Optimization of Container Terminal Operations

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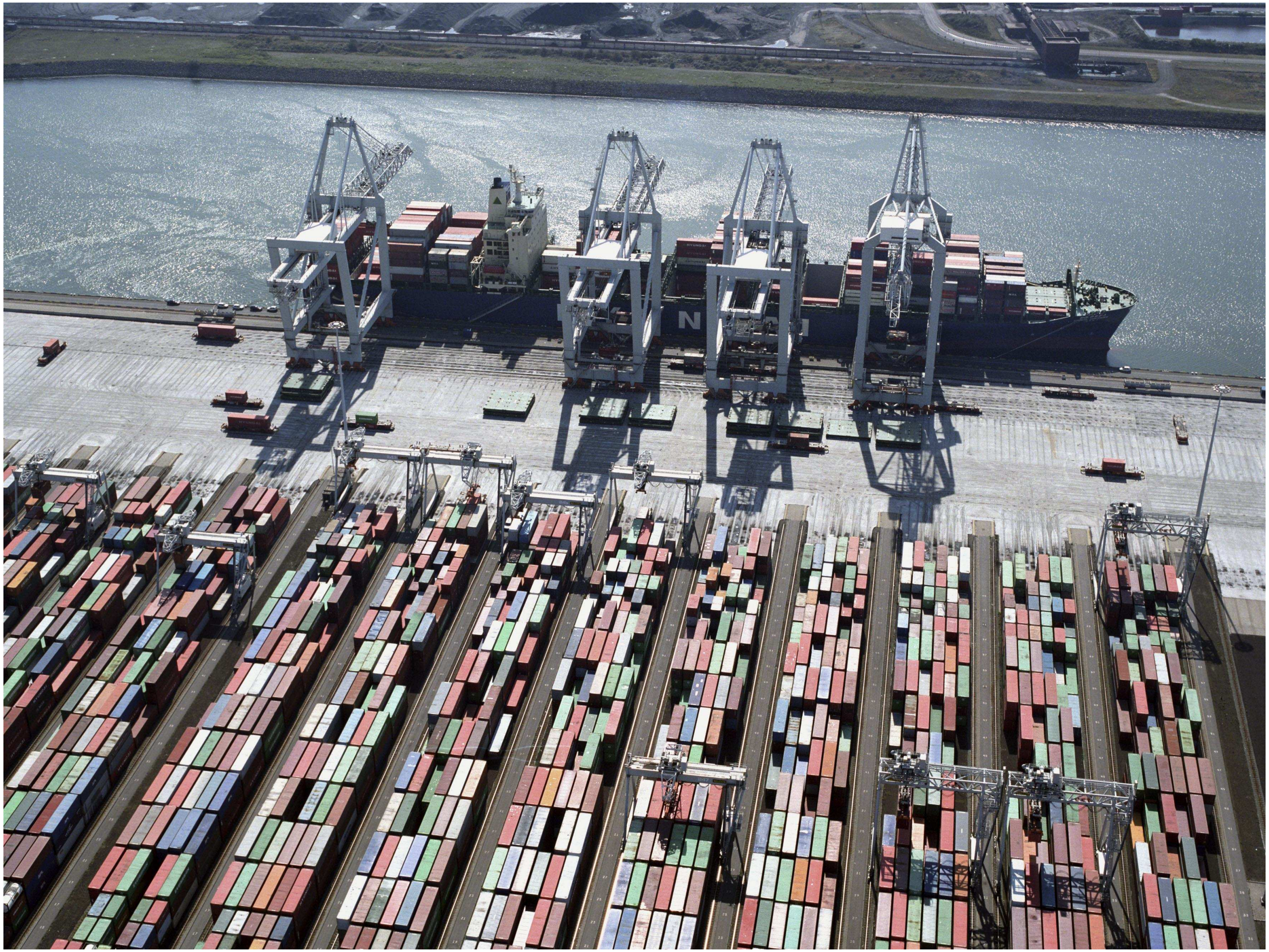
Outline

- Introduction
- Terminal overview
- Terminal operations
- Yard optimization
- Transshipment
- Conclusions

Introduction

- Growth of container sea-freight transportation
- Competition among terminals in terms of:
  - Service (ship's turnaround time)
  - Productivity (TEUs per year)
- Issues: traffic, congestion and capacity limits
- OR techniques to improve the efficiency of terminal operations

Terminal Overview



Terminal Operations

- Ship-to-Shore

  Berth Allocation; Quay Cranes Scheduling; Ship Loading Plan.
- Transfer

  Quay-Yard; Yard-Yard; Yard-Gate.
- Storage

  Yard Management (Block and Bay Allocation); Yard Crane Deployment
- Delivery and Receipt

  Gate management; Interface with trains and trucks.

