

MODEL:

!A Novel Multi-Objective Load Planning Model in An Intermodal Transportation Network Developed by Kemal SUBULAN;

SETS:

!Indices & Sets;

ORIGINS/1..3/;

RORO_TERMINALS/1..4/;

TRAIN_TERMINALS/1..6/;

DESTINATIONS/1..49/;

PERIODS/1..12/;

RESULTS/1..1/:ZCOST,Z1,Z2,Z3,Z4,ZENVIRONMENT,ZE1,ZE2,ZE3,ZE4,ZTIME,ZT1,ZT2,ZT3,ZT4;

SHIPPMENT_IMP (ORIGINS,DESTINATIONS,PERIODS):X_IMP,DE_IMP,C_SP_IMP,SP_IMP;

SHIPPMENT_EXP (DESTINATIONS,ORIGINS,PERIODS):X_EXP,DE_EXP,C_SP_EXP,SP_EXP;

MARILINK1 (ORIGINS,RORO_TERMINALS)/1 1, 1 2, 1 4, 2 2, 2 3, 3 2/:TT_IJ;

MARILINK2 (RORO_TERMINALS,ORIGINS)/1 1, 2 1, 4 1, 2 2, 3 2, 2 3/:TT_JI;

SEMI_INTERMODAL_IMP (MARILINK1,DESTINATIONS,PERIODS):Y_IMP;

SEMI_INTERMODAL_EXP (DESTINATIONS,MARILINK2,PERIODS):Y_EXP;

MARIRAILLINK1 (ORIGINS,RORO_TERMINALS,TRAIN_TERMINALS)/1 2 1, 1 2 2, 1 2 3, 1 2 4, 1 2 5, 1 2 6, 2 2 1, 2 2 2, 2 2 3, 2 2 4, 2 2 5, 2 2 6, 3 2 1, 3 2 2, 3 2 3, 3 2 4, 3 2 5, 3 2 6/;

MARIRAILLINK2 (TRAIN_TERMINALS,RORO_TERMINALS,ORIGINS)/1 2 1, 2 2 1, 3 2 1, 4 2 1, 5 2 1, 6 2 1, 1 2 2, 2 2 2, 3 2 2, 4 2 2, 5 2 2, 6 2 2, 1 2 3, 2 2 3, 3 2 3, 4 2 3, 5 2 3, 6 2 3/;

INTERMODAL_IMP (MARIRAILLINK1,DESTINATIONS,PERIODS):Z_IMP;

INTERMODAL_EXP (DESTINATIONS,MARIRAILLINK2,PERIODS):Z_EXP;

LINK_IJ1 (ORIGINS,RORO_TERMINALS)/1 1, 1 2, 2 3/:D_IJ;

LINK_JI1 (RORO_TERMINALS,ORIGINS)/1 1, 2 1, 3 2/:D_JI;

LINK_IJ11 (ORIGINS,RORO_TERMINALS)/1 2, 2 3/;

LINK_JI11 (RORO_TERMINALS,ORIGINS)/2 1, 3 2/;

LINK_SPOT_IMP (ORIGINS,RORO_TERMINALS)/1 2, 2 2, 3 2/:DS_IJ;

LINK_SPOT_EXP (RORO_TERMINALS,ORIGINS)/2 1, 2 2, 2 3/:DS_JI;

LINK_IJ2 (ORIGINS,RORO_TERMINALS)/1 2, 1 4, 2 2, 3 2/:PD_IJ;

LINK_JI2 (RORO_TERMINALS,ORIGINS)/2 1, 4 1, 2 2, 2 3/:PD_JI;

SHIPPMENT_IJ_IMP1 (LINK_IJ1,PERIODS):N_IMP,OWN_IMP,SIJ_IMP;

SHIPPMENT_IJ_IMP11 (LINK_IJ11,PERIODS):UTI_IMP;

SHIPPMENT_IJ_IMP2 (LINK_IJ2,PERIODS):PUB_IJ_IMP;

SHIPPMENT_JI_EXP1 (LINK_JI1,PERIODS):N_EXP,OWN_EXP,SJI_EXP;

SHIPPMENT_JI_EXP11 (LINK_JI11,PERIODS):UTI_EXP;

SHIPPMENT_JI_EXP2 (LINK_JI2,PERIODS):PUB_JI_EXP;

