A Hybrid Method for Bus-Network Design with High Seasonal Demand Variation

Session 7.b - 26th of July, CASPT-12, Santiago, Chile

Outline

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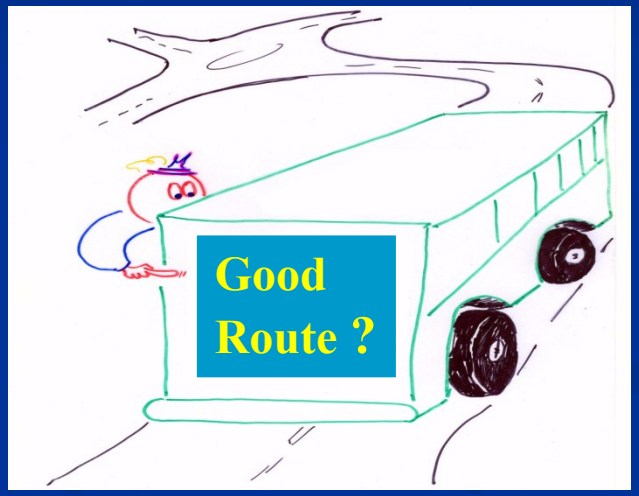

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Problem and Objective

There are a number of cities around the world that experience demand variations as a result of tourist arrivals and other demand-related activities

Objectives

What can happen if the network is not good…

1. **Developing a public-transit network that better/best matches supply and demand**

2. **To create and solve a model that takes into account the seasonal demand variation in the process of bus-network design.**

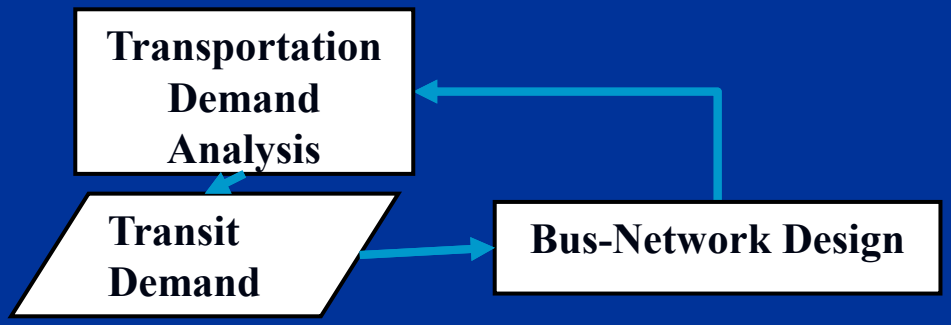
Note: The idea of this work is to construct a Base-Robust Network (BRN) considering the variation of demand throughout the year.

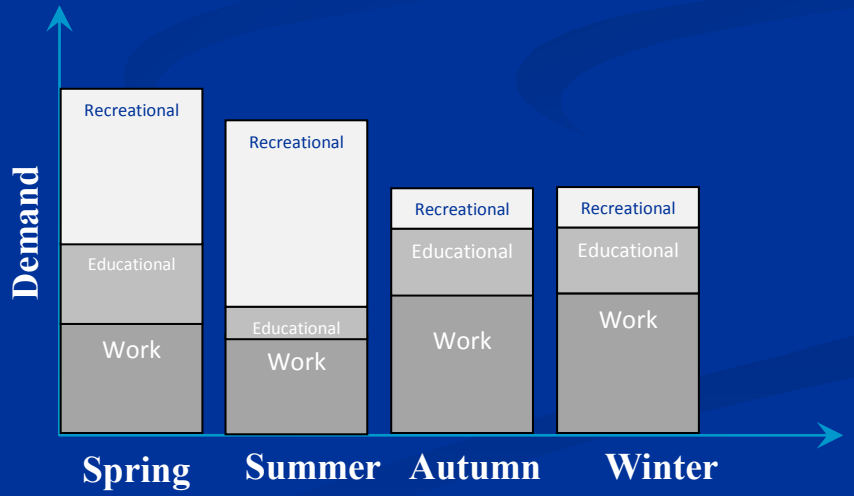
Notes on Transit Demand

- **The bus-network design process is extremely sensitive to passenger demand**
- **In the literature we can find three type of demand variation:**

