

# DYNAMIC FACILITY LOCATION PROBLEM FOR MAE MOH MINE

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## 1. Introduction

Electricity Generating Authority of Thailand was significant electricity generation to meet consumer requirements and sustain Mae Moh Mine business competition. Mining operation in EGAT Mae Moh was divided by two main categories which were mine haulage system and mining logistics supporting system. The mining logistics support system was integrated system about planning, operating and control to deliver resources to many centroids of mining machines in mine haulage system to meet some requirements. The mining operation in EGAT Mae Moh was shown in figure 1.

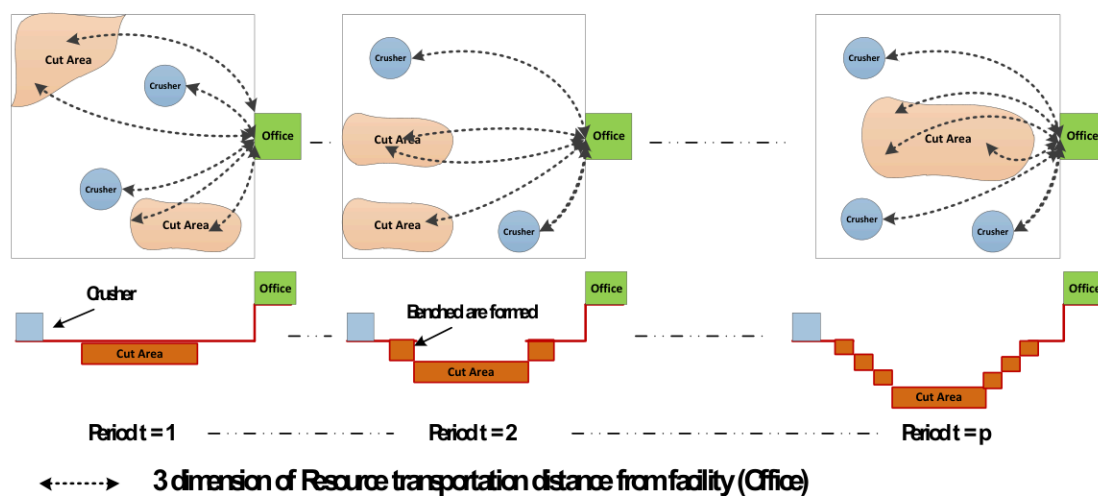


Figure 1: The traditional logistics support system efficiency was decreased because of increased line haul distance (EGAT, 2012).

Transportation activity was 1 of 7 wastes (Muda) in lean management (Rother & Shook, 1999; Bennet & Sutherland, 2007) so the logistics support system was significant this activity from facility. The facility was maintenance office that consisted sub divisions and departments were complex and multiple functions to haul resources such as maintenance, fuel delivery, electricity installation, mine surveying and others from monthly and daily planning of headquarter of EGAT. The current location of facility impacted the efficiency of logistics support system that the line haul distance was increased every mining period later because the centroid of mining machines was often moved to the deep of pit mine for productivity of mine haulage system. From the previous reason, the current logistics support system efficiency was decreased in the future that was shown figure 2. EGAT Mae Moh realized that the maintenance office should be relocated to pit mine but they had questions that “when do they start to relocate maintenance office station to pit mine and where do they install station to minimize total logistics cost since 2013-2047”. Similar ideas for minimization of total logistics cost in open pit mine context that was crusher location optimization (Chukit Luangjok, 2002; Konak, et al., 2007) so the concept of this optimization was select optimal location of crusher for minimization of truck haulage cost and removing/ installing cost of crusher with many constraints such as quantity of coal per area, geography, available site location and number of removing/ installing limitation. However, the research of direct facility location problem for maintenance was less to know. Hence this paper focused on optimization of selecting the mobile in-pit station that was one facility on the open pit mine line haul network all periods. A mathematical model was developed using multi period facility location problem (Wesolowsky, 1973; Wesolowsky & Truscott, 1975) so this problem was NP-Hard (Batta et al., 2003; Lim & Sonmez, 2012). This model dealt with the trade-offs between both transportation and facility costs at mobile in-pit station and aims to minimize the total of these two logistics costs. Within this

model, it determined location of candidate sites of maintenance mobile in-pit station all periods with many constraints such as open pit mine geography changing (distance, number of candidate sites and centroid of mining machines were changed), fleet management policy (hauling frequency and type of truck) and constant number of mining machines all periods. Therefore the model applied metaheuristic as a solution procedure to obtain an approximate optimal solution.

