Faculty of information technology
Department of System Analysis and Management

Національний технічний університет ДНІПРОВСЬКА ПОЛІТЕХНІКА 1899

Thesis

Analysis and optimization of resource costs in multi-stage rolling production

Dmytro Olegovich SERDIUK, group 124-17-1

Scientific adviser: Koriashkina L.S.

Protection date: 22.06.2021
Available for download on the department website: sau.nmu.org.ua

The purpose of the research

The object of this research is a two-stage process of metal distribution when producing rolling products.

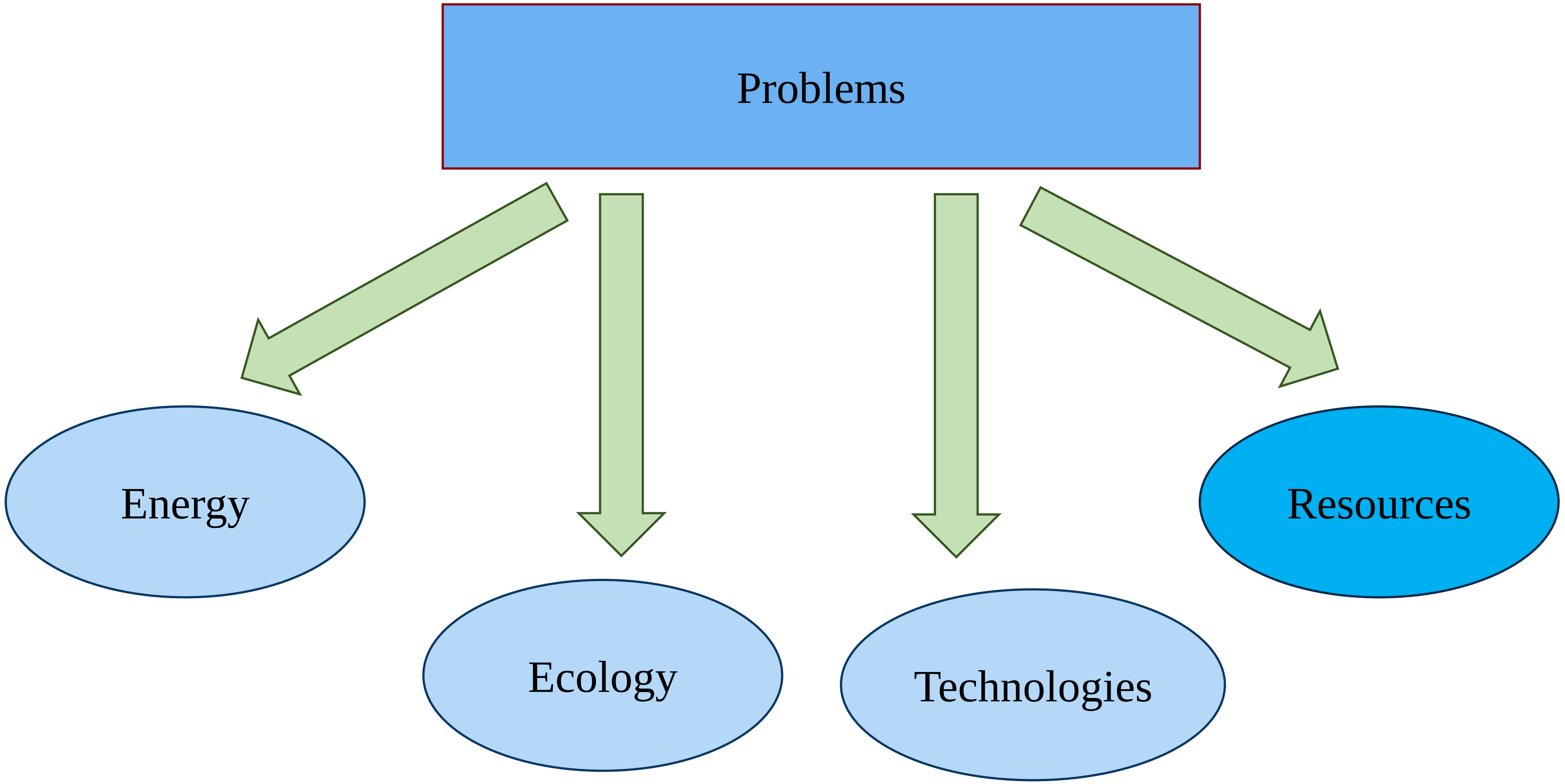
The subject is a mathematical model of steel consumption minimization considering the two-stage billets cutting and its program realization.

