Probabilistic Arc Routing Problem

by

Si Chen, Murray State University

Bruce Golden, University of Maryland

Richard Wong, United Parcel Service

Hongsheng Zhong, United Parcel Service

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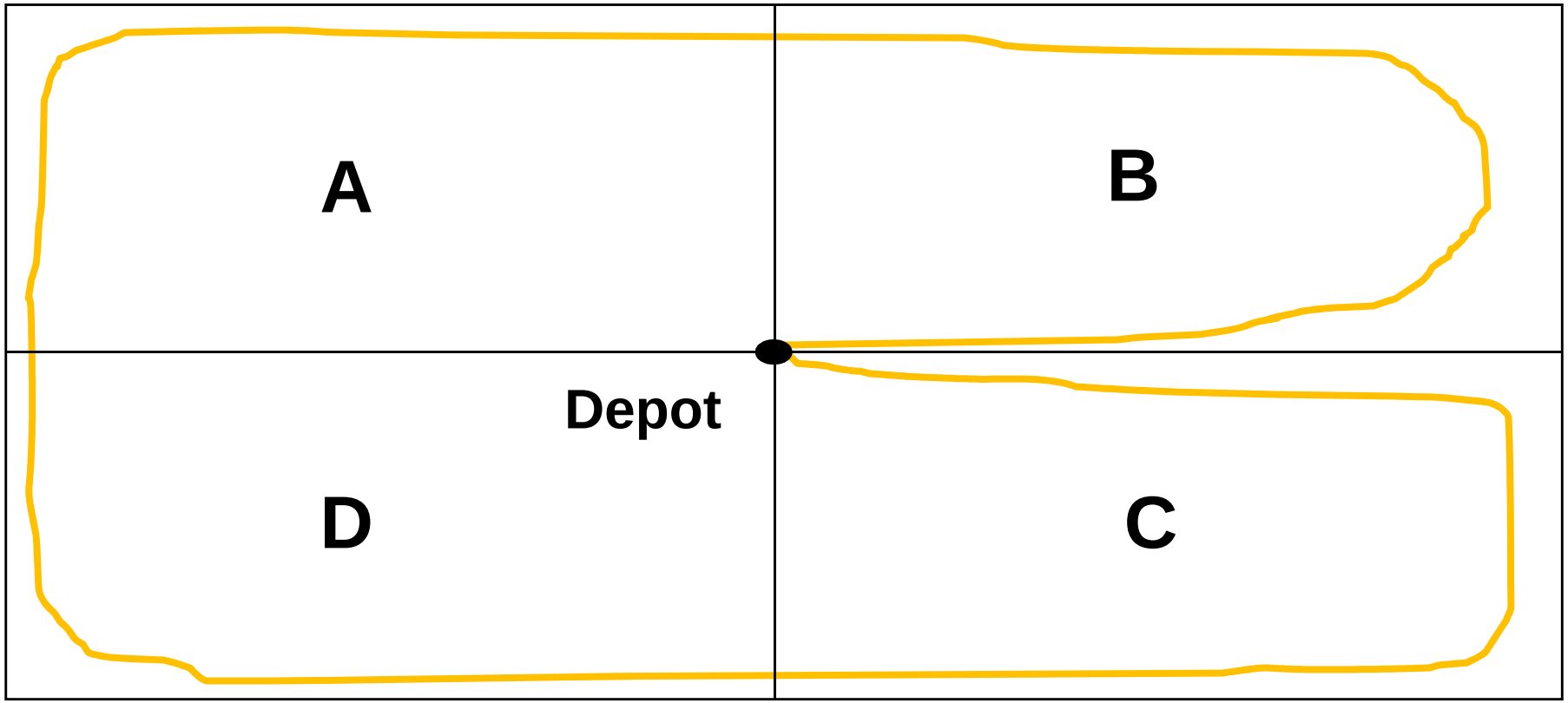
Outline

- Motivation
- Arc Routing Problem with Probability
- Proposed Solution Methods
- Computational Results
- Conclusion

Terminology



•**The rectangle represents a Service Territory serviced by four drivers.**

•**They are encouraged to follow a Master Route which defines a sequence of street segments.**

Benefits of Using Master Route

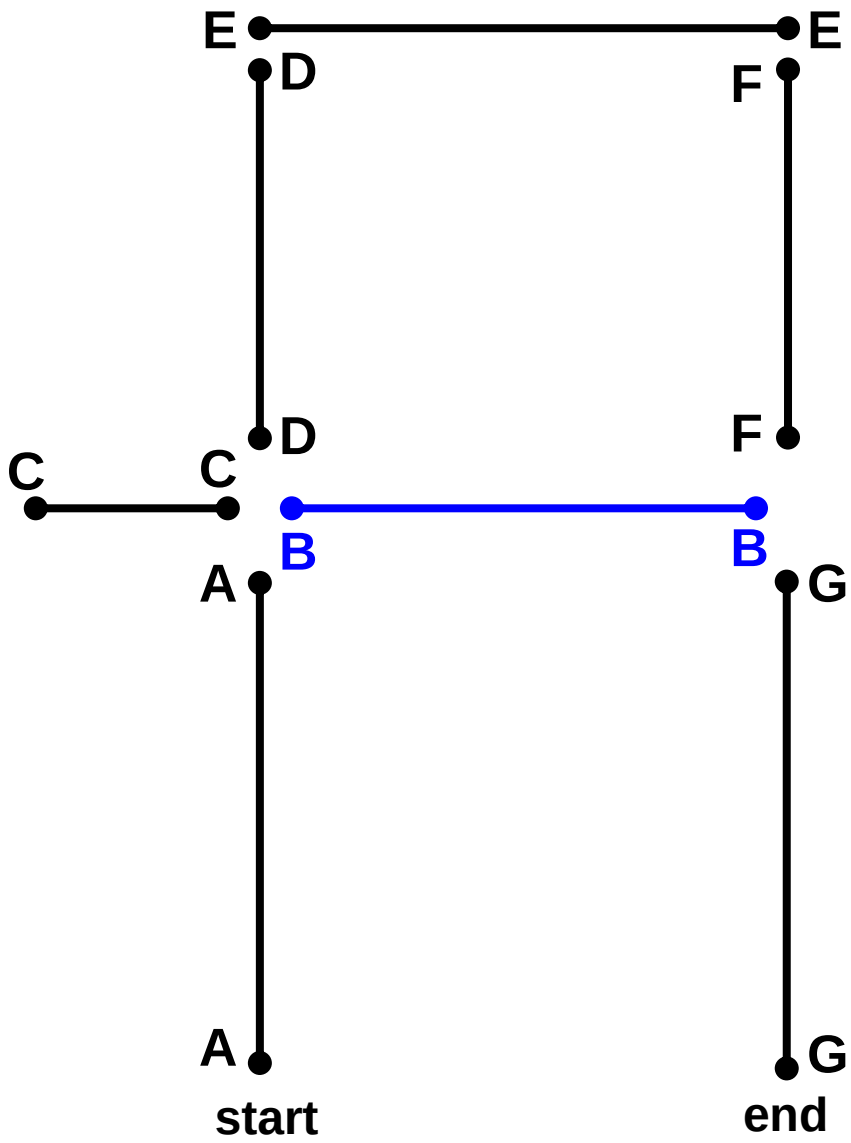
- Maintain the **consistency** of the routes
  - Each service provider serves roughly the same geographical area each day
  - Provide service at approximately the same time each day
- Improve the **efficiency** of delivery
  - Load packages into package cars in accordance with the pre-determined sequence