We scoped Mae Moh Mine's pit mines in yearly plan since 2012-2047 and had only one mobile in-pit station for consideration. We did not use plan to trial and evaluate real problem for outcome.

**2. Literature Review**

**2.1 Improving efficiency mining operations.**

Many researches of mining operations efficiency improvement were based on the mine-haulage system which included truck-shovel dispatching system (Alarie, et al., 2002; Bissiri, 2002; Ercelebi, et al., 2009; Limsiri, 2011), crusher location optimization (Chukit Luangjok, 2002; Konak, et al., 2007), blending and mix mine (Erarslan, et al., 2001; Liu, 2008), productivity improvement of conveyor (Theerapol Poolthawee, 2006) and mine production scheduling (Newman, et al., 2006; Rafiee, et al., 2008) while mining logistics support systems efficiency improvement such as minimization of total transportation cost that was fewer people to know.

**2.2 Facility location problem in open pit mine**

In this paper presented the planning of mining logistics support systems efficiency improvement by using applied facility location problem (FLP) approach. However, the research of facility location problem in open pit mine was fewer people to know. We found the FLP in this environment which were research of Chukij Luangjok (2002) that applied crusher location optimization in Mae Moh Mine for improving mine haulage system efficiency so the constraints included quality and quantity of mine in each workspace, the deep workspace was increased by mine production plan, and the number of allowed crusher relocation per year. Konak, et al., (2007) studied in-pit crusher location optimization in Turkey for reducing the haulage cost of truck so they considered haulage distance with difference height of benches in pit mine environment. However, the other facility was the mining logistics supporter included maintenance department that fewer person to know.

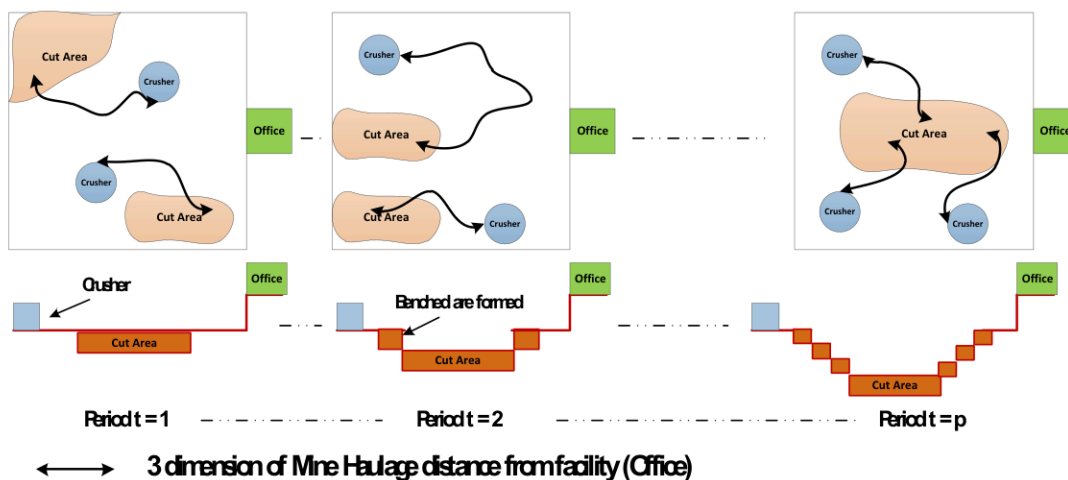


Figure 2: Model of transportation problem of r em so supporter from office was not related to improve mine operation system