The purpose is achievement a decrease in resource costs in the multi-stage production of rolled products within a given plan through the development of the appropriate math apparatus and software.

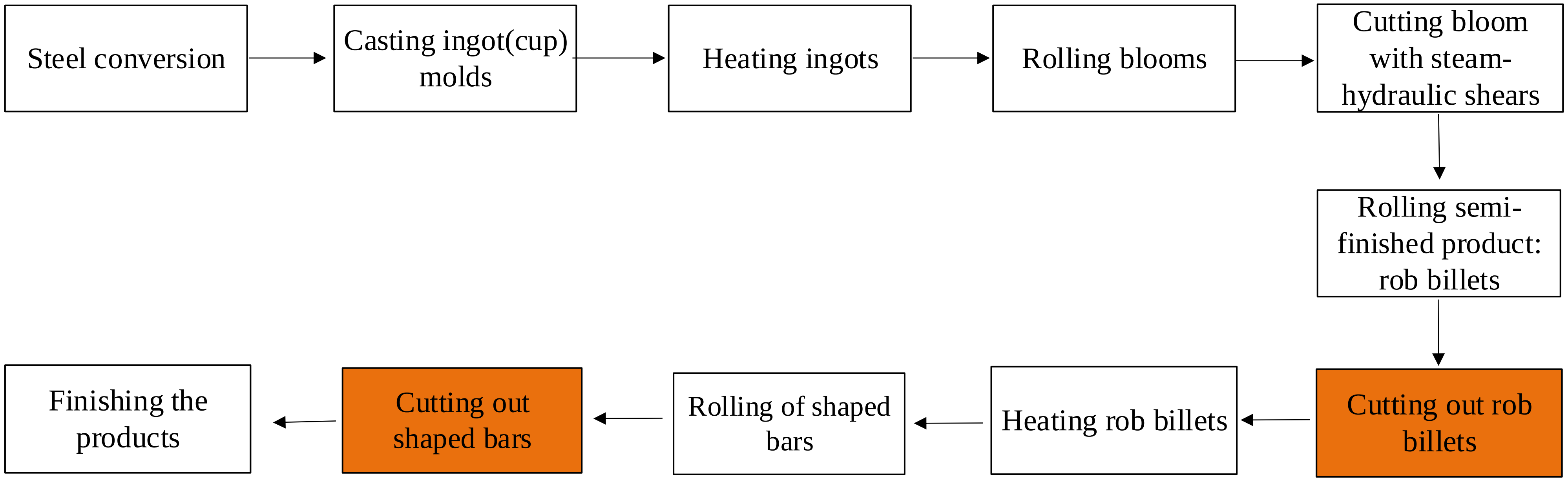
The main problems

1. Analysis of different problems of rolled products
2. General scheme of the multi-stage production of rolled products
3. Math problem of steel consumption minimization considering the two-stage billets cutting
4. Processing of orders
5. Program realization of the math model
6. Analysis of results

