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A GENETIC ALGORITHM FOR THE ALLOCATION OF DANGEROUS GOODS CONTAINERS IN A STORAGE YARD FOR FREIGHT VILLAGES AND DRY PORTS

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ABSTRACT

Increased trade volume between the countries and the resulting increase in container scheduling causes both space allocation problems and traffic congestion at ports, storage yards and terminals, finally leading to occupational accidents. Although there are various studies conducted on containers for non-dangerous goods and handling of them in storage yards, the number of studies on the allocation of dangerous goods containers is limited. Especially the recent explosion at the Tianjin Industrial Port, which was considered to be originated from dangerous goods, highlighted that handling and storage of dangerous goods at the yards must be carried out with more care and attention. This study deals with the optimization of space allocation for dangerous goods containers in the yards for freight villages, dry port and space efficiency for storage yards with limited space. During the analysis, the requirements specified in the segregation table for dangerous goods are taken into account.

Keywords: Dangerous Goods, Container Allocation, Genetic Algorithm

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TEHLİKELİ MADDE KONTEYNERLERLERİNİN LOJİSTİK KÖY VE KARA LİMANLARINA AİT DEPOLAMA ALANI İÇİNDEKİ YERLEŞİMİNİN GENETİK ALGORİTMA İLE BELİRLENMESİ

ÖZ

Ülkeler arası ticaret hacminin artması ve buna bağlı olarak artan konteyner döngüsü limanlarda, depolama alanlarında ve terminallerde hem alan hem de trafik sıkışıklıklarına yol açmakta ve iş kazalarına da neden olmaktadır. Bu anlamda her ne kadar tehlikeli madde taşımayan konteynerlerle ilgili ve bunların alan içinde yerleşimlerinin incelendiği pek çok çalışma ile karşılaşılsa da, tehlikeli madde taşıyan konteynerlerin depolama alanı içindeki yerleşiminin incelendiği çalışma çok azdır. Özellikle yakın zamanda Tianjin Endüstriyel Limanı'nda meydana gelen ve tehlikeli maddelerin karışımından kaynaklı olduğu düşünülen patlama, depolama alanlarında tehlikeli maddelerin istiflenmesi ve depolanmasının daha özenli ve dikkatli yapılması gerektiğini ortaya koymuştur. Çalışma tehlikeli madde konteynerlerinin lojistik köy ve kara limanlarına ait depolama alanı içindeki optimizasyonu ve depolama alanı geniş olmayan alanlarda alan verimliliğini sağlamakla ilgilenmektedir. Konu incelenirken, tehlikeli madde ayrım tablosunda belirtilen gereklilikler de esas alınmıştır.

Anahtar Kelimeler: Tehlikeli Madde, Konteyner Yerleşimi, Genetik Algoritma

INTRODUCTION

In today's world where the transportation cost minimization is a critical issue for companies, maritime transportation and containerization are of high importance. Especially in maritime transportation where containers are frequently used, interaction of goods categorized as dangerous is governed by various laws, thus requiring careful stowage of containers in the ships as well as their careful handling in the storage yards. The accidents in Turkey or around the world due to omissions and negligence that have emerged or may emerge during the transportation of dangerous goods cause environmental damage as well as losses of life and property. Especially the recent explosion at the Tianjin Industrial Port, which was considered to be originated from dangerous goods, highlighted that handling and storage of dangerous goods at the yards must be carried out with more care and attention. So, it is critical issue for freight villages and dry ports which have storage yards for dangerous goods containers.

1. FREIGHT VILLAGE AND DRY PORT

Freight villages are special transport nodes within supply chains which provide handling, transportation, export-import operations and other value added services to the relevant parties (Aydın ve Öğüt, 2011).

Karadeniz ve Akpınar (2010) mentioned that freight villages concept was introduced firstly in USA and the development of the industry was a catalyst for this development and it is important that such villages mostly located in the outside of the metropolitan areas.

Tsamboulas ve Kapros (2002) highlighted that a freight village constitutes an important place in transport chain which is an intermodal terminal where the related goods changed from one mode to the other.