(1) Service dependency: Transit demand is related to the utility of this mode

(2) Temporal variation: Transportation demand is naturally variable during hours of a day, days of a week, weeks of a month and months of a year





(3) Randomness: Transit demand is stochastic in nature

Approach

Motivation: Previous works does not take into account the seasonal demand variation, thus may result in a network that does not match well enough these variations

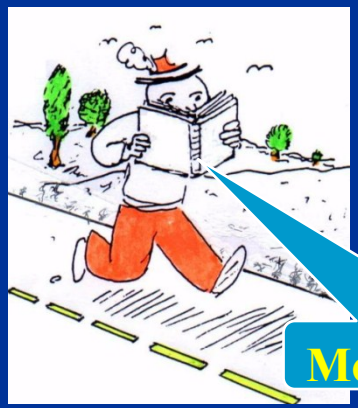
Approach:

- consider on a base-robust network (BRN) multiple demand matrices for each season rather than one demand matrix
- check the optimality of each possible network in all demand scenarios for best objective function (OF) values
- Check complexity for NP-hard, and consider heuristics

Problem Formulation

Let the objective function (OF) value for one network N_i defined as Z_i^j with i=index for a given network in a set NS, and j=index for a demand scenario (for a given season), and α = % of total yearly demand.

For each season j the base-robust network (BRN), i=r, is between best network for each season, i=j, and the single best network when considering the average yearly demand as an input:



$$\sum_{j \in DS} \alpha_j Z_j^j < \sum_{j \in DS} \alpha_j Z_r^j < \sum_{j \in DS} \alpha_j Z_i^j \qquad \forall i \in NS$$

More in the paper

Proposed Hybrid Method

Possibilities considered: (1) Math-Programming; (2) Meta-Heuristic (genetic, ant colony); (3) Heuristic; (4) Hybrid optimization- Chosen

- **Method (Hybrid) Chosen:**

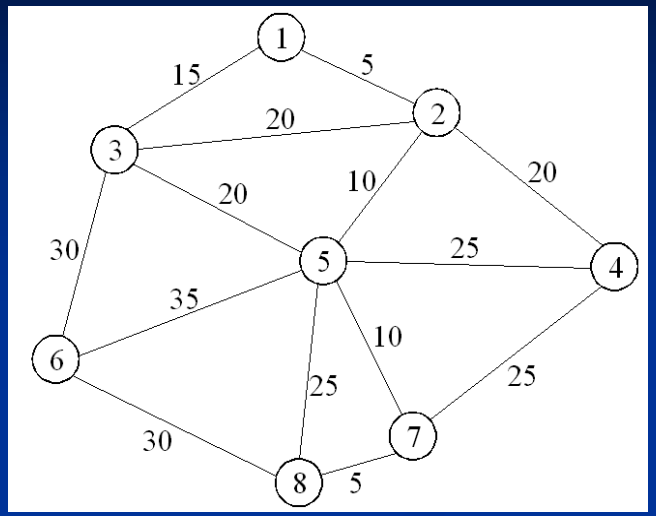
Route-level optimization limits the feasible solution area to routes that have more potential to enter the BRN