Problem Description: DARP

- The deterministic arc routing problem (DARP)
  - Given a service territory consisting of street segments
  - Construct the master route that traverses all the streets with the minimum length
  - On a particular day skip customers that do not require services

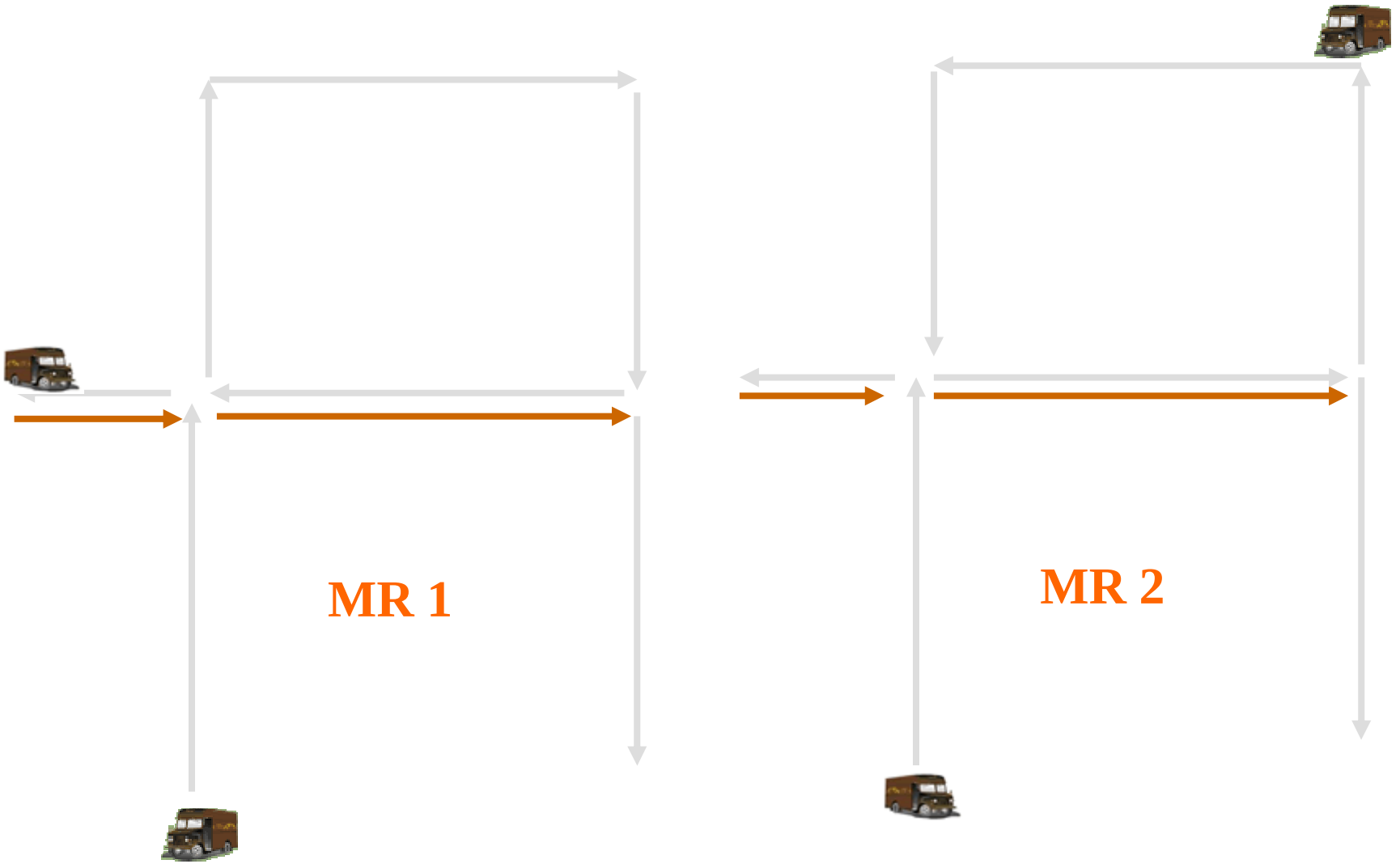
Street Segment Presence Probability

- Street segment presence probability
  - the probability that a street segment requires at least one stop during a given time period
  - high variability is observed from real-world industrial data
- Failure to address the variability due to street segment presence probability may cause inefficiency