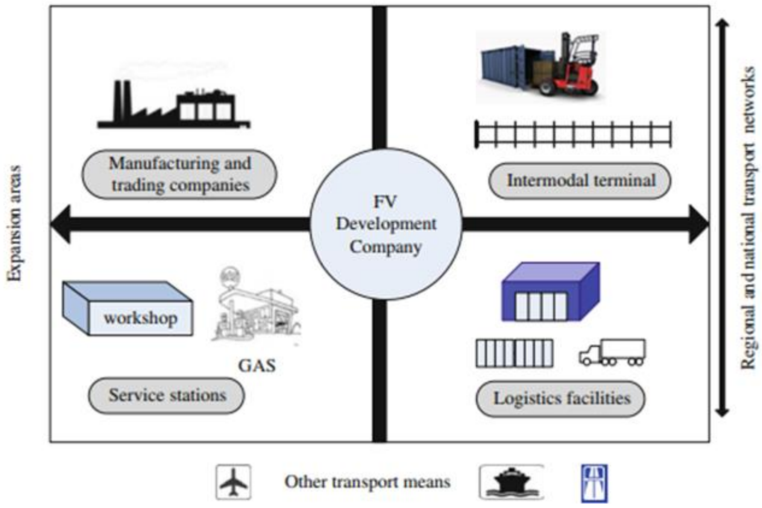


Figure 1- Basic functions of a freight village
(Source: Wu and Haasis, 2013, 65)

As seen in Figure-1 the basic functions of freight villages are mostly related with manufacturing organizations, logistics facilities, and other workshop stations.

Due to the increasing congestions in ports, container terminals the dry port concept becomes an important and useful areas for decreasing the burden of freight and traffic congestion from ports and terminals. The dry port concept was firstly defined by UNCTAD (United Nations Conference on Trade and Development) as an inland terminal which bill of lading operations of shipping lines is going to be issued (UNCTAD, 1982).

Leveque and Roso (2002) define dry port concept as that is an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardised units as if directly to a seaport.

Crainic et al. (2015) mentioned an extended gateway which the container and sorting operations, logistics operations and the other value added services are able to operated in an inland locations where more space is available. Thus, dry ports acts like an extended gateways for container terminals in order to decrease the congestion.

Roso (2009) has defined the dry port concept as:

“The dry port concept is based on a seaport directly connected by rail to inland intermodal terminals, where shippers can leave and/ or collect their goods in intermodal loading units as if directly at the seaport. In addition to the transhipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers and customs clearance are also available at dry ports."

Henttu and Hilmola (2011) also highlighted that dry ports are parts of the intermodal transportation and they have connections directly to the rail, seaport and other mediums of transportation.

According to Roso et al. (2009) there are some types of dry ports which mentioned below:

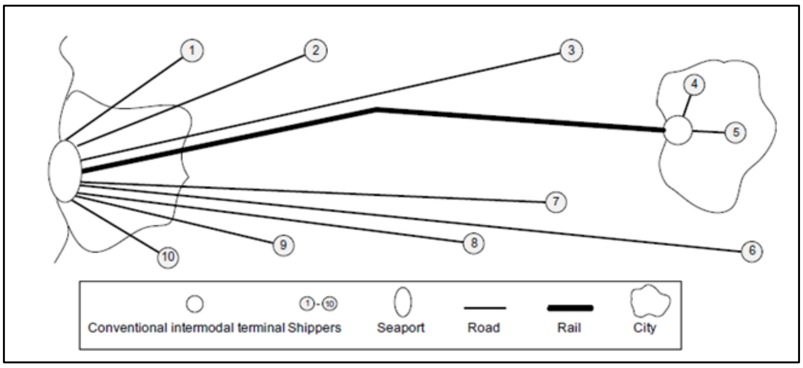


Fig. 1: A seaport and its connection to hinterland
(Roso et al. 2009)

As it can be seen in Figure 1, the seaport has a connection to the hinterland with both rail and road transportation systems. Furthermore, as Leveqe and Roso (2002) mentioned there are distant, mid-range and close distant dry ports. This classification was mentioned due to their range to related ports.