**2.3 Dynamic Facility Location Problems**

Daskin et al. (1992) described definition of the dynamic facility location problems (DFLPs) that “the objective of dynamic facility location planning should be to find an optimal or near optimal first period decision for the location problem over an infinitely long planning horizon”. Farahani and Arabani (2012) reviewed the number of dynamic facility location problems literatures that there were two main criteria affecting the decision to identify the right location for a facility: (1) cost for which a trade-off must be set between expenditures incurred by developing a new facility or revising the current facility and profits supposed to be acquired as a result of such development. (2) time for which the opening and closing of facilities are considered over the planning horizon. Furthermore, from another point of view, dynamic models can be divided into two sub-categories: (1) explicitly dynamic models in which

facilities are opened/closed at pre-specified times and locations and (2) facilities are supposed to be opened and remained open throughout the planning horizon at the beginning of the horizon (implicitly dynamic models). Although dynamic facility might cover a wide variety of conditions, looking at different areas of FLPs, one might arrive at different notions of what dynamic means, for example, dynamic models that might have interaction with multi-period models or time dependent (Farahani and Arabani, 2012) consist of

### 2.3.1 Dynamic deterministic facility location problem (DDFLPs)

From primary static models, facility location models should be chosen from set of candidate points. However, there might be some circumstances in which effective parameters (e.g. population, demand patterns, distribution cost, etc.) are being changed or modified over time. In fact, the mentioned static model can be modified to dynamic deterministic model in which  $p$  time periods are considered, an optimal location is identified such as the dynamic uncapacitated fixed charge location problem or dynamic facility location (Wesolowsky, 1973; Daskin et al., 1992) and dynamic single facility location problem (Puerto & Rodriguez-Chia, 2006)

### 2.3.2 Facility location-relocation problem (FLRPs)

From general point view, the relocation of facility is primarily concerned with the time of relocation, the number of relocation, and the cost of relocation. A decision-maker might come up with the following concerns in the relocation problem: in order to minimize cost, when and where to relocate? How to gradually phase-out the existing facility without violating firm's activities? What is the time schedule for relocating capacity? And how cost minimization can be compensated by reducing transit times? The emergency medical services applied this concept to ensure satisfactory response time to incidents (Alanis et al., 2013) and the ambulance deployment problem (Harewood, 2002).

### 2.3.3 Multi period facility location problems (MPFLPs)

The decision makers should think robust FLPs to operate in terms of multi-period time horizon such a planning horizon can be obtained: (1) the appropriate timing of location decision, (2) clarifying the best location(s), and (3) allowing a firm to better anticipate any favorable/unfavorable fluctuations in market demand in the corresponding time horizon such as paper of dynamic or multi-period location-allocation model (Wesolowsky & Truscott, 1975), multi-period incremental service facility location problem (Alberada-Sambola et al., 2009), and dynamic distribution model for combat logistics was also dynamic facility location problem (Gue, 2003).

### 2.3.4 Time-dependent facility location problems (TDFLPs)

Such as hospitals, traffic station and fire station are supposed to be operable at any specific time (according to the availability of locations and the corresponding demand). Farahani et al.(2009) presented single facility location problem with multiple relocation opportunity for new police station.

The facility location problem was NP-Complete problem that solved problem in large environment so the feasible solution was immense. Owen & Daskin (1998), Cheung, et al., (2002) and Wong, et al., (2010) presented the feasible solution estimation of static facility location problem of integer programming problem techniques for P-Median problem below as

Which,

$n$  = the number of available location for facility

$r$  = the number of facility need to be assignment

$$\text{Feasible Region} = \frac{n!}{r!(n-r)!} \text{ feasible solutions for static facility location problem}$$

From Eq. (1) if the number of available location for facility was many, it was large and complex to rapidly search optimal solution when number of available location and facility was many. Hence, the dynamic facility location problems is more complex than static problems for enumeration feasible solutions that dynamic problems is NP-Hard (Batta et al., 2003; Lim & Sonmez, 2012). Metaheuristic is applied to solve NP-Hard problem for rapid and easy optimal solution searching (Mawdesley, et al., 2002; Zouein, et al., 2002; Elbeltagi, et al., 2004; Pitakaso, 2011).

### 2.3 Metaheuristic

Pitakaso (2011) described heuristic which was independent methodology that established any processes or procedures to apply to search solution. Blum and Roli (2003) summarized metaheuristic principles below as

- Metaheuristic are strategies that “guide” the search process.
- The goal is to efficiently explore the search space in order to find (near-) optimal solutions.
- Techniques which constitute metaheuristic algorithms range from simple local search procedures to complex learning processes.
- Metaheuristic algorithms are approximate and usually non-deterministic.

