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Editorial for Volume 11 Number 3: Maritime Platform Transport Problem of Solid, Special, and Dangerous Waste

Ocotlán Díaz-Parra

Universidad Politécnica de Pachuca, México.
ocotlan@diazparra.net

Abstract. The Maritime Platform Transport Problem of Solid, Special and Dangerous Waste consists of to minimize the monetary value of carrying different types of waste from one location to another location using ships. We present a mathematical model and the use CPLEX to find the optimal values to solve the Solid, Special and Hazardous Waste Transportation Problem of offshore platforms instances of Mexican state-owned petroleum company (PEMEX). The set of instances used are WTPLib real instances and the tool CPLEX solver to solve the Problem.
Keywords: Oil Platform, Transport Problem, Waste.

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1 Introduction

The problem of waste is the biggest environmental problem it faces the World and Mexico, caused by people and businesses. The problem of Waste affects to the PEMEX. PEMEX [1] is the biggest company of Mexico and Latin America, and the most important fiscal contributor of Mexico. It is of the few oil companies of the world that develops all the productive chain of the industry, from the exploration, to the distribution and commercialization of all the products. PEMEX operates in the Southeast offshore (Campeche Sound is the maritime area corresponding to the submarine prolongation of the Yucatan Peninsula in the Gulf of Mexico) about 100 offshore platforms in living permanently-being rotated about 5000 people.

The activities that are carried performed in PEMEX to generate different types of waste, which must be handled according to regulations to prevent and control pollution and avoid risks to the environment and the health of employees [1]. PEMEX [1] and Subsidiary Entities through the Standardization Committee and Subsidiary Entities created a standard of reference for waste management in marine Platforms in order to unify criteria, build on experiences and combine results national and international research [1].The reference standard [1] establishes the requirements for the comprehensive management of waste generated on offshore platforms (it does not apply to vessel processing, storage, tugs, suppliers, and service dynamic positioning).The types of waste are:

- INCOMPATIBLES. The Incompatible wastes are those which when mixed with water, other materials or wastes, react producing heat, pressure, fire, particles, gases or vapours.
- SPECIAL HANDLING. The special handling wastes are those generated in the productive processes, which have not the characteristics to be considered as hazardous or solid waste, or are produced by large generators of municipal solid waste.
- URBAN SOLIDS. The Urban solid waste are those resulting from the disposal of materials used in housing activities, products that are consumed and their containers, packaging or packing; also the waste coming from any other activity inside the platform always which are not considered as other waste.
- HAZARDOUS WASTE. The hazardous wastes are those that have some of the characteristics of corrosivity, reactivity, explosivity, toxicity, flammability, or contain infectious agents which give them their danger, as well as packaging, containers and packaging that have been contaminated when transferring to another site.

- BIOLOGICAL-INFECTIOUS HAZARDOUS WASTE. The Biological-infectious hazardous waste containing bacteria, viruses or other microorganisms with the capacity to cause infection or that contains or may contain toxins produced by microorganisms that cause adverse effects to live organisms and the environment.

The waste collected in the containers must be brought to the area compaction, once compacted must be placed in the supersacks. The supersacks must meet the following specifications [1]: a) Must be white polypropylene laminate of 0.27 kg/m2 (8 ounces per square yard), athickness of 2.2 mm.b) At the bottom should have two bands stevedore loading to be attached to a pair of handles.c) In the upper supersacks must have a mouth load of white polypropylene fabric laminating of 10 kg/m2 (3 ounces per square yard), 80 cm length connected to the top of the supersacks.d) The dimensions of supersacks should be of two types: Type A: 95 cm x 95 cm x 135 cm (1,218 m3). Type B: 85 cm x 85 cm x 85 cm (0.614 m3). e) Must have four handles on the top and four handles at the bottom. Each handle must be polypropylene and have a total length of 160 cm by 5 cm wide and 2.2 mm thick, must be doubly stitched zig zag 40 cm from each end of the main body and must supersacks protrude 80 cm.