FULLTRAIN_IMP (RORO_TERMINALS,TRAIN_TERMINALS)/2 1, 2 2, 2 3, 2 4, 2 5, 2 6/:TR_JK;

FULLTRAIN_EXP (TRAIN_TERMINALS,RORO_TERMINALS)/1 2, 2 2, 3 2, 4 2, 5 2, 6 2/:TR_KJ;

LINK_JK (RORO_TERMINALS,TRAIN_TERMINALS)/2 2/:PD_JK;

LINK_KJ (TRAIN_TERMINALS,RORO_TERMINALS)/2 2/:PD_KJ;

PUBTRAINLINK1 (TRAIN_TERMINALS,TRAIN_TERMINALS)/4 5, 4 6/:D_SK;

PUBTRAINLINK2 (TRAIN_TERMINALS,TRAIN_TERMINALS)/5 4, 6 4/:D_KS;

TRAINLINK1 (RORO_TERMINALS,TRAIN_TERMINALS)/2 1, 2 3, 2 4/:DD_JK;

TRAINLINK2 (TRAIN_TERMINALS,RORO_TERMINALS)/1 2, 3 2, 4 2/:DD_KJ;

SHIPPMENT_JK_IMP (LINK_JK,PERIODS):PUB_JK_IMP;

SHIPPMENT_KJ_EXP (LINK_KJ,PERIODS):PUB_KJ_EXP;

SHIPPMENT_SJK_IMP (TRAINLINK1,PERIODS):SJK_IMP,M_IMP;

SHIPPMENT_SKJ_EXP (TRAINLINK2,PERIODS):SKJ_EXP,M_EXP;

SHIPPMENT_KK_IMP (PUBTRAINLINK1,PERIODS):PUB_SK_IMP;

SHIPPMENT_KK_EXP (PUBTRAINLINK2,PERIODS):PUB_KS_EXP;

COST_IJ1 (ORIGINS,RORO_TERMINALS)/1 1, 1 2, 2 3/:C_IJ,CAP_RORO_IMP;

COST_IJ2 (ORIGINS,RORO_TERMINALS)/1 2, 1 4, 2 2, 3 2/:C_IJ2;

COST_JI1 (RORO_TERMINALS,ORIGINS)/1 1, 2 1, 3 2/:C_JI,CAP_RORO_EXP;

COST_JI2 (RORO_TERMINALS,ORIGINS)/2 1, 4 1, 2 2, 2 3/:C_JI2;

COST_JK1 (RORO_TERMINALS,TRAIN_TERMINALS)/2 1, 2 3, 2 4/:C_JK,CAP_TRAIN_IMP,MU_IMP;

COST_JK2 (RORO_TERMINALS,TRAIN_TERMINALS)/2 2/:C_JK2,C_JK2P,C_JK2O;

COST_KJ1 (TRAIN_TERMINALS,RORO_TERMINALS)/1 2, 3 2, 4 2/:C_KJ,CAP_TRAIN_EXP,MU_EXP;

COST_KJ2 (TRAIN_TERMINALS,RORO_TERMINALS)/2 2/:C_KJ2;

COST_KK1 (TRAIN_TERMINALS,TRAIN_TERMINALS)/4 5, 4 6/:C_KK1;

