TRUCK SCHEDULING AT CONTAINER TERMINALS

MIE562F Project – Problem Definition

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INTRODUCTION

This project considers the scheduling of movement of ocean containers from the container terminal (sea-port) after discharge from a container ship to a ***transloading facility***. The transloading (cross-docking) facility transfers goods from the ocean containers to domestic containers owned by a distributor, and then loads the container on rail or road towards its next destination (typically a distribution center). To avoid financial penalties at the terminal and account for the varying processing times at the transloading facility, containers can be sent to a third external location called ***the stack*** for temporary storage at a fixed cost of entry but with much lower daily cost. (See Figure 1 for a diagram of locations).

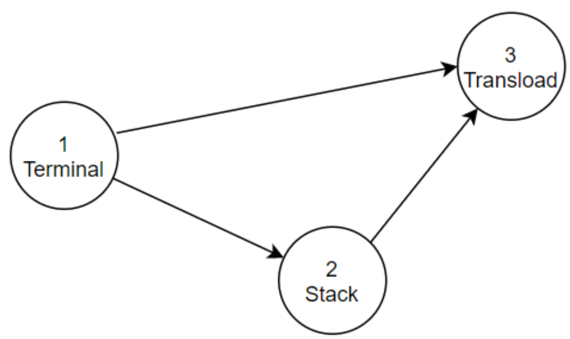


Figure 1: *Directed graph showing movement of containers between locations. Chassis may move bidirectionally between any two nodes.*

Containers are moved between locations using a container bed called a *chassis* attached to a truck. An external crane can pick up a container and place it on a chassis for transport. When a container is transported to the stack, it is removed from the chassis, and placed in a container pile. However, when a container is being processed at the transloading facility, the chassis is required to sit at the dock until the ocean container is empty because the crane at the transloading facility is unable to lift an ocean container full of goods. Therefore, the chassis must remain at the transloading facility until the container is processed. Chassis may move bidirectionally between any of the terminal, stack and transload.

PROJECT OBJECTIVE

The objective of this project is to evaluate the effectiveness of two different scheduling methods to determine the optimal schedule of container transport (defined by minimizing total cost). The scheduling decision is deciding when and where to send each container after it arrives at the terminal. Containers may either be transported directly from the terminal to the transload facility or be sent to the stack for a certain amount of time, and then onto the transloading facility.

This scheduling problem can be considered as a variant of the resource-constrained Job Shop Scheduling Problem. Alongside the regular JSP constraints (release dates, non-overlap on resource, etc.), there are additional components of: assigning containers to legs, chassis travel time between jobs, the priority of the job must be considered, and the objective is to minimize cost based on the tardiness of soft deadlines from when a container is discharged (at Terminal and Transload), rather than the total makespan.

SCHEDULING FACTORS

Several factors influence the optimal schedule:

- **Container Arrival Dates (Terminal).** We consider containers *released* when they are discharged from a container ship at the Terminal. Ships arrive on random dates and with a random quantity of ocean containers (Ex. Ship 1 arrives at time = 0 with 80 containers, Ship 2 arrives on time = 3 with 50 containers, etc.). We assume containers from a ship are all discharged on the same day.

- **Processing Capacity (Transloading Facility)**. Containers stay docked to chassis at the transloading facility. There is a processing time associated with processing a container which is typically 1-5 days. After processing, the chassis with the container is returned to the terminal.

- **Demurrage Costs (Tardiness at Terminal)**. Depending on the international shipping carrier, ocean containers have a few free storage days at the terminal after being discharged from a ship. After this period, there is a *Demurrage* cost incurred daily (Ex. Day 1-5: $0, Day 6+: $100/container/day).

$$\begin{aligned}&Demurrage\ Cost_{container\ k}\\ &\quad = Daily\ Cost\ at\ Terminal_{carrier\ j} \times \max\{Days\ at\ Terminal_{container\ k}\\ &\quad - Free\ Period_{carrier\ j}, 0\}\end{aligned}$$

- **Detention Costs ('Soft' Container Due Date)**. Depending on the international shipping carrier, ocean containers have a few weeks to be unloaded after being discharged from the ship. After this period, there is a *Detention* cost incurred daily until the container is returned to the terminal. ($200/container/day). After processing, containers are returned to the carrier without need for chassis.