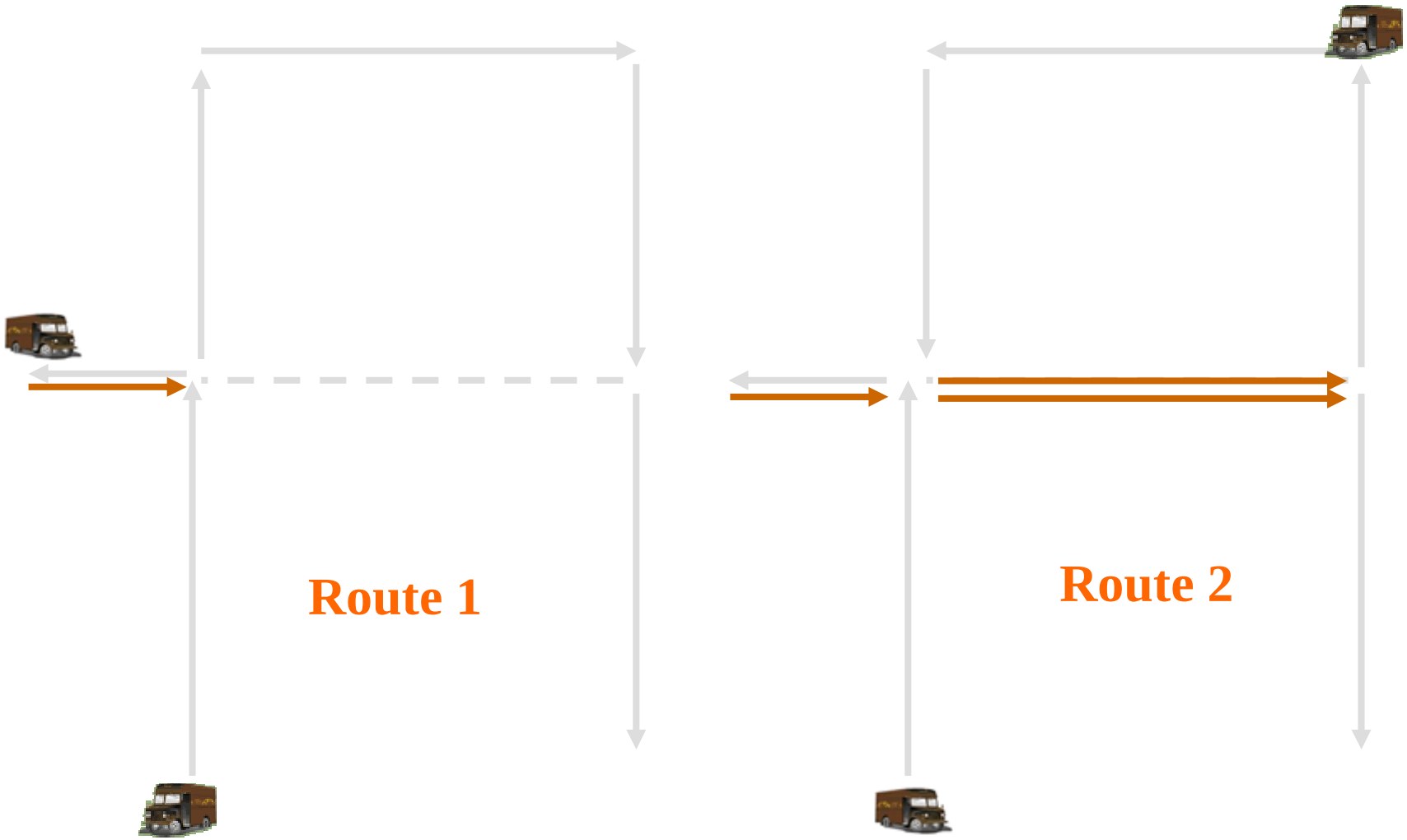


- 7 street segments
- **B** has a small presence probability

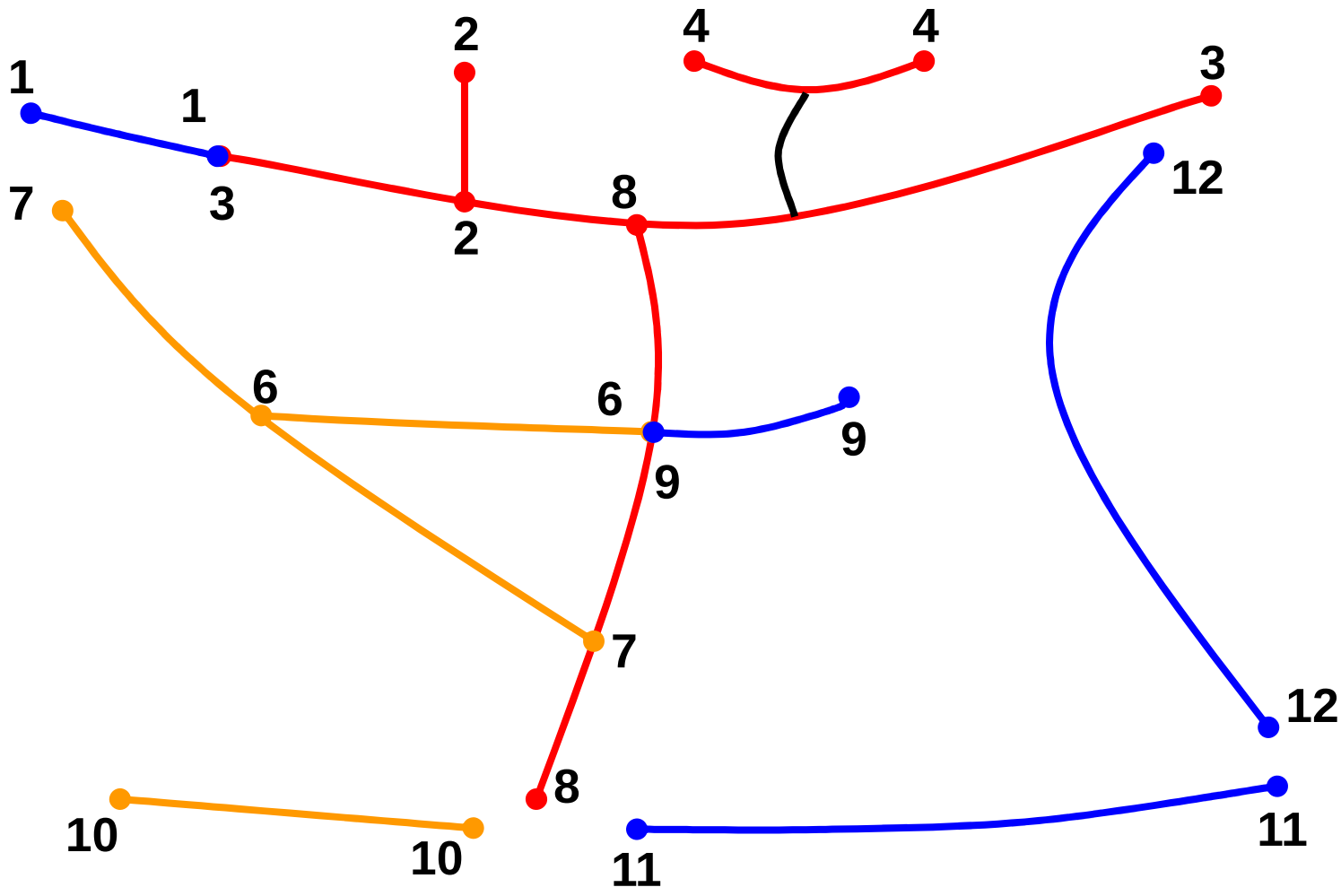
Master Route (MR) 1 and 2 have the same length



On a particular day, B does not require a service.