2.CONTAINERIZATION

Nowadays, the trade intensity which started with the globalization continues to progressively increase. Therefore, ensuring transportation of goods to their destination safely and without any loss is of great importance for the parties involved in the supply chain. At this point, containerization provides faster transportation of goods to the destination without any damage.

Malcolm P. McLean's idea of developing a means of transportation which serves the same purpose as standard transportation is considered as the beginning of containerization (Ateş et al. 2010: 85). Cudahy (2006: 6) indicated that Ideal X was the first ship that was used for containerization.

The word container is derived from the English verb “to contain” and has occupied a place in the literature and field meaning an enclosed and reusable transportation tool of standard size which can be transferred from one transport vehicle to another and is suitable for mechanical loading (MEB, 2011: 32).

This study deals with the storage and transportation of dangerous goods in containers. In this sense, the container types based on their usage and size are as follows (MEB, 2011: 41):

- Break (dry) bulk containers
- Bulk container
- Insulated containers
- Special purpose containers

In this study, the containers used for shipping the dangerous goods are divided into two as 20′ containers and 40′ containers. Table 1 and Table 2 shows inside and outside dimensions of these containers.

Table 1: Inside and outside dimensions of the 20′ containers

<table>
<tr><th colspan="9">20′ Steel Dry Cargo Container</th></tr>
<tr><td colspan="3">External Dimensions</td><td></td><td colspan="5">Internal Dimensions</td></tr>
<tr><td>Length</td><td>Width</td><td>Height</td><td rowspan="3"></td><td>Length</td><td colspan="2">Width</td><td colspan="2">Height</td></tr>
<tr><td>19′101/2"</td><td>8′0"</td><td>8′6"</td><td>19′41/5"</td><td colspan="2">7′81/2"</td><td colspan="2">7′97/8"</td></tr>
<tr><td>6.06m</td><td>2.44m</td><td>2.59m</td><td>5.90m</td><td colspan="2">2.35m</td><td colspan="2">2.39m</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="3">Weight</td><td rowspan="4"></td><td colspan="5">Door</td></tr>
<tr><td>Max. Gross</td><td>Tare</td><td>Payload</td><td colspan="2">Width</td><td colspan="3">Height</td></tr>
<tr><td>52,910lb</td><td>5,140lb</td><td>47,770lb</td><td colspan="2">7′-81/8"</td><td colspan="3">7′-53/4"</td></tr>
<tr><td>24,000kg</td><td>2,330kg</td><td>21,670kg</td><td colspan="2">2.343m</td><td colspan="3">2.280m</td></tr>
</table>

Source: http://www.mardas.com.tr/LimanIsletme/mardas.aspx?id=32&lang=en

Table 2: Inside and outside dimensions of the 40′ containers

<table>
<tr><th colspan="9">40′ Steel Dry Cargo Container</th></tr>
<tr><td colspan="3">External Dimensions</td><td></td><td colspan="5">Internal Dimensions</td></tr>
<tr><td>Length</td><td>Width</td><td>Height</td><td rowspan="3"></td><td>Length</td><td colspan="2">Width</td><td colspan="2">Height</td></tr>
<tr><td>40′0"</td><td>8′0"</td><td>8′6"</td><td>39′53/4"</td><td colspan="2">7′85/8"</td><td colspan="2">7′97/8"</td></tr>
<tr><td>12.19m</td><td>2.44m</td><td>2.59m</td><td>12.03m</td><td colspan="2">2.35m</td><td colspan="2">2.38m</td></tr>
<tr><td colspan="9"></td></tr>
<tr><td colspan="3">Weight</td><td rowspan="4"></td><td colspan="5">Door</td></tr>
<tr><td>Max. Gross</td><td>Tare</td><td>Payload</td><td colspan="2">Width</td><td colspan="3">Height</td></tr>
<tr><td>67,200lb</td><td>8,820lb</td><td>58,380lb</td><td colspan="2">7′-81/8"</td><td colspan="3">7′-53/4"</td></tr>
<tr><td>30,480kg</td><td>4,000kg</td><td>26,480kg</td><td colspan="2">2.343m</td><td colspan="3">2.280m</td></tr>
</table>