$$\begin{aligned}&Detention\ Cost_{container\ k}\\ &\quad = Daily\ Cost\ of\ Container_{carrier\ j} \times \max\{Days\ occupied_{container\ k}\\ &\quad - Days\ Free_{carrier\ j}, 0\}\end{aligned}$$

- **Container Priority**. Each container also has a priority level assigned by the company, which could be to prevent stock-outs of certain products further up the supply chain. These containers can have a priority of low, medium or high priority, defined by the intended distributor. Potential problem instances can consider a mix of priorities, such as a batch of high priority containers arriving on the same ship, or in quick succession. A cost penalty is assigned to each container at the time of departure from terminal which is scaled by the priority and time since container arrival (release date).

$$\begin{aligned}&Cost\ associated\ with\ Priority_{container\ k}\\ &\quad = Priority\ factor_{container\ k} \times (Start\ Time\ of\ transporting_{container\ k} - Release\ Time_{container\ k})\end{aligned}$$

- **Storage Costs (Stack)**. At the stack, a fixed cost is charged for loading and unloading into the yard with a cheap cost incurred daily (Ex. $200 + [day 1→$15, day 2 → $30, etc..]).

$$\begin{aligned}&If\ container\ k\ is\ going\ to\ Stack,\\ &\quad Storage\ Cost_{container\ k} = Fixed\ Cost\ at\ Stack - Daily\ Cost \times Days\ in\ Stack_{container\ k}\\ &Else,\\ &\quad Storage\ Cost_{container\ k} = 0\end{aligned}$$

- **Chassis Resource Constraints**. There is also a limited number of available chassis to move containers. Since a chassis is occupied for the duration of the transloading process, it cannot be used to move other containers from the terminal to the transloading facility or the stack. However, at the stack, this is not an issue since the container is removed from the chassis. When the transloading process is finished, the chassis (with ocean container) are picked back up by a random truck and the ocean container is returned to the terminal. Between transporting successive containers, chassis need to travel between the first container's drop off point to the next container's pickup point (see Appendix: A.1).

ASSUMPTIONS

- Chassis take the shortest path between start of jobs, with each leg constituting one job.
- A truck is available for whenever a chassis is scheduled to be transported.
- There are unlimited spots at the transloading facility for chassis to dock and be unloaded from.
- There is unlimited space at stack for containers.

CONCLUSION

This variant of resource-constrained Job Shop Scheduling problem with the objective to minimize cost associated with tardiness and external storage can be modelled as a Mixed Integer Programming (MIP) and a Constraint Programming (CP) problem using interval variables. An initial MIP formulation based on the disjunctive formulation for the JSP is included in Appendix: A.1.

APPENDIX

A.1

An initial MIP formulation for this truck scheduling problem.

$Sets$:

C	$Set\ of\ chassis, c \in C$
K	$Set\ of\ containers, k \in K$
J	$Set\ of\ carriers, j \in J$
L = {1, 2, 3}	$Set\ of\ travel\ legs, l \in L.$ 1: $terminal\ to\ transload, process, and\ back\ to\ terminal,$ 2: $terminal\ to\ stack,$ 3: $stack\ to\ transload, process, and\ back\ to\ terminal$

$Parameters$:

Φ_{kl}	$Time\ duration\ of\ leg\ l\ for\ container\ k\ [days], k \epsilon K, l \epsilon L$
$D_{ll'}$	$Delay\ required\ for\ a\ chassis\ [days] to\ start\ leg\ l'\ after\ completing\ l\ (includes\ travel)$
M	$some\ large\ number$
R_k	$Release\ time\ of\ container\ k\ [days]$
Γ_j	$Demurrage\ cost\ at\ terminal\ per\ unit\ time\ for\ carrier\ j\ after\ free\ period\ [\$/_{container * days}]$
Γ''_j	$Free\ period\ before\ demurrage\ cost\ for\ carrier\ j\ at\ terminal\ [days]$
S	$fixed\ cost\ at\ stack\ [\$/_{container}]$
S'	$unit\ cost\ at\ stack\ per\ unit\ time\ [\$/_{container * days}]$
δ''_j	$Free\ period\ before\ detention\ cost\ for\ some\ container\ of\ carrier\ j\ [days]$
δ_j	$Detention\ cost\ per\ unit\ time\ for\ some\ container\ of\ carrier\ j\ [\$/_{container * days}]$
Z_{jk}	$1\ if\ container\ k\ belongs\ to\ carrier\ j$
ρ_k	$Priority\ factor\ of\ container\ k, higher\ value\ is\ higher\ priority$

