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Improving BTS Capacity and Location using Particle Swarm Optimisation: A Case Study of South West Java

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ABSTRACT

Telecommunications operators need to solution to extend the lifecycle of **Base Transceiver Station** (BTS) to minimise their capital expenditure (Capex). Currently, there is a single tower for single operator, which means the business is not managed optimally. This study aims to optimise existing BTSs by maximising its capacity and its strategic location via Particle Swarm Optimisation (PSO). The PSO is aimed at reducing the number of towers and encourage sharing between operators. Based on PSO data by optimising existing BTS capacity and tower sharing, a 72% reduction in capex can be achieved. Therefore, infrastructure sharing is vital to reduce Capex problem faced by the operators. The study proposes open access among operators.

Keywords: Base Transceiver Station, capacity, location, operators, Particle Swarm Optimisation, tower sharing

INTRODUCTION

The number of Indonesia telecommunication subscribers, especially cellular users, has been increasing since 2010. However, the telecom operators must maintain or reduce their expenditure to ensure their survival.

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Table 1
PSTN, FWA and cellular subscribers (2010-2015)

Types	2010	2011	2012	2013	2015	2015
PSTN	9,349,998	8,650,716	7,667,184	10,085,624	9,885,971	10,378,037
Wireless	243,779,422	279,772,383	312,279,336	331,209,063	341,921,894	341,482,747
PWA	32,579,125	29,966,764	30,315,671	18,482,149	16,339,003	2,534,407
Cellular	211,200,297	249,805,619	281,963,665	313,226,914	325,582,891	338,948,340
Total Subscriber	253.129.420	288,423,099	319,946,520	341,794,687	351,807,865	351,860,784

Source: Badan Pusat Statistik Indonesia, 2017
(Central Statistics Body, Indonesia)

Based on Table 1, there is a decrease from year-to-year the number of cellular subscribers in Indonesia. This shows that the business tends to be mature in the lifecycle. Stiff competition among telecom operators means they must manage their business more efficiently. Moreover, the operators have faced increasing CAPEX in recent years.

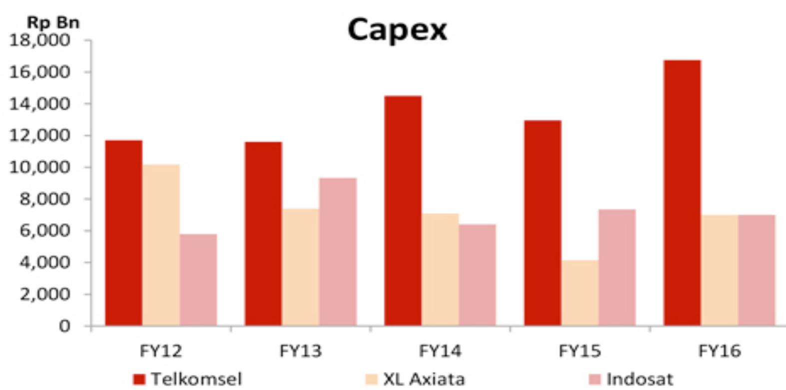

Figure 1. CAPEX of Telecom operators in Indonesia
Source: Operator Annual Reports

From the view of efficiency, we need synergies among operators for infrastructure sharing for "cost efficiency". Earlier studies examined optimising existing networks using various methods, namely genetic algorithm, simulated annealing, ABC algorithm. This study used Particle Swarm Optimization (PSO) to optimise network sharing.

LITERATURE REVIEW

Operations Management

Operations management is an important driver every organisation. It has many definitions and among there are:

1. ***"Operation management is about how organisation produce and deliver goods or services that defines their existence"*** (Porter, 2009)
2. ***"Operations management is about how organisations create and deliver services and products."*** (Slacks, Brandon-Jones, & Johnston, 2013)
3. ***"Operations management designs, operates, and improves productive systems for getting work done."*** (Russell & Taylor, 2011)

Therefore, operations management focuses on value creation of goods and services by changing input to output. The operations processes are defined by four Vs (volume, variety, variation in demand and visibility the customer level of appearance of the creation of their output (Slacks et al., 2013).