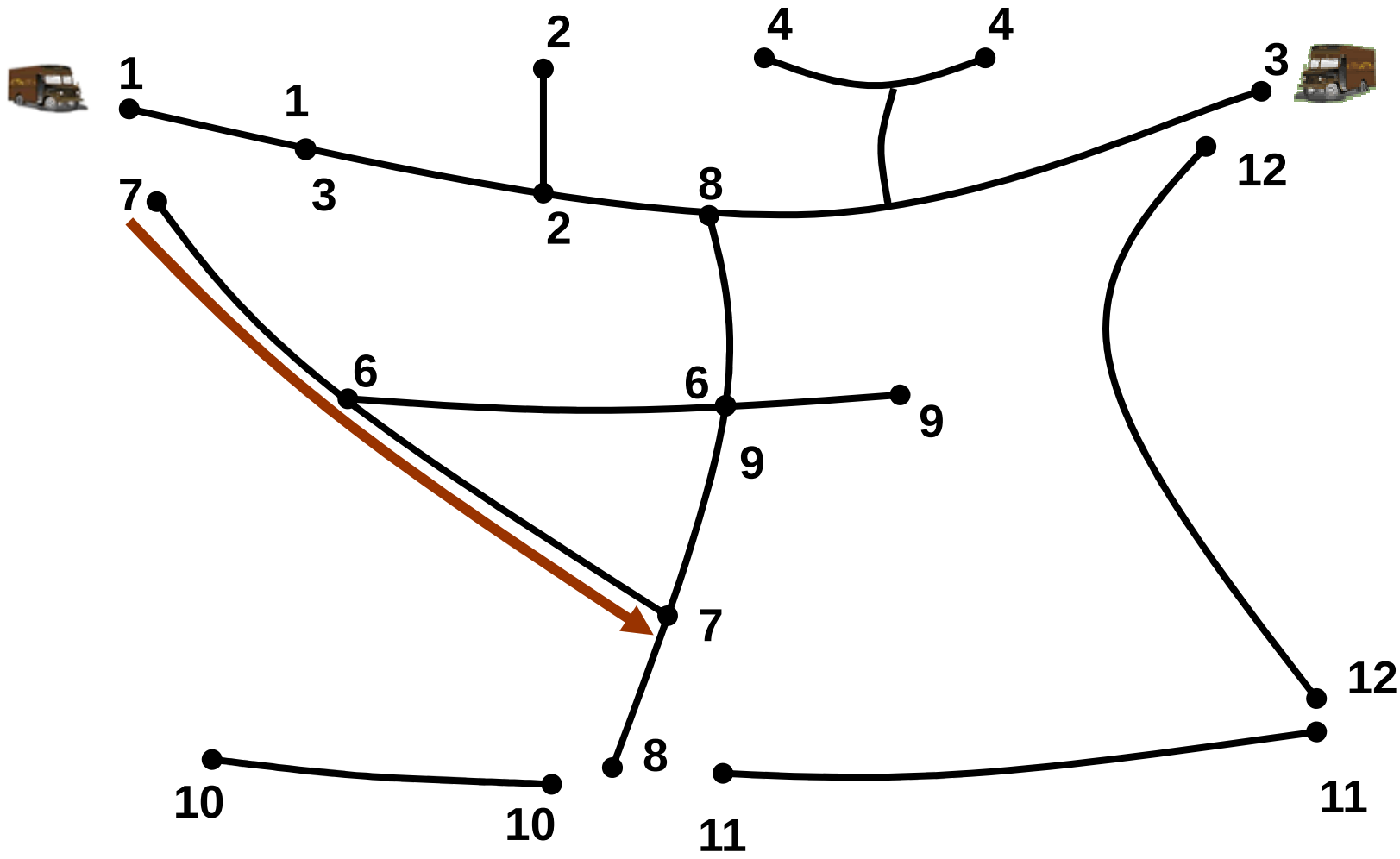


Apparently, Route 1 is better than Route 2.