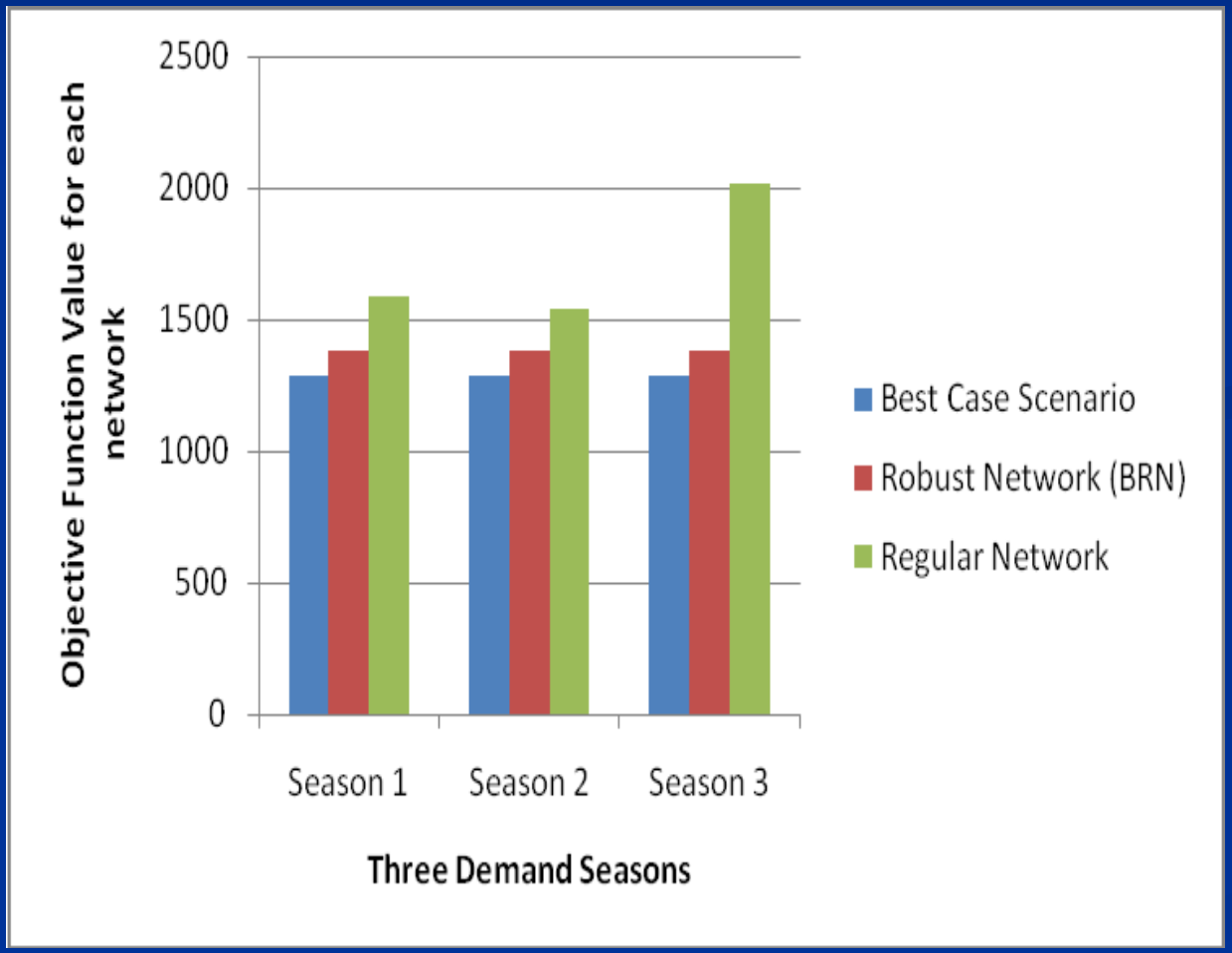
Network-level optimization is a hybrid method where the possible BRNs are created to check if they can be considered as robust based on the formulation.

Step-by-step procedure

- **Step 1: Gathering required data**
- **Step 2: Route-level optimization (Heuristic)**
  - ***Step 2.1: Creating the feasible solution area***
  - ***Step 2.2: Eliminating short or long routes***
  - ***Step 2.3: Important node coverage***
  - ***Step 2.4: Demand variability index***
  - ***Step 2.5: Practitioners' routes***
- **Step 3: Network-level optimization using Genetic algorithm (GA)**
- **Step 4: Route improvement (Heuristic)**

