Modelos Determinísticos de Investigação Operacional

Trabalho Prático 3

Programação Inteira

Licenciatura em Engenharia Informática

Departamento de Produção e Sistemas

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Introdução

No contexto do enunciado do terceiro trabalho prático da unidade curricular Modelos Determinísticos e Investigação Operacional, temos uma empresa que produz sumos de laranja, maçã e pêra, à base de concentrado. A produção consiste em misturar as matérias-primas, concentrado de sumo de fruta, água e açúcar, e encher os pacotes de sumo na única linha de engarrafamento. O tempo de produção de um dado sumo corresponde ao tempo de engarrafamento, dado que a mistura das matérias-primas é feita num tempo negligenciável. Existem dois armazéns, o de matérias-primas, onde são guardados os tambores com os concentrados de sumo, e o de produtos finais, que guarda as paletes com os pacotes de sumo.

Pretende-se elaborar um modelo de programação linear que permita determinar as quantidades a comprar, a produzir e a armazenar, em cada período e cada tipo de sumo, de modo a fornecer os pedidos dos clientes num horizonte de planeamento de doze meses, com um custo global mínimo.

As quantidades de concentrado serão expressas em unidades equivalentes (U.E.). Uma U.E. de concentrado de fruta é o peso de concentrado necessário para produzir uma tonelada de produto final (que equivale a uma U.E. de produto final).

Para além disso, o trabalho prático está dividido em cinco partes, cada uma com as suas especificações do modelo de programação linear principal. Iremos verificar que em certos casos não é possível satisfazer os requisitos necessários, e em ordem de resolver esses problemas, teremos que adicionar variáveis adicionais ao modelo para que este consiga determinar a solução ótima deste planeamento.

Parte I

Tendo em conta que os custos do concentrado de laranja estão sujeitos a grande volatilidade nas bolas de mercadorias e futuros, de acordo com os nossos número de alunos verificamos que o maior número de inscrição é o 67738 (ABCDE). Assim sendo, no nosso caso, os algarismos D e E indicam-nos que X=160 e Y=200, respetivamente.

1.1 – Modelo de Programação Linear

Apresentaremos em breve, o modelo de programação linear que usámos para resolver este planeamento. Antes de escrevermos o modelo em si, tenhamos em conta que queremos minimizar os seguintes custos.

1. Custos de compra de concentrado.
2. Custos de produção de sumo a partir de concentrado.
3. Custos de armazenamento de concentrado (matéria-prima) e sumo (produto final).

Por isso, a nossa função objetivo estará relacionada com estes três custos. Contudo, comecemos por declarar as variáveis de decisão do nosso modelo.

1.1.1 – Variáveis de decisão

Concentrado

- cl_i – Quantidade de concentrado de laranja a comprar no mês i.
- cm_i – Quantidade de concentrado de maçã a comprar no mês i.
- cp_i – Quantidade de concentrado de pera a comprar no mês i.
- i varia entre 1 e 12.

Armazém de concentrado

- acl_i – Quantidade de concentrado de laranja no armazém de matéria-prima no mês i.
- acm_i – Quantidade de concentrado de maçã no armazém de matéria-prima no mês i.
- acp_i – Quantidade de concentrado de pera no armazém de matéria-prima no mês i.
- i varia entre 1 e 13 (por questões de restrições).

Armazém de sumo

- asl_i – Quantidade de sumo de laranja no armazém de produto final no mês i.
- asm_i – Quantidade de sumo de maçã no armazém de produto final no mês i.
- asp_i – Quantidade de sumo de pera no armazém de produto final no mês i.
- i varia entre 1 e 13 (por questões de restrições).

Sumo Produzido

- spl_i – Quantidade de sumo de laranja produzido no mês i.
- spm_i – Quantidade de sumo de maçã produzido no mês i.
- spp_i – Quantidade de sumo de pera produzido no mês i.
- i varia entre 1 e 12.

1.1.2 – Função Objetivo

Por questões de facilidade iremos colocar uma *screenshot* da nossa função objetivo.

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de Armazem  / Custos de Armazem  */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2 + acp2 + 3asl2 + 3asm2 + 3asp2 +
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3 + acp3 + 3asl3 + 3asm3 + 3asp3 +
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4 + acp4 + 3asl4 + 3asm4 + 3asp4 +
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5 + acp5 + 3asl5 + 3asm5 + 3asp5 +
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6 + acp6 + 3asl6 + 3asm6 + 3asp6 +
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7 + acp7 + 3asl7 + 3asm7 + 3asp7 +
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8 + acp8 + 3asl8 + 3asm8 + 3asp8 +
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9 + acp9 + 3asl9 + 3asm9 + 3asp9 +
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 + acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 +
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11 + acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 +
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12 + acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 +
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13 + acm13 + acp13 + 3asl13 + 3asm13 + 3asp13;
```

Figura 1. Função objetivo

1.1.3 – Restrições

Restrições iniciais

- $acl_1 = acl_{13} = 16$;
- $acm_1 = acm_{13} = 8$;
- $acp_1 = acp_{13} = 6$;
- $asl_1 = asl_{13} = 20$;
- $asm_1 = asm_{13} = 10$;
- $aspl_1 = asp_{13} = 10$;

Capacidades de armazenamento

- $acl_i + acm_i + acp_i <= 30$;
- $asl_i + asm_i + asp_i <= 40$;
- i varia entre 1 e 13.

Atribuição das variáveis de armazém de concentrado

- $acl_{i+1} = acl_i + cl_i - spl_i$
- $acm_{i+1} = acm_i + cm_i - spm_i$
- $acp_{i+1} = acp_i + cp_i - spp_i$
- i varia entre 2 e 12.

Atribuição das variáveis de armazém de sumo

- $asl_{i+1} = asl_i + spl_i - svl_i$
- $asm_{i+1} = asm_i + spm_i - svm_i$
- $asp_{i+1} = asp_i + spp_i - svp_i$
- i varia entre 2 e 12.
- sv corresponde ao sumo vendido (tabela 1 do enunciado).

Atribuição das variáveis de sumo produzido

- $spl_i <= 45bl_i$
- $spm_i <= 45bm_i$
- $spp_i <= 45bp_i$
- i varia entre 1 e 12.

Capacidade de produção

- $spl_i + spm_i + spp_i <= 45;$
- i varia entre 1 e 12.

Atribuição das variáveis de compra de concentrado

- $cl_i = acl_{i+1} + spl_i – acl_i$
- $cm_i = acm_{i+1} + spm_i – acm_i$
- $cp_i = acp_{i+1} + spp_i – acp_i$
- i varia entre 1 e 12.

Atribuição das variáveis de sumo vendido (para confirmar com a tabela 1)

- $svl_i = asl_i + spl_i - asl_{i+1}$
- $svm_i = asm_i + spm_i - asm_{i+1}$
- $svp_i = asp_i + spp_i - asp_{i+1}$
- i varia entre 1 e 12.

Atribuição das variáveis binárias

- $bl_i + bm_{i+} bp_i <= 1$
- i varia entre 1 e 12

1.2 – Ficheiro de Input

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis
binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  / Custos de Armazem  */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 +
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 +
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 +
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 +
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 +
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 +
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 +
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 +
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 +
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 +
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 +
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13;

/* Variable bounds */
/* Restrições iniciais e finais  */
acl1 = 16;
acl13 = 16;

acm1 = 8;
acm13 = 8;

acp1 = 6;
acp13 = 6;

asl1 = 20;
asl13 = 20;

asm1 = 10;
asm13 = 10;

asp1 = 10;
asp13 = 10;

/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30;
acl4 + acm4 + acp4 <= 30;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
```

```
acl9 + acm9 + acp9 <= 30;
acl10 + acm10 + acp10 <= 30;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

asl1 + asm1 + asp1 <= 40;
asl2 + asm2 + asp2 <= 40;
asl3 + asm3 + asp3 <= 40;
asl4 + asm4 + asp4 <= 40;
asl5 + asm5 + asp5 <= 40;
asl6 + asm6 + asp6 <= 40;
asl7 + asm7 + asp7 <= 40;
asl8 + asm8 + asp8 <= 40;
asl9 + asm9 + asp9 <= 40;
asl10 + asm10 + asp10 <= 40;
asl11 + asm11 + asp11 <= 40;
asl12 + asm12 + asp12 <= 40;

/* Atribuição das variáveis do armazém de concentrado */
/* Laranja */
acl2 = acl1 + cl1 - spl1;
acl3 = acl2 + cl2 - spl2;
acl4 = acl3 + cl3 - spl3;
acl5 = acl4 + cl4 - spl4;
acl6 = acl5 + cl5 - spl5;
acl7 = acl6 + cl6 - spl6;
acl8 = acl7 + cl7 - spl7;
acl9 = acl8 + cl8 - spl8;
acl10 = acl9 + cl9 - spl9;
acl11 = acl10 + cl10 - spl10;
acl12 = acl11 + cl11 - spl11;

/* Maçã */
acm2 = acm1 + cm1 - spm1;
acm3 = acm2 + cm2 - spm2;
acm4 = acm3 + cm3 - spm3;
acm5 = acm4 + cm4 - spm4;
acm6 = acm5 + cm5 - spm5;
acm7 = acm6 + cm6 - spm6;
acm8 = acm7 + cm7 - spm7;
acm9 = acm8 + cm8 - spm8;
acm10 = acm9 + cm9 - spm9;
acm11 = acm10 + cm10 - spm10;
acm12 = acm11 + cm11 - spm11;

/* Pêra */
acp2 = acp1 + cp1 - spp1;
acp3 = acp2 + cp2 - spp2;
acp4 = acp3 + cp3 - spp3;
acp5 = acp4 + cp4 - spp4;
acp6 = acp5 + cp5 - spp5;
acp7 = acp6 + cp6 - spp6;
acp8 = acp7 + cp7 - spp7;
acp9 = acp8 + cp8 - spp8;
acp10 = acp9 + cp9 - spp9;
acp11 = acp10 + cp10 - spp10;
acp12 = acp11 + cp11 - spp11;

/* Atribuição das variáveis do armazém de sumo */
/* Laranja */
asl2 = asl1 + spl1 - 9;
```

```
asl3 = asl2 + spl2 - 9;
asl4 = asl3 + spl3 - 9;
asl5 = asl4 + spl4 - 12;
asl6 = asl5 + spl5 - 16;
asl7 = asl6 + spl6 - 17;
asl8 = asl7 + spl7 - 19;
asl9 = asl8 + spl8 - 19;
asl10 = asl9 + spl9 - 16;
asl11 = asl10 + spl10 - 12;
asl12 = asl11 + spl11 - 10;
asl13 = asl12 + spl12 - 9;

/* Maçã */
asm2 = asm1 + spm1 - 5;
asm3 = asm2 + spm2 - 5;
asm4 = asm3 + spm3 - 5;
asm5 = asm4 + spm4 - 6;
asm6 = asm5 + spm5 - 8;
asm7 = asm6 + spm6 - 9;
asm8 = asm7 + spm7 - 10;
asm9 = asm8 + spm8 - 10;
asm10 = asm9 + spm9 - 8;
asm11 = asm10 + spm10 - 6;
asm12 = asm11 + spm11 - 5;
asm13 = asm12 + spm12 - 5;

/* Pêra */
asp2 = asp1 + spp1 - 4;
asp3 = asp2 + spp2 - 4;
asp4 = asp3 + spp3 - 4;
asp5 = asp4 + spp4 - 5;
asp6 = asp5 + spp5 - 6;
asp7 = asp6 + spp6 - 7;
asp8 = asp7 + spp7 - 8;
asp9 = asp8 + spp8 - 8;
asp10 = asp9 + spp9 - 6;
asp11 = asp10 + spp10 - 5;
asp12 = asp11 + spp11 - 4;
asp13 = asp12 + spp12 - 4;

/* Restrições de produção com
as variáveis binárias */
/* Janeiro */
spl1 <= 45bl1;
spm1 <= 45bm1;
spp1 <= 45bp1;

/* Fevereiro */
spl2 <= 45bl2;
spm2 <= 45bm2;
spp2 <= 45bp2;

/* Março */
spl3 <= 45bl3;
spm3 <= 45bm3;
spp3 <= 45bp3;

/* Abril */
spl4 <= 45bl4;
spm4 <= 45bm4;
spp4 <= 45bp4;
```

```
/* Maio */
spl5 <= 45bl5;
spm5 <= 45bm5;
spp5 <= 45bp5;

/* Junho */
spl6 <= 45bl6;
spm6 <= 45bm6;
spp6 <= 45bp6;

/* Julho */
spl7 <= 45bl7;
spm7 <= 45bm7;
spp7 <= 45bp7;

/* Agosto */
spl8 <= 45bl8;
spm8 <= 45bm8;
spp8 <= 45bp8;

/* Setembro */
spl9 <= 45bl9;
spm9 <= 45bm9;
spp9 <= 45bp9;

/* Outubro */
spl10 <= 45bl10;
spm10 <= 45bm10;
spp10 <= 45bp10;

/* Novembro */
spl11 <= 45bl11;
spm11 <= 45bm11;
spp11 <= 45bp11;

/* Dezembro */
spl12 <= 45bl12;
spm12 <= 45bm12;
spp12 <= 45bp12;

/* Atribuição das variáveis de concentrado comprado */
/* Laranja */
cl1 = spl1 + acl2 - acl1;
cl2 = spl2 + acl3 - acl2;
cl3 = spl3 + acl4 - acl3;
cl4 = spl4 + acl5 - acl4;
cl5 = spl5 + acl6 - acl5;
cl6 = spl6 + acl7 - acl6;
cl7 = spl7 + acl8 - acl7;
cl8 = spl8 + acl9 - acl8;
cl9 = spl9 + acl10 - acl9;
cl10 = spl10 + acl11 - acl10;
cl11 = spl11 + acl12 - acl11;
cl12 = spl12 + acl13 - acl12;

/* Maçã */
cm1 = spm1 + acm2 - acm1;
cm2 = spm2 + acm3 - acm2;
cm3 = spm3 + acm4 - acm3;
cm4 = spm4 + acm5 - acm4;
```

```
cm5 = spm5 + acm6 - acm5;
cm6 = spm6 + acm7 - acm6;
cm7 = spm7 + acm8 - acm7;
cm8 = spm8 + acm9 - acm8;
cm9 = spm9 + acm10 - acm9;
cm10 = spm10 + acm11 - acm10;
cm11 = spm11 + acm12 - acm11;
cm12 = spm12 + acm13 - acm12;

/* Pêra */
cp1 = spp1 + acp2 - acp1;
cp2 = spp2 + acp3 - acp2;
cp3 = spp3 + acp4 - acp3;
cp4 = spp4 + acp5 - acp4;
cp5 = spp5 + acp6 - acp5;
cp6 = spp6 + acp7 - acp6;
cp7 = spp7 + acp8 - acp7;
cp8 = spp8 + acp9 - acp8;
cp9 = spp9 + acp10 - acp9;
cp10 = spp10 + acp11 - acp10;
cp11 = spp11 + acp12 - acp11;
cp12 = spp12 + acp13 - acp12;

/* Sumo vendido em cada mês - Serve para confirmar */
/* Laranja */
svl1 = asl1 + spl1 - asl2;
svl2 = asl2 + spl2 - asl3;
svl3 = asl3 + spl3 - asl4;
svl4 = asl4 + spl4 - asl5;
svl5 = asl5 + spl5 - asl6;
svl6 = asl6 + spl6 - asl7;
svl7 = asl7 + spl7 - asl8;
svl8 = asl8 + spl8 - asl9;
svl9 = asl9 + spl9 - asl10;
svl10 = asl10 + spl10 - asl11;
svl11 = asl11 + spl11 - asl12;
svl12 = asl12 + spl12 - asl13;

/* Maçã */
svm1 = asm1 + spm1 - asm2;
svm2 = asm2 + spm2 - asm3;
svm3 = asm3 + spm3 - asm4;
svm4 = asm4 + spm4 - asm5;
svm5 = asm5 + spm5 - asm6;
svm6 = asm6 + spm6 - asm7;
svm7 = asm7 + spm7 - asm8;
svm8 = asm8 + spm8 - asm9;
svm9 = asm9 + spm9 - asm10;
svm10 = asm10 + spm10 - asm11;
svm11 = asm11 + spm11 - asm12;
svm12 = asm12 + spm12 - asm13;

/* Pêra */
svp1 = asp1 + spp1 - asp2;
svp2 = asp2 + spp2 - asp3;
svp3 = asp3 + spp3 - asp4;
svp4 = asp4 + spp4 - asp5;
svp5 = asp5 + spp5 - asp6;
svp6 = asp6 + spp6 - asp7;
svp7 = asp7 + spp7 - asp8;
svp8 = asp8 + spp8 - asp9;
```

```
svp9 = asp9 + spp9 - asp10;
svp10 = asp10 + spp10 - asp11;
svp11 = asp11 + spp11 - asp12;
svp12 = asp12 + spp12 - asp13;

/* Variáveis binárias e restrições */
bl1 + bm1 + bp1 <= 1;
bl2 + bm2 + bp2 <= 1;
bl3 + bm3 + bp3 <= 1;
bl4 + bm4 + bp4 <= 1;
bl5 + bm5 + bp5 <= 1;
bl6 + bm6 + bp6 <= 1;
bl7 + bm7 + bp7 <= 1;
bl8 + bm8 + bp8 <= 1;
bl9 + bm9 + bp9 <= 1;
bl10 + bm10 + bp10 <= 1;
bl11 + bm11 + bp11 <= 1;
bl12 + bm12 + bp12 <= 1;

Bin bl1,bm1,bp1,
    bl2,bm2,bp2,
    bl3,bm3,bp3,
    bl4,bm4,bp4,
    bl5,bm5,bp5,
    bl6,bm6,bp6,
    bl7,bm7,bp7,
    bl8,bm8,bp8,
    bl9,bm9,bp9,
    bl10,bm10,bp10,
    bl11,bm11,bp11,
    bl12,bm12,bp12;
```

1.3 – Ficheiro de Output

Os resultados obtidos foram os seguintes.

Variables	MILP Feasible 53898	MILP Better 53864	MILP Better 53637	MILP Better 53404	result 53404
cl1	0	0	0	3	3
cm1	0	0	0	0	0
cp1	7	7	0	0	0
spl1	0	0	0	0	0
spm1	0	0	0	0	0
spp1	13	13	6	6	6
acl2	16	16	16	19	19
acm2	8	8	8	8	8
acp2	0	0	0	0	0
asl2	11	11	11	11	11
asm2	5	5	5	5	5
asp2	19	19	12	12	12
cl2	0	0	0	0	0
cm2	0	0	11	0	0
cp2	0	0	0	0	0
spl2	0	0	0	19	19
spm2	8	8	19	0	0
spp2	0	0	0	0	0
acl3	16	16	16	0	0
acm3	0	0	0	8	8
acp3	0	0	0	0	0
asl3	2	2	2	21	21
asm3	8	8	19	0	0
asp3	15	15	8	8	8
cl3	3	3	3	0	0
cm3	30	30	30	49	49
cp3	0	0	0	0	0
spl3	19	19	19	0	0
spm3	0	0	0	27	27
spp3	0	0	0	0	0
acl4	0	0	0	0	0
acm4	30	30	30	30	30
acp4	0	0	0	0	0
asl4	12	12	12	12	12
asm4	3	3	14	22	22
asp4	11	11	4	4	4
cl4	0	0	0	0	0
cm4	30	33	0	0	0
cp4	0	0	22	22	22
spl4	0	0	0	0	0
spm4	30	33	0	0	0
spp4	0	0	22	22	22
acl5	0	0	0	0	0
acm5	30	30	30	30	30
acp5	0	0	0	0	0
asl5	0	0	0	0	0
asm5	27	30	8	16	16
asp5	6	6	21	21	21
cl5	33	33	33	33	33
cm5	0	0	0	0	0
cp5	0	0	0	0	0
spl5	33	33	33	33	33
spm5	0	0	0	0	0
spp5	0	0	0	0	0
acl6	0	0	0	0	0
acm6	30	30	30	30	30
acp6	0	0	0	0	0
asl6	17	17	17	17	17
asm6	19	22	0	8	8
asp6	0	0	15	15	15
cl6	0	0	0	0	0
cm6	0	0	33	25	25
cp6	34	29	0	0	0
spl6	0	0	0	0	0
spm6	0	0	37	29	29
spp6	34	29	0	0	0
acl7	0	0	0	0	0
acm7	30	30	26	26	26

acp7	0	0	0	0	0
asl7	0	0	0	0	0
asm7	10	13	28	28	28
asp7	27	22	8	8	8
cl7	40	42	41	41	41
cm7	0	0	0	0	0
cp7	0	0	0	0	0
spl7	40	42	41	41	41
spm7	0	0	0	0	0
spp7	0	0	0	0	0
acl8	0	0	0	0	0
acm8	30	30	26	26	26
acp8	0	0	0	0	0
asl8	21	23	22	22	22
asm8	0	2,99999999999999	18	18	18
asp8	19	14	0	0	0
cl8	0	0	0	0	0
cm8	0	0	0	0	0
cp8	0	0	19	19	19
spl8	0	0	0	0	0
spm8	18	21	0	0	0
spp8	0	0	19	19	19
acl9	0	0	0	0	0
acm9	12	8,99999999999999	26	26	26
acp9	0	0	0	0	0
asl9	2	4,00000000000001	3	3	3
asm9	8	14	8	8	8
asp9	11	6	11	11	11
cl9	45	45	45	45	45
cm9	0	0	0	0	0
cp9	0	0	0	0	0
spl9	45	45	45	45	45
spm9	0	0	0	0	0
spp9	0	0	0	0	0
acl10	0	0	0	0	0
acm10	12	8,99999999999998	26	26	26
acp10	0	0	0	0	0
asl10	31	33	32	32	32
asm10	0	6	0	0	0
asp10	5	0	5	5	5
cl10	0	0	0	0	0
cm10	14	11	0	0	0
cp10	0	23	0	0	0
spl10	0	0	0	0	0
spm10	26	0	26	26	26
spp10	0	23	0	0	0
acl11	0	0	0	0	0
acm11	0	20	0	0	0
acp11	0	0	0	0	0
asl11	19	21	20	20	20
asm11	20	0	20	20	20
asp11	0	18	0	0	0
cl11	30	30	30	30	30
cm11	0	0	0	0	0
cp11	18	0	18	18	18
spl11	0	0	0	0	0
spm11	0	20	0	0	0
spp11	18	0	18	18	18
acl12	30	30	30	30	30
acm12	0	0	0	0	0
acp12	0	0	0	0	0
asl12	8,99999999999999	11	9,99999999999999	9,99999999999999	9,99999999999999
asm12	15	15	15	15	15
asp12	14	14	14	14	14

cl12	6,000000000001	4	5,000000000002	5,000000000002	5,000000000002
cm12	8	8	8	8	8
cp12	6	6	6	6	6
spl12	20	18	19	19	19
spm12	0	0	0	0	0
spp12	0	0	0	0	0
acl13	16	16	16	16	16
acm13	8	8	8	8	8
acp13	6	6	6	6	6
asl13	20	20	20	20	20
asm13	10	10	10	10	10
asp13	10	10	10	10	10
acl1	16	16	16	16	16
acm1	8	8	8	8	8
acp1	6	6	6	6	6
asl1	20	20	20	20	20
asm1	10	10	10	10	10
asp1	10	10	10	10	10
bl1	0	0	0	0	0
bm1	0	0	0	0	0
bp1	1	1	1	1	1
bl2	0	0	0	1	1
bm2	1	1	1	0	0
bp2	0	0	0	0	0
bl3	1	1	1	0	0
bm3	0	0	0	1	1
bp3	0	0	0	0	0
bl4	0	0	0	0	0
bm4	1	1	0	0	0
bp4	0	0	1	1	1
bl5	1	1	1	1	1
bm5	0	0	0	0	0
bp5	0	0	0	0	0
bl6	0	0	0	0	0
bm6	0	0	1	1	1
bp6	1	1	0	0	0
bl7	1	1	1	1	1
bm7	0	0	0	0	0
bp7	0	0	0	0	0
bl8	0	0	0	0	0
bm8	1	1	0	0	0
bp8	0	0	1	1	1
bl9	1	1	1	1	1
bm9	0	0	0	0	0
bp9	0	0	0	0	0
bl10	0	0	0	0	0
bm10	1	0	1	1	1
bp10	0	1	0	0	0
bl11	0	0	0	0	0
bm11	0	1	0	0	0
bp11	1	0	1	1	1
bl12	1	1	1	1	1
bm12	0	0	0	0	0
bp12	0	0	0	0	0
svl1	9	9	9	9	9
svl2	9	9	9	9	9
svl3	9	9	9	9	9
svl4	12	12	12	12	12
svl5	16	16	16	16	16
svl6	17	17	17	17	17
svl7	19	19	19	19	19
svl8	19	19	19	19	19
svl9	16	16	16	16	16
svl10	12	12	12	12	12
svl11	10	10	10	10	10
svl12	9	9	9	9	9
svm1	5	5	5	5	5
svm2	5	5	5	5	5
svm3	5	5	5	5	5
svm4	6	6	6	6	6
svm5	8	8	8	8	8
svm6	9	9	9	9	9
svm7	10	10	10	10	10
svm8	10	10	10	10	10

svm9	8	8	8	8	8
svm10	6	6	6	6	6
svm11	5	5	5	5	5
svm12	5	5	5	5	5
svp1	4	4	4	4	4
svp2	4	4	4	4	4
svp3	4	4	4	4	4
svp4	5	5	5	5	5
svp5	6	6	6	6	6
svp6	7	7	7	7	7
svp7	8	8	8	8	8
svp8	8	8	8	8	8
svp9	6	6	6	6	6
svp10	5	5	5	5	5
svp11	4	3,99999999999999	4	4	4
svp12	4	4	4	4	4

