2020-2021 Academic Year

OPTIMIZATION OF SEMI-FINISHED CABLE FLOW USING NETWORK MODEL WITH TIME WINDOWS

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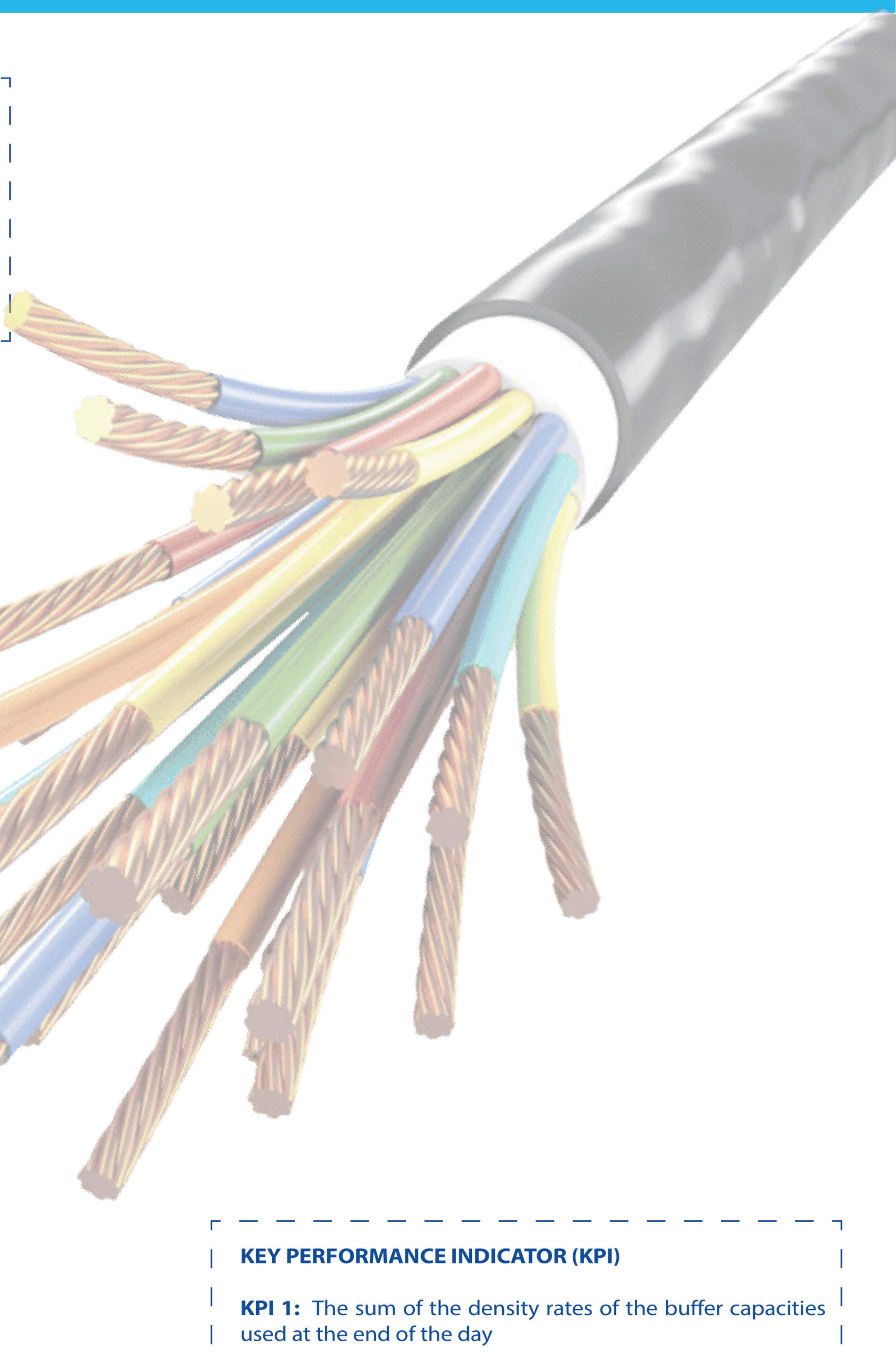


INTRODUCTION

The study is carried out in HES Cable A.Ş. and it aims to develop a network model with time window that will optimize the drums that semi-finished cables are wound on. For the purpose of the model, 3 key performance indicators (KPI) are defined. The defined KPI's are the sum of the density rates of the buffer capacities used at the end of the day, number of drums waiting in the buffer stock areas in production area at the end of the day and the highest density rate of buffer stock area capacities. 2 different network models are provided as a solution proposal. While the aim of the first model is to minimize the number of drums waiting at the end of the day, second model aims to minimize the maximum density of the buffer stock areas used for each time period. The results of the models are compared with each other based on their KPI values. Moreover, the financial benefits are calculated for both models seperately.