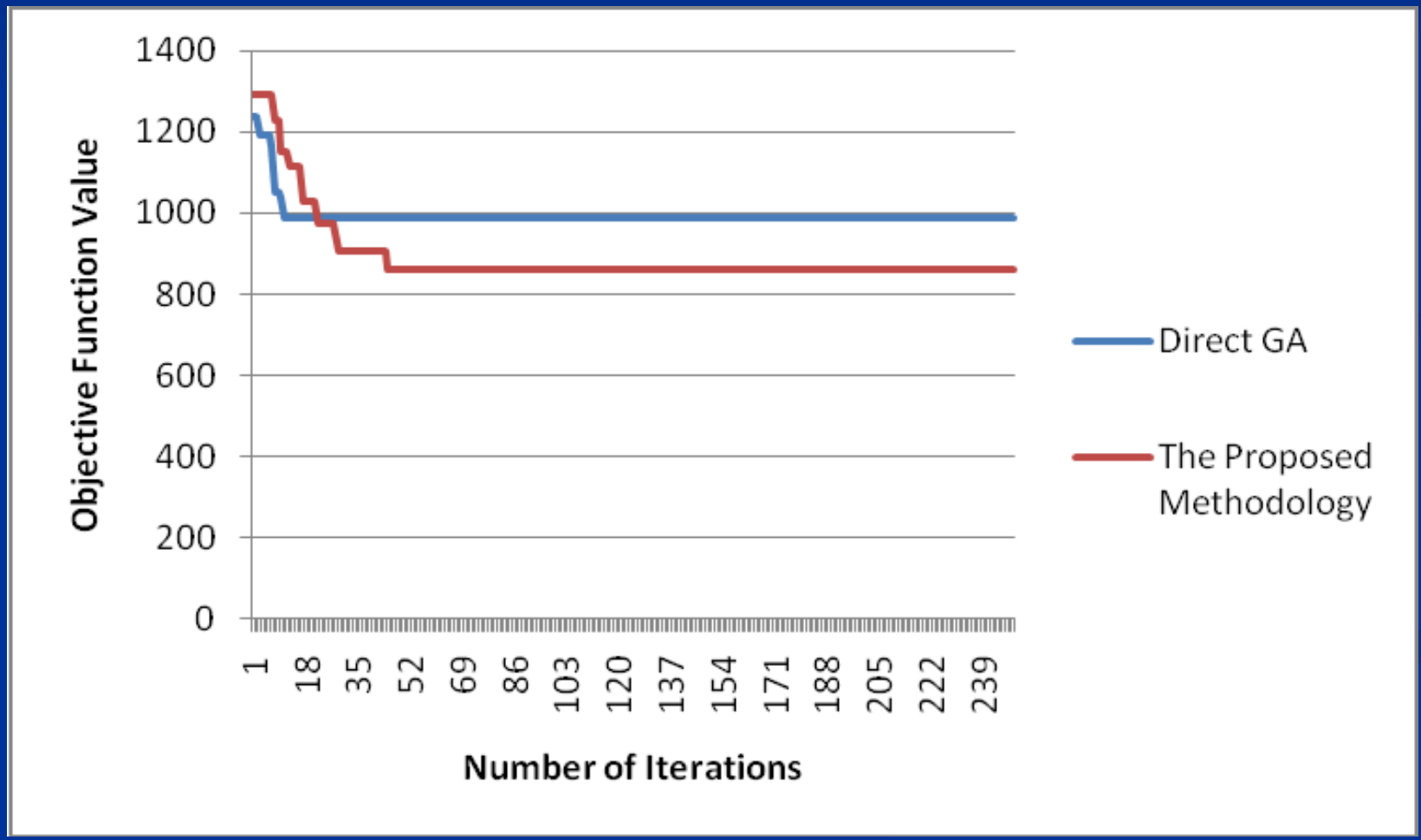
Example Network (1)





