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INCREASING THE EFFICIENCY OF AUTOMATED STORAGE AND RETRIEVAL SYSTEM USED IN A LOGISTICS COMPANY

DAMLA OKYAY, MUJGAN MUTLU, GULCIN DINC YALCIN, AND REFAIL KASIMBEYLI

Abstract. An automated storage and retrieval system (AS/RS) is for automatically placing and retrieving loads from defined storage locations. In this study, a mathematical model is proposed to increase the efficiency of the AS/RS used in the warehouse area of a logistics company. The aim is to minimize the time spent for which the pallets have been taken by the AS/RS from buffers then delivered to the storage locations they were assigned. By using the developed mathematical model, a dynamic decision support system is established, and the code is written in the GAMS software package.

1. Introduction

Efficient storage and retrieval of components, tools, raw materials and subassemblies are required in modern manufacturing systems like automated factories, distribution centers, warehousing, and non-manufacturing environments [17]. Economic factors such as high initial investment, inflexible layout and fixed storage capacity, force us to carefully evaluate the system structure (e.g. the layout and dimensions of the racks, S/R mechanism) and operational policies (e.g. allocation of storage cells and scheduling of the tasks) [10].

In light of similar studies for the solution to this problem, we first examine the most commonly recognized problems in optimization such as Assignment, Transportation, Vehicle Routing and Travelling Salesman problems. One of the most important and successful applications of quantitative analysis to solving business problems has been in the physical distribution of products, commonly referred to as transportation problems. Basically, the purpose is to minimize the cost of shipping goods from one location to another so that the needs of each arrival area are met and every shipping location operates within its capacity [15]. In our problem, the AS/RS has a similar objective that minimizes the time spent needed for a movement from one position to another.

In the assignment problem, the best assignment of a set of persons to a set of jobs is examined [12]. In general, the assignment problem is the problem of assigning n different relativistic elements to n different jobs. The cost of making the ith person jth job is c_{ij}. In this case, the problem can be defined as having a set to minimize the objective function. The simplex method and the Hungarian method are used to solve the assignment problems(see e.g. [2, 4, 5, 9, 12]). The Hungarian method is a simple and easy to understand and highly effective solution method developed in [12]. Assignment problems are the special case of transportation problems where

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the row and column numbers are equal and the values on the right side are 1. If we consider assignment problems as a transportation problem, then the problem can be solved by using the " Transportation Technique " that is a version of the simplex method. In our problem, the products are assigned to suitable warehouses with defining the sequence of the buffer of the AS/RS.

The traveling salesman problem (TSP) is aimed to find the shortest possible route that visits every city in a set. The route starts at and endsto the starting point. Many exact solution algorithms are proposed for TSP, e.g. the branch-and-bound method. Additionally, heuristic and metaheuristic algorithms are developed (see e.g. [1, 6, 7, 11, 13, 14]). The vehicle routing problem (VRP) is a generalization TSP. A route is designed that every point is visited once and the total demand of all points on a given route cannot exceed the allocated vehicle capacity. The objectives may be to minimize the number of vehicles to be used and minimize the total distance or total time, and to minimize the cost function. Heuristic methods are preferred for solving these problems (see e.g. [3, 8, 15, 16, 18]).

In our problem, the AS/RS has a bounded capacity and the number of each product is considered as demands. The aim is to find the best routes that give the minimum time.

In the current system of the firm, the AS/RS takes the unnecessary path. Our aim is to minimize the time spent of the AS/RS with determining an order in which products in the buffer is taken to the channels they are assigned to. In this paper, we develope a mathematical model to obtain the best routes. The computational results show the improvement between our solution and the current solution.

The rest of the paper is organized as follows: Section 2 presents the problem definition and its mathematical model. We define the problem, give the proposed mathematical model, and explain how the parameters A and D matrixes are generated. We discuss the results obtained from the mathematical model of the problem and draw some conclusions in Section 3 and 4, respectively.