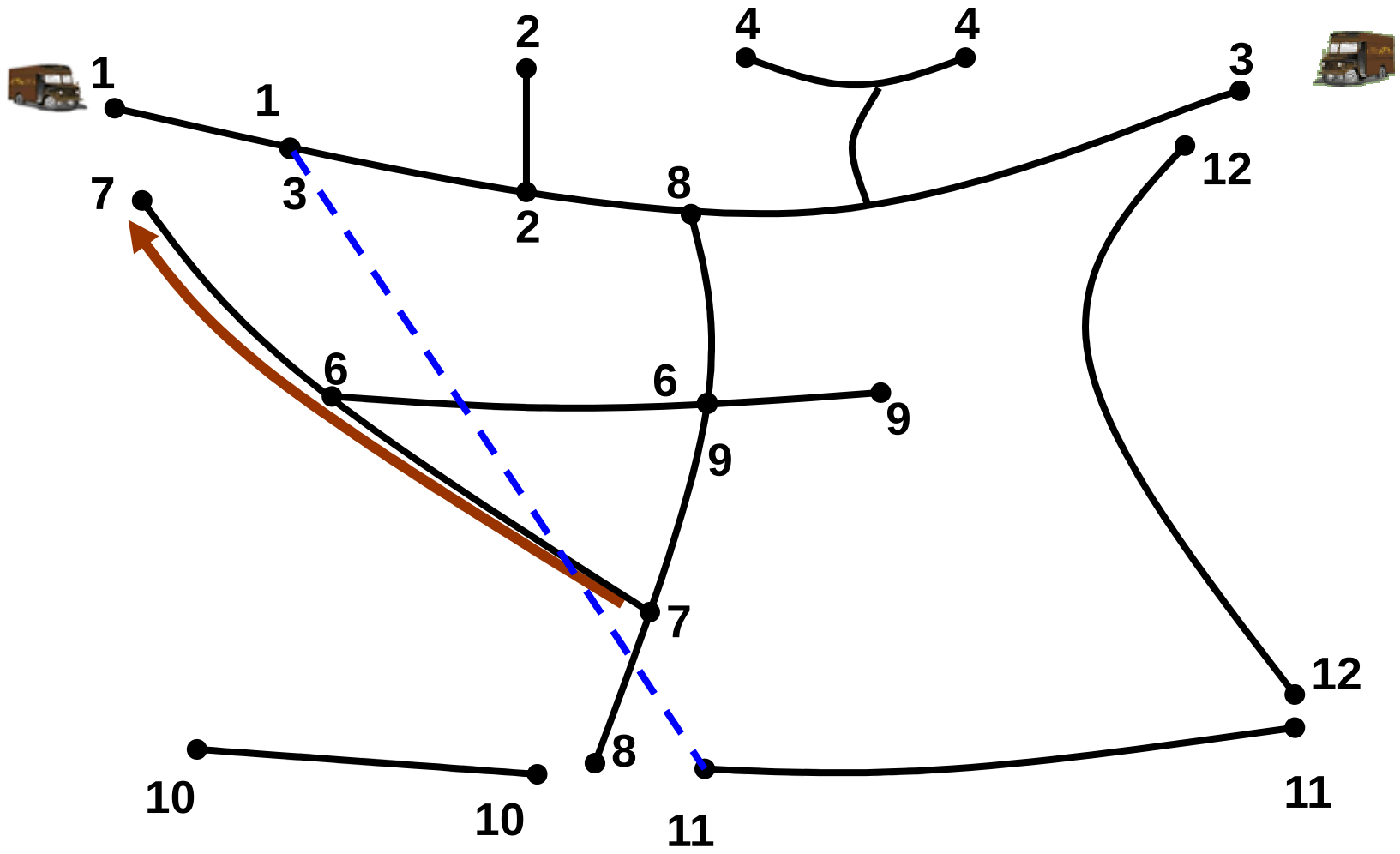


Street Segment Presence Probability

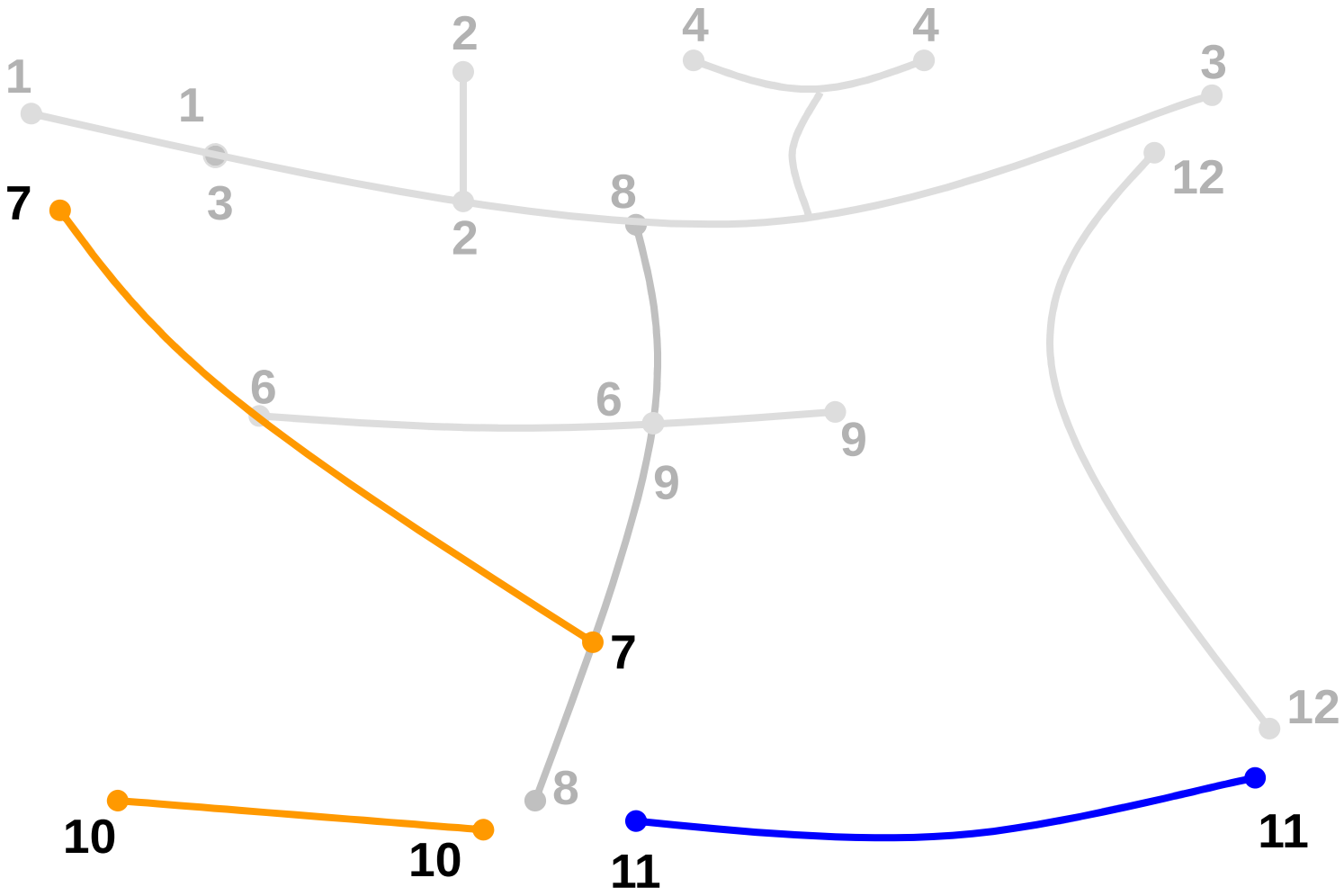
Red: [0, 0.2] **Blue: (0.2, 0.6]** **Orange: (0.6, 1]**



