BACKHAUL OPTIMIZATION

Consider the common backhaul scenarios shown in Figure I of the Appendix.

1. General form of Linear Programming (LP) Model for Backhauls (Empty Mile-based)

$Method\ (1)$: $Minimize\ \ z = \sqrt{dist(a,d)^2 + dist(b,c)^2}$

$Subject\ to$:
$dist(b,c) + dist(c,d) + dist(d,a) \geq dist(a,b)$
$dist(a,b),\ dist(b,c),\ dist(c,d),\ dist(a,d) \geq 0$

Notes on Method (1):

- Considers **loaded miles** from dist(a,b) and dist(c,d) as a **value-added** service.
- Considers **empty miles** from dist(a,d) and dist(b,c) as a **non-value-added** service.
- This model seeks to minimize the non-value-added distance traveled (empty miles from (1) the destination to the pick-up location and (2) the drop-off location to the origin).

2. General form of Linear Programming (LP) Model for Backhauls (Distance-based)

$Method\ (2)$: $Minimize\ \ z = \ dist(b,c) + dist(c,d) + dist(d,a) - dist(a,b)$

$Subject\ to$:
$dist(b,c) + dist(c,d) + dist(d,a) \geq dist(a,b)$
$dist(c,d) \geq 100$
$dist(c,d) \geq 0.5 \times dist(a,b)$
$dist(a,b),\ dist(b,c),\ dist(c,d),\ dist(a,d) \geq 0$

Notes on Method (2):

- This model aims to minimize the total round-trip distance by considering that the shortest possible return path would be if the following equation were true: $dist(b,c) + dist(c,d) + dist(d,a) = dist(a,b)$.
- The additional constraints handle cases where the backhaul pick-up and drop-off locations are along the same path as the actual return, but only make up a small portion of the journey back, resulting in excess empty miles traveled.

3. General form of Linear Programming (LP) Model for Backhauls (Cost-based)

$Method\ (3)$: $Minimize\ z\ = \ cpm_1\big(dist(a,b) + dist(b,c) + dist(c,d) + dist(d,a)\big) - cpm_2(dist(c,d))$

$Subject\ to$:
$dist(b,c) + dist(c,d) + dist(d,a) \geq dist(a,b)$
$dist(a,b),\ dist(b,c),\ dist(c,d),\ dist(a,d) \geq 0$

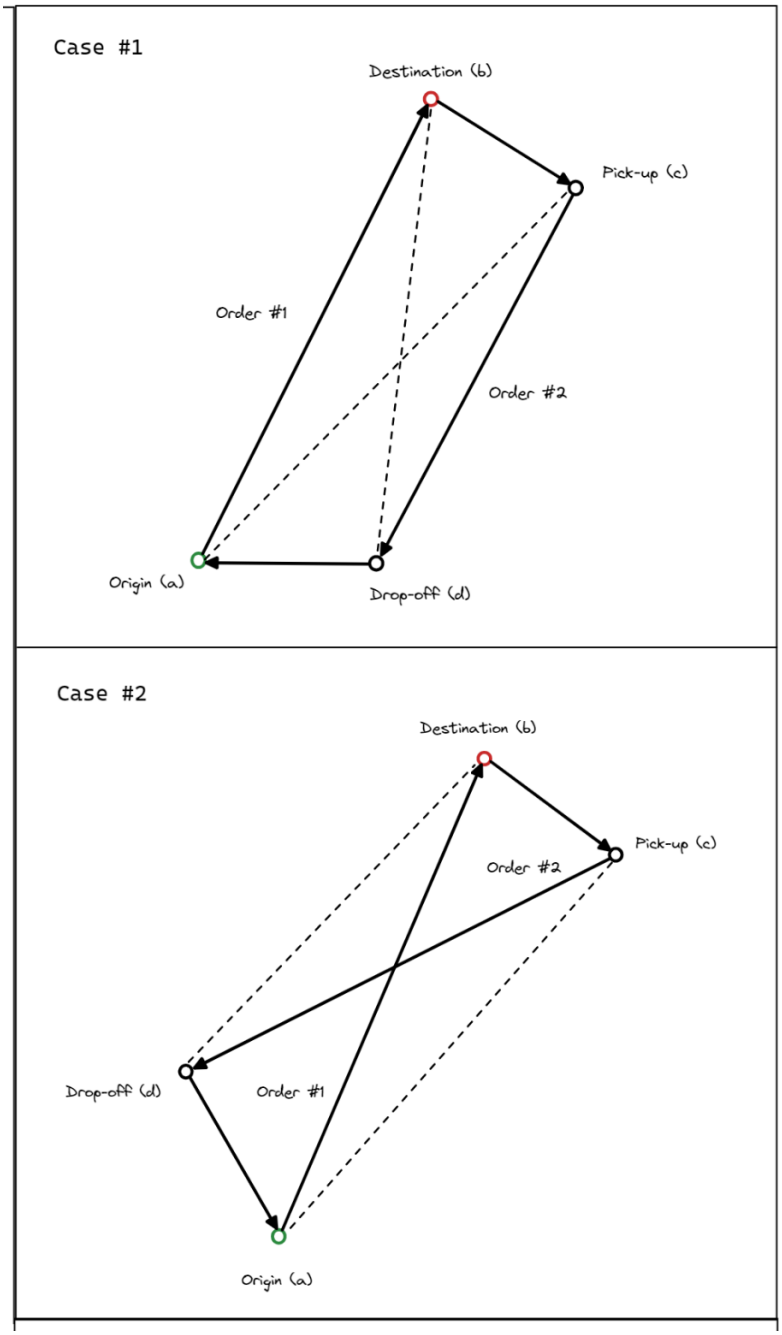
Where $\boldsymbol{cpm_1 = cost\ per\ mile}$ $(\boldsymbol{standard})$ *and* $\boldsymbol{cpm_2 = revenue\ per\ mile}$ $(\boldsymbol{backhaul})$

Notes on Method (3):

- This model seeks to minimize an estimate of the **total round-trip cost less backhaul revenue** using the straight-line distance between two locations.

APPENDIX

Figure I: Common Backhaul Scenarios



Cost Equations (Actual)

(1) $Actual\ OD\ Pair\ Cost = Round\ Trip\ Miles \times CPM\ (standard) - Backhaul\ Revenue$

(2) $Actual\ OD\ Pair\ CPM = \frac{Actual\ OD\ Pair\ Cost}{OD\ Pair\ Loaded\ Miles\ (one\ way)}$

Note: Miles are actual road miles driven.