# Container Stowage Planning Problem

## A comprehensive survey


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# Overview

1. Introduction
2. Problem Description
3. Literature Review
4. Conclusion

# Introduction

# Ocean Transport


**Pros and Cons**

- – Long transit time
- + Most carbon-efficient solution
- + Cheaper than other transport modes

# Huge Vessels


(a) MSC Irina

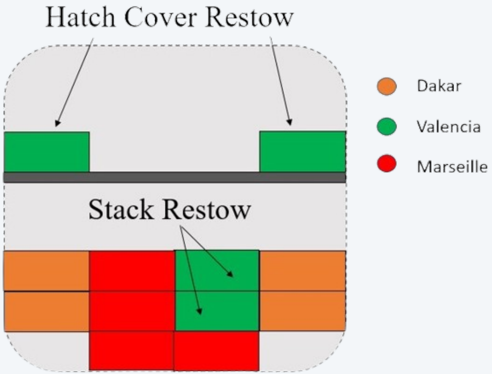

(b) CMA CGM Jacques Saade

# How to efficiently stow cargo inside container ships?

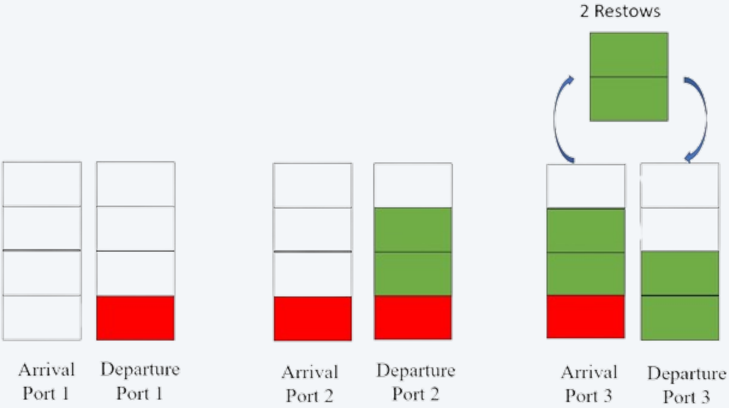
# Problem Description

# Restow

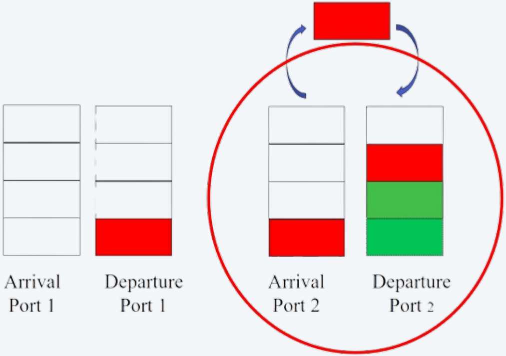

Marseille
Barcelona
Valencia
Algeciras
Tanger Med
Dakar
Conakry
Abidjan


Hatch Cover Restow
Stack Restow
Dakar
Valencia
Marseille

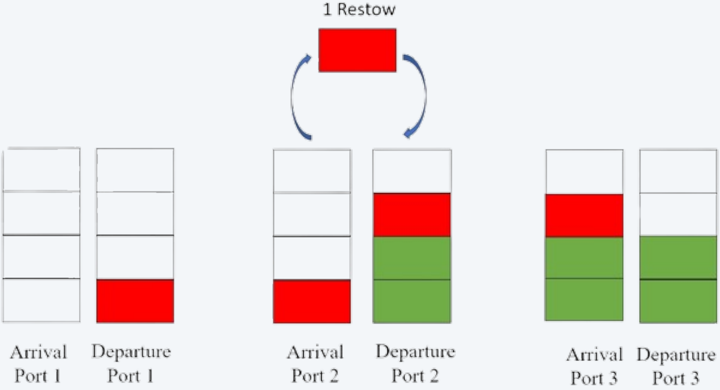
# Restow


2 Restows
Arrival
Port 1
Departure
Port 1
Arrival
Port 2
Departure
Port 2
Arrival
Port 3
Departure
Port 3

# Restow anticipation



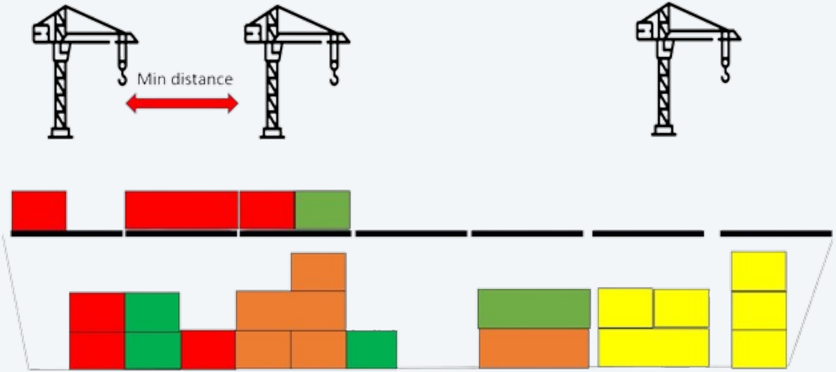
# Restow anticipation



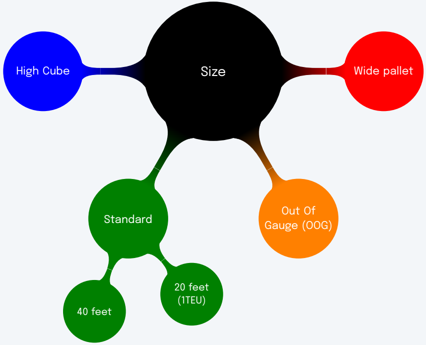

Minimizing restows inside stacks proved NP-Hard by Avriel et al. (2000), Container ship stowage problem: complexity and connection to the coloring of circle graphs, Discrete Applied Mathematics
Minimizing hatch cover's restows proved NP-Hard by Tierney et al. (2014), On the complexity of container stowage planning problems, Discrete Applied Mathematics