1.4 – Plano detalhado de produção

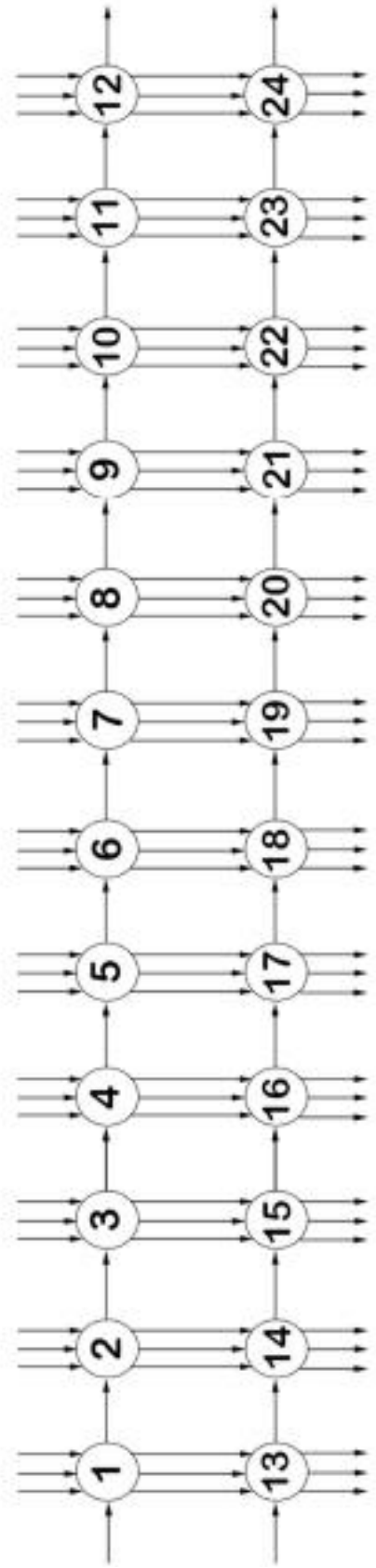

Figura 2. Plano detalhado de produção da parte 1

1.5 – Validação do modelo

A validação do modelo divide-se em duas partes. A primeira parte foca-se na conservação de fluxo nos nodos, enquanto que a segunda parte confirma o custo final somando os custos individualmente.

1.5.1 – Conservação de Fluxo

A tabela representa a conservação de fluxo nos nodos.

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

1.5.2 – Somatório dos custos

Parte 2

2.1 – Formulação do problema

As alterações relevantes em relação ao modelo da parte 1 são das seguintes.

```
/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30 - 30blf;    /* Limpeza */
acl4 + acm4 + acp4 <= 30 - 30blm;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
acl9 + acm9 + acp9 <= 30 - 30bla;        /* Limpeza */
acl10 + acm10 + acp10 <= 30 - 30bls;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

…

/* Março */
spl3 <= 45bl3 - 30bm3l;
spm3 <= 45bm3 - 30bm3m; /* manutenção */
spp3 <= 45bp3 - 30bm3p;

…

/* Setembro */
spl9 <= 45bl9 - 30bm9l;
spm9 <= 45bm9 - 30bm9m; /* manutenção */
spp9 <= 45bp9 - 30bm9p;

…

/* Escolhe o mês de manutenção */
bm3l + bm3m + bm3p + bm9l + bm9m + bm9p = 1;

/* Escolhe o mês onde vai fazer
limpeza do armazém */
blf + blm + bla + bls = 1;
blf + blm = bm3l + bm3m + bm3p;
bla + bls = bm9l + bm9m + bm9p;

/* Variáveis binárias para decisão do
mês de manutenção */
Bin bm3l,bm3m,bm3p,bm9l,bm9m,bm9p;

/* Variáveis binárias para a decisão do
mês em que vai fazer limpeza */
Bin blf,blm,bla,bls;
```

2.2 – Ficheiro de Input

```
/* Objective function */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  / Custos de Armazem    / Custo de Manutenção */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 +
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 +
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 + 400bm3l + 400bm3m + 400bm3p +
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 +
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 +
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 +
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 +
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 +
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 + 220bm9l + 220bm9m + 220bm9p
+
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 +
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 +
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13;

/* Variable bounds */
/* Restrições iniciais e finais  */
acl1 = 16;
acl13 = 16;

acm1 = 8;
acm13 = 8;

acp1 = 6;
acp13 = 6;

asl1 = 20;
asl13 = 20;

asm1 = 10;
asm13 = 10;

asp1 = 10;
asp13 = 10;

/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30 - 30blf;   /* Limpeza */
acl4 + acm4 + acp4 <= 30 - 30blm;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
acl9 + acm9 + acp9 <= 30 - 30bla;       /* Limpeza */
```

```
acl10 + acm10 + acp10 <= 30 - 30bls;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

asl1 + asm1 + asp1 <= 40;
asl2 + asm2 + asp2 <= 40;
asl3 + asm3 + asp3 <= 40;
asl4 + asm4 + asp4 <= 40;
asl5 + asm5 + asp5 <= 40;
asl6 + asm6 + asp6 <= 40;
asl7 + asm7 + asp7 <= 40;
asl8 + asm8 + asp8 <= 40;
asl9 + asm9 + asp9 <= 40;
asl10 + asm10 + asp10 <= 40;
asl11 + asm11 + asp11 <= 40;
asl12 + asm12 + asp12 <= 40;

/* Atribuição das variáveis do armazém de concentrado */
/* Laranja */
acl2 = acl1 + cl1 - spl1;
acl3 = acl2 + cl2 - spl2;
acl4 = acl3 + cl3 - spl3;
acl5 = acl4 + cl4 - spl4;
acl6 = acl5 + cl5 - spl5;
acl7 = acl6 + cl6 - spl6;
acl8 = acl7 + cl7 - spl7;
acl9 = acl8 + cl8 - spl8;
acl10 = acl9 + cl9 - spl9;
acl11 = acl10 + cl10 - spl10;
acl12 = acl11 + cl11 - spl11;

/* Maçã */
acm2 = acm1 + cm1 - spm1;
acm3 = acm2 + cm2 - spm2;
acm4 = acm3 + cm3 - spm3;
acm5 = acm4 + cm4 - spm4;
acm6 = acm5 + cm5 - spm5;
acm7 = acm6 + cm6 - spm6;
acm8 = acm7 + cm7 - spm7;
acm9 = acm8 + cm8 - spm8;
acm10 = acm9 + cm9 - spm9;
acm11 = acm10 + cm10 - spm10;
acm12 = acm11 + cm11 - spm11;

/* Pêra */
acp2 = acp1 + cp1 - spp1;
acp3 = acp2 + cp2 - spp2;
acp4 = acp3 + cp3 - spp3;
acp5 = acp4 + cp4 - spp4;
acp6 = acp5 + cp5 - spp5;
acp7 = acp6 + cp6 - spp6;
acp8 = acp7 + cp7 - spp7;
acp9 = acp8 + cp8 - spp8;
acp10 = acp9 + cp9 - spp9;
acp11 = acp10 + cp10 - spp10;
acp12 = acp11 + cp11 - spp11;

/* Atribuição das variáveis do armazém de sumo */
/* Laranja */
asl2 = asl1 + spl1 - 9;
asl3 = asl2 + spl2 - 9;
```

```
asl4 = asl3 + spl3 - 9;
asl5 = asl4 + spl4 - 12;
asl6 = asl5 + spl5 - 16;
asl7 = asl6 + spl6 - 17;
asl8 = asl7 + spl7 - 19;
asl9 = asl8 + spl8 - 19;
asl10 = asl9 + spl9 - 16;
asl11 = asl10 + spl10 - 12;
asl12 = asl11 + spl11 - 10;
asl13 = asl12 + spl12 - 9;

/* Maçã */
asm2 = asm1 + spm1 - 5;
asm3 = asm2 + spm2 - 5;
asm4 = asm3 + spm3 - 5;
asm5 = asm4 + spm4 - 6;
asm6 = asm5 + spm5 - 8;
asm7 = asm6 + spm6 - 9;
asm8 = asm7 + spm7 - 10;
asm9 = asm8 + spm8 - 10;
asm10 = asm9 + spm9 - 8;
asm11 = asm10 + spm10 - 6;
asm12 = asm11 + spm11 - 5;
asm13 = asm12 + spm12 - 5;

/* Pêra */
asp2 = asp1 + spp1 - 4;
asp3 = asp2 + spp2 - 4;
asp4 = asp3 + spp3 - 4;
asp5 = asp4 + spp4 - 5;
asp6 = asp5 + spp5 - 6;
asp7 = asp6 + spp6 - 7;
asp8 = asp7 + spp7 - 8;
asp9 = asp8 + spp8 - 8;
asp10 = asp9 + spp9 - 6;
asp11 = asp10 + spp10 - 5;
asp12 = asp11 + spp11 - 4;
asp13 = asp12 + spp12 - 4;

/* Restrições de produção com
as variáveis binárias */
/* Janeiro */
spl1 <= 45bl1;
spm1 <= 45bm1;
spp1 <= 45bp1;

/* Fevereiro */
spl2 <= 45bl2;
spm2 <= 45bm2;
spp2 <= 45bp2;

/* Março */
spl3 <= 45bl3 - 30bm3l;
spm3 <= 45bm3 - 30bm3m; /* 20 x 1.5 = 30 */
spp3 <= 45bp3 - 30bm3p;

/* Abril */
spl4 <= 45bl4;
spm4 <= 45bm4;
spp4 <= 45bp4;
```

```
/* Maio */
spl5 <= 45bl5;
spm5 <= 45bm5;
spp5 <= 45bp5;

/* Junho */
spl6 <= 45bl6;
spm6 <= 45bm6;
spp6 <= 45bp6;

/* Julho */
spl7 <= 45bl7;
spm7 <= 45bm7;
spp7 <= 45bp7;

/* Agosto */
spl8 <= 45bl8;
spm8 <= 45bm8;
spp8 <= 45bp8;

/* Setembro */
spl9 <= 45bl9 - 30bm9l;
spm9 <= 45bm9 - 30bm9m; /* 20 x 1.5 = 30 */
spp9 <= 45bp9 - 30bm9p;

/* Outubro */
spl10 <= 45bl10;
spm10 <= 45bm10;
spp10 <= 45bp10;

/* Novembro */
spl11 <= 45bl11;
spm11 <= 45bm11;
spp11 <= 45bp11;

/* Dezembro */
spl12 <= 45bl12;
spm12 <= 45bm12;
spp12 <= 45bp12;

/* Atribuição das variáveis de concentrado comprado */
/* Laranja */
cl1 = spl1 + acl2 - acl1;
cl2 = spl2 + acl3 - acl2;
cl3 = spl3 + acl4 - acl3;
cl4 = spl4 + acl5 - acl4;
cl5 = spl5 + acl6 - acl5;
cl6 = spl6 + acl7 - acl6;
cl7 = spl7 + acl8 - acl7;
cl8 = spl8 + acl9 - acl8;
cl9 = spl9 + acl10 - acl9;
cl10 = spl10 + acl11 - acl10;
cl11 = spl11 + acl12 - acl11;
cl12 = spl12 + acl13 - acl12;

/* Maçã */
cm1 = spm1 + acm2 - acm1;
cm2 = spm2 + acm3 - acm2;
cm3 = spm3 + acm4 - acm3;
cm4 = spm4 + acm5 - acm4;
```

```
cm5 = spm5 + acm6 - acm5;
cm6 = spm6 + acm7 - acm6;
cm7 = spm7 + acm8 - acm7;
cm8 = spm8 + acm9 - acm8;
cm9 = spm9 + acm10 - acm9;
cm10 = spm10 + acm11 - acm10;
cm11 = spm11 + acm12 - acm11;
cm12 = spm12 + acm13 - acm12;

/* Pêra */
cp1 = spp1 + acp2 - acp1;
cp2 = spp2 + acp3 - acp2;
cp3 = spp3 + acp4 - acp3;
cp4 = spp4 + acp5 - acp4;
cp5 = spp5 + acp6 - acp5;
cp6 = spp6 + acp7 - acp6;
cp7 = spp7 + acp8 - acp7;
cp8 = spp8 + acp9 - acp8;
cp9 = spp9 + acp10 - acp9;
cp10 = spp10 + acp11 - acp10;
cp11 = spp11 + acp12 - acp11;
cp12 = spp12 + acp13 - acp12;

/* Sumo vendido em cada mês - Serve para confirmar */
/* Laranja */
svl1 = asl1 + spl1 - asl2;
svl2 = asl2 + spl2 - asl3;
svl3 = asl3 + spl3 - asl4;
svl4 = asl4 + spl4 - asl5;
svl5 = asl5 + spl5 - asl6;
svl6 = asl6 + spl6 - asl7;
svl7 = asl7 + spl7 - asl8;
svl8 = asl8 + spl8 - asl9;
svl9 = asl9 + spl9 - asl10;
svl10 = asl10 + spl10 - asl11;
svl11 = asl11 + spl11 - asl12;
svl12 = asl12 + spl12 - asl13;

/* Maçã */
svm1 = asm1 + spm1 - asm2;
svm2 = asm2 + spm2 - asm3;
svm3 = asm3 + spm3 - asm4;
svm4 = asm4 + spm4 - asm5;
svm5 = asm5 + spm5 - asm6;
svm6 = asm6 + spm6 - asm7;
svm7 = asm7 + spm7 - asm8;
svm8 = asm8 + spm8 - asm9;
svm9 = asm9 + spm9 - asm10;
svm10 = asm10 + spm10 - asm11;
svm11 = asm11 + spm11 - asm12;
svm12 = asm12 + spm12 - asm13;

/* Pêra */
svp1 = asp1 + spp1 - asp2;
svp2 = asp2 + spp2 - asp3;
svp3 = asp3 + spp3 - asp4;
svp4 = asp4 + spp4 - asp5;
svp5 = asp5 + spp5 - asp6;
svp6 = asp6 + spp6 - asp7;
svp7 = asp7 + spp7 - asp8;
svp8 = asp8 + spp8 - asp9;
```

```
svp9 = asp9 + spp9 - asp10;
svp10 = asp10 + spp10 - asp11;
svp11 = asp11 + spp11 - asp12;
svp12 = asp12 + spp12 - asp13;

/* Variáveis binárias e restrições */
bl1 + bm1 + bp1 <= 1;
bl2 + bm2 + bp2 <= 1;
bl3 + bm3 + bp3 <= 1;
bl4 + bm4 + bp4 <= 1;
bl5 + bm5 + bp5 <= 1;
bl6 + bm6 + bp6 <= 1;
bl7 + bm7 + bp7 <= 1;
bl8 + bm8 + bp8 <= 1;
bl9 + bm9 + bp9 <= 1;
bl10 + bm10 + bp10 <= 1;
bl11 + bm11 + bp11 <= 1;
bl12 + bm12 + bp12 <= 1;

/* Escolhe o mês de manutenção */
bm3l + bm3m + bm3p + bm9l + bm9m + bm9p = 1;

/* Escolhe o mês onde vai fazer
limpeza do armazém */
blf + blm + bla + bls = 1;
blf + blm = bm3l + bm3m + bm3p;
bla + bls = bm9l + bm9m + bm9p;

/* Variáveis binárias para decisão do
mês de manutenção */
Bin bm3l,bm3m,bm3p,bm9l,bm9m,bm9p;

/* Variáveis binárias para a decisão do
mês em que vai fazer limpeza */
Bin blf,blm,bla,bls;

/* Variáveis binárias para decisão do
fruto a produzir por mês */
Bin bl1,bm1,bp1,
    bl2,bm2,bp2,
    bl3,bm3,bp3,
    bl4,bm4,bp4,
    bl5,bm5,bp5,
    bl6,bm6,bp6,
    bl7,bm7,bp7,
    bl8,bm8,bp8,
    bl9,bm9,bp9,
    bl10,bm10,bp10,
    bl11,bm11,bp11,
    bl12,bm12,bp12;
```

2.3 – Ficheiro de Output

Variables	MILP Feasible	MILP Better	MILP Better	result
	56183	54570	54536	54536
cl1	0	3	3	3
cm1	0	0	0	0
cp1	0	7	7	7
spl1	16	0	0	0
spm1	0	0	0	0
spp1	0	13	13	13
acl2	0	19	19	19
acm2	8	8	8	8
acp2	6	0	0	0
asl2	27	11	11	11
asm2	5	5	5	5
asp2	6	19	19	19
cl2	0	0	0	0
cm2	0	0	0	0
cp2	14	0	0	0
spl2	0	19	19	19
spm2	0	0	0	0
spp2	20	0	0	0
acl3	0	0	0	0
acm3	8	8	8	8
acp3	0	0	0	0
asl3	18	21	21	21
asm3	0	0	0	0
asp3	22	15	15	15
cl3	0	0	0	0
cm3	6,99999999999999	6,99999999999999	6,99999999999999	6,99999999999999
cp3	0	0	0	0
spl3	0	0	0	0
spm3	15	15	15	15
spp3	0	0	0	0
acl4	0	0	0	0
acm4	0	0	0	0
acp4	0	0	0	0
asl4	9	12	12	12
asm4	9,99999999999999	9,99999999999999	9,99999999999999	9,99999999999999
asp4	18	11	11	11
bm3l	0	0	0	0
bm3m	1	1	1	1
bm3p	0	0	0	0
cl4	19	0	0	0
cm4	30	53	56	56
cp4	0	0	0	0
spl4	19	0	0	0
spm4	0	23	26	26
spp4	0	0	0	0
acl5	0	0	0	0
acm5	30	30	30	30
acp5	0	0	0	0
asl5	16	0	0	0
asm5	3,99999999999999	27	30	30
asp5	13	6	6	6
cl5	30	33	33	33
cm5	3,00000000000003	0	0	0
cp5	0	0	0	0
spl5	0	33	33	33
spm5	33	0	0	0
spp5	0	0	0	0
acl6	30	0	0	0
acm6	0	30	30	30
acp6	0	0	0	0

asl6	0	17	17	17
asm6	29	19	22	22
asp6	7	0	0	0
cl6	6	0	0	0
cm6	0	0	0	0
cp6	27	34	29	29
spl6	36	0	0	0
spm6	0	0	0	0
spp6	0	34	29	29
acl7	0	0	0	0
acm7	0	30	30	30
acp7	27	0	0	0
asl7	19	0	0	0
asm7	20	10	13	13
asp7	0	27	22	22
cl7	30	40	42	42
cm7	0	0	0	0
cp7	0	0	0	0
spl7	0	40	42	42
spm7	0	0	0	0
spp7	27	0	0	0
acl8	30	0	0	0
acm8	0	30	30	30
acp8	0	0	0	0
asl8	0	21	23	23
asm8	10	0	3	3
asp8	19	19	14	14
cl8	4,99999999999999	0	0	0
cm8	0	0	0	0
cp8	0	0	0	0
spl8	35	0	0	0
spm8	0	18	21	21
spp8	0	0	0	0
acl9	0	0	0	0
acm9	0	12	8,999999999999	8,999999999999
acp9	0	0	0	0
asl9	16	2	4	4
asm9	0	8	14	14
asp9	11	11	6	6
cl9	30	45	45	45
cm9	34	0	0	0
cp9	0	0	0	0
spl9	0	45	45	45
spm9	34	0	0	0
spp9	0	0	0	0
acl10	30	0	0	0
acm10	0	12	8,999999999999	8,999999999999
acp10	0	0	0	0
asl10	0	31	33	33
asm10	26	0	6	6
asp10	5	5	0	0
bm9l	0	0	0	0
bm9m	0	0	0	0
bm9p	0	0	0	0
cl10	0	0	0	0
cm10	0	14	11	11
cp10	0	0	23	23
spl10	30	0	0	0
spm10	0	26	0	0
spp10	0	0	23	23
acl11	0	0	0	0
acm11	0	0	20	20
acp11	0	0	0	0
asl11	18	19	21	21
asm11	20	20	0	0
asp11	0	0	18	18
cl11	30	30	30	30
cm11	0	0	0	0
cp11	18	18	0	0
spl11	0	0	0	0

spm11	0	0	20	20
spp11	18	18	0	0
acl12	30	30	30	30
acm12	0	0	0	0
acp12	0	0	0	0
asl12	8	9	11	11
asm12	15	15	15	15
asp12	14	14	14	14
cl12	7	6	4	4
cm12	8	8	8	8
cp12	6	6	6	6
spl12	21	20	18	18
spm12	0	0	0	0
spp12	0	0	0	0
acl13	16	16	16	16
acm13	8	8	8	8
acp13	6	6	6	6
asl13	20	20	20	20
asm13	10	10	10	10
asp13	10	10	10	10
acl1	16	16	16	16
acm1	8	8	8	8
acp1	6	6	6	6
asl1	20	20	20	20
asm1	10	10	10	10
asp1	10	10	10	10
blf	0	0	0	0
blm	1	1	1	1
bla	0	0	0	0
bls	0	0	0	0
bl1	1	0	0	0
bm1	0	0	0	0
bp1	0	1	1	1
bl2	0	1	1	1
bm2	0	0	0	0
bp2	1	0	0	0
bl3	0	0	0	0
bm3	1	1	1	1
bp3	0	0	0	0
bl4	1	0	0	0
bm4	0	1	1	1
bp4	0	0	0	0
bl5	0	1	1	1
bm5	1	0	0	0
bp5	0	0	0	0
bl6	1	0	0	0
bm6	0	0	0	0
bp6	0	1	1	1
bl7	0	1	1	1
bm7	0	0	0	0
bp7	1	0	0	0
bl8	1	0	0	0
bm8	0	1	1	1
bp8	0	0	0	0
bl9	0	1	1	1
bm9	1	0	0	0
bp9	0	0	0	0
bl10	1	0	0	0
bm10	0	1	0	0
bp10	0	0	1	1
bl11	0	0	0	0
bm11	0	0	1	1
bp11	1	1	0	0
bl12	1	1	1	1
bm12	0	0	0	0
bp12	0	0	0	0
svl1	9	9	9	9
svl2	9	9	9	9
svl3	9	9	9	9
svl4	12	12	12	12
svl5	16	16	16	16
svl6	17	17	17	17
svl7	19	19	19	19
svl8	19	19	19	19
svl9	16	16	16	16
svl10	12	12	12	12

svl11	10	10	10	10
svl12	9	9	9	9
svm1	5	5	5	5
svm2	5	5	5	5
svm3	5	5	5	5
svm4	6	6	6,000000000001	6,000000000001
svm5	8	8	8	8
svm6	9	9	9	9
svm7	10	10	10	10
svm8	10	10	10	10
svm9	8	8	8	8
svm10	6	6	6	6
svm11	5	5	5	5
svm12	5	5	5	5
svp1	4	4	4	4
svp2	4	4	4	4
svp3	4	4	4	4
svp4	5	5	5	5
svp5	6	6	6	6
svp6	7	7	7	7
svp7	8	8	8	8
svp8	8	8	8	8
svp9	6	6	6	6
svp10	5	5	5	5
svp11	4	4	3,999999999999	3,999999999999
svp12	4	4	4	4