$Variables$:

x_{klc}	$1\ if\ container\ k\ is\ transported\ across\ leg\ l\ using\ chassis\ c, 0\ otherwise$
s_{klc}	$Start\ time\ of\ transporting\ container\ k\ across\ leg\ l\ using\ chassis\ c.$ $0\ if\ x_{klc} is\ 0. Otherwise > 0$

$$
min \sum_{k\epsilon K}\sum_{c\epsilon C}\sum_{l\epsilon\{1,2\}}\sum_{j\epsilon J}\Gamma_j * \max\{(s_{klc} - R_k - \Gamma_j^{"})Z_{jk}, 0\}
$$

$$
+\sum_{k\epsilon K}\sum_{c\epsilon C}\sum_{l\epsilon\{1,3\}}\sum_{j\epsilon J}\delta_j * \max\{(s_{klc} + \phi_{kl} - R_k - \delta"_j)x_{klc}Z_{jk}, 0\}
$$

$$
+\sum_{k\epsilon K}\sum_{c\epsilon C}x_{k2c}\left(S + S'(s_{k3c} - s_{k2c})\right)
$$

$$
+\sum_{k\epsilon K}\sum_{c\epsilon C}\sum_{l\epsilon\{1,2\}}\sum_{j\epsilon J}\rho_k(s_{klc} - R_k)x_{klc}Z_{jk}
$$

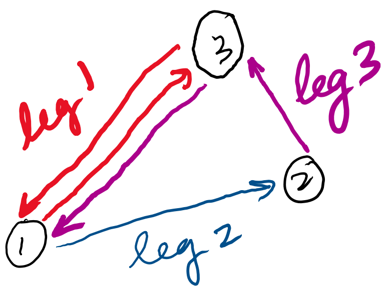
#	***subject to***:		***description***
1	$\max\,(M(1 - x_{klc}), M(1 - x_{k'l'c}), \lvert s_{klc} - s_{k'l'c}\rvert) \geq \Phi_{kl} + D_{ll'}$	$for\ all\ c\ \epsilon\ C,$ $for\ all\ k, k'\epsilon\ K$ $for\ all\ l, l'\epsilon\ L$ $s.t.$ $NOT\ AND$ $(k = k', l = l')$	For each chassis, jobs can't overlap, and chassis may have to travel between jobs.
2	$s_{klc} \geq R_k x_{klc}$	$for\ all\ k\ \epsilon\ K,$ $for\ all\ l\ \epsilon\ L,$ $for\ all\ c\ \epsilon\ C$	Release time constraint
3	$\sum_{c\epsilon C} x_{k2c} = \sum_{c\epsilon C} x_{k3c}$	$for\ all\ k\ \epsilon\ K$	Containers going through leg 2 must also go through leg 3
4	$\sum_{c\epsilon C} x_{k2c} + \sum_{c\epsilon C} x_{k1c} = 1$	$for\ all\ k\ \epsilon\ K$	Containers go through leg 1 OR leg 2/3
5	$M\sum_{c\epsilon C} x_{k1c} + \sum_{c\epsilon C} x_{k3c}s_{k3c} \geq \sum_{c\epsilon C} x_{k2c}s_{k2c} + \Phi_{k2}$	$for\ all\ k\ \epsilon\ K$	leg 2 to 3 precedence constraint
6	$s_{klc} \geq 0$	$for\ all\ k \in K$ $for\ all\ l \in L$ $for\ all\ c \in C$	Domain of s
7	$x_{klc} = [0,1]$	$for\ all\ k \in K$ $for\ all\ l \in L$ $for\ all\ c \in C$	Domain of x

A.2

Visual explanation for Constraint 1.

chassis constraints:

→ chassis must stay with container at 3 and return it to 1



1 : terminal

2 : stack

3 : transload

Each chassis may take any 2 legs in succession. However, the spacing between legs varies. i.e. leg 3 → leg 3 : spacing between start times ≥ duration of leg 3 + travel time from 1 to 2. etc.