From literature were reviewed, we applied to integrate the facility location problem using by spreadsheet modeling concept and search near-optimal solution with metaheuristic optimization for improving logistics support systems efficiency in open pit mine environment. The detail was described in sector 3 model.

### 3. Model

The model described here aimed to identify the optimal location of single maintenance in-pit station. Figure 3 show the structure of mining logistics support system that was investigated within this paper. It was assumed that the movement of resources was resource transportation with fleet of supporter departments on open pit mine streets that went deep pit mine. Sometimes resources may be stored at facility, but no inventory and no soil stability of candidate sites were considered in this study. Points where fleet was generated by supporter department policies and was set for resource delivery within open pit mine streets all periods. These points were referred to as centroids of mining operation so they were changed position to locate at deep area by mining plan.

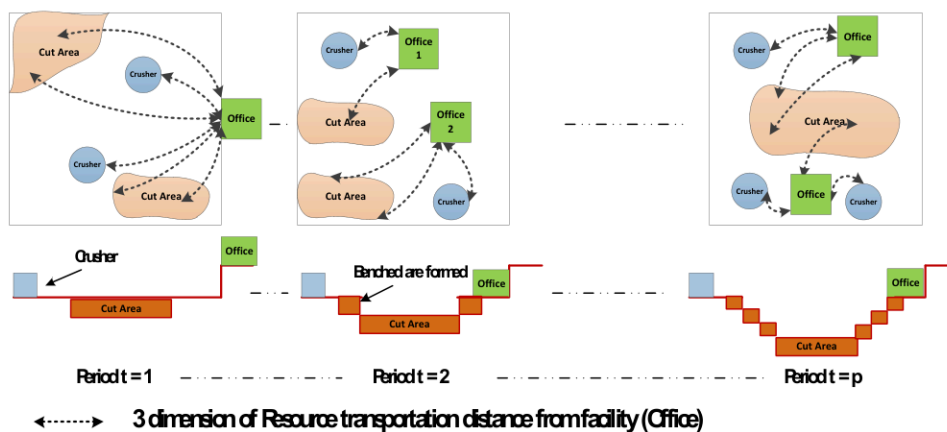


Figure 3: Facility location optimization structure of logistics support system for mine operation.

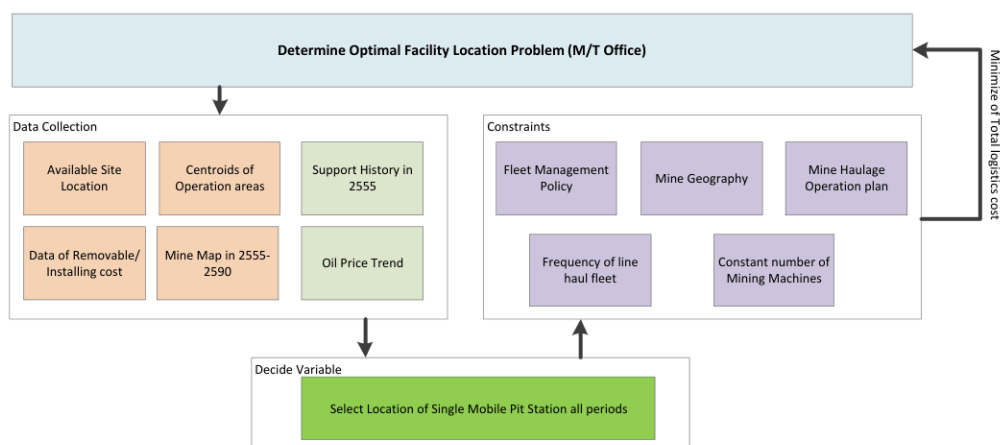


Figure 4: Structure of mathematical modeling of logistics support system in open pit mine context. Figure 4 indicated the structure of a mathematical model that described the behavior of the planner for minimizing the total logistics cost, which consisted of both resource transportation costs and facility costs. The mathematical formulation of the model (Wesolowsky & Truscott, 1975) was given below.