2. Problem Definition and Mathematical Model

We first give the definition of the problem and then explain the developed model for the related AS/RS problem.

2.1. **Problem definition.** In the current situation of the AS/RS, the decision is made at the beginning of the day in which order to leave the products by the AS/RS from the output buffers. The current situation in the firm, the products are transported to the shuttle in the channels, the routes are defined by roughly. The problem is to define the route of the AS/RS by minimizing the waste of time. Our aim is to specify in which order pallets assigned to channels is received from buffers and delivered to the channels by the AS/RS.

In the system, the products are transported by the AS/RS to the channels in the order shown in Fig. 1. In this case, the route taken by AS/RS is 2400 cm (720 + 120 + 1440 + 120). However, if the products are to be transported in the opposite order by ASRS as shown in Fig. 2, the route taken by AS/RS is 1800 cm (720 + 120 + 840 + 120). This means that the difference between the two choices is 600 cm.

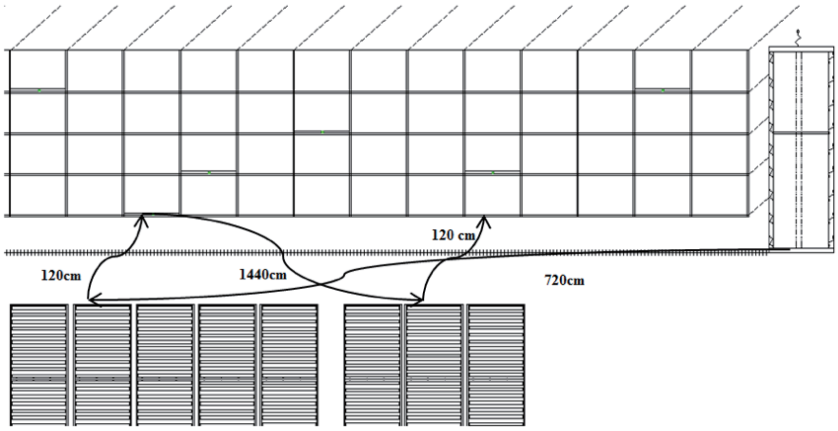


FIGURE 1. An example of current the AS/RS.

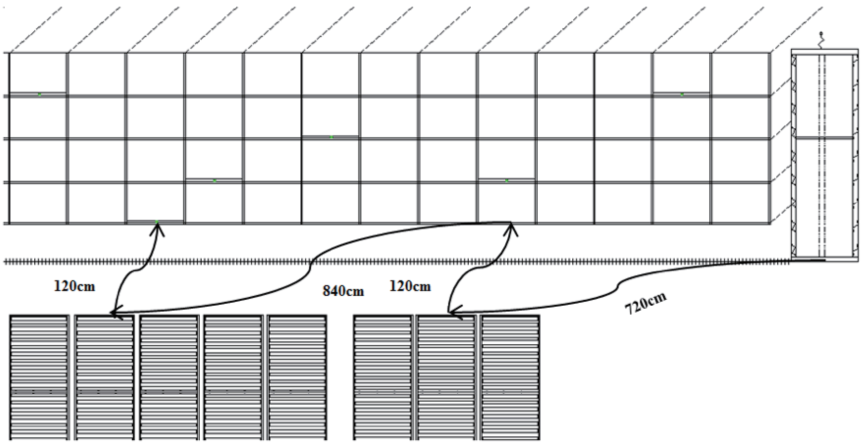


FIGURE 2. An example of improved the AS/RS.

2.2. **The mathematical model.** The time that the AS/RS spends at the vertical axis is negligible since the channels to which the products are assigned are fixed, the AS/RS has to take that route under all conditions. For this reason, the time spent on the vertical axis is not considered. The time that AS/RS spends at the horizontal axis is a key factor.