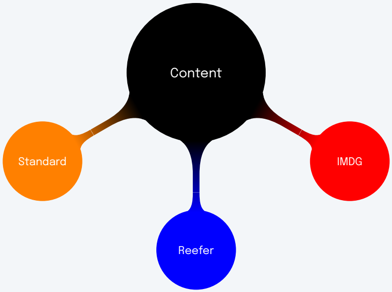
# Crane Operations

### Crane Makespan and Idle time



# Containers

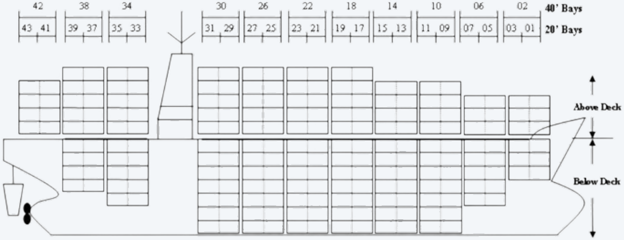

Size
High Cube
Wide pallet
Standard
Out Of Gauge (OOG)
40 feet
20 feet (1TEU)

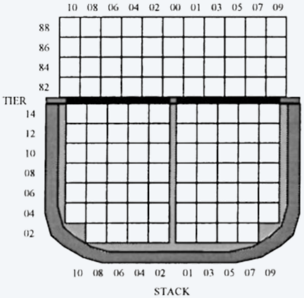

Content
Standard
IMDG
Reefer

# Constraints on containers

- No 20 feet on top of 40
- Wide pallets on top of the stacks, or in specific bays
- High cube must be considered to calculate the stack height
- OOG on top or directly on the bridge
- OOG should be stowed efficiently to minimize position loss
- Reefer containers should be near plugs
- Dangerous goods should be segregated according to the IMDG code

# Vessel Layout



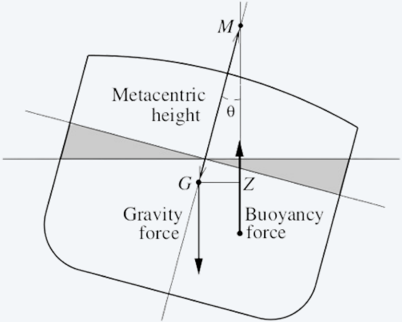
# Seaworthiness

## Trim and Draft


- Trim and draft should be within limits

# Seaworthiness

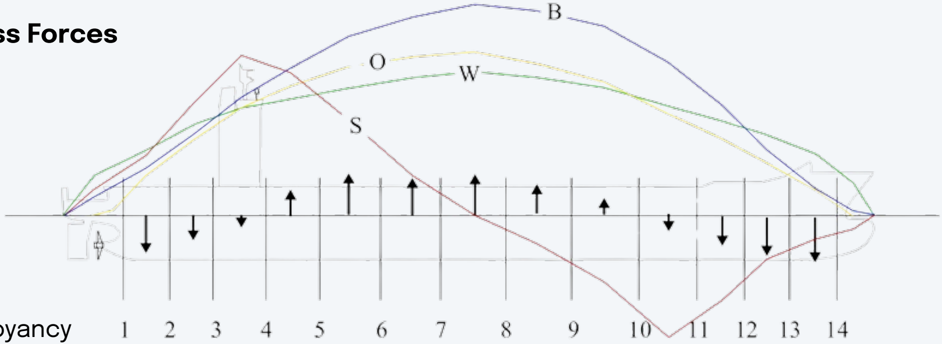
## Metacentric Height




- GM should be higher than 1m

# Seaworthiness

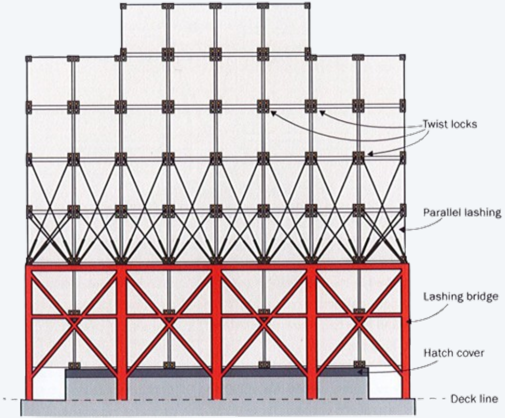
**Stress Forces**




O: Buoyancy
B: Bending moments
S: Shear forces
W: Weight

# Seaworthiness

## Lashing Forces




- All those equipments have limited stength
- Complex mechanical models are used to calculate the lashing forces
- Containers should be stacked from heaviest to lightest to fulfill this requirement