2.4 – Plano detalhado de produção

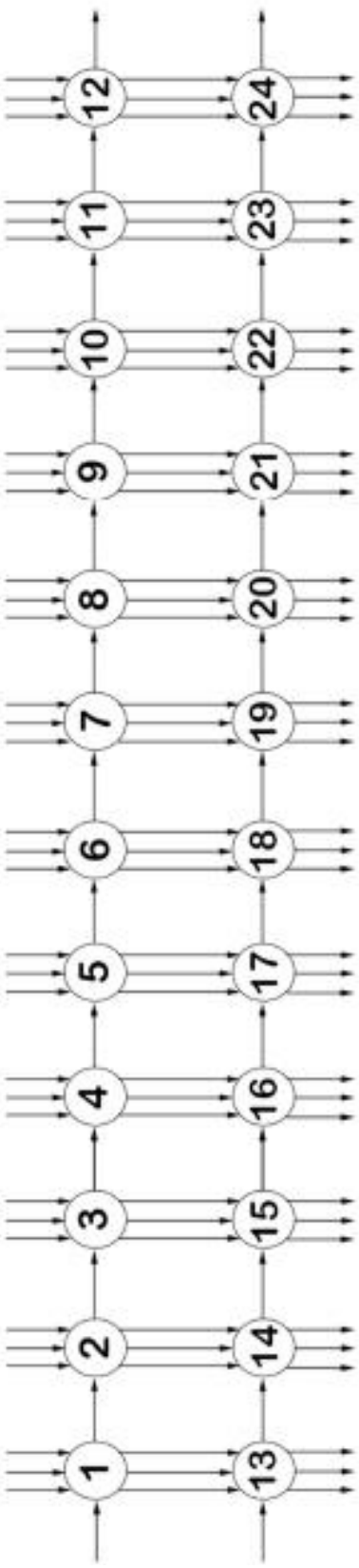

Figura 3. Plano detalhado de produção da parte 2

2.5 – Validação do modelo

2.5.1 – Conservação de fluxo

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

2.5.2 – Somatório dos custos

Parte 3

3.1 – Formulação do problema

De acordo com o modelo da parte 1, as diferenças significativas são as que se seguem.

```
/* Restrições de produção com
as variáveis binárias */
/* Janeiro */
spl1 <= 39bl1;
spm1 <= 39bm1;
spp1 <= 45bp1; /* No mês 12 do ano passado produziu-se pêra */

/* Fevereiro       se mudou */
spl2 <= 33bl2 + 6-6bm1 + 6-6bp1;
spm2 <= 33bm2 + 6-6bl1 + 6-6bp1;
spp2 <= 33bp2 + 6-6bl1 + 6-6bm1;

/* Março           se mudou*/
spl3 <= 33bl3 + 6-6bm2 + 6-6bp2;
spm3 <= 33bm3 + 6-6bl2 + 6-6bp2;
spp3 <= 33bp3 + 6-6bl2 + 6-6bm2;

/* Abril */
spl4 <= 33bl4 + 6-6bm3 + 6-6bp3;
spm4 <= 33bm4 + 6-6bl3 + 6-6bp3;
spp4 <= 33bp4 + 6-6bl3 + 6-6bm3;

/* Maio */
spl5 <= 33bl5 + 6-6bm4 + 6-6bp4;
spm5 <= 33bm5 + 6-6bl4 + 6-6bp4;
spp5 <= 33bp5 + 6-6bl4 + 6-6bm4;

/* Junho */
spl6 <= 33bl6 + 6-6bm5 + 6-6bp5;
spm6 <= 33bm6 + 6-6bl5 + 6-6bp5;
spp6 <= 33bp6 + 6-6bl5 + 6-6bm5;

/* Julho */
spl7 <= 33bl7 + 6-6bm6 + 6-6bp6;
spm7 <= 33bm7 + 6-6bl6 + 6-6bp6;
spp7 <= 33bp7 + 6-6bl6 + 6-6bm6;

/* Agosto */
spl8 <= 33bl8 + 6-6bm7 + 6-6bp7;
spm8 <= 33bm8 + 6-6bl7 + 6-6bp7;
spp8 <= 33bp8 + 6-6bl7 + 6-6bm7;

/* Setembro */
spl9 <= 33bl9 + 6-6bm8 + 6-6bp8;
spm9 <= 33bm9 + 6-6bl8 + 6-6bp8;
spp9 <= 33bp9 + 6-6bl8 + 6-6bm8;

/* Outubro */
spl10 <= 33bl10 + 6-6bm9 + 6-6bp9;
spm10 <= 33bm10 + 6-6bl9 + 6-6bp9;
spp10 <= 33bp10 + 6-6bl9 + 6-6bm9;
```

```
/* Novembro */
spl11 <= 33bl11 + 6-6bm10 + 6-6bp10;
spm11 <= 33bm11 + 6-6bl10 + 6-6bp10;
spp11 <= 33bp11 + 6-6bl10 + 6-6bm10;

/* Dezembro */
spl12 <= 33bl12 + 6-6bm11 + 6-6bp11;
spm12 <= 33bm12 + 6-6bl11 + 6-6bp11;
spp12 <= 33bp12 + 6-6bl11 + 6-6bm11;
```

3.2 – Ficheiro de Input

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis
binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  / Custos de Armazem  */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 +
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 +
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 +
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 +
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 +
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 +
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 +
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 +
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 +
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 +
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 +
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13;

/* Variable bounds */
/* Restrições iniciais e finais  */
acl1 = 16;
acl13 = 16;

acm1 = 8;
acm13 = 8;

acp1 = 6;
acp13 = 6;

asl1 = 20;
asl13 = 20;

asm1 = 10;
asm13 = 10;

asp1 = 10;
```

```
asp13 = 10;

/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30;
acl4 + acm4 + acp4 <= 30;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
acl9 + acm9 + acp9 <= 30;
acl10 + acm10 + acp10 <= 30;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

asl1 + asm1 + asp1 <= 40;
asl2 + asm2 + asp2 <= 40;
asl3 + asm3 + asp3 <= 40;
asl4 + asm4 + asp4 <= 40;
asl5 + asm5 + asp5 <= 40;
asl6 + asm6 + asp6 <= 40;
asl7 + asm7 + asp7 <= 40;
asl8 + asm8 + asp8 <= 40;
asl9 + asm9 + asp9 <= 40;
asl10 + asm10 + asp10 <= 40;
asl11 + asm11 + asp11 <= 40;
asl12 + asm12 + asp12 <= 40;

/* Atribuição das variáveis do armazém de concentrado */
/* Laranja */
acl2 = acl1 + cl1 - spl1;
acl3 = acl2 + cl2 - spl2;
acl4 = acl3 + cl3 - spl3;
acl5 = acl4 + cl4 - spl4;
acl6 = acl5 + cl5 - spl5;
acl7 = acl6 + cl6 - spl6;
acl8 = acl7 + cl7 - spl7;
acl9 = acl8 + cl8 - spl8;
acl10 = acl9 + cl9 - spl9;
acl11 = acl10 + cl10 - spl10;
acl12 = acl11 + cl11 - spl11;

/* Maçã */
acm2 = acm1 + cm1 - spm1;
acm3 = acm2 + cm2 - spm2;
acm4 = acm3 + cm3 - spm3;
acm5 = acm4 + cm4 - spm4;
acm6 = acm5 + cm5 - spm5;
acm7 = acm6 + cm6 - spm6;
acm8 = acm7 + cm7 - spm7;
acm9 = acm8 + cm8 - spm8;
acm10 = acm9 + cm9 - spm9;
acm11 = acm10 + cm10 - spm10;
acm12 = acm11 + cm11 - spm11;

/* Pêra */
acp2 = acp1 + cp1 - spp1;
acp3 = acp2 + cp2 - spp2;
acp4 = acp3 + cp3 - spp3;
acp5 = acp4 + cp4 - spp4;
```

```
acp6 = acp5 + cp5 - spp5;
acp7 = acp6 + cp6 - spp6;
acp8 = acp7 + cp7 - spp7;
acp9 = acp8 + cp8 - spp8;
acp10 = acp9 + cp9 - spp9;
acp11 = acp10 + cp10 - spp10;
acp12 = acp11 + cp11 - spp11;

/* Atribuição das variáveis do armazém de sumo */
/* Laranja */
asl2 = asl1 + spl1 - 9;
asl3 = asl2 + spl2 - 9;
asl4 = asl3 + spl3 - 9;
asl5 = asl4 + spl4 - 12;
asl6 = asl5 + spl5 - 16;
asl7 = asl6 + spl6 - 17;
asl8 = asl7 + spl7 - 19;
asl9 = asl8 + spl8 - 19;
asl10 = asl9 + spl9 - 16;
asl11 = asl10 + spl10 - 12;
asl12 = asl11 + spl11 - 10;
asl13 = asl12 + spl12 - 9;

/* Maçã */
asm2 = asm1 + spm1 - 5;
asm3 = asm2 + spm2 - 5;
asm4 = asm3 + spm3 - 5;
asm5 = asm4 + spm4 - 6;
asm6 = asm5 + spm5 - 8;
asm7 = asm6 + spm6 - 9;
asm8 = asm7 + spm7 - 10;
asm9 = asm8 + spm8 - 10;
asm10 = asm9 + spm9 - 8;
asm11 = asm10 + spm10 - 6;
asm12 = asm11 + spm11 - 5;
asm13 = asm12 + spm12 - 5;

/* Pêra */
asp2 = asp1 + spp1 - 4;
asp3 = asp2 + spp2 - 4;
asp4 = asp3 + spp3 - 4;
asp5 = asp4 + spp4 - 5;
asp6 = asp5 + spp5 - 6;
asp7 = asp6 + spp6 - 7;
asp8 = asp7 + spp7 - 8;
asp9 = asp8 + spp8 - 8;
asp10 = asp9 + spp9 - 6;
asp11 = asp10 + spp10 - 5;
asp12 = asp11 + spp11 - 4;
asp13 = asp12 + spp12 - 4;

/* Restrições de produção com
as variáveis binárias */
/* Janeiro */
spl1 <= 39bl1;
spm1 <= 39bm1;
spp1 <= 45bp1; /* No mês 12 do ano passado produziu-se pêra */

/* Fevereiro */
spl2 <= 33bl2 + 6-6bm1 + 6-6bp1;
spm2 <= 33bm2 + 6-6bl1 + 6-6bp1;
```

```
spp2 <= 33bp2 + 6-6bl1 + 6-6bm1;

/* Março */
spl3 <= 33bl3 + 6-6bm2 + 6-6bp2;
spm3 <= 33bm3 + 6-6bl2 + 6-6bp2;
spp3 <= 33bp3 + 6-6bl2 + 6-6bm2;

/* Abril */
spl4 <= 33bl4 + 6-6bm3 + 6-6bp3;
spm4 <= 33bm4 + 6-6bl3 + 6-6bp3;
spp4 <= 33bp4 + 6-6bl3 + 6-6bm3;

/* Maio */
spl5 <= 33bl5 + 6-6bm4 + 6-6bp4;
spm5 <= 33bm5 + 6-6bl4 + 6-6bp4;
spp5 <= 33bp5 + 6-6bl4 + 6-6bm4;

/* Junho */
spl6 <= 33bl6 + 6-6bm5 + 6-6bp5;
spm6 <= 33bm6 + 6-6bl5 + 6-6bp5;
spp6 <= 33bp6 + 6-6bl5 + 6-6bm5;

/* Julho */
spl7 <= 33bl7 + 6-6bm6 + 6-6bp6;
spm7 <= 33bm7 + 6-6bl6 + 6-6bp6;
spp7 <= 33bp7 + 6-6bl6 + 6-6bm6;

/* Agosto */
spl8 <= 33bl8 + 6-6bm7 + 6-6bp7;
spm8 <= 33bm8 + 6-6bl7 + 6-6bp7;
spp8 <= 33bp8 + 6-6bl7 + 6-6bm7;

/* Setembro */
spl9 <= 33bl9 + 6-6bm8 + 6-6bp8;
spm9 <= 33bm9 + 6-6bl8 + 6-6bp8;
spp9 <= 33bp9 + 6-6bl8 + 6-6bm8;

/* Outubro */
spl10 <= 33bl10 + 6-6bm9 + 6-6bp9;
spm10 <= 33bm10 + 6-6bl9 + 6-6bp9;
spp10 <= 33bp10 + 6-6bl9 + 6-6bm9;

/* Novembro */
spl11 <= 33bl11 + 6-6bm10 + 6-6bp10;
spm11 <= 33bm11 + 6-6bl10 + 6-6bp10;
spp11 <= 33bp11 + 6-6bl10 + 6-6bm10;

/* Dezembro */
spl12 <= 33bl12 + 6-6bm11 + 6-6bp11;
spm12 <= 33bm12 + 6-6bl11 + 6-6bp11;
spp12 <= 33bp12 + 6-6bl11 + 6-6bm11;

/* Atribuição das variáveis de concentrado comprado */
/* Laranja */
cl1 = spl1 + acl2 - acl1;
cl2 = spl2 + acl3 - acl2;
cl3 = spl3 + acl4 - acl3;
cl4 = spl4 + acl5 - acl4;
cl5 = spl5 + acl6 - acl5;
cl6 = spl6 + acl7 - acl6;
cl7 = spl7 + acl8 - acl7;
```

```
cl8 = spl8 + acl9 - acl8;
cl9 = spl9 + acl10 - acl9;
cl10 = spl10 + acl11 - acl10;
cl11 = spl11 + acl12 - acl11;
cl12 = spl12 + acl13 - acl12;

/* Maçã */
cm1 = spm1 + acm2 - acm1;
cm2 = spm2 + acm3 - acm2;
cm3 = spm3 + acm4 - acm3;
cm4 = spm4 + acm5 - acm4;
cm5 = spm5 + acm6 - acm5;
cm6 = spm6 + acm7 - acm6;
cm7 = spm7 + acm8 - acm7;
cm8 = spm8 + acm9 - acm8;
cm9 = spm9 + acm10 - acm9;
cm10 = spm10 + acm11 - acm10;
cm11 = spm11 + acm12 - acm11;
cm12 = spm12 + acm13 - acm12;

/* Pêra */
cp1 = spp1 + acp2 - acp1;
cp2 = spp2 + acp3 - acp2;
cp3 = spp3 + acp4 - acp3;
cp4 = spp4 + acp5 - acp4;
cp5 = spp5 + acp6 - acp5;
cp6 = spp6 + acp7 - acp6;
cp7 = spp7 + acp8 - acp7;
cp8 = spp8 + acp9 - acp8;
cp9 = spp9 + acp10 - acp9;
cp10 = spp10 + acp11 - acp10;
cp11 = spp11 + acp12 - acp11;
cp12 = spp12 + acp13 - acp12;

/* Sumo vendido em cada mês - Serve para confirmar */
/* Laranja */
svl1 = asl1 + spl1 - asl2;
svl2 = asl2 + spl2 - asl3;
svl3 = asl3 + spl3 - asl4;
svl4 = asl4 + spl4 - asl5;
svl5 = asl5 + spl5 - asl6;
svl6 = asl6 + spl6 - asl7;
svl7 = asl7 + spl7 - asl8;
svl8 = asl8 + spl8 - asl9;
svl9 = asl9 + spl9 - asl10;
svl10 = asl10 + spl10 - asl11;
svl11 = asl11 + spl11 - asl12;
svl12 = asl12 + spl12 - asl13;

/* Maçã */
svm1 = asm1 + spm1 - asm2;
svm2 = asm2 + spm2 - asm3;
svm3 = asm3 + spm3 - asm4;
svm4 = asm4 + spm4 - asm5;
svm5 = asm5 + spm5 - asm6;
svm6 = asm6 + spm6 - asm7;
svm7 = asm7 + spm7 - asm8;
svm8 = asm8 + spm8 - asm9;
svm9 = asm9 + spm9 - asm10;
svm10 = asm10 + spm10 - asm11;
svm11 = asm11 + spm11 - asm12;
```

```
svm12 = asm12 + spm12 - asm13;

/* Pêra */
svp1 = asp1 + spp1 - asp2;
svp2 = asp2 + spp2 - asp3;
svp3 = asp3 + spp3 - asp4;
svp4 = asp4 + spp4 - asp5;
svp5 = asp5 + spp5 - asp6;
svp6 = asp6 + spp6 - asp7;
svp7 = asp7 + spp7 - asp8;
svp8 = asp8 + spp8 - asp9;
svp9 = asp9 + spp9 - asp10;
svp10 = asp10 + spp10 - asp11;
svp11 = asp11 + spp11 - asp12;
svp12 = asp12 + spp12 - asp13;

/* Variáveis binárias e restrições */
bl1 + bm1 + bp1 <= 1;
bl2 + bm2 + bp2 <= 1;
bl3 + bm3 + bp3 <= 1;
bl4 + bm4 + bp4 <= 1;
bl5 + bm5 + bp5 <= 1;
bl6 + bm6 + bp6 <= 1;
bl7 + bm7 + bp7 <= 1;
bl8 + bm8 + bp8 <= 1;
bl9 + bm9 + bp9 <= 1;
bl10 + bm10 + bp10 <= 1;
bl11 + bm11 + bp11 <= 1;
bl12 + bm12 + bp12 <= 1;