The assumptions are listed as follows:

Assumption 2.1. We treat the channel capacity as unlimited in our work. Because when the duct is fed from one side, it is discharged from the other side for shipment. Transfer shuttles located in the system regularly carry the pallets on the side where the channel is fed to the empty areas on the shipment side. So it is not encountered with the problem that indicates the entire channels are full.

Assumption 2.2. Since shuttles are much faster than the AS/RS, we have the assumption that shuttles are always ready.

Assumption 2.3. The initial position of the AS/RS is assumed to be in front of the channel in the 23rd column. (K2301)

The sets, parameters and decision variables of the mathematical model are as follows.

Sets:

$u =$ Product$(\overline{1,14})$
$b =$ Buffer$(\overline{1,8})$
$k =$ Channels$(\overline{1,23})$
$s =$ The sequence in the buffer $(\overline{1,15})$
$i =$ The arrival sequence of the AS/RS to buffer $(\overline{1,68})$

Parameters:

$t_{bk} =$ Duration of the transport from bth buffer to kth channels
$D_{bs} =$ Position number of the product in bth buffer and sth sequence

$$A_{uk} = \begin{cases} 1 & \text{if } u\text{th product is assigned to } k\text{th channels,} \\ 0 & \text{otherwise.} \end{cases}$$

Decision variables:

$$X_{ubsi} = \begin{cases} 1 & \text{if } u\text{th product product is taken from } b\text{th buffer } s\text{th sequence when } i\text{th arrival,} \\ 0 & \text{otherwise.} \end{cases}$$

$$Y_{kbi} = \begin{cases} 1 & \text{if ASRS comes from } k\text{th channels to } b\text{th buffer } i\text{th times ,} \\ 0 & \text{otherwise.} \end{cases}$$

$$F_{bi} = \begin{cases} 1 & \text{if ASRS comes to } b\text{th buffer at } i\text{th times ,} \\ 0 & \text{otherwise.} \end{cases}$$

$P_{bs} =$ ith of the product received in bth buffer sth sequence (integer variable)

Mathematical model:

$$\min \sum_u \sum_b \sum_k \sum_s \sum_i t_{bk} A_{uk} X_{ubsi} + \sum_i \sum_k \sum_b t_{bk} Y_{kbi} \tag{2.1}$$

subject to

$$\sum_i X_{ubsi} = 1 \quad \forall u, i, b, s \quad \text{if} \quad \frac{D_{bs}}{u} = 1 \tag{2.2}$$

$$\sum_i X_{ubsi} = 0 \quad \forall u, i, b, s \quad \text{if} \quad \frac{D_{bs}}{u} \neq 1 \tag{2.3}$$

$$\sum_{u}\sum_{b}\sum_{s} X_{ubsi} \leq 2 \quad \forall i \tag{2.4}$$

$$\sum_{u}\sum_{s} X_{ubsi} \geq F_{bi} \quad \forall b, i \tag{2.5}$$

$$\sum_{u}\sum_{s} X_{ubsi} \leq 2F_{bi} \quad \forall b, i \tag{2.6}$$

$$\sum_{b} F_{bi} = 1 \quad \forall i \tag{2.7}$$

$$\sum_{i} X_{ubsi} i = P_{bs} \quad \forall u, b, i \quad \text{if} \quad \frac{D_{bs}}{u} = 1 \tag{2.8}$$

$$P_{bs} \leq P_{b(s+1)} \quad \forall b, s \quad (s \neq 15) \tag{2.9}$$

$$\sum_{u} X_{ubsi} + X_{ub(s+1)i} \leq 2 \quad \forall b, i, s(s \neq 15) \quad \text{if} D_{b(s+1)} = D_{bs} \tag{2.10}$$

