A Framework for Integrating Planning Activities in Container Terminals

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- Introduction
- The framework for planning procedure
- Resource planning
- Conclusions

- **Introduction**
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- Resource planning
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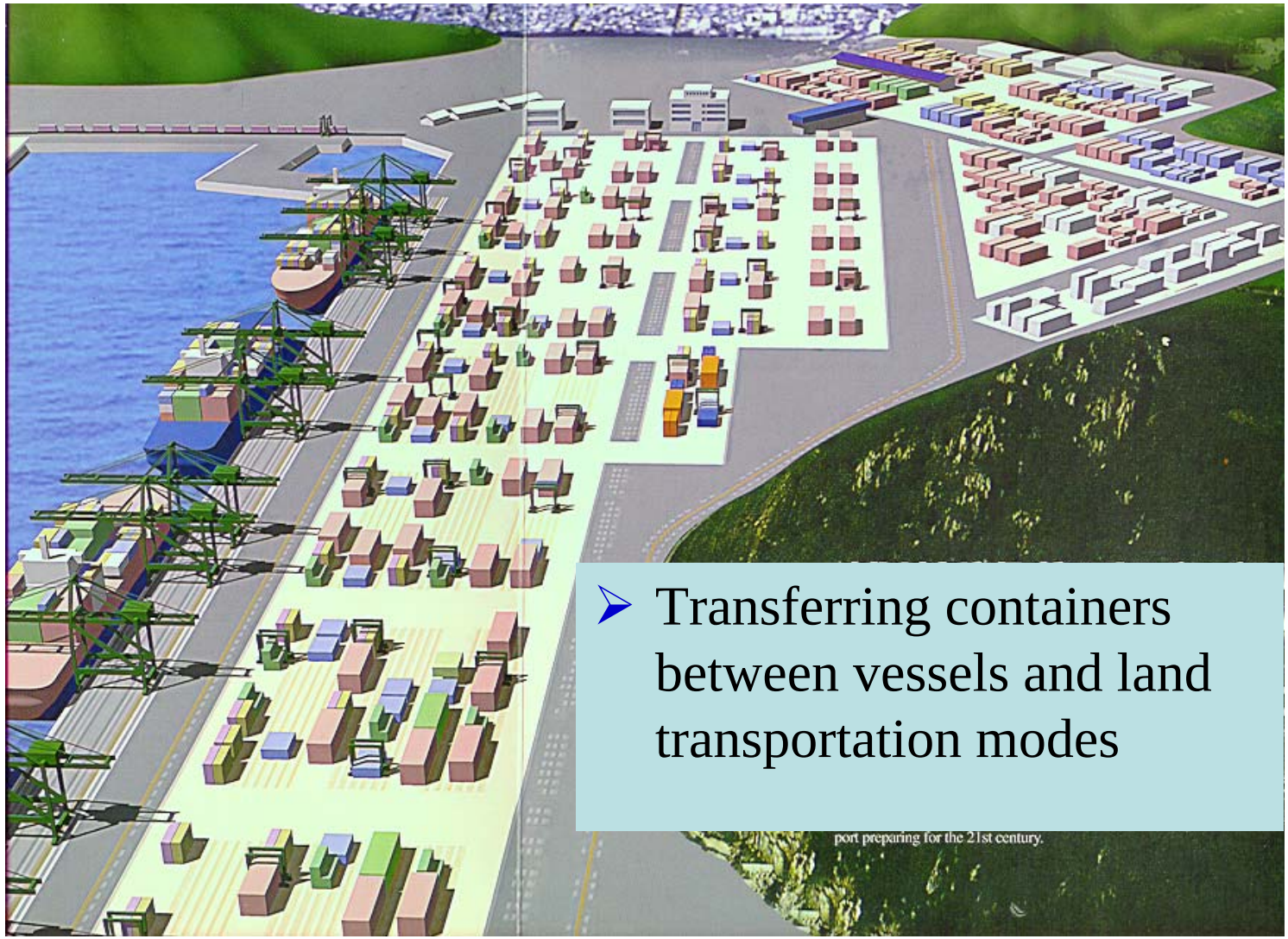
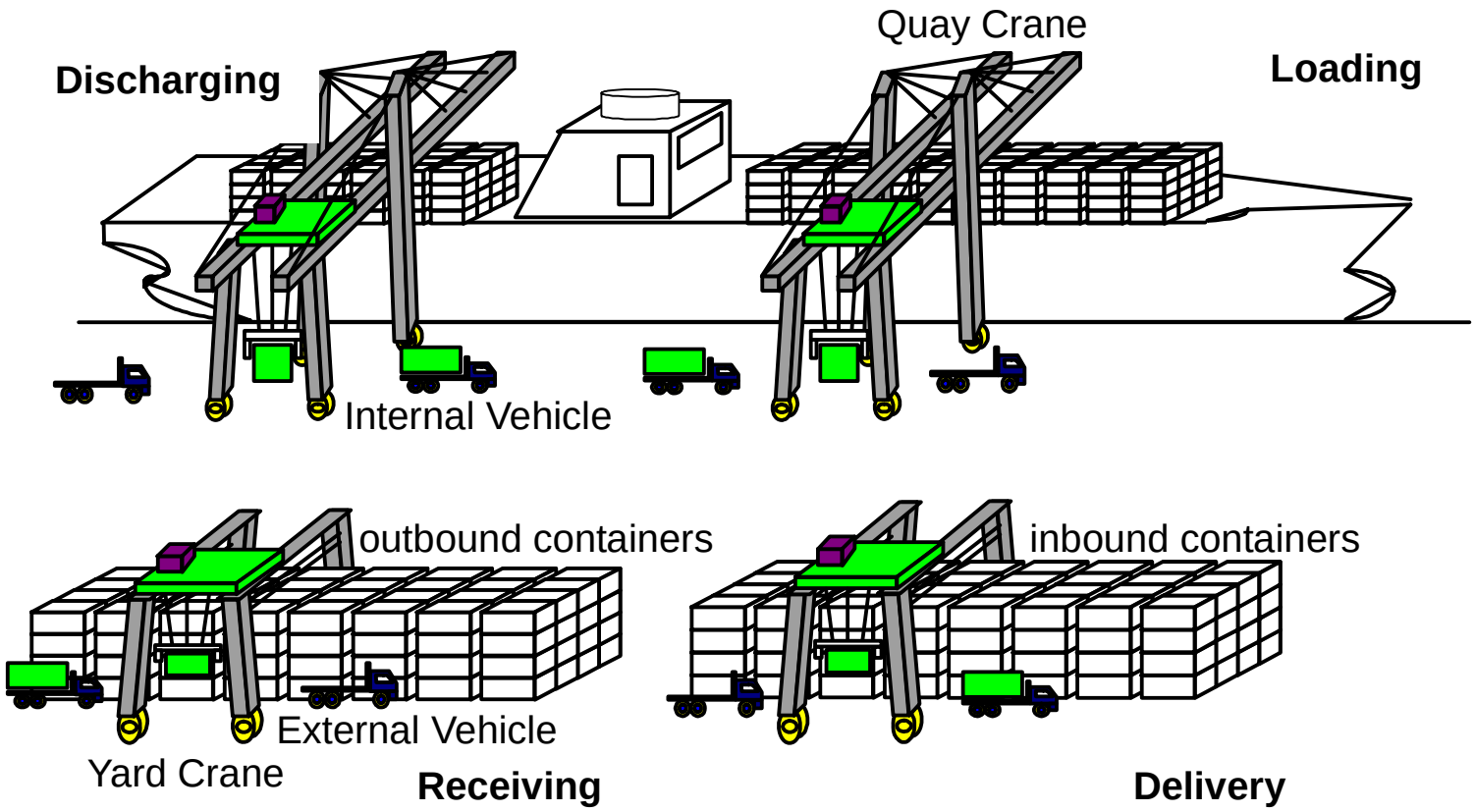
Port container terminals



