SUMMARY OF MY RESEARCH

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From The Academia to The Industry: The Precious Journey

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ABSTRACT

Summary of the research I have done in the past almost ten years. More information can be found here: https://www.siyangxie.com

PUBLICATIONS

Most of the contents in the book have appeared previously in the following publications:

This is the current list of my publications

Paper Published In Journals

[1] Kun An, Siyang Xie, and Yanfeng Ouyang. "Reliable sensor location for object positioning and surveillance via trilateration." In: *Transportation Research Part B: Methodological* (2017).

[2] Siyang Xie, Xi Chen, Zhaodong Wang, Yanfeng Ouyang, Kamalesh Somani, and Jing Huang. "Integrated Planning for Multiple Types of Locomotive Work Facilities Under Location, Routing, and Inventory Considerations." In: *Interfaces* 46.5 (2016), pp. 391–408.

[3] Chiwei Yan, Hai Jiang, and Siyang Xie. "Capacity optimization of an isolated intersection under the phase swap sorting strategy." In: *Transportation Research Part B: Methodological* 60 (2014), pp. 85 –106.

Manuscripts Submitted or In Preparation

[1] Zhaodong Wang, Siyang Xie, and Yanfeng Ouyang. "Planning facility location in a continuous space under congestion and disruption risks." In: *In preparation* (2017).

[2] Siyang Xie, Kun An, and Yanfeng Ouyang. "Planning facility location under generally correlated facility disruptions: use of supporting stations and quasi-probabilities." In: *Transportation Research Part B: Methodological* (2018), Revision under review.

There is no mistake in a tango,

not like life.

— Al Pacino as Lieutenant Colonel Frank Slade, Scent of a Woman

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Part I

PHD DISSERTATION: RELIABLE FACILITY LOCATION

1 INTRODUCTION

1.1 MOTIVATION

Facility location decisions lie at the center of planning many infrastructure systems. In many practice, public agencies (e.g., governments) and private companies (e.g., retailers) both need to locate their facilities to serve spatially distributed demands/-customers. For example, governments locate various public facilities, such as hospitals, schools, fire stations, to provide public services; retail companies determine the locations of their facilities including warehouses, assembly plants, stores, etc, to sell goods and provide business. The design of all such facility systems generally involves considerations of fixed investment of facility construction and transportation cost of serving demands, so as to maximize the operational efficiency and service profit of the system [1].

1.2 OUTLINE

This dissertation is organized as follows. Chapter 2 applies the reliable facility location modeling framework to sensor deployment context, in which sensors work in combinations to provide combinatorial service. The ideas of supporting stations are adopted with adjustment to represent the combinations of sensors. A mixed-integer mathematical model is formulated to determine the optimal sensor locations, the sensor combination plans, and the backup assignment decisions. Several approximation subroutines are carefully designed inside a Lagrangian relaxation framework to solve the model.

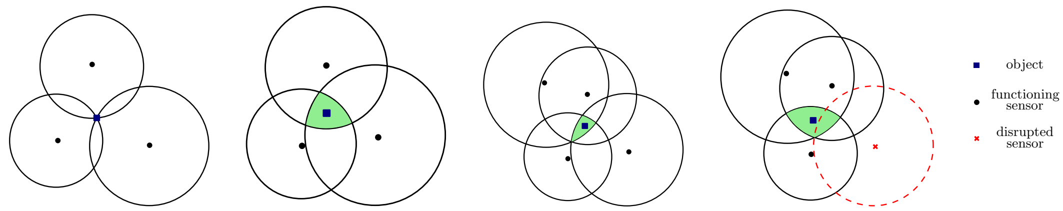
2

RFL WITH FACILITY COMBINATIONS: RELIABLE SENSOR DEPLOYMENT FOR POSITIONING/SURVEILLANCE VIA TRILATERATION

In this chapter, we incorporate the impacts of sensor disruptions into a reliable sensor deployment framework by extending the ideas of assigning backup sensors as well as correlation decomposition via supporting stations.

