

# Smart Logistics Framework: A Case Study of Phuket RO Water System

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**Abstract.** The product transportation is an important procedure in businesses, which consumes costs and times. Effective transportation management can reduce expenses significantly. New technologies such as Global Position System (GPS), maps, notification and network connection can be integrated all together in one small smart phone that provides accessing from anytime and anywhere. In this paper, we propose a smart logistics framework that combines different technologies in order to solve management and tracking issues in a real transportation environment.

## 1 Introduction

Nowadays a business of drinking water delivery has great potential for life that people would care more about their health. Drinking water demand has been significantly increased that widely attracts a large number of drinking water delivery companies. Even more companies try to join this businesses, they are still strongly competitive. A company that stays with traditional product delivery will face difficult management. For example, a manager needs to call to delivery staffs to know their locations, how it goes and manually checks the product stock periodically. All sale transactions are written in expensive sale slips. Moreover, transaction reports need to re-input all data from sale slips to a complex spreadsheet which leads human errors and can be easily lost.

All previously described issues require a smart system that offers the simple management to a manager. The system should provide features such as product stock checking and delivery staff route tracking. An effective logistics framework is the solution in order to manage the stock and location tracking for delivery staffs to a manager and show customer destinations to a delivery staff since one of the main costs is the product delivery. The products must be correctly shipped to customers on time in order to provide the greatest services and make business more valuable.

A smart system must be able to monitor location of delivery staffs to protect their cheating. Stock checking with notification can be used to effectively control products in warehouses. In this paper, the smart logistics framework has been proposed to introduce stock and tracking features by testing with Phuket RO Water company, Co., Ltd.

This paper is organized as follows. In Section 2 we present an overview of logistics and vehicle routing optimisation. In Section 3, we propose smart logistics framework and architecture based on the case study. In Section 4 we present our evaluation results and analysis. Finally, in Section 5 we summarize and conclude with open problems.

## 2 Literature review

### 2.1 Logistics and Milk Run

Logistics is the delivery of goods, information or resources from one place to another, such as from a seller to a buyer, from a supplier to a seller, from a supplier to a supplier. It can be divided into 3 types:

#### 2.1.1. Direct shipment

Direct shipment is a direct delivery to a customer destination. It will not stop the increase or reduce products on the way, such as from a seller to a customer directly, this method will be faster, but it will cost more. A company must have a very good transport staff and the distance must not be too far.

#### 2.1.2. Milk run

Milk-run is defined as “A route on which a truck either delivers product from a single supplier to multiple retailers or goes from multiple suppliers to a single buyer location” [1]. Milk-run comes from the concept that a milkman must bring a bottle to deliver to customers every morning when

a delivery is to bring the old bottle back in order to prepare and deliver it again. It is the source of the milk transport method.

### 2.1.3 Transportation with cross docking

Transportation with cross docking is a delivery from a source to a distribution point or a warehouse and then from a warehouse to a warehouse nearby [2]. It allows products to be delivered to a customer faster but a staff has to check a warehouse. This may be done to change the type of conveyance, to sort material intended for different destinations, or to combine material from different origins into transport vehicles (or containers) with the same or similar destinations.

To create routes for delivering to customers easier, we need to group customers who stay closely to a zone, and then assign a delivery staff to that zone. However, if the zone is quite large or has complex constraints such as some customers have high priority to firstly receive products, some roads have been closed, there is a traffic jam, and an accident with road blocking, etc.; the routing algorithm with constraint checking must be added.

## 2.2 Vehicle Routing Optimisation

Minimizing path distance is a good way to reduce estimated time and fuel consumption in the product transportation procedure. Presently, the demands and supplies are bigger scale than the past and they are growing more in the future because the online shopping is easier and faster. Thus, the suppliers have to deliver many products to various locations each run.

Vehicle Routing Problem (VRP) is a problem given many vehicles, warehouse locations, customers' locations and try to find the optimal solution. The goal is to have all vehicle loaded at a warehouse, deliver items to customers and back to a warehouse. Moreover, other constraints, such as capacity of vehicle, fuel, delivery time, priority and more, can be taken into account.

### 2.2.1 Travelling Salesman Problem Heuristic

The vehicle routing problem can be composed of multiple travelling salesman problem (TSP). TSP is a well-known NP-hard combinatorial optimisation problem. Goal of the TSP is to find shortest tour for given locations. The direct method is to try all permutations of given locations and compute the path distance. However, the time complexity of this method is worst as it would take  $O(n!)$ . So this brute force method is impractical even for a problem instance with small amount of locations. Aside brute force algorithm, there are other better exact algorithms to find an optimal solution. For example, the Held-Karp dynamic programming algorithm is able to solve TSP in  $O(n^2 2^n)$  [3].