- Transferring containers between vessels and land transportation modes

Operations in container terminals



Related researches

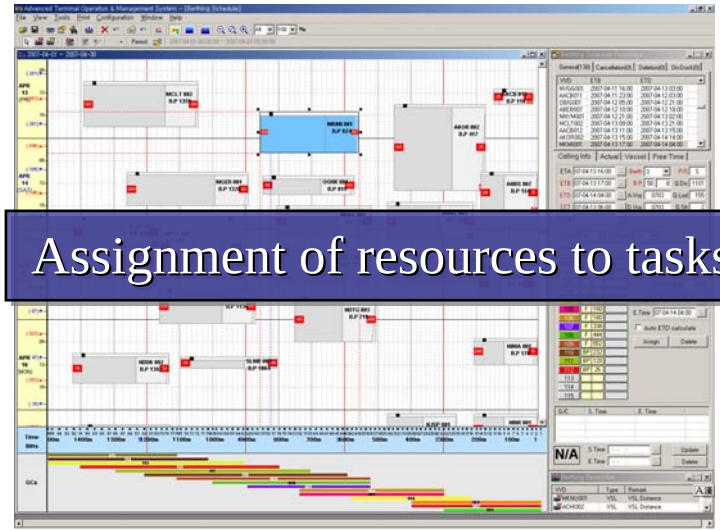
- Reviewed the planning problems for operations in container terminals

Berth planning	Long	Planning berthing activities of vessels
QC scheduling	Long	Scheduling QC operations
Space planning	Long	Allocating storage space for containers
Discharge/load sequencing	Short	Determining discharging and loading operations
Equipment deployment	Short	Allocate yard cranes or vehicles to a type of jobs
Equipment dispatching	Real time	Assign a vehicle or crane to a handling task
Locating containers	Real time	Assign a storage slot to a container

Operations in container terminals

- What is operation planning in container terminals?

Planning operations



Assignment of resources to tasks

The assignment of resources to tasks have been major concerns of planning activities.

Approach in this study

- This study provides an integrated framework for various planning activities in container terminals

