# DETERMINING THE ROUTE FOR SOLID WASTE TRANSPORTATION FROM TPS TO SPA USING VRP – NEAREST NEIGHBOR FOR 10m 3 VEHICLE ON SERVICE AREA SOUTHERN BANDUNG AND EASTERN BANDUNG

*by* Wahyukaton -

# PROCEEDING

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# 9TH ISIEM

## 9th INTERNATIONAL SEMINAR ON INDUSTRIAL ENGINEERING & MANAGEMENT

ISIEM

"COLLABORATIVE INNOVATION TOWARDS BORDERLESS INDUSTRIAL AND ECONOMIC SYSTEM"

GRAND INNA MUARA
HOTEL CONVENTION & EXHIBITION
PADANG, WEST SUMATERA, INDONESIA
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# PROCEEDING

# 9th ISIEM

## The 9th International Seminar on Industrial Engineering and Management

Grand Inna Muara Hotel Convention & Exhibition Padang,
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# PREFACE

Dear Presenters and Delegates,

On behalf of the Organizing Committee, I am honored to welcome you to the 9th International Seminar on Industrial Engineering and Management (ISIEM). This seminar is organized by the Industrial Engineering Department from eight Universities, namely Trisakti University, Telkom University, Tarumanagara University, Atma Jaya Catholic University of Indonesia, Al Azhar Indonesia University, Esa Unggul University, Pasundan University, and Bung Hatta University.

The theme **"Collaborative Innovation Towards Borderless Industrial and Economic System"** which in accordance with the current economic era, we hope that through the exchange of ideas, experiences and recent progress in Industrial Engineering and Management from academicians, engineers, professionals and practitioners from Universities, research institutions, government agencies and industries be able to help us to deal with future challenges.

We hope that our presenter and delegates will gain many shared ideas and great experiences from this conference and also acquire additional insights from our honorable speakers, **Gursel Ilipinar, PhD** from ESADE Business School – Barcelona, **Profesor Emeritus Dato' Ir. Dr. Zainai Bin Mohamed** from UTM Razak School of Engineering and Advance Technology – Malaysia, **Milko-Pierre Papazoff** from Vice President of French External Trade Counsellor (Malaysian Chapter).

The success of this seminar is due to the hard efforts of many people who we gratefully acknowledge. Special thank to all reviewers, speakers, and presenters, also highly appreciate to the committee for mutual effort and invaluable contribution.

Finally, we hope you will enjoy this conference and the natural beauty of Padang city – Indonesia and see you in the next ISIEM.

Best wishes,

Chair of the 9th ISIEM 2016

Dr. Wisnu Sakti Dewobroto, M.Sc

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# AGENDA

## September 20, 2016

| | |
|---|---|
| 18:00 - 18:30 | Registration |
| 18:30 - 19:30 | Dinner |
| 19:30 - 19:40 | Padang Dance by Bung Hatta University |
| 19:40 - 19:45 | Welcoming Speech from Head of Committee ISIEM 9th |
| 19:45 - 20:00 | Opening Ceremony by Bung Hatta University Rector |
| 20:00 - 21:00 | Keynote Speech # 1<br>**Prof. Emeritus Dato' Ir. Dr. Zainai Bin Mohamed**<br>**(UTM Razak School of Engineering and Advanced Technology,**<br>**UTM International Campus – Malaysia)**<br>**Moderator:** Dr. Adianto, M.Sc. |
| 21:00 - 21:15 | Photo Session with all participants |

## September 21, 2016

| | |
|---|---|
| 6:30 - 8:00 | Breakfast and Registration |
| 8:00 - 9:00 | Keynote Speech # 2<br>**Gursel Ilipinar, PhD**<br>**(Innovation Management Expert**<br>**ESADE Business School – Barcelona)**<br>**Moderator:** Ir. Wahyukaton, M.T. |
| 9:00 - 10:00 | Keynote Speech # 3<br>**Milko-Pierre Papazoff**<br>**VP of French External Trade Counsellor (Malaysian Chapter)**<br>**Moderator:** Dr. Ir. Syarif Hidayat, M.Eng.Sc, M.M. |
| 10:00 - 10:30 | Question and Answer |
| 10:30 - 11:15 | Coffee and Tea Break |
| 11:15 - 12:35 | Parallel session #1 |
| 12:35 - 13:30 | Lunch break |
| 13:30 - 16:30 | Parallel session #2 |
| 15:00 - 15:15 | Coffee and Tea Break |
| 18:30 - 20:00 | Dinner |