Source: http://www.mardas.com.tr/LimanIsletme/mardas.aspx?id=32&lang=en

3. PREVIOUS STUDIES ON THE ALLOCATION OF CONTAINERS IN STORAGE YARDS

Han et al. (2008: 698) indicates that multi-level stacking of containers is a common practice in places where the volume of container traffic is heavy and the land is scarce, emphasizing that this cause traffic congestion of the vehicles used in the area. In their study, they generate a yard template to ensure transportation with minimum number of vehicles in the storage yard where the handling of containers are carried out. Kim and Kim (2002: 821-822) pointed out the lack of studies on container yards and dealt with minimum space allocation for containers and cost-minimization for cranes. Zhang et al. (2003: 887) studied the storage space problems at container terminals and reported that this problem was related to all resources used at the terminal (quay cranes, yard cranes, information technologies etc.). They solved this problem with the use of a rolling-horizon planning method where the problem was divided into two levels for each planning horizon and each level was formulated as a mathematical programming model.

Kozan and Preston (2006: 520) developed a model that determines the optimal storage strategy and container-handling schedule. Their model allows for minimum handling of export containers in an area from the storage yard to the ship as well as providing information about the transfer times of containers.

Bazzazi et al. (2009: 45) developed a genetic algorithm model to solve the storage space allocation problem and used this model on the yard that included regular, empty and refrigerated containers in order to minimize the storage and retrieval times of containers.

Another field of study in the literature that attracted interest other than those conducted on handling of full containers in the storage yards is the storage of empty containers and keeping them available.

Lai et al. (1995: 687) indicated that proper allocation of empty containers that were transported from the Middle East to ports in the Far East had a decreasing impact on the relevant costs and provision of empty containers when requested by customers increased the customer satisfaction. In their study, they employed heuristic search to reveal the relevant costs.

Another issue that has been emphasized is whether the containers are import or export containers. Kim and Kim (1999: 822) studied how to allocate the import containers in storage yards and aimed to minimize the number of rehandles. They analyzed the cases in which the arrival rate of import containers was constant, cyclic, and dynamic.

Kim et al. (2000: 90) developed a model that allows determining the storage location of export containers considering its weight. The dynamic programming model they formulated determines the storage location to minimize the number of relocation movements for the loading operation.

The studies on allocation of containers in the storage yards inside or outside the ports are mostly focused on reducing the vehicle movements and cost minimization. However, there is a limited number of studies in the literature conducted on optimization of space allocation for dangerous goods containers. Aiming to increase space efficiency, this study tries to deal with optimizing the allocation of dangerous goods containers based on the segregation groups in the IMDG CODE (International Maritime Dangerous Goods Code) defined by the IMO (International Maritime Organization).

4. CONTAINERIZATION OF DANGEROUS GOODS

The accidents in Turkey or around the world due to omissions and neglect that have emerged or may emerge during the transportation of dangerous goods cause environmental damage as well as losses of life and property. Especially the recent explosion at the Tianjin Industrial Port is known to have killed more than 50 people and caused significant losses (http://www.bbc.com/news/world-asia-china-33844084, Date of access: 26/08/2015).

The problems experienced during the transportation and storage of dangerous goods can be of infrastructural, human or environmental origin and the irreversible nature of the results led to the countries and various decision making bodies to make some arrangements about this situation.

Table 3 shows the authorized institutions and conventions regarding the transport of dangerous goods.