Example Network (1) – comparison with GA

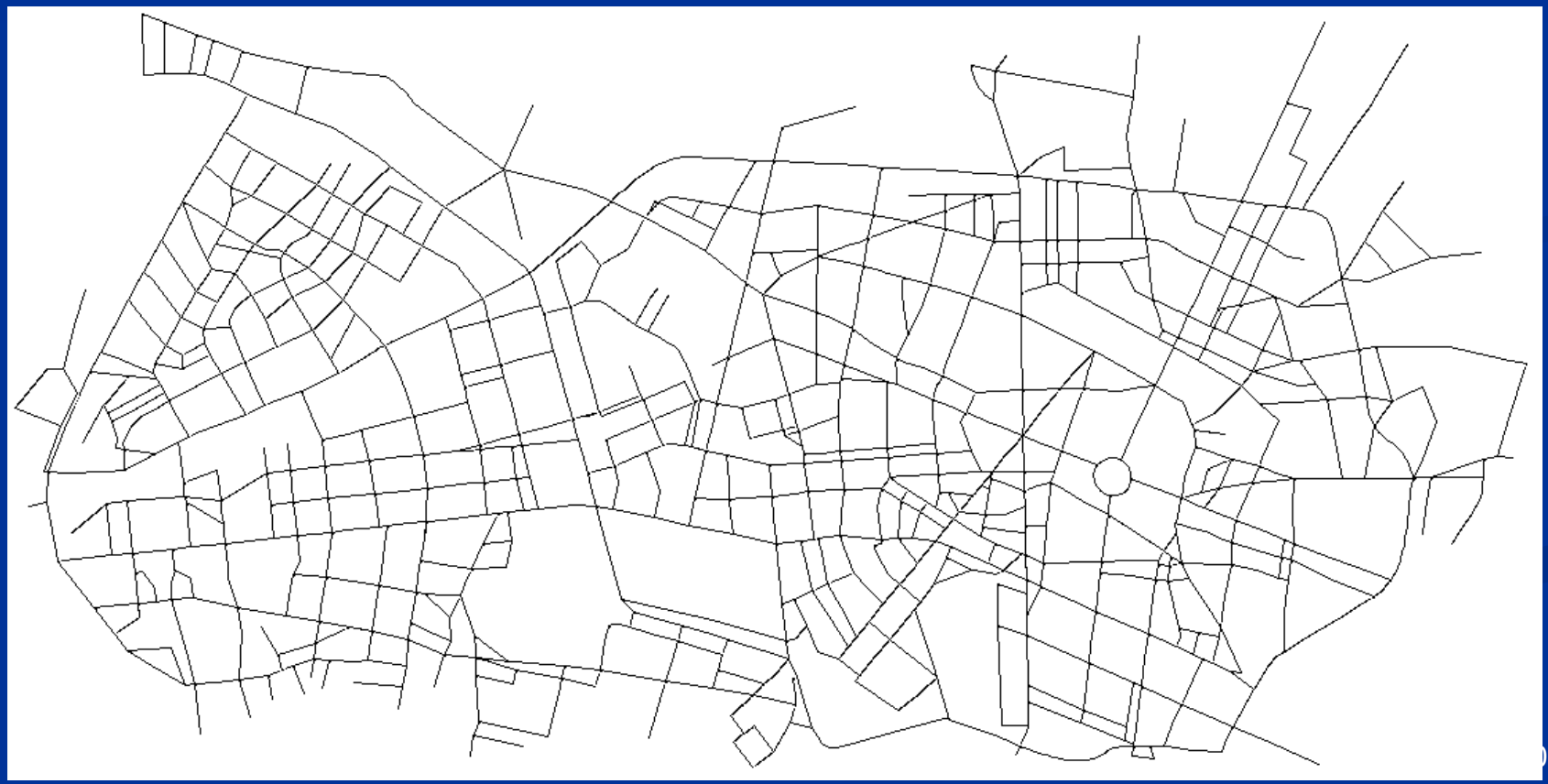
- The proposed procedure converges to a better solution than using only (direct) GA



