Problem – D (Assembly)

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/*********************************************
 * OPL 12.6.0.0 Model
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 * Creation Date: Apr 13, 2017 at 2:45:29 PM
 *********************************************/
// Converting IP/MIP to LP
//main{
//thisOplModel.convertAllIntVars();
//thisOplModel.generate();
//cplex.solve();
//
//writeln("Relaxed Model");
//writeln("OBJECTIVE: ",cplex.getBestObjValue());
//}

execute TIMELIMIT {
    cplex.tilim = 3600; // stops and returns the current solution after 3600 seconds
//    //cplex.threads = 2; // Number of threads
}

//main{
// thisOplModel.generate();
// if(cplex.solve()){
//  writeln("Solve successful; solve status="+cplex.getCplexStatus());
//  writeln("Objective value="+cplex.getObjValue());
// }
// else{
//  writeln("Solve failed; CPLEX status="+cplex.getCplexStatus());
//  writeln("Calling printConflict (CONFLICT REFINER)");
//  writeln(thisOplModel.printConflict());
//  writeln("Printing conflicts using conflictIterator");
//  var confIter = thisOplModel.conflictIterator;
//  for(var x in confIter){
//   writeln("Member name:"+x.ct.name);
//   writeln("Conflict type:"+x.info);
//  }
//  writeln("Calling printRelaxation (FEASOPT)");
//  writeln(thisOplModel.printRelaxation());
//  writeln("Printing relaxations using relaxationIterator");
//  var relaxIter = thisOplModel.relaxationIterator;
//  for(x in relaxIter){
//   writeln("Member name:"+x.ct.name);
//   writeln("Old bound:"+x.info);
//   writeln("New bound:"+x.info2);
//   writeln("Bound changed to:"+x.info3);
//  }
// }
//}


// Define and Initialize INDICES & PARAMETERS DATA
   int FP=...;          range Final_Products=1..FP;
   int RP=...;          range Remaining_Products=3..RP;
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   int J=...;           range products=1..J;               // Represents All the
products
   int L=...;           range productionstages=1..L;
   int S=...;           range microperiods=1..S;
   int T=...;           range macroperiods=1..T;

// Define & Initialize Sets
      {int} allproductsonstage1 = ...; // All products at Stage One
      {int} allproductsonstage2_1 = ...;
      {int} allproductsonstage2_2 = ...;
      {int} allproductsonstage3 = ...;
      {int} allproductsonstage4 = ...;
      {int} allproductsonstage5 = ...;
      {int} family1stage1 = ...;          // Family-1 who has same successor in the
following stage
      {int} family2stage1 = ...;
      {int} family3stage1 = ...;
      {int} family4stage1 = ...;
      {int} family5stage1 = ...;
      {int} family1stage2_1 = ...;
      {int} family2stage2_1 = ...;
      {int} family3stage2_1 = ...;
      {int} family4stage2_1 = ...;
      {int} family5stage2_1 = ...;
      {int} family6stage2_1 = ...;
      {int} family1stage2_2 = ...;
      {int} family2stage2_2 = ...;
      {int} family3stage2_2 = ...;
      {int} family4stage2_2 = ...;
      {int} family5stage2_2 = ...;
      {int} family6stage2_2 = ...;
      {int} family7stage2_2 =...;
      {int} family1stage3 = ...;
      {int} family2stage3 = ...;
      {int} family3stage3 = ...;
      {int} family4stage3 = ...;
      {int} family5stage3 = ...;
      {int} family6stage3 = ...;
      {int} family7stage3 = ...;
      {int} family8stage3 = ...;
      {int} family9stage3 = ...;
      {int} family10stage3 = ...;
      {int} family11stage3 = ...;
      {int} family12stage3 = ...;
      {int} family1stage4 = ...;
      {int} family2stage4 = ...;
      {int} family3stage4 = ...;
      {int} family4stage4 = ...;
      {int} family5stage4 = ...;
      {int} family6stage4 = ...;
      {int} family1stage5 = ...;
      {int} family2stage5 = ...;