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COST_KK2(TRAIN_TERMINALS,TRAIN_TERMINALS)/5 4, 6 4/:C_KKK2;
DISTANCE_JL(RORO_TERMINALS,DESTINATIONS):D_JL,T_JL;
DISTANCE_LJ(DESTINATIONS,RORO_TERMINALS):D_LJ,T_LJ;
DISTANCE_KL(TRAIN_TERMINALS,DESTINATIONS):D_KL,T_KL;
DISTANCE_LK(DESTINATIONS,TRAIN_TERMINALS):D_LK,T_LK;
DISTANCE_IL(ORIGINS,DESTINATIONS):D_IL,T_IL;
DISTANCE_LI(DESTINATIONS,ORIGINS):D_LI,T_LI;
ENDSETS
DATA:
!Data set of the real-life application;
DE_IMP,DE_EXP,C_SP_IMP,C_SP_EXP,N_IMP,N_EXP,M_IMP,M_EXP,C_IJ,C_JI,CAP_RORO_IMP,CAP_RORO_EXP,C_IJ2,C_JI2,C_JK,C_KJ,CAP_TRAIN_IMP,CAP_TRAIN_EXP,C_KJ2,C_KJ2,C_KKK1,C_KKK2,D_JL,D_LJ,D_KL,D_LK,D_IL,D_LI,C_ROAD,MU_IMP,MU_EXP,TT_IJ,TT_JI,TR_KJ,TR_JK,T_IL,T_LI,T_JL,T_LJ,T_KL,T_LK,CO2_KARA,CO2_DENIZ,CO2_TREN,EN,D_IJ,D_J,PD_IJ,PD_JI,DD_JK,DD_KJ,PD_JK,PD_KJ,D_SK,D_KS,Rate_K,Rate_KD,DS_IJ,DS_JI=
@OLE('C:\Users\kemal.subulan\Desktop\San-Tez_Toplanti_2(12_Aralik)\guncel_veri.xlsx','DE_IMP','DE_EXP','C_SP_IMP','C_SP_EXP','N_IMP','N_EXP','M_IMP','M_EXP','C_IJ','C_JI','CAP_RORO_IMP','CAP_RORO_EXP','C_IJ2','C_JI2','C_JK','C_KJ','CAP_TRAIN_IMP','CAP_TRAIN_EXP','C_KJ2','C_KJ2','C_KKK1','C_KKK1','C_KKK2','D_JL','D_LJ','D_KL','D_LK','D_IL','D_LI','C_ROAD','MU_IMP','MU_EXP','TT_IJ','TT_JI','TR_KJ','TR_JK','T_IL','T_LI','T_JL','T_LJ','T_KL','T_LK','CO2_KARA','CO2_DENIZ','CO2_TREN','D_IJ','D_JI','PD_IJ','PD_JI','DD_JK','DD_KJ','PD_JK','PD_KJ','D_SK','D_KS','Rate_K','Rate_KD','DS_IJ','DS_JI');
!Writing the values of decision variables on Excel files;
@OLE('C:\Users\kemal.subulan\Desktop\San-Tez_Toplanti_2(12_Aralik)\yuk_planlama.xlsx','OWN_IMP','OWN_EXP','PUB_IJ_IMP','PUB_JI_EXP','SJK_IMP','SKJ_EXP','PUB_JK_IMP','PUB_KJ_EXP','PUB_SK_IMP','PUB_KS_EXP','X_IMP','Y_IMP','Z_IMP','X_EXP','Y_EXP','Z_EXP','UTI_IMP1','UTI_EXP1','SIJ_IMP11','SJI_EXP11','SP_IL','SP_LI','AYLIK_MALIYE_T','ZCOST','Z_1','Z_2','Z_3','Z_4','Aylik_Surem','Aylik_CO2','Z_TIME','ZT_1','ZT_2','ZT_3','ZT_4','Z_ENVIRONMENT','ZE_1','ZE_2','ZE_3','ZE_4')=OWN_IMP,OWN_EXP,PUB_IJ_IMP,PUB_JI_EXP,SJK_IMP,SKJ_EXP,PUB_KJ_EXP,PUB_SK_IMP,PUB_KS_EXP,X_IMP,Y_IMP,Z_IMP,X_EXP,Y_EXP,Z_EXP,UTI_IMP,UTI_EXP,SIJ_IMP,SJI_EXP,SP_IMP,SP_EXP,Aylik_Maliyet,ZCOST,Z1,Z2,Z3,Z4,Aylik_Sure,Aylik_CO2,ZTIME,ZT1,ZT2,ZT3,ZT4,ZENVIRONMENT,ZE1,ZE2,ZE3,ZE4;
ENDDATA