Containers with lids, that are appropriately labelled for subsequent transport. In the case of scrap, because of its dimensions can be collected into containers, must be disposed of in the transfer area. The metal container used to transfer the offshore platform scrap the ship must comply with the following [1]: The dimensions may vary depending on the needs of the installation, one example of the dimensions is 2.50 m of length, 2.00 m of width, and 1.70 of high. Containers used for the collection, transfer, transfer and transport of hazardous waste, except medical waste must meet the following specifications [1]: a) The container must be designed for a capacity of 25 barrels and a maximum permissible load of 10 metric tons and should consider the following dimensions, High: 1 651.0 mm (65 in), width: 1 854.2 mm (73 in) and length: 2 438.4 mm (96 in). b) Structure made of structural steel ASTM A-36 or equivalent, envelope steel sheet of 6.35 mm (0.25 in) thick A-36, with structural reinforcement channels 101.6 mm (4 in) and thickness of 4.76 mm (0.1875 in) A-36 in periphery, Bases loaded by forklift manufacturer channels formed of 152.4 mm (6 in) and a thickness of 4.76 mm (0.1875 in) A-36, bottom, 4 hooks top of 25.4 mm (1 in.) thick A-36, 4 hooks bottom of 25.4 mm (1 in.) thick A-36 to move with crane, two lids on top, folding part, made of sheet 6.35 mm (0.25 in) thick A-36 packages on the shore and closing system, and primary corrosion coating and finishing.

For the management of biological-infectious hazardous waste generated in areas of health care (doctor or occupational health units), they must comply with [1]: A) Polyethylene bags. The bags must be mentioned red translucent polyethene, 200 gauge minimum and 300 minimum gauge translucent yellow, waterproof, free Chlorine, heavy metal content of no more than one part per million. The bags should be filled to about 80 percent of its capacity, must be closed with closure tracts before being landed marine platform. B) Deposits tight. Hermetic deposits must be rigid polypropylene, free Chlorine with heavy metal content of not more than one part per million, resistant to fractures and loss of contents from falling, destructible by physical methods, with a low penetration resistance of 12.5 Newtons in all its parts. Deposits of hazardous sharps waste must be red, which should allow for checking the volume occupied in it, must have a needle separator and an opening in the container must have a cover (s) of insurance and closing assembly permanently.

This paper proposes a new mathematical model to the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste, the proof that this problem is NP-Hard/NP-Complete Problem, the characterization of Solid, Special and Hazardous Waste Transportation Problem instances of PEMEX, and the solutions by the CPLEX solver.

2 Related Works

The Kalelkar and Brooks [2] and Shobrys [3] work represents the first attempt to treat the multiple objective framework in hazmat transportation explicitly. But the first Minimax method was proposed by Kuby et al. [4] in the context of "multicommodity flow" problems called the multi-commodity minimum cost flow model (MMCFM).

Fagerholt and Heimdal [5] solved the problem of transporting ballast (water) between ballast tanks on an offshore production platform to do this as quickly and efficiently, but also taking into account the security, stability and strength of the platform. They used two algorithms: one mixed integer programming (MIP) model and one heuristic algorithm. The heuristic algorithm is installed in control systems in a platform operating in the North Sea, and the experience so far has been good.

Iakovou et al. [6] consider the strategic level routing problem of hazardous materials in marine waters over a multicommodity network with multiple origins-destinations. They proposed a solution methodology illustrated through a single Hazard Material (HAZMAT) problem followed by a large scale case study of the marine transportation system of oil products in the Gulf of Mexico.

Frank et al. [7] propose a working spatial decision support system (SDSS) called Hazmat Path is developed. The proposed hazmat routing SDSS overcomes three significant challenges, namely handling a realistic network, offering sophisticated route generating heuristics and functioning of a desktop personal computer. The paper discusses creative approaches to data manipulation, data and solution visualization, user interfaces, and optimization heuristics implemented in Hazmat Path to meet these challenges.

Iakovou [8] presented the development of a medium-range strategic maritime oil transportation problem that addresses some of the issues and concerns raised by the Oil Pollution Act of 1990 - OPA 90. The maritime oil transportation problem is formulated as a multiobjective, multicommodity, multiple origin-destination, multimodal problem and deployment an interactive solution methodology with a Web-based decision-support module - IOTS.

Kara et al. [9] propose two path-selection algorithms for the transport of hazardous materials. The algorithms can deal with link impedances that are path-dependent.

