International Journal of Advances in Applied Sciences (IJAAS)
Vol. 2, No. 4, December 2013, pp. 193~200
ISSN: 2252-8814

The Preprocessing and Probing Technique of Open Capacitated Vehicle Routing Problem with Split and Time Deadline (OCVRP-St) Model In Rubbish Transportation Problem

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Article Info

Article history:

Received May 12, 2013
Revised Jul 7, 2013
Accepted Jul 26, 2013

Keyword:

Open Capacitated Vehicle Routing Problem (OCVRP)
Optimal routes
Preprocessing technique
Probing technique

ABSTRACT

The activity of rubbish transportation in Palembang is one of the applications of *Vehicle Routing Problem* (VRP) in transporting rubbish in Sako Palembang by applying preprocessing and probing techniques to obtain simplest OCVRP model. The solution is conducted by using LINDO software. The results show that the optimal routes in Sukarami before and after applying the tehniques are the same routes. In addition, we obtain the reduction of constraints and variables, the reduction of iteration numbers and the optimal value did not change.

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1. INTRODUCTION

Rubbish problem is a major problem in a city that should be handled by the government especially by Dinas Kebersihan dan Pemakaman (DKP). The rubbish disposal in Palembang is conducted into steps. The rubbish were collected from homes to the nearest Temporary Rubbish Disposal (TRD). Then, the rubbish will be transported by the officers from Palembang Hygiene Service Unit by using vehicles such as dump trucks or amroll to Final Rubbish Disposal (FRD) or depot in Sukawinatan or Karya Jaya. The rubbish transportation is grouped into Working Area for each driver of vehicle.

The rubbish transportation is one of the example of *Vehicle Routing Problem* (VRP) to find minimum routes. IF it is focussed on one depot and general vehicle capacity, then it is called *Capacitated Vehicle Routing Problem* (CVRP). If the customers can be visited clockwise or anti clockwise routes along the arcs, then the problem is called *Symmetric Capacitated Vehicle Routing Problem* (SCVRP).

In the classic VRP, the vehicles should go back to the depot after finishing the journey. However, in more improved case, after finishing the journey, the vehicles need not to go back to the depot. This will result in open path where the vehicle starts from the depot and ends in one of the customers [1]. That situation occurs in rubbish transportation in Palembang. The vehicles usually are not in depot after transporting the rubbish. The routes will be open routes and we call it Open Capacitated Vehicle Routing Problem (OCVRP). If we focus on one depot and the capacity of the vehicles then the problem will be Open Capacitated Vehicle Routing Problem (OCVRP).

Savelsbergh [2] gave detail explanation about tightening the relaxed Linear Program in Mixed Integer Liniear Program (MILP) by utilizing *probing* and *preprocessing* techniques which result in the reduction in bounds and size of coefficient of constraint matrices. In this case, Savelsbergh [2] generate the framework to draw various techniques preprocessing and probing in MILP so that set of the feasible solutions of relaxed linear programming can be reduced but the set of the feasible solutions of MILP will not change.

In fact, the probing and preprocessing technique basically attempt to check and change a formulation of the constraints so that that formulation can be solved easily. For instance, in real case of Fixed-Charge Network Flow Problems [3]. The preprocessing technique is already applied in previous research on CVRP [4]-[9].

So, in this paper, the contribution will be based on applying *probing* and *preprocessing* of OCVRP especially for identifying nonfeasible constraints, redundant variables, improving bounds and coefficient and arrangement of variable values. We then validate the model and compare to initial model. He rubbish transportation model is focused on rubbish transportation in Kecamatan Sako Palembang.

2. RESEARCH METHOD

To simplify the model of that transportation system, we conduct three stages as follows.

1. Form the OVCRP model
   The model is formed according to rubbish transportation data in Kecamatan Sako Palembang such as routes, distance between FRD and TRDs, vehicle's capacity, number of vehicles used and rubbish volume. We obtain the data through surveying and interviewing in details' to staff of rubbish management in FRD of Sukabangun area and several drivers of rubbish trucks.
2. Simplify the OCVRP model
   To simplify the model, we conduct steps such as strengthening the bounds of constraint variables, eliminating redundant constraints and fixing variables.
3. Solve the OCVRP model
   The solution is to obtain optimal objective function and each decision variables of the model. The solution is based on non-simplified model and simplified model and we seek to compare that simplified model yield efficient result.