!(1)First Objective Function: Minimize total transport costs;
!(1); MIN=ZCOST(1);
ZCOST(1)=Z1(1)+Z2(1)+Z3(1)+Z4(1);
Z1(1)=@SUM(COST_IJ1(I,J):@SUM(PERIODS(T):OWN_IMP(I,J,T)*C_IJ(I,J)))
+@SUM(COST_IJ2(I,J):@SUM(PERIODS(T):PUB_IJ_IMP(I,J,T)*C_IJ2(I,J)))
+@SUM(COST_JI1(J,I):@SUM(PERIODS(T):OWN_EXP(J,I,T)*C_JI(J,I)))
+@SUM(COST_JI2(J,I):@SUM(PERIODS(T):PUB_JI_EXP(J,I,T)*C_JI2(J,I)));
Z2(1)=@SUM(COST_JK1(J,K):@SUM(PERIODS(T):SJK_IMP(J,K,T)*C_JK(J,K)))
+@SUM(COST_JK2(J,K):@SUM(PERIODS(T):PUB_JK_IMP(J,K,T)*C_JK2(J,K)))
+@SUM(COST_KK1(S,K):@SUM(PERIODS(T):PUB_SK_IMP(S,K,T)*C_KKK1(S,K)))
+@SUM(COST_KK2(K,S):@SUM(PERIODS(T):PUB_KS_EXP(K,S,T)*C_KKK2(K,S)))
+@SUM(COST_KJ1(K,J):@SUM(PERIODS(T):SKJ_EXP(K,J,T)*C_KJ(K,J)))
+@SUM(COST_KJ2(K,J):@SUM(PERIODS(T):PUB_KJ_EXP(K,J,T)*C_KJ2(K,J)));
Z3(1)=@SUM(SEMI_INTERMODAL_IMP(I,J,L,T):Y_IMP(I,J,L,T)*D_JL(J,L)*C_ROAD)+@SUM(SEMI_INTERMODAL_EXP(L,J,I,T):Y_EXP(L,J,I,T)*D_LJ(L,J)*C_ROAD)
+@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(I,J,K,L,T)*D_KL(K,L)*C_ROAD)+@SUM(INTERMODAL_EXP(L,K,J,I,T):Z_EXP(L,K,J,I,T)*D_LK(L,K)*C_ROAD)
+@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_IMP(I,L,T)*D_IL(I,L)*C_ROAD)))
+@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_EXP(L,I,T)*D_LI(L,I)*C_ROAD)));
Z4(1)=@SUM(SHIPMENT_IMP(I,L,T):SP_IMP(I,L,T)*C_SP_IMP(I,L,T))
+@SUM(SHIPMENT_EXP(L,I,T):SP_EXP(L,I,T)*C_SP_EXP(L,I,T));

!(2) Second objective Function: Minimize total transit time;
ZTIME(1)=ZT1(1)+ZT2(1)+ZT3(1)+ZT4(1);
ZT1(1)=@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_IMP(I,L,T)*T_IL(I,L))))
+@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_EXP(L,I,T)*T_LI(L,I))));
ZT2(1)=@SUM(SEMI_INTERMODAL_IMP(I,J,L,T):Y_IMP(I,J,L,T)*(TT_IJ(I,J)+T_JL(J,L)))
+@SUM(SEMI_INTERMODAL_EXP(L,J,I,T):Y_EXP(L,J,I,T)*(TT_JI(J,I)+T_LJ(L,J)));
ZT3(1)=@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(I,J,K,L,T)*(TT_IJ(I,J)+TR_JK(J,K)+T_KL(K,L)))
+@SUM(INTERMODAL_EXP(L,K,J,I,T):Z_EXP(L,K,J,I,T)*(TT_JI(J,I)+TR_KJ(K,J)+T_LK(L,K)));
ZT4(1)=@SUM(SHIPMENT_IMP(I,L,T):SP_IMP(I,L,T)*T_IL(I,L)*Rate_K)
+@SUM(SHIPMENT_EXP(L,I,T):SP_EXP(L,I,T)*T_LI(L,I)*Rate_K)
+@SUM(SHIPMENT_IMP(I,L,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_IMP(I,L,T)*Rate_KD*(TT_IJ(I,J)+T_JL(J,L))))
+@SUM(SHIPMENT_EXP(L,I,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_EXP(L,I,T)*Rate_KD*(TT_JI(J,I)+T_LJ(L,J))));

