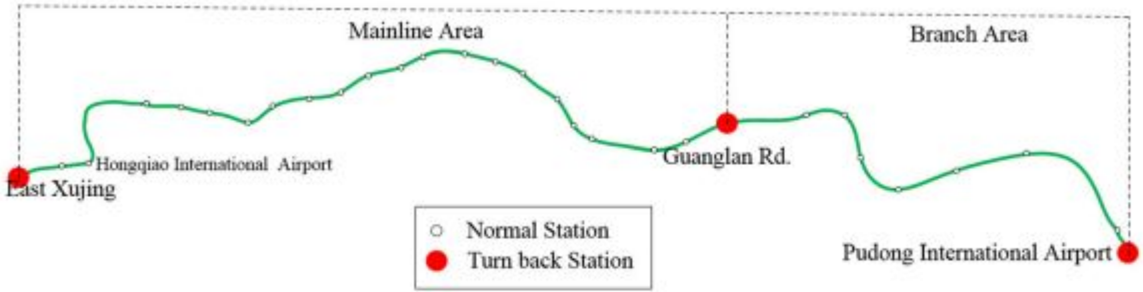

Fig. 1 Existing operating pattern of Shanghai Metro Line 2

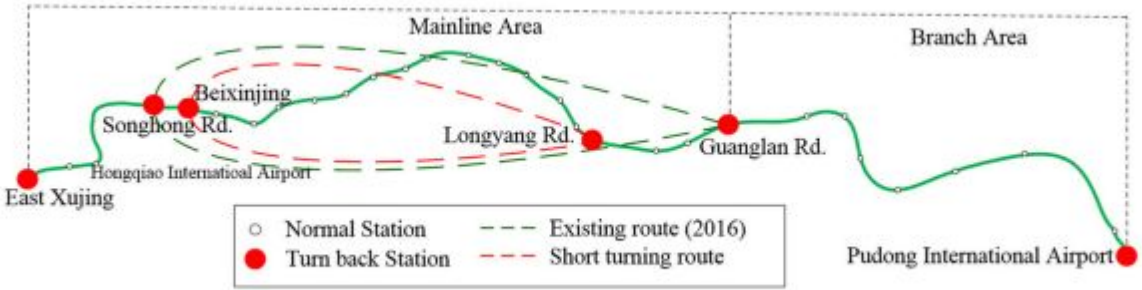

Fig. 6 Existing route (2016) and short turning route proposed

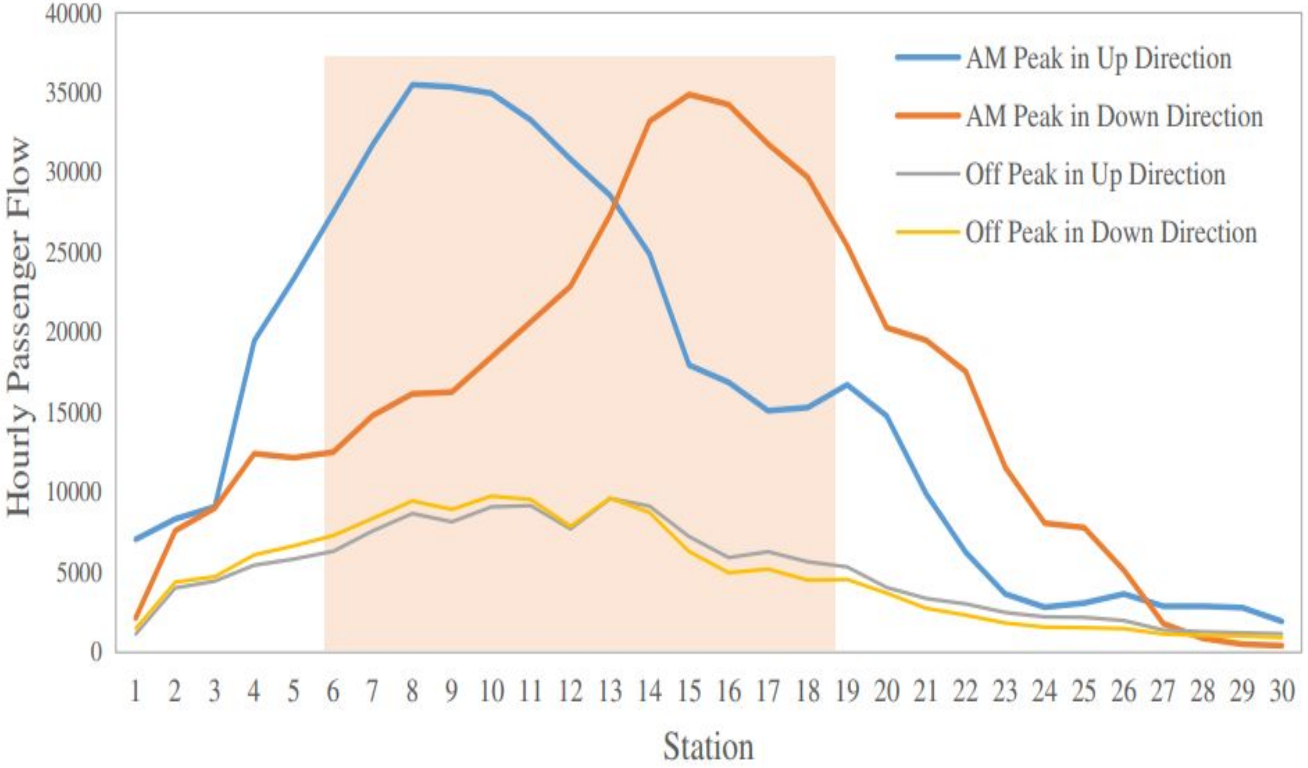

Fig. 2 Hourly passenger flow of Shanghai Metro Line 2 during AM and PM peaks (AM peak 7:30–8:30, Off Peak 14:30–15:30, Sept. 16, 2014)

Assumptions :

1. For both full length and short turning services, all rakes have to stop at every station in between and operate at the same speed with fixed headway.
2. No turn around constraints exist along a line since turn around facilities can be built without many particular difficulties, although only a subset of stations containing short-turning facilities may be established.
3. All passengers waiting on the platforms take the recent arrival train and are able to aboard.
4. Passengers arrive uniformly during the peak period regardless of stochastic demand.

MODELLING :

- A metro line is modeled as a graph , G = (V, L), where the stations are represented by the vertex set and 'L' denotes the link set(the link between consecutive stations)
- OD-matrix (The Origin- Destination matrix) : Gives the information about the Number of passengers travelling from one station to another(from origin to the destination). The OD-matrix data is practically useful in calculating other useful parameters like the Service matrix, passenger inflows and outflows.
- Lines : The path in a public transportation network. It consists of the list of stations that the rake is travelling to.

Eg :- Red line, Yellow line, Blue line in Delhi Metro System.

- Headway : It refers to the amount of time between two consecutive trains passing through a specific point on the track. It is typically measured as the time elapsed from when the front of one train passes a specific point until the front of the following train passes the same point.
- Hourly demands : This refers to the number of passengers travelling from one station to another in an hour.

Constraints :

- Capacity constraints : The load factor 'η' is restricted to lie in between 0.8 and 1.2, to ensure that the rake is not overly crowded, also to avoid resource wasting. Now, we make sure that hourly demand is less than the practical capacity during peak hours. This capacity constraints are to be applied to Full-length service trains in and outside the short turning zone, to the Short-turning service separately
- Headway constraint : The cumulative frequency at for any station k should be less than the maximum frequency(inverse of minimum headway)
- Turnaround constraints : Similar to the headway constraints, the cumulative frequency should not exceed inverse of minimum turnaround time.