2.1 INTRODUCTION

High-accuracy object positioning has been playing a critical role in various application contexts such as: (i) civilian uses, including vehicle navigation, driver guidance, activity tracking; (ii) industrial uses, such as aircraft tracking, regional surveillance, extrasolar planets detection; and (iii) military uses, such as search/rescue missions, missile and projectile guidance.



(a) ideal case (b) three sensors (c) multiple sensors (d) disruption scenario

Figure 2.1: Position error illustration in trilateration.

The remainder of this chapter is organized as follows. Section 2.2 introduces the methodology we develop for the reliable sensor deployment problem, including the effectiveness measurements and the model formulation. Section 2.3 presents the solution algorithm. Section 2.4 demonstrates the applicability of the model and solution algorithm on a series of examples.

2.2 MODEL FORMULATION

This sensor location problem (SLP) can now be formulated as the following mixed-integer non-linear program:

$$\text{(SLP)} \quad \min_{\mathbf{X},\mathbf{Y},\mathbf{Z},\mathbf{P}} \quad \sum_{j\in J} f_j X_j - \alpha \sum_{i\in I}\sum_{k\in K}\sum_{r=1}^{|\mathcal{J}|} v_i e_{ik} P_{ikr} Y_{ikr} \tag{2.1a}$$

$$\text{s.t.} \quad \sum_{r=1}^{|\mathcal{J}|} Z_{ijr} \leq X_j, \; \forall j \in J, i \in I, \tag{2.1b}$$

$$\sum_{r=1}^{|\mathcal{J}|} Z_{ijr} \leq 1, \; \forall j \in J, i \in I, \tag{2.1c}$$

Proposition 1. *The assignment probability P_{ikr} can be calculated recursively by* (2.1b)*.*

Proof. We substitute P_{ikr-1} in the right hand side of (2.1c),

$$P_{ikr} = \frac{\prod_{j\in J}\left(1-p_j\right)^{a_{kj}}}{\prod_{j\in J} p_j^{a_{kj}}} \prod_{s\leq r}\left[\sum_{j\in\mathcal{J}} Z_{ijs}\left(p_j\right)^{1_{[j\in J]}}\right]. \tag{2.2}$$

This completes the proof. □

2.3 SOLUTION ALGORITHM

2.3.1 *Lagrangian Relaxation*

In (LSLP), the sensor location variables $\mathbf{X}$ are correlated with the sensor level assignment variables $\mathbf{Z}$ by constraints (2.1b).

$$\text{(RSLP)} \quad \min_{\mathbf{X},\mathbf{Y},\mathbf{Z},\mathbf{P}} \quad \sum_{j\in J}(f_j - \sum_{i\in I}\mu_{ij})X_j \tag{2.3a}$$

$$\text{s.t.} \quad (2.1b) - (2.1c).$$

In this way, a very large portion of the district options is eliminated from the initial set. The pseudo-code for filtering the district options is summarized as Algorithm 1.

2.4 NUMERICAL EXAMPLES

2.4.1 *Hypothetical Grid Networks*

A 2×3 rectangle grid network and six $n\times n$ square grid networks for $n \in \{3, 4, 5, 6, 7, 8\}$ are generated to represent various hypothetical study regions.

Algorithm 1 Generate the set of feasible district options

DistrictGeneration()

```
for i ∈ 𝓘 do
  sourceHeap← createHeap(i), stack← ∅, districts← ∅
  stack.push(DFSNode(i, sourceHeap, districts))
  while stack is not empty do
    node ← stack.pop()
    if W_weight· node.demand ·(1 − q) + W_compact· node.compact ≤ W̄ then
      if node.hash is in districts.hashList then
        districts.setList.add(node.set), district.hashList.add(node.hash)
      end if
    end if
  end while
  remove i from 𝓖
end for
```

createHeap(i, visitedNodes)

```
newHeap ← ∅
for n ∈ 𝓔(i) do
  if n is not in visitedNodes then
    newHeap.insert(n)
  end if
end for
return newHeap
```

Table 2.1: Algorithm performance comparison for the 7 hypothetical cases.