3. RESULTS AND ANALYSIS

In this part, we describe the steps of simplifying OCVRP model using preprocessing techniques.

For Working Area 1 Sako

Model OCVRP after setting up the probing technique is

$$Min\ z = 6{,}5y_{01}+2y_{02}+6y_{03}+8{,}5y_{04}+8.5x_{12}+13{,}5x_{13}+15x_{14}+8{,}5x_{21}+4x_{23}+6{,}5x_{24}+13{,}5x_{31}+4x_{32}+2{,}5x_{34}+15x_{41} +6{,}5\ x_{42}+2{,}5x_{43} \quad (1)$$

Subject to

$$x_{12} + x_{13} = 1 \quad (2a)$$

$$y_{03} + y_{30} = 1 \quad (4a)$$

$$x_{31} + x_{32} = 1 \quad (4b)$$

$$y_{04} + y_{40} = 2 \quad (5a)$$

$$y_{01} + y_{02} + y_{03} + y_{04} + y_{10} + y_{20} + y_{30} + y_{40} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 4.2 \quad (6)$$

$$y_{10} + y_{20} + y_{30} + y_{40} - y_{01} - y_{02} - y_{03} - y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 0 \quad (7)$$

$$y_{10} + y_{20} + y_{30} + y_{40} = 1 \quad (8)$$

Nonnegativity requirements:

$x_{12} \geq 0$; $x_{13} \geq 0$; $x_{14} \geq 0$; $x_{21} \geq 0$; $x_{23} \geq 0$; $x_{24} \geq 0$; $x_{31} \geq 0$; $x_{32} \geq 0$; $x_{34} \geq 0$; $x_{41} \geq 0$; $x_{42} \geq 0$; $x_{43} \geq 0$; $y_{01} \geq 0$; $y_{02} \geq 0$; $y_{03} \geq 0$; $y_{04} \geq 0$; $y_{10} \geq 0$; $y_{20} \geq 0$; $y_{30} \geq 0$; $y_{40} \geq 0$.

$x_{12}, x_{13}, x_{14}, x_{21}, x_{23}, x_{24}, x_{31}, x_{32}, x_{34}, x_{41}, x_{42}, x_{43} \in \{0, 1, 2\}$

$y_{01}, y_{02}, y_{03}, y_{04}, y_{10}, y_{20}, y_{30}, y_{40} \in \{0, 1\}$

We continue to preprocessing tehnique as follows.

$$x_{12} + x_{13} \leq 1 \quad (2a^*)$$

$$y_{03} + y_{30} \leq 1 \quad (4a^*)$$

$$x_{31} + x_{32} \leq 1 \quad (4b^*)$$

$$y_{04} + y_{40} \leq 1 \quad (5a*)$$
$$y_{10} + y_{20} + y_{30} + y_{40} \leq 1 \quad (8*)$$

Preprocessing Technique

1. Strengthen the bounds of constraint variables

x_{12}, x_{13}, x_{14}, x_{21}, x_{23}, x_{24}, x_{31}, x_{32}, x_{34}, x_{41}, x_{42}, $x_{43} \in \{0, 1, 2\}$ dan setiap variabel mempunyai batasan nonnegatif ≥ 0, maka, apabila dimisalkan $x_{12}=0$; $x_{13}=1$; $x_{14}=0$; $x_{21}=2$; $x_{23}=0$; $x_{24}=0$; $x_{31}=1$; $x_{32}=0$; $x_{34}=0$; $x_{41}= 0$; $x_{42}=1$; $x_{43}=2$. y_{01}, y_{02}, y_{03}, y_{04}, y_{10}, y_{20}, y_{30}, $y_{40} \in \{0, 1\}$ dan setiap variabel mempunyai batasan nonnegatif ≥ 0, maka, dimisalkan $y_{01}=1$; $y_{02}=1$; $y_{03}=1$; $y_{04}=1$; $y_{10}=0$; $y_{2}=0$; $y_{30}=0$; $y_{40}=1$.

