Empty Container Reuse

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Motivation

- Increasing umber of containers going through the Los Angeles / Long Beach port complex
- The growth of traffic is a major contributor to regional traffic congestion, service delay, air pollution, etc.
- Numerous ways have been suggested to resolve these problems; developing an expanding facilities, deploying advanced information technologies, and improving operational characteristics
- Feasible options rely on more intelligent decision making to make current operations more efficient without expanding the infrastructure

Objectives

- Study the exchange of empty containers outside of the port
- Investigate the possibility of substituting different types of empty containers outside terminal
- Find an approximated solution of the empty container reuse problem in stochastic environment

Problem formulation

- The empty container reuse problem can be modeled as a conventional transportation problem by adapting Depot-Direct and Street-Turn methodologies
- Substitutions in the empty container reusing problem is implemented for the multi-commodity transportation problem, which is modeled as an integer programming problem.
- Empty container reuse with stochastic demands is modeled as a two-stage stochastic programming

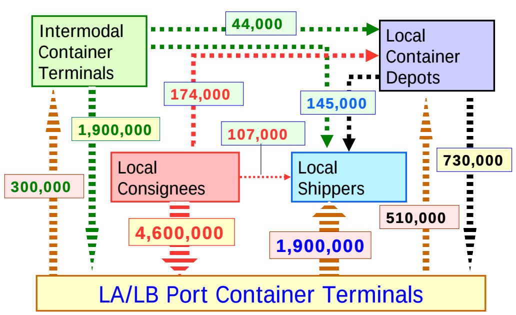
$$\text{Minimize} \quad \sum_{i=1}^{m+p}\sum_{j=1}^{n+p} c_{ij}x_{ij}$$

$$\text{Subject to} \quad \sum_{j=1}^{n+p} x_{ij} = s_i \qquad \forall i \in I \cup P$$

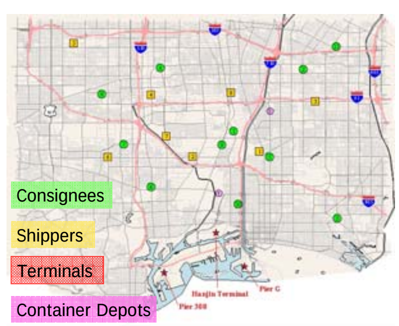
$$\sum_{i=1}^{m+p} x_{ij} = d_j \qquad \forall j \in J$$

$$x_{ij} \ge 0, \text{ integer}, \qquad \forall i \in I \cup P, j \in J$$

Estimates of Annual Flows of empty Containers in 2020 (Base Line: No Reuse)



Locations Used for Simulation Scenarios



Comparison of Base Line Scenarios (No Reuse) to Scenarios with Empty Container Reuse

Scenario	Supply Empties at Consign	Demand Empties at Shippers	Base line: Cost	Base line: Empty Trips	Empty Reuse: Cost	Empty Reuse: Empty Trips to Port & Depots
2000-A	219	14	5,483	326	2,466	142
2000-B	547	267	13,832	814	6,182	349
2010	985	534	25,568	1519	10,572	587
2020	2,188	908	52,857	3096	25,608	1506

Multi-commodity substitution problem (MC)

$$\text{Minimize} \quad \sum_{t\in T}\sum_{i=1}^{m+p}\sum_{j=1}^{n+p} c_{ij}^t x_{ij}^t + \sum_{t\in T}\sum_{i=1}^{m+p}\sum_{k=1}^{\bar{n}} c_{ik}^t x_{ik}^t$$

$$\text{subject to} \quad \sum_{j=1}^{n+p} x_{ij}^t + \sum_{k=1}^{\bar{n}} x_{ik}^t = s_i^t, \qquad \forall\ i \in I \cup P,\ t \in T$$

$$\sum_{i=1}^{m+p} x_{ij}^t = d_j^t, \qquad \forall\ j \in J,\ t \in T$$

$$\sum_{t\in T}\sum_{i=1}^{m+p} r_{ik}^t x_{ik}^t = e_k, \qquad \forall\ k \in \bar{J}$$

$$x_{ij}^t,\ x_{ik}^t \ge 0,\ \text{integer}, \qquad \forall\ i,\ j,\ k,\ t$$

Decomposed IP method for MC

1. Calculate an optimal solution to **MCR**.
2. Decompose into **MCF** and **MCN** and combine the set of non-integer variables.
   $y = \left\{x_{ij}^t :\ (i,j,t) \in F\right\} \cup \left\{x_{ik}^t :\ x_{ik}^t - \lfloor x_{ik}^t \rfloor \ne 0,\ (i,k,t) \in S\right\}$
3. If $y = \phi$, go to step 6.
4. Solve **MCF** by applying the BNB method only on y variables.
5. Update $y = \left\{x_l : x_l - \lfloor x_l \rfloor \ne 0,\ x_l \in \mathbf{x}_{\text{MCF}}^*\right\}$ and go to step 3.
6. Combine the solution $\left\{x_{ij}^t : (i,j,t) \in N\right\} \cup \left\{x_l :\ x_l \in \mathbf{x}_{\text{MCF}}^*\right\}$, where $\mathbf{x}_{\text{MCF}}^*$ is an optimal solution to **MCF**.