      {int} microperiods1tomacroperiod = ...;
      {int} microperiods2tomacroperiod = ...;
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      {int} microperiods3tomacroperiod = ...;
      {int} microperiods4tomacroperiod = ...;
      {int} microperiods5tomacroperiod = ...;
      {int} microperiods6tomacroperiod = ...;
      {int} microperiods7tomacroperiod = ...;
      {int} microperiods8tomacroperiod = ...;
      {int} microperiods9tomacroperiod = ...;
      {int} microperiods10tomacroperiod = ...;
      {int} microperiods11tomacroperiod = ...;
      {int} microperiods12tomacroperiod = ...;
      {int} microperiods13tomacroperiod = ...;
      {int} microperiods14tomacroperiod = ...;
      {int} microperiods15tomacroperiod = ...;
      {int} microperiods16tomacroperiod = ...;

// Declare & Initialize CONSTANT DATA
   // Minimum Lotsize of the jth product
         int min_lotsize=...;
   // Production cost per unit
         int production_cost=...;
   // production time per unit
         int production_time=...;
   // Idle time (i.e. Stand by) cost
         int standby_cost=...;
   /* Pijl --> Number of units of product 'i' required to produce
      one unit of product 'j' on production stage 'l'*/
         int BOM = ...;
         int BigM = ...;

// Arrays Delcarations through indicies & tuple sets
   // Capacity of the Production Stages
         float productstagecapacity[productionstages]=...;
   // Product Holding Cost
         int holdingcost[products]=...;
   // Products Changeover Cost
         float setupcost[products]=...;
   // Products Changeover Time
         int setuptime[products]=...;
   // Products Demand
         float primary_demand[Final_Products][macroperiods]=...;
         float secondary_demand[Remaining_Products][macroperiods]=...;

// Defining Decision Variables
      // Inventory Level of jth Product on Lth production stage in Tth macroperiod
         dvar float+ inventory[products][0..T];
      // Total Production Quality of the products on machines'm' in 't'
         dvar float+ productionquantity[products][productionstages][microperiods];
      // Product Changeover in Microperiod 's'
         dvar float+ Pchangeover[products][products][productionstages][microperiods];
      // Fractional setup time for changeover at the begining of microperiod 's'
         dvar float+ B_setuptime[productionstages][microperiods];
      // Fractional setup time for changeover at the end of microperiod 's'
         dvar float+ E_setuptime[productionstages][microperiods];
      // Standby (idle) time on machine 'l' in microperiod 's'
         dvar float+ sb[productionstages][microperiods];
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            //dvar float+ sb[allproductstage][micro_macroperiods];
      // Lth Machine setup for jth Product in sth Microperiod
            dvar boolean stagesetup[products][productionstages][microperiods];

// Computing the objective function value
      dexpr float TotalProductionCost = sum(j in products, l in productionstages, s in
microperiods)

      production_cost*productionquantity[j][l][s];
      dexpr float TotalHoldingCost = sum(j in products, t in macroperiods)

      holdingcost[j]*inventory[j][t];
      dexpr float TotalSetupCost = sum(i,j in products, l in productionstages, s in
microperiods)

      setupcost[j]*Pchangeover[i][j][l][s];
      dexpr float TotalStandbyCost = sum(l in productionstages, s in microperiods)

      standby_cost*sb[l][s];
      // Total Value of the Objective Function
      dexpr float TOTAL_COST = TotalProductionCost + TotalHoldingCost + TotalSetupCost +
TotalStandbyCost;

// The Model
minimize TOTAL_COST;
subject to
      {
      // Inventory Balancing constraints for final_products on final_stage
      forall (j in Final_Products, l in productionstages:l==L, t in macroperiods)
       Inventory_Balancing: {
       if(t==1)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==2)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==3)
            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==4)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==5)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==6)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==7)
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            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==8)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==9)
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==10)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==11)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==12)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==13)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==14)
            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==15)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];
       if(t==16)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + primary_demand[j][t];