- Strengthen the bound for variable x_{12}, x_{13} in (2a*).
- Strengthen the bound for variable y_{03}, y_{30} in (4a*).
- Strengthen the bound for variable x_{31}, x_{32} in (4b*).
- Strengthen the bound for variable y_{04}, y_{40} in (5a*).
- Variable $y_{01}, y_{02}, y_{03}, y_{04}, y_{10}, y_{10}, y_{20}, y_{30}$ and y_{40} in (6) cannot be strengthened.
- Variable x_{12}, x_{13}, x_{14}, x_{21}, x_{23}, x_{24}, x_{31}, x_{32} x_{34} x_{41}, x_{42} and x_{43} in (6) cannot be strengthened.
- Variable y_{10} y_{20} y_{30} y_{40} y_{01} y_{02} y_{03} y_{04} x_{12} x_{13} x_{14} x_{21} x_{23} x_{2} x_{31} x_{32} x_{34} x_{41} x_{42} x_{43} in (7) cannot be strengthened.
- Strengthen the bound for variable $y_{10} y_{20} y_{30} y_{40}$ in (8).

2. Eliminate Redundant variables

For Constraint (6)

a. We got the nonnegative bound after strengthening the bounds that are $x_{12}\geq 0$; $0\leq x_{13}\leq 1$; $x_{14}=0$; $x_{21}=2$; $x_{23}=0$; $x_{24}=0$; $0\leq x_{31}\leq 1$; $x_{32}\geq 0$; $x_{34}=0$; $x_{41}=0$; $x_{42}=1$; $x_{43}=2$; $y_{01}=1$; $y_{02}=1$; $0\leq y_{03}\leq 1$; $0\leq y_{04}\leq 1$; $y_{10}=0$; $y_{20}=0$; $y_{30}\geq 0$; $0\leq y_{40}\leq 1$. By using upper bound, we obtain that (6) satisfy the upper bound of nonnegativity constraint.

b. We got the nonnegative bound after strengthening the bounds that are $x_{12}=0$; $x_{13}=1$; $x_{14}=0$; $x_{21}=2$; $x_{23}=0$; $x_{24}=0$; $x_{31}=1$; $x_{32}=0$; $x_{34}=0$; $x_{41}=0$; $x_{42}=1$; $x_{43}=2$; $y_{02}=1$; $y_{03}=1$; $y_{04}=1$; $y_{10}=0$; $y_{20}=0$; $y_{30}=0$; $y_{40}=1$. By using lower bound, we obtain that (6) satisfy the lower bound of n onnegativity constraint. We conclude that (3.6) is redundant. Hence, we can eliminate (6).

For Constraint (7)

We obtain that (7) satisfy the upper bound and lower of nonnegativity constraint. Hence, it can be eliminated since it is redundant.

3. Fix the variables

a. Evaluate variable x_{13}. Since the constraint (2a*) has the number of biggest constraints exceed RHS, then that constraint should be eliminated.

b. Evaluate variable x_{31}. Since the constraint (4b*) has the number of biggest constraints exceed RHS, then that constraint should be eliminated.

We obtain new OCVRP model as follows.

Min z = $6{,}5\, y_{01} + 2\, y_{02} + 6\, y_{03} + 8{,}5\, y_{04} + 8.5\, x_{12} + 13{,}5\, x_{13} + 15\, x_{14} + 8{,}5\, x_{21} + 4\, x_{23} + 6{,}5\, x_{24} + 13{,}5\, x_{31} + 4\, x_{32} + 2{,}5\, x_{34} + 15\, x_{41} + 6{,}5\, x_{42} + 2{,}5\, x_{43}$ (1*)

Subject to

$$x_{12} \leq 1 \quad (2a**)$$
$$y_{03} + y_{30} \leq 1 \quad (4a*)$$
$$x_{32} \leq 1 \quad (4b**)$$
$$y_{04} + y_{40} \leq 2 \quad (5a*)$$
$$y_{10} + y_{20} + y_{30} + y_{40} \leq 1 \quad (8*)$$

and

$x_{12} \geq 0$; $0 \leq x_{13} \leq 1$; $x_{14} = 0$; $x_{21} = 2$; $x_{23} = 0$; $x_{24} = 0$; $0 \leq x_{31} \leq 1$; $x_{32} \geq 0$; $x_{34} = 0$; $x_{41}=0$; $x_{42}=1$; $x_{43}=2$; $y_{01} =1$; $y_{02} = 1$; $0 \leq y_{03} \leq 1$; $0 \leq y_{04} \leq 1$; $y_{10} = 0$; $y_{20} = 0$; $y_{30} \geq 0$; $0\leq y_{40} \leq 1$.