# PARALLEL SESSION

**SEPTEMBER 21, 2016 SESSION 1 ROOM 1**
Moderator : Dr. Lamto Widodo, S.T., M.T.

| Time | Paper | Code | Paper Code |
|---|---|---|---|
| 11.15-11.25 | **MAINTENANCE PERFORMANCE MEASUREMENT TRANSJAKARTA BUS AT PERUM DAMRI SBU BUSWAY CORRIDOR I & VIII USING MAINTENANCE SCORECARD**<br>Didien Suhardini, Iveline Anne Marie, Amal Witonohadi, Auliandi Fahriditya Putra<br>Jurusan Teknik Industri, Fakultas Teknologi Industri, Universitas Trisakti, Jakarta, Indonesia | IM | 110 |
| 11.25-11.35 | **IDENTIFICATION OF SUPPLY CHAIN PERFORMANCE INDICATORS AND STRATEGIC OBJECTIVES USING THE BALANCED SCORECARD**<br>Dwi Kurniawan, Adela Anggun Pertiwi, Lisye Fitria<br>Industrial Engineering Department, Institut Teknologi Nasional, Bandung, Indonesia | SCM | 26 |
| 11.35-11.45 | **IMPROVEMENT TO QUALITY OF TELECOMMUNICATION SERVICE BY MINIMIZE FAILURE OF SIMKARI APPLICATION DEVICE (A CASE STUDY IN PT DATALINK SOLUTION)**<br>M. Hudori<br>Department of Logistic Management, Citra Widya Edukasi Polytechnic of Palm Oil, Bekasi, Indonesia | QM | 79 |
| 11.45-11.55 | **POSITIONING ANALYSIS FOR HIGHER EDUCATION BASED ON PERCEPTUAL MAPPING USING MULTIDIMENSIONAL SCALING**<br>Hafizh Suharja, Yati Rohayati, Rio Aurachman<br>School of Industrial and System Engineering, Telkom University, Bandung, Indonesia | IM | 16 |
| 11.55-12.05 | **IMPROVING THE SERVICE QUALITY OF DISTANCE EDUCATION USING INTEGRATION SERVICE QUALITY FOR HIGHER EDUCATION AND KANO**<br>Istianah Nedia, Yati Rohayati, Maria Dellarosawati Idawicasakti<br>School of Industrial and System Engineering, Telkom University, Bandung, Indonesia | QM | 40 |
| 12.05-12.15 | **DESIGN OF STANDARD OPERATING PROCEDURE (SOP) OF DESIGN AND DEVELOPMENT OF PRODUCT ACCORDING TO ISO 9001:2015 CLAUSE 8.3 BASED ON RISK BASED THINKING BY BUSINESS PROCESS IMPROVEMENT METHOD AT CV. XYZ**<br>Rindy Aprilina Gita Prastyanti[1], Sri Widaningrum, Heriyono Lalu<br>Faculty of Industrial Engineering, Telkom University, Bandung, Indonesia | QM | 52 |
| 12.15-12.25 | **DESIGN OF NONCONFORMITY AND CORRECTIVE ACTION STANDARD OPERATING PROCEDURE BASED ON INTEGRATED REQUIREMENTS FROM ISO 9001 AND ISO 14001**<br>Rahmah Fadhilah, Sri Widaningrum, Heriyono Lalu<br>Industrial Engineering Department, Telkom University of Engineering, Bandung Indonesia | QM | 53 |

**SEPTEMBER 22, 2016 SESSION 3 ROOM 1**
Moderator : Dr. Rina Fitriana, S.T., M.M.

| Time | Paper | Code | Paper Code |
|---|---|---|---|
| 08.20-08.30 | **CONCEPTUAL MODEL OF SUPPLY CHAIN MANAGEMENT FOR HIGHER EDUCATION**<br>Fajar Kurniawan<br>Saint Mary's University of Hong Kong | 105 | SCM |
| 08.30-08.40 | **FEEDBACK FROM USERS ON A DESIGN OF WEB-BASED INVENTORY AND PRODUCT ORDERING SYSTEM FOR A UNIFORM MAKER**<br>Gamma Habie Azzaky, Endang Chumaidiyah, Wawan Tripiawan<br>Industrial Engineering Faculty, Telkom University, Bandung, Indonesia | 88 | DSS |
| 08.40-08.50 | **FACTORS INFLUENCING INNOVATION MANAGEMENT PRACTICES IN NIGERIA TEXTILE MANUFACTURING FIRM'S**<br>Mohammed Ndaliman Abubakar<br>Department of Business Admin & Management, The Federal Polytechnic (FPB), Niger State, Nigeria | 112 | IM |