View the planning problems as resource scheduling problems

Identify resources related to each planning activity

Develop a resource constrained planning method for each problem

- Introduction
- **The framework for operation planning procedure**
- Resource planning
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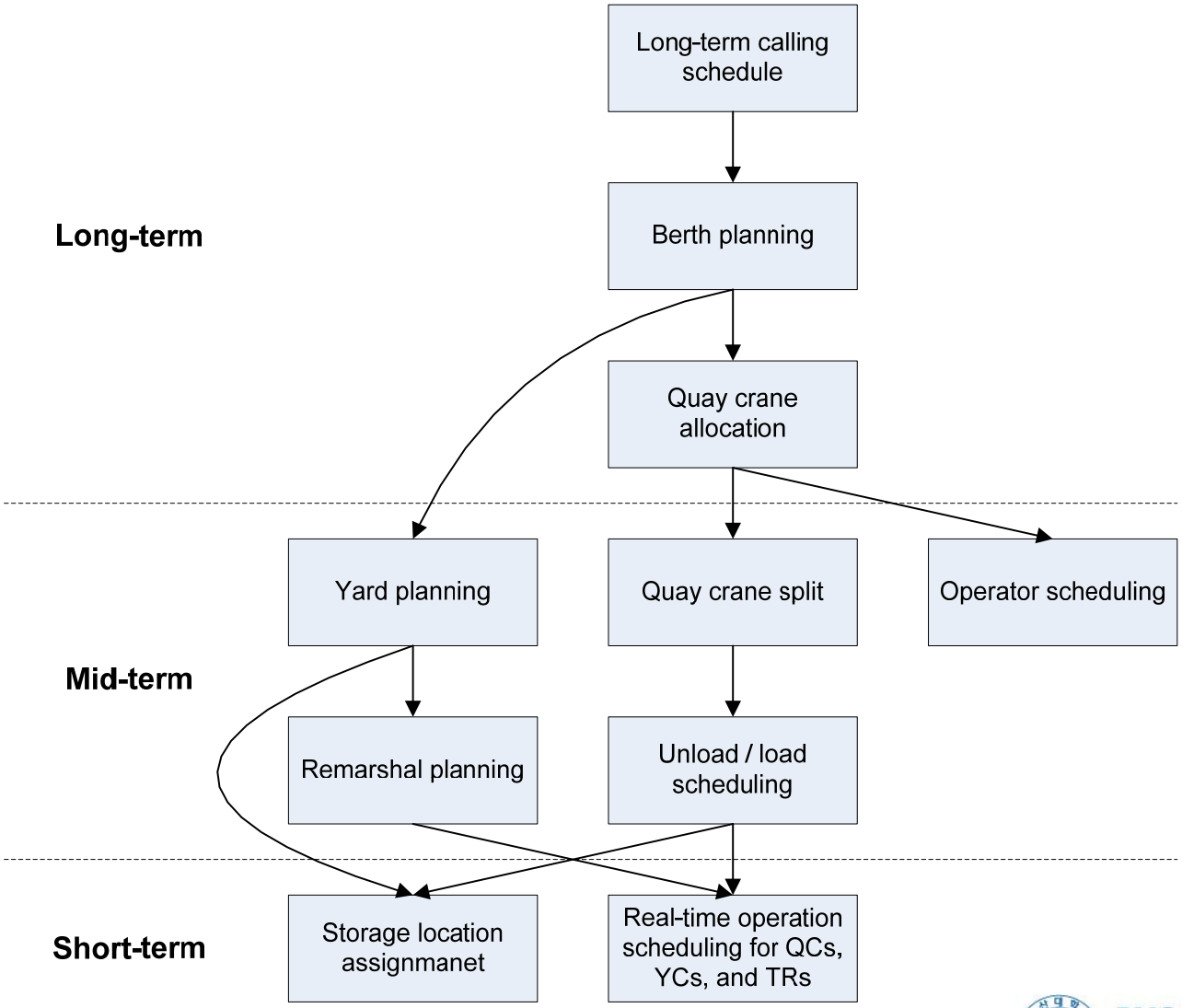
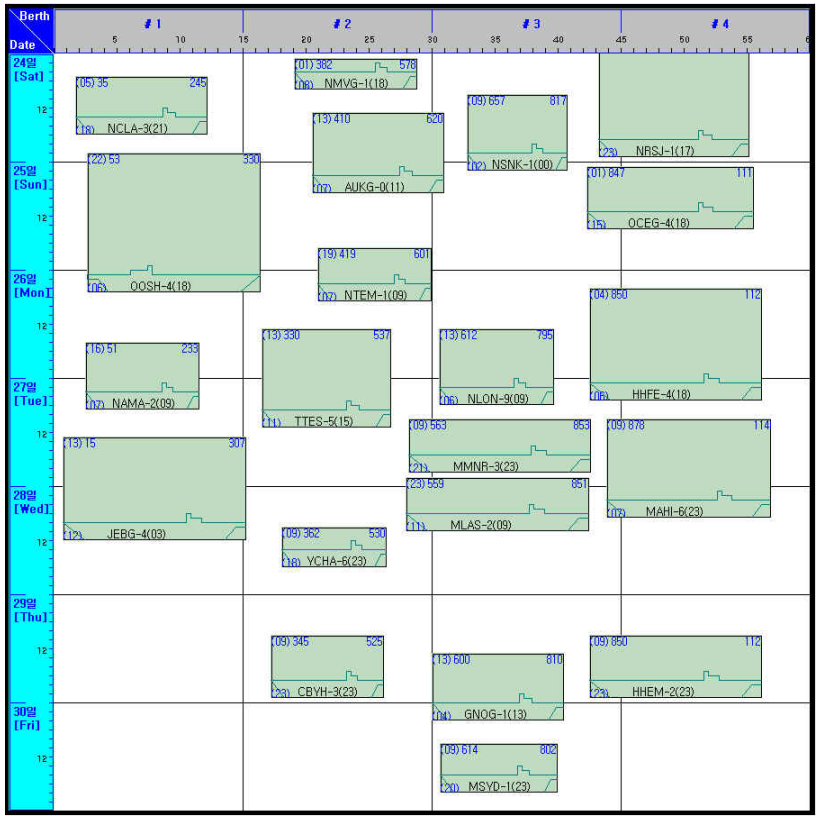
Operational Plans in Container Terminals