/* Variáveis binárias que decidem que sumo
se produz em cada mês*/
Bin bl1,bm1,bp1,
    bl2,bm2,bp2,
    bl3,bm3,bp3,
    bl4,bm4,bp4,
    bl5,bm5,bp5,
    bl6,bm6,bp6,
    bl7,bm7,bp7,
    bl8,bm8,bp8,
    bl9,bm9,bp9,
    bl10,bm10,bp10,
    bl11,bm11,bp11,
    bl12,bm12,bp12;
```

3.3 – Ficheiro de Output

Variables	MILP Feasible 52882	MILP Better 52751	MILP Better 52679	result 52679
cl1	0	0	0	0
cm1	0	0	0	0
cp1	0	0	0	0
spl1	0	0	0	0
spm1	0	0	0	0
spp1	0	0	0	0
acl2	16	16	16	16
acm2	8	8	8	8
acp2	6	6	6	6
asl2	11	11	11	11
asm2	5	5	5	5
asp2	6	6	6	6
cl2	0	0	0	0
cm2	0	0	0	0
cp2	0	0	0	0
spl2	0	0	0	0
spm2	0	0	0	0
spp2	0	0	0	0
acl3	16	16	16	16
acm3	8	8	8	8
acp3	6	6	6	6
asl3	2	2	2	2
asm3	0	0	0	0
asp3	2	2	2	2
cl3	3	3	3	3
cm3	51	51	51	51
cp3	0	0	0	0
spl3	7	7	7	7
spm3	41	41	41	41
spp3	6,000000000000001	6	6	6
acl4	12	12	12	12
acm4	18	18	18	18
acp4	0	0	0	0
asl4	0	0	0	0
asm4	36	36	36	36
asp4	4	4	4	4
cl4	0	0	0	0
cm4	13	13	13	13
cp4	6,999999999999999	7	7	7
spl4	12	12	12	12
spm4	7	7,000000000000001	7	7
spp4	0,9999999999999991	0,9999999999999999	0,9999999999999999	0,9999999999999999
acl5	0	0	0	0
acm5	24	24	24	24
acp5	6	6	6	6
asl5	0	0	0	0
asm5	37	37	37	37
asp5	0	0	0	0
cl5	33	33	33	33
cm5	0	0	0	0
cp5	0	0	0	0
spl5	25	23	25	25
spm5	2,000000000000002	3,999999999999999	2	2
spp5	6	6	6	6
acl6	8,000000000000002	9,999999999999999	7,999999999999999	7,999999999999999
acm6	22	20	22	22

acp6	0	0	0	0
asl6	8,99999999999998	7,00000000000001	9,00000000000001	9,00000000000001
asm6	31	33	31	31
asp6	0	0	0	0
cl6	0	0	0	0
cm6	0	3,99999999999999	0	0
cp6	15	15	15	15
spl6	8,00000000000002	9,99999999999999	7,99999999999999	7,99999999999999
spm6	0	0	0	0
spp6	7	9	7	7
acl7	0	0	0	0
acm7	22	24	22	22
acp7	8,00000000000002	6	7,99999999999999	7,99999999999999
asl7	0	0	0	0
asm7	22	24	22	22
asp7	0	2	0	0
cl7	38	38	38	38
cm7	0	0	0	0
cp7	0	0	0	0
spl7	38	38	38	38
spm7	0	0	0	0
spp7	8	6	7,99999999999999	7,99999999999999
acl8	0	0	0	0
acm8	22	24	22	22
acp8	0	0	0	0
asl8	19	19	19	19
asm8	12	14	12	12
asp8	0	0	0	0
cl8	0	0	0	0
cm8	0	0	0	0
cp8	16	14	14	14
spl8	0	0	0	0
spm8	0	0	0	0
spp8	8	8	8	8
acl9	0	0	0	0
acm9	22	24	22	22
acp9	7,99999999999999	6	6	6
asl9	0	0	0	0
asm9	2	4	2	2
asp9	0	0	0	0
cl9	28	28	28	28
cm9	0	0	0	0
cp9	3,00000000000001	0	0	0
spl9	16	16	16	16
spm9	6	6	6	6
spp9	11	6	6	6
acl10	12	12	12	12
acm10	16	18	16	16
acp10	0	0	0	0
asl10	0	0	0	0
asm10	0	2	0	0
asp10	5	0	0	0
cl10	0	0	0	0
cm10	4,00000000000001	0	0	0
cp10	6	5	5	5
spl10	12	12	12	12
spm10	8	6	6	6
spp10	6	5	5	5
acl11	0	0	0	0
acm11	12	12	10	10

acp11	0	0	0	0
asl11	0	0	0	0
asm11	2	2	0	0
asp11	6	0	0	0
cl11	55	55	55	55
cm11	0	0	0	0
cp11	14	20	24	24
spl11	33	33	39	39
spm11	12	12	8,000000000000001	8,000000000000001
spp11	6	12	12	12
acl12	22	22	16	16
acm12	0	0	1,999999999999999	1,999999999999999
acp12	7,999999999999999	7,999999999999999	12	12
asl12	23	23	29	29
asm12	9	9	3	3
asp12	8	8	8	8
cl12	0	0	0	0
cm12	14	14	18	18
cp12	4,000000000000001	4,000000000000001	0	0
spl12	6,000000000000001	6,000000000000001	0	0
spm12	6	6	12	12
spp12	6	6	6	6
acl13	16	16	16	16
acm13	8	8	8	8
acp13	6	6	6	6
asl13	20	20	20	20
asm13	10	10	10	10
asp13	10	10	10	10
acl1	16	16	16	16
acm1	8	8	8	8
acp1	6	6	6	6
asl1	20	20	20	20
asm1	10	10	10	10
asp1	10	10	10	10
bl1	0	0	0	0
bm1	0	0	0	0
bp1	0	0	0	0
bl2	0	0	0	0
bm2	0	0	0	0
bp2	0	0	0	0
bl3	0	0	0	0
bm3	1	1	1	1
bp3	0	0	0	0
bl4	1	1	1	1
bm4	0	0	0	0
bp4	0	0	0	0
bl5	1	1	1	1
bm5	0	0	0	0
bp5	0	0	0	0
bl6	0	0	0	0
bm6	0	0	0	0
bp6	1	1	1	1
bl7	1	1	1	1
bm7	0	0	0	0
bp7	0	0	0	0
bl8	0	0	0	0
bm8	0	0	0	0
bp8	1	1	1	1
bl9	1	1	1	1
bm9	0	0	0	0
bp9	0	0	0	0
bl10	0	0	0	0
bm10	1	0	0	0
bp10	0	0	0	0
bl11	1	1	1	1
bm11	0	0	0	0

bp11	0	0	0	0
bl12	1	1	0	0
bm12	0	0	1	1
bp12	0	0	0	0
svl1	9	9	9	9
svl2	9	9	9	9
svl3	9	9	9	9
svl4	12	12	12	12
svl5	16	16	16	16
svl6	17	17	17	17
svl7	19	19	19	19
svl8	19	19	19	19
svl9	16	16	16	16
svl10	12	12	12	12
svl11	10	10	10	10
svl12	9	9	9	9
svm1	5	5	5	5
svm2	5	5	5	5
svm3	5	5	5	5
svm4	5,99999999999999	6	6	6
svm5	8	8	8	8
svm6	9	9	9	9
svm7	10	10	10	10
svm8	10	10	10	10
svm9	8	8	8	8
svm10	6	6	6	6
svm11	5	5	5	5
svm12	5	5	5	5
svp1	4	4	4	4
svp2	4	4	4	4
svp3	4,00000000000001	4	4	4
svp4	4,99999999999999	5	5	5
svp5	6	6	6	6
svp6	7	7	7	7
svp7	8	8	7,99999999999999	7,99999999999999
svp8	8	8	8	8
svp9	6	6	6	6
svp10	5	5	5	5
svp11	4	4	4	4
svp12	4	4	4	4

3.4 – Plano detalhado de produção

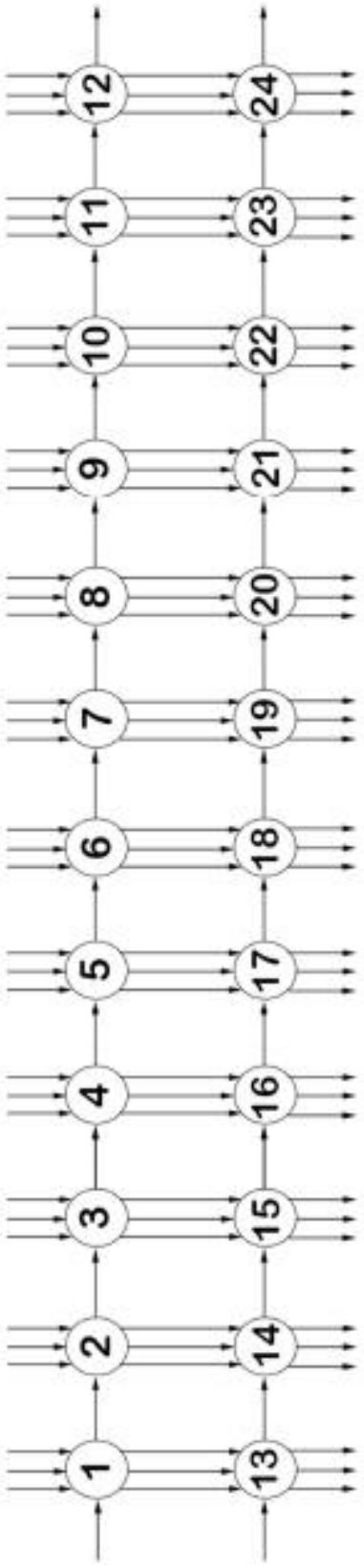

Figura 4. Plano detalhado de produção da parte 3

3.5 – Validação do modelo

3.5.1 – Conservação de fluxo

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

3.5.2 – Somatório dos custos

Parte 4

4.1 – Formulação do problema

Partindo do modelo da parte 3, as alterações feitas são as que enunciamos abaixo.

```
/* Janeiro */
spl1p1 <= 45ll1 + 45lm1 + 45lp1;
spm1p1 <= 45ml1 + 45mm1 + 45mp1;
spp1p1 <= 45pl1 + 45pm1 + 45pp1;

spl1p2 <= 45ll1 + 45ml1 + 45pl1;
spm1p2 <= 45lm1 + 45mm1 + 45pm1;
spp1p2 <= 45lp1 + 45mp1 + 45pp1;

spl1 = spl1p1 + spl1p2;
spm1 = spm1p1 + spm1p2;
spp1 = spp1p1 + spp1p2;

/* Fevereiro */
spl2p1 <= 45ll2 + 45lm2 + 45lp2;
spm2p1 <= 45ml2 + 45mm2 + 45mp2;
spp2p1 <= 45pl2 + 45pm2 + 45pp2;

spl2p2 <= 45ll2 + 45ml2 + 45pl2;
spm2p2 <= 45lm2 + 45mm2 + 45pm2;
spp2p2 <= 45lp2 + 45mp2 + 45pp2;

spl2 = spl2p1 + spl2p2;
spm2 = spm2p1 + spm2p2;
spp2 = spp2p1 + spp2p2;

/* Março */
spl3p1 <= 45ll3 + 45lm3 + 45lp3;
spm3p1 <= 45ml3 + 45mm3 + 45mp3;
spp3p1 <= 45pl3 + 45pm3 + 45pp3;

spl3p2 <= 45ll3 + 45ml3 + 45pl3;
spm3p2 <= 45lm3 + 45mm3 + 45pm3;
spp3p2 <= 45lp3 + 45mp3 + 45pp3;

spl3 = spl3p1 + spl3p2;
spm3 = spm3p1 + spm3p2;
spp3 = spp3p1 + spp3p2;

/* Abril */
spl4p1 <= 45ll4 + 45lm4 + 45lp4;
spm4p1 <= 45ml4 + 45mm4 + 45mp4;
spp4p1 <= 45pl4 + 45pm4 + 45pp4;

spl4p2 <= 45ll4 + 45ml4 + 45pl4;
spm4p2 <= 45lm4 + 45mm4 + 45pm4;
spp4p2 <= 45lp4 + 45mp4 + 45pp4;

spl4 = spl1p4 + spl4p2;
spm4 = spm1p4 + spm4p2;
spp4 = spp1p4 + spp4p2;

/* Maio */
spl5p1 <= 45ll5 + 45lm5 + 45lp5;
```

```
spm5p1 <= 45ml5 + 45mm5 + 45mp5;
spp5p1 <= 45pl5 + 45pm5 + 45pp5;

spl5p2 <= 45ll5 + 45ml5 + 45pl5;
spm5p2 <= 45lm5 + 45mm5 + 45pm5;
spp5p2 <= 45lp5 + 45mp5 + 45pp5;

spl5 = spl5p1 + spl5p2;
spm5 = spm5p1 + spm5p2;
spp5 = spp5p1 + spp5p2;

/* Junho */
spl6p1 <= 45ll6 + 45lm6 + 45lp6;
spm6p1 <= 45ml6 + 45mm6 + 45mp6;
spp6p1 <= 45pl6 + 45pm6 + 45pp6;

spl6p2 <= 45ll6 + 45ml2 + 45pl6;
spm6p2 <= 45lm6 + 45mm2 + 45pm6;
spp6p2 <= 45lp6 + 45mp2 + 45pp6;

spl6 = spl6p1 + spl1p2;
spm6 = spm6p1 + spm1p2;
spp6 = spp6p1 + spp1p2;

/* Julho */
spl7p1 <= 45ll7 + 45lm7 + 45lp7;
spm7p1 <= 45ml7 + 45mm7 + 45mp7;
spp7p1 <= 45pl7 + 45pm7 + 45pp7;

spl7p2 <= 45ll7 + 45ml7 + 45pl7;
spm7p2 <= 45lm7 + 45mm7 + 45pm7;
spp7p2 <= 45lp7 + 45mp7 + 45pp7;

spl7 = spl7p1 + spl7p2;
spm7 = spm7p1 + spm7p2;
spp7 = spp7p1 + spp7p2;

/* Agosto */
spl8p1 <= 45ll8 + 45lm8 + 45lp8;
spm8p1 <= 45ml8 + 45mm8 + 45mp8;
spp8p1 <= 45pl8 + 45pm8 + 45pp8;

spl8p2 <= 45ll8 + 45ml8 + 45pl8;
spm8p2 <= 45lm8 + 45mm8 + 45pm8;
spp8p2 <= 45lp8 + 45mp8 + 45pp8;

spl8 = spl8p1 + spl8p2;
spm8 = spm8p1 + spm8p2;
spp8 = spp8p1 + spp8p2;

/* Setembro */
spl9p1 <= 45ll9 + 45lm9 + 45lp9;
spm9p1 <= 45ml9 + 45mm9 + 45mp9;
spp9p1 <= 45pl9 + 45pm9 + 45pp9;

spl9p2 <= 45ll9 + 45ml9 + 45pl9;
spm9p2 <= 45lm9 + 45mm9 + 45pm9;
spp9p2 <= 45lp9 + 45mp9 + 45pp9;

spl9 = spl9p1 + spl9p2;
spm9 = spm9p1 + spm9p2;
```

```
spp9 = spp9p1 + spp9p2;

/* Outubro */
spl10p1 <= 45ll10 + 45lm10 + 45lp10;
spm10p1 <= 45ml10 + 45mm10 + 45mp10;
spp10p1 <= 45pl10 + 45pm10 + 45pp10;

spl10p2 <= 45ll10 + 45ml10 + 45pl10;
spm10p2 <= 45lm10 + 45mm10 + 45pm10;
spp10p2 <= 45lp10 + 45mp10 + 45pp10;

spl10 = spl10p1 + spl10p2;
spm10 = spm10p1 + spm10p2;
spp10 = spp10p1 + spp10p2;

/* Novembro */
spl11p1 <= 45ll11 + 45lm11 + 45lp11;
spm11p1 <= 45ml11 + 45mm11 + 45mp11;
spp11p1 <= 45pl11 + 45pm11 + 45pp11;

spl11p2 <= 45ll11 + 45ml11 + 45pl11;
spm11p2 <= 45lm11 + 45mm11 + 45pm11;
spp11p2 <= 45lp11 + 45mp11 + 45pp11;

spl11 = spl11p1 + spl11p2;
spm11 = spm11p1 + spm11p2;
spp11 = spp11p1 + spp11p2;

/* Dezembro */
spl12p1 <= 45ll12 + 45lm12 + 45lp12;
spm12p1 <= 45ml12 + 45mm12 + 45mp12;
spp12p1 <= 45pl12 + 45pm12 + 45pp12;

spl12p2 <= 45ll12 + 45ml12 + 45pl12;
spm12p2 <= 45lm12 + 45mm12 + 45pm12;
spp12p2 <= 45lp12 + 45mp12 + 45pp12;

spl12 = spl12p1 + spl12p2;
spm12 = spm12p1 + spm12p2;
spp12 = spp12p1 + spp12p2;


…

/* Restrições das variáveis binárias  */
ll1 + lm1 + lp1 + ml1 + mm1 + mp1 + pl1 + pm1 + pp1 = 1;
ll2 + lm2 + lp2 + ml2 + mm2 + mp2 + pl2 + pm2 + pp2 = 1;
ll3 + lm3 + lp3 + ml3 + mm3 + mp3 + pl3 + pm3 + pp3 = 1;
ll4 + lm4 + lp4 + ml4 + mm4 + mp4 + pl4 + pm4 + pp4 = 1;
ll5 + lm5 + lp5 + ml5 + mm5 + mp5 + pl5 + pm5 + pp5 = 1;
ll6 + lm6 + lp6 + ml6 + mm6 + mp6 + pl6 + pm6 + pp6 = 1;
ll7 + lm7 + lp7 + ml7 + mm7 + mp7 + pl7 + pm7 + pp7 = 1;
ll8 + lm8 + lp8 + ml8 + mm8 + mp8 + pl8 + pm8 + pp8 = 1;
ll9 + lm9 + lp9 + ml9 + mm9 + mp9 + pl9 + pm9 + pp9 = 1;
ll10 + lm10 + lp10 + ml10 + mm10 + mp10 + pl10 + pm10 + pp10 = 1;
ll11 + lm11 + lp11 + ml11 + mm11 + mp11 + pl11 + pm11 + pp11 = 1;
ll12 + lm12 + lp12 + ml12 + mm12 + mp12 + pl12 + pm12 + pp12 = 1;


ll2 + lm2 + lp2 = ll1 + ml1 + pl1 + mm1 + pp1;
ml2 + mm2 + mp2 = lm1 + mm1 + pm1 + ll1 + pp1;
```

```
pl2 + pm2 + pp2 = lp1 + mp1 + pp1 + ll1 + mm1;

ll3 + lm3 + lp3 = ll2 + ml2 + pl2 + mm2 + pp2;
ml3 + mm3 + mp3 = lm2 + mm2 + pm2 + ll2 + pp2;
pl3 + pm3 + pp3 = lp2 + mp2 + pp2 + ll2 + mm2;

ll4 + lm4 + lp4 = ll3 + ml3 + pl3 + mm3 + pp3;
ml4 + mm4 + mp4 = lm3 + mm3 + pm3 + ll3 + pp3;
pl4 + pm4 + pp4 = lp3 + mp3 + pp3 + ll3 + mm3;

ll5 + lm5 + lp5 = ll4 + ml4 + pl4 + mm4 + pp4;
ml5 + mm5 + mp5 = lm4 + mm4 + pm4 + ll4 + pp4;
pl5 + pm5 + pp5 = lp4 + mp4 + pp4 + ll4 + mm4;

ll6 + lm6 + lp6 = ll5 + ml5 + pl5 + mm5 + pp5;
ml6 + mm6 + mp6 = lm5 + mm5 + pm5 + ll5 + pp5;
pl6 + pm6 + pp6 = lp5 + mp5 + pp5 + ll5 + mm5;

ll7 + lm7 + lp7 = ll6 + ml6 + pl6 + mm6 + pp6;
ml7 + mm7 + mp7 = lm6 + mm6 + pm6 + ll6 + pp6;
pl7 + pm7 + pp7 = lp6 + mp6 + pp6 + ll6 + mm6;

ll8 + lm8 + lp8 = ll7 + ml7 + pl7 + mm7 + pp7;
ml8 + mm8 + mp8 = lm7 + mm7 + pm7 + ll7 + pp7;
pl8 + pm8 + pp8 = lp7 + mp7 + pp7 + ll7 + mm7;

ll9 + lm9 + lp9 = ll8 + ml8 + pl8 + mm8 + pp8;
ml9 + mm9 + mp9 = lm8 + mm8 + pm8 + ll8 + pp8;
pl9 + pm9 + pp9 = lp8 + mp8 + pp8 + ll8 + mm8;

ll10 + lm10 + lp10 = ll9 + ml9 + pl9 + mm9 + pp9;
ml10 + mm10 + mp10 = lm9 + mm9 + pm9 + ll9 + pp9;
pl10 + pm10 + pp10 = lp9 + mp9 + pp9 + ll9 + mm9;

ll11 + lm11 + lp11 = ll10 + ml10 + pl10 + mm10 + pp10;
ml11 + mm11 + mp11 = lm10 + mm10 + pm10 + ll10 + pp10;
pl11 + pm11 + pp11 = lp10 + mp10 + pp10 + ll10 + mm10;

ll12 + lm12 + lp12 = ll11 + ml11 + pl11 + mm11 + pp11;
ml12 + mm12 + mp12 = lm11 + mm11 + pm11 + ll11 + pp11;
pl12 + pm12 + pp12 = lp11 + mp11 + pp11 + ll11 + mm11;