**SEPTEMBER 22, 2016 SESSION 3 ROOM 2**
Moderator : Dr. Ir. Nofi Erni, M.M.

| Time | Paper | Code | Paper Code |
|---|---|---|---|
| 08.00-08.10 | **BUSINESS INTELLIGENCE SYSTEM MODEL PROPOSALS TO IMPROVE THE QUALITY OF SERVICE AT PT GIA**<br>Rina Fitriana, Johnson Saragih, M. Andika Firmansyah<br>System and Industrial Simulation Laboratory, Department of Industrial Engineering, Faculty of Industrial Technology, Trisakti University, Jakarta, Indonesia | 86 | QM |
| 08.10-08.20 | **WORK RISK ASSESSMENT TOWARDS WOOD FURNITURE PRODUCTION ACTIVITIES USING MANUAL TASK RISK ASSESSMENT METHOD AND RODGERS MUSCLE FATIGUE ANALYSIS METHOD**<br>Cindy Wibisono, Vivi Triyanti<br>Department of Industrial Engineering, Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia | 4 | ER |
| 08.20-08.30 | **EXPERIMENTAL DESIGN OF CLASS CHARACTERISTIC FACTORS AGAINST ENERGY EXPENDITURE, MENTAL FATIGUE AND PERFORMANCE USING ANOVA METHOD**<br>Albertus Steven, Vivi Triyanti<br>Industrial Engineering Studies Program – Faculty Of Engineering Atma Jaya Indonesian Catholic University, Jakarta, Indonesia | 32 | ER |
| 08.30-08.40 | **WORKLOAD ANALYSIS OF THE CONTAINER UNLOADING PROCESS WORKER**<br>Lamto Widodo, I Wayan Sukania,Cynthia Kristiani<br>Industrial Engineering Department, Enginering Faculty, Tarumanagara University, Jakarta, Indonesia | 1 | ER |
| 08.40-08.50 | **DETERMINING THE ROUTE FOR SOLID WASTE TRANSPORTATION FROM TPS TO SPA USING VRP – NEAREST NEIGHBOR FOR 10m$^3$ VEHICLE ON SERVICE AREA SOUTHERN BANDUNG AND EASTERN BANDUNG**<br>Wahyukaton, Anni Rochaeni, Sunarya<br>Industrial Engineering Pasundan University, Bandung, Indonesia<br>Environmental Engineering Pasundan University, Bandung, Indonesia | 21 | OR |

# DETERMINING THE ROUTE FOR SOLID WASTE TRANSPORTATION FROM TPS TO SPA USING VRP – NEAREST NEIGHBOR FOR 10m$^3$ VEHICLE ON SERVICE AREA SOUTHERN BANDUNG AND EASTERN BANDUNG

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***ABSTRACT***

*One of reason to manage solid waste problem is to make the waste transportation effectively. Route effectivity is measured by transported solid waste volume and the distance from transfer station (TPS) to intermediate facility (SPA) then from SPA to landfill (TPA), however, in this research was subjected to transported solid waste from TPS to SPA and for 10m$^3$ dump truck (DT).*

*This research objective was to find an alternative effective route of waste transporting and to find the number of vehicle be used to serve solid waste transportation using Nearest Neighbor (NN) method by Vehicle Routing Problem with Multiple Trips and Intermediate Facility (VRPMTIF).*

*VRPMTIF is a model that can be applied to solid waste transportation problem on PD Kebersihan Bandung, in area of Southern Bandung and Eastern Bandung*

*For area of Eastern Bandung, there were 3 DT involved covering 68.73 km of total distance for 12 TPS's, while on area of Southern Bandung, there were 4 DT involved covering 123.43 km of total distance for 11 TPS's.*

*Keywords: VRP, Nearest Neighbor, Solid Waste Transportation*

## 1. INTRODUCTION

Waste or garbage has become a common problem in the cities in Indonesia, it starting from littering, waste transportation, until the problem at landfill (TPA).

Managing the waste, usually starting from settlements to TPS, from TPS to TPA. Bandung has another policy concerning the waste management, which is build an intermediate facility (SPA) due to large amount of solid waste volume, and traffic problem, so that the solid waste will be transferred from TPS to SPA then with another vehicle the solid waste will be transferred to landfill (TPA).

Based on the above scheme, it can be described that the logistics system is a system that addresses the relationship between the entities as an integrated logistics activity from solid waste generation to SPA for each distribution networks to generate the waste transportation. Planning a public waste management also requires the design and operation of the logistics system in order to create efficiency and effectiveness of transporting waste. Thus in order to obtain orders, cleanliness and beauty, need to research about the route of transporting waste in Bandung.

### 1.1 Research Identification

The basic problem on waste transportation in Bandung is less effective of solid waste transportation in many TPS in several areas.