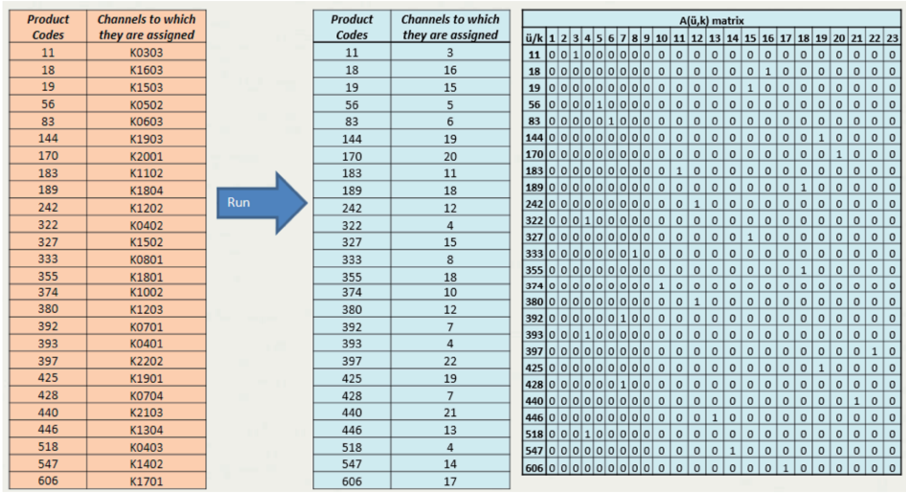
$$\sum_{u} X_{ubsi} + X_{ub(s+1)i} \leq 1 \quad \forall b, i, s(s \neq 15) \quad \text{if} D_{b(s+1)} \neq D_{bs} \tag{2.11}$$

$$\frac{1}{2}\sum_{u}\sum_{s} X_{ubsi} \leq \sum_{k} Y_{kbi} \quad \forall b, i \tag{2.12}$$

$$\sum_{u}\sum_{s} X_{ubsi} \geq \sum_{k} Y_{kbi} \quad \forall b, i \tag{2.13}$$

(2.1) is to minimize the time spent on the AS/RS. (2.2) and (2.3) indicates that if the product u place in b. buffer and s. sequence, the product must be taken any i. arrival of the AS/RS. (2.4) is that the AS/RS has 2 transport capacities in one pass. That is, a maximum of two products can be carried in one i. (2.5), (2.6) and (2.7) show that products in different buffers cannot be moved at the same i. (2.8) and (2.9) means that the products are not removed from the back without taking the front product. (2.10) and (2.11) indicate that if there are two products with the same code one after the other, carry the products together. (2.12) and (2.13) show that the AS/RS must go the next product ’ s buffer from the previous product ’ s warehouse.

2.3. **Generating the parameters.** Each product is assigned to a channel that has a specific code such as K0303, K1603, etc. These first two numbers of these codes show the number of the warehouse channel. Using this information, we create the matrix $A(u, k)$ formed with 0 and 1. In addition, to describe the order in which the products are located in the buffer, we create the matrix $D(b, s)$. In order to create this matrix automatically, a code was written in the base of the Excel VBA. As shown in Fig. 3 and 4, when pressing the ”Run” icon, the program automatically generates the matrix $A(u, k)$ and $D(b, s)$, respectively.