Example Network (2) – city of Mashhad

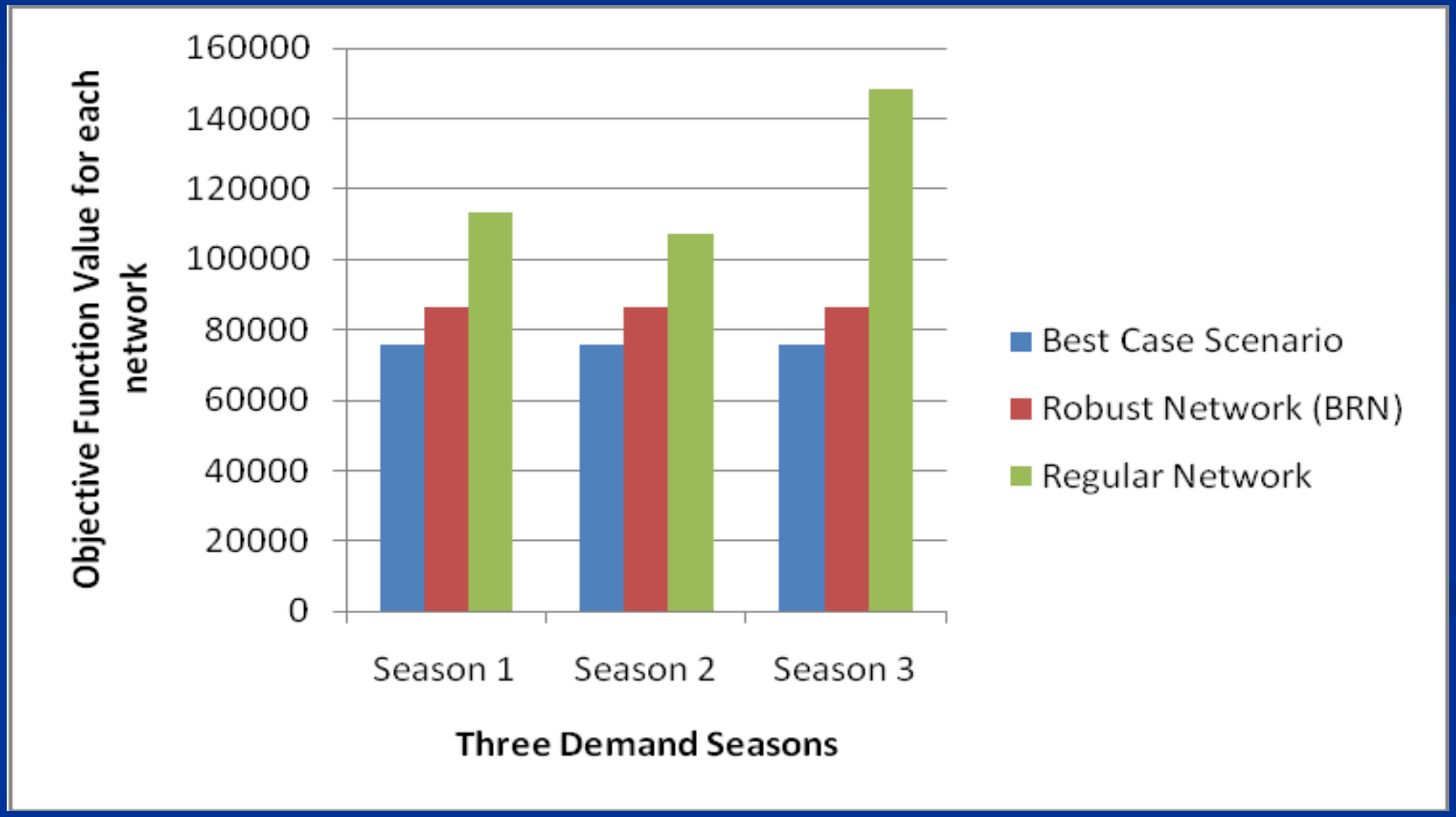
- 3 million residents
- 20 million annual visitors – a typical case of demand variation