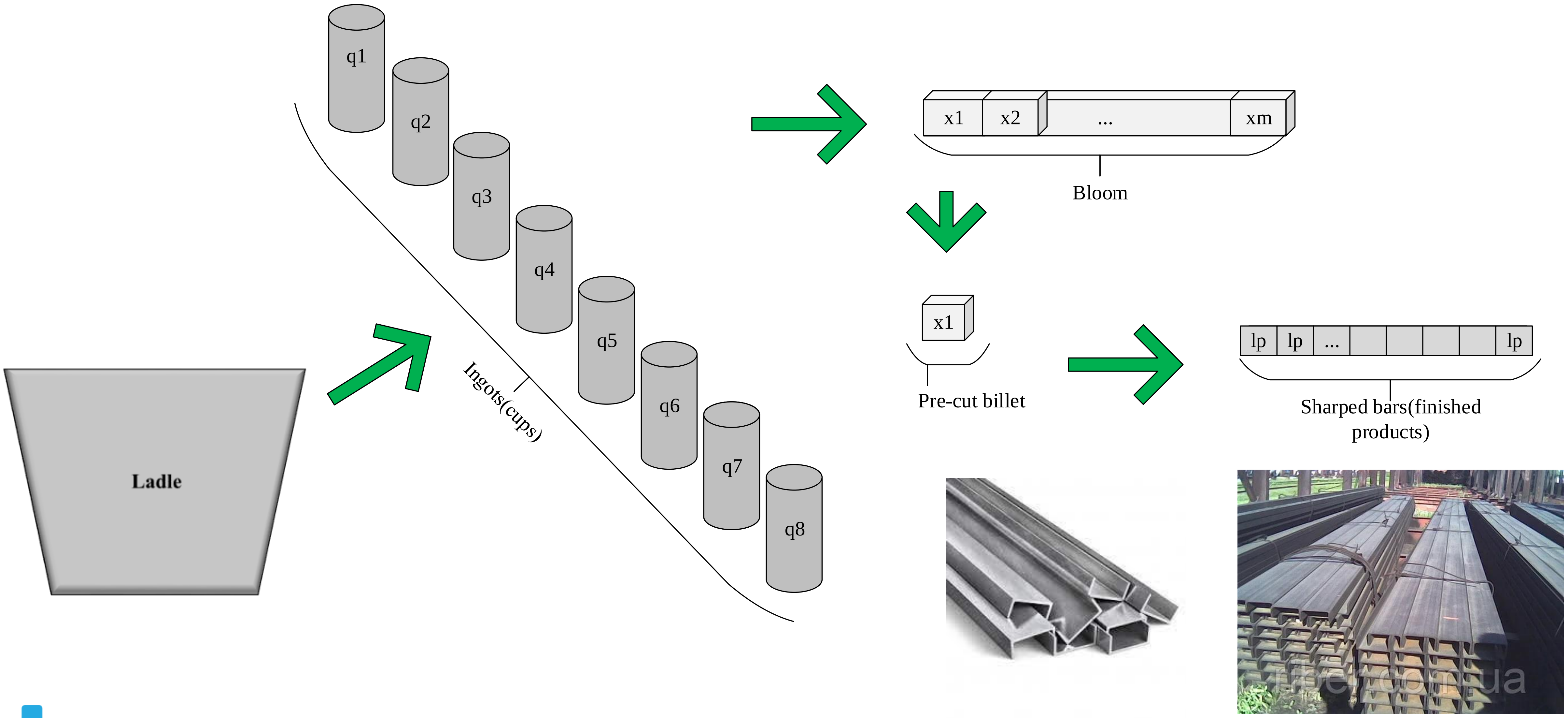
Different problems in the production of rolled products



Stage of technological process of graded rolled products



The scheme with the entered designations in mathematical model



Second-stage billets cutting

Length of the final product, m	Mass of 1 running meter, kg	Optimal billet length, m	Cogged ingot length , m	Number of rods, pcs.	Cut-offs, m / %	
11,7	7,034	2,85	47,2	4	0,44	0,94
12,0	7,034	2,90	48,1	4	0,07	0,15
9,0	7,034	2,75	45,6	5	0,58	1,28
6,0	7,034	2,90	48,1	8	0,07	0,15

Optimal length of a pre-cut billet of channel 8U depending on the rod length

First-stage billets cutting

$$minimize\ Z(q,x) = \sum_{n=1}^{N}\left(l_n - \sum_{m=\overline{1,M}:\ \sigma_{nm}=1}\ \sum_{p=1}^{4} length_m^p \cdot x_m^{p,n}\right)$$

$$q_1 + q_2 + \ldots + q_n \leq Q; \qquad (1)$$

$$\sum_{n=1}^{N} x_m^{p,n} = Number\_Zag_m^p, \qquad m = 1,2,\ldots,M;\ p = 1,2,3,4; \qquad (2)$$

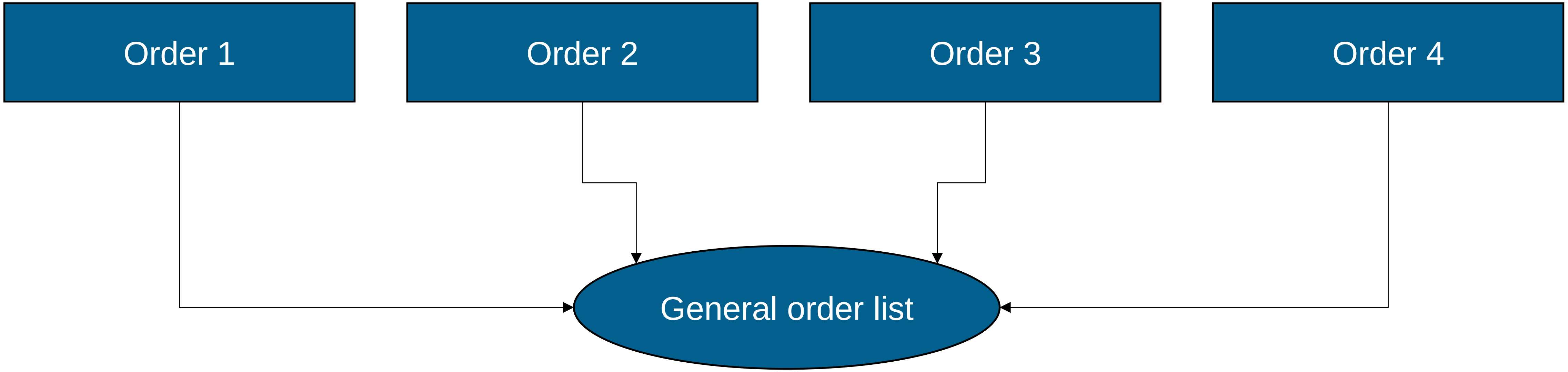
$$\sum_{m=\overline{1,M}:\ \sigma_{nm}=1}\ \sum_{p=1}^{4} length_m^{\mathrm{p}} \cdot x_m^{\mathrm{p},n} - \frac{q_n}{a_n c_n \rho} \leq 0, n = 1,2,\ldots,N; \qquad (3)$$

