The Berth Allocation Problem in Bulk Ports

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Outline

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- **Introduction to bulk ports**
  - Bulk port operations and equipment
  - Case Study of SAQR
- **Research Objectives**
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Motivation

- Significantly less attention to bulk port terminals than container terminals in the field of large scale optimization

- High level of uncertainty due to weather conditions, mechanical problems etc.

  - Disrupt the normal functioning of the port
  - Require quick real time action.

- The major objective of planning robust port operations is to minimize operational costs while maximizing system reliability.

Bulk terminal operations

- Vessel and Berth Activities

- Ship Loading or Discharge

- **Apron to Storage Transfer**

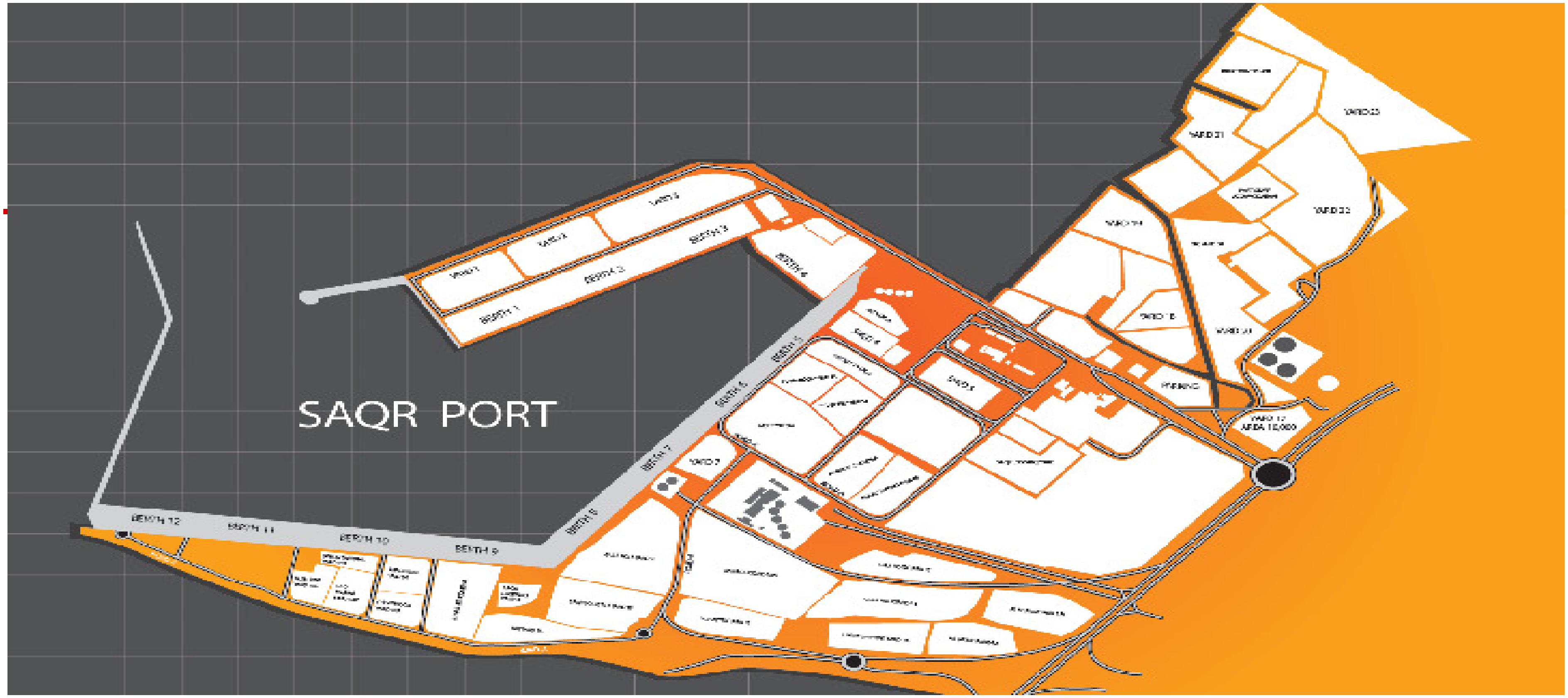


- **Storage**


- **Intermodal transfer and inland distribution**

Case Study: SAQR Port, Ras Al Khaimah, UAE

- Biggest bulk port in the entire middle east, handling 30 million tons of bulk and assorted cargo annually
- Deals with a wide variety of imported and exported commodities- aggregates, cement, coal, clinker, iron ore, feldspar, clay, soda ash, petroleum products etc.