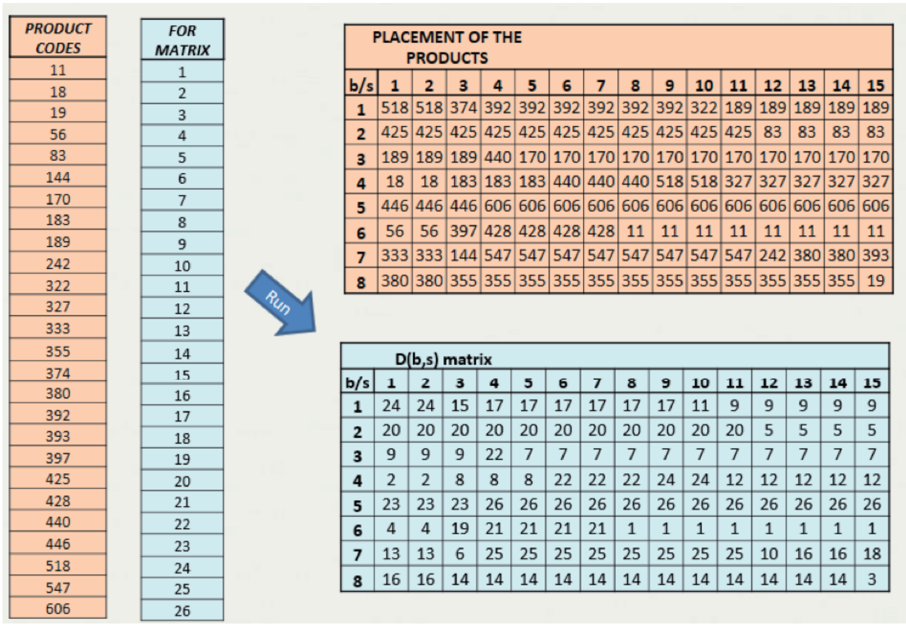
Product Codes	Channels to which they are assigned
11	K0303
18	K1603
19	K1503
56	K0502
83	K0603
144	K1903
170	K2001
183	K1102
189	K1804
242	K1202
322	K0402
327	K1502
333	K0801
355	K1801
374	K1002
380	K1203
392	K0701
393	K0401
397	K2202
425	K1901
428	K0704
440	K2103
446	K1304
518	K0403
547	K1402
606	K1701

Product Codes	Channels to which they are assigned
11	3
18	16
19	15
56	5
83	6
144	19
170	20
183	11
189	18
242	12
322	4
327	15
333	8
355	18
374	10
380	12
392	7
393	4
397	22
425	19
428	7
440	21
446	13
518	4
547	14
606	17

A(ü,k) matrix

ü/k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
56	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
183	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
189	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
242	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
322	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
333	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
355	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
374	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
380	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
392	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
393	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
397	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
425	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
428	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
446	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
518	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
547	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
606	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

FIGURE 3. Using Excel Macro for Automatic Creation of A Matrix.



PRODUCT CODES	FOR MATRIX
11	1
18	2
19	3
56	4
83	5
144	6
170	7
183	8
189	9
242	10
322	11
327	12
333	13
355	14
374	15
380	16
392	17
393	18
397	19
425	20
428	21
440	22
446	23
518	24
547	25
606	26

PLACEMENT OF THE PRODUCTS

b/s	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	518	518	374	392	392	392	392	392	392	322	189	189	189	189	189
2	425	425	425	425	425	425	425	425	425	425	425	83	83	83	83
3	189	189	189	440	170	170	170	170	170	170	170	170	170	170	170
4	18	18	183	183	183	440	440	440	518	518	327	327	327	327	327
5	446	446	446	606	606	606	606	606	606	606	606	606	606	606	606
6	56	56	397	428	428	428	428	11	11	11	11	11	11	11	11
7	333	333	144	547	547	547	547	547	547	547	547	242	380	380	393
8	380	380	355	355	355	355	355	355	355	355	355	355	355	355	19

D(b,s) matrix

b/s	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	24	24	15	17	17	17	17	17	17	11	9	9	9	9	9
2	20	20	20	20	20	20	20	20	20	20	20	5	5	5	5
3	9	9	9	22	7	7	7	7	7	7	7	7	7	7	7
4	2	2	8	8	8	22	22	22	24	24	12	12	12	12	12
5	23	23	23	26	26	26	26	26	26	26	26	26	26	26	26
6	4	4	19	21	21	21	21	1	1	1	1	1	1	1	1
7	13	13	6	25	25	25	25	25	25	25	25	10	16	16	18
8	16	16	14	14	14	14	14	14	14	14	14	14	14	14	3

FIGURE 4. Using Excel Macro for Automatic Creation of D Matrix.

3. COMPUTATIONAL RESULTS

The company that we co-operate within this study, aims to be as flexible as possible against possible situations such as lagging trucks carrying products, or failure of any machine used in the system. For this reason, the AS/RS ' s product transport orders can be carried out via 1-hour data which corresponds to an average of 15 products assigned to a buffer.