/* Variáveis binárias que decidem que sumo
se produz em cada parte do mês */
Bin ll1,lm1,lp1,ml1,mm1,mp1,pl1,pm1,pp1,
    ll2,lm2,lp2,ml2,mm2,mp2,pl2,pm2,pp2,
    ll3,lm3,lp3,ml3,mm3,mp3,pl3,pm3,pp3,
    ll4,lm4,lp4,ml4,mm4,mp4,pl4,pm4,pp4,
    ll5,lm5,lp5,ml5,mm5,mp5,pl5,pm5,pp5,
    ll6,lm6,lp6,ml6,mm6,mp6,pl6,pm6,pp6,
    ll7,lm7,lp7,ml7,mm7,mp7,pl7,pm7,pp7,
    ll8,lm8,lp8,ml8,mm8,mp8,pl8,pm8,pp8,
    ll9,lm9,lp9,ml9,mm9,mp9,pl9,pm9,pp9,
    ll10,lm10,lp10,ml10,mm10,mp10,pl10,pm10,pp10,
    ll11,lm11,lp11,ml11,mm11,mp11,pl11,pm11,pp11,
    ll12,lm12,lp12,ml12,mm12,mp12,pl12,pm12,pp12;
```

4.2 – Ficheiro Input

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis
binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  / Custos de Armazem  */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 +
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 +
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 +
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 +
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 +
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 +
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 +
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 +
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 +
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 +
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 +
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13;

/* Variable bounds */
/* Restrições iniciais e finais  */
acl1 = 16;
acl13 = 16;

acm1 = 8;
acm13 = 8;

acp1 = 6;
acp13 = 6;

asl1 = 20;
asl13 = 20;

asm1 = 10;
asm13 = 10;

asp1 = 10;
asp13 = 10;

/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30;
acl4 + acm4 + acp4 <= 30;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
```

```
acl9 + acm9 + acp9 <= 30;
acl10 + acm10 + acp10 <= 30;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

asl1 + asm1 + asp1 <= 40;
asl2 + asm2 + asp2 <= 40;
asl3 + asm3 + asp3 <= 40;
asl4 + asm4 + asp4 <= 40;
asl5 + asm5 + asp5 <= 40;
asl6 + asm6 + asp6 <= 40;
asl7 + asm7 + asp7 <= 40;
asl8 + asm8 + asp8 <= 40;
asl9 + asm9 + asp9 <= 40;
asl10 + asm10 + asp10 <= 40;
asl11 + asm11 + asp11 <= 40;
asl12 + asm12 + asp12 <= 40;

/* Atribuição das variáveis do armazém de concentrado */
/* Laranja */
acl2 = acl1 + cl1 - spl1;
acl3 = acl2 + cl2 - spl2;
acl4 = acl3 + cl3 - spl3;
acl5 = acl4 + cl4 - spl4;
acl6 = acl5 + cl5 - spl5;
acl7 = acl6 + cl6 - spl6;
acl8 = acl7 + cl7 - spl7;
acl9 = acl8 + cl8 - spl8;
acl10 = acl9 + cl9 - spl9;
acl11 = acl10 + cl10 - spl10;
acl12 = acl11 + cl11 - spl11;

/* Maçã */
acm2 = acm1 + cm1 - spm1;
acm3 = acm2 + cm2 - spm2;
acm4 = acm3 + cm3 - spm3;
acm5 = acm4 + cm4 - spm4;
acm6 = acm5 + cm5 - spm5;
acm7 = acm6 + cm6 - spm6;
acm8 = acm7 + cm7 - spm7;
acm9 = acm8 + cm8 - spm8;
acm10 = acm9 + cm9 - spm9;
acm11 = acm10 + cm10 - spm10;
acm12 = acm11 + cm11 - spm11;

/* Pêra */
acp2 = acp1 + cp1 - spp1;
acp3 = acp2 + cp2 - spp2;
acp4 = acp3 + cp3 - spp3;
acp5 = acp4 + cp4 - spp4;
acp6 = acp5 + cp5 - spp5;
acp7 = acp6 + cp6 - spp6;
acp8 = acp7 + cp7 - spp7;
acp9 = acp8 + cp8 - spp8;
acp10 = acp9 + cp9 - spp9;
acp11 = acp10 + cp10 - spp10;
acp12 = acp11 + cp11 - spp11;

/* Atribuição das variáveis do armazém de sumo */
/* Laranja */
asl2 = asl1 + spl1 - 9;
```

```
asl3 = asl2 + spl2 - 9;
asl4 = asl3 + spl3 - 9;
asl5 = asl4 + spl4 - 12;
asl6 = asl5 + spl5 - 16;
asl7 = asl6 + spl6 - 17;
asl8 = asl7 + spl7 - 19;
asl9 = asl8 + spl8 - 19;
asl10 = asl9 + spl9 - 16;
asl11 = asl10 + spl10 - 12;
asl12 = asl11 + spl11 - 10;
asl13 = asl12 + spl12 - 9;

/* Maçã */
asm2 = asm1 + spm1 - 5;
asm3 = asm2 + spm2 - 5;
asm4 = asm3 + spm3 - 5;
asm5 = asm4 + spm4 - 6;
asm6 = asm5 + spm5 - 8;
asm7 = asm6 + spm6 - 9;
asm8 = asm7 + spm7 - 10;
asm9 = asm8 + spm8 - 10;
asm10 = asm9 + spm9 - 8;
asm11 = asm10 + spm10 - 6;
asm12 = asm11 + spm11 - 5;
asm13 = asm12 + spm12 - 5;

/* Pêra */
asp2 = asp1 + spp1 - 4;
asp3 = asp2 + spp2 - 4;
asp4 = asp3 + spp3 - 4;
asp5 = asp4 + spp4 - 5;
asp6 = asp5 + spp5 - 6;
asp7 = asp6 + spp6 - 7;
asp8 = asp7 + spp7 - 8;
asp9 = asp8 + spp8 - 8;
asp10 = asp9 + spp9 - 6;
asp11 = asp10 + spp10 - 5;
asp12 = asp11 + spp11 - 4;
asp13 = asp12 + spp12 - 4;

/* Restrições de produção com
as variáveis binárias */
spl1 + spm1 + spp1 <= 45;
spl2 + spm2 + spp2 <= 45;
spl3 + spm3 + spp3 <= 45;
spl4 + spm4 + spp4 <= 45;
spl5 + spm5 + spp5 <= 45;
spl6 + spm6 + spp6 <= 45;
spl7 + spm7 + spp7 <= 45;
spl8 + spm8 + spp8 <= 45;
spl9 + spm9 + spp9 <= 45;
spl10 + spm10 + spp10 <= 45;
spl11 + spm11 + spp11 <= 45;
spl12 + spm12 + spp12 <= 45;

/* Janeiro */
spl1p1 <= 45ll1 + 45lm1 + 45lp1;
spm1p1 <= 45ml1 + 45mm1 + 45mp1;
spp1p1 <= 45pl1 + 45pm1 + 45pp1;

spl1p2 <= 45ll1 + 45ml1 + 45pl1;
```

```
spm1p2 <= 45lm1 + 45mm1 + 45pm1;
spp1p2 <= 45lp1 + 45mp1 + 45pp1;

spl1 = spl1p1 + spl1p2;
spm1 = spm1p1 + spm1p2;
spp1 = spp1p1 + spp1p2;

/* Fevereiro */
spl2p1 <= 45ll2 + 45lm2 + 45lp2;
spm2p1 <= 45ml2 + 45mm2 + 45mp2;
spp2p1 <= 45pl2 + 45pm2 + 45pp2;

spl2p2 <= 45ll2 + 45ml2 + 45pl2;
spm2p2 <= 45lm2 + 45mm2 + 45pm2;
spp2p2 <= 45lp2 + 45mp2 + 45pp2;

spl2 = spl2p1 + spl2p2;
spm2 = spm2p1 + spm2p2;
spp2 = spp2p1 + spp2p2;

/* Março */
spl3p1 <= 45ll3 + 45lm3 + 45lp3;
spm3p1 <= 45ml3 + 45mm3 + 45mp3;
spp3p1 <= 45pl3 + 45pm3 + 45pp3;

spl3p2 <= 45ll3 + 45ml3 + 45pl3;
spm3p2 <= 45lm3 + 45mm3 + 45pm3;
spp3p2 <= 45lp3 + 45mp3 + 45pp3;

spl3 = spl3p1 + spl3p2;
spm3 = spm3p1 + spm3p2;
spp3 = spp3p1 + spp3p2;

/* Abril */
spl4p1 <= 45ll4 + 45lm4 + 45lp4;
spm4p1 <= 45ml4 + 45mm4 + 45mp4;
spp4p1 <= 45pl4 + 45pm4 + 45pp4;

spl4p2 <= 45ll4 + 45ml4 + 45pl4;
spm4p2 <= 45lm4 + 45mm4 + 45pm4;
spp4p2 <= 45lp4 + 45mp4 + 45pp4;

spl4 = spl1p4 + spl4p2;
spm4 = spm1p4 + spm4p2;
spp4 = spp1p4 + spp4p2;

/* Maio */
spl5p1 <= 45ll5 + 45lm5 + 45lp5;
spm5p1 <= 45ml5 + 45mm5 + 45mp5;
spp5p1 <= 45pl5 + 45pm5 + 45pp5;

spl5p2 <= 45ll5 + 45ml5 + 45pl5;
spm5p2 <= 45lm5 + 45mm5 + 45pm5;
spp5p2 <= 45lp5 + 45mp5 + 45pp5;

spl5 = spl5p1 + spl5p2;
spm5 = spm5p1 + spm5p2;
spp5 = spp5p1 + spp5p2;

/* Junho */
spl6p1 <= 45ll6 + 45lm6 + 45lp6;
```

```
spm6p1 <= 45ml6 + 45mm6 + 45mp6;
spp6p1 <= 45pl6 + 45pm6 + 45pp6;

spl6p2 <= 45ll6 + 45ml2 + 45pl6;
spm6p2 <= 45lm6 + 45mm2 + 45pm6;
spp6p2 <= 45lp6 + 45mp2 + 45pp6;

spl6 = spl6p1 + spl1p2;
spm6 = spm6p1 + spm1p2;
spp6 = spp6p1 + spp1p2;

/* Julho */
spl7p1 <= 45ll7 + 45lm7 + 45lp7;
spm7p1 <= 45ml7 + 45mm7 + 45mp7;
spp7p1 <= 45pl7 + 45pm7 + 45pp7;

spl7p2 <= 45ll7 + 45ml7 + 45pl7;
spm7p2 <= 45lm7 + 45mm7 + 45pm7;
spp7p2 <= 45lp7 + 45mp7 + 45pp7;

spl7 = spl7p1 + spl7p2;
spm7 = spm7p1 + spm7p2;
spp7 = spp7p1 + spp7p2;

/* Agosto */
spl8p1 <= 45ll8 + 45lm8 + 45lp8;
spm8p1 <= 45ml8 + 45mm8 + 45mp8;
spp8p1 <= 45pl8 + 45pm8 + 45pp8;

spl8p2 <= 45ll8 + 45ml8 + 45pl8;
spm8p2 <= 45lm8 + 45mm8 + 45pm8;
spp8p2 <= 45lp8 + 45mp8 + 45pp8;

spl8 = spl8p1 + spl8p2;
spm8 = spm8p1 + spm8p2;
spp8 = spp8p1 + spp8p2;

/* Setembro */
spl9p1 <= 45ll9 + 45lm9 + 45lp9;
spm9p1 <= 45ml9 + 45mm9 + 45mp9;
spp9p1 <= 45pl9 + 45pm9 + 45pp9;

spl9p2 <= 45ll9 + 45ml9 + 45pl9;
spm9p2 <= 45lm9 + 45mm9 + 45pm9;
spp9p2 <= 45lp9 + 45mp9 + 45pp9;

spl9 = spl9p1 + spl9p2;
spm9 = spm9p1 + spm9p2;
spp9 = spp9p1 + spp9p2;

/* Outubro */
spl10p1 <= 45ll10 + 45lm10 + 45lp10;
spm10p1 <= 45ml10 + 45mm10 + 45mp10;
spp10p1 <= 45pl10 + 45pm10 + 45pp10;

spl10p2 <= 45ll10 + 45ml10 + 45pl10;
spm10p2 <= 45lm10 + 45mm10 + 45pm10;
spp10p2 <= 45lp10 + 45mp10 + 45pp10;

spl10 = spl10p1 + spl10p2;
spm10 = spm10p1 + spm10p2;
```

```
spp10 = spp10p1 + spp10p2;

/* Novembro */
spl11p1 <= 45ll11 + 45lm11 + 45lp11;
spm11p1 <= 45ml11 + 45mm11 + 45mp11;
spp11p1 <= 45pl11 + 45pm11 + 45pp11;

spl11p2 <= 45ll11 + 45ml11 + 45pl11;
spm11p2 <= 45lm11 + 45mm11 + 45pm11;
spp11p2 <= 45lp11 + 45mp11 + 45pp11;

spl11 = spl11p1 + spl11p2;
spm11 = spm11p1 + spm11p2;
spp11 = spp11p1 + spp11p2;

/* Dezembro */
spl12p1 <= 45ll12 + 45lm12 + 45lp12;
spm12p1 <= 45ml12 + 45mm12 + 45mp12;
spp12p1 <= 45pl12 + 45pm12 + 45pp12;

spl12p2 <= 45ll12 + 45ml12 + 45pl12;
spm12p2 <= 45lm12 + 45mm12 + 45pm12;
spp12p2 <= 45lp12 + 45mp12 + 45pp12;

spl12 = spl12p1 + spl12p2;
spm12 = spm12p1 + spm12p2;
spp12 = spp12p1 + spp12p2;

/* Atribuição das variáveis de concentrado comprado */
/* Laranja */
cl1 = spl1 + acl2 - acl1;
cl2 = spl2 + acl3 - acl2;
cl3 = spl3 + acl4 - acl3;
cl4 = spl4 + acl5 - acl4;
cl5 = spl5 + acl6 - acl5;
cl6 = spl6 + acl7 - acl6;
cl7 = spl7 + acl8 - acl7;
cl8 = spl8 + acl9 - acl8;
cl9 = spl9 + acl10 - acl9;
cl10 = spl10 + acl11 - acl10;
cl11 = spl11 + acl12 - acl11;
cl12 = spl12 + acl13 - acl12;

/* Maçã */
cm1 = spm1 + acm2 - acm1;
cm2 = spm2 + acm3 - acm2;
cm3 = spm3 + acm4 - acm3;
cm4 = spm4 + acm5 - acm4;
cm5 = spm5 + acm6 - acm5;
cm6 = spm6 + acm7 - acm6;
cm7 = spm7 + acm8 - acm7;
cm8 = spm8 + acm9 - acm8;
cm9 = spm9 + acm10 - acm9;
cm10 = spm10 + acm11 - acm10;
cm11 = spm11 + acm12 - acm11;
cm12 = spm12 + acm13 - acm12;

/* Pêra */
cp1 = spp1 + acp2 - acp1;
cp2 = spp2 + acp3 - acp2;
cp3 = spp3 + acp4 - acp3;
```

```
cp4 = spp4 + acp5 - acp4;
cp5 = spp5 + acp6 - acp5;
cp6 = spp6 + acp7 - acp6;
cp7 = spp7 + acp8 - acp7;
cp8 = spp8 + acp9 - acp8;
cp9 = spp9 + acp10 - acp9;
cp10 = spp10 + acp11 - acp10;
cp11 = spp11 + acp12 - acp11;
cp12 = spp12 + acp13 - acp12;

/* Sumo vendido em cada mês - Serve para confirmar */
/* Laranja */
svl1 = asl1 + spl1 - asl2;
svl2 = asl2 + spl2 - asl3;
svl3 = asl3 + spl3 - asl4;
svl4 = asl4 + spl4 - asl5;
svl5 = asl5 + spl5 - asl6;
svl6 = asl6 + spl6 - asl7;
svl7 = asl7 + spl7 - asl8;
svl8 = asl8 + spl8 - asl9;
svl9 = asl9 + spl9 - asl10;
svl10 = asl10 + spl10 - asl11;
svl11 = asl11 + spl11 - asl12;
svl12 = asl12 + spl12 - asl13;

/* Maçã */
svm1 = asm1 + spm1 - asm2;
svm2 = asm2 + spm2 - asm3;
svm3 = asm3 + spm3 - asm4;
svm4 = asm4 + spm4 - asm5;
svm5 = asm5 + spm5 - asm6;
svm6 = asm6 + spm6 - asm7;
svm7 = asm7 + spm7 - asm8;
svm8 = asm8 + spm8 - asm9;
svm9 = asm9 + spm9 - asm10;
svm10 = asm10 + spm10 - asm11;
svm11 = asm11 + spm11 - asm12;
svm12 = asm12 + spm12 - asm13;

/* Pêra */
svp1 = asp1 + spp1 - asp2;
svp2 = asp2 + spp2 - asp3;
svp3 = asp3 + spp3 - asp4;
svp4 = asp4 + spp4 - asp5;
svp5 = asp5 + spp5 - asp6;
svp6 = asp6 + spp6 - asp7;
svp7 = asp7 + spp7 - asp8;
svp8 = asp8 + spp8 - asp9;
svp9 = asp9 + spp9 - asp10;
svp10 = asp10 + spp10 - asp11;
svp11 = asp11 + spp11 - asp12;
svp12 = asp12 + spp12 - asp13;

/* Restrições das variáveis binárias  */
ll1 + lm1 + lp1 + ml1 + mm1 + mp1 + pl1 + pm1 + pp1 = 1;
ll2 + lm2 + lp2 + ml2 + mm2 + mp2 + pl2 + pm2 + pp2 = 1;
ll3 + lm3 + lp3 + ml3 + mm3 + mp3 + pl3 + pm3 + pp3 = 1;
ll4 + lm4 + lp4 + ml4 + mm4 + mp4 + pl4 + pm4 + pp4 = 1;
ll5 + lm5 + lp5 + ml5 + mm5 + mp5 + pl5 + pm5 + pp5 = 1;
ll6 + lm6 + lp6 + ml6 + mm6 + mp6 + pl6 + pm6 + pp6 = 1;
ll7 + lm7 + lp7 + ml7 + mm7 + mp7 + pl7 + pm7 + pp7 = 1;
```

```
ll8 + lm8 + lp8 + ml8 + mm8 + mp8 + pl8 + pm8 + pp8 = 1;
ll9 + lm9 + lp9 + ml9 + mm9 + mp9 + pl9 + pm9 + pp9 = 1;
ll10 + lm10 + lp10 + ml10 + mm10 + mp10 + pl10 + pm10 + pp10 = 1;
ll11 + lm11 + lp11 + ml11 + mm11 + mp11 + pl11 + pm11 + pp11 = 1;
ll12 + lm12 + lp12 + ml12 + mm12 + mp12 + pl12 + pm12 + pp12 = 1;

ll2 + lm2 + lp2 = ll1 + ml1 + pl1 + mm1 + pp1;
ml2 + mm2 + mp2 = lm1 + mm1 + pm1 + ll1 + pp1;
pl2 + pm2 + pp2 = lp1 + mp1 + pp1 + ll1 + mm1;

ll3 + lm3 + lp3 = ll2 + ml2 + pl2 + mm2 + pp2;
ml3 + mm3 + mp3 = lm2 + mm2 + pm2 + ll2 + pp2;
pl3 + pm3 + pp3 = lp2 + mp2 + pp2 + ll2 + mm2;

ll4 + lm4 + lp4 = ll3 + ml3 + pl3 + mm3 + pp3;
ml4 + mm4 + mp4 = lm3 + mm3 + pm3 + ll3 + pp3;
pl4 + pm4 + pp4 = lp3 + mp3 + pp3 + ll3 + mm3;

ll5 + lm5 + lp5 = ll4 + ml4 + pl4 + mm4 + pp4;
ml5 + mm5 + mp5 = lm4 + mm4 + pm4 + ll4 + pp4;
pl5 + pm5 + pp5 = lp4 + mp4 + pp4 + ll4 + mm4;

ll6 + lm6 + lp6 = ll5 + ml5 + pl5 + mm5 + pp5;
ml6 + mm6 + mp6 = lm5 + mm5 + pm5 + ll5 + pp5;
pl6 + pm6 + pp6 = lp5 + mp5 + pp5 + ll5 + mm5;

ll7 + lm7 + lp7 = ll6 + ml6 + pl6 + mm6 + pp6;
ml7 + mm7 + mp7 = lm6 + mm6 + pm6 + ll6 + pp6;
pl7 + pm7 + pp7 = lp6 + mp6 + pp6 + ll6 + mm6;

ll8 + lm8 + lp8 = ll7 + ml7 + pl7 + mm7 + pp7;
ml8 + mm8 + mp8 = lm7 + mm7 + pm7 + ll7 + pp7;
pl8 + pm8 + pp8 = lp7 + mp7 + pp7 + ll7 + mm7;

ll9 + lm9 + lp9 = ll8 + ml8 + pl8 + mm8 + pp8;
ml9 + mm9 + mp9 = lm8 + mm8 + pm8 + ll8 + pp8;
pl9 + pm9 + pp9 = lp8 + mp8 + pp8 + ll8 + mm8;

ll10 + lm10 + lp10 = ll9 + ml9 + pl9 + mm9 + pp9;
ml10 + mm10 + mp10 = lm9 + mm9 + pm9 + ll9 + pp9;
pl10 + pm10 + pp10 = lp9 + mp9 + pp9 + ll9 + mm9;

ll11 + lm11 + lp11 = ll10 + ml10 + pl10 + mm10 + pp10;
ml11 + mm11 + mp11 = lm10 + mm10 + pm10 + ll10 + pp10;
pl11 + pm11 + pp11 = lp10 + mp10 + pp10 + ll10 + mm10;

ll12 + lm12 + lp12 = ll11 + ml11 + pl11 + mm11 + pp11;
ml12 + mm12 + mp12 = lm11 + mm11 + pm11 + ll11 + pp11;
pl12 + pm12 + pp12 = lp11 + mp11 + pp11 + ll11 + mm11;

/* Variáveis binárias que decidem que sumo
se produz em cada parte do mês */
Bin ll1,lm1,lp1,ml1,mm1,mp1,pl1,pm1,pp1,
    ll2,lm2,lp2,ml2,mm2,mp2,pl2,pm2,pp2,
    ll3,lm3,lp3,ml3,mm3,mp3,pl3,pm3,pp3,
    ll4,lm4,lp4,ml4,mm4,mp4,pl4,pm4,pp4,
    ll5,lm5,lp5,ml5,mm5,mp5,pl5,pm5,pp5,
    ll6,lm6,lp6,ml6,mm6,mp6,pl6,pm6,pp6,
    ll7,lm7,lp7,ml7,mm7,mp7,pl7,pm7,pp7,
    ll8,lm8,lp8,ml8,mm8,mp8,pl8,pm8,pp8,
```

```
ll9,lm9,lp9,ml9,mm9,mp9,pl9,pm9,pp9,
ll10,lm10,lp10,ml10,mm10,mp10,pl10,pm10,pp10,
ll11,lm11,lp11,ml11,mm11,mp11,pl11,pm11,pp11,
ll12,lm12,lp12,ml12,mm12,mp12,pl12,pm12,pp12;
```

4.3 – Ficheiro de Output

Variables	MILP Better 52938	MILP Better 52932	MILP Better 52920	MILP Better 52868	MILP Better 52820	MILP Better 52810	MILP Better 52780	MILP Better 52766	result 52766
cl1	0	0	2	0	0	0	0	0	0
cm1	0	0	0	0	0	0	0	0	0
cp1	0	0	0	0	0	0	0	0	0
spl1	0	0	18	13	13	14	7	0	0
spm1	0	0	0	0	0	0	0	0	0
spp1	0	0	0	0	0	0	0	0	0
acl2	16	16	0	3	3	2	9	16	16
acm2	8	8	8	8	8	8	8	8	8
acp2	6	6	6	6	6	6	6	6	6
asl2	11	11	29	24	24	25	18	11	11
asm2	5	5	5	5	5	5	5	5	5
asp2	6	6	6	6	6	6	6	6	6
cl2	0	0	0	0	0	0	0	0	0
cm2	0	0	0	0	0	0	0	0	0
cp2	0	0	0	0	0	0	0	0	0
spl2	0	0	0	0	0	0	0	9	9
spm2	8	8	0	0	0	0	2	0	0
spp2	0	0	0	0	0	0	0	0	0
acl3	16	16	0	3	3	2	9	7	7
acm3	0	0	8	8	8	8	6	8	8
acp3	6	6	6	6	6	6	6	6	6
asl3	2	2	20	15	15	16	9	11	11
asm3	8	8	0	0	0	0	2	0	0
asp3	2	2	2	2	2	2	2	2	2
cl3	3	3	0,9999999999999	3	3	3	3	3	3
cm3	30	30	48	51	51	51	51	51	51
cp3	0	0	0	0	0	0	0	0	0
spl3	19	19	0	0	0	0	0	0	0
spm3	0	0	27	35	35	34	40	42	42
spp3	6	6	6	6	6	6	5	2,9999999999999	2,9999999999999
acl4	0	0	0,9999999999999	5,9999999999999	5,9999999999999	4,9999999999999	12	10	10
acm4	30	30	29	24	24	25	17	17	17
acp4	0	0	0	0	0	0	1	3,00000000000001	3,00000000000001
asl4	12	12	11	6,00000000000001	6,00000000000001	7	0	2	2
asm4	3	3	22	30	30	29	37	37	37
asp4	4	4	4	4	4	4	3	0,9999999999993	0,9999999999993
cl4	0	0	0	0	0	0	0	0	0
cm4	26	29	0,9999999999999	5,9999999999999	5,9999999999999	5	8	8,00000000000001	8,00000000000001
cp4	15	12	22	14	14	15	12	12	12
spl4	0	0	0,9999999999999	5,9999999999999	5,9999999999999	4,9999999999999	12	10	10
spm4	26	34	0	0	0	0	0	0	0
spp4	15	7	22	14	14	15	8,00000000000001	10	10
acl5	0	0	0	0	0	0	0	0	0
acm5	30	25	30	30	30	30	25	25	25

acp5	0	5	0	0	0	0	5	5	5
asl5	0	0	0	0	0	0	0	0	0
asm5	23	31	16	24	24	23	31	31	31
asp5	14	6	21	13	13	14	6	6	6
cl5	33	33	33	33	33	33	33	33	33
cm5	0	0	0	0	0	0	0	0	0
cp5	0	0	0	0	0	0	0	0	0
spl5	33	33	33	33	33	33	33	33	33
spm5	0	0	0	0	0	0	0	0	0
spp5	0	0	0	0	0	0	0	0	0
acl6	0	0	0	0	0	0	0	0	0
acm6	30	25	30	30	30	30	25	25	25
acp6	0	5	0	0	0	0	5	5	5
asl6	17	17	17	17	17	17	17	17	17
asm6	15	23	8	16	16	15	23	23	23
asp6	8	0	15	7	7	8	0	0	0
cl6	0	0	0	0	0	0	0	0	0
cm6	3,0000000000001	0	10	2,0000000000001	2,0000000000001	3,0000000000001	0	0	0
cp6	7	10	0	8	8	7	10	10	10
spl6	0	0	0	0	0	0	0	0	0
spm6	10	0	10	13	13	10	0	0	0
spp6	0	10	0	0	0	0	10	10	10
acl7	0	0	0	0	0	0	0	0	0
acm7	23	25	30	19	19	23	25	25	25
acp7	7	4,9999999999999	0	8	8	7	5	4,9999999999999	4,9999999999999
asl7	0	0	0	0	0	0	0	0	0
asm7	16	14	9	20	20	16	14	14	14
asp7	1	3,0000000000001	8	0	0	1	3	3,0000000000001	3,0000000000001
cl7	38	38	38	38	38	38	38	38	38
cm7	0	0	0	0	0	0	0	0	0
cp7	0	0	0	0	0	0	0	0	0
spl7	38	38	38	37	37	38	38	38	38
spm7	0	0	7	0	0	0	0	0	0
spp7	7	4,9999999999999	0	8	8	7	5	4,9999999999999	4,9999999999999
acl8	0	0	0	1	1	0	0	0	0
acm8	23	25	23	19	19	23	25	25	25
acp8	0	0	0	0	0	0	0	0	0
asl8	19	19	19	18	18	19	19	19	19
asm8	6,0000000000001	4	6	10	10	6,0000000000001	4	4	4
asp8	0	0	0	0	0	0	0	0	0
cl8	0	0	0	0	0	0	0	0	0
cm8	0	0	0	0	0	0	0	0	0
cp8	14	14	14	19	14	14	14	14	14
spl8	0	0	0	1	1	0	0	0	0
spm8	3,9999999999999	6	23	0	0	3,9999999999999	6	6	6
spp8	14	14	8	19	14	14	14	14	14
acl9	0	0	0	0	0	0	0	0	0
acm9	19	19	0	19	19	19	19	19	19
acp9	0	0	6	0	0	0	0	0	0
asl9	0	0	0	0	0	0	0	0	0
asm9	0	0	19	0	0	0	0	0	0
asp9	6	6	0	11	6	6	6	6	6
cl9	32	32	32	32	32	32	32	32	32
cm9	0	0	0	0	0	0	0	0	0
cp9	0	0	0	0	0	0	0	0	0
spl9	16	16	16	16	32	16	16	16	16
spm9	19	19	0	8	8	19	19	19	19
spp9	0	0	6	0	0	0	0	0	0
acl10	16	16	16	16	0	16	16	16	16
acm10	0	0	0	11	11	0	0	0	0
acp10	0	0	0	0	0	0	0	0	0
asl10	0	0	0	0	16	0	0	0	0
asm10	11	11	11	0	0	11	11	11	11
asp10	0	0	0	5	0	0	0	0	0