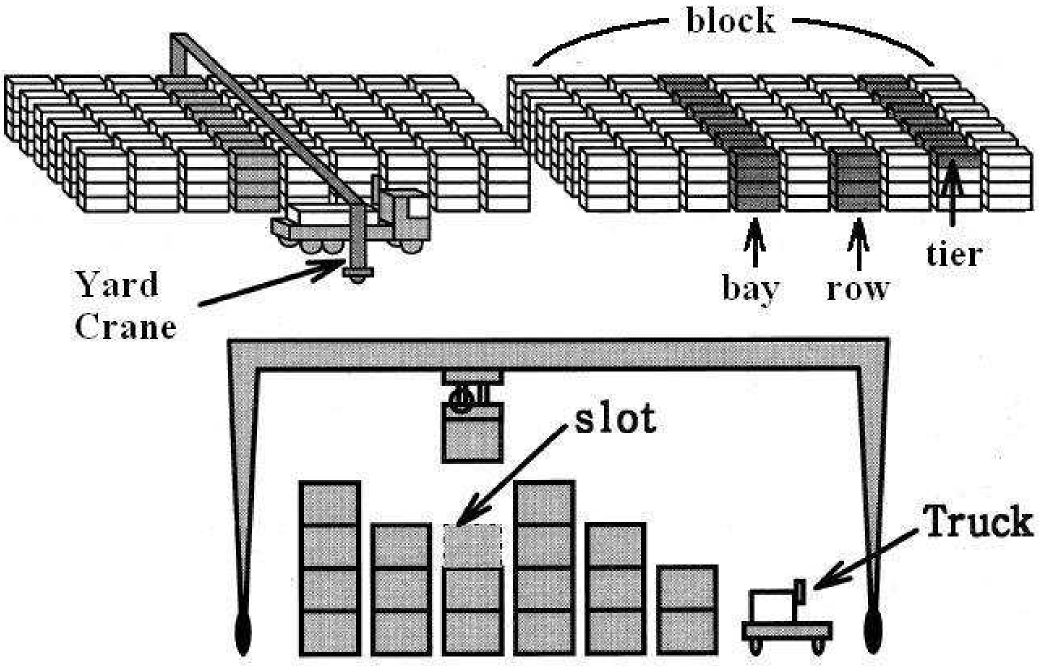
In addition to the traditional flow: transshipment containers, empty containers and human resources management.

Vis and de Koster (2003); Steenken et al. (2004); Henesey (2006)

Yard Overview

The yard serves as a buffer for loading, unloading and transshipping containers.

The yard is separated into blocks. The position of the container inside a block is identified by bay, row and tier.



Yard Optimization

- **Storage policies** for groups of containers at block and bay level, in order to:
  - balance the workload among blocks;
  - minimize the total distance covered to shift containers from quay to yard.

  de Castilho and Daganzo (1993); Kim et al. (2000); Kim and Park (2003); Zhang et al. (2003); Kim and Hong (2006); Kang et al. (2006); Lee et al. (2006).

- **Re-marshalling of containers** according the ship loading plan, in order to:
  - speed-up loading operations and thus minimize ship's turnaround time.

  Kim and Bae (1998); Lee and Hsu (in press).

- **Yard cranes deployment** (allocation of cranes among blocks, routing and scheduling of operations), in order to:
  - minimize the completion time of jobs.

  Kim and Kim (1997); Linn et al. (2003); Zhang et al. (2002); Kim et al. (2003); Ng and Mak (2005); Ng (2005); Kim et al. (2006); Jung and Kim (2006).

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Issues in Yard Management

The yard is usually the bottleneck of the terminal.

Traffic, congestion and capacity issues originate from here.

Main issue: the “schedule” of the outgoing flow is unknown to the terminal.

- Import/export terminals: yard management is strictly connected to gate operations (trucks and trains).
- Transshipment terminals: yard management is strictly connected to mother vessels and feeders.

Transshipment

- Players in transshipment: mother vessels and feeders;
- Peculiarities of the transshipment flow:
  - known arrival and departure positions;
  - known arrival and departure times;
  - concurrency of loading and unloading operations.
- Definition of new transshipment-related problems:
  - Service Allocation Problem *(Cordeau et al., 2007)*;
  - Group Allocation Problem *(Moccia and Astorino, June 2007)*.

  - Short Sea Shipping: recent study on barge rotation planning in the port of Rotterdam *(Douma et al., June 2007)*.