The mathematical model is coded in the GAMS program. Table 1 shows the order in which the products are taken from the buffers and transferred to the channels in the current situation in the system and the time spent in this transportation is as in Table 1. In the current state, the time to move for all products for 1 hour corresponds to 3347.5290938 seconds.

Table 1: Current State of the AS/RS system (Initial position of AS/RS: K2301)

i	**product**	**buffer**	**channel**	**from channel to buffer (seconds)**	**From buffer to channel (seconds)**	**Total (seconds)**
1	446	5	K1304	37.71086	8.137714	45.84857
2	446	5	K1304	8.13771	8.13771	16.27543
3	189	3	K1804	0.2231429	25.64314	25.86628
4	189	3	K1804	25.64314	25.64314	51.28628
5	425	2	K1901	30.06114	34.14686	64.20800
6	425	2	K1901	34.14686	34.14686	68.29372
7	425	2	K1901	34.14686	34.14686	68.29372
8	425	2	K1901	34.14686	34.14686	68.29372
9	425	2	K1901	34.14686	34.14686	68.29372
10	425	2	K1901	34.14686	34.14686	68.29372
11	56	6	K0502	12.25714	49.93428	62.19142
12	333	7	K0801	54.16286	41.90572	96.06858
13	18	4	K1603	24.34229	13.33486	37.67715
14	518	1	K0403	26.01429	28.00571	54.02000
15	380	8	K1203	62.47714	29.79143	92.26857
16	183	4	K1102	7.999429	12.08514	20.08457
17	183	4	K1102	12.08514	12.08514	24.17028
18	397	6	K2202	25.42000	24.51429	49.93429
19	144	7	K1903	20.28572	8.02857	28.31429
20	355	8	K1801	3.8	0.2857143	4.08571
21	355	8	K1801	0.2857143	0.2857143	0.57143
22	355	8	K1801	0.2857143	0.2857143	0.57143
23	355	8	K1801	0.2857143	0.2857143	0.57143
24	355	8	K1801	0.2857143	0.2857143	0.57143
25	355	8	K1801	0.2857143	0.2857143	0.57143
26	374	1	K1002	34.18571	3.49143	37.67714
27	428	6	K0704	29.50571	41.76286	71.26857
28	428	6	K0704	41.76286	41.76286	83.52572
29	440	3	K2103	24.29114	37.90028	62.19142
30	547	7	K1402	16.2	17.39143	33.59143
31	547	7	K1402	17.39143	17.39143	34.78286
32	547	7	K1402	17.39143	17.39143	34.78286
33	547	7	K1402	17.39143	17.39143	34.78286