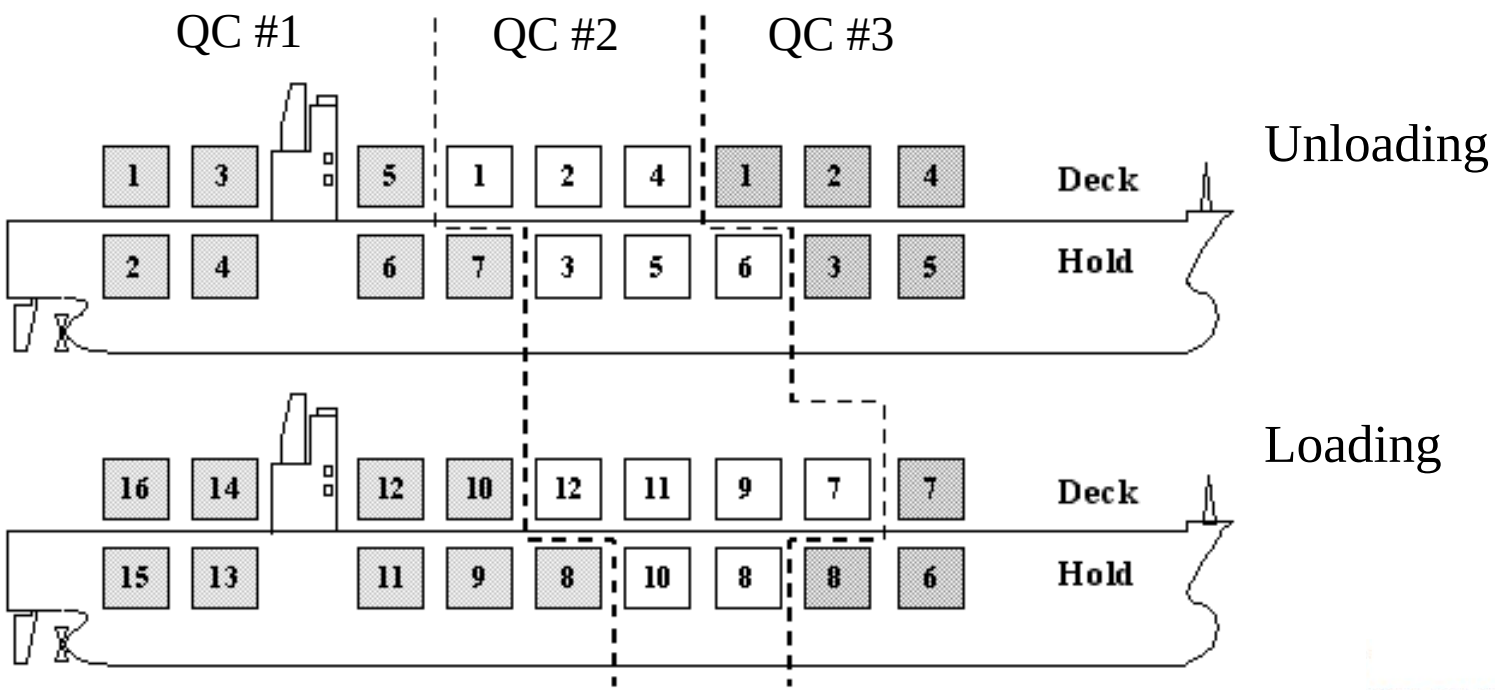
Decision for operational plans

Berth planning	
Activity to be planned	Berthing of each vessel
Resources	Berth, storage space, quay cranes, yard trucks
Contents of decision to be made	Berthing position and time of each vessel



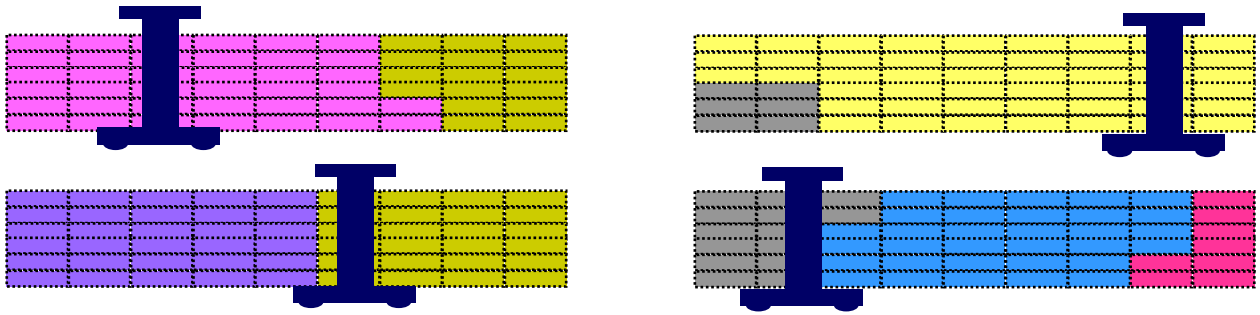
Decision for operational plans (Cont.)

QC work scheduling	
Activity to be planned	Loading or unloading task on deck or in hold of a bay by a QC
Resources	QC, storage space, yard cranes
Contents of decision to be made	Schedule for a QC to discharge and load containers on a vessel



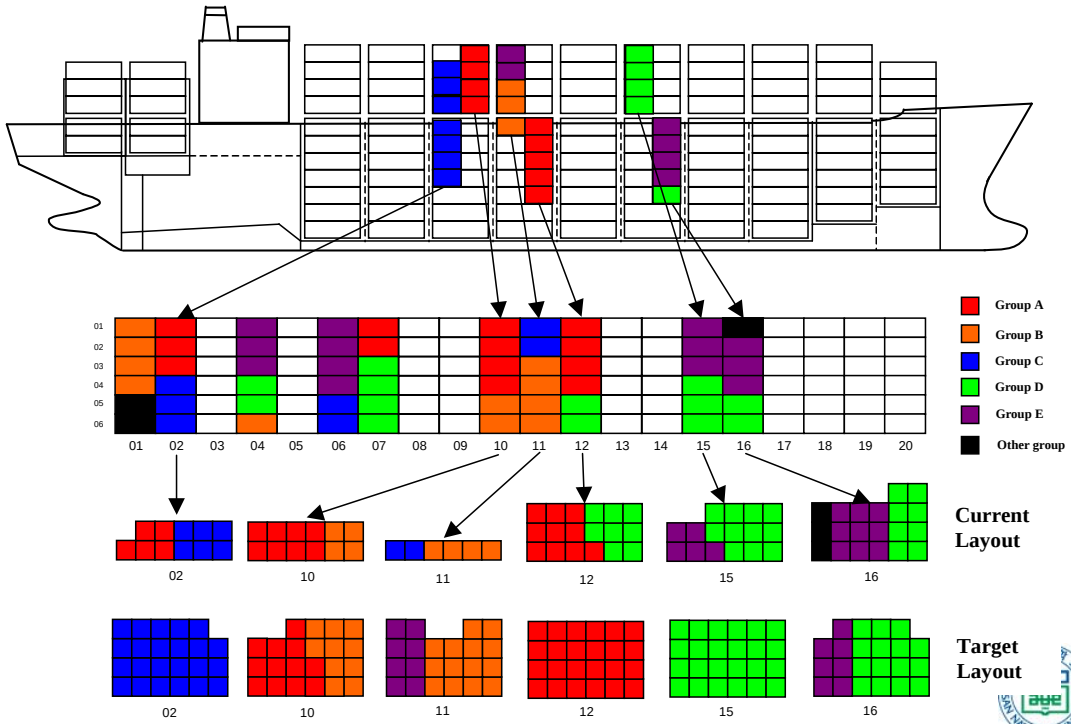
Decision for operational plans (Cont.)