	Sensor network	Neighborhood network	No. of sensors	Final UB	Final LB	Final gap (%)	CPU time (s)
CPLEX	2 × 3	1 × 2	2	-1.31	-1.30	0	1.6
	3 × 3	2 × 2	4	-14.01	fail	100	3600
	4 × 4	3 × 3	-	-	-	fail	3600
	...	...	-	-	-	fail	3600
	8 × 8	7 × 7	-	-	-	fail	3600
LR+B&B	2 × 3	1 × 2	2	-1.31	-1.31	0	0.1
	3 × 3	2 × 2	4	-24.28	-24.28	0	0.1
	4 × 4	3 × 3	5	-77.38	-77.38	0	0.4
	5 × 5	4 × 4	8	-150.78	-150.78	0	0.8
	6 × 6	5 × 5	14	-243.48	-243.48	0	38
	7 × 7	6 × 6	21	-360.99	-360.99	0	181
	8 × 8	7 × 7	29	-489.07	-500.41	2.32	3600

Part II

RAILROAD PLANNING AND OPTIMIZATION

3

INTEGRATED PLANNING FOR MULTIPLE TYPES OF LOCOMOTIVE WORK FACILITIES UNDER LOCATION, ROUTING, AND INVENTORY CONSIDERATIONS

3.1 PROBLEM DESCRIPTION

The assignment of repair, service, and fueling demands to various suitable facilities is determined holistically, and is represented by the solid and dashed arrows in Figure 3.1.

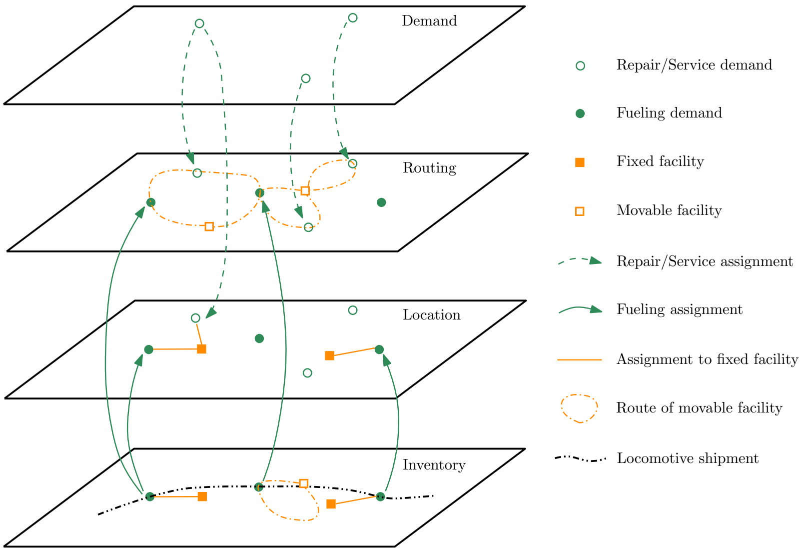


Figure 3.1: The planning problems consist of multiple layers of decisions.

3.2 MODEL FORMULATION

In this section, we present the model formulation of solving the integrated locomotive facility planning problem, with explaination of the network transformation methods in mathematical details.

3.2.1 *Notation*

We first describe the notation used in the model formulation.

3.2.1.1 *Sets*

$\mathcal{F}$ set of fixed facility types.
$\mathcal{M}$ set of movable facility types.
$\mathcal{S}$ set of work types, excluding fueling.

3.2.1.2 *Parameters*

F_n^α	Annual fixed cost of operating a facility of type α at candidate location n.
C_n^α	Cost of unit capacity at a facility of type α at yard n.
$Q_n^{\alpha,\max}$	Maximum (minimum) allowable capacity of facility type α at yard n.

3.2.2 *Location-Inventory Problem Formulation*

Below, we present the formulation for the location-inventory problem.