i	**product**	**buffer**	**channel**	**from channel to buffer (seconds)**	**From buffer to channel to which they are assigned (seconds)**	**Total (seconds)**
34	392	1	K0701	12.85143	15.74857	28.60000
35	392	1	K0701	15.74857	15.74857	31.49714
36	392	1	K0701	15.74857	15.74857	31.49714
37	322	1	K0402	15.74857	28.00571	43.75428
38	170	3	K2001	36.54829	33.81457	70.36286
39	170	3	K2001	33.81457	33.81457	67.62914
40	170	3	K2001	33.81457	33.81457	67.62914
41	170	3	K2001	33.81457	33.81457	67.62914
42	170	3	K2001	33.81457	33.81457	67.62914
43	170	3	K2001	33.81457	33.81457	67.62914
44	606	5	K1701	25.45371	13.19657	38.65028
45	606	5	K1701	13.19657	13.19657	26.39314
46	606	5	K1701	13.19657	13.19657	26.39314
47	606	5	K1701	13.19657	13.19657	26.39314
48	606	5	K1701	13.19657	13.19657	26.39314
49	606	5	K1701	13.19657	13.19657	26.39314
50	11	6	K0303	4.085714	58.10571	62.19142
51	11	6	K0303	58.10571	58.10571	116.21142
52	11	6	K0303	58.10571	58.10571	116.21142
53	11	6	K0303	58.10571	58.10571	116.21142
54	440	4	K2103	44.77086	33.76343	78.53429
55	440	4	K2103	33.76343	33.76343	67.52686
56	518	4	K0403	33.76343	40.68514	74.44857
57	189	1	K1804	28.00571	34.18571	62.19142
58	189	1	K1804	34.18571	34.18571	68.37142
59	189	1	K1804	34.18571	34.18571	68.37142
60	327	4	K1502	21.50629	4.257714	25.76400
61	327	4	K1502	4.257714	4.257714	8.51543
62	327	4	K1502	4.25771	4.25771	8.51543
63	242	7	K1202	13.30571	25.56286	38.86857
64	380	7	K1203	25.56286	25.56286	51.12572
65	83	2	K0603	0.5554286	23.95886	24.51429
66	83	2	K0603	23.95886	23.95886	47.91772
67	393	7	K0401	50.07714	58.24857	108.32571
68	19	8	K1503	62.47714	17.53429	80.01143
					total =	**3347.52909**

Table 2 shows the result of the model. The time spent was reduced to 3031.15048 seconds.

Table 2: Solution of the mathematical model of the AS/RS system

i	product	buffer	channel	from channel to buffer (seconds)	From buffer to channel (seconds)	Total (seconds)
1	333	7	8	24.37143	41.90572	66.27715
2	518	1	4	11.66286	28.00571	39.66857
3	189	3	18	36.54829	25.64314	62.19143
4	56	6	5	8.171429	49.93428	58.105709
5	374	1	10	23.92000	3.49143	27.41143
6	18	4	16	16.17086	13.33486	29.50572
7	392	1	7	26.01429	15.74857	41.76286
8	392	1	7	15.74857	15.74857	31.49714
9	144	7	19	45.99143	8.02857	54.02000
10	183	4	11	25.59200	12.08514	37.67714
11	446	5	13	16.30914	8.137714	24.446854
12	189	3	18	0.2231429	25.64314	25.8662829
13	446	5	13	17.28229	8.13771	25.42000
14	425	2	19	4.64114	34.14686	38.78800
15	380	8	12	3.8	29.79143	33.59143
16	547	7	14	25.56286	17.39143	42.95429
17	425	2	19	8.726857	34.14686	42.873717
18	397	6	22	12.25714	24.51429	36.77143
19	547	7	14	20.28572	17.39143	37.67715
20	440	3	21	4.30886	37.90028	42.20914
21	425	2	19	42.31829	34.14686	76.46515
22	170	3	20	29.72886	33.81457	63.54343
23	355	8	18	7.885714	0.2857143	8.1714283
24	425	2	19	30.06114	34.14686	64.208
25	170	3	20	29.72886	33.81457	63.54343
26	355	8	18	7.885714	0.2857143	8.1714283
27	606	5	17	17.28229	13.19657	30.47886
28	606	5	17	13.19657	13.19657	26.39314
29	355	8	18	4.371428	0.2857143	4.6571423
30	428	6	7	8.171429	41.76286	49.934289
31	428	6	7	41.76286	41.76286	83.52572
32	183	4	11	28.428	12.08514	40.51314
33	440	4	21	12.08514	33.76343	45.84857
34	440	4	21	33.76343	33.76343	67.52686
35	355	8	18	11.97143	0.28571	12.25714
36	355	8	18	0.28571	0.28571	0.57142
37	19	8	15	0.28571	17.53429	17.82000
38	606	5	17	0.0334	13.19657	13.22997
39	547	7	14	0.1428571	17.39143	17.5342871