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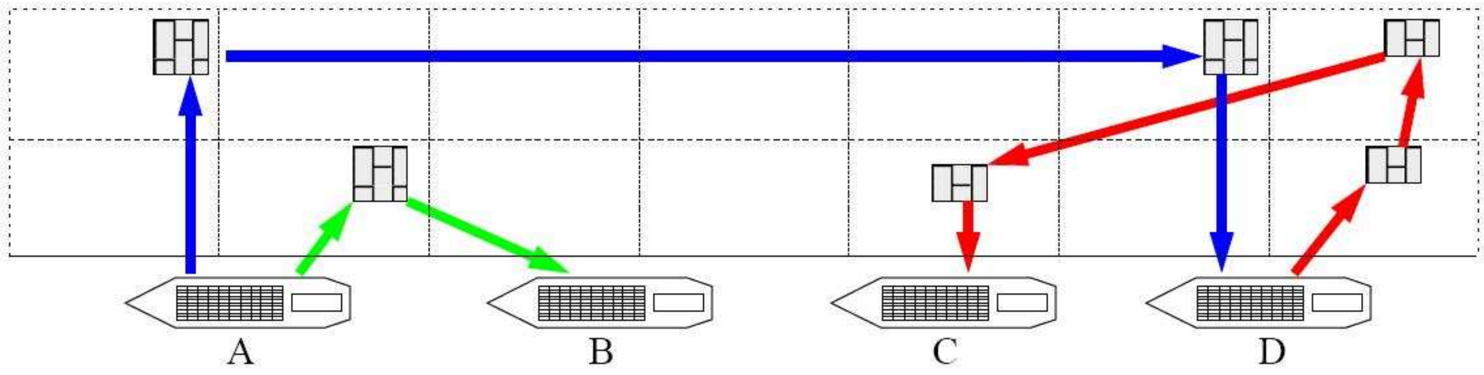
The Service Allocation Problem

Cordeau et al. (2007)

- Tactical problem (3-month horizon) arising in yard management of transshipment terminals (case study: port of Gioia Tauro, Italy);
- A service (also called port route) is the sequence of ports visited by a vessel;
- Services periodically call at the terminal: they need to be assigned a favorite area along the quayside and in the yard;
- Service allocation has an impact on the number of handling operations inside the yard (housekeeping).



The Service Allocation Problem

- N, the set of services, $|N| = n$;
- M, the set of bays, $|M| = m$;
- t_{ij}, the traffic intensity between service $i \in N$ and $j \in N$;
- q_i, the space requirement of service $i \in N$;
- Q_k, the space available at bay $k \in M$;
- c_i, the average number of crane moves required for service $i \in N$;
- C_k, the average number of crane moves allowed at bay $k \in M$;
- $M(i)$, the set of feasible bay assignments for service $i \in N$;
- d_{hk}, the distance between bay $h \in M$ and bay $k \in M$.

- $x_{ik} = \begin{cases} 1 & \text{if service } i \text{ is assigned to bay } k; \\ 0 & \text{otherwise.} \end{cases}$

The Service Allocation Problem

$$min \sum_{i \in N} \sum_{j \in N} \sum_{h \in M} \sum_{k \in M} t_{ij} d_{hk} x_{ih} x_{jk} \quad (1)$$

$$s.t. \sum_{k \in M(i)} x_{ik} = 1 \ \forall i \in N, \quad (2)$$

$$\sum_{i \in N} q_i x_{ik} \leq Q_k \ \forall k \in M, \quad (3)$$

$$\sum_{i \in N} c_i x_{ik} \leq C_k \ \forall k \in M, \quad (4)$$

$$x_{ik} \in \{0, 1\} \ \forall i \in N, \forall k \in M. \quad (5)$$

The Group Allocation Problem

Moccia and Astorino (June 2007).

- Operational problem arising in yard management of transshipment terminals (case study: port of Gioia Tauro, Italy);
- A container group is a set of container of same type, same origin, same destination;
- Arrival/departure times and arrival/departure positions along the quay are known in advance (input: Berth Allocation Plan);
- Objective: minimize housekeeping.

Transshipment: A New Approach

- Several players: terminal, mother vessels and feeders;
- Negotiation between terminal and feeders on the arrival time;
- Integration of berth and block allocation;
- Objectives: minimize total distance quay-yard; minimize congestion in yard blocks; balance workload among blocks.

Research plan on 2 levels:

1. Optimization framework for the simultaneous assignment of berths and blocks with feasible scheduling of feeders;
2. Definition of ad-hoc pricing policies to support the terminal in the negotiation with feeders.

Conclusions

- OR techniques are worth being applied to improve the efficiency of terminal operations.
- Focus on yard management and its interactions with:
  - gate operations;
  - transshipment flow.
- A new approach in the management of transshipment operations.
- Investigation of possible negotiation and cooperation between the terminal and the other market players.

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