Yard planning	
Activity to be planned	Receiving outbound containers of a group for a vessel or unloading inbound containers by a QC for a vessel for a period
Resources	Storage space, yard cranes, transfer area
Contents of decision to be made	Storage positions for receiving or unloading containers



Decision for operational plans (Cont.)

Re-marshal planning	
Activity to be planned	Moving a set of containers from one block to another for a period
Resources	Storage space, yard cranes, YTs, transfer area
Contents of decision to be made	Containers to be moved and their source and destination positions for a period



Previous Approaches

- Example of Space planning
  - Outbound containers for a vessel must not be distributed over more than three blocks.
  - Containers bound for the same port must be distributed over more than one block.
  - Containers bound for the same port must be grouped together in the yard.
  - Inbound containers must not be discharged at the same block where large amount of arrivals of outbound containers are expected.
  - Congestion in truck traffic must be avoided.
- Difficult to define problems
  - Too many requirements from people in practice
  - Too many constraints to be satisfied by the algorithm
  - Some requirements contradict each other.

Current practice of planning process

- Hierarchical planning process – Plans in higher hierarchies constrain plans in lower hierarchies, which results in lower adaptability to changes.
- Long planning time – Inflexibility to the last minutes changes, longer lead time for shippers
- Inconsistency among different plans
- Lack of global view of individual planner – local optimal decision

Approaches for new solutions

Allow distributed/unsynchronized decision-making by planners

Provide a tool to communicate among different planners

Share information on the available amount of resources Among planners

Resources in container terminals

- Container terminals are carrying out various handling operations by utilizing the following facilities

Quay or berth

Quay crane

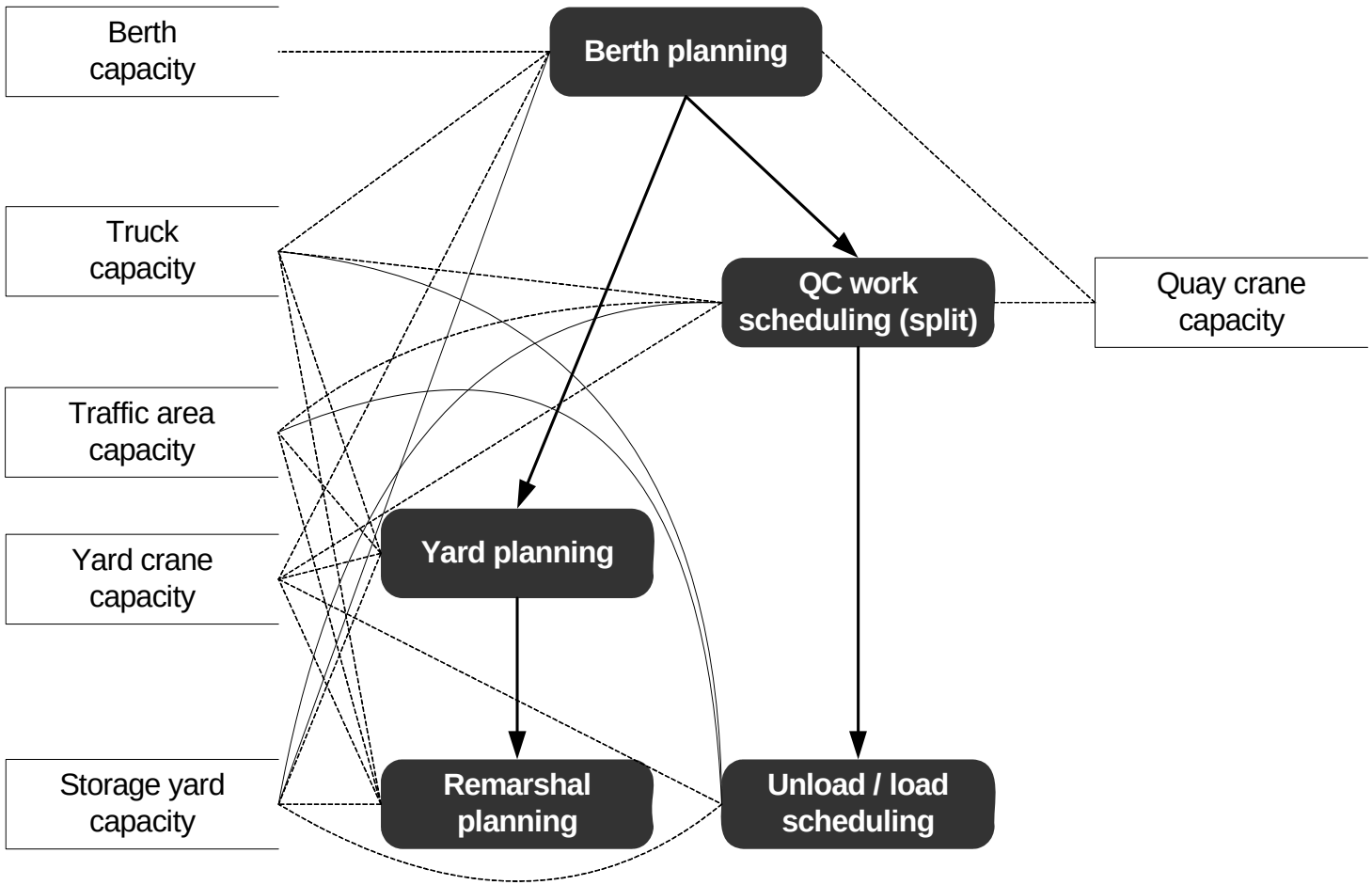
Storage yard

Yard crane

Straddle carrier

Yard truck

Operational plans considering resources



Estimating resources required

Berth

(Length of vessel) × (Occupation time of vessel)