1. How to determine an alternative route of solid waste transportation to minimized operational cost in a single trip per day.
2. How many vehicle needs to pick up the solid waste in order to all TPS will be served in a single trip per day.

### 1.2 Research Objectives

1. To determine an alternative route of solid waste transportation to minimized operational cost in a single trip per day.
2. To determine number of vehicle needs to pick up the solid waste in order to all TPS will be served in a single trip per day.

## 2. THEORETICAL BACKGROUND

Vehicle Routing Problem (VRP) is the backbone in distribution management and physical distribution (Laporte, 1992a; Ghiani, Guerriero, Laporte, & Musmanno, 2003). It can be described as the "problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints" (Laporte, 1992a). VRPs are combinatorial optimization problems (NP-hard). Optimization problems can be divided into two categories: problems with continuous variables and problems with discrete variables, which are called combinatorial. In combinatorial problems, the goal is to find the best solution among a set of finite solutions (Papadimitriou & Steiglitz, 1998). Some examples of combinatorial optimization problems are: integer programming, vehicle routing problem, traveling salesman problem, etc. Mathematical definition of VRP is as follows:

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Let $G = (V, A)$ be a graph, where $V = \{1, \dots, n\}$ is a set of vertices (nodes) representing cities, where *depot* is located at node 1, and A is the set of arcs (edges). With every arc $(i, j)$ $i \neq j$ there is a corresponding non-negative distance matrix $C = (c_{ij})$. In some cases, $c_{ij}$ can be interpreted as travel cost or travel time between nodes $i$ and $j$. When $C$ is symmetrical (travel cost of node $i$ to $j$ is equal to travel cost of node $j$ to $i$), it is convenient to consider the set arcs as a set $E$ of undirected arcs. Furthermore, assume there are m vehicles available at depot to service the nodes (customers), where $mL \leq m \leq mU$. When $mL = mU$, number of vehicles ($m$) is said to be fixed. When $mL = 1$ and $mU = n - 1$, $m$ is said to be free. When m is not fixed, it is logical to consider a fixed cost associated with use of a vehicle but usually for the sake of simplicity, this cost is ignored. All vehicles are considered to be identical and have the fixed capacity. The VRP is to design vehicle routes with least cost in such a way that:

(i) each city in $V\backslash\{1\}$ is visited only once and once by exactly one vehicle;

(ii) depot is the origin and the destination of all routs;

(iii) some side constraints are satisfied. (Laporte, 1992a)

A typical VRP solution is showed in Figure 1. As illustrated in this figure, nodes (cities or customers) are scattered around depot and 4 vehicle routs starting and ending at depot are
designed to serve all the customers.

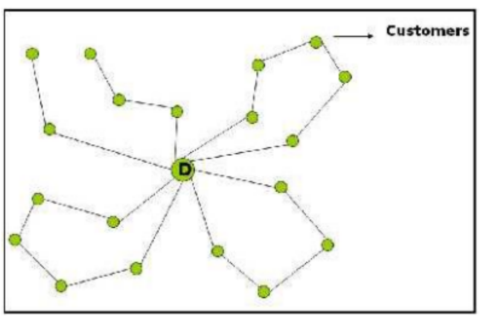


Figure 1: A typical VRP solution with 4 vehicle routes

Different classes of VRPs have been developed to model the problems faced in of real world. Each of VRP categories answers to the specific needs of customers, logistics and distribution departments or both of them. The categories of research in VRP are Capacitated VRPs (CVRPs), Distance-constrained VRPs (DVRPs), VRPs with Time Windows (VRPTW), VRPs with Backhauls (VRPBs) (Toth & Viego, 2002), VRPs with Pick up and Deliveries (VRPPD), (Toth & Viego, 2002), Heterogeneous Fleet Vehicle Routing Problem (HVRP) (Gendreau, Laporte, Musaraganyi, Taillard, 1999).

**Nearest Neighbor**

This method first introduced in 1983 and it is a simple method. On each iteration, a search of a nearest costumer which is closest to the last customer was done to be will added to the end of a route. A new route will start the same way if there is no feasible position for placing new customer due to capacity or time windows (Braysy & Gendreau, 2005).

Nearest neighbor method is originally a traveling salesman problem (TSP) heuristic. TSP could be defined as the following:

Let $G = (V, A)$ be a graph which V is a set of nodes and $A$ is a set of arcs. $A$ matrix $C = (c_{ij})$ represents the distances (costs) of going from node $i$ to node $j$. The problem is to determine the shortest path which goes through all the nodes only once and once.

TSP like VRP is a NP-hard combinatorial problem and there is a rich literature on its heuristics.