- Wide range of equipment facilities including MHC’s, shovels, loaders
- Variable demand across different berths owing to fixed specialized equipment facilities and environmental reasons.



- **Port Layout**
  - 12 berths, with alongside depth of 12.2 meters at mean low water spring tide
  - 8 x 200 meters bulk handling berths, 3 x 200 meters container handling berths and 1 general purpose roll-on/roll-off berth
  - Conveyors at berths 5 and 7; pipelines at berths 6,7 and 11

Research challenges

- **Key issues and sources of disruption at SAQR**: High waiting times and delays at berths owing to
  - Congestion at berths
  - Unavailability of required number and type of equipment when needed
  - *Uncertainty in arrivals* of vessels and cargo trucks

Research Objectives

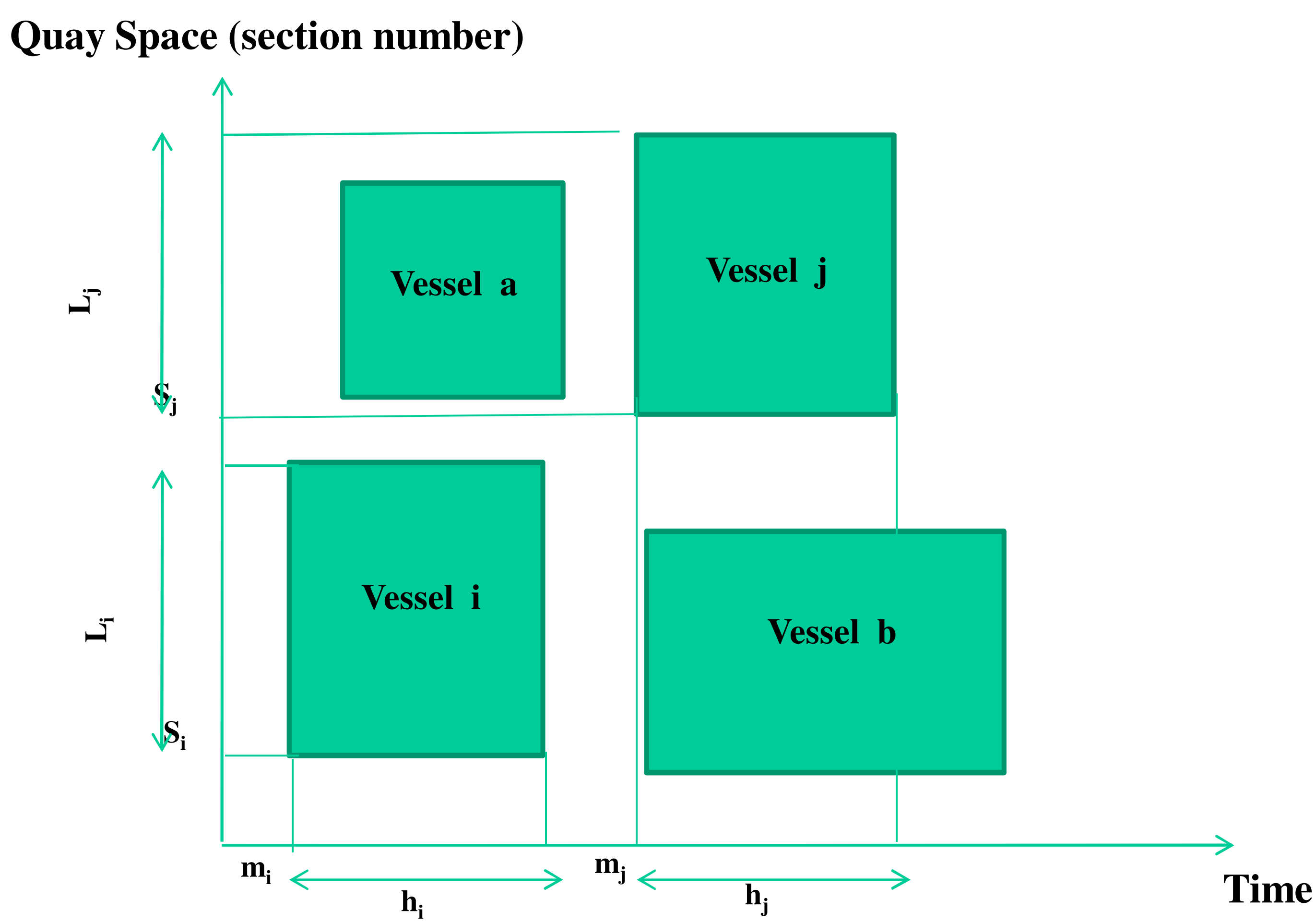
- ***Integration of the two crucial problems of berth allocation and yard allocation*** for better coordination between berthing and yard activities
- Include ***robustness*** in planning process to account for uncertainties in arrival times of vessels and cargo trucks which lead to unforeseen disruptions and delays in operations.
- Develop methodologies and algorithms that can be extended to other domains such as container ports, railways and airlines.