The following symbols are defined:

M	Set of all possible located positions of facility so $i \in m$ .
N	Set of all centroids of mine operation so $j \in n$ .
P	Set of yearly logistics support system plans so $t \in p$
$A_{ijt}$	Resource transportation cost from facility was located $i$ to centroid $j$ in period $t$
$R_{it}$	Removing cost of facility was located $i$ in period $t$
$O_{it}$	Installing cost of facility was located $i$ in period $t$
$N_t$	Number of centroids of mine operation in period $t$
$x_{ijt}$	Decision variable detailed that facility was located $i$ service centroid $j$ in period $t$
$y_{it}$	Decision variable detailed that facility was removed from $i$ in period $t$
$z_{it}$	Decision variable detailed that facility was installed at $i$ in period $t$
$u_{it}$	Decision variable detailed that facility was exist at $i$ in period $t$

Decision variable

$x_{ijt} =$	$\left\{ \begin{array}{l} 1, \text{ if facility was located } i \text{ serviced centroid } j \text{ in} \\ 1, \text{ if facility was removed from } i \text{ in period } t \\ 1, \text{ if facility was installed at } i \text{ in period } t \\ 1, \text{ if facility was existed at } i \text{ in period } t \end{array} \right.$
$y_{it} =$	
$z_{it} =$	
$u_{it} =$	

The objective function in this paper was determination the optimal location of single mobile in-pit station from candidate sites so it was trade-offs between resource transportation costs and facility cost all periods continuously.

Objective Function

$$\text{Min } Z = \sum_{i=1}^m \sum_{j=1}^n \sum_{t=1}^p A_{ijt} x_{ijt} + \sum_{i=1}^m \sum_{t=2}^p (R_{it} \cdot y_{it} + O_{it} \cdot z_{it}) \quad (1)$$

Subject to

Eq. (2) was constraint that identified each centroid of mine operation  $j$  must be serviced by facility was located  $i$  in period  $t$  only 1 site of facility.

$$\sum_{i=1}^m x_{ijt} = 1, \quad \{\forall j, t\} \quad (2)$$

Eq. (3) was constraint that identified facility was located at  $i$  must service all  $N$  centroids of mine operation with this single facility was existed at  $i$  in period  $t$ .

$$\sum_{j=1}^n x_{ijt} = N_t u_{it}, \quad \{\forall i, t\} \quad (3)$$

Eq. (4) was constraint that identified facility was existed at  $i$  in period  $t$  (no removing) so it was only one site of facility in period  $t$ .

$$\sum_{i=1}^m u_{it} = 1, \quad \{\forall t\} \quad (4)$$

Eq. (5) was constraint that identified facility was the maximum number of facility location changes allowed no more than 1 facility in period  $t = 2, 3, \dots, p$

$$\sum_{i=1}^m y_{it} \leq 1, \quad \{t = 2, 3, \dots, p\} \quad (5)$$

Eq. (6) was constraint that identified facility was existed  $i$  in the period  $t-1$  but not period  $t$ , the removing status at point  $i$  was investigated. In the other hand, facility was existed  $i$  in the period  $t$  but not period  $t-1$ , the installing status at point  $i$  was investigated.

$$u_{it} - u_{i,t-1} + y_{it} - z_{it} = 0, \quad \{\forall i; t = 2, 3, \dots, p\} \quad (6)$$

Eq. (7)-(10) was constraint that identified decision variables were binary variable.

$$x_{ij}^t \in \{0,1\} \quad \{\forall i, j, t\} \quad (7)$$

$$y_j^t \in \{0,1\} \quad \{\forall j, t\} \quad (8)$$

$$z_j^t \in \{0,1\} \quad \{\forall j, t\} \quad (9)$$

$$u_j^t \in \{0,1\} \quad \{\forall j, t\} \quad (10)$$

#### 4. Application to an actual logistics support system

The model in Figure 3 and 4 were applied to an actual logistics support system in Mae Moh Mine. For maintenance mobile in-pit station were specified along with several logistics support plans. The current location of facility for maintenance department was analyzed anby fuel consumption and support activities history that they were multiplied to logistics cost per years. The current system was evaluated logistics cost approximately 29,983,644 Baht for the serie years since 2012-2047. From the previous reason, the initial cost should be improved by strategic planning tools for reducing transportation activities so it was one of waste in lean management principle that was applied dynamic facility location problems.