$$q_{min} \leq q_n \leq q_{max}, n = 1,2,\ldots,N; \qquad (4)$$

$$x_m^{p,n} \geq 0, x_m^{p,n} - \text{цілі}, p = 1,2,3,4;\ m = \overline{1,M}; n = \overline{1,N}: \sigma_{nm} = 1. \qquad (5)$$

$$Number\_Zag_m^{\mathrm{p}} = \frac{b_m^p}{amount_m^{\mathrm{p}}}, m = 1,2,\ldots,M;\ p = 1,2,3,4 \qquad (6)$$

Order



Channel №	Length(m)	Mass (t)
8	12	10
12	12	23
14	11,7	10
10	6	10

Order processing

Channel №	Length(m)	Mass (t)
8	9	44
8	12	10
10	11.7	20
10	12	25
10	6	10
10	9	15
12	6	105
12	9	20
12	12	23
14	11.7	37

Channel №	Length(m)	Mass (t)
12	6	52.5

Channel №	Length(m)	Mass (t)
8	9	44
8	12	10

Channel №	Length(m)	Mass (t)
10	11.7	20
10	6	10
10	9	15

First-stage billets cutting

Channel №	Length(m)	Mass (t)	Plan(pcs.)	Number of billets(pcs.)
8	9	44	695	139
8	12	10	116	29

$$F = \frac{1}{0.125*0.125*7856} q_1 + \dots + \frac{1}{0.125*0.125*7856} q_8 - 2{,}75 * x_1^1 - 2{,}9 * x_1^2 - 2{,}75 * x_2^1 - 2{,}9 * x_2^2 - \dots - 2{,}75 * x_8^1 - 2{,}9 * x_8^2 \to min$$