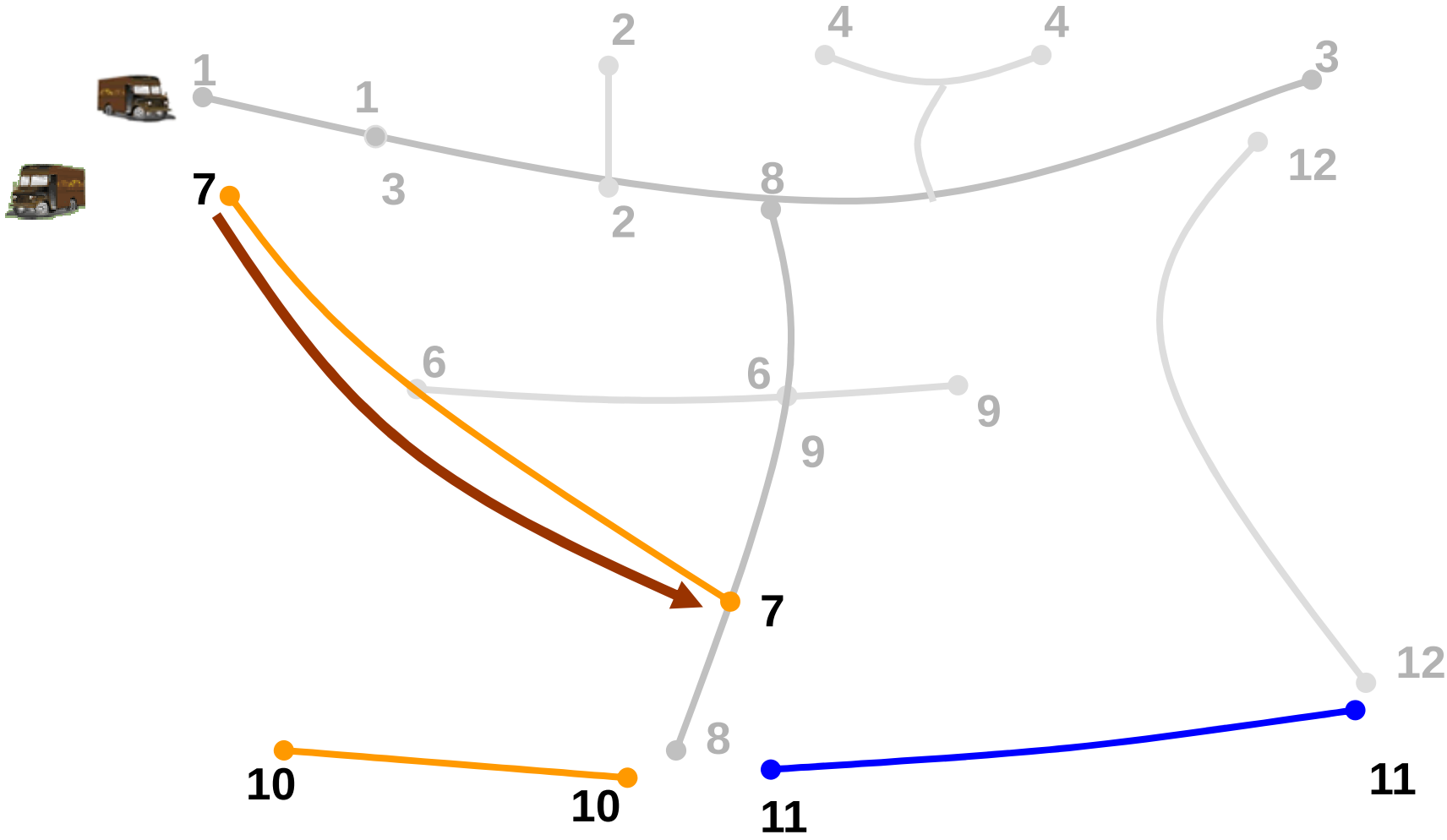
DARP Master Route



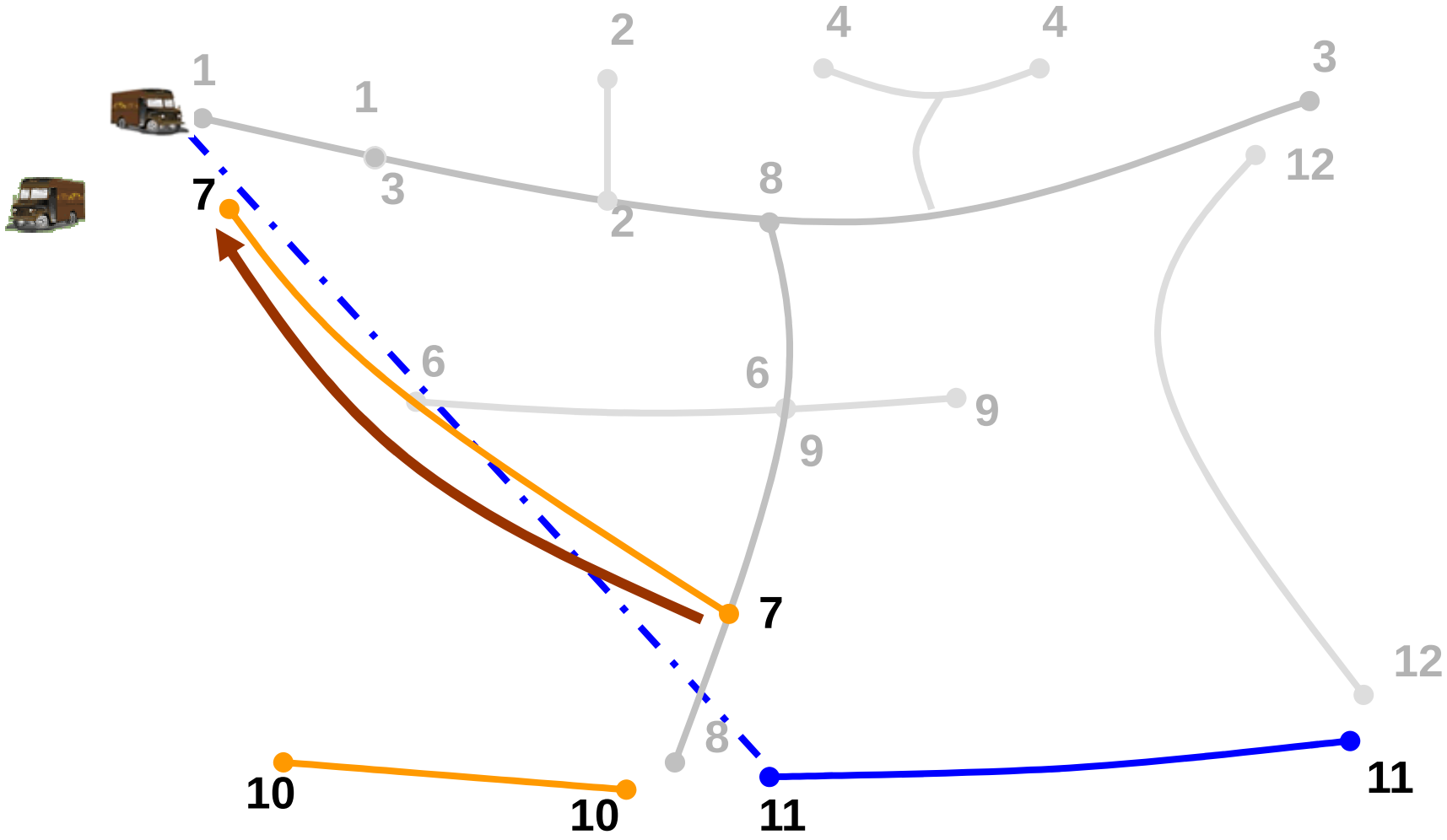
Probabilistic Master Route



Streets that need to be visited on a particular day



The Route Generated From DARP Master Route



The Route Generated From Probabilistic Master Route

Study ARP in a Probabilistic Context

- Two approaches that take into account the uncertainty in street segment presence
  - The probabilistic arc routing problem (PARP)
  - The multi-period arc routing problem (MARP)

Problem Description: PARP

- The probabilistic arc routing problem (PARP)
  - Given a service territory consisting of street segments
  - Construct a master route that traverses all the street segments with the minimum **expected** length