Quay crane

(Number of containers) × (Standard handling time per container)

Yard truck

(Number of containers) × (Average transportation time per container)

Yard crane

(Number of containers) × (Standard handling time per container)

Traffic area

Expected future occupation time of TAs by trucks

Storage yard

(Reservation before storage of containers) + (Actual occupation by containers)

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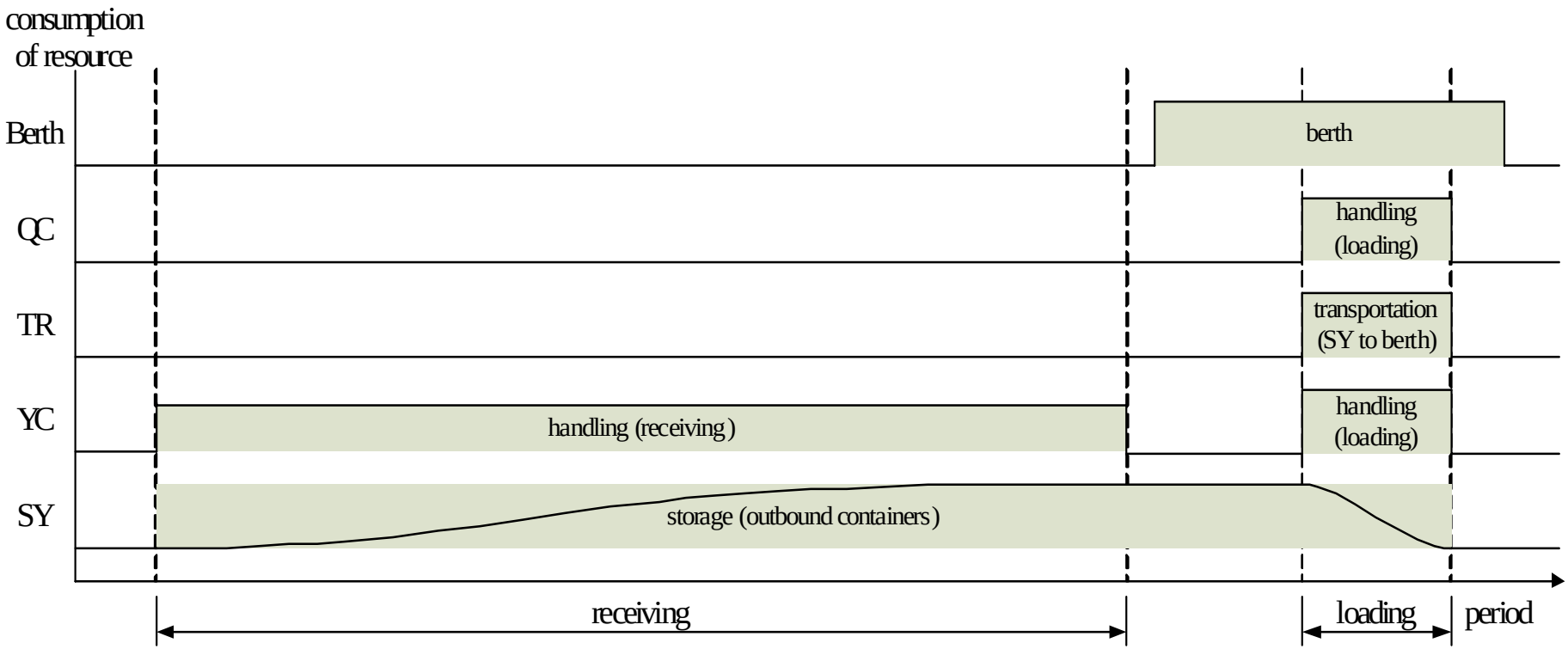
Example of a berth planning problem

Input parameters	Calling schedule Favorable berthing location of each vessel Length of each vessel Draft required for each vessel Number of unloading and loading containers of each vessel Resource profiles
Decision variables	Berthing position of each vessel Berth time of each vessel
Objectives	To minimize delays in departure of vessels To minimize travel distances between shore and yard for all containers of vessels
Constraints	Depth of water for berths Due time for departure of vessels Availability of resources