cl10	0	0	0	0	0	0	0	0	0
cm10	0	0	0	0	0	0	0	0	0
cp10	5	5	5	0	5	5	5	5	5
spl10	16	16	16	16	0	16	16	16	16
spm10	0	0	0	11	11	0	0	0	0
spp10	5	5	5	0	5	5	5	5	5
acl11	0	0	0	0	0	0	0	0	0
acm11	0	0	0	0	0	0	0	0	0
acp11	0	0	0	0	0	0	0	0	0
asl11	3,9999999999999	3,9999999999999	3,9999999999999	3,9999999999998	3,9999999999999	3,9999999999999	3,9999999999999	3,9999999999999	3,9999999999999
asm11	5	5	5	5	5	5	5	5	5
asp11	0	0	0	0	0	0	0	0	0
cl11	51	51	51	51	51	51	51	51	51
cm11	0	0	0	0	0	0	0	0	0
cp11	24	24	24	24	24	24	24	24	24
spl11	27	27	27	35	27	27	27	27	27
spm11	0	0	0	0	0	0	0	0	0
spp11	18	18	18	9,9999999999999	18	18	18	18	18
acl12	24	24	24	16	24	24	24	24	24
acm12	0	0	0	0	0	0	0	0	0
acp12	6	6	6	14	6	6	6	6	6
asl12	21	21	21	29	21	21	21	21	21
asm12	0	0	0	0	0	0	0	0	0
asp12	14	14	14	5,9999999999999	14	14	14	14	14
cl12	0	0	0	0	0	0	0	0	0
cm12	23	23	23	23	23	23	23	23	23
cp12	0	0	0	0	0	0	0	0	0
spl12	8	8	8	0	8	8	8	8	8
spm12	15	15	15	15	15	15	15	15	15
spp12	0	0	0	8,00000000000001	0	0	0	0	0
acl13	16	16	16	16	16	16	16	16	16
acm13	8	8	8	8	8	8	8	8	8
acp13	6	6	6	6	6	6	6	6	6
asl13	20	20	20	20	20	20	20	20	20
asm13	10	10	10	10	10	10	10	10	10
asp13	10	10	10	10	10	10	10	10	10
acl1	16	16	16	16	16	16	16	16	16
acm1	8	8	8	8	8	8	8	8	8
acp1	6	6	6	6	6	6	6	6	6
asl1	20	20	20	20	20	20	20	20	20
asm1	10	10	10	10	10	10	10	10	10
asp1	10	10	10	10	10	10	10	10	10
spl1p1	0	0	18	13	13	14	7	0	0
ll1	0	0	0	0	0	0	0	0	0
lm1	1	1	1	1	1	1	1	0	0
lp1	0	0	0	0	0	0	0	0	0
spm1p1	0	0	0	0	0	0	0	0	0
ml1	0	0	0	0	0	0	0	0	0
mm1	0	0	0	0	0	0	0	0	0
mp1	0	0	0	0	0	0	0	0	0
spp1p1	0	0	0	0	0	0	0	0	0
pl1	0	0	0	0	0	0	0	1	1
pm1	0	0	0	0	0	0	0	0	0
pp1	0	0	0	0	0	0	0	0	0
spl1p2	0	0	0	0	0	0	0	0	0
spm1p2	0	0	0	0	0	0	0	0	0
spp1p2	0	0	0	0	0	0	0	0	0
spl2p1	0	0	0	0	0	0	0	9	9
ll2	0	0	0	0	0	0	0	0	0
lm2	0	0	0	0	0	0	0	1	1
lp2	0	0	0	0	0	0	0	0	0
spm2p1	8	8	0	0	0	0	2	0	0
ml2	1	1	0	0	0	0	0	0	0
mm2	0	0	0	0	0	0	0	0	0
mp2	0	0	1	1	1	1	1	0	0
spp2p1	0	0	0	0	0	0	0	0	0
pl2	0	0	0	0	0	0	0	0	0
pm2	0	0	0	0	0	0	0	0	0

pp2	0	0	0	0	0	0	0	0	0
spl2p2	0	0	0	0	0	0	0	0	0
spm2p2	0	0	0	0	0	0	0	0	0
spp2p2	0	0	0	0	0	0	0	0	0
spl3p1	19	19	0	0	0	0	0	0	0
ll3	0	0	0	0	0	0	0	0	0
lm3	0	0	0	0	0	0	0	0	0
lp3	1	1	0	0	0	0	0	0	0
spm3p1	0	0	0	0	0	0	0	42	42
ml3	0	0	0	0	0	0	0	0	0
mm3	0	0	0	0	0	0	0	0	0
mp3	0	0	0	0	0	0	0	1	1
spp3p1	0	0	6	6	6	6	5	0	0
pl3	0	0	0	0	0	0	0	0	0
pm3	0	0	1	1	1	1	1	0	0
pp3	0	0	0	0	0	0	0	0	0
spl3p2	0	0	0	0	0	0	0	0	0
spm3p2	0	0	27	35	35	34	40	0	0
spp3p2	6	6	0	0	0	0	0	2,9999999999999999	2,9999999999999999
spl4p1	0	0	0	0	0	0	0	0	0
ll4	0	0	0	0	0	0	0	0	0
lm4	0	0	0	0	0	0	0	0	0
lp4	0	0	0	0	0	0	0	0	0
spm4p1	0	0	0	0	0	0	0	0	0
ml4	0	0	1	1	1	1	1	0	0
mm4	0	0	0	0	0	0	0	0	0
mp4	0	0	0	0	0	0	0	0	0
spp4p1	0	0	0	0	0	0	0	0	0
pl4	1	1	0	0	0	0	0	1	1
pm4	0	0	0	0	0	0	0	0	0
pp4	0	0	0	0	0	0	0	0	0
spl4p2	0	0	0,9999999999999999	5,9999999999999999	5,9999999999999999	5	12	10	10
spm4p2	0	0	0	0	0	0	0	0	0
spp4p2	0	0	0	0	0	0	0	0	0
spl1p4	0	0	0	0	0	0	0	0	0
spm1p4	26	34	0	0	0	0	0	0	0
spp1p4	15	7	22	14	14	15	8,0000000000000001	10	10
spl5p1	33	33	33	33	33	33	33	33	33
ll5	0	0	0	0	0	0	0	0	0
lm5	1	0	1	1	1	1	0	0	0
lp5	0	1	0	0	0	0	1	1	1
spm5p1	0	0	0	0	0	0	0	0	0
ml5	0	0	0	0	0	0	0	0	0
mm5	0	0	0	0	0	0	0	0	0
mp5	0	0	0	0	0	0	0	0	0
spp5p1	0	0	0	0	0	0	0	0	0
pl5	0	0	0	0	0	0	0	0	0
pm5	0	0	0	0	0	0	0	0	0
pp5	0	0	0	0	0	0	0	0	0
spl5p2	0	0	0	0	0	0	0	0	0
spm5p2	0	0	0	0	0	0	0	0	0
spp5p2	0	0	0	0	0	0	0	0	0
spl6p1	0	0	0	0	0	0	0	0	0
ll6	0	0	0	0	0	0	0	0	0
lm6	0	0	0	0	0	0	0	0	0
lp6	0	0	0	0	0	0	0	0	0
spm6p1	10	0	10	13	13	10	0	0	0
ml6	1	0	1	1	1	1	0	0	0
mm6	0	0	0	0	0	0	0	0	0
mp6	0	0	0	0	0	0	0	0	0
spp6p1	0	10	0	0	0	0	10	10	10
pl6	0	1	0	0	0	0	1	1	1
pm6	0	0	0	0	0	0	0	0	0
pp6	0	0	0	0	0	0	0	0	0
spl6p2	0	0	0	0	0	0	0	0	0
spm6p2	0	0	0	0	0	0	0	0	0
spp6p2	0	0	0	0	0	0	0	0	0
spl7p1	38	38	38	37	37	38	38	38	38
ll7	0	0	0	0	0	0	0	0	0
lm7	0	0	1	0	0	0	0	0	0

lp7	1	1	0	1	1	1	1	1	1
spm7p1	0	0	0	0	0	0	0	0	0
ml7	0	0	0	0	0	0	0	0	0
mm7	0	0	0	0	0	0	0	0	0
mp7	0	0	0	0	0	0	0	0	0
spp7p1	0	0	0	0	0	0	0	0	0
pl7	0	0	0	0	0	0	0	0	0
pm7	0	0	0	0	0	0	0	0	0
pp7	0	0	0	0	0	0	0	0	0
spl7p2	0	0	0	0	0	0	0	0	0
spm7p2	0	0	7	0	0	0	0	0	0
spp7p2	7	4,9999999999999999	0	8	8	7	5	4,9999999999999999	4,9999999999999999
spl8p1	0	0	0	0	0	0	0	0	0
ll8	0	0	0	0	0	0	0	0	0
lm8	0	0	0	0	0	0	0	0	0
lp8	0	0	0	0	0	0	0	0	0
spm8p1	0	0	23	0	0	0	0	0	0
ml8	0	0	0	0	0	0	0	0	0
mm8	0	0	0	0	0	0	0	0	0
mp8	0	0	1	0	0	0	0	0	0
spp8p1	14	14	0	19	14	14	14	14	14
pl8	0	0	0	1	1	0	0	0	0
pm8	1	1	0	0	0	1	1	1	1
pp8	0	0	0	0	0	0	0	0	0
spl8p2	0	0	0	1	1	0	0	0	0
spm8p2	3,9999999999999999	6	0	0	0	3,9999999999999999	6	6	6
spp8p2	0	0	8	0	0	0	0	0	0
spl9p1	0	0	0	16	32	0	0	0	0
ll9	0	0	0	0	0	0	0	0	0
lm9	0	0	0	1	1	0	0	0	0
lp9	0	0	0	0	0	0	0	0	0
spm9p1	19	19	0	0	0	19	19	19	19
ml9	1	1	0	0	0	1	1	1	1
mm9	0	0	0	0	0	0	0	0	0
mp9	0	0	0	0	0	0	0	0	0
spp9p1	0	0	6	0	0	0	0	0	0
pl9	0	0	1	0	0	0	0	0	0
pm9	0	0	0	0	0	0	0	0	0
pp9	0	0	0	0	0	0	0	0	0
spl9p2	16	16	16	0	0	16	16	16	16
spm9p2	0	0	0	8	8	0	0	0	0
spp9p2	0	0	0	0	0	0	0	0	0
spl10p1	16	16	16	0	0	16	16	16	16
ll10	0	0	0	0	0	0	0	0	0
lm10	0	0	0	0	0	0	0	0	0
lp10	1	1	1	0	0	1	1	1	1
spm10p1	0	0	0	11	11	0	0	0	0
ml10	0	0	0	1	0	0	0	0	0
mm10	0	0	0	0	0	0	0	0	0
mp10	0	0	0	0	1	0	0	0	0
spp10p1	0	0	0	0	0	0	0	0	0
pl10	0	0	0	0	0	0	0	0	0
pm10	0	0	0	0	0	0	0	0	0
pp10	0	0	0	0	0	0	0	0	0
spl10p2	0	0	0	16	0	0	0	0	0
spm10p2	0	0	0	0	0	0	0	0	0
spp10p2	5	5	5	0	5	5	5	5	5
spl11p1	0	0	0	35	0	0	0	0	0
ll11	0	0	0	0	0	0	0	0	0
lm11	0	0	0	0	0	0	0	0	0
lp11	0	0	0	1	0	0	0	0	0
spm11p1	0	0	0	0	0	0	0	0	0
ml11	0	0	0	0	0	0	0	0	0
mm11	0	0	0	0	0	0	0	0	0
mp11	0	0	0	0	0	0	0	0	0
spp11p1	18	18	18	0	18	18	18	18	18
pl11	1	1	1	0	1	1	1	1	1
pm11	0	0	0	0	0	0	0	0	0
pp11	0	0	0	0	0	0	0	0	0
spl11p2	27	27	27	0	27	27	27	27	27
spm11p2	0	0	0	0	0	0	0	0	0

spp11p2	0	0	0	9,9999999999999999	0	0	0	0	0
spl12p1	8	8	8	0	8	8	8	8	8
ll12	0	0	0	0	0	0	0	0	0
lm12	1	1	1	0	1	1	1	1	1
lp12	0	0	0	0	0	0	0	0	0
spm12p1	0	0	0	0	0	0	0	0	0
ml12	0	0	0	0	0	0	0	0	0
mm12	0	0	0	0	0	0	0	0	0
mp12	0	0	0	0	0	0	0	0	0
spp12p1	0	0	0	8,00000000000001	0	0	0	0	0
pl12	0	0	0	0	0	0	0	0	0
pm12	0	0	0	1	0	0	0	0	0
pp12	0	0	0	0	0	0	0	0	0
spl12p2	0	0	0	0	0	0	0	0	0
spm12p2	15	15	15	15	15	15	15	15	15
spp12p2	0	0	0	0	0	0	0	0	0
svl1	9	9	9	9	9	9	9	9	9
svl2	9	9	9	9	9	9	9	9	9
svl3	9	9	9	9	9	9	9	9	9
svl4	12	12	12	12	12	12	12	12	12
svl5	16	16	16	16	16	16	16	16	16
svl6	17	17	17	17	17	17	17	17	17
svl7	19	19	19	19	19	19	19	19	19
svl8	19	19	19	19	19	19	19	19	19
svl9	16	16	16	16	16	16	16	16	16
svl10	12	12	12	12	12	12	12	12	12
svl11	10	10	10	10	10	10	10	10	10
svl12	9	9	9	9	9	9	9	9	9
svm1	5	5	5	5	5	5	5	5	5
svm2	5	5	5	5	5	5	5	5	5
svm3	5	5	5	5	5	4,9999999999999999	5	5	5
svm4	6	6	6	6	6	6	6	6	6
svm5	8	8	8	8	8	8	8	8	8
svm6	9	9	9	9	9	9	9	9	9
svm7	10	10	10	10	10	10	10	10	10
svm8	10	10	9,9999999999999999	10	10	10	10	10	10
svm9	8	8	8	8	8	8	8	8	8
svm10	6	6	6	6	6	6	6	6	6
svm11	5	5	5	5	5	5	5	5	5
svm12	5	5	5	5	5	5	5	5	5
svp1	4	4	4	4	4	4	4	4	4
svp2	4	4	4	4	4	4	4	4	4
svp3	4	4	4	4	4	4	4	4	4
svp4	5	5	5	5	5	5	5	5	5
svp5	6	6	6	6	6	6	6	6	6
svp6	7	7	7	7	7	7	7	7	7
svp7	8	8	8	8	8	8	8	8	8
svp8	8	8	8	8	8	8	8	8	8
svp9	6	6	6	6	6	6	6	6	6
svp10	5	5	5	5	5	5	5	5	5
svp11	4	4	4	4	4	4	4	4	4
svp12	4	4	4	4	4	4	4	4	4

4.4 – Plano detalhado de produção

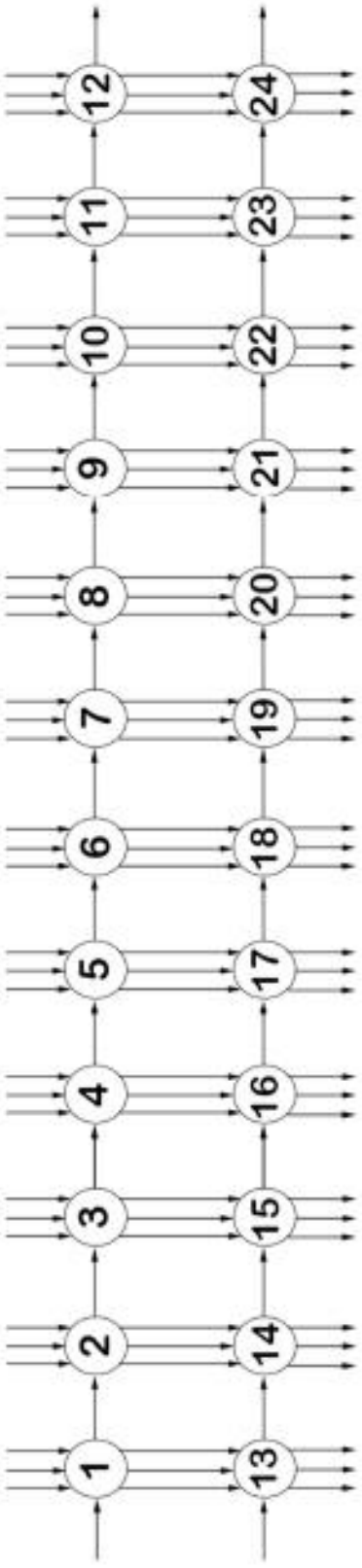

Figura 5. Plano detalhado da parte 4

4.5 – Validação do modelo

4.5.1 – Conservação de fluxo

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

4.5.2 – Somatório dos custos

Parte 5

5.1 – Formulação do problema

Para a parte 5, usamos o modelo da parte 4 como referência adicionando as seguintes modificações.

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis
binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  /  Custos de Armazem   / Custo de mudar sumo */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 + 100ms1
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 + 100ms2
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 + 100ms3
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 + 100ms4
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 + 100ms5
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 + 100ms6
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 + 100ms7
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 + 100ms8
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 + 100ms9
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 + 100ms10
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 + 100ms11
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13 + 100ms12;

…

/* Restrições de produção com
as variáveis binárias */
spl1 + spm1 + spp1 <= 45 - 6ms1;
spl2 + spm2 + spp2 <= 45 - 6ms2;
spl3 + spm3 + spp3 <= 45 - 6ms3;
spl4 + spm4 + spp4 <= 45 - 6ms4;
spl5 + spm5 + spp5 <= 45 - 6ms5;
spl6 + spm6 + spp6 <= 45 - 6ms6;
spl7 + spm7 + spp7 <= 45 - 6ms7;
spl8 + spm8 + spp8 <= 45 - 6ms8;
spl9 + spm9 + spp9 <= 45 - 6ms9;
spl10 + spm10 + spp10 <= 45 - 6ms10;
spl11 + spm11 + spp11 <= 45 - 6ms11;
spl12 + spm12 + spp12 <= 45 - 6ms12;

…
```

```
/* Atribuição das variáveis de mudança
de sumo produzido */
ms1 = lm1 + lp1 + ml1 + mp1 + pl1 + pm1;
ms2 = lm2 + lp2 + ml2 + mm2 + mp2 + pl2;
ms3 = lm3 + lp3 + ml3 + mp3 + pl3 + pm3;
ms4 = lm4 + lp4 + ml4 + mp4 + pl4 + pm4;
ms5 = lm5 + lp5 + ml5 + mp5 + pl5 + pm5;
ms6 = lm6 + lp6 + ml6 + mp6 + pl6 + pm6;
ms7 = lm7 + lp7 + ml7 + mp7 + pl7 + pm7;
ms8 = lm8 + lp8 + ml8 + mp8 + pl8 + pm8;
ms9 = lm9 + lp9 + ml9 + mp9 + pl9 + pm9;
ms10 = lm10 + lp10 + ml10 + mp10 + pl10 + pm10;
ms11 = lm11 + lp11 + ml11 + mp11 + pl11 + pm11;
ms12 = lm12 + lp12 + ml12 + mp12 + pl12 + pm12;
```

5.2 – Ficheiro de Input

```
/* Objective function */
/* PARTE V - Alterações nas restrições com a inserção de variáveis
binárias */
/*     Compra de Concentrado  /    Custos de Produção     / Custos de
Armazem  /  Custos de Armazem   / Custo de mudar sumo */
min: 160cl1 + 231cm1 + 116cp1 + 10spl1 + 10spm1 + 10spp1 + acl2 + acm2
+ acp2 + 3asl2 + 3asm2 + 3asp2 + 100ms1
     200cl2 + 199cm2 + 116cp2 + 10spl2 + 10spm2 + 10spp2 + acl3 + acm3
+ acp3 + 3asl3 + 3asm3 + 3asp3 + 100ms2
     160cl3 + 187cm3 + 124cp3 + 10spl3 + 10spm3 + 10spp3 + acl4 + acm4
+ acp4 + 3asl4 + 3asm4 + 3asp4 + 100ms3
     200cl4 + 198cm4 + 120cp4 + 10spl4 + 10spm4 + 10spp4 + acl5 + acm5
+ acp5 + 3asl5 + 3asm5 + 3asp5 + 100ms4
     160cl5 + 210cm5 + 132cp5 + 10spl5 + 10spm5 + 10spp5 + acl6 + acm6
+ acp6 + 3asl6 + 3asm6 + 3asp6 + 100ms5
     200cl6 + 208cm6 + 128cp6 + 10spl6 + 10spm6 + 10spp6 + acl7 + acm7
+ acp7 + 3asl7 + 3asm7 + 3asp7 + 100ms6
     160cl7 + 211cm7 + 136cp7 + 10spl7 + 10spm7 + 10spp7 + acl8 + acm8
+ acp8 + 3asl8 + 3asm8 + 3asp8 + 100ms7
     200cl8 + 220cm8 + 116cp8 + 12spl8 + 12spm8 + 12spp8 + acl9 + acm9
+ acp9 + 3asl9 + 3asm9 + 3asp9 + 100ms8
     160cl9 + 217cm9 + 120cp9 + 10spl9 + 10spm9 + 10spp9 + acl10 +
acm10 + acp10 + 3asl10 + 3asm10 + 3asp10 + 100ms9
     200cl10 + 216cm10 + 108cp10 + 10spl10 + 10spm10 + 10spp10 + acl11
+ acm11 + acp11 + 3asl11 + 3asm11 + 3asp11 + 100ms10
     160cl11 + 221cm11 + 100cp11 + 10spl11 + 10spm11 + 10spp11 + acl12
+ acm12 + acp12 + 3asl12 + 3asm12 + 3asp12 + 100ms11
     200cl12 + 217cm12 + 116cp12 + 10spl12 + 10spm12 + 10spp12 + acl13
+ acm13 + acp13 + 3asl13 + 3asm13 + 3asp13 + 100ms12;

/* Variable bounds */
/* Restrições iniciais e finais  */
acl1 = 16;
acl13 = 16;

acm1 = 8;
acm13 = 8;

acp1 = 6;
acp13 = 6;

asl1 = 20;
asl13 = 20;
```

```
asm1 = 10;
asm13 = 10;

asp1 = 10;
asp13 = 10;

/* Limitações de armazéns */
acl1 + acm1 + acp1 <= 30;
acl2 + acm2 + acp2 <= 30;
acl3 + acm3 + acp3 <= 30;
acl4 + acm4 + acp4 <= 30;
acl5 + acm5 + acp5 <= 30;
acl6 + acm6 + acp6 <= 30;
acl7 + acm7 + acp7 <= 30;
acl8 + acm8 + acp8 <= 30;
acl9 + acm9 + acp9 <= 30;
acl10 + acm10 + acp10 <= 30;
acl11 + acm11 + acp11 <= 30;
acl12 + acm12 + acp12 <= 30;

asl1 + asm1 + asp1 <= 40;
asl2 + asm2 + asp2 <= 40;
asl3 + asm3 + asp3 <= 40;
asl4 + asm4 + asp4 <= 40;
asl5 + asm5 + asp5 <= 40;
asl6 + asm6 + asp6 <= 40;
asl7 + asm7 + asp7 <= 40;
asl8 + asm8 + asp8 <= 40;
asl9 + asm9 + asp9 <= 40;
asl10 + asm10 + asp10 <= 40;
asl11 + asm11 + asp11 <= 40;
asl12 + asm12 + asp12 <= 40;

/* Atribuição das variáveis do armazém de concentrado */
/* Laranja */
acl2 = acl1 + cl1 - spl1;
acl3 = acl2 + cl2 - spl2;
acl4 = acl3 + cl3 - spl3;
acl5 = acl4 + cl4 - spl4;
acl6 = acl5 + cl5 - spl5;
acl7 = acl6 + cl6 - spl6;
acl8 = acl7 + cl7 - spl7;
acl9 = acl8 + cl8 - spl8;
acl10 = acl9 + cl9 - spl9;
acl11 = acl10 + cl10 - spl10;
acl12 = acl11 + cl11 - spl11;