The approximation algorithm using heuristic can find a solution faster than exact algorithm. The solution found by an approximation algorithm is not the global optimum but reasonably good enough for limited computation time. Moreover, they work well even on extremely huge (over ten-thousand locations) problem instance.

The nearest neighbour (NN) heuristic algorithm [4] is to repetitively pick a location and greedily find for nearest unvisited neighbour. After a whole repetition is done, the starting point can be changed to explore other possible solutions.

### 2.2.2 Swarm Intelligence

Swarm intelligence is a concept of optimisation algorithms that explore search space using many agents. Agents can interact or communicate to each other and adapt to search space to reach optimal solution. Most swarm optimisation has an ability to avoid local minima, which is not so good solution, to find global optimum.

Ant Colony algorithm is one of notable swarm optimisation algorithms. Its concept is sending out virtual ants (agents) to explore the map and leave pheromone trails inversely proportion to the tour length. So that the shortest tour, the most pheromone deposited path over time [5].

Other swarm optimisation also works on TSP. For example, Artificial Bee Colony (ABC) [6], Particle Swarm Optimisation (PSO) [7], Cuckoo Search (CS) [8].

### 2.2.3 Integer Linear Programming

Linear programming problem has a linear objective function and linear constraints. Given constraints are formed an intersection area called feasible region. The goal is to optimise the objective function having all variables within feasible region. The simplex algorithm and interior point method are known to solve linear programming efficiently.

The vehicle routing problem is resolvable using linear programming with integer constraints, namely Integer Linear Programming (ILP). A capacitated vehicle routing problem (CVRP) can be formulated [9] as

$$\begin{aligned} & \text{minimize } \sum_{j=1}^{|R|} \gamma_j x_j \\ & \text{subject to } \sum_{j=1}^{|R|} a_{ij} x_j = 1 \quad ; \quad \forall i \in V \setminus \{0\}, \\ & \sum_{j=1}^{|R|} x_j = K, \\ & x_j \in \{0,1\} \quad ; \quad j = 1, 2, \dots, |R|, \end{aligned}$$

where  $R$  is a set of all feasible routes, each route  $R_j$  costs  $\gamma_j$ . The binary coefficient  $a_{ij}$  is 1 if and only if vertex  $j$  is covered in the route  $R_j$ . If the route  $R_j$  is selected in the solution,  $x_j$  will be 1 and will be 0 otherwise.

So the objective is to minimize the cost of chosen routes, having constraints that each vertex (customer) is visited by exactly one route and exactly  $K$  vehicles required. This problem formulation is similar to a set

partitioning problem. It can be relaxed to be a set covering model and solved using integer linear programming. Furthermore, this problem can be formulated using flow model then apply either column generation or branch-cut-and-price techniques to improve the performance [10].

**Algorithm Comparison**

The nearest neighbour heuristic algorithm is easy to implement and the local optima solution can be found over iterations. The solution is reasonably good for a limited computation time. Besides heuristic algorithms, swarm intelligence is capable of medium-large problem size and able to avoid local minima to search for better solutions. The simplex and interior-point methods, on the other hand, are optimisation algorithms for ILP formulated CVRP. It is able to solve even more constraints, such as time windows or priority customers, included in the problem instance.

**3 Propose smart logistics framework**

“Phuket RO Water System” is selected to be the delivery testbed as Milk Run delivery style for smart logistics framework implementation. Stock management and tracking System are the main components of this framework.

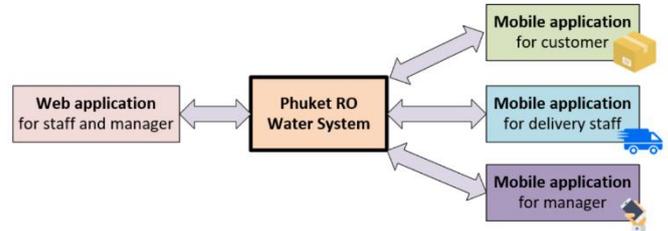
**3.1 Architecture**

Fig. 1 shows the smart logistics architecture. A delivery staff uses a mobile application, called Service Delivery, to deliver products to customers. It supports to pick up products from other warehouses. The application connects to the cloud server via 4G or WiFi and sends information for each transaction. A manager can check product stock,

staffs, and customers in real-time. It will help to significantly increase business values.

**3.2 Application Components**

We design and implement mobile and web applications for service delivery to customers. The applications offer quickly accessing and reduce communication errors.