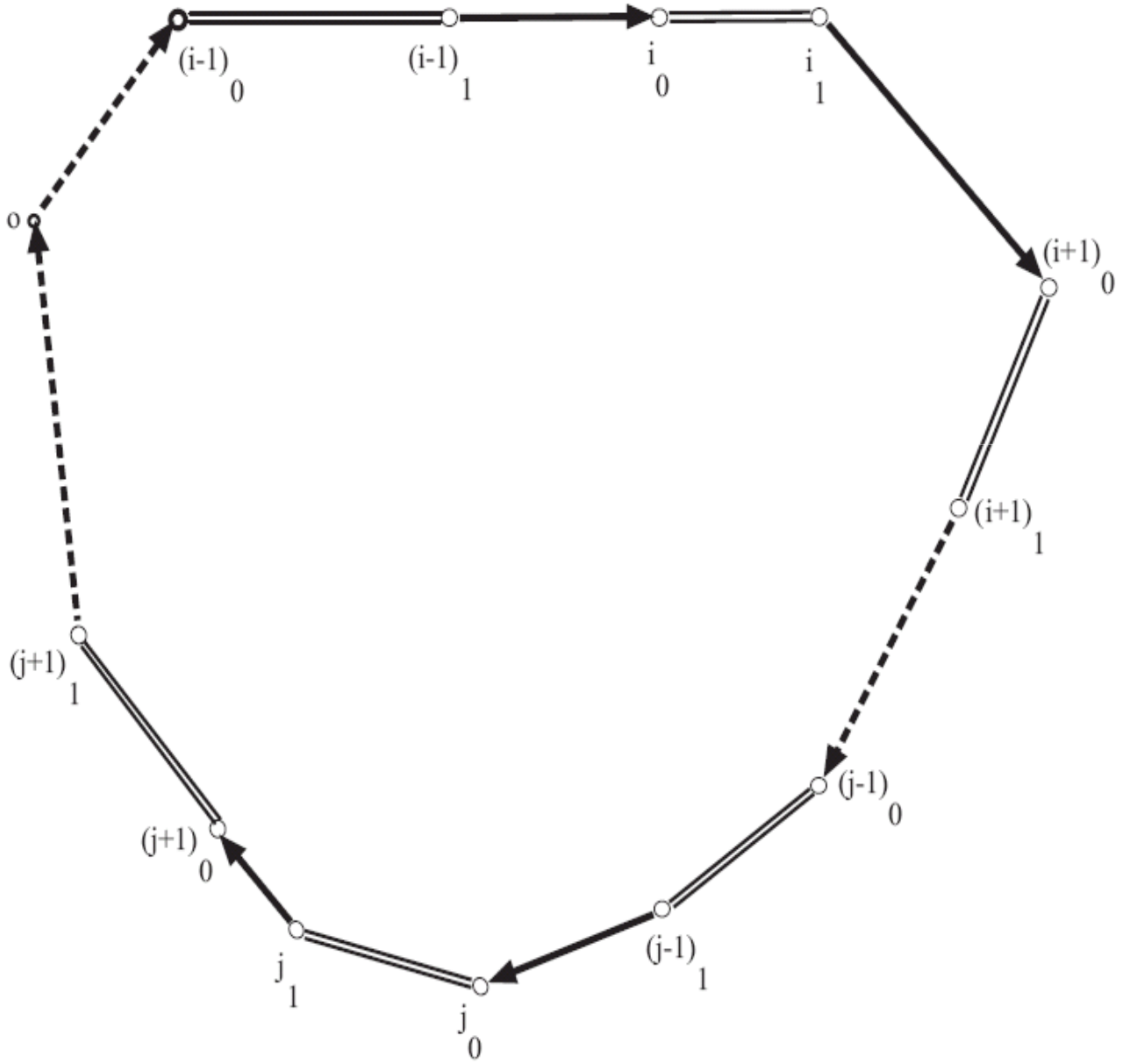
Problem Description: MARP

- The Multi-period arc routing problem (MARP)
  - Given
    - a service territory consisting of street segments
    - a set of time periods (days)
    - a set of street segments that need to be serviced on each day
  - Construct a master route that traverses all the street segments with the minimum **average** length over all of the days

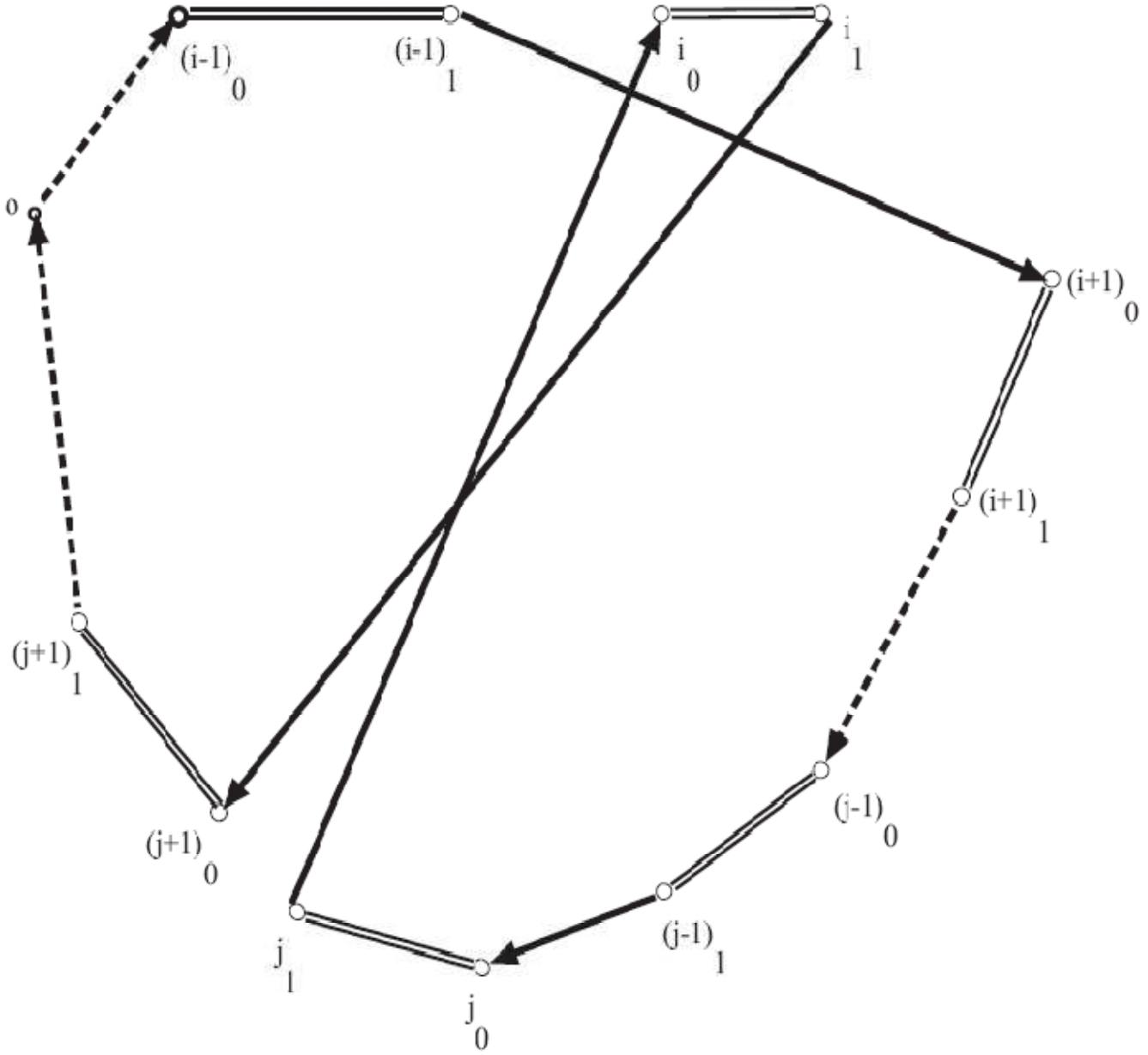
Solution Approach

- The procedure for DARP is provided by the small-package delivery company
- We propose
  - A Probabilistic Local Search Procedure for PARP
  - A Multi-Period Evaluation Procedure for MARP
  - Both procedures utilize local search routines
    - 1-Shift and 2-OPT