TSP heuristics could be divided into two main categories (Laporte, 1992b):

(i) tour construction procedures and

(ii) tour improvement procedures. Nearest neighbor belongs to the tour construction heuristics and tries to get the maximum benefit from going one step to the next one.

Hence these kind of heuristics are sometimes called "greedy heuristics". Nearest neighbor algorithm steps according to the Laporte (1992b) are:

(Algorithm 1)

(i) Select an arbitrary point as starting point

(ii) Determine the closest node to the last one already considered and add it to the tour.
Repeat step (ii) if any nodes are not included in the tour.

(iii) Link the last node of the tour to the start point

These steps are designed for TSP. However, Laporte (1992a) argues that TSP algorithms can often be used for solving VRPs. He adds that nearest neighbor method can be used to solve CVRP almost without modification. Hence, steps needed to solve a CVRP with the nearest neighbor algorithm could be defined as follows:

(Algorithm 2)

(i) Dispatch a vehicle from the depot to the closest node to the depot.

(ii) Determine the closest node to the last one already considered and add it to the vehicle tour. Repeat step (ii) as long as vehicle capacity allows.

(iii) Repeat steps (i) and (ii) for new vehicles if any nodes are not visited yet.

## 3. RESEARCH METHOD

To solve the problem as mentioned earlier, Vehicle Routing Problem was used as a technique to solve a transportation problem involving vehicle routes to serve spreading customer.

Waste transportation service in Bandung is divided into 4 solid waste transportation regions as seen on Figure 2.

The solid waste transporting in Bandung is done by two systems, which are Haul Container System (HCS) and Stationary Container System (SCS). This research was focused on SCS because it will serve more than one TPS in every trip, so that it needs an effective route.
This research is discussing for area of Southern Bandung and Eastern Bandung because the number of TPS's by SCS in those areas are more than area of Northern and Western Bandung, and 10m$^3$ vehicles/dump trucks to transporting solid waste from 12 transfer stations (TPS's) in Southern Bandung to SPA and 10 TPS's in Eastern Bandung to intermediate facility (SPA). The location of SPA is in Gede Bage while the landfill (TPA) is in Legoknangka

| | ke | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dari | TPS | pol | panorama | simpang sari | buni sari | rs hermina | cicukang | bojong awi | griya uber | tanabe | sentosa asih | saluyu | cipamokolan |
| 1 | pol | | | | | | | | | | | | |
| 2 | panorama | 2,675 | | | | | | | | | | | |
| 3 | simpang sari | 2,795 | 120 | | | | | | | | | | |
| 4 | buni sari | 3,065 | 390 | 270 | | | | | | | | | |
| 5 | rs hermina | 2,965 | 355 | 475 | 745 | | | | | | | | |
| 6 | cicukang | 3,130 | 2,410 | 2,530 | 2,800 | 2,635 | | | | | | | |
| 7 | bojong awi | 3,005 | 2,285 | 2,405 | 2,675 | 2,510 | 875 | | | | | | |
| 8 | griya uber | 4,970 | 4,250 | 4,370 | 4,640 | 4,475 | 2,840 | 2,235 | | | | | |
| 9 | tanabe | 5,755 | 5,035 | 5,155 | 5,425 | 5,260 | 3,625 | 3,020 | 1,865 | | | | |
| 10 | sentosa asih | 9,755 | 9,035 | 9,155 | 9,425 | 9,260 | 7,625 | 7,020 | 5,865 | 4,000 | | | |
| 11 | saluyu | 10,395 | 9,675 | 9,795 | 10,065 | 9,900 | 8,265 | 7,660 | 6,505 | 4,640 | 640 | | |
| 12 | cipamokolan | 9,860 | 9,140 | 9,260 | 9,530 | 9,365 | 7,730 | 7,125 | 5,970 | 4,105 | 875 | 1,515 | |

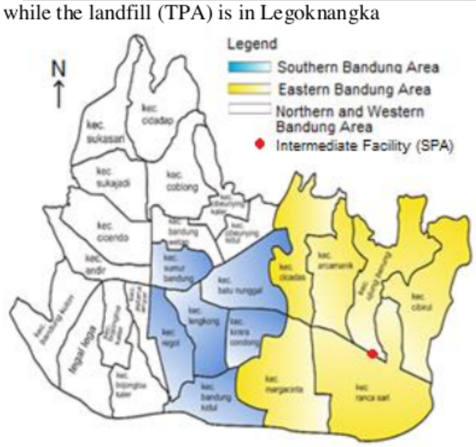


Figure 2. Map of Bandung Service Area

Using Nearest Neighbor (NN) – Vehicle Routing Problem Multiple Trips and Intermediate Facility (VRPMTI) – to solve a route problem by determining a closest node with a shortest distance. It becomes a measurement of whether the system can work well to optimize the waste transportation by one round so that there will be no solid waste were stacked at TPS.