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!(3) Third objective function: Minimize the total environmental impact;
ZENVIROMENT(1)=ZE1(1)+ZE2(1)+ZE3(1)+ZE4(1);
ZE1(1)=@SUM(COST_IJ1(I,J):@SUM(PERIODS(T):OWN_IMP(I,J,T)*D_IJ(I,J)*CO2_DENIZ))
+@SUM(COST_IJ2(I,J):@SUM(PERIODS(T):PUB_IJ_IMP(I,J,T)*PD_IJ(I,J)*CO2_DENIZ))
+@SUM(COST_JI1(J,I):@SUM(PERIODS(T):OWN_EXP(J,I,T)*D_JI(J,I)*CO2_DENIZ))
+@SUM(COST_JI2(J,I):@SUM(PERIODS(T):PUB_JI_EXP(J,I,T)*PD_JI(J,I)*CO2_DENIZ));
ZE2(1)=@SUM(COST_JK1(J,K):@SUM(PERIODS(T):SJK_IMP(J,K,T)*CAP_TRAIN_IMP(J,K)*CO2_TREN*DD_JK(J,K))
+@SUM(COST_JK2(J,K):@SUM(PERIODS(T):PUB_JK_IMP(J,K,T)*CO2_TREN*PD_JK(J,K))
+@SUM(COST_KK1(S,K):@SUM(PERIODS(T):PUB_SK_IMP(S,K,T)*CO2_TREN*D_SK(S,K))
+@SUM(COST_KK2(K,S):@SUM(PERIODS(T):PUB_KS_EXP(K,S,T)*CO2_TREN*D_KS(K,S))
+@SUM(COST_KJ1(K,J):@SUM(PERIODS(T):SKJ_EXP(K,J,T)*CAP_TRAIN_EXP(K,J)*CO2_TREN*DD_KJ(K,J))
+@SUM(COST_KJ2(K,J):@SUM(PERIODS(T):PUB_KJ_EXP(K,J,T)*CO2_TREN*PD_KJ(K,J)));
ZE3(1)=@SUM(SEMI_INTERMODAL_IMP(I,J,L,T):Y_IMP(I,J,L,T)*D_JL(J,L)*CO2_KARA)+@SUM(SEMI_INTERMODAL_EXP(L,J,I,T):Y_EXP(L,J,I,T)*D_LJ(L,J)*CO2_KARA)
+@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(I,J,K,L,T)*D_KL(K,L)*CO2_KARA)+@SUM(INTERMODAL_EXP(L,K,J,I,T):Z_EXP(L,K,J,I,T)*D_LK(L,K)*CO2_KARA)
+@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_IMP(I,L,T)*D_IL(I,L)*CO2_KARA))
+@SUM(ORIGINS(I):@SUM(DESTINATIONS(L):@SUM(PERIODS(T):X_EXP(L,I,T)*D_LI(L,I)*CO2_KARA));
ZE4(1)=@SUM(SHIPMENT_IMP(I,L,T):SP_IMP(I,L,T)*CO2_KARA*D_IL(I,L)*Rate_K)
+@SUM(SHIPMENT_EXP(L,I,T):SP_EXP(L,I,T)*CO2_KARA*D_LI(L,I)*Rate_K)
+@SUM(SHIPMENT_IMP(I,L,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_IMP(I,L,T)*Rate_K*DS_IJ(I,J)*CO2_DENIZ))
+@SUM(SHIPMENT_EXP(L,I,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_EXP(L,I,T)*Rate_K*DS_JI(J,I)*CO2_DENIZ))
+@SUM(SHIPMENT_IMP(I,L,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_IMP(I,L,T)*CO2_KARA*D_JL(J,L)*Rate_K))
+@SUM(SHIPMENT_EXP(L,I,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_EXP(L,I,T)*Rate_K*DS_JI(J,I)*CO2_DENIZ))
+@SUM(SHIPMENT_EXP(L,I,T):@SUM(RORO_TERMINALS(J)|J#EQ#2:SP_EXP(L,I,T)*CO2_KARA*D_LJ(L,J)*Rate_K));
!*****MODEL CONSTRAINTS*****;
!(4);@FOR(DESTINATIONS(L):@FOR(PERIODS(T):@FOR(ORIGINS(I):X_IMP(I,L,T)+@SUM(SEMI_INTERMODAL_IMP(I,J,L,T):Y_IMP(I,J,L,T))+@SUM(INTERMODAL_IMP(I,J,K,L,
T):Z_IMP(I,J,K,L,T))
+SP_IMP(I,L,T)=DE_IMP(I,L,T)));
!(5);@FOR(DESTINATIONS(L):@FOR(PERIODS(T):@FOR(ORIGINS(I):X_EXP(L,I,T)+@SUM(SEMI_INTERMODAL_EXP(L,J,I,T):Y_EXP(L,J,I,T))+@SUM(INTERMODAL_EXP(L,K,J,I,
T):Z_EXP(L,K,J,I,T))
+SP_EXP(L,I,T)=DE_EXP(L,I,T)));
!-----Marine Transportation Constraints-----;
!(6);@FOR(RORO_TERMINALS(J)|J#EQ#1:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))<=N_IMP(I,J,T)*CAP_RORO_IMP(I,J)-
@SUM(RORO_TERMINALS(J)|J#EQ#2:
@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))-@SUM(INTERMODAL_IMP(I,J,K,L,T)|J#EQ#2:Z_IMP(I,J,K,L,T)))));
!(7);@FOR(RORO_TERMINALS(J)|J#EQ#1:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))<=N_EXP(J,I,T)*CAP_RORO_EXP(J,I)-
@SUM(RORO_TERMINALS(N)|J#EQ#2:
@SUM(DESTINATIONS(L):Y_EXP(L,N,I,T))-@SUM(INTERMODAL_EXP(L,K,J,I,T)|J#EQ#2:Z_EXP(L,K,J,I,T)))));
!(8);@FOR(RORO_TERMINALS(J)|J#EQ#3:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#2:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))<=N_IMP(I,J,T)*CAP_RORO_IMP(I,J)));
!(9);@FOR(RORO_TERMINALS(J)|J#EQ#3:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#2:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))<=N_EXP(J,I,T)*CAP_RORO_EXP(J,I)));
!(10);@FOR(RORO_TERMINALS(J)|J#EQ#1:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))=OWN_IMP(I,J,T)));
!:@FOR(RORO_TERMINALS(J)|J#EQ#3:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#2:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))=OWN_IMP(I,J,T)));
!(11);@FOR(RORO_TERMINALS(J)|J#EQ#1:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))=OWN_EXP(J,I,T)));
!:@FOR(RORO_TERMINALS(J)|J#EQ#3:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#2:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))=OWN_EXP(J,I,T)));
!(12);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))+@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(
I,J,K,L,T))<=(N_IMP(I,J,T)*CAP_RORO_IMP(I,J)-@SUM(DESTINATIONS(L):@SUM(RORO_TERMINALS(J)|J#EQ#1:Y_IMP(I,J,L,T)))+PUB_IJ_IMP(I,J,T))));
!(13);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))+@SUM(INTERMODAL_EXP(L,K,J,I,T):Z_EXP(
L,K,J,I,T))<=(N_EXP(J,I,T)*CAP_RORO_EXP(J,I)-@SUM(DESTINATIONS(L):@SUM(RORO_TERMINALS(J)|J#EQ#1:Y_EXP(L,J,I,T)))+PUB_JI_EXP(J,I,T))));
!(14);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))+@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(
I,J,K,L,T))=OWN_IMP(I,J,T)+PUB_IJ_IMP(I,J,T)));
!(15);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))+@SUM(INTERMODAL_EXP(L,K,J,I,T):Z_EXP(
L,K,J,I,T))=OWN_EXP(J,I,T)+PUB_JI_EXP(J,I,T)));
!(16);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#GT#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))+@SUM(INTERMODAL_IMP(I,J,K,L,T):Z_IMP(
I,J,K,L,T))<=PUB_IJ_IMP(I,J,T)));
!(17);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#GT#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))+@SUM(INTERMODAL_IMP(L,K,J,I,T):Z_EXP(
L,K,J,I,T))<=PUB_JI_EXP(J,I,T)));
!(18);@FOR(RORO_TERMINALS(J)|J#EQ#4:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_IMP(I,J,L,T))<=PUB_IJ_IMP(I,J,T)));
!(19);@FOR(RORO_TERMINALS(J)|J#EQ#4:@FOR(PERIODS(T):@FOR(ORIGINS(I)|I#EQ#1:@SUM(DESTINATIONS(L):Y_EXP(L,J,I,T))<=PUB_JI_EXP(J,I,T)));
!(20);@FOR(RORO_TERMINALS(J)|J#EQ#2:@FOR(ORIGINS(I)|I#EQ#1:@FOR(PERIODS(T):(@SUM(RORO_TERMINALS(J)|J#EQ#1:OWN_IMP(I,J,T))+OWN_IMP(I,J,T))/CAP_RORO_IM
P(I,J)=SIJ_IMP(I,J,T)));