Zografos and Androutsopoulos [10] present a heuristic algorithm for solving the bi-objective vehicle routing and scheduling problem. The results of these applications seem to be quite encouraging. The algorithm has been integrated within a GIS-based decision support system for hazardous materials logistics operations providing valid preliminary results on a set of case studies. The determination of hazardous materials distribution routes can be defined as a bi-objective vehicle routing problem with time windows since risk minimization accompanies the cost minimization in the objective function.

Erkut and Ingolfsson [11] propose path evaluation functions for hazardous materials transport use approximation and models to satisfy the axioms and are relatively tractable.

Grob [12] solves the Maritime surface surveillance Problem carried out by maritime platforms such as frigates; helicopters or maritime patrol aircraft by SURPASS (an acronym of SURface Picture ASSessment). The model SURPASS provides insight into the platforms and sensors needed for a surveillance operation and the effectiveness of various existing and newly developed rules for surveillance tactics.

Gribkovskai, Laporte and Shlopak [13] introduce a pickup and delivery problem encountered in the servicing of offshore oil and gas platforms of Haltenbankenin the Norwegian Sea. This paper describes several construction heuristics and a tabu search algorithm to solve the problem.

Alumur and Kara [14] propose a multiobjective location-routing model is proposed. The purpose of the model is to answer the questions: where to open treatment centres and with which technologies, where to open disposal centres, how to route different types of hazardous waste to which of the compatible treatment technologies, and how to route waste residues to disposal centres. The model has the objective of minimizing the total cost and transportation risk. Large-Scale implementation of the model in the Central Anatolian region of Turkey is presented.

Erkut and Gzara [15] consider the problem of network design for hazardous material transportation where the government designates a network, and the carriers choose the routes on the network. We model the problem as a bi-level network flow formulation and analyze the bi-level design problem by comparing it to three other decision scenarios. They propose a heuristic solution method to exploit the network flow structure at both levels to overcome the difficulty and instability of the believe integer programming model.

Pradhananga et al. [16] present a new meta-heuristic algorithm using an ant colony system (ACS) for multi-objective optimisation of hazardous material (HAZMAT) transportation. They focus on the vehicle routing problem with time windows (VRPTW) aspect of HAZMAT transportation problem. A VRPTW formulation considering multiple attributes in an application to HAZMAT transportation is provided. ACS in the proposed algorithm works in the framework of Pareto-optimal for routing and integrates a labelling algorithm for finding non-dominated paths for path choice purpose.

Kazantzi et al. [17] present a systematic framework for the development of a Transportation Model for Hazardous Materials (HazMat). The research study identifies and evaluates different risk factors that influence the problem and graphically using nodes and arcs and optimal conditions are identified by solving the associated minimum cost flow network problem. The results show safety levels that help to make informed decisions on choosing the optimal transportation configuration for hazardous material shipments. The methodological approach is employed to demonstrate the utility of proper analytical tools in decision making and particularly in ensuring that scientifically informed safety procedures are in place while transporting goods that can be potentially proven dangerous to the public and the surroundings.

Velasco et al. [18] modelled a pick-up and delivery problem where a set of transportation requests should be scheduled in routes, minimizing the total transportation cost while the most urgent requests are satisfied by priority for oil companies that use helicopters to transport engineers, technicians and assistant personnel from platform to platform. They use a Non-dominated Sorting Genetic Algorithm (NSGA-II) to solve the problem.

Xie, et al. [19] propose a multi-objective and multimodal model that can simultaneously optimize transfer yard locations and hazardous materials (HAZMAT) transportation routes subject to risk and cost constraints. The model is formulated as a mixed-integer linear program and coded in CPLEX studio using OPL. It is also extensively tested on two sample multimodal networks consisting of highways and railways. The developed model is applied to two case studies of different network sizes to demonstrate its applicability.

Boyer et al. [20] present a bi-objective mixed-integer programming model for location-routing industrial hazardous waste with two objectives is developed. The first objective is the total cost minimization including transportation cost, operation cost, initial investment cost, and cost-saving from selling recycled waste. The second objective is the minimization of transportation risk. To solve the problem GAMS software with CPLEX solver is used. The problem is applied in Markazi province in Iran.