The NN method on each iteration is searching a nearest customer to the last customer to be added into that last route. The steps are as follows,

Step 1. Set a node pool (depot) and node TPS or waste bin for each vehicle on transporting solid waste area.

Step 2. Make a distance matrix to describe TPS locations and the distance inter TPS.

Step 3. Searching for shortest distance. Starting from vehicle pool, then searching a TPS with the shortest distance to vehicle pool as the first location.

Step 4. Continue to the next TPS location with the shortest distance to selected TPS earlier and the solid waste volume does not exceed the vehicle capacity.

a. If there is a selected TPS as a next TPS location and there is a remaining capacity on the vehicle, back to step 4.
b. If there is no remaining capacity on the vehicle, back to step 3.
c. If there is TPS location is selected due to waste volume has exceed the vehicle capacity, then back to step 3.
d. Start again from the pool to visit TPS location that has not been visited and has the closest distance. If all TPS has been visited right one time, then the algorithm is ended.

Step 5. Optimal calculation by summing the starting distance to the end of the trip.

## 4. RESULT AND DISCUSSION

### 4.1 Route

Every vehicle was operated daily from 04:00 until 17:00 or 19:00, it is depending on solid waste volume to be transported and traffic. The fix service route is Pool – TPS's – SPA – TPA. Vehicle pool for Southern Bandung is in Jl. Soekarno-Hatta, while vehicle pool for Eastern Bandung is in Pasir Impun.
From vehicle pool, the vehicle will go to TPS on stated route then collecting solid waste to the vehicle on that TPS. If there was a remaining capacity on the vehicle, the vehicle will go to the next TPS on the next stated route to do the same job. If the capacity has achieved, then the vehicle will go to SPA at Gede Bage, Eastern Bandung. And from SPA there will be another vehicle to transporting the solid waste to the landfill (TPA) at Legoknangka, Kabupaten Bandung.
Figure 3 and 4 show waste transporting route for Eastern Bandung and Southern Bandung

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| | ke | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dari | TPS | pol | SDM | RM sari sunda | Primarasa | jl Windu | SMA BPI | slai brand | pasar kosambi | TD cicaheum | RHB | borma antapani |
| 1 | pol | | | | | | | | | | | |
| 2 | SDM | 2,000 | | | | | | | | | | |
| 3 | RM sari sunda | 2,530 | 530 | | | | | | | | | |
| 4 | Primarasa | 1,700 | 2,730 | 2,200 | | | | | | | | |
| 5 | jl Windu | 4,000 | 5,030 | 4,500 | 2,300 | | | | | | | |
| 6 | SMA BPI | 4,640 | 5,670 | 5,140 | 2,940 | 640 | | | | | | |
| 7 | slai brand | 6,600 | 10,570 | 10,040 | 4,900 | 3,340 | 2,700 | | | | | |
| 8 | pasar kosambi | 7,520 | 11,490 | 10,960 | 5,820 | 4,260 | 3,620 | 920 | | | | |
| 9 | TD cicaheum | 8,400 | 9,430 | 8,900 | 6,700 | 8,660 | 8,020 | 5,320 | 4,400 | | | |
| 10 | RHB | 12,520 | 10,670 | 10,140 | 7,940 | 5,640 | 5,000 | 6,820 | 5,900 | 1,500 | | |
| 11 | borma antapani | 12,865 | 11,015 | 10,485 | 8,285 | 5,985 | 5,345 | 7,165 | 6,245 | 1,845 | 345 | |


Figure 3. Route for Eastern Bandung

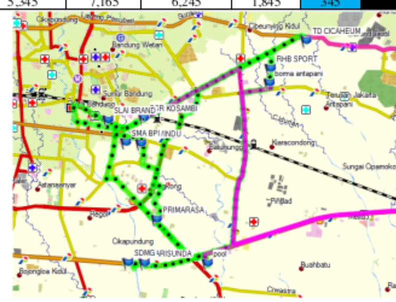


Figure 4. Route for Southern Bandung

Table 1. Distance Matrix for Eastern Bandung

Table 2. Waste Capacity for Eastern Bandung

| No | TPS | TPS Capacity ($m^3$) | Loading Time (minute) |
|---|---|---|---|
| 1 | a (Panorama) | 3 | 54 |
| 2 | b (Simpang sari) | 3 | 54 |
| 3 | c (Buni sari) | 4 | 72 |
| 4 | d (RS. Hermina) | 2 | 36 |
| 5 | e (Cicukang) | 6 | 108 |
| 6 | f (Bojong awi) | 2 | 36 |
| 7 | g (Griya Uber) | 2 | 36 |
| 8 | h (Tanabe) | 2 | 36 |