Table 3: Current conventions on the transport of dangerous goods

Transportation Mode	Agency	Convention
Maritime	IMO (International Maritime Organisation)	IMDG-CODE
Railway	OTIF (Intergovernmental Railway Organisation)	RID
Airway	ICAO (International Civil Aviation Organisation)	TIs
Inland Waterway	UNECE (United Nations Economic Comission for Europe)	ADN
Road	UNECE (United Nations Economic Comission for Europe)	ADR

Source: Evaluation of EU Policy on the Transport of Dangerous Goods Since 1994, 2005:11

In a study on the management of dangerous goods in a container terminal, Hamidou et al. (2014:2) reported that many operations occur within the storage area and these operations require respecting many rules in order to guarantee some important criteria such as the port safety. Combining a cellular automation and a multi-agent system, they developed a model with an aim to improve the container terminal configuration by putting security into the forefront. Table 4 shows the IMDG classification and segregation groups. In the table, 1 represents 3 m, 2 represents 6 m, 3 represents 12 m, 4 represents 24 m and X represents 0 m separation distance (ASEAN – German Technical Cooperation Sustainable Port development in the ASEAN Region, 2011:34).

Table 4: IMDG classes and segregation groups

CLASSES		***2.1***	***2.2***	***2.3***	***3***	***4.1***	***4.2***	***4.3***	***5.1***	***5.2***	***6.1***	***8***	***9***
Flammable gas	***2.1***	x	x	x	2	1	2	x	2	2	x	1	x
Non-Flammable, compressed gas	***2.2***	x	x	x	1	x	1	x	x	1	x	x	x
Toxic or poisonous gas	***2.3***	x	x	x	2	x	2	x	x	2	x	x	x
Flammable liquids	***3***	2	1	2	x	x	2	1	2	2	x	x	x
Flammable solids	***4.1***	1	x	x	x	x	1	x	1	2	x	1	x
Spontaneously combustible solids	***4.2***	2	1	2	2	1	x	1	2	2	1	1	x
Combustible solids when in contact with water	***4.3***	x	x	x	1	x	1	x	2	2	x	1	x
Oxidizer	***5.1***	2	x	x	2	1	2	2	x	2	1	2	x
Organic peroxide	***5.2***	2	1	2	2	2	2	2	2	x	1	2	x
Toxic substances	***6.1***	x	x	x	x	x	1	x	1	1	x	x	x
Corrosive substances	***8***	1	x	x	x	1	1	1	2	2	x	x	x
Miscellaneous dangerous substances and articles	***9***	x	x	x	x	x	x	x	x	x	x	x	x

Source: Handling Dangerous Goods in Ports Participants' Manual, 2011:32

The following process applies as per Section 2, Article 11 (n) of the "Regulation on the Carriage of Dangerous Goods by Sea" (http://www.resmigazete.gov.tr/eskiler/2015/03/20150303-6.htm, Date of Access:27/08/2015):

"A storage area shall be allocated for dangerous goods containers in accordance with the rules for separation and stowage, and all kinds of fire safety, environmental safety and other safety measures required for the storage area shall be taken. While providing loading, unloading and limbo services for dangerous goods, the ship authorities and those providing the abovementioned services shall take the necessary safety measures against heat and other hazards, especially during hot weather. Inflammable materials shall be kept away from spark ignition processes and no spark-ignition vehicle or device shall be operated in the yards used for handling of dangerous goods." According to the Mersin International Port, Procedure for Loading, Unloading and Transport of Dangerous Goods at the Port, it is the agencies and owners of the goods that shall be held responsible for ensuring that dangerous goods containers meet the requirements specified in the International Convention for Safe Containers (CSC, 1972) or ensuring that packing/containers of dangerous goods are intact and have labels including necessary information, and the labels are readable and not damaged (MIP Management Inc., 2007:5).

As specified in the relevant Article in the legislation regarding the containerization and storage of dangerous goods, allocation of a proper storage area conforming to the separation and stowage rules, especially involves the efficient use of the ports and storage yards with limited storage space. Therefore, the maintenance of security and efficient use of storage areas are both important.

5. GENETIC ALGORITHM

This study deals with the development of a model that will allow minimum space allocation for the dangerous goods containers in a storage yard, considering the IMDG segregation restrictions and departure times of the containers. The aim is to develop an allocation plan that will meet the requirements in the segregation table given above as well as the sequence of the containers to be transferred based on the customer needs. In the problem addressed in this study, up to 15 containers, exact methods and optimal solutions were achieved within effective time required for solution. However, the problem becomes NP-hard when the number of containers increases, resulting in failure in achieving optimal solutions in effective times. Therefore, use of heuristic methods is required when the number of containers increases.

