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Class Based Storage with Mixed Integer Linear Programming Approach for Hazardous Materials Storage

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The paper presents storage location assignment problem using a new mixed integer linear programming approach for class based storage assignment in hazardous materials storage. Class-based storage strategy is widely used in practical division of all stored items into a number of classes according to their turnover. Material safety data sheets are used for determining the special needs of storing criteria. Storage location assignment problem problem is solved using a new proposed mixed integer linear programming model. Main objective of our approach is directed to a class of items with higher turnover allocated to region closer to the warehouse depot. As a result, materials are assigned onto dedicated storage areas while considering the storage constraints of item-to-location and item-to-item in chemical warehouse. Moreover, the item-to-location constraints mean that the item has specified characteristics and needs to be stored into specified racks. For item-to-item constraints, some items should not be stored close to each other. These constraints confine the storage assignment strategy environment. Mixed integer linear model is solved using the Branch and Bound algorithm to minimize travelling distance inside the warehouse. The results indicated that the proposed approach improved the picking efficiency significantly and decreased prevalence of all unexpected situations such as death due to danger, injury, and trouble.

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1. Introduction

Hazardous material storages (HMS) store easily flammable chemical substances, corrosive, toxic, oxidizing, explosive substances, and compressed gases. Some precautions have been taken because of several possible risks in these warehouses. Implementations of several tools or applying strict rules provide safety in HMS where warehouse optimisation and management subjects are generally ignored in practice.

Turkish Chemical Manufacturers Association translates a document being written by German Chemical Manufacturers Association related with mixed type of hazardous material storages [1].

According to the International Labour Organization (ILO) 24% of major chemical accidents happen in warehouses. The risks usually occur when chemical materials are moved in warehouse area. For that reason, some precautions must be taken when chemical materials are moved so the transportation of the chemical materials should be reduced in storage area. This will reduce the accidental risks in HMS. If there are some undesirable circumstances in package of products like smash, blow-out, or leakage, they should move into quarantine area (QA). Products are with possibility to face this unexpected circumstances, should be stored closer to QA [2–4].

The classes of chemical materials interaction matrix are shown in Table I.

Chemical materials must not be able to react with each other in warehouse areas. When it is only considered with this point of view, warehouse optimisation and management can be disregarded that chemical materials must be moved more than needed. This attitude increases risks of unexpected circumstances. This study presents an approach where not only chemical products should be stored by hazards parameters, but also the movements of the chemical materials are reduced [6].

2. Mixed integer linear programming model

Specific characteristics and possible reactions of products have been considered during the mixed type storage of chemical products. After the material safety data sheets (MSDS) of stored materials must be examined carefully, they should be stored by minimizing the movement of materials in warehouse. For that reason, a mixed integer linear programming (MILP) model was built for assigning materials to storage areas.

Minimize

$$f(x)=\sum_{i=1}^{I}\sum_{j=1}^{J}H_i t_j x_{ij}+\sum_{i=1}^{I}\sum_{j=1}^{J}\frac{T_i}{S_i}d_j x_{ij}, \tag{1}$$

$$\sum_{i=1}^{I}x_{ij}=1 \quad \text{for all } j, \tag{2}$$

$$\sum_{j=1}^{J}x_{ij}=1 \quad \text{for all } i, \tag{3}$$

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TABLE I

The classes of chemical materials interaction matrix

	Flammable gasses	Nonflammable and nontoxic gasses	Toxic gasses	Flammable liquids	Flammable solids	Spontaneous combustion	The hazardous substances having been contact with water	Oxidant	Organic peroxides	Toxic	Corrosive
Flammable gasses	A	E	C	B	B	D	B	D	D	C	D
Nonflammable and nontoxic gasses	E	A	B	E	E	E	E	B	E	B	B
Toxic gasses	C	B	A	C	C	C	C	C	C	B	B
Flammable liquid	B	E	C	A	B	D	B	D	D	C	B
Flammable solids	B	E	C	B	A	D	B	D	D	C	B
Spontaneous combustion	D	E	C	D	D	A	B	D	D	C	B
The hazardous substances having been contact with water	B	E	C	B	B	B	A	D	D	C	D
Oxidant	D	B	C	D	D	D	D	A	D	F	D
Organic peroxides	D	E	C	D	D	D	D	D	A	F	D
Toxic	C	B	B	C	C	C	C	F	F	A	B
Corrosive	B	B	B	B	B	B	D	D	D	B	G