OBJECTIVE FUNCTION :

- Average waiting time is taken as the objective function.
- It is to be minimized subject to the above constraints

SOFTWARES USED :

- Softwares such as CPLEX, Xpress-MP and GLPK are used to solve the MILP

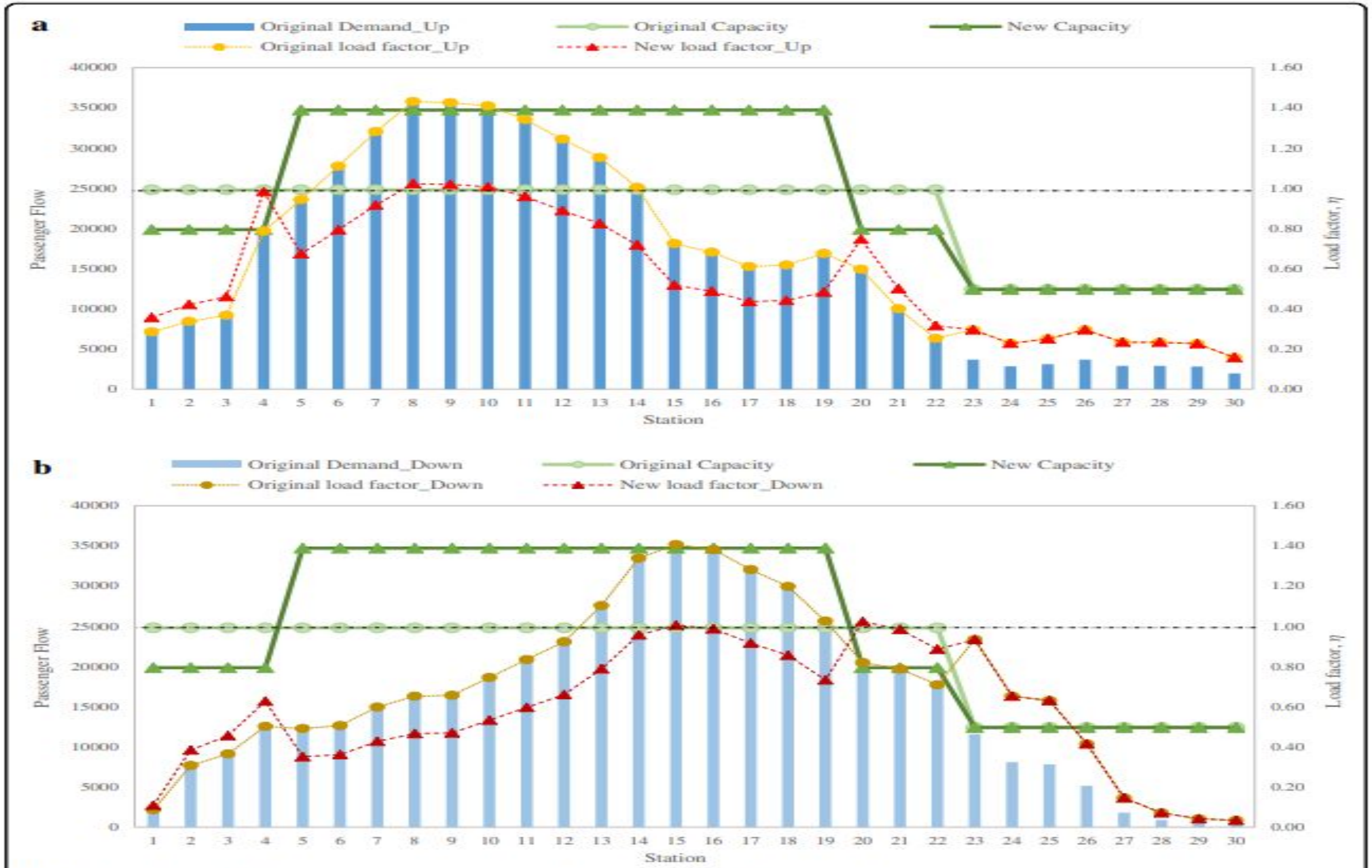

Fig. 5 Capacity, demand and load factor (η) of original and new routes, (**a**) Up direction; (**b**) Down direction