Resource profile for berthing a vessel

- For outbound containers



Resource profile for berthing a vessel

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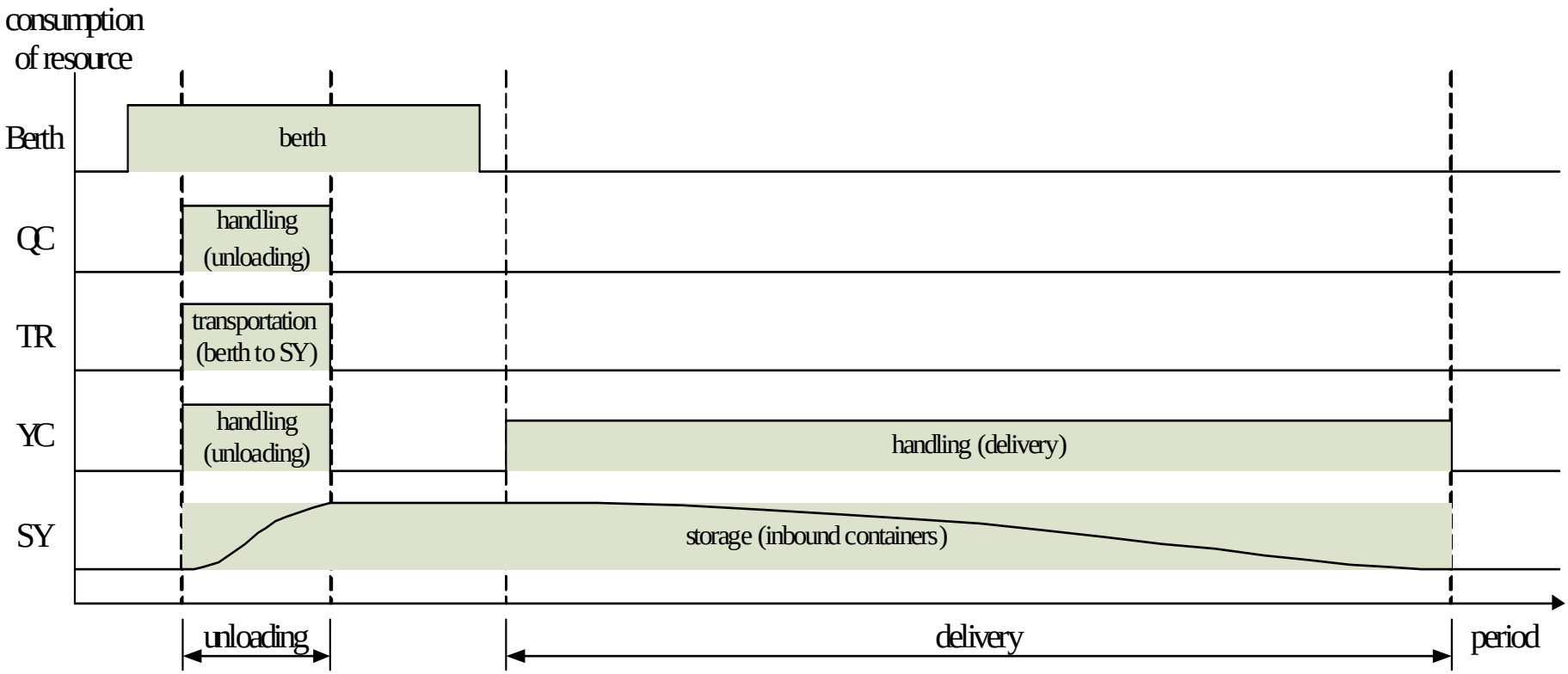


Notations

r	Index for the type of resources where $r = H$ (berth), C (QC), R (TR), Y (YC), A (TA), and S (SY)
t	Index for periods where $t = 1, 2, \ldots, m$
a	Index for activities where $a = 1, 2, \ldots, n$
s_{ar}^{t}	Unit amount of resource r which must be used with time offset of t for carrying out activity a In berth planning, for example, if a vessel is decided to berth at quay at period p (let this be activity B), the unit operation time of QCs at period ($p + t$) will be required by amount of s_{BC}^{t} This is a basic datum for calculating resource profile

Example of calculating resource profiles

- For activity *of* ***berthing***, resource Y (YC), and $t < 0$
- s_{BY}^{t} = (Time for a YC to receive an outbound container from an external truck) × (Percentage of containers, among all outbound containers, arriving at SY on $|t|$ th day before loading)

Time for a YC to receive an outbound container from an external truck = 1.521 minutes

Percentage of containers arrived at SY on $|t|$ th day before loading

t	-6	-5	-4	-3	-2	-1
%	2	5	6	10	12	65

t	-6	-5	-4	-3	-2	-1
s_{BY}^{t}	**0.030**	**0.076**	**0.091**	**0.152**	**0.183**	**0.989**

Data for calculating resource profile in berth planning

Length of the vessel plus allowance between adjacent vessels	300 m
Berthing duration of the vessel	18 hrs
Number of loading containers for the vessel	540
Number of unloading containers for the vessel	560
Time for a QC to transfer an outbound container to a slot of the vessel	1.9 mins
Time for a QC to transfer an inbound container to a TR	1.9 mins
Turnaround time for a TR to travel between shore and yard	10 mins
Time for a YC to transfer an inbound container to an external truck	2.242 mins
Time for a YC to transfer an outbound container to a TR	1.134 mins
Time for a YC to receive an inbound container from a TR	1.114 mins
Storage duration of the container for a period	24 hrs

- Percentage of containers left the terminal on *n*th day after unloading

n	1	2	3	4	5	6
%	35	22	15	14	11	4

Resource profile for berthing a vessel

t / *r*	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
Quay	-	-	-	-	-	-	324,000	-	-	-	-	-	-
QC	-	-	-	-	-	-	1.9	-	-	-	-	-	-
Truck	-	-	-	-	-	-	10	-	-	-	-	-	-
YC	0.03	.08	0.09	0.15	.18	0.96	1.12	0.76	0.49	0.34	0.31	0.25	0.09
Storage	29	101	187	331	504	1,440	1,440	1,440	950	634	418	216	58

Resource profile of space allocation for an outbound container

Unit: minute

period / *resources*	0	1	2	3	4	5	6
Truck	–	–	–	–	–	–	10
Yard crane	0.030	0.076	0.091	0.152	0.183	0.989	1.1
Transfer area	0.06	0.15	0.18	0.3	0.36	1.95	3
Storage space	28.8	100.8	187.2	331.2	504	1,440	1,440

Resource profile of space allocation for an inbound container

period / *resource*	0	1	2	3	4	5	6
Truck	10	–	–	–	–	–	–
Yard crane	1.114	0.762	0.493	0.336	0.314	0.247	0.090
Transfer area	3	1.02	0.66	0.45	0.42	0.33	0.12
Storage space	1,440	1,440	950.4	633.6	417.6	216	57.6

