















## APPENDIX

LINGO solution for the non-shared drop-and-pull stations in hub-and-spoke networks

```
[OBJ]MAX=@SUM(ROUTE1(I,J):(1/(C(I,J)^2))*P(J)*Q(J)*X(I,J)))+@SUM(ROUTE2(J,K):(1/(D(J,K)^2))*P(J)*Q(J)*Y(J,K));
@SUM(ROUTE1(I,J):T*P(J)*C(I,J)*X(I,J)+g*P(J)*X(I,J))+@SUM(ROUTE2(J,K):T*P(J)*D(J,K)*Y(J,K))+@SUM(WAREHOUSES(J):P(J)*U(J))<=Z;
@SUM(WAREHOUSES(J):P(J)*K(J)*3.14*40000/179770)>=alpha;
@FOR(WAREHOUSES(J):A(I)=P(J)*X(I,J));
@FOR(WAREHOUSES(J):B(K)=P(J)*Y(J,K));
@FOR(WAREHOUSES(J):P(J)*M(J)>=(@SUM(FROM(I):P(J)*X(I,J))));
@FOR(TO(K):@SUM(WAREHOUSES(J):P(J)*Y(J,K))>=B(K));
@FOR(WAREHOUSES(J):@SUM(FROM(I):X(I,J))=@SUM(TO(K):Y(J,K)));
@FOR(ROUTE1(I,J):X(I,J)>=0);
@FOR(ROUTE2(J,K):Y(J,K)>=0);
@FOR(WAREHOUSES(J):@BIN(P(J)));
@FOR(WAREHOUSES(J):P(J)=@IF(@SUM(FROM(I):X(I,J))#NE#0,1,0));
END
```

LINGO solution for the shared drop-and-pull stations in hub-and-spoke networks

```
[OBJ]MAX=@SUM(ROUTE1(I,J):(1/(C(I,J)^2))*P(J)*Q(J)*X(I,J)))+@SUM(ROUTE2(J,K):(1/(D(J,K)^2))*P(J)*Q(J)*Y(J,K));
@SUM(ROUTE1(I,J):T*P(J)*C(I,J)*X(I,J)+g*P(J)*X(I,J))+@SUM(ROUTE2(J,K):T*P(J)*D(J,K)*Y(J,K))+@SUM(WAREHOUSES(J):P(J)*U(J))<=Z;
@SUM(WAREHOUSES(J):P(J)*K(J)*3.14*40000/179770)>=alpha;
@FOR(WAREHOUSES(J):P(J)*M(J)>=(@SUM(FROM(I):P(J)*X(I,J))));
@FOR(TO(K):@SUM(WAREHOUSES(J):P(J)*Y(J,K))>=B(K));
@FOR(WAREHOUSES(J):@SUM(FROM(I):X(I,J))=@SUM(TO(K):Y(J,K)));
@FOR(ROUTE1(I,J):X(I,J)>=0);
@FOR(ROUTE2(J,K):Y(J,K)>=0);
@FOR(WAREHOUSES(J):@BIN(P(J)));
@FOR(WAREHOUSES(J):P(J)=@IF(@SUM(FROM(I):X(I,J))#NE#0,1,0));
@FOR(FROM(I):A(I)=@SUM(WAREHOUSES(J):P(J)*X(I,J)));
END
```