Zhou et al. [21] developed an algorithm based on the epsilon-Constraint and Fuzzy Logic-Based Optimization of Hazardous Material Transportation via Lane. Pareto optimal solutions are obtained by the former, and a preferred solution is selected by the fuzzy-logic-based approach.
Samanlioglu [22] formulates a three-objective location-routing mathematical model for industrial hazardous materials (HAZMAT) management decisions. A lexicographic weighted Tchebycheff formulation is developed and computed with CPLEX software to find representative efficient solutions to the problem. Data related to the Marmara region is obtained by utilizing Arcview 9.3 GIS software and Marmara (Turkey) region geographical database.

Raemdonck et al. [23] show a literature study on risk analysis systems for the transport of hazardous materials. They propose a framework that allows setting up an overall risk map for hazmat transport by different transport modes, a methodology to calculate a local accident risk, which takes local infrastructure parameters and accident data into account. The evaluation framework makes it possible to estimate the risks of hazmat transport along a specific route for transport by road, rail, inland navigation and even pipelines.

3 Maritime Platform Transport Problem of Solid, Special and Dangerous Waste

The Maritime Platform Transport Problem of Solid, Special and Dangerous Waste (a variant of the Oil Platform Transport Problem [24] mixed with Hazardous Material Transportation problem or HAZMAT [25]) consist of to minimize the cost of carry different types of waste from one location (port / platform) to another location (port/platform) using ships or similar with some restrictions of capacity and time windows.

We propose a new mathematical model to the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste (MPTP-W). The mathematical model of MPTP-W is formed by the equations 1-5: The equation (1) is minimization of the cost (*C*) by the route (x_{ij}) performed by the ship (b_k). The equation (2) represents the total capacity of the ship considering the types and sizes of containers and the capacity must not be exceeded by the sum of the demands on each platform. The equation (3) is the total length of the ships of all the routes of each ship serving a set of platforms or nodes. The equation (4) mentions that each route taken by a ship must start at node zero and end at node zero. The equation (5) is the maximum weight allowed by the load of the ship and it must not be exceeded by the sum of the weights of containers.

$$\min Z = \sum_{i=0}^{n} C x_{ij} b_k \tag{1}$$

$$Q_{bk} \leq \sum_{i=1}^{n} d_{pi}; \quad Q_{bk} = \{qso, qsp, qh\} \tag{2}$$

$$X_{ijb_k} = \sum_{i=0}^{n} x_{ijb_k} \tag{3}$$

$$x_{ijb_k} = \sum_{i=0}^{n} x_{ijb_k} + \sum_{i=j}^{0} x_{i0} \tag{4}$$

$$W_{b_k} \leq \sum_{i=0}^{n} wd_{ib_k} \tag{5}$$

where: X_{ijbk} is the route X_{ij} traced by ship b_k, *ij* is the places to visit (platforms) defined by *i* starting platform and *j* the end platform, defining platform $i = 0$ as the central point where the boats depart and return upon completion of their journey. $D = [dp_1, \ldots, d_{pn}]$ is the total demand for transport containers that represents the sum of the demands d_i of every platform. De demand is considered heterogeneous; it can be of different types and sizes of containers which are transported. The types of containers depend on the type of waste to be handled. Currently, there are five types: 1) Incompatible (p_{t1}), 2) Special Handling (p_{t2}), 3) Urban and Solid (p_{t3}), 4) Hazardous waste (p_{t4}), 5) biological-infectious Hazardous waste (p_{t5}). For example, if in the platform 1 is requested to transport 3 containers of type 1, 3 containers type 5 and 1 container of type 1, then the total demand of the platform are:$d_{p1}=3_{pt11}+3_{pt41}+1_{pt51}$, or $d_{pi}=3_{pt1i}+3_{pt4i}+1_{pt5i}$. The demand of the container transportation is directly related to the capacity and the weight of the ship. Q_{bk} is the capacity of the ship to transport containers, for a ship is considered three different sizes-small, medium and large, q_{so} is the number of containers for Solid Waste, q_{sp} is the number of containers for special waste, q_h is the number of containers for hazardous waste. The capacity of the container is measured at 20 cubic feet (Twenty-foot Equivalent Unit, TEU) corresponding to a measuring container which corresponds to a container with 20 x 8 x 8.5 feet (6.1 x 2.4 x 2.6 m), the most common is currently 40 x 8 x 8.5 feet. A small-sized ship considers 20X8X8.5 feet in the container loading area, a medium-sized ship consider 30X8X8.5 feet in the container loading area, a large-sized ship consider 40X8X8.5 feet in the container loading area. W_{bk} is the total weight allowed by the ship, it considers the weights of the containers on the ship b_k, then $W_{bk} \leq wd_{p1bk1}+wd_{p2bk2}+wd_{p3bk3}+\ldots+wd_{pi-1bkm-1}+wd_{pibkm}$, the wd_{pibkm} represents, the variable wd_{pibkm} represents the weight of the container, the variable m represents the number of containers in the b_k ship. *B* represents the fleet (number of vessels or ships with homogeneous or heterogeneous capacity), the fleet is represented by a vector $B = [b_1, b_2, b_3, ..., b_{k-1}, b_k]$.