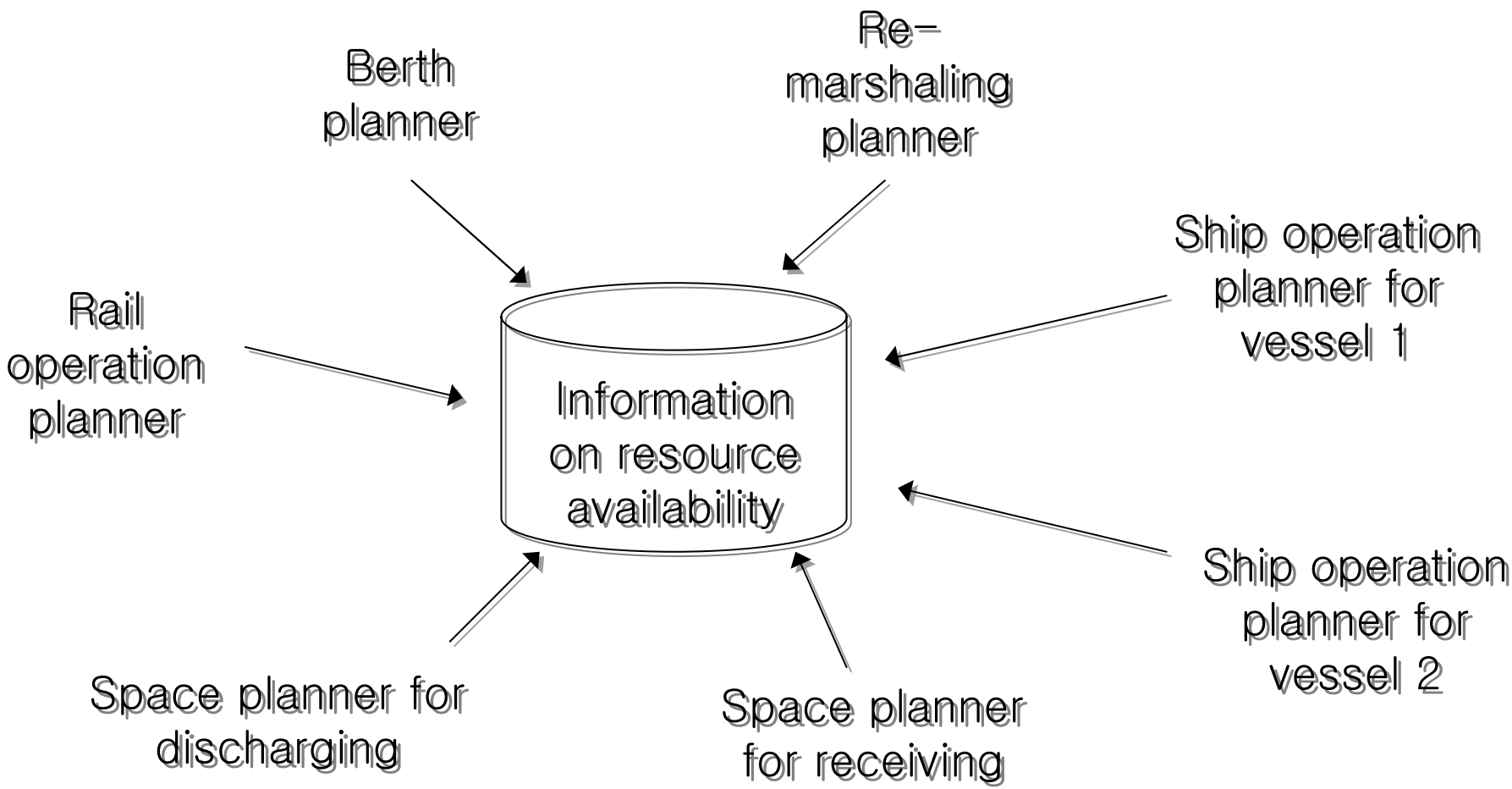
An Example of a Space Plan

Storage block	1	2	3	4	5	6	7
Number of inbound containers	220	200	140	–	–	–	–
Number of outbound containers	–	–	90	120	111	102	117

An Example of a Capacity Plan of Block 1 for Storage Planning

t	1	2	3	4	5	6	7	8	9
Yard Crane									
Capacity	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440
Reserved	1,255	1,200	1,108	1,100	1,090	1,050	1,070	1,050	–
Available	185	240	332	340	350	390	370	390	1,440
Required	–	245	168	108	74	69	54	20	–
Transfer Area									
Capacity	4,320	4,320	4,320	4,320	4,320	4,320	4,320	4,320	4,320
Reserved	3,010	3,770	3,700	3,600	3,500	3,400	3,300	3,200	–
Available	1,310	550	620	720	820	920	1,020	1,120	4,320
Required	–	660	224	145	99	92	73	26	–
Storage Space									
Capacity	1,512	1,512	1,512	1,512	1,512	1,512	1,512	1,512	1,512
Reserved	1,157	1,140	1,104	1,103	1,102	1,101	1,100	1,099	–
Available	355	372	408	409	410	411	412	413	1,512
Required	–	317	317	209	139	93	48	13	–

Sharing information on resources among planners



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Conclusions

- Proposed an integrated framework for various planning activities in container terminals
- Applied a concept of the resource planning to each planning activity
- Illustrated the resource profile and resource planning process

Conventional method	New framework using resource planning
Handling capacities have been considered as constraints or rules during planning process	Handling capacities can be explicitly considered by using the resource profile during planning process

Future Studies

- Re-design processes of various planning activities
- Re-defining operation planning problems
- Re-design software framework, data base structure for terminal operation systems
- Developing decision-making methods for various planning activities