SYSTEM UNDER CONSIDERATION

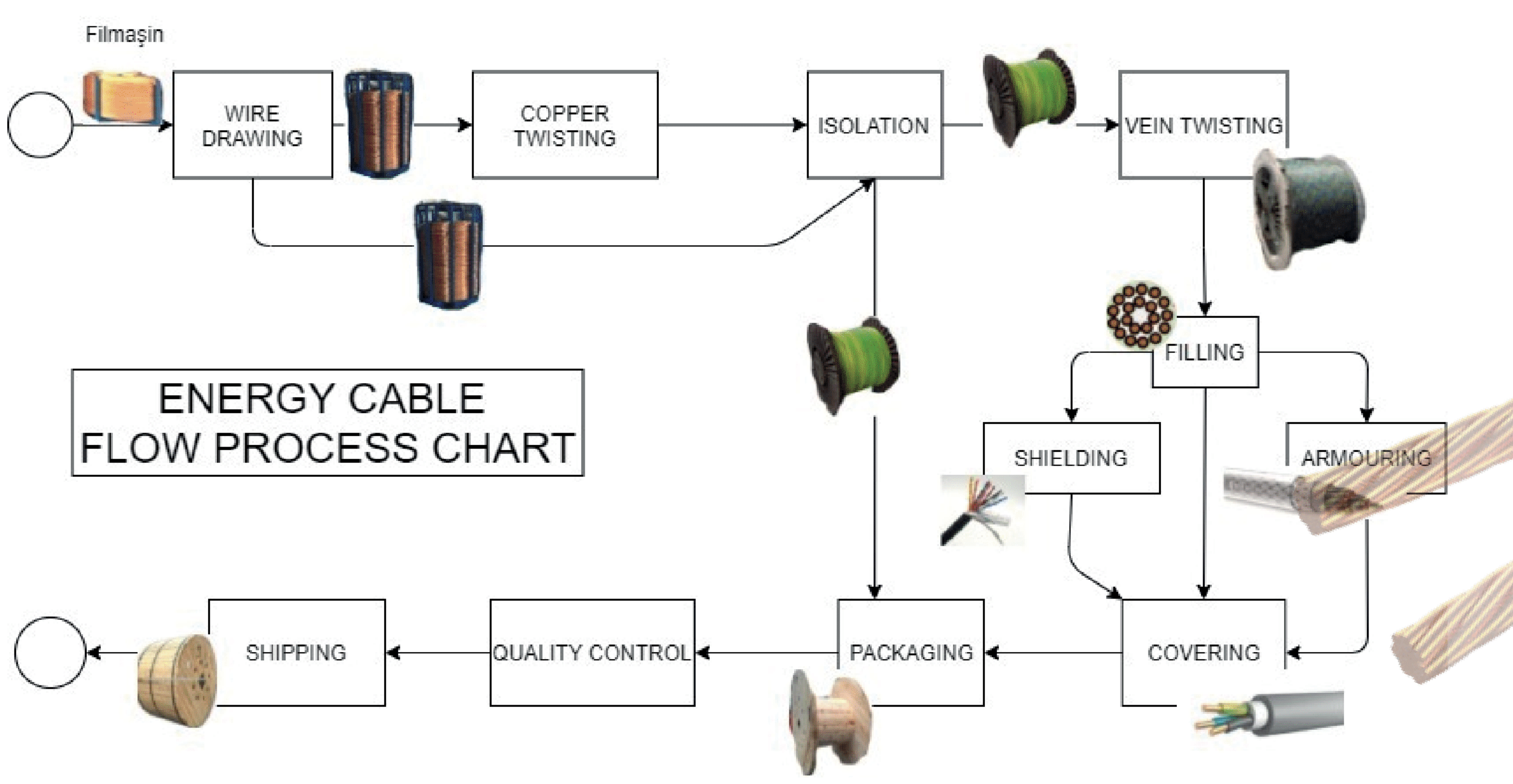


Figure 1. Energy Cables Production Process

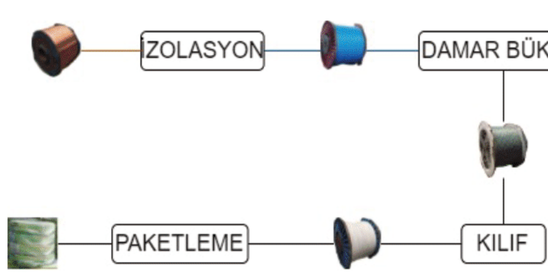
PROBLEM DEFINITON

Observations & Symptoms

Figure 2. Drum

- High number of semi-finished drums
- Unevenly distributed drums in the buffer stock areas
- Irregularity in the production area
- Difficult to track the drums