Table 3 Algorithm Result for Vehicle 1 Eastern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| a | 3 $m^3$ | 71 | Route (K) = 1 Trip (t) = 1 |
| b | 3 $m^3$ | 56 | |
| c | 4 $m^3$ | 78 | |
| d | 2 $m^3$ | 48 | |
| Total | 12 $m^3$ | 253 | |

Table 4 Algorithm Result for Vehicle 2 Eastern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| e | 6 $m^3$ | 120 | Rute (K) = 2 Trip (t) = 2 |
| f | 2 $m^3$ | 43 | |
| g | 2 $m^3$ | 49 | |
| h | 2 $m^3$ | 27 | |
| Total | 12 $m^3$ | 253 | |

Table 5 Algorithm Result for Vehicle 3 Eastern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| i | 4 $m^3$ | 111 | Rute (K) = 3 Trip (t) = 3 |
| j | 4 $m^3$ | 81 | |
| k | 4,5 $m^3$ | 101 | |
| Total | 12,5 $m^3$ | 293 | |

- $T_{max}$ = 370 minutes, the average of total trip time from Pool to the last TPS and it was added by total loading time.
- Maximum vehicle's capacity is 10 $m^3$ but it has to be added by compaction factor 1.2, so that the final vehicle's capacity is 10 + (10 x 1.2) = 12 $m^3$

Table 6 Total Distance for Eastern Bandung

| Vehicle | Distance (meters) | | | |
|---|---|---|---|---|
| | Vehicle Trip | Last TPS to SPA | SPA to Pool | Total |
| D 8733 A | 3.810 | 7.100 | 10.100 | 21.010 |
| D 8730 A | 8.105 | 1.900 | 10.100 | 20.105 |
| D 8249 C | 11.910 | 5.600 | 10.100 | 27.610 |
| Total | 23.825 | | | 68.725 |

Table 7 Distance Matrix for Southern Bandung

Table 8. Waste Capacity for Eastern Bandung

| No | TPS | TPS Capacity ($m^3$) | Loading Time (minute) |
|---|---|---|---|
| 1 | a (SDM) | 2 | 36 |
| 2 | b (RM. Sari Sunda) | 2 | 36 |
| 3 | c (Primarasa) | 1,5 | 27 |
| 4 | d (Jl. Windu) | 2 | 36 |
| 5 | e (SMA BPI) | 2 | 36 |
| 6 | f (Slai Brand) | 0,5 | 10 |
| 7 | g (Psr Kosambi) | 12 | 180 |
| 8 | h (TD Cicaheum) | 20 | 324 |
| 9 | i (RHB) | 3 | 54 |
| 10 | j (Borma Antapani) | 1,5 | 27 |

Table 9. Algorithm Result for Vehicle 1 Southern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| a | 2 $m^3$ | 58 | Rute (K) = 1 Trip (t) = 1 |
| b | 2 $m^3$ | 40 | |
| c | 1,5 $m^3$ | 44 | |
| d | 2 $m^3$ | 48 | |
| e | 2 $m^3$ | 40 | |
| i | 3 $m^3$ | 76 | |
| Total | 12,5 $m^3$ | 306 | |

Table 10. Algorithm Result for Vehicle 2 Southern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| f | 0,5 $m^3$ | 40 | Rute (K) = 2 Trip (t) = 2 |
| g | 12 $m^3$ | 188 | |
| Total | 12,5 $m^3$ | 228 | |

Table 11. Algorithm Result for Vehicle 3 Southern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| h | 12 $m^3$ | 213 menit | Rute (K) = 3 Trip (t) = 3 |
| total | 12 $m^3$ | 213 menit | |

Table 12. Algorithm Result for Vehicle 4 Southern Bandung

| Route | TPS Capacity (Q) | Completion Time (CT) (minute) | |
|---|---|---|---|
| h | 8 $m^3$ | 177 menit | Rute (K) = 4 Trip (t) = 4 |
| j | 1,5 $m^3$ | 29 menit | |
| ttotal | 10 $m^3$ | 226 menit | |

- $T_{max}$ = 353 minutes, the average of total trip time from Pool to the last TPS and it was added by total loading time.
- Maximum vehicle's capacity is 10 $m^3$ but it has to be added by compaction factor 1.2, so that the final vehicle's capacity is 10 + (10 x 1.2) = 12 $m^3$