In this sense, a genetic algorithm method was used both to ensure the efficient use of the storage area and to achieve the other aims of the study.

The idea of genetic algorithm was first introduced by Holland and his students in 1975. The basic principle of genetic algorithms is “survival of the fittest”. Whitley (1994:1) indicates that genetic algorithms are population based models in which new sample points in a search space are generated through selection and recombination. Among the metaheuristic methods, GA is a random search technique aiming to find the optimal solution in a complex search space (Mori and Tseng, 1997:135).

In the genetic algorithm technique where every individual in the population are coded to chromosomes that show the potential solution, the objective function determines the fitness of each individual and the fitness shows to how optimal the solution is (Kulluk and Türkbey, 2004:2).

Xiao (2008: 798) summarizes the implementation procedure of GAs as follows:

Step 1: t=0
Step 2: Initialize population P(t)
Step 3: **repeat until** {termination criterion is satisfied}
Step 4: Evaluate all individuals in P(t)
Step 5: Generate offspring from P(t)
Step 6: Copy offspring to P(t)
Step 7: t = t+1

Mitchell (1998:124) mentions that GAs have been proposed for solving the combinatorial optimization problems experienced during the real–world applications. GA provides proper solutions to the NP-hard problems such as the problem of determining the allocation of dangerous goods in storage yards that were examined within the scope of this study. GAs do not guarantee the optimal solution, but usually gives the near-optimal solutions. However, since they do not search the whole space, they accomplish an effective search, achieving solution in a shorter period of time compared to the traditional methods (Goldberg, 1989:3). GAs can quickly find a near-optimal solution in a large solution space. Nowadays, the competitive business environment compels the businesses to find acceptable solutions in a quicker way, instead of finding optimal ones in a slower way (Kocamaz and Çiçekli, 2010: 200). In GAs, the smallest unit is called a gene that represents meaningful information on its own. The genes combine to form the chromosomes. Each chromosome consisting of genes has a structure that encodes the solution to the problem.

GAs use three operators: selection, crossover and mutation. Figure 2 shows the image of a chromosome, genes and mutation in an individual.

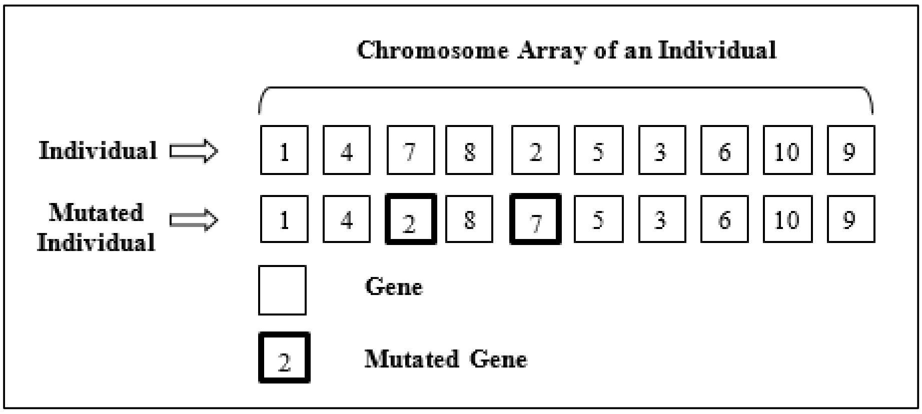


Figure 2: Image of a chromosome, genes and mutation in an individual.

6. IMPLEMENTATION

This study, carried out in a company that provides logistic services, sought to optimize the allocation of dangerous goods containers in a storage yard. Upon the request by the company, the name of the company was not revealed. In the problem addressed within the scope of the study, there are 78 20' dangerous goods containers with different departure times during the day chosen. Priority deadlines were set based on the departure times of the containers. The departure times of the containers were sorted from early departure to late departure, and the priority deadlines were defined in the ascending order. Table 5 shows information regarding the IMDG and priority deadlines. Containers that do not have an early deadline, are required to be allocated in a way not to impede the handling of other containers. The study aims to minimize the space allocation for the dangerous goods containers in a storage yard in line with the IMDG segregation restrictions and departure times.