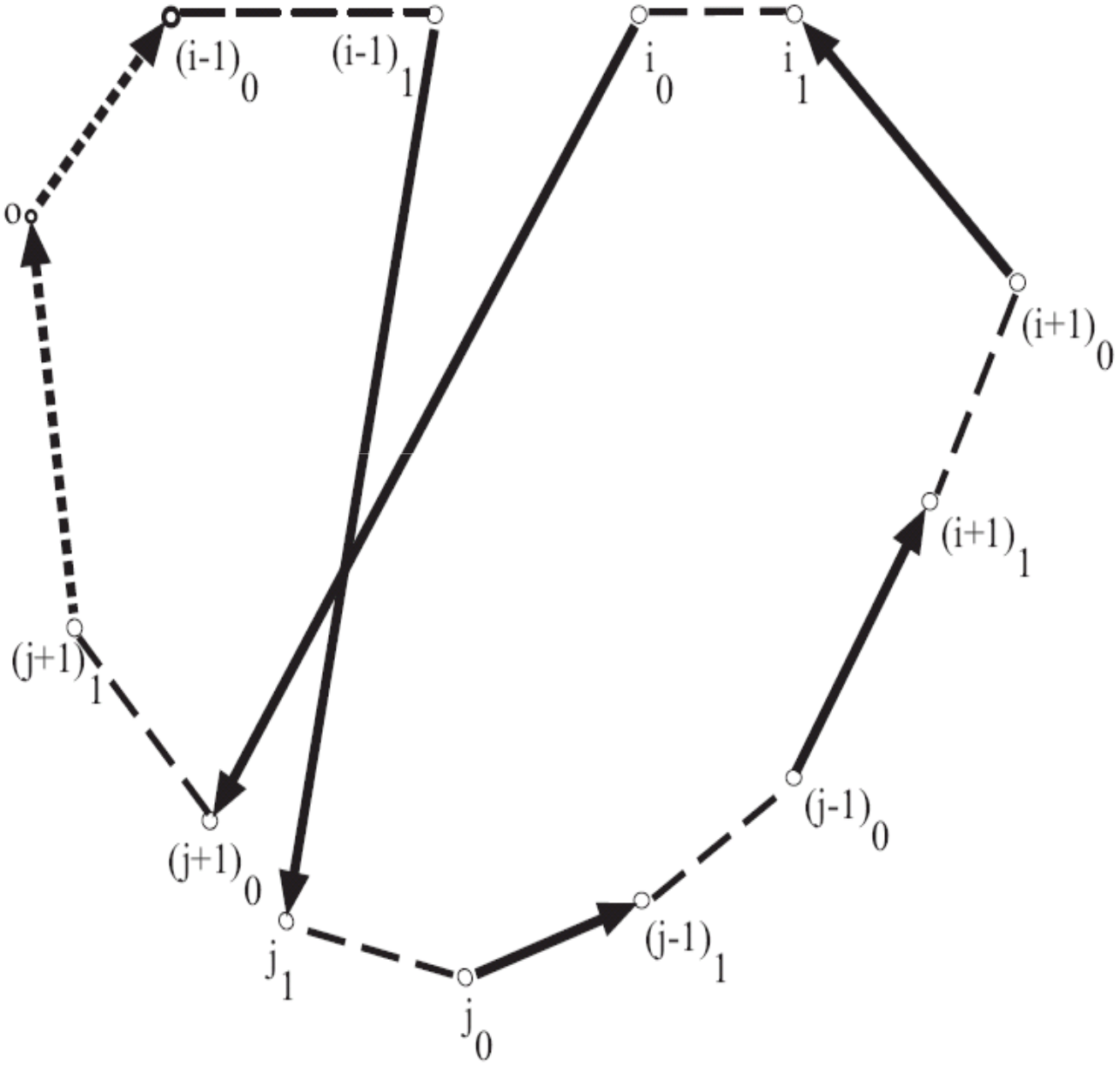
Original Master Route



1-Shift



2-OPT



Probabilistic Local Search Procedure

- Use the DARP master route as Initial Solution
- Apply 1-Shift and 2-OPT
- Use the ***expected*** length to evaluate each local search movement

Multi-period Evaluation Procedure

- Use the DARP master route as the initial solution
- Apply 1-Shift and 2-OPT
- Use the **average** length over all of the days to evaluate each local search movement

Computational Experiments

- Compare the performances of the master route from DARP, PARP, and MARP over
  - deterministic length
  - expected length
  - average length
- Test problems include industrial data and computer generated data (not reported here due to the length of the presentation)
- We use VC++ 6.0 and a PC with Pentium IV 2 GHz and 1.24G RAM

Industrial Test Problem Description

Index	# of Street Segments	# of days
1	235	30
2	228	30
3	226	20
4	169	30
5	147	30

Running Time Comparison I

Index	PARP (sec)	MARP (sec)
1	13553	15
2	11818	13
3	11482	9
4	2761	5
5	1567	3

Deterministic Length Comparison I

Index	DARP Master Route	PARP Master Route	MARP Master Route
1	1	1.1042	1.1206
2	1	1.1873	1.2045
3	1	1.1611	1.0869
4	1	1.0852	1.0585
5	1	1.1427	1.1448

Expected Length Comparison I

Index	DARP Master Route	PARP Master Route	MARP Master Route
1	1	0.9783	0.9841
2	1	0.9502	0.9522
3	1	0.9768	0.9817
4	1	0.9883	0.9888
5	1	0.9831	0.9885

Average Length Comparison I

Index	DARP Master Route	PARP Master Route	MARP Master Route
1	1	0.9795	0.9810
2	1	0.9577	0.9455
3	1	0.9799	0.9753
4	1	0.9925	0.9876
5	1	0.9892	0.9754

Conclusion

- Studied the arc routing models for small package local routing
- PARP and MARP address the variability due to street segment presence probability
- Propose a probabilistic local search procedure and a multi-period evaluation procedure
- Computational results demonstrate savings in mileages