/* Maçã */
acm2 = acm1 + cm1 - spm1;
acm3 = acm2 + cm2 - spm2;
acm4 = acm3 + cm3 - spm3;
acm5 = acm4 + cm4 - spm4;
acm6 = acm5 + cm5 - spm5;
acm7 = acm6 + cm6 - spm6;
acm8 = acm7 + cm7 - spm7;
acm9 = acm8 + cm8 - spm8;
acm10 = acm9 + cm9 - spm9;
acm11 = acm10 + cm10 - spm10;
acm12 = acm11 + cm11 - spm11;
```

```
/* Pêra */
acp2 = acp1 + cp1 - spp1;
acp3 = acp2 + cp2 - spp2;
acp4 = acp3 + cp3 - spp3;
acp5 = acp4 + cp4 - spp4;
acp6 = acp5 + cp5 - spp5;
acp7 = acp6 + cp6 - spp6;
acp8 = acp7 + cp7 - spp7;
acp9 = acp8 + cp8 - spp8;
acp10 = acp9 + cp9 - spp9;
acp11 = acp10 + cp10 - spp10;
acp12 = acp11 + cp11 - spp11;

/* Atribuição das variáveis do armazém de sumo */
/* Laranja */
asl2 = asl1 + spl1 - 9;
asl3 = asl2 + spl2 - 9;
asl4 = asl3 + spl3 - 9;
asl5 = asl4 + spl4 - 12;
asl6 = asl5 + spl5 - 16;
asl7 = asl6 + spl6 - 17;
asl8 = asl7 + spl7 - 19;
asl9 = asl8 + spl8 - 19;
asl10 = asl9 + spl9 - 16;
asl11 = asl10 + spl10 - 12;
asl12 = asl11 + spl11 - 10;
asl13 = asl12 + spl12 - 9;

/* Maçã */
asm2 = asm1 + spm1 - 5;
asm3 = asm2 + spm2 - 5;
asm4 = asm3 + spm3 - 5;
asm5 = asm4 + spm4 - 6;
asm6 = asm5 + spm5 - 8;
asm7 = asm6 + spm6 - 9;
asm8 = asm7 + spm7 - 10;
asm9 = asm8 + spm8 - 10;
asm10 = asm9 + spm9 - 8;
asm11 = asm10 + spm10 - 6;
asm12 = asm11 + spm11 - 5;
asm13 = asm12 + spm12 - 5;

/* Pêra */
asp2 = asp1 + spp1 - 4;
asp3 = asp2 + spp2 - 4;
asp4 = asp3 + spp3 - 4;
asp5 = asp4 + spp4 - 5;
asp6 = asp5 + spp5 - 6;
asp7 = asp6 + spp6 - 7;
asp8 = asp7 + spp7 - 8;
asp9 = asp8 + spp8 - 8;
asp10 = asp9 + spp9 - 6;
asp11 = asp10 + spp10 - 5;
asp12 = asp11 + spp11 - 4;
asp13 = asp12 + spp12 - 4;

/* Restrições de produção com
as variáveis binárias */
spl1 + spm1 + spp1 <= 45 - 6ms1;
spl2 + spm2 + spp2 <= 45 - 6ms2;
spl3 + spm3 + spp3 <= 45 - 6ms3;
```

```
spl4 + spm4 + spp4 <= 45 - 6ms4;
spl5 + spm5 + spp5 <= 45 - 6ms5;
spl6 + spm6 + spp6 <= 45 - 6ms6;
spl7 + spm7 + spp7 <= 45 - 6ms7;
spl8 + spm8 + spp8 <= 45 - 6ms8;
spl9 + spm9 + spp9 <= 45 - 6ms9;
spl10 + spm10 + spp10 <= 45 - 6ms10;
spl11 + spm11 + spp11 <= 45 - 6ms11;
spl12 + spm12 + spp12 <= 45 - 6ms12;

/* Janeiro */
spl1p1 <= 45ll1 + 45lm1 + 45lp1;
spm1p1 <= 45ml1 + 45mm1 + 45mp1;
spp1p1 <= 45pl1 + 45pm1 + 45pp1;

spl1p2 <= 45ll1 + 45ml1 + 45pl1;
spm1p2 <= 45lm1 + 45mm1 + 45pm1;
spp1p2 <= 45lp1 + 45mp1 + 45pp1;

spl1 = spl1p1 + spl1p2;
spm1 = spm1p1 + spm1p2;
spp1 = spp1p1 + spp1p2;

/* Fevereiro */
spl2p1 <= 45ll2 + 45lm2 + 45lp2;
spm2p1 <= 45ml2 + 45mm2 + 45mp2;
spp2p1 <= 45pl2 + 45pm2 + 45pp2;

spl2p2 <= 45ll2 + 45ml2 + 45pl2;
spm2p2 <= 45lm2 + 45mm2 + 45pm2;
spp2p2 <= 45lp2 + 45mp2 + 45pp2;

spl2 = spl2p1 + spl2p2;
spm2 = spm2p1 + spm2p2;
spp2 = spp2p1 + spp2p2;

/* Março */
spl3p1 <= 45ll3 + 45lm3 + 45lp3;
spm3p1 <= 45ml3 + 45mm3 + 45mp3;
spp3p1 <= 45pl3 + 45pm3 + 45pp3;

spl3p2 <= 45ll3 + 45ml3 + 45pl3;
spm3p2 <= 45lm3 + 45mm3 + 45pm3;
spp3p2 <= 45lp3 + 45mp3 + 45pp3;

spl3 = spl3p1 + spl3p2;
spm3 = spm3p1 + spm3p2;
spp3 = spp3p1 + spp3p2;

/* Abril */
spl4p1 <= 45ll4 + 45lm4 + 45lp4;
spm4p1 <= 45ml4 + 45mm4 + 45mp4;
spp4p1 <= 45pl4 + 45pm4 + 45pp4;

spl4p2 <= 45ll4 + 45ml4 + 45pl4;
spm4p2 <= 45lm4 + 45mm4 + 45pm4;
spp4p2 <= 45lp4 + 45mp4 + 45pp4;

spl4 = spl1p4 + spl4p2;
spm4 = spm1p4 + spm4p2;
spp4 = spp1p4 + spp4p2;
```

```
/* Maio */
spl5p1 <= 45ll5 + 45lm5 + 45lp5;
spm5p1 <= 45ml5 + 45mm5 + 45mp5;
spp5p1 <= 45pl5 + 45pm5 + 45pp5;

spl5p2 <= 45ll5 + 45ml5 + 45pl5;
spm5p2 <= 45lm5 + 45mm5 + 45pm5;
spp5p2 <= 45lp5 + 45mp5 + 45pp5;

spl5 = spl5p1 + spl5p2;
spm5 = spm5p1 + spm5p2;
spp5 = spp5p1 + spp5p2;

/* Junho */
spl6p1 <= 45ll6 + 45lm6 + 45lp6;
spm6p1 <= 45ml6 + 45mm6 + 45mp6;
spp6p1 <= 45pl6 + 45pm6 + 45pp6;

spl6p2 <= 45ll6 + 45ml2 + 45pl6;
spm6p2 <= 45lm6 + 45mm2 + 45pm6;
spp6p2 <= 45lp6 + 45mp2 + 45pp6;

spl6 = spl6p1 + spl1p2;
spm6 = spm6p1 + spm1p2;
spp6 = spp6p1 + spp1p2;

/* Julho */
spl7p1 <= 45ll7 + 45lm7 + 45lp7;
spm7p1 <= 45ml7 + 45mm7 + 45mp7;
spp7p1 <= 45pl7 + 45pm7 + 45pp7;

spl7p2 <= 45ll7 + 45ml7 + 45pl7;
spm7p2 <= 45lm7 + 45mm7 + 45pm7;
spp7p2 <= 45lp7 + 45mp7 + 45pp7;

spl7 = spl7p1 + spl7p2;
spm7 = spm7p1 + spm7p2;
spp7 = spp7p1 + spp7p2;

/* Agosto */
spl8p1 <= 45ll8 + 45lm8 + 45lp8;
spm8p1 <= 45ml8 + 45mm8 + 45mp8;
spp8p1 <= 45pl8 + 45pm8 + 45pp8;

spl8p2 <= 45ll8 + 45ml8 + 45pl8;
spm8p2 <= 45lm8 + 45mm8 + 45pm8;
spp8p2 <= 45lp8 + 45mp8 + 45pp8;

spl8 = spl8p1 + spl8p2;
spm8 = spm8p1 + spm8p2;
spp8 = spp8p1 + spp8p2;

/* Setembro */
spl9p1 <= 45ll9 + 45lm9 + 45lp9;
spm9p1 <= 45ml9 + 45mm9 + 45mp9;
spp9p1 <= 45pl9 + 45pm9 + 45pp9;

spl9p2 <= 45ll9 + 45ml9 + 45pl9;
spm9p2 <= 45lm9 + 45mm9 + 45pm9;
spp9p2 <= 45lp9 + 45mp9 + 45pp9;
```

```
spl9 = spl9p1 + spl9p2;
spm9 = spm9p1 + spm9p2;
spp9 = spp9p1 + spp9p2;

/* Outubro */
spl10p1 <= 45ll10 + 45lm10 + 45lp10;
spm10p1 <= 45ml10 + 45mm10 + 45mp10;
spp10p1 <= 45pl10 + 45pm10 + 45pp10;

spl10p2 <= 45ll10 + 45ml10 + 45pl10;
spm10p2 <= 45lm10 + 45mm10 + 45pm10;
spp10p2 <= 45lp10 + 45mp10 + 45pp10;

spl10 = spl10p1 + spl10p2;
spm10 = spm10p1 + spm10p2;
spp10 = spp10p1 + spp10p2;

/* Novembro */
spl11p1 <= 45ll11 + 45lm11 + 45lp11;
spm11p1 <= 45ml11 + 45mm11 + 45mp11;
spp11p1 <= 45pl11 + 45pm11 + 45pp11;

spl11p2 <= 45ll11 + 45ml11 + 45pl11;
spm11p2 <= 45lm11 + 45mm11 + 45pm11;
spp11p2 <= 45lp11 + 45mp11 + 45pp11;

spl11 = spl11p1 + spl11p2;
spm11 = spm11p1 + spm11p2;
spp11 = spp11p1 + spp11p2;

/* Dezembro */
spl12p1 <= 45ll12 + 45lm12 + 45lp12;
spm12p1 <= 45ml12 + 45mm12 + 45mp12;
spp12p1 <= 45pl12 + 45pm12 + 45pp12;

spl12p2 <= 45ll12 + 45ml12 + 45pl12;
spm12p2 <= 45lm12 + 45mm12 + 45pm12;
spp12p2 <= 45lp12 + 45mp12 + 45pp12;

spl12 = spl12p1 + spl12p2;
spm12 = spm12p1 + spm12p2;
spp12 = spp12p1 + spp12p2;

/* Atribuição das variáveis de concentrado comprado */
/* Laranja */
cl1 = spl1 + acl2 - acl1;
cl2 = spl2 + acl3 - acl2;
cl3 = spl3 + acl4 - acl3;
cl4 = spl4 + acl5 - acl4;
cl5 = spl5 + acl6 - acl5;
cl6 = spl6 + acl7 - acl6;
cl7 = spl7 + acl8 - acl7;
cl8 = spl8 + acl9 - acl8;
cl9 = spl9 + acl10 - acl9;
cl10 = spl10 + acl11 - acl10;
cl11 = spl11 + acl12 - acl11;
cl12 = spl12 + acl13 - acl12;
```

```
/* Maçã */
cm1 = spm1 + acm2 - acm1;
cm2 = spm2 + acm3 - acm2;
cm3 = spm3 + acm4 - acm3;
cm4 = spm4 + acm5 - acm4;
cm5 = spm5 + acm6 - acm5;
cm6 = spm6 + acm7 - acm6;
cm7 = spm7 + acm8 - acm7;
cm8 = spm8 + acm9 - acm8;
cm9 = spm9 + acm10 - acm9;
cm10 = spm10 + acm11 - acm10;
cm11 = spm11 + acm12 - acm11;
cm12 = spm12 + acm13 - acm12;

/* Pêra */
cp1 = spp1 + acp2 - acp1;
cp2 = spp2 + acp3 - acp2;
cp3 = spp3 + acp4 - acp3;
cp4 = spp4 + acp5 - acp4;
cp5 = spp5 + acp6 - acp5;
cp6 = spp6 + acp7 - acp6;
cp7 = spp7 + acp8 - acp7;
cp8 = spp8 + acp9 - acp8;
cp9 = spp9 + acp10 - acp9;
cp10 = spp10 + acp11 - acp10;
cp11 = spp11 + acp12 - acp11;
cp12 = spp12 + acp13 - acp12;

/* Sumo vendido em cada mês - Serve para confirmar */
/* Laranja */
svl1 = asl1 + spl1 - asl2;
svl2 = asl2 + spl2 - asl3;
svl3 = asl3 + spl3 - asl4;
svl4 = asl4 + spl4 - asl5;
svl5 = asl5 + spl5 - asl6;
svl6 = asl6 + spl6 - asl7;
svl7 = asl7 + spl7 - asl8;
svl8 = asl8 + spl8 - asl9;
svl9 = asl9 + spl9 - asl10;
svl10 = asl10 + spl10 - asl11;
svl11 = asl11 + spl11 - asl12;
svl12 = asl12 + spl12 - asl13;

/* Maçã */
svm1 = asm1 + spm1 - asm2;
svm2 = asm2 + spm2 - asm3;
svm3 = asm3 + spm3 - asm4;
svm4 = asm4 + spm4 - asm5;
svm5 = asm5 + spm5 - asm6;
svm6 = asm6 + spm6 - asm7;
svm7 = asm7 + spm7 - asm8;
svm8 = asm8 + spm8 - asm9;
svm9 = asm9 + spm9 - asm10;
svm10 = asm10 + spm10 - asm11;
svm11 = asm11 + spm11 - asm12;
svm12 = asm12 + spm12 - asm13;

/* Pêra */
svp1 = asp1 + spp1 - asp2;
svp2 = asp2 + spp2 - asp3;
svp3 = asp3 + spp3 - asp4;
```

```
svp4 = asp4 + spp4 - asp5;
svp5 = asp5 + spp5 - asp6;
svp6 = asp6 + spp6 - asp7;
svp7 = asp7 + spp7 - asp8;
svp8 = asp8 + spp8 - asp9;
svp9 = asp9 + spp9 - asp10;
svp10 = asp10 + spp10 - asp11;
svp11 = asp11 + spp11 - asp12;
svp12 = asp12 + spp12 - asp13;

/* Atribuição das variáveis de mudança
de sumo produzido */
ms1 = lm1 + lp1 + ml1 + mp1 + pl1 + pm1;
ms2 = lm2 + lp2 + ml2 + mm2 + mp2 + pl2;
ms3 = lm3 + lp3 + ml3 + mp3 + pl3 + pm3;
ms4 = lm4 + lp4 + ml4 + mp4 + pl4 + pm4;
ms5 = lm5 + lp5 + ml5 + mp5 + pl5 + pm5;
ms6 = lm6 + lp6 + ml6 + mp6 + pl6 + pm6;
ms7 = lm7 + lp7 + ml7 + mp7 + pl7 + pm7;
ms8 = lm8 + lp8 + ml8 + mp8 + pl8 + pm8;
ms9 = lm9 + lp9 + ml9 + mp9 + pl9 + pm9;
ms10 = lm10 + lp10 + ml10 + mp10 + pl10 + pm10;
ms11 = lm11 + lp11 + ml11 + mp11 + pl11 + pm11;
ms12 = lm12 + lp12 + ml12 + mp12 + pl12 + pm12;

/* Restrições das variáveis binárias  */
ll1 + lm1 + lp1 + ml1 + mm1 + mp1 + pl1 + pm1 + pp1 = 1;
ll2 + lm2 + lp2 + ml2 + mm2 + mp2 + pl2 + pm2 + pp2 = 1;
ll3 + lm3 + lp3 + ml3 + mm3 + mp3 + pl3 + pm3 + pp3 = 1;
ll4 + lm4 + lp4 + ml4 + mm4 + mp4 + pl4 + pm4 + pp4 = 1;
ll5 + lm5 + lp5 + ml5 + mm5 + mp5 + pl5 + pm5 + pp5 = 1;
ll6 + lm6 + lp6 + ml6 + mm6 + mp6 + pl6 + pm6 + pp6 = 1;
ll7 + lm7 + lp7 + ml7 + mm7 + mp7 + pl7 + pm7 + pp7 = 1;
ll8 + lm8 + lp8 + ml8 + mm8 + mp8 + pl8 + pm8 + pp8 = 1;
ll9 + lm9 + lp9 + ml9 + mm9 + mp9 + pl9 + pm9 + pp9 = 1;
ll10 + lm10 + lp10 + ml10 + mm10 + mp10 + pl10 + pm10 + pp10 = 1;
ll11 + lm11 + lp11 + ml11 + mm11 + mp11 + pl11 + pm11 + pp11 = 1;
ll12 + lm12 + lp12 + ml12 + mm12 + mp12 + pl12 + pm12 + pp12 = 1;

ll2 + lm2 + lp2 = ll1 + ml1 + pl1 + mm1 + pp1;
ml2 + mm2 + mp2 = lm1 + mm1 + pm1 + ll1 + pp1;
pl2 + pm2 + pp2 = lp1 + mp1 + pp1 + ll1 + mm1;

ll3 + lm3 + lp3 = ll2 + ml2 + pl2 + mm2 + pp2;
ml3 + mm3 + mp3 = lm2 + mm2 + pm2 + ll2 + pp2;
pl3 + pm3 + pp3 = lp2 + mp2 + pp2 + ll2 + mm2;

ll4 + lm4 + lp4 = ll3 + ml3 + pl3 + mm3 + pp3;
ml4 + mm4 + mp4 = lm3 + mm3 + pm3 + ll3 + pp3;
pl4 + pm4 + pp4 = lp3 + mp3 + pp3 + ll3 + mm3;

ll5 + lm5 + lp5 = ll4 + ml4 + pl4 + mm4 + pp4;
ml5 + mm5 + mp5 = lm4 + mm4 + pm4 + ll4 + pp4;
pl5 + pm5 + pp5 = lp4 + mp4 + pp4 + ll4 + mm4;

ll6 + lm6 + lp6 = ll5 + ml5 + pl5 + mm5 + pp5;
ml6 + mm6 + mp6 = lm5 + mm5 + pm5 + ll5 + pp5;
pl6 + pm6 + pp6 = lp5 + mp5 + pp5 + ll5 + mm5;
```

```
ll7 + lm7 + lp7 = ll6 + ml6 + pl6 + mm6 + pp6;
ml7 + mm7 + mp7 = lm6 + mm6 + pm6 + ll6 + pp6;
pl7 + pm7 + pp7 = lp6 + mp6 + pp6 + ll6 + mm6;

ll8 + lm8 + lp8 = ll7 + ml7 + pl7 + mm7 + pp7;
ml8 + mm8 + mp8 = lm7 + mm7 + pm7 + ll7 + pp7;
pl8 + pm8 + pp8 = lp7 + mp7 + pp7 + ll7 + mm7;

ll9 + lm9 + lp9 = ll8 + ml8 + pl8 + mm8 + pp8;
ml9 + mm9 + mp9 = lm8 + mm8 + pm8 + ll8 + pp8;
pl9 + pm9 + pp9 = lp8 + mp8 + pp8 + ll8 + mm8;

ll10 + lm10 + lp10 = ll9 + ml9 + pl9 + mm9 + pp9;
ml10 + mm10 + mp10 = lm9 + mm9 + pm9 + ll9 + pp9;
pl10 + pm10 + pp10 = lp9 + mp9 + pp9 + ll9 + mm9;

ll11 + lm11 + lp11 = ll10 + ml10 + pl10 + mm10 + pp10;
ml11 + mm11 + mp11 = lm10 + mm10 + pm10 + ll10 + pp10;
pl11 + pm11 + pp11 = lp10 + mp10 + pp10 + ll10 + mm10;

ll12 + lm12 + lp12 = ll11 + ml11 + pl11 + mm11 + pp11;
ml12 + mm12 + mp12 = lm11 + mm11 + pm11 + ll11 + pp11;
pl12 + pm12 + pp12 = lp11 + mp11 + pp11 + ll11 + mm11;