3.2.2.1 *Objective*

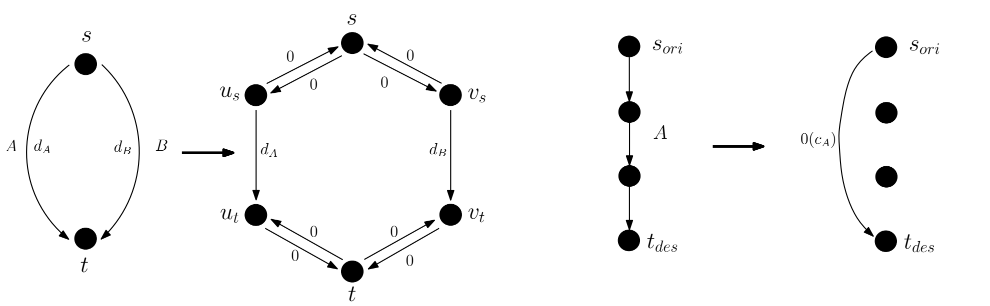
$$\begin{aligned}\text{Minimize} \quad & \sum_{\alpha\in\mathcal{F}\cup\mathcal{M}}\sum_{n\in\mathcal{N}_\alpha} x_n^\alpha F_n^\alpha + \sum_{\alpha\in\mathcal{F}}\sum_{n\in\mathcal{N}_\alpha} q_n^\alpha C_n^\alpha + \sum_{l\in\mathcal{M}}\sum_{n\in\mathcal{N}_l}\left(h_n^l\cdot F_l + t_n^l\cdot V_l\right)\\ & + \sum_{\alpha\in\mathcal{F}}\sum_{n\in\mathcal{N}_\alpha}\sum_{n_1\in\mathcal{N}}\sum_{\beta\in\mathcal{S}} D_{n_1}^\beta\cdot y_{n_1,\beta}^{n,\alpha}\cdot C_{n_1,n} + \sum_{\alpha\in\mathcal{F}}\sum_{r\in\mathcal{R}}\sum_{s\in\mathcal{S}_r}\sum_{n\in\mathcal{N}_\alpha}\sum_{n_1\in\mathcal{N}} G_{r,s}^{n_1}\cdot d_{r,s}^{n,\alpha}\cdot C_{n_1,n}\\ & + \sum_{r\in\mathcal{R}}\sum_{s\in\mathcal{S}_r} E_r\left[h_r^s\sum_{n\in\mathcal{N}}\left(G_{r,s}^n\cdot C_n\right) + p_r^s\sum_{n\in\mathcal{N}}\left(G_{r,s}^n\cdot C_{n,0}\right) + v_r^s\cdot CV + pv_r^s\cdot CV_0\right]\end{aligned}$$

3.2.2.2 *Demand-Satisfaction Constraints*

$$\sum_{\alpha\in\mathcal{F}\cup\mathcal{M}}\sum_{n\in\mathcal{N}_\alpha} y_{n_1,\beta}^{n,\alpha} = 1,\ \forall n_1\in\mathcal{N},\beta\in\mathcal{S} \tag{3.1}$$

$$\sum_{\alpha\in\mathcal{F}\cup\mathcal{M}}\sum_{n\in\mathcal{N}_\alpha} d_{r,s}^{n,\alpha} = E_r\cdot p_r^s,\ \forall r\in\mathcal{R},s\in\mathcal{S}_r \tag{3.2}$$

3.3 SOLUTION APPROACH



(a) Transformation for train network [2]

(b) Transformation for free-move network

Figure 3.2: The two figures illustrate how we transform train network and free-move network by adding new nodes and new edges.

3.4 FIELD IMPLEMENTATION

We implemented the presented algorithm in C# on a computer with a three-GHz CPU and four GB of RAM.

Cost	total	capacity	locomotive shipping	truck	regular fueling	vendor fueling
Change (10^6 \$)	-72.25	-0.68	-109.34	36.02	-7.40	6.75

Table 3.2: We summarize our comparison of the clean-slate scenario and base-case solutions.

	Cost	total	capacity	locomotive shipping	truck	regular fueling	vendor fueling
Scenario 1	change (10^6 \$)	-14.32	0.17	-13.67	-0.01	1.87	-2.69
Scenario 2	change (10^6 \$)	-44.90	0	-69.06	4.00	-20.73	40.91

Table 3.3: We summarize our comparison of the incremental scenarios and base-case solutions.

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