Table 13. Total Distance for Southern Bandung

| Vehicle | Distance (meters) | | | |
|---|---|---|---|---|
| | Vehicle Trip | Last TPS to SPA | SPA to Pool | Total |
| D 8728 A | 12.670 | 10.900 | 9.500 | 33.070 |
| D 8249 C | 7.520 | 12.800 | 9.500 | 29.820 |
| D 8364 C | 8.400 | 12.300 | 9.500 | 30.200 |
| D xxxx A | 10.245 | 10.600 | 9.500 | 30.345 |
| Total | 38.835 | | | 123.435 |

The result of Southern Bandung's iterations, the new route cannot make shorten the distance due to there was an addition of one vehicle to serve the untransported solid wasted on a certain TPS, so that the new route will travel 123 km, that was longer than the existing route was 110 km, and travel time will be 6 – 7 hours. The operational cost cannot be lowered but serving for solid waste transporting became more efficient, because solid waste transporting can be done in one trip in one day.

### 4.2 Cost

To obtain the total variable cost is given by the formulas,

TVC = Total Variable Cost (Rp)
VC = Distance Variable Cost (Rp)
Q = Trip Mileage (km)
= Fuel Index (0.33) x Vehicle Trip (km)
TVC = VC x Q

a. Existing Route

Eastern Bndung
$VC_{D\ 8733\ A}$ = 0.33 x 30 = 9.9
TVC = 5,000 x 9.9 = Rp 49,500

$VC_{D\ 8730\ A}$ = 0.33 x 28 = 9.24
TVC = 5,000 x 9.24 = Rp 46,200

$VC_{D\ 8249\ C}$ = 0.33 x 40 = 13.2
TVC = 5,000 x 13.2 = Rp 66,000

Total Cost = Rp (49,500 + 46,200 + 66,000) = Rp 161,700

Southern Bandung
$VC_{D\ 8728\ A}$ = 0.33 x 46 = 15.18
TVC = 5,000 x 15.18 = 75,900

$VC_{D\ 8364\ A}$ = 0.33 x 26 = 8.58
TVC = 5,000 x 8.58 = 42,900

$VC_{D\ 8249\ C}$ = 0.33 x 38 = 12.54
TVC = 5,000 x 12.54 = 62,700

Total Cost = Rp (75,900 + 42,900 + 62,700) = Rp 181,500

b. Alternative New Route

Eastern Bandung
$VC_{D\ 8733\ A}$ = 0.33 x 21 = 6.93
TVC = 5,000 x 6.93 = 34,650

$VC_{D\ 8730\ A}$ = 0.33 x 20 = 6.6
TVC = 5,000 x 6.6 = 33,000

$VC_{D\ 8249\ C}$ = 0.33 x 27 = 8.91
TVC = 5,000 x 8.91 = 44,550

Total Cost = Rp (34,650 + 33.000 + 44.550) = Rp 112,200

Southern Bandung
$VC_{D\ 8728\ A}$ = 0.33 x 33 = 10.89
TVC = 5,000 x 10.89 = 54,450

$VC_{D\ 8364\ A}$ = 0.33 x 29 = 9.57
TVC = 5,000 x 9.57 = 47,850

$VC_{D\ 8249\ C}$ = 0.33 x 30 = 9.9
TVC = 5,000 x 9.9 = 49,500

$VC_{D\ xxxx\ A}$ = 0.33 x 30 = 9.9
TVC = 5,000 x 9.9 = 49,500

Total Cost = Rp (54,450 + 47,850 + 49,500 + 49,500) = Rp 201,300

All those Total Costs were calculated for one-day operation ofr solid waste transporting by 10 $m^3$ SCS vehicles/dump trucks.

## 5. CONCLUSION

1. The new route in Eastern Bandung can be an alternative to minimized operational cost, because the new route has shortened the distance from 98 km to 68 km (one trip in one day) with travel time 5 – 6 hours. While the new route in Southern Bandung cannot shortened the distance, it was 110 km to 123 km (one trip in one day) with travel time 6 – 7 hours.
2. Addition a vehicle was done in order to maximized the service of solid waste transporting for one trip in one day. Eastern Bandung area was served one trip in one day without addition of vehicle, while Southern Bandung area has to add one vehicle up in order to serve the solid waste transporting due to waste capacity was larger than the existing vehicles capacity.

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# DETERMINING THE ROUTE FOR SOLID WASTE TRANSPORTATION FROM TPS TO SPA USING VRP – NEAREST NEIGHBOR FOR 10m 3 VEHICLE ON SERVICE AREA SOUTHERN BANDUNG AND EASTERN BANDUNG

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