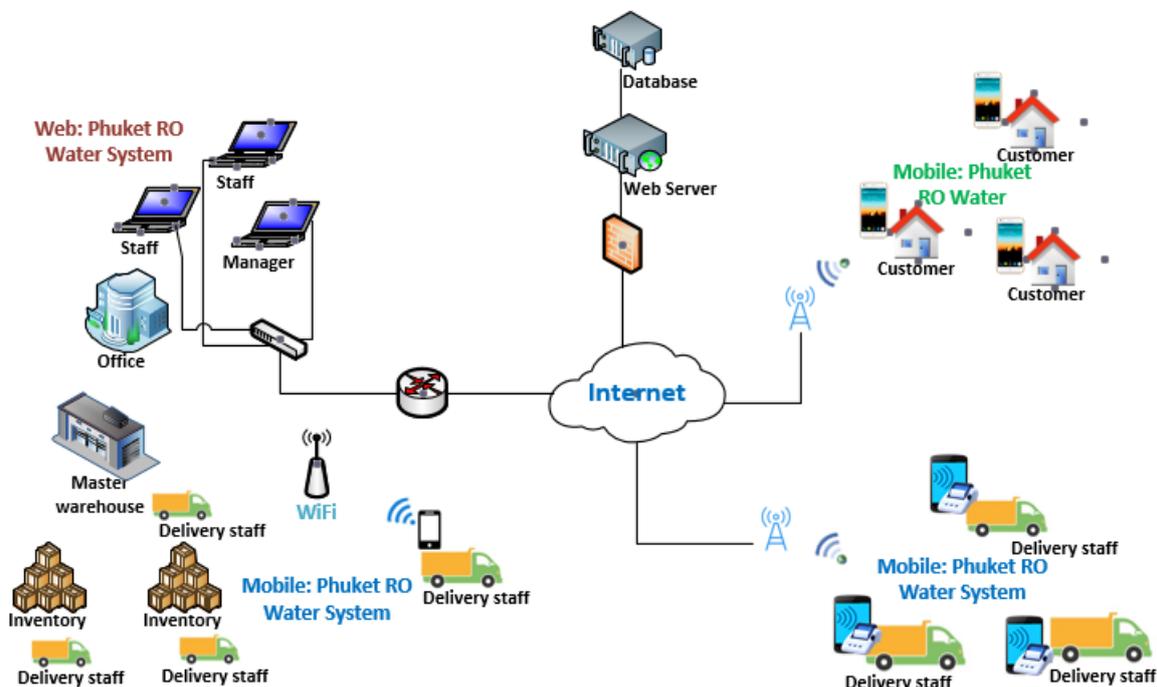
**Figure 2.** Smart logistics application components

The important features of smart logistics framework will be highlighted in order to present the different services of existing applications.

The framework, called Phuket RO Water system, consists of three mobile applications and one web application as summarized in Fig. 2.

**3.2.1 Customer service mobile application**

The customer service is developed for a customer who can order products online, check their order history, promotions, contact to the company, etc. One important problem of a customer is the product arrival time. With Geo-Fencing technology, a customer can setup application notification in order to alert after the delivery staff nearby in 500 meters approximately. Notification can be extended to alert via social network such as Facebook or Twitter, etc.



**Figure 1.** Smart logistics architecture

### 3.2.2 Service delivery mobile application

On the first step, a delivery staff takes products to a truck and asks for approval from a manager via a service delivery application. Next, he can drive to customers as illustrated in the map with route optimisation in Fig 3. The nearest neighbour algorithm is taken to apply with this application since it is the fastest and easiest way.