       }

       // WIP Balancing constraints
      forall (j in Remaining_Products, l in productionstages:l<=L-1, t in macroperiods)
       WIPInventory_Balancing: {
       if(t==1 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==2 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==3 && j in allproductsonstage1 && l==1)
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            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==4 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==5 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==6 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==7 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==8 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==9 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==10 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==11 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==12 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==13 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==14 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==15 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==16 && j in allproductsonstage1 && l==1)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
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            == inventory[j][t] + BOM * secondary_demand[j][t];

       if(t==1 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==2 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==3 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==4 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==5 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==6 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==7 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==8 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==9 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==10 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==11 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==12 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==13 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==14 && j in allproductsonstage2_1 && l==2)
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            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==15 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==16 && j in allproductsonstage2_1 && l==2)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];

       if(t==1 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==2 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==3 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==4 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==5 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==6 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==7 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==8 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==9 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==10 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==11 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
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            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==12 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==13 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==14 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==15 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==16 && j in allproductsonstage2_2 && l==3)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];

       if(t==1 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==2 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==3 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==4 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==5 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==6 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==7 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==8 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==9 && j in allproductsonstage3 && l==4)
```

```
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==10 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==11 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==12 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==13 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==14 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==15 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==16 && j in allproductsonstage3 && l==4)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];

       if(t==1 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods1tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==2 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods2tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==3 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods3tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==4 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods4tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==5 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods5tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==6 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods6tomacroperiod)
productionquantity[j][l][s]
```

```
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==7 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods7tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==8 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods8tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==9 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods9tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==10 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods10tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==11 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods11tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==12 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods12tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==13 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods13tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==14 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods14tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==15 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods15tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];
       if(t==16 && j in allproductsonstage4 && l==5)
            inventory[j][t-1] + sum(s in microperiods16tomacroperiod)
productionquantity[j][l][s]
            == inventory[j][t] + BOM * secondary_demand[j][t];

       }
      //Capacity Constraints
         forall (l in productionstages, t in macroperiods)
          Capacity_Stage: {
           if(l==1 && t==1)
            sum(j in allproductsonstage1, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods1tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==2)
```

```
            sum(j in allproductsonstage1, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==3)
            sum(j in allproductsonstage1, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==4)
            sum(j in allproductsonstage1, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==5)
            sum(j in allproductsonstage1, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==6)
            sum(j in allproductsonstage1, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==7)
            sum(j in allproductsonstage1, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==8)
            sum(j in allproductsonstage1, s in microperiods8tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==9)
            sum(j in allproductsonstage1, s in microperiods9tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
```

```
           if(l==1 && t==10)
            sum(j in allproductsonstage1, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==11)
            sum(j in allproductsonstage1, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==12)
            sum(j in allproductsonstage1, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==13)
            sum(j in allproductsonstage1, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==14)
            sum(j in allproductsonstage1, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==15)
            sum(j in allproductsonstage1, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods15tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==1 && t==16)
            sum(j in allproductsonstage1, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage1, s in
microperiods16tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==1)
            sum(j in allproductsonstage2_1, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods1tomacroperiod)
```

```
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==2)
            sum(j in allproductsonstage2_1, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==3)
            sum(j in allproductsonstage2_1, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==4)
            sum(j in allproductsonstage2_1, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==5)
            sum(j in allproductsonstage2_1, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==2 && t==6)
            sum(j in allproductsonstage2_1, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==7)
            sum(j in allproductsonstage2_1, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==8)
            sum(j in allproductsonstage2_1, s in microperiods8tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==9)
            sum(j in allproductsonstage2_1, s in microperiods9tomacroperiod)
production_time*
```

```
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==10)
            sum(j in allproductsonstage2_1, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==11)
            sum(j in allproductsonstage2_1, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==12)
            sum(j in allproductsonstage2_1, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==13)
            sum(j in allproductsonstage2_1, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==14)
            sum(j in allproductsonstage2_1, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==15)
            sum(j in allproductsonstage2_1, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods15tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==2 && t==16)
            sum(j in allproductsonstage2_1, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_1, s in
microperiods16tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
          if(l==3 && t==1)
```

```
            sum(j in allproductsonstage2_2, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods1tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==2)
            sum(j in allproductsonstage2_2, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==3)
            sum(j in allproductsonstage2_2, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==4)
            sum(j in allproductsonstage2_2, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==5)
            sum(j in allproductsonstage2_2, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==6)
            sum(j in allproductsonstage2_2, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==7)
            sum(j in allproductsonstage2_2, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==8)
            sum(j in allproductsonstage2_2, s in microperiods8tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];
```