$x_{12}, x_{13}, x_{14}, x_{21}, x_{23}, x_{24}, x_{31}, x_{32}, x_{34}, x_{41}, x_{42}, x_{43} \in \{0, 1, 2\}$

$y_{01}, y_{02}, y_{03}, y_{04}, y_{10}, y_{20}, y_{30}, y_{40} \in \{0, 1\}$

We transform into initial form as follows.

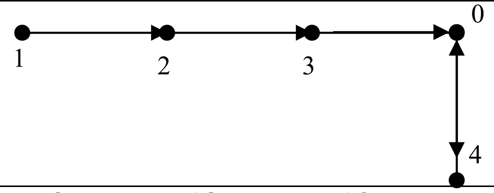
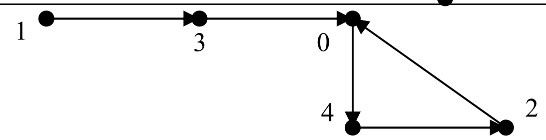
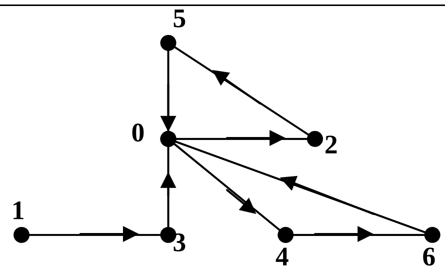
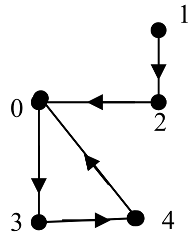
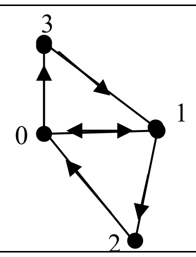
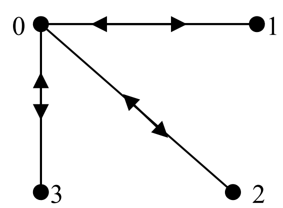
Min z = $6{,}5\, y_{01} + 2\, y_{02} + 6\, y_{03} + 8{,}5\, y_{04} + 8.5\, x_{12} + 13{,}5\, x_{13} + 15\, x_{14} + 8{,}5\, x_{21} + 4\, x_{23} + 6{,}5\, x_{24} + 13{,}5\, x_{31} + 4\, x_{32} + 2{,}5\, x_{34} + 15\, x_{41} + 6{,}5\, x_{42} + 2{,}5\, x_{43}$ (9)

Subject to

$$x_{12} = 1 \quad (10)$$
$$y_{03} + y_{30} = 1 \quad (11)$$
$$x_{32} = 1 \quad (12)$$
$$y_{04} + y_{40} = 2 \quad (13)$$
$$y_{10} + y_{20} + y_{30} + y_{40} = 1 \quad (14)$$

and
$x_{12} \geq 0$; $0 \leq x_{13} \leq 1$; $x_{14} = 0$; $x_{21} = 2$; $x_{23} = 0$; $x_{24} = 0$; $0 \leq x_{31} \leq 1$; $x_{32} \geq 0$; $x_{34} = 0$; $x_{41}=0$; $x_{42}=1$; $x_{43}=2$; $y_{01}=1$; $y_{02}=1$; $0 \leq y_{03} \leq 1$; $0 \leq y_{04} \leq 1$; $y_{10} = 0$; $y_{20} = 0$; $y_{30} \geq 0$; $0 \leq y_{40} \leq 1$.
$x_{12}, x_{13}, x_{14}, x_{21}, x_{23}, x_{24}, x_{31}, x_{32}, x_{34}, x_{41}, x_{42}, x_{43} \in \{0, 1, 2\}$.
$y_{01}, y_{02}, y_{03}, y_{04}, y_{10}, y_{20}, y_{30}, y_{40} \in \{0, 1\}$. For the rest of Working Area, we conduct the same steps as above, and it is summarized into Table 1 below.