# Uncertainty

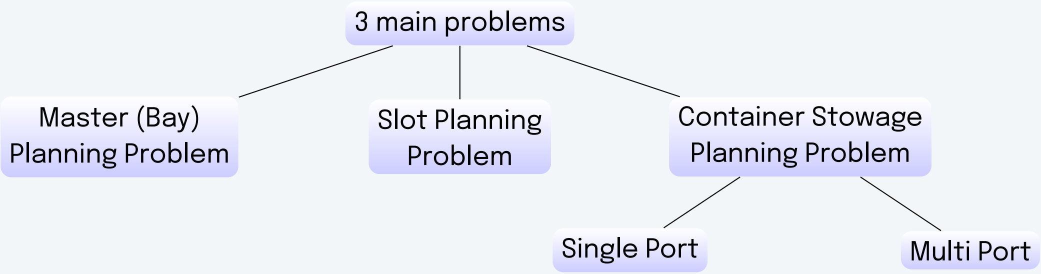
- $\Rightarrow$ Stowage plan is prepared prior to arrival
- $\Rightarrow$ Unknown details about containers
- $\Rightarrow$ Delayed or canceled cargo

# In Summary

| | |
|---|---|
| Goal | Generate a stowage plan |
| Objec-tives | Minimize Restow, Optimize crane utilisation |
| Con-straints | Ensure the safety of the vessel, crew, and containers Respect stacking rules |
| Perfor-mance | Generate a plan in minimum time |

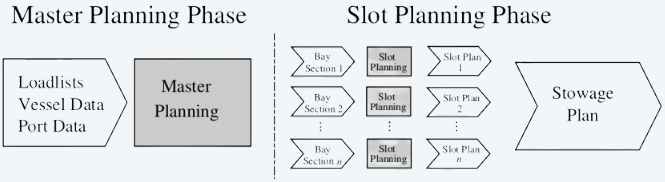
# Literature Review

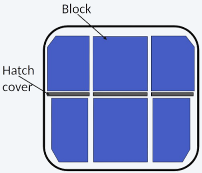
# Classification of literature publications




Classification scheme proposed by Twiller et al. (2023), Literature survey on the container stowage planning problem

# Hierarchical decomposition




Proposed for the first time by Wilson and Roach (1999), Container Stowage Planning: A Methodology for Generating Computerised Solutions, The Journal of the Operational Research Society,

# Master Bay Planning Problem

| Paper | Solution Method |
|---|---|
| Pacino et al. (2011) | IP |
| Pacino (2013) | Large Neighborhood Search |
| Ambrosino et al. (2015a) | Metaheuristic |
| Ambrosino et al. (2015b) | MIP |
| Ambrosino et al. (2017) | MIP |

# Slot Planning Problem

| Paper | Solution Method |
|---|---|
| Pacino and Jensen (2009) | 3 Phases Heuristic |
| Delgado et al. (2012) | Constraint Programming |
| Pacino and Jensen (2013) | Constraint Based Local Search |
| Parreño et al. (2016) | Greedy Heuristic |

# Multi Port CSPP

| Paper | Solution Method |
| --- | --- |
| Avriel et al. (1998) | Greedy Heuristic |
| Wilson and Roach (1999) | Branch and Bound / Tabu Search |
| Kang and Kim (2002) | Greedy Heuristic / Enumeration Tree |
| Dubrovsky et al. (2002) | Genetic Algorithm |
| Tavares de Azevedo et al. (2014) | Metaheuristics |
| Ding and Chou (2015) | Greedy Heuristic |
| Parreño-Torres et al. (2019) | IP and Greedy Heuristic |
| Bilican et al. (2020) | IP / Local Exchange |
| Parreño-Torres et al. (2021) | IP and Metaheuristic |

# Single Port CSPP

| Paper | Solution Method |
|---|---|
| Ambrosino and Sciomachen (1998) | CSP |
| Ambrosino et al. (2004) | IP and 3 Phases Heuristic |
| Ambrosino et al. (2006) | 3 Phases Heuristic |
| Ambrosino et al. (2010) | Ant Colony Optimisation |
| Larsen and Pacino (2021) | Large Neighborhood Search |
| El Yaagoubi et al. (2022) | NSGA2 |

# Conclusion

# Conclusion

- CSPP plays an important role in maritime industry

- Scarce literature compared to other areas of Operational Research.

# Thank you for your attention

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