```
           if(l==3 && t==9)
            sum(j in allproductsonstage2_2, s in microperiods9tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==10)
            sum(j in allproductsonstage2_2, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==11)
            sum(j in allproductsonstage2_2, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==12)
            sum(j in allproductsonstage2_2, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==13)
            sum(j in allproductsonstage2_2, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==14)
            sum(j in allproductsonstage2_2, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==15)
            sum(j in allproductsonstage2_2, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods15tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==3 && t==16)
            sum(j in allproductsonstage2_2, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage2_2, s in
microperiods16tomacroperiod)
```

```
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==1)
            sum(j in allproductsonstage3, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods1tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==2)
            sum(j in allproductsonstage3, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==3)
            sum(j in allproductsonstage3, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==4)
            sum(j in allproductsonstage3, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==5)
            sum(j in allproductsonstage3, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==6)
            sum(j in allproductsonstage3, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==7)
            sum(j in allproductsonstage3, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==8)
            sum(j in allproductsonstage3, s in microperiods8tomacroperiod)
production_time*
```

```
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==9)
            sum(j in allproductsonstage3, s in microperiods9tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==10)
            sum(j in allproductsonstage3, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==11)
            sum(j in allproductsonstage3, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==12)
            sum(j in allproductsonstage3, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==13)
            sum(j in allproductsonstage3, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==14)
            sum(j in allproductsonstage3, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==15)
            sum(j in allproductsonstage3, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods15tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==4 && t==16)
```

```
            sum(j in allproductsonstage3, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage3, s in
microperiods16tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==1)
            sum(j in allproductsonstage4, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods1tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==2)
            sum(j in allproductsonstage4, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==3)
            sum(j in allproductsonstage4, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==4)
            sum(j in allproductsonstage4, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==5)
            sum(j in allproductsonstage4, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==6)
            sum(j in allproductsonstage4, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==7)
            sum(j in allproductsonstage4, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
```

```
           if(l==5 && t==8)
            sum(j in allproductsonstage4, s in microperiods8tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==9)
            sum(j in allproductsonstage4, s in microperiods9tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==10)
            sum(j in allproductsonstage4, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==11)
            sum(j in allproductsonstage4, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==12)
            sum(j in allproductsonstage4, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==13)
            sum(j in allproductsonstage4, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==14)
            sum(j in allproductsonstage4, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==15)
            sum(j in allproductsonstage4, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods15tomacroperiod)
```

```
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==5 && t==16)
            sum(j in allproductsonstage4, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage4, s in
microperiods16tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==1)
            sum(j in allproductsonstage5, s in microperiods1tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods1tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods1tomacroperiod)
sb[l][s] <= productstagecapacity[l];


           if(l==6 && t==2)
            sum(j in allproductsonstage5, s in microperiods2tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods2tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods2tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==3)
            sum(j in allproductsonstage5, s in microperiods3tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods3tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods3tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==4)
            sum(j in allproductsonstage5, s in microperiods4tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods4tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods4tomacroperiod)
sb[l][s] <= productstagecapacity[l];


           if(l==6 && t==5)
            sum(j in allproductsonstage5, s in microperiods5tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods5tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods5tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==6)
            sum(j in allproductsonstage5, s in microperiods6tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods6tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods6tomacroperiod)
sb[l][s] <= productstagecapacity[l];
```

```
           if(l==6 && t==7)
            sum(j in allproductsonstage5, s in microperiods7tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods7tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods7tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==8)
            sum(j in allproductsonstage5, s in microperiods8tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods8tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods8tomacroperiod)
sb[l][s] <= productstagecapacity[l];


           if(l==6 && t==9)
            sum(j in allproductsonstage5, s in microperiods9tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods9tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods9tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==10)
            sum(j in allproductsonstage5, s in microperiods10tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods10tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods10tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==11)
            sum(j in allproductsonstage5, s in microperiods11tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods11tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods11tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==12)
            sum(j in allproductsonstage5, s in microperiods12tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods12tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods12tomacroperiod)
sb[l][s] <= productstagecapacity[l];


           if(l==6 && t==13)
            sum(j in allproductsonstage5, s in microperiods13tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods13tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods13tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==14)
```