The Berth Allocation Problem

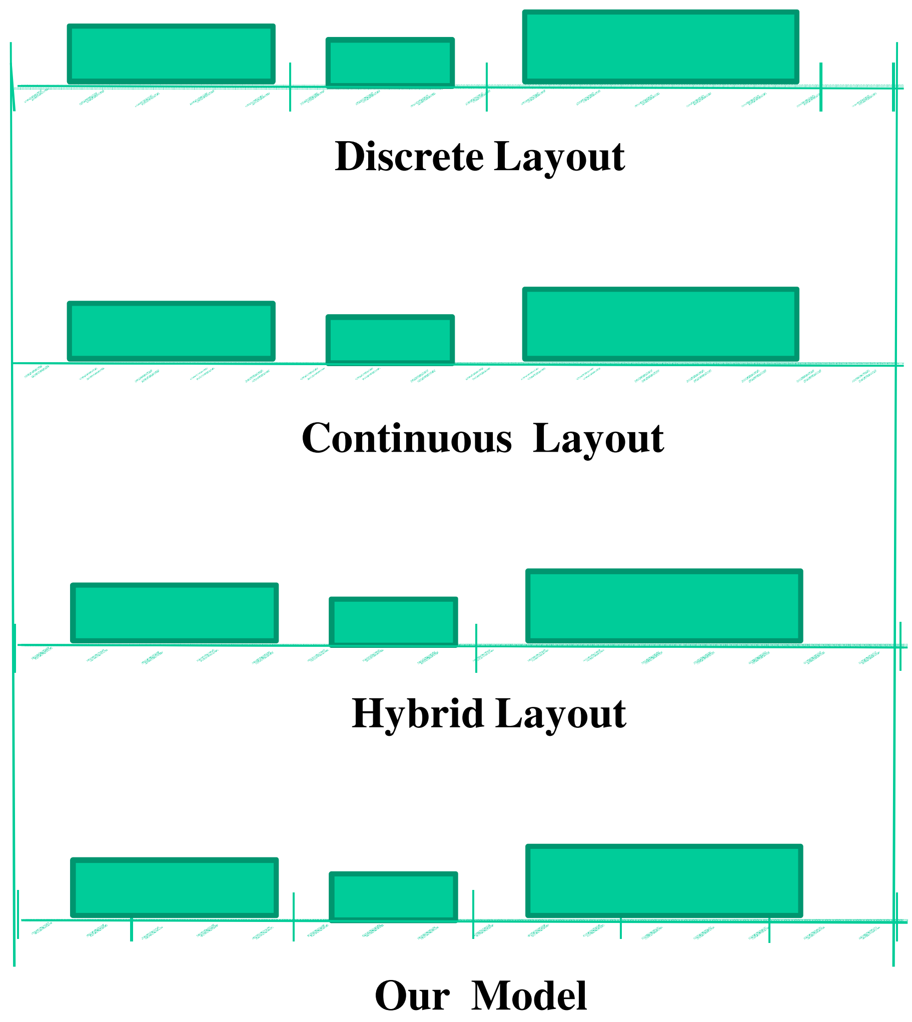
Problem Definition

- **Find**
  - Berthing assignment and schedule of vessels along the quay
- **Given**
  - Time windows on arrivals of vessels
  - Handling times dependent on berthing position and cargo type
- **Objective**
  - Minimize total service times of vessels berthing at the port

BAP Solution



Discretization



BAP Model

Objective Function

$$\min \sum_{i \in N} (m_i - a_i + h_i)$$

Decision variables:

m_i	starting time of handling of vessel $i \in N$;
a_i	arrival time of vessel $i \in N$;
h_i	total handling time of vessel $i \in N$;

BAP Model

Dynamic vessel arrival constraints

$$m_i - a_i \geq 0 \qquad \forall i \in N,$$

$$a_i = A_i r_i + U_i (1 - r_i) \qquad \forall i \in N,$$

A_i expected arrival time of vessel $i \in N$;

U_i upper bound to the arrival time of vessel $i \in N$;

BAP Model

- **Non overlapping constraints**
- **Section covering constraints**
- **Draft Restrictions**

$$(d_k - D_i)x_{ik} \geq 0 \qquad \forall i \in N, \forall k \in M,$$

D_i draft of vessel $i \in N$;

d_k draft of section $k \in M$;

BAP Model

Determination of Handling Times

$$h_i \geq h_k^{iw} p_{isk} Q_i s_k^i \qquad \forall i \in N, \forall k \in M, w \in W_i$$

Q_i quantity of cargo to be loaded on or discharged from vessel i

h_k^{iw} handling time for unit quantity of cargo $w \in$ when vessel $i \in N$ is berthed in section $k \in M$;

Generation of Instances

- Instances based on data from SAQR port
  - Quay length of 1600 meters and vessel lengths in the range 80-260 meters

- Test 5 instances each for $|N|$ = 5,10 and 15 vessels, and $|M|$ = 10,20 and 30 sections