Table 1. Optimal Route for each Working Area in Sako

Working Area	Route
I	
II	
III	
IV	
V	
VI	

Tabel 2. OCVRP Model Before Applying Preprocessing Technique

WA	Model OCVRP Model Before Applying Preprocessing Technique			
	Iteration Number	Variable Number	Cosntraint Number	Model
I	9	24	7	$Z = 6{,}5\, y_{01} + 2\, y_{02} + 6\, y_{03} + 8{,}5\, y_{04} + 8{,}5\, x_{12} + 13{,}5\, x_{13} + 15\, x_{14} + 8{,}5\, x_{21} + 4\, x_{23} + 6{,}5\, x_{24} + 13{,}5\, x_{31} + 4\, x_{32} + 2{,}5\, x_{34} + 15\, x_{41} + 6{,}5\, x_{42} + 2{,}5\, x_{43}$ Kendala : $x_{12} = 1$ $y_{03} + y_{30} = 1$ $x_{32} = 1$ $y_{04} + y_{40} = 2$ $y_{10}+y_{20}+y_{30}+y_{40}+y_{01}+y_{02}+y_{03}+y_{04}+x_{12}+x_{13}+x_{14}+x_{21}+x_{23}+x_{24}+x_{31}+x_{32}+x_{34}+x_{41}+x_{42}+x_{43} \geq 4{,}2$ $y_{10} + y_{20} + y_{30} + y_{40} - y_{01} - y_{02} - y_{03} - y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 0$ $y_{10} + y_{20} + y_{30} + y_{40} = 1$
II	6	21	8	$Z = 6{,}5\, y_{01} + 9\, y_{02} + 8{,}5\, y_{03} + 9\, y_{04} + 15{,}5\, x_{12} + 15\, x_{13} + 15{,}5\, x_{14} + 15{,}5\, x_{21} + 0{,}5\, x_{23} + x_{24} + 15\, x_{31} + 0{,}5\, x_{32} + 0{,}5\, x_{34} + 15{,}5\, x_{41} + x_{42} + 0{,}5\, x_{43}$ Kendala : $x_{13} + x_{14} = 1$ $y_{02} + y_{20} = 1$ $x_{24} = 1$ $y_{03} + y_{30} = 1$ $y_{04} + y_{40} = 1$ $y_{10} + y_{20} + y_{30} + y_{40} + y_{01} + y_{02} + y_{03} + y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 4{,}6$ $y_{10} + y_{20} + y_{30} + y_{40} - y_{01} - y_{02} - y_{03} - y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 0$ $Y_{10} + y_{20} + y_{30} + y_{40} = 1$
III	6	42	11	$Z = 9\, y_{01} + 6\, y_{02} + 5.5\, y_{03} + 8\, y_{04} + 9 y_{05} + 15 y_{06} + 3\, x_{12} + 3{,}5\, x_{13} + 6{,}5\, x_{14} + 7{,}5\, x_{15} + 13{,}5\, x_{16} + 3\, x_{21} + 0{,}5\, x_{23} + 3\, x_{24} + 4\, x_{25} + 10{,}5\, x_{26} + 3{,}5\, x_{31} + 0{,}5\, x_{32} + 2{,}5\, x_{34} + 3{,}5\, x_{35} + 10\, x_{36} + 6{,}5\, x_{41} + 3\, x_{42} + 2{,}5\, x_{43} + x_{45} + 7{,}5\, x_{46} + 7{,}5\, x_{51} + 4\, x_{52} + 3{,}5\, x_{53} + x_{54} + 6{,}5\, x_{56} + 13{,}5\, x_{61} + 10{,}5\, x_{62} + 10\, x_{63} + 7{,}5\, x_{64} + 6{,}5\, x_{65}$ Kendala : $y_{02} + y_{20} = 1$ $x_{25} = 1$ $y_{03} + y_{30} = 1$ $x_{31} = 1$ $y_{04} + y_{40} = 1$ $x_{46} = 1$ $y_{05} + y_{50} = 1$ $y_{60} = 1$ $y_{10} + y_{20} + y_{30} + y_{40} + y_{01} + y_{02} + y_{03} + y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 6{,}73$ $y_{10} + y_{20} + y_{30} + y_{40} - y_{01} - y_{02} - y_{03} - y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 0$ $y_{01} + y_{02} + y_{03} + y_{04} + y_{05} + y_{06} = 1$
IV	6	20	8	$Z = 2\, y_{01} + 8\, y_{02} + 10\, y_{03} + 11\, y_{04} + 9\, x_{12} + 11\, x_{13} + 12\, x_{14} + 9\, x_{21} + 2\, x_{23} + 3\, x_{24} + 11\, x_{31} + 2\, x_{32} + x_{34} + 12\, x_{41} + 3 x_{42} + x_{43}$ Kendala : $x_{12} + x_{13} = 1$ $y_{02} + y_{20} = 1$ $y_{03} + y_{30} = 1$ $y_{04} + y_{40} = 1$ $x_{43} = 1$ $y_{10} + y_{20} + y_{30} + y_{40} + y_{01} + y_{02} + y_{03} + y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 4{,}2$ $y_{10} + y_{20} + y_{30} + y_{40} - y_{01} - y_{02} - y_{03} - y_{04} + x_{12} + x_{13} + x_{14} + x_{21} + x_{23} + x_{24} + x_{31} + x_{32} + x_{34} + x_{41} + x_{42} + x_{43} \geq 0$ $Y_{10} + y_{20} + y_{30} + y_{40} = 1$
V	3	12	6	$Z = 1{,}6\, x_{01} + 2\, x_{02} + 3\, x_{03} + 11\, x_{04} + 1{,}6\, x_{10} + x_{12} + 2\, x_{13} + 2\, x_{20} + x_{21} + x_{23} + 3\, x_{30} + 2\, x_{31} + x_{32}$ Kendala : $x_{01} + x_{02} + x_{03} = 2$ $x_{12} + x_{13} = 1$ $x_{20} + x_{21} + x_{23} = 1$ $x_{30} + x_{31} = 2$ $x_{01} + x_{02} + x_{03} + x_{04}+x_{10}+x_{12}+x_{13}+x_{20}+x_{21}+x_{23}+x_{30}+x_{31}+x_{32} \geq 0$