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!(21);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (ORIGINS (I) |I#EQ#1:@FOR (PERIODS (T) :(@SUM (RORO_TERMINALS (J) |J#EQ#1:OWN_EXP (J, I, T))+OWN_EXP (J, I, T))/CAP_RORO_EXP (J, I)=SJI_EXP (J, I, T)))));
!(22);@FOR (RORO_TERMINALS (J) |J#EQ#3:@FOR (ORIGINS (I) |I#EQ#2:@FOR (PERIODS (T) :OWN_IMP (I, J, T)/CAP_RORO_IMP (I, J)=SIJ_IMP (I, J, T)))));
!(23);@FOR (RORO_TERMINALS (J) |J#EQ#3:@FOR (ORIGINS (I) |I#EQ#2:@FOR (PERIODS (T) :OWN_EXP (J, I, T)/CAP_RORO_EXP (J, I)=SJI_EXP (J, I, T)))));
!:@FOR (RORO_TERMINALS (J) |J#EQ#1:@FOR (ORIGINS (I) |I#EQ#1:@FOR (PERIODS (T) :OWN_IMP (I, J, T)/CAP_RORO_IMP (I, J)=SIJ_IMP (I, J, T)))));
!:@FOR (RORO_TERMINALS (J) |J#EQ#1:@FOR (ORIGINS (I) |I#EQ#1:@FOR (PERIODS (T) :OWN_EXP (J, I, T)/CAP_RORO_EXP (J, I)=SJI_EXP (J, I, T)))));
!(24);@FOR (SHIPMENT_IJ_IMP1 (I, J, T) :UTI_IMP (I, J, T)=SIJ_IMP (I, J, T)/N_IMP (I, J, T));
!(25);@FOR (SHIPMENT_JI_EXP1 (J, I, T) :UTI_EXP (J, I, T)=SJI_EXP (J, I, T)/N_EXP (J, I, T));
!(22);@FOR (RORO_TERMINALS (J) |J#EQ#3:@FOR (ORIGINS (I) |I#EQ#2:@FOR (PERIODS (T) :UTI_IMP (I, J, T)>=0.5)));
!(22);@FOR (RORO_TERMINALS (J) |J#EQ#3:@FOR (ORIGINS (I) |I#EQ#2:@FOR (PERIODS (T) :UTI_EXP (J, I, T)>=0.5)));
!-----Railway Transportation Constraints-----;
!(26);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#3) #AND# (K#NE#2) :@FOR (PERIODS (T) :@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_IMP (I, J, K, L, T)))<=SJK_IMP (J, K, T)*CAP_TRAIN_IMP (J, K)))));
!(27);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#3) #AND# (K#NE#2) :@FOR (PERIODS (T) :@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_EXP (L, K, J, I, T)))<=SKJ_EXP (K, J, T)*CAP_TRAIN_EXP (K, J)))));
!(28);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) |K#EQ#2:@FOR (PERIODS (T) :@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_IMP (I, J, K, L, T)))<=PUB_JK_IMP (J, K, T)))));
!(29);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) |K#EQ#2:@FOR (PERIODS (T) :@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_EXP (L, K, J, I, T)))<=PUB_KJ_EXP (K, J, T)))));
!(30);@FOR (PERIODS (T) :@FOR (TRAIN_TERMINALS (S) |S#EQ#4:@FOR (RORO_TERMINALS (J) |J#EQ#2:@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_IMP (I, J, S, L, T)))+@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :@SUM (TRAIN_TERMINALS (K) |K#GE#5:Z_IMP (I, J, K, L, T))))<=SJK_IMP (J, S, T)*CAP_TRAIN_IMP (J, S)))));
!(31);@FOR (PERIODS (T) :@FOR (TRAIN_TERMINALS (S) |S#EQ#4:@FOR (RORO_TERMINALS (J) |J#EQ#2:@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :Z_EXP (L, S, J, I, T)))+@SUM (DESTINATIONS (L) :@SUM (ORIGINS (I) :@SUM (TRAIN_TERMINALS (K) |K#GE#5:Z_EXP (L, K, J, I, T))))<=SKJ_EXP (S, J, T)*CAP_TRAIN_EXP (S, J)))));