```
            sum(j in allproductsonstage5, s in microperiods14tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods14tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods14tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==15)
            sum(j in allproductsonstage5, s in microperiods15tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods15tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods15tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           if(l==6 && t==16)
            sum(j in allproductsonstage5, s in microperiods16tomacroperiod)
production_time*
            productionquantity[j][l][s] + sum(i,j in allproductsonstage5, s in
microperiods16tomacroperiod)
            setuptime[j]*Pchangeover[i][j][l][s] + sum(s in microperiods16tomacroperiod)
sb[l][s] <= productstagecapacity[l];
           }

      //Production Flow between Stages (Sequence & Position) Constraints
       forall (j in allproductsonstage1, p in allproductsonstage2_1, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence1:{
         if (j in family1stage1 && p in family1stage2_1 && l==1)
                  BigM * (stagesetup[j][l][s]-1) + sb[l][s] + E_setuptime[l][s]<=
BigM*(1-stagesetup[p][l+1][s])+
                  sb[l+1][s] + E_setuptime[l+1][s];
         if (j in family2stage1 && p in family2stage2_1 && l==1)
                  BigM * (stagesetup[j][l][s]-1) + sb[l][s] + E_setuptime[l][s]<=
BigM*(1-stagesetup[p][l+1][s])+
                  sb[l+1][s] + E_setuptime[l+1][s];
         }
      forall (j in allproductsonstage1, p in allproductsonstage2_2, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence2:{
         if (j in family3stage1 && p in family1stage2_2 && l==1)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         if (j in family4stage1 && p in family2stage2_2 && l==1)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         if (j in family5stage1 && p in family3stage2_2 && l==1)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         }
```

```
      forall (j in allproductsonstage2_1, p in allproductsonstage3, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence3:{
         if (j in family3stage2_1 && p in family1stage3 && l==2)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         if (j in family4stage2_1 && p in family2stage3 && l==2)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         if (j in family5stage2_1 && p in family3stage3 && l==2)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
            if (j in family6stage2_1 && p in family4stage3 && l==2)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+2][s])+ B_setuptime[l+2][s] +
production_time*productionquantity[p][l+2][s];
         }
      forall (j in allproductsonstage2_2, p in allproductsonstage3, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence4:{
         if (j in family4stage2_2 && p in family5stage3 && l==3)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         if (j in family5stage2_2 && p in family6stage3 && l==3)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         if (j in family6stage2_2 && p in family7stage3 && l==3)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
            if (j in family7stage2_2 && p in family8stage3 && l==3)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         }
      forall (j in allproductsonstage3, p in allproductsonstage4, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence5:{
         if (j in family9stage3 && p in family1stage4 && l==4)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
```

```
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         if (j in family10stage3 && p in family2stage4 && l==4)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         if (j in family11stage3 && p in family3stage4 && l==4)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
            if (j in family12stage3 && p in family4stage4 && l==4)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         }
      forall (j in allproductsonstage4, p in allproductsonstage5, l in
productionstages:l<=L-1, s in microperiods)
         Position_Sequence6:{
         if (j in family5stage4 && p in family1stage5 && l==5)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         if (j in family6stage4 && p in family2stage5 && l==5)
                  BigM * (stagesetup[j][l][s]-1) + B_setuptime[l][s] +
production_time*productionquantity[j][l][s]
                  <= BigM*(1-stagesetup[p][l+1][s])+ B_setuptime[l+1][s] +
production_time*productionquantity[p][l+1][s];
         }

      //Upper bound on production quantities
        forall (j in products, l in productionstages, s in microperiods)
            UB_ProductionQTY:{
             if(j in allproductsonstage1 && l==1)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
               if(j in allproductsonstage2_1 && l==2)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
               if(j in allproductsonstage2_2 && l==3)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
               if(j in allproductsonstage3 && l==4)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
               if(j in allproductsonstage4 && l==5)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
               if(j in allproductsonstage5 && l==6)
                  productionquantity[j][l][s] <=
(productstagecapacity[l]/production_time) * stagesetup[j][l][s];
                  }
```

```
      //Lower bound on production quantities - Minimum Lot-size needed / Triangle
inequality not always true
        forall (j in products, l in productionstages, s in microperiods)
              min_litsizes:{
              if(s==1){
                if(j in allproductsonstage1 && l==1)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);
                if(j in allproductsonstage2_1 && l==2)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);
                if(j in allproductsonstage2_2 && l==3)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);
                if(j in allproductsonstage3 && l==4)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);
                if(j in allproductsonstage4 && l==5)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);
                if(j in allproductsonstage5 && l==6)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]);