PT extra demand can't be handled like in this case



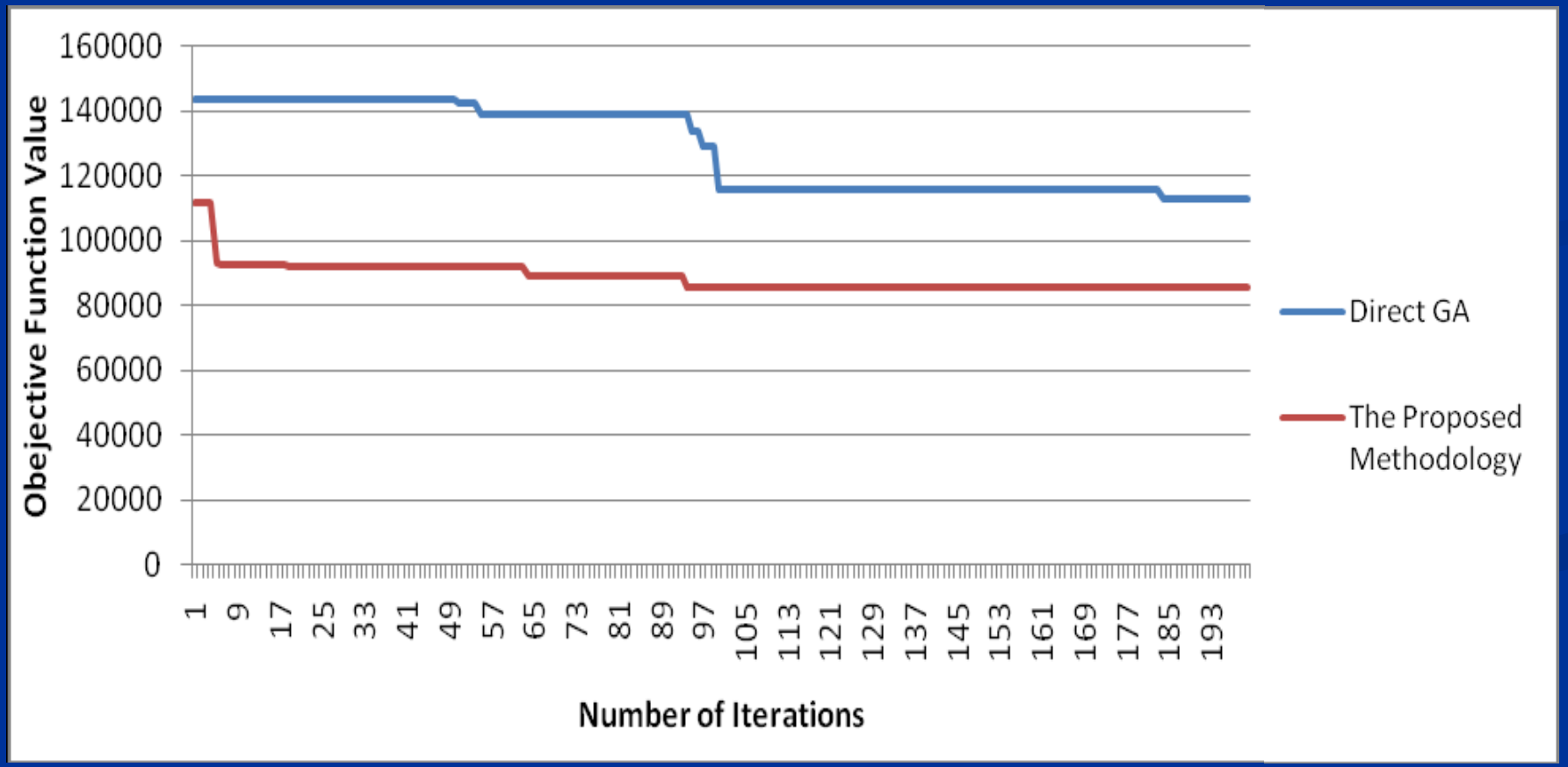
Example Network (2) – city of Mashhad Results

- BRN provides a good solution to match with the variable demand



Example Network (2) – city of Mashhad
Comparison with GA

- Note that the proposed method starts from a better point because of the filtering of initial population; then converges to a better solution



Conclusions

Considering variable nature of transit demand in designing the bus network is essential in cities characterized by such

The complexity of the variable-demand transit network problem can be approached using heuristics

The hybrid-optimization (heuristic-based) method proposed provides promising results

Further work is recommended using meta-heuristic and other methods

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End of Presentation

Thank-you!

Glad to
take questions…