A — compatible materials; B — compatible but MSDS should be checked; C — usually non-reacting materials; D — possible reaction to each other; E — even if the products are oxidant, D is valid, in other cases B; F — even if the products are flammable, D is valid, in other cases B; G — both a product is a strong acid and the other is a strong alkaline D is valid, in other cases A [5].

$$R_{kl} + x_{kj} + x_{l(j-1)} + x_{l(j+1)} \leq 2 \quad \text{for all } jkl \text{ and } k \neq l, \tag{4}$$

$$R_{kl} = (0,1) \quad \text{for all } k \text{ and } l, \tag{5}$$

$$x_{ij} = (0,1) \quad \text{for all } i \text{ and } j, \tag{6}$$

where I — total product number, J — total storage number, H_i — hazard parameters of product i, S_i — storage volume for product i, T_i — frequency of product i, d_j — distance of storage j to I/O point, t_j — distance of storage j to QA and

$$x_{ij} = \begin{cases} 1 & \text{if product } i \text{ assign to storage } j \\ 0 & \text{other case} \end{cases}$$

$$R_{kl} = \begin{cases} 1 & \text{if product } k \text{ react to product } l \\ 0 & \text{other case} \end{cases}$$

The objective function (1) of the proposed MILP model, which is given above, minimizes the total transportation distance by assigning the products to storage areas. Equation (2) determines the storing of a single type of product in any storage area. Equation (3) provides assignment of any product type to only a storage area. Equation (4) ensures to block the item to item reactions. Equations (5) and (6) determine the variables as binary.

3. The problem

Class based storage strategy which minimizes total order picking time or distance, confines to determine an assignment of items to locations in a warehouse. The frequency of products are used when the problem is modelled. High frequency of products should be stored closer to depot for minimizing the movement. At the same time, the chemical products that have possibility to react each other should be stored closer to the QA and far away from each other.

4. Case study

In this study, an automotive company's hazardous raw material storage is examined. The MSDS of stored products in warehouse are analysed and the products are separated into 12 different classes. Frequency parameters, hazard parameters, the distance of storage areas to depot, and the distance of storage areas to QA are presented in Table II.

The proposed MILP model is solved using the Branch and Bound algorithm with the parameters in Table II. The high frequency products are assigned closer the depot area using the proposed model. The high hazard products are stored closer to QA. Both class 6 and 1 and class 4 and 7 have possibility to react each other, so the proposed model assigns these classes far away among each other like in Fig. 1.

TABLE II

MILP model parameters

	1	2	3	4	5	6	7	8	9	10	11	12
d_j	6	9	12	15	3	6	9	12	6	9	12	15
t_j	15	12	9	6	12	9	6	3	15	12	9	6
H_i	0.28	0.15	0.42	0.55	0.21	0.36	0.62	0.45	0.17	0.75	0.59	0.68
T_i	0.30	0.42	0.27	0.55	0.65	0.32	0.49	0.68	0.25	0.38	0.48	0.58

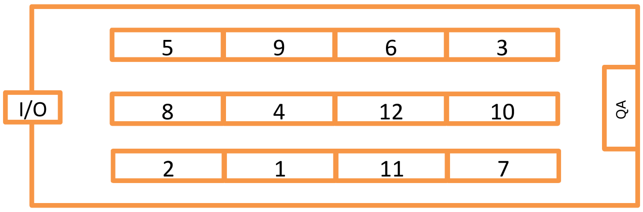

Fig. 1. The assignment of chemical material classes.

5. Conclusion

This study determines the class-based storage strategy for chemical products with a new MILP approach. Main objective of our approach is to assign a class of items with higher turnover allocated to region closer to the warehouse depot. The hazard parameters of products are used for assigning the products closer to QA. Also, the chemical materials assign in dedicated storage areas with considering item-to-item constraint for minimizing risk of unexpected circumstances. Consequently, this study confines that the storage assignment strategy in HMS is more environmental.

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