Analyses



PROCESS	NUMBER OF WAITING DAYS
ISOLATION	1.3
VEIN TWISTING	2.7
COVERING	5
PACKAGING	0.5
TOTAL: 9.5 DAYS	

Figure 3. Analyses

Problem Definition

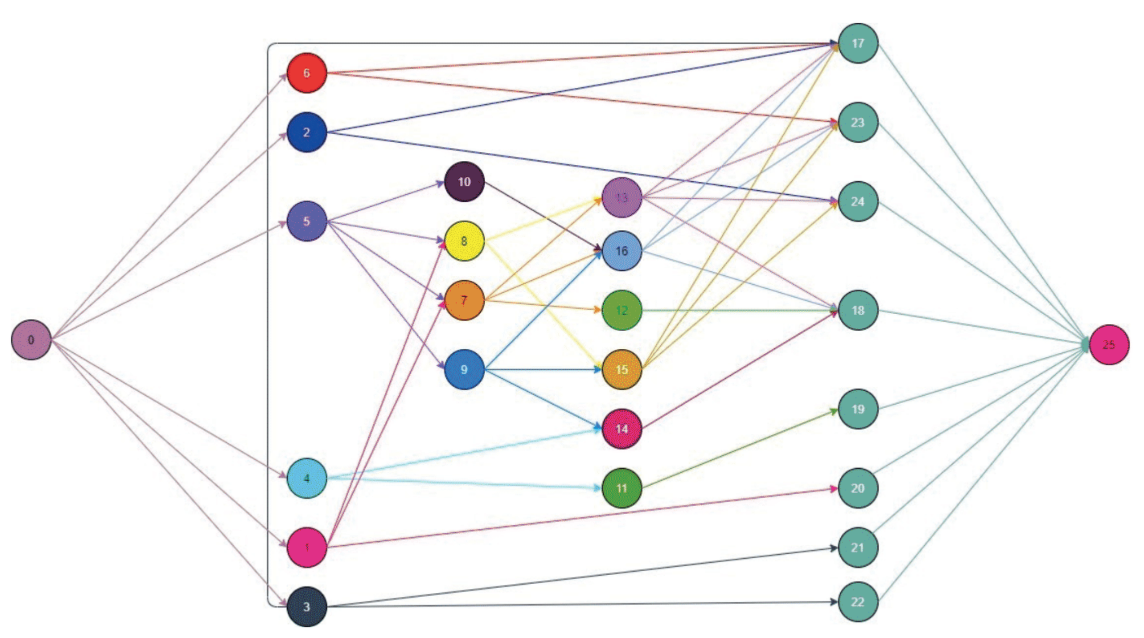


Figure 4. Network of semi-finished drum flow

- The right quantity of drum to the right machine in the right time is not transported.
- Network Model with Time Windows is created and solved in GAMS.

PROPOSED METHODOLOGY

After analyzing the problem, 2 different mathematical models are provided as a solution proposal. Firstly, Model 1 is provided and its aim is to minimize the sum of the buffer stock areas used at the end of the day. On the other hand, Model 2 aims to minimize the use of maximum buffer stock areas in each time period. The purpose of providing 2 models is to compare the results for different KPI's and propose the best model.

Mathematical Model 1

İndices

i machines(i=0,1,2,…,25)

t time periods (t=0,…,5)

Parameters

D_{jt} drum demand of machine j in time period t

C_i capacity of output buffer area of machine i in period t

G_i machine set that can send drums to the i.th machine

L_i machine set that can take drums from the i.th machine

Decision variables

X_{ijt} number of drums transferred from machine i to machine j in time period t

Y_{it} number of drums not transferred from machine i in period t

Objective function

$Z^{*}=\min Z \sum^{16}_{i=1} Y_i{'5'}/C_i$ (1)

Constraints

$Y_{it} \leq C_i$, $\forall it$ (2)

$\sum_{iEGj} X_{ijt} = D_{jt}$ $\forall jt$ (3)

$Y_{i(t-1)} + \sum_{jEGi} X_{ijt} = \sum_{jELi} X_{ijt} + Y_{it}$ $\forall it$ (4)

$Y_i 0=0$, $\forall i$ (5)

$Y_{it} \geq 0$, $\forall it$ (6)

$X_{ijt} \geq 0$, $\forall ijt$ (7)