The number of space solutions was very large to search the best solutions within short time because of  $\left(\frac{22!}{2!(22-2)!}\right)^7 \times 22^9$  solutions that was exploding growth rate of time complexity function exact algorithm when problem size was increased. Hence, the metaheuristic was applied to search nearly optimal solution for time complexity function algorithm reduction so we applied genetic algorithm approach with finished software which added on spreadsheet modeling in Microsoft Excel. We set genetic operator for search optimal solution included;

- Crossover rate = 0.7,
- Mutation rate = 0.005,
- Population size = 184 (2 times of number real available site in series 16 yearly plans)
- Number of trials = 200,000

From the current value was 29,983,644 Baht to finised at 28,820,984 Baht or 3.87% reducing total logistics cost for solution 1 and 29,101,147 Baht or 2.94% reducing total logistics cost for solution 2. Figure 5 indicated the optimal solution of selected stations that compared the costs current solution and other solution. The comparison denoted that cost incurred that relocation of maintenance office had a relatively resonable difference in each solution, the resource transportation cost had a great differences. This implied that facility relocation greatly affected the optimal solution although this approach must trade-offs facility costs.

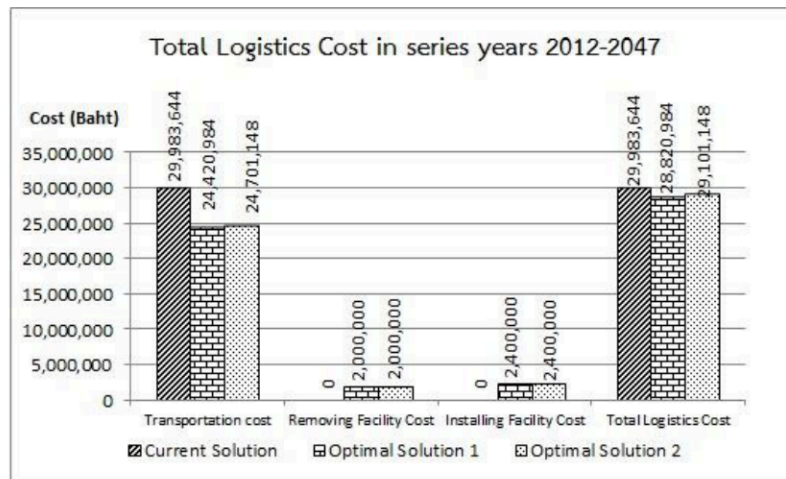


Figure 5 Comparison of costs for optimal and other solutions.

## 6. Conclusion

The logistics support system in open pit mine with maintenance mobile in-pit station optimization was special problem that less person knew about this context. From we reviewed improving efficiency mining operations and FLP approaches, we found less researches about direct logistics support systems efficiency because only crusher location optimization was FLPs in open pit mine context. Wesolowsky (1973) concluded that dynamic facility location was NP-Hard whereas static facility location was linear programming model. Hence, we applied multi periods facility location problems (MPFLPs) of Wesolowsky and Truscott (1975) which one of categories of dynamic facility location problem to develop mathematical modeling to adopt actual logistics support systems which selected location of maintenance mobile in-pit station in open pit mine for minimization of total logistics cost. The spreadsheet modeling was applied by mathematical modeling and search optimal solution by metaheuristic because  $\left(\frac{22!}{2!(22-2)!}\right)^7 \times 22^9$  solutions that was exploding growth rate of time complexity function exact algorithm when input problem size was increased so it was NP-Hard problem. This research methodology could save planner time and work plans.

The result of current mining logistics support system evaluation since year 2012-2047 was 29,983,644 Baht of total cost. The improving result searched optimal solution from 880,510,464,000 feasible solutions that optimal solution's total operation cost was 14,682,9343 Baht so it can save cost 51.03%. We established strategic planning model to improve logistics support system efficiency with dynamic facility location problem for innovation and knowledge of logistics support system.

## 7. Future Research

In this study scoped only dynamic facility location-allocation problems to make decision planning with metaheuristic. In the future, we will compare efficiency between exact algorithms and metaheuristic. Finally we will use optimal plan to evaluate real situation for improving efficiency of logistics support systems in Mae Moh Mine.

## 8. Acknowledgement

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