- Choosing the discretization along the quay is critical!

- Rate of handling is 15 hours per 10^4 tonnes per crane, and number of cranes dependent on length of each section

- Drafts of all vessels D_i are less than the minimum draft along the quay.

Preliminary Results

N=5	
M	**obj**
10	52.5
20	29.03
30	29.42

- Solved in less than a second
- Objective function value much less for larger number of sections

N = 10	
M	**obj**
10	104.31
20	79.81
30	66.93

- Solved within few seconds
- Objective function decreases with increase in number of sections

N = 15		
M	Obj (gap%)	t (s)
10	120 .00 (5.17%)	7200
	118.48 (4.08%)	7200
	117.50 (0.00%)	3613.09
	111.31 (0.00%)	10.53
	112.20 (0.00%)	25.81
20	118.14 (0.10%)	7200
	118.03	2.6
	118.03	3.36
	118.03	2.23
	118.03	2.04
30	112.74	8.45
	112.74	15.03
	112.75	8.72
	112.74	4.13
	112.74	4.25

- Most instances solved within few seconds
- Objective function decreases with increase in number of sections
- Arrival times are more critical for larger lengths of sections

Summary of Results

- All instances up to 10 vessels solved within few seconds.
- Most instances containing 15 vessels solved within few seconds
- Improvement in solution quality with increase in number of sections
- Arrival times are more critical when sections are larger in length!

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Future Work

- Sensitivity analysis for different parameters in the current model
- Model the BAP using a column generation based approach
- Account for uncertainties!
- Possibly explore heuristic approaches for faster results
- Integration of the berth allocation problem with yard allocation

Thank you!