!(32);@FOR (PERIODS (T) :@FOR (TRAIN_TERMINALS (K) |K#GE#5:@FOR (TRAIN_TERMINALS (S) |S#EQ#4:@SUM (ORIGINS (I) :@SUM (DESTINATIONS (L) :@SUM (RORO_TERMINALS (J) |J#EQ#2:Z_IMP (I, J, K, L, T))))<=PUB_SK_IMP (S, K, T)))));
!(33);@FOR (PERIODS (T) :@FOR (TRAIN_TERMINALS (K) |K#GE#5:@FOR (TRAIN_TERMINALS (S) |S#EQ#4:@SUM (ORIGINS (I) :@SUM (DESTINATIONS (L) :@SUM (RORO_TERMINALS (J) |J#EQ#2:Z_EXP (L, K, J, I, T))))<=PUB_KS_EXP (K, S, T)))));
!(34); @FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (PERIODS (T) :SJK_IMP (J, K, T)<=M_IMP (J, K, T)))));
!; @FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (PERIODS (T) :SKJ_EXP (K, J, T)<=M_EXP (K, J, T)))));
!(35); @FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (PERIODS (T) :SJK_IMP (J, K, T)>=MU_IMP (J, K, T)))));
!; @FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (PERIODS (T) :SKJ_EXP (K, J, T)>=MU_EXP (K, J, T)))));
!(36);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (PERIODS (T) :SJK_IMP (J, K, T)-SKJ_EXP (K, J, T)<=1)))));
!;@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@FOR (PERIODS (T) :SKJ_EXP (K, J, T)-SJK_IMP (J, K, T)<=1)))));
!(37);@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@SUM (PERIODS (T) :SJK_IMP (J, K, T)-SKJ_EXP (K, J, T)<=1)))));
!;@FOR (RORO_TERMINALS (J) |J#EQ#2:@FOR (TRAIN_TERMINALS (K) | (K#LE#4) #AND# (K#NE#2) :@SUM (PERIODS (T) :SKJ_EXP (K, J, T)-SJK_IMP (J, K, T)<=1)))));
@FOR (PERIODS (T) :@FOR (MARIRAILLINK1 (I, J, K) |K#GE#5:@FOR (DESTINATIONS (L) |L#NE#27#AND#L#NE#33#AND#L#NE#34#AND#L#NE#37:Z_IMP (I, J, K, L, T)<=0)))));
@FOR (PERIODS (T) :@FOR (MARIRAILLINK2 (K, J, I) |K#GE#5:@FOR (DESTINATIONS (L) |L#NE#27#AND#L#NE#33#AND#L#NE#34#AND#L#NE#37:Z_EXP (L, K, J, I, T)<=0)))));
!(38)@FOR (SHIPMENT_IMP:@GIN (X_IMP));
@FOR (SHIPMENT_EXP:@GIN (X_EXP));
@FOR (SEMI_INTERMODAL_IMP:@GIN (Y_IMP));
@FOR (SEMI_INTERMODAL_EXP:@GIN (Y_EXP));
@FOR (INTERMODAL_IMP:@GIN (Z_IMP));
@FOR (INTERMODAL_EXP:@GIN (Z_EXP));
@FOR (SHIPMENT_IJ_IMP2:@GIN (PUB_IJ_IMP));
@FOR (SHIPMENT_JI_EXP2:@GIN (PUB_JI_EXP));
@FOR (SHIPMENT_SJK_IMP:@GIN (SJK_IMP));
@FOR (SHIPMENT_SKJ_EXP:@GIN (SKJ_EXP));
@FOR (SHIPMENT_JK_IMP:@GIN (PUB_JK_IMP));
@FOR (SHIPMENT_KJ_EXP:@GIN (PUB_KJ_EXP));
@FOR (SHIPMENT_KK_IMP:@GIN (PUB_SK_IMP));
@FOR (SHIPMENT_KK_EXP:@GIN (PUB_KS_EXP));
@FOR (SHIPMENT_IMP:@GIN (SP_IMP));
@FOR (SHIPMENT_EXP:@GIN (SP_EXP));
@FOR (SHIPMENT_IJ_IMP1:@GIN (OWN_IMP));
@FOR (SHIPMENT_JI_EXP1:@GIN (OWN_EXP));
!(39)@FOR (SHIPMENT_IJ_IMP1:@BND (0, UTI_IMP, 1));
@FOR (SHIPMENT_JI_EXP1:@BND (0, UTI_EXP, 1));

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