                  }
              if(s>1){
                if(j in allproductsonstage1 && l==1)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                if(j in allproductsonstage2_1 && l==2)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                if(j in allproductsonstage2_2 && l==3)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                if(j in allproductsonstage3 && l==4)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                if(j in allproductsonstage4 && l==5)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                if(j in allproductsonstage5 && l==6)
                  productionquantity[j][l][s] >= min_lotsize* (stagesetup[j][l][s]-
stagesetup[j][l][s-1]);
                  }
    }

      //Only one production stage setup allowed in each microperiod
        forall (l in productionstages, s in microperiods)
               {
               if(l==1)
                  sum(j in allproductsonstage1)
                        stagesetup[j][l][s]==1;
                  if(l==2)
                  sum(j in allproductsonstage2_1)
                        stagesetup[j][l][s]==1;
               if(l==3)
                  sum(j in allproductsonstage2_2)
                        stagesetup[j][l][s]==1;
               if(l==4)
```

```
                sum(j in allproductsonstage3)
                      stagesetup[j][l][s]==1;
                if(l==5)
                sum(j in allproductsonstage4)
                      stagesetup[j][l][s]==1;
               if(l==6)
                sum(j in allproductsonstage5)
                      stagesetup[j][l][s]==1;
                }

      //Only one product changeover allowed in each microperiod
        forall (l in productionstages, s in microperiods:s>=2)
              Onlyone_Changeover: {
              if (l==1)
                  sum (i,j in allproductsonstage1)
                        Pchangeover[i][j][l][s]==1;
              if (l==2)
                  sum (i,j in allproductsonstage2_1)
                        Pchangeover[i][j][l][s]==1;
              if (l==3)
                  sum (i,j in allproductsonstage2_2)
                        Pchangeover[i][j][l][s]==1;
              if (l==4)
                  sum (i,j in allproductsonstage3)
                        Pchangeover[i][j][l][s]==1;
              if (l==5)
                  sum (i,j in allproductsonstage4)
                        Pchangeover[i][j][l][s]==1;
              if (l==6)
                  sum (i,j in allproductsonstage5)
                        Pchangeover[i][j][l][s]==1;
              }

       //Setup Spliting idea constrinats
         forall (l in productionstages, s in microperiods:s>=2)
         Setup_Splitting:
         {
         if (l==1)
                  E_setuptime[l][s-1] + B_setuptime[l][s] ==
                  sum (i,j in allproductsonstage1) setuptime[j]*Pchangeover[i][j][l][s];
         if (l==2)
                  E_setuptime[l][s-1] + B_setuptime[l][s] ==
                  sum (i,j in allproductsonstage2_1)
setuptime[j]*Pchangeover[i][j][l][s];
         if (l==3)
                  E_setuptime[l][s-1] + B_setuptime[l][s] ==
                  sum (i,j in allproductsonstage2_2)
setuptime[j]*Pchangeover[i][j][l][s];
         if (l==4)
                  E_setuptime[l][s-1] + B_setuptime[l][s] ==
                  sum (i,j in allproductsonstage3) setuptime[j]*Pchangeover[i][j][l][s];
            if (l==5)
                  E_setuptime[l][s-1] + B_setuptime[l][s] ==
                  sum (i,j in allproductsonstage4) setuptime[j]*Pchangeover[i][j][l][s];
            if (l==6)
```

```
                E_setuptime[l][s-1] + B_setuptime[l][s] ==
                sum (i,j in allproductsonstage5) setuptime[j]*Pchangeover[i][j][l][s];

        }

    //Linking between product changeover and machine setup constrinats
        forall (i,j in products, l in productionstages, s in microperiods:s>=2)
        Changeover_setup:
        {
       if(l==1)
        Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-1;
        if(l==2)
              Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-
1;
        if(l==3)
              Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-
1;
        if(l==4)
              Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-
1;
        if(l==5)
              Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-
1;
        if(l==6)
              Pchangeover[i][j][l][s] >= stagesetup[i][l][s-1]+ stagesetup[j][l][s]-
1;
        }
}
```