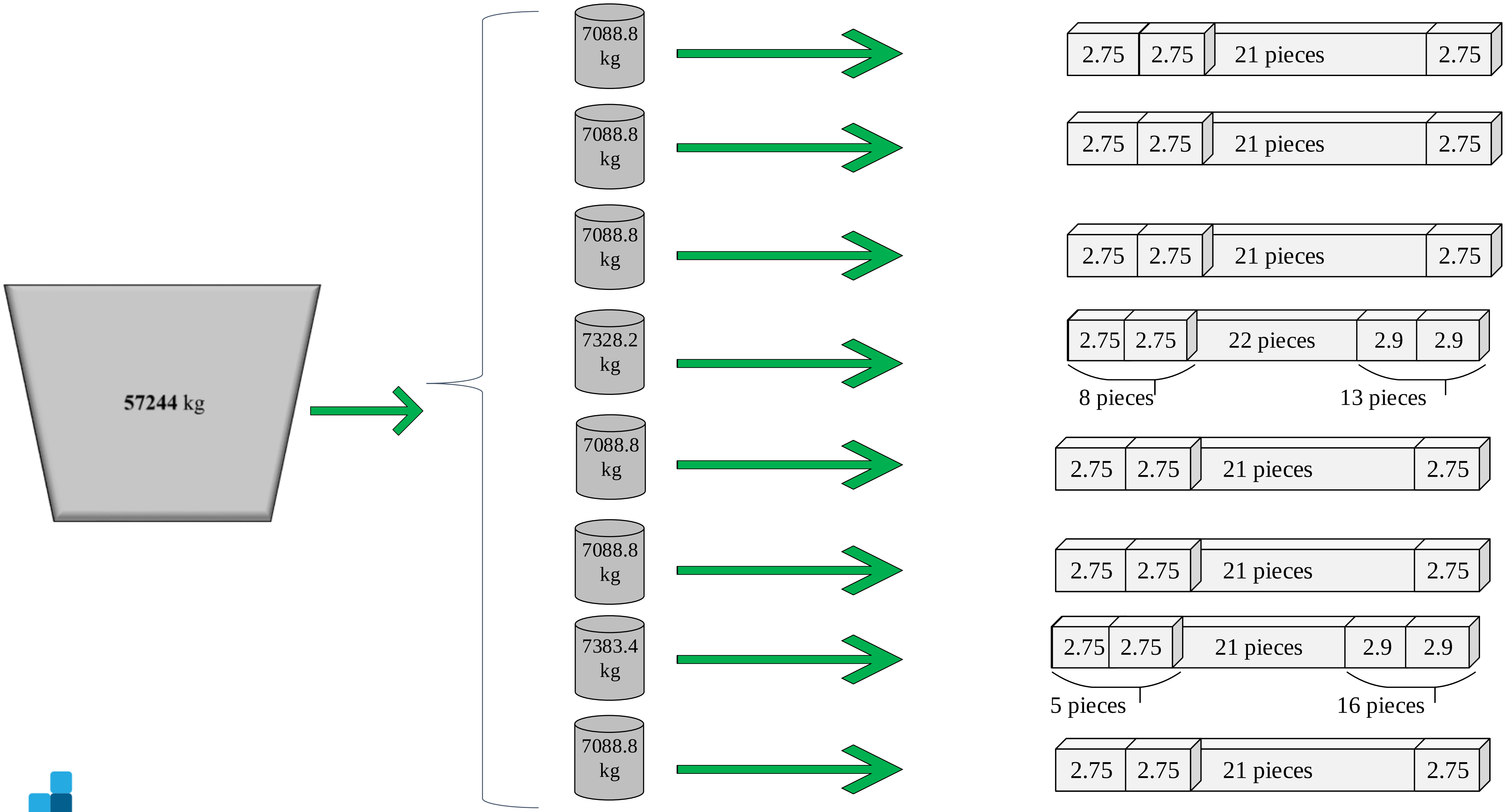
$$\begin{cases} q_1 + \dots + q_8 \le 60000 \\ x_1^1 + \dots + x_8^1 = 139 \\ x_1^2 + \dots + x_8^2 = 29 \\ \frac{1}{0.125 * 0.125 * 7856} q_1 - 2.75 * x_1^1 - 2.9 * x_1^2 \ge 0 \\ \dots \\ \frac{1}{0.125 * 0.125 * 7856} q_8 - 2.75 * x_8^1 - 2.9 * x_8^2 \ge 0 \\ 4400 \le q_1, \dots, q_8 \le 7400 \\ x_1^1, \dots, x_8^1, x_1^2, \dots, x_8^2 - \text{цілі} \end{cases}$$

Analysis of results

n	a_n(m)	c_n(m)	q_n(kg)	x_{1n}(pcs.)	x_{2n}(pcs.)
1	0.125	0.125	7088.8	21	0
2	0.125	0.125	7088.8	21	0
3	0.125	0.125	7088.8	21	0
4	0.125	0.125	7328.2	8	13
5	0.125	0.125	7088.8	21	0
6	0.125	0.125	7088.8	21	0
7	0.125	0.125	7383.4	5	16
8	0.125	0.125	7088.8	21	0

The amount of metal in the blooms is 57244 kg, and therefore the excess production is 5.67%, which means that the order, firstly, is fulfilled, and secondly, the answer is optimal.

The result of optimization of the first stage of cutting(subtask 2)



Conclusion

Number of parts	Total mass of part of order (kg)	The resulting mass of metal fed into the ladle (kg)	Difference (%)
1	54000	57244	5,67
2	45000	46840	3,93
3, 4	52500	55794	5,9
5	47000	49610	5,26
6	51000	53196	4,13
7	47000	49440	4,94

$$Mean\% = \frac{57244 \cdot 5{,}67 + 46840 \cdot 3{,}93 + \cdots + 49440 \cdot 4{,}94}{57244 + 46840 + \cdots + 49440} = 5{,}01\%$$

Since in practice the value is allowed up to 10%, it can be concluded that the developed mathematical model and its software implementation allows to solve the problem of overconsumption of metal during the production of metallurgical plants and quantitatively justify the relevant decisions. Modification of the model is possible, due to the specification of the objective function and constraints.