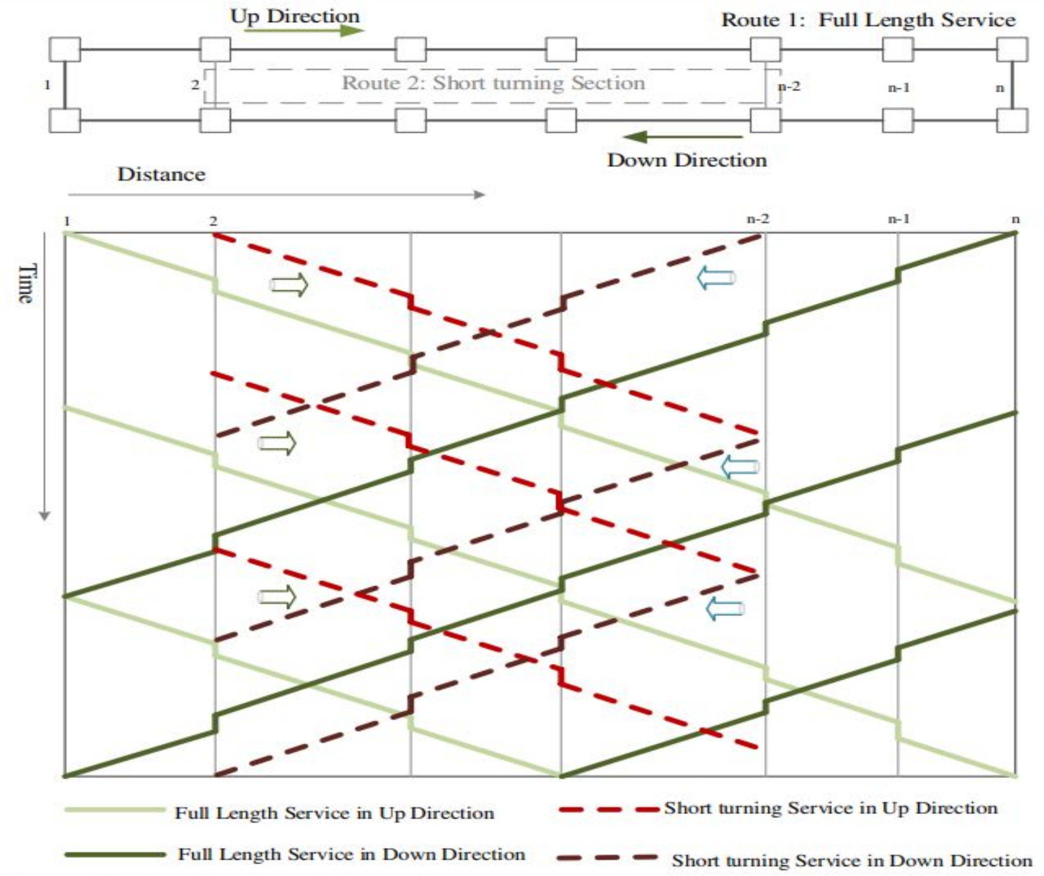

Fig. 3 Space-time diagram of full length service and short turning strategy

Publication	Objective	Decision variables	Solution approach
Wang [26]	minimize the number of trains	short turning service headway and cycles	fuzzy optimization
Wang and Ni [23]	minimize the passenger travel cost and enterprise operation cost	short turning offsets, turn back station	ideal point method
Canca et al. [21]	reduce the passenger waiting time	turn back points location, departure and arrival times, short turning offsets	MILP
Bai et al. [24]	minimize the number of trains	turn back point location, headway, turning times	enumeration method
Ghaemi et al. [22]	minimize the delays and canceled services after blockage	short turning stations routes and platform tracks	MILP

References :

1. Xueqing Ding, Shituo Guan, Daniel Jian Sun, Limin Jia (2018) https://etrr.springeropen.com/articles/10.1186/s12544-018-0293-9
2. Miao Zhang, Yihui Wang , Shuai Su, Tao Tang, Bin Ning(2018) https://www.hindawi.com/journals/jat/2018/5367295/