Tabel 3. OCVRP Model AfterApplying Preprocessing Technique

WA	Model OCVRP Model After Applying Preprocessing Technique			
	Iteration Number	Variable number	Constraint Number	Model
I	4	4	6	Z = $6{,}5y_{01}+2y_{02}+6y_{03}+8{,}5y_{04}+8{,}5x_{12}+15x_{14}+8{,}5x_{21}+4x_{23}+6{,}5x_{24}+4x_{32}+2{,}5x_{34}+15x_{41}+6{,}5x_{42}+2{,}5x_{43}$ Kendala : $x_{12} = 1$ $y_{03} + y_{30} = 1$ $x_{32} = 1$ $y_{04} + y_{40} = 2$ $y_{10} + y_{20} + y_{30} + y_{40} = 1$
II	2	5	6	$Z = 6{,}5\, y_{01}+9y_{02} +8{,}5y_{03} +9y_{04}+15x_{13}+15{,}5x_{14}+0{,}5\, x_{23} +x_{24} + 15x_{31}+ 0{,}5\, x_{32} + 0{,}5\, x_{34} + 15{,}5\, x_{41} + x_{42} + 0{,}5\, x_{43}$ Kendala : $x_{13} + x_{14} = 1$ $y_{02} + y_{20} = 1$ $x_{24} = 1$ $y_{03} + y_{30} = 1$ $y_{04} + y_{40} = 1$ $y_{10} + y_{20} + y_{30} + y_{40} = 1$
III	4	8	9	$Z = 9\, y_{01} + 8\, y_{04} + 9y_{05} + 15y_{06} +3\, x_{12} + 3{,}5\, x_{13} + 6{,}5\, x_{14} + 7{,}5\, x_{15} + 13{,}5\, x_{16} + 3\, x_{21} + 0{,}5\, x_{23} + 3\, x_{24} + 4\, x_{25} + 10{,}5\, x_{26} +3{,}5\, x_{31} + 0{,}5\, x_{32} + 2{,}5\, x_{34} + 3{,}5\, x_{35} + 10\, x_{36} + 6{,}5\, x_{41} + 3\, x_{42} + 2{,}5\, x_{43} + x_{45} + 7{,}5\, x_{46} +7{,}5\, x_{51} + 4\, x_{52} + 3{,}5\, x_{53} + x_{54} + 6{,}5\, x_{56} + 13{,}5\, x_{61} + 10{,}5\, x_{62} + 10\, x_{63} + 7{,}5\, x_{64} + 6{,}5\, x_{65}$ Kendala : $y_{02} + y_{20} = 1$ $x_{25} = 1$ $y_{03} + y_{30} = 1$ $x_{31} = 1$ $y_{04} + y_{40} = 1$ $x_{46} = 1$ $y_{05} + y_{50} = 1$ $y_{60} = 1$ $y_{01} + y_{02} + y_{03} + y_{04} + y_{05} + y_{06} =1$
IV	2	6	6	$Z= 2\, y_{01} + 8\, y_{02} + 10\, y_{03} + 11\, y_{04} + 9\, x_{12} + 11\, x_{13} + 9\, x_{21} + 2\, x_{23} + 3\, x_{24} + 11\, x_{31} + 2\, x_{32} + x_{34} + 3x_{42} + x_{43}$ Kendala : $x_{12} + x_{13} = 1$ $y_{02} + y_{20} = 1$ $y_{03} + y_{30} = 1$ $y_{04} + y_{40} = 1$ $x_{43} = 1$ $y_{10} + y_{20} + y_{30} + y_{40} = 1$
V	2	5	5	$Z = 1{,}6\, x_{01} + 2\, x_{02} + 3\, x_{03} + 11\, x_{04} + 1{,}6\, x_{10} + 2\, x_{13} + 2\, x_{20} + x_{23} + 3\, x_{30} + 2\, x_{31} + x_{32}$ Kendala : $x_{01} + x_{02} + x_{03} = 2$ $x_{13} = 1$ $x_{20} + x_{23} = 1$ $x_{30} + x_{31} = 2$