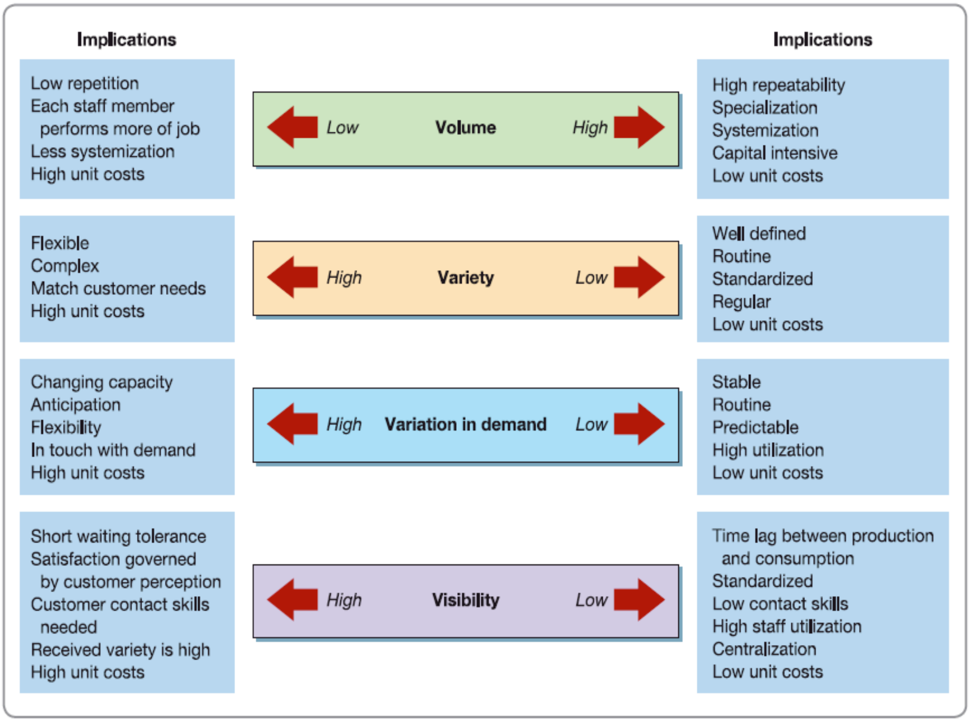

Figure 2. A topology of operation
Source: (Slacks et al., 2013)

Efficient operations provide the company with a competitive advantage. This is measured by cost, time, quality and flexibility (Porter, 2009).

1. **Cost,** if price is an important factor in winning competition, then it is important to keep it lower than the competition. Cost plays an important role in bringing the product into a competitive market that is not easily matched by others.
2. **Time,** measures delay or how fast the operations is from the time of request to the time of receipt. Speed is crucial for customers in making decision.
3. **Quality,** covers process and quality of the product/service.
4. **Flexibility,** flexibility is needed so the organisation can adapt to changing customer needs in terms of product range and varying demand and can cope with capacity shortfalls due to equipment breakdown or component shortage.

Below are the activities that are listed under production and operations management functions (Kumar & Suresh, 2016):

1. **Location of facilities** is a long-term capacity decision which involves a long-term commitment about the geographically static factors that affect a business organisation.
2. **Plant layouts and material handling,** refer to the physical arrangement of facilities. It is the configuration of departments, work centres and equipment in the conversion process.
3. **Product design,** refers to the translation of idea to a potential product. Product design and development is connected marketing and customer needs and expectations.
4. **Process design,** is a macroscopic decision-making of an overall process route for converting raw materials into finished goods.
5. **Production and planning control,** is the process of planning the production ahead, determining the flow from production to retail as well as track its progress.
6. **Quality control,** may be defined as a system that is used to maintain a desired level of quality in a product or service.
7. **Materials management,** is the aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and the flow of goods and services connected with the production process having some predetermined objectives in view.
8. **Maintenance management,** in modern industry, equipment and machinery are a very important part of the total production.

Capacity

Capacity is the maximum level of value-added activity over a period of time that the process can achieve under normal operating conditions (Slacks et al., 2013). To define capacity, one need to include both the volume and time based on capacity. Therefore, capacity could be considered as the degree to which the organisation is capable of providing service and goods to its customer in a timely manner (Porter, 2009).

Decision and capacity have an effect on cost. If capacity is big, it may not increase manufacturing cost (Sarjono, Kusuma, Hamali, & Mulyono, 2016). Measuring demand and capacity is important.

The decisions taken by operations managers in devising their capacity plans will affect several different aspects of performance (Slacks et al., 2013):

- **Costs** will be determined by the balance between capacity and demand. If capacity is higher, the system becomes underutilised and hence, high unit costs.
- **Revenues** relate to the difference between capacity and demand in such a way, when capacity levels equal to or higher than demand at all time that guarantee all demand is satisfied, and no potential revenue will be lost.
- **Working capital** - if an operation decides to keep finished goods for future demand. This might allow demand to be satisfied, but the organisation will have to fund the inventory until it can be sold.
- **Quality** of goods or services relate to changing capacity level due to fluctuating demand that require the operation to hiring and firing option. The use of temporary hires may result in poor product and service quality.
- **Speed** in responding to customer need can be improved by providing enough inventory and ensure capacity level well above the maximum demand.
- **Dependability** of input will also be determined by how close order levels are to capacity.
- **Flexibility,** in volume flexibility capacity well above the maximum demand can be achieved. If there is a balance between demand and capacity, the ability to unprepared change will not be achieved.

Location

Location decisions has an impact on cost and the business ability to serve its customer. It is also true that businesses cannot easily change their location. Moving an operation to a new place is costly and also cause inconvenience to existing customers (Slacks et al., 2013).