The Maritime Platform Transport Problem of Solid, Special and Dangerous Waste (L_1) is a variant of the Hazardous Material Transportation problem or HAZMAT (L_2), the HAZMAT is NP-hard. The L_1 was transformed into the L_2 ($L_1 \leq_P L_2$) or (MPTP-W $\leq_P$ HAZMAT). Then, with the polynomial transformation of the MPTP-W instances for the HAZMAT instances, we conclude that the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste is NP-hard.

4 Experimentation and Results

In this section, we show the results of the CPLEX solver for solving the instances of the Solid, Special and Hazardous Waste Transportation Problem of offshore platforms. The results were obtained from the CPLEX solver to find the optimal cost of the waste transportation contains in the Platforms on a server IBM Proliant with 32 cores and 4 GB RAM.

We present the parameters or characterization of the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste instances of PEMEX. We generated an instance set with 50 cases of randomly generated instances and real instances (with GIS data) of PEMEX offshore platforms. We used the nomenclature of instances: PEMEX (name of the enterprise), P (number of platforms), T (type of transportation, Air, Land or Maritime), # (number of cases), .wtp (extension of the file), for example: PEMEX-36M-10.wtp. In Table 1, we present the parameters or characterization used for generating the instances.

Table 1. Parameters of WTP instances

Parameter	Description of date
Fleet	Type
Number of Platforms	Number
Capacity qso	Number
Capacity qsp	Number
Capacity qh	Number
CapacityContainers	Number
Time	Range
InstanceNumber	$I_{1...}I_{36}$
Latitude	$X_1 \ldots X_{36}$
Length	$Y_1 \ldots Y_{36}$
Demand Supersacks	$S_1 \ldots S_{36}$
Polyethene Bags	$B_1 \ldots B_{36}$
Containers	$C_1 \ldots C_{36}$
Earliest Due	$ED_1 \ldots ED_{36}$
Due Date	$DD_1 \ldots DD_{36}$
Riding Time	$RD_1 \ldots RD_{36}$

Table 2 shows the results of the depository of instances of the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste by the experimentation of CPLEX solver. We obtain the total cost of transportation.

Table 2. Results of the test instances of Waste Transportation Problem

Instances	Demands	Cost	Ships
WTP-36M-1	1577	$15,334.74	2
WTP-36M-2	1803	$16,922.44	2
WTP-36M-3	1661	$15,526.75	2
WTP-36M-4	1792	$17,027.77	2
WTP-36M-5	1736	$16,498.36	2
WTP-36M-6	1594	$15,030.55	2
WTP-36M-7	1687	$16,011.41	2
WTP-36M-8	1794	$17,080.47	2
WTP-36A-9	1768	$16,697.44	2
WTP-36M-10	1661	$15,788.87	2

Table 3. Mean of Cost and Number of ships of the WTP-36 Maritime instances set

Instances set	Mean of Cost	Mean of Number of Ships
WTP-36M	$16,191.88	2

5 Conclusions

The main contribution of this work is the proposal of a variant problem called the Maritime Platform Transport Problem of Solid, Special and Dangerous Waste, a mathematical model of the MPTP-W, the characterization of the MPTP-W test instances of PEMEX, and the use the CPLEX solver to find the optimal cost of Waste Transportation.

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