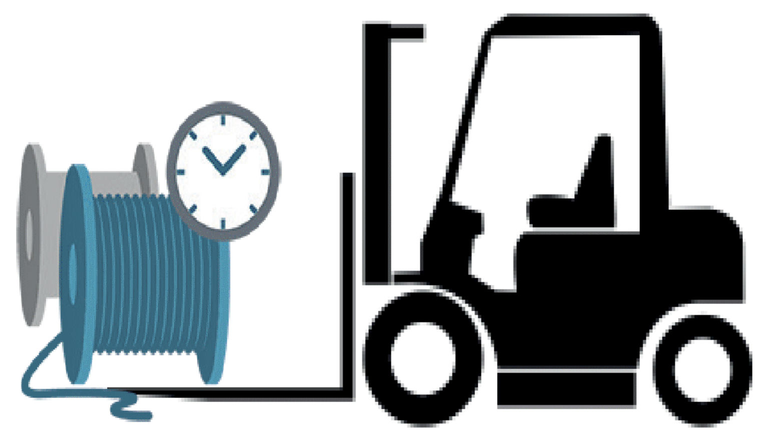
Equation (1) shows the objective function that minimizes the total density of buffer stock areas at the end of the day. Constraint (2) ensures that the capacity of buffer stock areas cannot be exceeded. Constraint (3) ensures that demand of machine is met. Constraint (4) ensures that input of machine is equal to output of machine. Constraint (5) indicates that all machines should send their drums to the next machines in time period 0. The constraints (6) and (7) show that the decision variables can not take negative values.

KEY PERFORMANCE INDICATOR (KPI)

KPI 1: The sum of the density rates of the buffer capacities used at the end of the day

KPI 2: Number of drums waiting in the buffer stock areas in production area at the end of the day

KPI 3: The highest density rate of buffer stock area capacities



Mathematical Model 2

Objective Function

$Z^{*}=\min Z$ (8)

The added decision variable

V_{it} the ratio of the number of drums waiting in front of buffer area of machine i in time period t to the capacity of the buffer area

The added constraints

$V_{it}=Y_{it}/C_i$ (9)

$Z \geq V_{it}$ (10)

Equation (8) expresses the objective function. The objective function of the Mathematical Model 2 aims to minimize the maximum buffer capacity used in each period. Constraint (9) shows the ratio of the drums waiting in buffer areas to capacity of the buffer area and is calculated for each period and machine. Constraint (10) states that the 'z' expression that is minimized in the objective function must be greater than all capacity density rates. The rest of the constraints remains same as it is in the first model.

RESULT OF MODEL1

MODEL 1					
Z= 5.34					
Machine i	Time Period t				
	1	2	3	4	5
1	17	14	11		
2	5	2			
3	30	30	30	30	30
4	8	16	24	32	32
5				8	8
6	10	10	14	18	18
7		7	11	15	27
8			3	2	6
9				4	8
10					3
11		8	16	24	34
12			3	6	9
13			1		5
14			2	4	6
15					5
16			3	6	9

Figure 5. Results of Model 1

KPIs	Model 1
KPI 1	5.34
KPI 2	200
KPI 3	0.9

The first performance indicator is found as 5.34. This value represents the sum of the density rates of the buffer capacities used at the end of the day. The second performance indicator represent the number of drums waiting in the buffer areas of the machines at the end of the day and is found as 200 drums. The third KPI is found as 0.9. It means that the density rate in the buffer areas is up to 90%.

RESULT OF MODEL1

MODEL 2					
Z= 0.8					
Machine i	Time Period t				
	1	2	3	4	5
1	17	14			
2	5	2	4	1	1
3	30	30	30	30	30
4	8	16	24	32	32
5			11	8	8
6	10	10	5	15	15
7		1	2	4	16
8		3	2		4
9			4	8	12
10		3	6	9	12
11		8	16	24	34
12			3	2	5
13			1	3	8
14		2	4	6	8
15			5	3	8
16			3	6	9

Figure 6. Results of Model 2

KPIs	Model 2
KPI 1	5.91
KPI 2	202
KPI 3	0.8

The first performance indicator is found as 5.91. This value represents the sum of the density rates of the buffer capacities used at the end of the day. The second performance indicator represent the number of drums waiting in the buffer areas of the machines at the end of the day and is found as 202 drums. The third KPI is found as 0.8. It means that the density rate in the buffer areas is up to 80%.

CONCLUSION

	MODEL 1	MODEL 2
	3000 Meter Daily; 2.409.000₺ Annual	1000 Meter Daily; 803.000₺ Annual
KPI 1	23% ✓	15%
KPI 2	1% ✓	0.5%
KPI 3	10%	20% ✓
	2.409.000₺	803.000₺

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