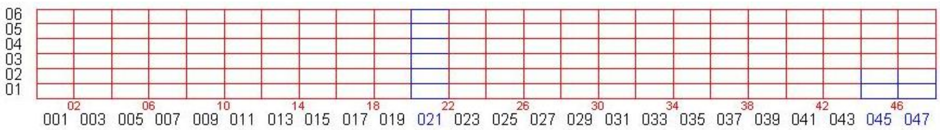
Table 5: Information about the containers

Container No	*Imdg Code*	*Priority Deadline*	*Container No*	*Imdg Code*	*Priority Deadline*	*Container No*	*Imdg Code*	*Priority Deadline*
1	2.1	2	27	6.1	5	53	9	5
2	2.1	2	28	8	3	54	4.3	2
3	9	3	29	9	2	55	9	4
4	9	3	30	3	4	56	9	1
5	3	3	31	3	4	57	4.1	2
6	3	2	32	3	2	58	9	1
7	9	4	33	9	5	59	2.3	3
8	4.3	3	34	5.1	4	60	9	3
9	9	4	35	3	1	61	9	3
10	3	2	36	3	1	62	3	2
11	3	1	37	3	2	63	3	2
12	2.2	4	38	3	2	64	9	3
13	3	1	39	2.3	4	65	9	3
14	9	5	40	5.2	1	66	9	5
15	9	5	41	9	5	67	2.2	3
16	3	3	42	9	4	68	9	5
17	8	3	43	9	6	69	9	3
18	3	3	44	8	2	70	9	5
19	3	3	45	9	2	71	5.2	1
20	3	1	46	9	2	72	9	6
21	3	1	47	4.3	3	73	9	3
22	9	5	48	9	4	74	4.2	2
23	4.3	3	49	9	3	75	9	3
24	4.2	5	50	9	3	76	9	2
25	9	4	51	4.2	3	77	9	5
26	9	4	52	9	5	78	6.1	4

Dangerous goods containers require a space allocation. However, no optimization study has been carried out in this field to this date and the container allocation has been done only based on the IMDG segregation requirements. Table 6 shows the yard used for allocation of dangerous goods. RTG cranes are used in this yard. Between each lane, there is a 5m distance allocated for truck traffic.

RTG cranes can stack 6 containers horizontally and 5 containers vertically. In this storage yard, once the dangerous goods containers are stacked, other containers can be stacked over a certain amount of distance from the former. Therefore, minimization of the space allocated for dangerous goods containers is of high importance.

Table 6: Storage yard for the dangerous goods containers



In order to minimize the space allocation for the dangerous goods containers in the storage yard based on the IMDG segregation restrictions and departure times, a permutation-based genetic algorithm model was used. A chromosome was generated in a way to assign a gene to each place in which a container can be stacked. This chromosome was designed for stacking of 6x5x14=420 containers. In the objective function, the aim was to minimize the rectangular area, the corners of which were marked by the containers at the edges, in line with the specified restrictions.

In the objective function, the restrictions were priority deadlines and IMDG segregation requirements. GA aims to find the optimum value for the objective function instead of focusing on sub-optimization. Therefore, the restrictions were included in the objective function for minimization purposes. The model developed in this study can be reused with the incoming dangerous goods containers to the storage yards. An important point that needs to be considered is identification of the containers in the storage yard into the system. In doing so, no container stacking will be carried out in the specified locations.

In this sudy, Frontline Solver was used to solve problem. Population size is 200 and the maximum time without improvement is 60 seconds. Precision, convergence and mutation rate are decided by experiment. The parameters, such as convergence and mutation rate are determined at value which produces the best value and average of results, obtained by 25 trials for the initial population on this problem. From the results of experiments, precision is 0,000001, Convergence is 0,0001 and mutation rate is 0,075.