/* Variáveis binárias que decidem que sumo
se produz em cada parte do mês */
Bin ll1,lm1,lp1,ml1,mm1,mp1,pl1,pm1,pp1,
    ll2,lm2,lp2,ml2,mm2,mp2,pl2,pm2,pp2,
    ll3,lm3,lp3,ml3,mm3,mp3,pl3,pm3,pp3,
    ll4,lm4,lp4,ml4,mm4,mp4,pl4,pm4,pp4,
    ll5,lm5,lp5,ml5,mm5,mp5,pl5,pm5,pp5,
    ll6,lm6,lp6,ml6,mm6,mp6,pl6,pm6,pp6,
    ll7,lm7,lp7,ml7,mm7,mp7,pl7,pm7,pp7,
    ll8,lm8,lp8,ml8,mm8,mp8,pl8,pm8,pp8,
    ll9,lm9,lp9,ml9,mm9,mp9,pl9,pm9,pp9,
    ll10,lm10,lp10,ml10,mm10,mp10,pl10,pm10,pp10,
    ll11,lm11,lp11,ml11,mm11,mp11,pl11,pm11,pp11,
    ll12,lm12,lp12,ml12,mm12,mp12,pl12,pm12,pp12;
```

5.3 – Ficheiro de Output

Variables	MILP Better 54219	MILP Better 54218	MILP Better 54211	MILP Better 54204	MILP Better 53996	MILP Better 53988	MILP Better 53964	MILP Better 53922	result 53922
cl1	0	0	0	0	0	0	0	0	0
cm1	0	0	0	0	0	0	0	0	0
cp1	5	2,000000000000001	0	0	0	0	2	0	0
spl1	0	0	1	0	1	7	10	7	7
spm1	0	0	0	0	0	0	0	0	0
spp1	11	8,000000000000001	6	1,000000000000001	6	6	8	0	0
acl2	16	16	15	16	15	9	6	9	9
acm2	8	8	8	8	8	8	8	8	8
acp2	0	0	0	4,999999999999999	0	0	0	6	6
asl2	11	11	12	11	12	18	21	18	18
asm2	5	5	5	5	5	5	5	5	5
asp2	17	14	12	7,000000000000001	12	12	14	6	6
ms1	1	1	1	1	1	1	1	1	1
cl2	0	0	0	0	0	0	0	0	0
cm2	0	0	0	0	0	0	0	0	0
cp2	0	0	0	0	0	0	0	0	0
spl2	0	0	0	0	0	0	0	0	0
spm2	4	7	8	8	8	1,999999999999999	0	2	2
spp2	0	0	0	4,999999999999999	0	0	0	6	6
acl3	16	16	15	16	15	9	6	9	9
acm3	4	1	0	0	0	6,000000000000001	8	6	6
acp3	0	0	0	0	0	0	0	0	0
asl3	2	2	3	2	3	9	12	9	9
asm3	4	7	8	8	8	1,999999999999999	0	2	2
asp3	13	10	8	8	8	8	10	8	8
ms2	0	0	0	0	0	0	0	0	0
cl3	3	3	3	2,999999999999999	3	3	3	3	3
cm3	46	49	51	50	51	51	49	51	51
cp3	0	0	0	0	0	0	0	0	0
spl3	19	19	14	19	14	0	0	0	0
spm3	20	20	25	20	25	39	36	39	39
spp3	0	0	0	0	0	0	0	0	0
acl4	0	0	3,999999999999999	0	3,999999999999999	12	9	12	12
acm4	30	30	26	30	26	18	21	18	18
acp4	0	0	0	0	0	0	0	0	0
asl4	12	12	8,000000000000001	12	8,000000000000001	0	3	0	0
asm4	19	22	28	23	28	36	31	36	36
asp4	9,000000000000001	6,000000000000001	4	4	4	4	6	4	4
ms3	1	1	1	1	1	1	1	1	1
cl4	0	0	0	0	0	0	0	0	0
cm4	0	0	3,999999999999999	0	3,999999999999999	12	9	8,000000000000001	8,000000000000001
cp4	20	20	16	21	16	8	11	12	12

spl4	0	0	3,99999999999999	0	3,99999999999999	12	9	12	12
spm4	0	0	0	0	0	0	0	0	0
spp4	20	20	16	21	16	8	11	8	8
acl5	0	0	0	0	0	0	0	0	0
acm5	30	30	30	30	30	30	30	26	26
acp5	0	0	0	0	0	0	0	3,99999999999999	3,99999999999999
asl5	0	0	0	0	0	0	0	0	0
asm5	13	16	22	17	22	30	25	30	30
asp5	24	21	15	20	15	7	12	7	7
ms4	1	1	1	1	1	1	1	1	1
cl5	33	33	33	33	33	33	33	33	33
cm5	0	0	0	0	0	0	0	0	0
cp5	0	0	0	0	0	0	0	0	0
spl5	20	16	25	25	19	33	33	33	33
spm5	13	17	8,000000000000002	7,99999999999999	14	0	0	0	0
spp5	0	0	0	0	0	0	0	0	0
acl6	13	17	8,000000000000002	7,99999999999999	14	0	0	0	0
acm6	17	13	22	22	16	30	30	26	26
acp6	0	0	0	0	0	0	0	3,99999999999999	3,99999999999999
asl6	3,99999999999999	0	8,99999999999998	9,000000000000001	2,99999999999999	17	17	17	17
asm6	18	25	22	17	28	22	17	22	22
asp6	18	15	9	14	9	1	6	0,99999999999998	0,99999999999998
ms5	1	1	1	1	1	1	1	1	1
cl6	0	0	0	0	0	0	0	0	0
cm6	13	2,000000000000001	8,000000000000002	0	4,000000000000001	0	0,99999999999998	0	0
cp6	11	8	6	1,000000000000001	6	14	9	10	10
spl6	13	17	8,000000000000003	7,99999999999999	14	0	0	0	0
spm6	0	0	0	0	0	8,000000000000001	2	0	0
spp6	11	8	6	1,000000000000001	6	6	8	13	13
acl7	0	0	0	0	0	0	0	0	0
acm7	30	15	30	22	20	22	29	26	26
acp7	0	0	0	0	0	8	0,99999999999999	1	1
asl7	0	0	0	0	0	0	0	0	0
asm7	9,000000000000001	16	13	7,99999999999999	19	21	10	13	13
asp7	22	16	8	8	8	0	7	7	7
ms6	1	1	1	1	1	1	1	1	1
cl7	38	54	38	38	38	38	38	38	38
cm7	0	0	0	0	0	0	0	0	0
cp7	0	0	0	0	0	0	0	0	0
spl7	28	35	24	19	19	31	38	38	38
spm7	11	4,000000000000001	15	20	20	0	0	0	0
spp7	0	0	0	0	0	8	0,99999999999999	0,99999999999999	0,99999999999999

acl8	9,999999999999999	19	14	19	19	6,999999999999999	0	0	0
acm8	19	11	15	2,000000000000001	0	22	29	26	26
acp8	0	0	0	0	0	0	0	0	0
asl8	9,000000000000001	16	5,000000000000001	0	0	12	19	19	19
asm8	10	10	18	18	29	11	0	2,999999999999999	2,999999999999999
asp8	14	8	0	0	0	0	0	0	0
ms7	1	1	1	1	1	1	1	1	1
cl8	0	0	0	0	0	0	0	0	0
cm8	0	0	0	0	0	0	0	0	0
cp8	0	6	23	19	14	14	14	14	14
spl8	9,999999999999999	19	14	19	19	6,999999999999999	0	0	0
spm8	0	0	0	0	0	0	10	7	7
spp8	0	0	8	19	8	14	14	14	14
acl9	0	0	0	0	0	0	0	0	0
acm9	19	11	15	2,000000000000001	0	22	19	19	19
acp9	0	6	15	0	6	0	0	0	0
asl9	0	16	0	0	0	0	0	0	0
asm9	0	0	8	8	19	0,999999999999999	0	0	0
asp9	6	0	0	11	0	6	6	6	6
ms8	1	1	1	1	1	1	1	1	1
cl9	38	22	28	67	38	32	38	38	38
cm9	0	8,000000000000001	0	0	0	0	0	0	0
cp9	0	0	0	0	0	0	0	0	0
spl9	16	0	16	39	16	32	16	16	16
spm9	19	19	0	0	0	7	19	19	19
spp9	0	6	15	0	6	0	0	0	0
acl10	22	22	12	28	22	0	22	22	22
acm10	0	0	15	2,000000000000001	0	15	0	0	0
acp10	0	0	0	0	0	0	0	0	0
asl10	0	0	0	23	0	16	0	0	0
asm10	11	11	0	0	11	0	11	11	11
asp10	0	0	9	5	0	0	0	0	0
ms9	1	1	1	0,999999999999999	1	1	1	1	1
cl10	0	0	0	0	0	0	0	0	0
cm10	0	0	11	8,999999999999999	0	0	0	0	0
cp10	5	5	0	0	5	11	5	5	5
spl10	22	22	12	28	22	0	22	22	22
spm10	0	0	22	6	0	15	0	0	0
spp10	5	5	0	0	5	11	5	5	5
acl11	0	0	0	0	0	0	0	0	0
acm11	0	0	3,999999999999999	5	0	0	0	0	0
acp11	0	0	0	0	0	0	0	0	0
asl11	10	10	0	39	10	4,000000000000001	10	10	10
asm11	5,000000000000001	5,000000000000001	16	0	5	8,999999999999999	5,000000000000001	5	5
asp11	0	0	4	0	0	6	0	0	0
ms10	1	1	1	1	1	1	1	1	1
cl11	45	45	55	16	45	51	45	45	45
cm11	0	0	0	0	0	0	0	0	0

cp11	24	24	10	24	24	18	24	24	24
spl11	21	29	35	0	21	27	21	21	21
spm11	0	0	3,99999999999999	5	0	0	0	0	0
spp11	18	10	0	10	18	12	18	18	18
acl12	24	16	20	16	24	24	24	24	24
acm12	0	0	0	0	0	0	0	0	0
acp12	6	14	10	14	6	6	6	6	6
asl12	21	29	25	29	21	21	21	21	21
asm12	0	0	15	0	0	3,99999999999999	0	0	0
asp12	14	6	0	6	14	14	14	14	14
ms11	1	1	1	1	1	1	1	1	1
cl12	0	0	0	0	0	0	0	0	0
cm12	23	23	8,000000000000001	23	23	19	23	23	23
cp12	0	0	9,99999999999999	0	0	0	0	0	0
spl12	8	0	3,99999999999999	0	8	8	8	8	8
spm12	15	15	0	15	15	11	15	15	15
spp12	0	8	14	8	0	0	0	0	0
acl13	16	16	16	16	16	16	16	16	16
acm13	8	8	8	8	8	8	8	8	8
acp13	6	6	6	6	6	6	6	6	6
asl13	20	20	20	20	20	20	20	20	20
asm13	10	10	10	10	10	10	10	10	10
asp13	10	10	10	10	10	10	10	10	10
ms12	1	1	1	1	1	1	1	1	1
acl1	16	16	16	16	16	16	16	16	16
acm1	8	8	8	8	8	8	8	8	8
acp1	6	6	6	6	6	6	6	6	6
asl1	20	20	20	20	20	20	20	20	20
asm1	10	10	10	10	10	10	10	10	10
asp1	10	10	10	10	10	10	10	10	10
spl1p1	0	0	1	0	1	7	10	7	7
ll1	0	0	0	0	0	0	0	0	0
lm1	0	0	0	0	0	0	0	0	0
lp1	1	1	1	1	1	1	1	1	1
spm1p1	0	0	0	0	0	0	0	0	0
ml1	0	0	0	0	0	0	0	0	0
mm1	0	0	0	0	0	0	0	0	0
mp1	0	0	0	0	0	0	0	0	0
spp1p1	0	0	0	0	0	0	0	0	0
pl1	0	0	0	0	0	0	0	0	0
pm1	0	0	0	0	0	0	0	0	0
pp1	0	0	0	0	0	0	0	0	0
spl1p2	0	0	0	0	0	0	0	0	0
spm1p2	0	0	0	0	0	0	0	0	0
spp1p2	11	8,000000000000001	6	1,000000000000001	6	6	8	0	0
spl2p1	0	0	0	0	0	0	0	0	0
ll2	0	0	0	0	0	0	0	0	0
lm2	0	0	0	0	0	0	0	0	0
lp2	0	0	0	0	0	0	0	0	0
spm2p1	0	0	0	0	0	0	0	0	0
ml2	0	0	0	0	0	0	0	0	0
mm2	0	0	0	0	0	0	0	0	0
mp2	0	0	0	0	0	0	0	0	0
spp2p1	0	0	0	4,99999999999999	0	0	0	6	6
pl2	0	0	0	0	0	0	0	0	0
pm2	1	1	1	1	1	1	1	1	1
pp2	0	0	0	0	0	0	0	0	0
spl2p2	0	0	0	0	0	0	0	0	0
spm2p2	4	7	8	8	8	1,99999999999999	0	2	2
spp2p2	0	0	0	0	0	0	0	0	0

spl3p1	0	0	0	0	0	0	0	0	0
ll3	0	0	0	0	0	0	0	0	0
lm3	0	0	0	0	0	0	0	0	0
lp3	0	0	0	0	0	0	0	0	0
spm3p1	20	20	25	20	25	39	36	39	39
ml3	1	1	1	1	1	0	0	0	0
mm3	0	0	0	0	0	0	0	0	0
mp3	0	0	0	0	0	1	1	1	1
spp3p1	0	0	0	0	0	0	0	0	0
pl3	0	0	0	0	0	0	0	0	0
pm3	0	0	0	0	0	0	0	0	0
pp3	0	0	0	0	0	0	0	0	0
spl3p2	19	19	14	19	14	0	0	0	0
spm3p2	0	0	0	0	0	0	0	0	0
spp3p2	0	0	0	0	0	0	0	0	0
spl4p1	0	0	0	0	0	0	0	0	0
ll4	0	0	0	0	0	0	0	0	0
lm4	1	1	1	1	1	0	0	0	0
lp4	0	0	0	0	0	0	0	0	0
spm4p1	0	0	0	0	0	0	0	0	0
ml4	0	0	0	0	0	0	0	0	0
mm4	0	0	0	0	0	0	0	0	0
mp4	0	0	0	0	0	0	0	0	0
spp4p1	0	0	0	0	0	0	0	0	0
pl4	0	0	0	0	0	1	1	1	1
pm4	0	0	0	0	0	0	0	0	0
pp4	0	0	0	0	0	0	0	0	0
spl4p2	0	0	0	0	0	12	9	12	12
spm4p2	0	0	0	0	0	0	0	0	0
spp4p2	0	0	0	0	0	0	0	0	0
spl1p4	0	0	3,99999999999999	0	3,99999999999999	0	0	0	0
spm1p4	0	0	0	0	0	0	0	0	0
spp1p4	20	20	16	21	16	8	11	8	8
spl5p1	0	0	0	0	0	33	33	33	33
ll5	0	0	0	0	0	0	0	0	0
lm5	0	0	0	0	0	1	1	0	0
lp5	0	0	0	0	0	0	0	1	1
spm5p1	13	17	8,000000000000002	7,99999999999999	14	0	0	0	0
ml5	1	1	1	1	1	0	0	0	0
mm5	0	0	0	0	0	0	0	0	0
mp5	0	0	0	0	0	0	0	0	0
spp5p1	0	0	0	0	0	0	0	0	0
pl5	0	0	0	0	0	0	0	0	0
pm5	0	0	0	0	0	0	0	0	0
pp5	0	0	0	0	0	0	0	0	0
spl5p2	20	16	25	25	19	0	0	0	0
spm5p2	0	0	0	0	0	0	0	0	0
spp5p2	0	0	0	0	0	0	0	0	0
spl6p1	13	17	8,000000000000002	7,99999999999999	14	0	0	0	0
ll6	0	0	0	0	0	0	0	0	0
lm6	1	1	1	1	1	0	0	0	0
lp6	0	0	0	0	0	0	0	0	0
spm6p1	0	0	0	0	0	8,000000000000001	2	0	0
ml6	0	0	0	0	0	1	1	0	0
mm6	0	0	0	0	0	0	0	0	0
mp6	0	0	0	0	0	0	0	0	0
spp6p1	0	0	0	0	0	0	0	13	13
pl6	0	0	0	0	0	0	0	1	1
pm6	0	0	0	0	0	0	0	0	0
pp6	0	0	0	0	0	0	0	0	0
spl6p2	0	0	0	0	0	0	0	0	0
spm6p2	0	0	0	0	0	0	0	0	0
spp6p2	0	0	0	0	0	0	0	0	0
spl7p1	0	0	0	0	0	31	38	38	38
ll7	0	0	0	0	0	0	0	0	0
lm7	0	0	0	0	0	0	0	0	0
lp7	0	0	0	0	0	1	1	1	1

spm7p1	11	4,000000000000001	15	20	20	0	0	0	0
ml7	1	1	1	1	1	0	0	0	0
mm7	0	0	0	0	0	0	0	0	0
mp7	0	0	0	0	0	0	0	0	0
spp7p1	0	0	0	0	0	0	0	0	0
pl7	0	0	0	0	0	0	0	0	0
pm7	0	0	0	0	0	0	0	0	0
pp7	0	0	0	0	0	0	0	0	0
spl7p2	28	35	24	19	19	0	0	0	0
spm7p2	0	0	0	0	0	0	0	0	0
spp7p2	0	0	0	0	0	8	0,999999999999999	0,999999999999999	0,999999999999999
spl8p1	9,999999999999999	19	14	19	19	0	0	0	0
ll8	0	0	0	0	0	0	0	0	0
lm8	1	1	0	0	0	0	0	0	0
lp8	0	0	1	1	1	0	0	0	0
spm8p1	0	0	0	0	0	0	0	0	0
ml8	0	0	0	0	0	0	0	0	0
mm8	0	0	0	0	0	0	0	0	0
mp8	0	0	0	0	0	0	0	0	0
spp8p1	0	0	0	0	0	14	14	14	14
pl8	0	0	0	0	0	1	0	0	0
pm8	0	0	0	0	0	0	1	1	1
pp8	0	0	0	0	0	0	0	0	0
spl8p2	0	0	0	0	0	6,999999999999999	0	0	0
spm8p2	0	0	0	0	0	0	9,999999999999999	7	7
spp8p2	0	0	8	19	8	0	0	0	0
spl9p1	0	0	0	0	0	32	0	0	0
ll9	0	0	0	0	0	0	0	0	0
lm9	0	0	0	0	0	1	0	0	0
lp9	0	0	0	0	0	0	0	0	0
spm9p1	19	19	0	0	0	0	19	19	19
ml9	1	0	0	0	0	0	1	1	1
mm9	0	0	0	0	0	0	0	0	0
mp9	0	1	0	0	0	0	0	0	0
spp9p1	0	0	15	0	6	0	0	0	0
pl9	0	0	1	1	1	0	0	0	0
pm9	0	0	0	0	0	0	0	0	0
pp9	0	0	0	0	0	0	0	0	0
spl9p2	16	0	16	39	16	0	16	16	16
spm9p2	0	0	0	0	0	7	0	0	0
spp9p2	0	6	0	0	0	0	0	0	0
spl10p1	22	0	12	28	22	0	22	22	22
ll10	0	0	0	0	0	0	0	0	0
lm10	0	0	1	1	0	0	0	0	0
lp10	1	0	0	0	1	0	1	1	1
spm10p1	0	0	0	0	0	15	0	0	0
ml10	0	0	0	0	0	0	0	0	0
mm10	0	0	0	0	0	0	0	0	0
mp10	0	0	0	0	0	1	0	0	0
spp10p1	0	5	0	0	0	0	0	0	0
pl10	0	1	0	0	0	0	0	0	0
pm10	0	0	0	0	0	0	0	0	0
pp10	0	0	0	0	0	0	0	0	0
spl10p2	0	22	0	0	0	0	0	0	0
spm10p2	0	0	22	6	0	0	0	0	0
spp10p2	5	0	0	0	5	11	5	5	5
spl11p1	0	29	0	0	0	0	0	0	0
ll11	0	0	0	0	0	0	0	0	0
lm11	0	0	0	0	0	0	0	0	0
lp11	0	1	0	0	0	0	0	0	0
spm11p1	0	0	3,999999999999999	5	0	0	0	0	0
ml11	0	0	1	0	0	0	0	0	0
mm11	0	0	0	0	0	0	0	0	0
mp11	0	0	0	1	0	0	0	0	0

spp11p1	18	0	0	0	18	12	18	18	18
pl11	1	0	0	0	1	1	1	1	1
pm11	0	0	0	0	0	0	0	0	0
pp11	0	0	0	0	0	0	0	0	0
spl11p2	21	0	35	0	21	27	21	21	21
spm11p2	0	0	0	0	0	0	0	0	0
spp11p2	0	10	0	10	0	0	0	0	0
spl12p1	8	0	3,99999999999999	0	8	8	8	8	8
ll12	0	0	0	0	0	0	0	0	0
lm12	1	0	0	0	1	1	1	1	1
lp12	0	0	1	0	0	0	0	0	0
spm12p1	0	0	0	0	0	0	0	0	0
ml12	0	0	0	0	0	0	0	0	0
mm12	0	0	0	0	0	0	0	0	0
mp12	0	0	0	0	0	0	0	0	0
spp12p1	0	8	0	8	0	0	0	0	0
pl12	0	0	0	0	0	0	0	0	0
pm12	0	1	0	1	0	0	0	0	0
pp12	0	0	0	0	0	0	0	0	0
spl12p2	0	0	0	0	0	0	0	0	0
spm12p2	15	15	0	15	15	11	15	15	15
spp12p2	0	0	14	0	0	0	0	0	0
svl1	9	9	9	8,999999999999999	9	9	9	9	9
svl2	9	9	9	9	9	9	9	9	9
svl3	9	9	9	9	9	9	9	9	9
svl4	12	12	12	12	12	12	12	12	12
svl5	16	16	16	16	16	16	16	16	16
svl6	17	17	17	17	17	17	17	17	17
svl7	19	19	19	19	19	19	19	19	19
svl8	19	19	19	19	19	19	19	19	19
svl9	16	16	16	16	16	16	16	16	16
svl10	12	12	12	12	12	12	12	12	12
svl11	10	10	10	10	10	10	10	10	10
svl12	9	9	9	9	9	9,000000000000001	9	9	9
svm1	5	5	5	5	5	5	5	5	5
svm2	5	5	5	5	5	5	5	5	5
svm3	5	5	5	5	5	5	5	5	5
svm4	6	6	6	6	6	6	6	6	6
svm5	8	8	8	8	8	8	8	8	8
svm6	9	9	9	9	9	9	9	9	9
svm7	10	10	10	10	10	10	10	10	10
svm8	10	10	10	10	10	10	10	10	10
svm9	8	8	8	8	8	8	8	8	8
svm10	6	6	6	6	6	6	6	6	6
svm11	5	5,000000000000001	5	5	5	5	5	5	5
svm12	5	5	5	5	5	5	5	5	5
svp1	4	4	4	4	4	4	4	4	4
svp2	4	4	4	4	4	4	4	4	4
svp3	4	4	4	4	4	4	4	4	4
svp4	5	5	5	5	5	5	5	5	5
svp5	6	6	6	6	6	6	6	6	6
svp6	7	7	7	7	7	7	7	7	7
svp7	8	8	8	8	8	8	8	8	8
svp8	8	8	8	8	8	8	8	8	8
svp9	6	6	6	6	6	6	6	6	6
svp10	5	5	5	5	5	5	5	5	5
svp11	4	4	4	4	4	4	4	4	4
svp12	4	4	4	4	4	4	4	4	4

5.4 – Plano detalhado de produção

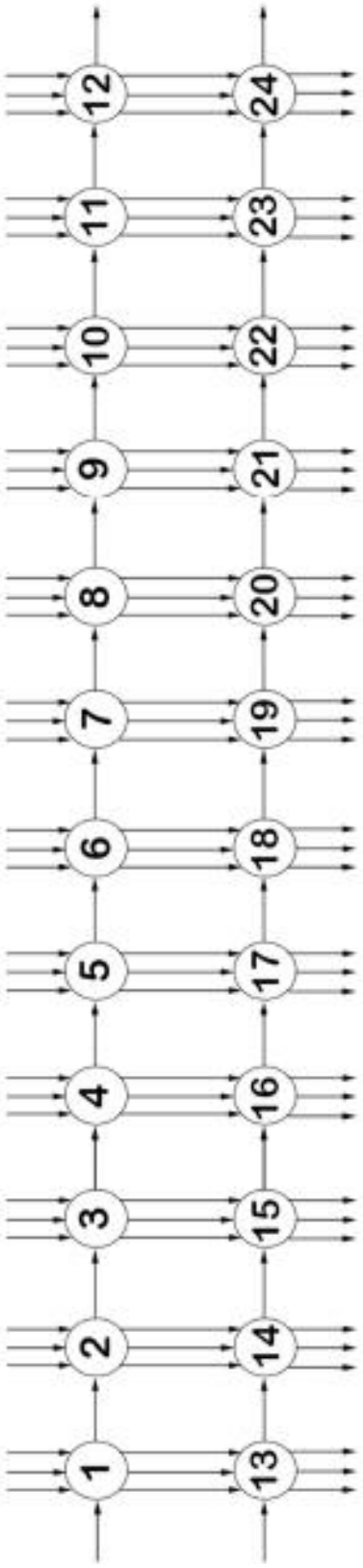

Figura 6. Plano de produção da parte 5

5.5 – Validação do modelo

5.5.1 – Conservação de fluxo

1	13
2	14
3	15
4	16
5	17
6	18
7	19
8	20
9	21
10	22
11	23
12	24

5.5.2 – Somatório de custos

Conclusão

Como podemos observar, o valor da solução ótima na parte 1 foi de 53404 U.M. De referir, que esta parte vai servir como base de comparação para as restantes partes. Na parte 2, a solução ótima foi de 54536 U.M., e era de esperar um aumento, uma vez que obrigamos a uma paragem na linha de produção durante 20 dias devido a uma operação de manutenção. Por sua vez na parte 3 , a solução ótima tomou o valor de 52679 U.M. (mais baixo do que a parte 2) o que nos leva a concluir que perda de capacidade de produção por causa da mudança do tipo de sumo produzido de um mês para o outro, de 45 U.E. para 39 U.E., é pouco relevante. Se virmos bem, são raros os casos em que a produção atinge valores próximo de 39 mesmo com a mudança do tipo de sumo em cada mês. Na parte 4, o valor da solução ótima (52766 U.M.) é ligeiramente superior ao da parte 3. Nesta parte existe uma maior dinâmica na produção, pois já é possível mudar o tipo de sumo a ser produzido a meio do mês e portanto o valor da solução ótima é justificado por esse acontecimento. Por último, na parte 5, tivemos uma solução ótima de 53922. Concluindo , tendo em conta que esta parte se baseia na parte 4, mas com custos de 100 U.M. e redução da capacidade de produção em 6 unidades associados à mudança do tipo de sumo produzido, podemos conferir que o custo adicional está relacionado essencialmente devido à troca de tipo de sumo produzido. Repare que

$$53922 - 52766 = 1156 \ (\approx 12 * 100)$$