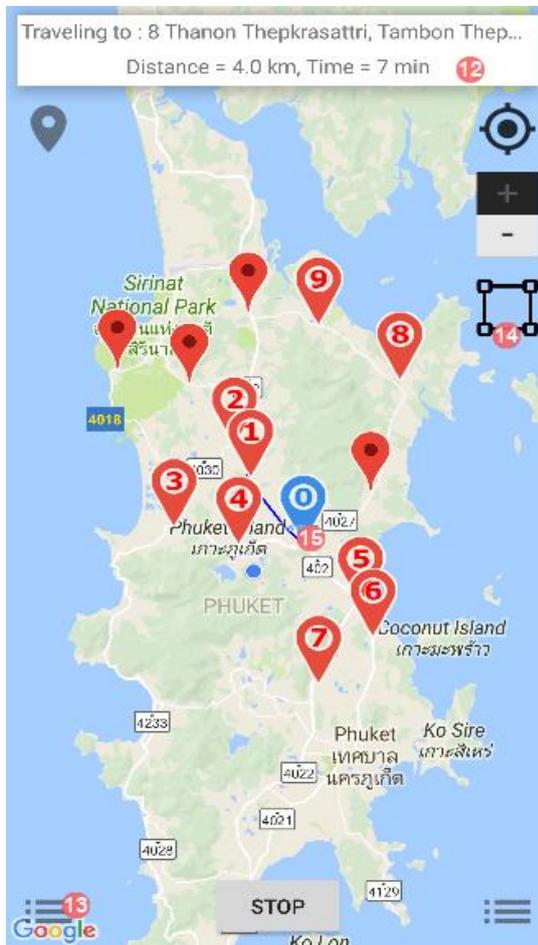


Figure 3. Route suggestion for product delivery

When a delivery staff arrives to a customer, he can deliver products, print slip using a small thermal printer connecting via Bluetooth. All transaction will be sent to the cloud server. Compare to the manual system, this will significantly reduce man-hours times from using hand writing slip and re-input information again in a complex spreadsheet that may cause human errors too. In case of no Internet signal, offline process can be done in an application, it will be synchronized again after reaching an Internet connection automatically.

### 3.2.3 Delivery manager mobile application

A manager can track all locations of delivery staffs. If they drive outside the customer routes, take a break for too much time, or accidents, etc. A manager can easily verify their cheating or performance and solve the problem rapidly from anywhere and anytime by his mobile phone.

### 3.2.4 Web application

An office staff can use a web application to fulfil some incomplete data from customers, reconcile data and access on some reports for stock monitoring. A manager can access a whole system to manage and assess a business plan.

The presented features may be existed, however, they are not completely integrated in one mobile phone by three mobile applications and one web application. For example, tracking service may be deployed by other tracking devices which are increasing the budget and most of them lag Geo-Fencing with notification features. Our proposed logistics framework make use of all integrated technologies in a mobile phone. Route optimization and zone of customers will help delivery staffs to service customers effectively.

## 4 Evaluation

After smart logistics framework has been developed, we test the system, collect transaction data in order to manage product stock and tracking effectively. The web and database servers are deployed on cloud servers from Digital Ocean [11] cloud platform with the cheapest droplet (5 USD/month). They run smoothly. NodeJS [12] and ReactJS [13] are chosen to be backend and frontend systems respectively. Responsive designed is used to support a mobile web view.

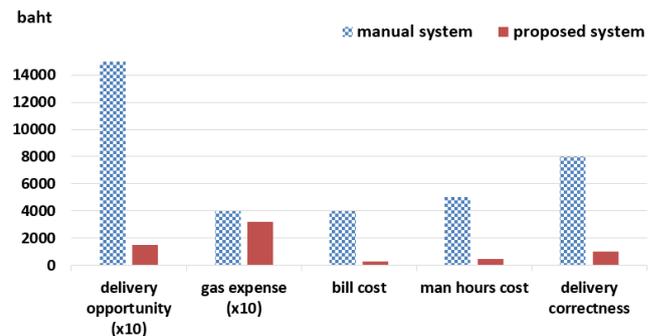


Figure 4. Monthly delivery expense analysis

Fig 4 illustrates the monthly delivery expenses. It reveals that our system can greatly reduce costs of transportation and management. The main impact is delivery opportunity cost since delivery staffs will deliver products to customers on time when customers required products. The explanation for all tasks is described in Table 1.

From table 1, these values are given by Phuket RO Water, Co., Ltd. which has used the smart logistics framework and collected data for several months with the previous manual system for many years. In addition, the proposed system is designed to support horizontal scale up by simply adding a number of cheap cloud servers in order to serve more customers with less increasing cost.

Table 1. Delivery cost analysis

Tasks	Manual system	Proposed system
Delivery opportunity, delivery staffs may arrive to a customer who may not need a product on that period	15% of product sales as 150,000 baht	With analytic and predictable system, the cost will be 10% of manual system, since less chance to deliver on wrong period
Gas expenses and truck maintenances	40,000 baht/month	20% decrease with routing optimisation
Bill slips	4,000 baht/month (0.5 - 1 baht/slip)	0.04 baht/slip for a thermal printing slip plus overhead of the first initial printer
Man-hours to input and analyse data to system	5,000 baht/month	Real-time information updating and less errors from human writing since it directly inputs from the mobile application
Delivery correctness, delivery staffs may forget some customers or cannot deliver products on time	8,000 baht/month	Less occurred with the proposed system since delivery staffs can check a customer list immediately.

## 5 Conclusion and future works

This research can be used to reduce several service expenses and open more opportunities to have more customers since the great services are provided. Our proposed mobile and web applications may be separately existing, however, the main contribution of this work is to

serve seamless integration and implementation of the logistics application components that are deployed and used on a small smart phone. Logistics and shortest tour algorithms have been reviewed, we are going to test and implement more algorithms with more supported constraints to offer better services in the future. Moreover, other maps will be taken into account since Google is going to start having usage fees for maps APIs (Application Programming Interfaces).

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