$N = \left\{(i,j,t):\ x_{ij}^{t\,*} = \text{integer}\right\} \quad \forall\ i,\ j,\ t$

$F = \left\{(i,j,t):\ x_{ij}^{t\,*} = \text{non-integer}\right\} \quad \forall\ i,\ j,\ t$

$S = \left\{(i,k,t):\ x_{ik}^{t\,*}\right\} \quad \forall\ i,\ k,\ t$

Case study simulation

2010 projection scenario: 534 request and 985 supplies per day

substitutable requests ratio [%]	combination of types [%]: supply t1	supply t2	supply t3	demand t1	demand t2	demand t3	Relaxed LP: cost [miles]	Relaxed LP: reduction [%]	Decomposed IP: cost [miles]	Decomposed IP: reduction [%]
0	50	25	25	50	25	25	10235.83	0	D/N	0
20							9649.13	5.73	9657.77	5.65
40							9609.13	6.12	9619.08	6.03
60							9606.05	6.15	9617.18	6.04
80							9597.78	6.23	9615.61	6.06
100							9597.55	6.24	9611.91	6.10
0	50	25	25	25	25	50	10962.64	0	D/N	0
20							9801.63	10.59	9814.04	10.48
40							9629.49	12.16	9647.43	12.00
60							9607.52	12.36	9626.63	12.19
80							9597.55	12.45	9616.03	12.28
100							9597.55	12.45	9611.91	12.32
0	70	20	10	70	20	10	10235.83	0	D/N	0
20							9753.30	4.71	9757.35	4.67
40							9728.27	4.96	9735.49	4.89
60							9728.05	4.96	9733.01	4.91
80							9727.58	4.97	9736.83	4.88
100							9727.58	4.97	9738.20	4.86
0	70	20	10	20	10	70	17288.96	0	D/N	0
20							14720.94	14.85	14723.97	14.84
40							12365.06	28.48	12366.44	28.47
60							11005.61	36.34	11006.99	36.34
80							9413.19	45.55	9423.02	45.50
100							9381.49	45.74	9389.44	45.69
Base scenario							25578.11			

Reuse problem with stochastic demands

$$\min\ \mathbf{c}^T\mathbf{x} + E_\omega[\mathbf{q}^T\mathbf{y}]$$

$$s.t.\quad \mathbf{A}_U\mathbf{x} = \mathbf{s}$$

$$\mathbf{A}_L\mathbf{x} + \mathbf{W}\mathbf{y} = \mathbf{d}(\omega) \qquad \omega \in \Omega$$

$$\mathbf{x},\ \mathbf{y} \ge \mathbf{0}$$

where $\mathbf{W} = [\mathbf{I}_m\ \ -\mathbf{I}_m]$ is the recourse matrix

$$v^* = \min_{x\in S}\left\{ f(\mathbf{x}) \equiv E_\omega\left[g\left(\mathbf{x}, \mathbf{d}(\omega)\right)\right]\right\}$$

where $S \equiv \left\{\mathbf{x} \,\middle|\, \mathbf{A}_U\mathbf{x} = \mathbf{s},\ \mathbf{x} \ge 0\right\}$

and $g\left(\mathbf{x}, \mathbf{d}(\omega)\right) \equiv \mathbf{c}^T\mathbf{x} + \min_{\mathbf{y}\ge 0}\left\{\mathbf{q}^T\mathbf{y} \,\middle|\, \mathbf{W}\mathbf{y} = \mathbf{d}(\omega) - \mathbf{A}_L\mathbf{x}\right\}$

Expected value solution (EEV)

Demand Set	N	worst-case [miles]	Expected value solution: EV [miles]	Expected value solution: EEV [miles]	(EEV-EV)/EV [%]
Set 1 $I_5 = \{0,\cdots,5\}$	100	10614.81	10291.35 (59.67%)	10514.43	2.1676
	200			10516.71	2.1898
	300			10518.57	2.2079
	1000			10519.66	2.2185
	10000			10515.41	2.1772
Set 2 $I_{10} = \{0,\cdots,10\}$	100	10633.98	10240.45 (59.96%)	10505.59	2.5891
	200			10505.38	2.5871
	300			10505.59	2.5891
	1000			10503.82	2.5719
	10000			10504.32	2.5767
Set 3 $I_{15} = \{0,\cdots,15\}$	100	10727.65	10018.77 (61.20%)	10460.43	4.4083
	200			10471.15	4.5153
	300			10469.01	4.4940
	1000			10466.62	4.4701
	10000			10469.62	4.5001

Stochastic solution (SS)

Demand Set	N	EEV [miles]	confidence interval [miles]: 90%	confidence interval [miles]: 95%	ESS [miles] (M=10)	VSS [miles]	VSS/ESS [%]
Set 1 $I_5 = \{0,\cdots,5\}$	100	10514.43	±16.45	±19.66	10503.62	10.81	0.1029
	200	10516.71	±11.84	±14.14	10508.21	8.50	0.0809
	300	10518.57	±9.62	±11.47	10512.62	5.95	0.0566
Set 2 $I_{10} = \{0,\cdots,10\}$	100	10505.59	±20.35	±24.32	10489.42	16.27	0.1551
	200	10505.38	±14.46	±17.26	10499.50	5.88	0.0560
	300	10505.59	±10.92	±13.03	10497.46	8.13	0.0774
Set 3 $I_{15} = \{0,\cdots,15\}$	100	10460.43	±34.56	±41.30	10453.63	6.80	0.0650
	200	10471.15	±24.35	±29.06	10454.39	16.76	0.1603
	300	10469.01	±21.38	±25.50	10452.77	16.24	0.1554

This research was supported by the METRANS Transportation Center under grants from the US Department of Transportation and California Department of Transportation. For further information, see www.metrans.org/research