The model developed through GA was run 100 times and various solutions were obtained. The average solution time was 612 seconds. If the solutions are found insufficient, the time can be extended. Since the time was sufficient for this data set, no time extension was required. When the solutions obtained are examined, it can be seen that the containers are stacked in an average area of 38.7 containers. In the optimal solution, in conformity with IMDG segregation requirements and priority deadlines, 78 containers were stacked in an area of 36 containers (arranged as 6x6). The solution was found to be appropriate by the company. Table 7 shows the container allocation plan obtained from the solution, while Table 8 shows the priority deadlines for the relevant allocation plan. No container is available in the areas defined as "(empty)" in the tables.

Table 7: Container allocation plan obtained from the solution

	1	***3***	***5***	***7***	***9***	***11***
6	(empty) 40 58 71 72	(empty) (empty) (empty) 56 3	(empty) (empty) 2 45 1	(empty) (empty) (empty) 67 12	(empty) (empty) (empty) 69 34	(empty) (empty) (empty) (empty) (empty)
5	(empty) (empty) (empty) 60 7	(empty) (empty) (empty) 61 9	(empty) 54 47 23 8	(empty) (empty) 41 15 14	(empty) (empty) (empty) 59 39	(empty) (empty) (empty) (empty) (empty)
4	(empty) (empty) 26 25 22	(empty) (empty) (empty) 29 33	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)
3	(empty) (empty) (empty) 78 27	(empty) (empty) (empty) 76 49	46 73 65 64 42	(empty) 70 68 66 43	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)
2	21 20 19 18 16	13 11 10 6 5	(empty) (empty) 75 50 48	(empty) (empty) 44 28 17	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)

1	36 35 32 31 30	57 63 62 38 37	(empty) (empty) (empty) 77 52	(empty) (empty) (empty) 4 53	(empty) (empty) (empty) (empty) 55	(empty) (empty) 74 51 24

Table 8: Priority deadlines for the relevant allocation plan

	1	***3***	***5***	***7***	***9***	***11***
6	(empty) 1 1 1 6	(empty) (empty) (empty) 1 3	(empty) (empty) 2 2 2	(empty) (empty) (empty) 3 4	(empty) (empty) (empty) 3 4	(empty) (empty) (empty) (empty) (empty)
5	(empty) (empty) (empty) 3 4	(empty) (empty) (empty) 3 4	(empty) 2 3 3 3	(empty) (empty) 5 5 5	(empty) (empty) (empty) 3 4	(empty) (empty) (empty) (empty) (empty)
4	(empty) (empty) 4 4 5	(empty) (empty) (empty) 2 5	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)
3	(empty) (empty) (empty) 4 5	(empty) (empty) (empty) 2 3	2 3 3 3 4	(empty) 5 5 5 6	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)
2	1 1 3 3 3	1 1 2 2 3	(empty) (empty) 3 3 4	(empty) (empty) 2 3 3	(empty) (empty) (empty) (empty) (empty)	(empty) (empty) (empty) (empty) (empty)
1	1 1 2 4 4	2 2 2 2 2	(empty) (empty) (empty) 5 5	(empty) (empty) (empty) 3 5	(empty) (empty) (empty) (empty) 4	(empty) (empty) 2 3 5

CONCLUSION

Recent events highlighted the importance of the handling of dangerous goods containers in storage areas in accordance with the restrictions, first in terms of security of life, and then in terms of environmental and product safety.

The aim of the study was to minimize the space allocation for the dangerous goods containers in storage yards in line with the restrictions such as the IMDG segregation requirements and container departure times. These are critical issue for freight villages and dry ports which have storage yards for dangerous goods containers. The problem addressed within the scope of this study included 78 20' containers with different departure times on the day chosen. In the future studies, 40' containers will be included in the model. In order not to impede the vehicle traffic (trucks and handling equipment) in the area specified by the company, minimization of space allocation for dangerous goods containers were carried out within the specified restrictions and based on the distance table provided. In the optimal solution, in conformity with IMDG segregation requirements and priority deadlines, 78 containers were stacked in an area of 36 containers (arranged as 6x6).

In the future studies, this model is planned to be used with different data sets and restrictions and for different purposes.

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