Table 2 and Table 3 explain that OCVRP model by applying preprocessing technique will yield simpler OCVRP model compared to model by not applying that technique by showing the reduction in number of iteration and reduction in number of constraints.

Figure 1 below shows us the comparison between OCVRP model before and after applying the preprocessing and probing technique. We can see that the number of iteration, variable and constraint reduce significantly after applying the preprocessing technique. For example, in term of number of variable , we have tremendous reduction in number of variables after applying the preprocessing and probing technique.

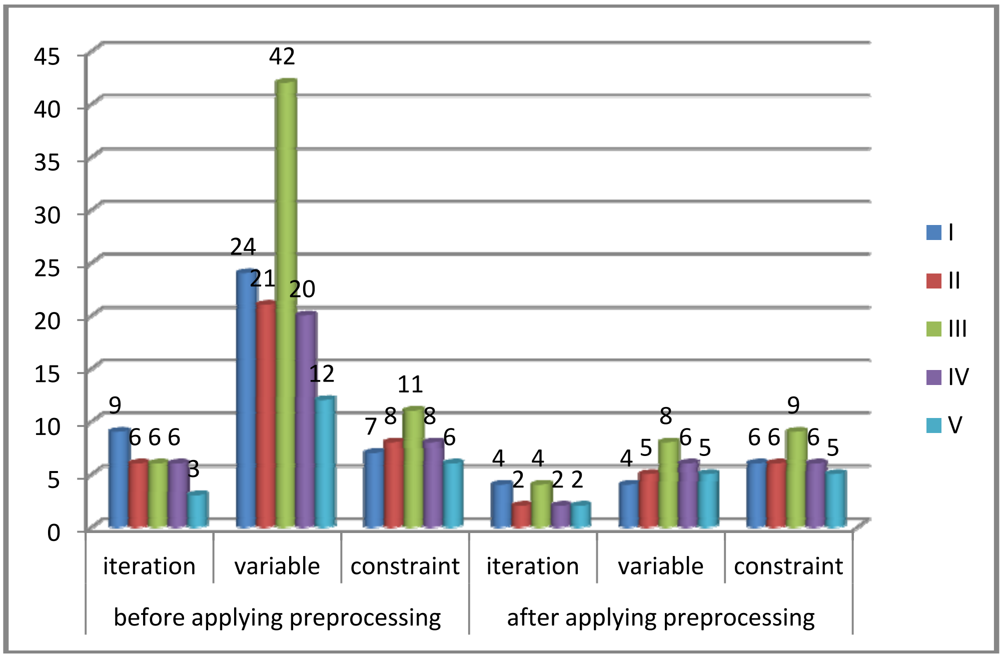


Figure 1. Comparison of Number of Iterations, Variables and Cosntraints Before and After Applying Preprocessing and Probing Techniques

4. CONCLUSION

We can conclude that by applying preprocessing tehcnique in the problem of transporting the rubbish, the simpler OCVRP model can be obtained, the faster optimal solution can be achieved compared to not applying the preprocessing technique. In addition, by applying the preprocessing technique, the number of iteration and constraint is also reduced.

ACKNOWLEDGEMENTS

This research was partially supported by Hibah Bersaing Grant of Directorate General of Higher Education of Indonesia (DIKTI) year 2011. The authors would also like to thank to the editor and referees for their valuable comments and suggestion.

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