i	product	buffer	channel	from channel to buffer (seconds)	From buffer to channel to which they are assigned (seconds)	Total (seconds)
40	606	5	17	4.052	13.19657	17.24857
41	547	7	14	0.1428	17.39143	17.53423
42	606	5	17	4.052	13.19657	17.24857
43	242	7	12	0.14286	25.56286	25.70572
44	392	1	7	4.68	15.74857	20.42857
45	322	1	4	15.74857	28.00500	43.75357
46	606	5	17	44.90914	13.19657	58.10571
47	380	7	12	0.1428	25.56286	25.70566
48	425	2	19	0.5554	34.14686	34.70226
49	393	7	4	8.02857	58.24000	66.26857
50	189	1	18	28.00571	34.18571	62.19142
51	170	3	20	25.64314	33.81457	59.45771
52	518	4	4	29.6777	40.68514	70.36284
53	327	4	15	40.68514	4.25771	44.94285
54	327	4	15	4.25771	4.25771	8.51542
55	327	4	15	4.25771	4.25771	8.51542
56	170	3	20	8.394571	33.81457	42.209141
57	170	3	20	33.814	33.81457	67.62857
58	170	3	20	33.81400	33.81457	67.62857
59	425	2	19	38.23257	34.14686	72.37943
60	83	2	6	34.14686	23.95886	58.10572
61	83	2	6	23.95886	23.95886	47.91772
62	189	1	18	19.834	34.18571	54.01971
63	11	6	3	8.17143	58.10571	66.27714
64	189	1	18	32.09143	34.18571	66.27714
65	11	6	3	8.17143	58.10571	66.27714
66	11	6	3	58.10571	58.10571	116.21142
67	11	6	3	58.10571	58.10571	116.21142
68	11	6	3	58.10571	58.10571	116.21142
					total =	**3031.15048**

The time is reduced from 3347.5290938 seconds to 3031.15048 seconds. For only 1 hour a profit of 316.3786138 seconds (5.2729 minutes) is obtained.

According to the system used in the current state in the company, the order in which AS/RS takes the products and puts them on their channels is based on the experience and in this case, many unnecessary movements are observed in the system. After running the Gams program using the mathematical model we have established, the optimum values are reached, the time profits obtained when we compare the current system assignments with the optimum values are as in Table

3. By virtue of the model that is clearly seen in the Table 3, an efficiency increase of 17.58% is achieved.

TABLE 3. Profit Table

Time Frame	**Profit**
1 hour	10.55 minutes
1 day	4.218 hours
1 month (30 days)	5.27 days
1 year	2.109 months

4. CONCLUSION

In this study, the time spent of the AS/RS used in the logistics sector is aimed to be minimized. For this purpose, we propose a mathematical model. In addition, we use Excel Macro for the automatic creation of the parameters A and D matrices. We solved the problem for the proposed mathematical model. In the current system, 3347.5290938 seconds is needed to move all products within an hour. The solution of the proposed mathematical model gives 3031.15048 seconds. The time waste is reduced by 17.58%. This means that 2.109 months is gained within a year.

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D. Okyay
Eskisehir Technical University, Faculty of Engineering, Department of Industrial Engineering, Iki Eylul Campus, 26555 Tepebasi / Eskisehir/TURKEY
E-mail address: damlaokyay@anadolu.edu.tr

M. Mutlu
Eskisehir Technical University, Faculty of Engineering, Department of Industrial Engineering, Iki Eylul Campus, 26555 Tepebasi / Eskisehir/TURKEY
E-mail address: mujganmutlu@anadolu.edu.tr

G. Dinc Yalcin
Eskisehir Technical University, Faculty of Engineering, Department of Industrial Engineering, Iki Eylul Campus, 26555 Tepebasi / Eskisehir/TURKEY
E-mail address: gdinc@eskisehir.edu.tr

R. Kasimbeyli
Eskisehir Technical University, Faculty of Engineering, Department of Industrial Engineering, Iki Eylul Campus, 26555 Tepebasi / Eskisehir/TURKEY
E-mail address: rkasimbeyli@eskisehir.edu.tr