The organisation should take into account the location. In order to serve customer's needs better and for long term demand consideration, location has to be considered carefully. The consideration includes but not limited to competition, cost and the size of the facility. Company's location will have an impact on costs and competitiveness. Since production and delivery of goods are part of the operation, a convenient location is vital and will better serve the customer. There are three location factors (Porter, 2009):

1. Proximity to customer
2. Proximity to supplier
3. Proximity to labour

It can be concluded that a strategic location is beneficial for the company.

Capital Expenditure (Capex)

Capital spending is sometimes associated with investment or development spending, where expenditures have benefits extending into years (Jacobs, 2009). Specifically, capital expenditure is related to acquisition or construction of a fixed asset (land, building, vehicle, and equipment) or enhancement of an existing fixed asset, and whose benefits will be realised over a time greater than one year. Capital expenditures is one of the largest and riskiest in corporate financial statements. An understanding of motivators for capital investment decisions is valuable for investors, regulators, auditors, and the public at large (Litt, 2013). The decision of Capex will affect the future of company's cost structure. Capital expenditure decisions should be based on a consolidated budget approach, incorporating all revenues and expenditures with a medium-term budget perspective (Jacobs, 2009).

Telecommunication Infrastructure

Telecoms infrastructure for operators primarily consists of (KPMG Africa, 2011):

- Active infrastructure (such as spectrum, switches, antenna)
- Passive infrastructure (such as towers, BTS shelters, power)
- Backhaul.

Figure 3. Telecoms infrastructure for operators
Source: (KPMG Africa, 2011)

Operators face two challenges: manage competition and increase their profit margins. Building infrastructure is very expensive and hence, towers that are shared would reduce costs (KPMG Africa, 2011):

- **Mature networks:** Tower sharing is an important sign of Network maturity. Sharing tower, in general, is less likely in a developing country due to competition.
- **Growing market:** Growing markets mean an ever-increasing need to expand network for the operators. If operators have the ability to share towers, they will typically be able to roll networks out much faster
- **High cost regional/rural areas still being rolled out:** Operators tend to have a rollout obligation as part of their licencing requirements. In certain sparsely populated rural areas the operator may need to have their own network, and this could mean an unprofitable investment. In this case it is better to share towers so that each operator will not rely on their own network to cover the unprofitable areas.
- **New entrants looking to build scale:** Sharing towers with existing operators would help new entrants in rolling out the program.
- **Pressure on costs:** Sharing towers will improve competitiveness due to a low investment cost, which is key to profitability.

Communication tower means a principal structure that is intended to support communication equipment for telephone, radio and similar communication purposes. The term "communication tower" shall not include towers not exceeding 75 feet in height. Communication towers are generally described as either monopole (freestanding), lattice (self-supporting), or guyed (anchored with guy wires or cables), (Taylor Government, 2008). Technically, the type of tower (tower height) to be constructed is adapted to the area of the tower (open area, rural area, sub-urban areas, or urban area).

Following are costs involved in tower construction:

1. Licensing: costs incurred to manage towers.
2. Site Acquisition (SITAC): cost involved in the erection of a tower.
3. Tower Foundation; costs incurred to create the basic foundation of the tower.
4. Shelter Work: the cost to build the technical tower.
5. Fence and Landscape work: the costs related to the work associated with the fence and the ground.
6. Mechanical and Electrical equipment and installation: costs incurred for equipment and electrical installations.

Particle Swarm Optimisation

Kennedy as the initiator of particle swarms idea (a social psychologist) and

Eberhart (an electrical engineer) created computational intelligence by investigating simple similarity of social interaction, rather than a single cognition in 1995. As described by Eberhart, Shi and Kennedy (2010), the PSO algorithm is an adaptive algorithm based on a social-psychological metaphor; a population of individuals (referred to as particles) adapts by returning stochastically toward previously successful region (Eberhart et al., 2001)

In PSO, several simple units—the particles—are put in the search space of some problem or function, and each investigates the objective function at its present position (Van & Bergh, 2001). Each particle then calculates its motion through the search space by putting together some aspects of the previous best position to other member of the swarm, with some random perturbations. The next iteration takes place after all particles have been moved. Instead of using evolutionary operators to manipulate the individual particle, each particle is treated as a valueless particle in D-dimensional search space and keeps track of its coordinates in the problem space associated with the best solution (evaluating value) (Gaing, 2004). This value is called best. Hence, the current position $\vec{x_i}$, the previous best position $\vec{p_i}$, and the velocity $\vec{v_i}$.

The current position $\vec{x_i}$, can be considered as a set of coordinates describing a point in space. In every algorithm iteration, the present location is a problem solution. If that location is better than any that has been found so far, then the coordinates are stored in the second vector, $\vec{p_i}$,. The value of the best function result so far is stored in a variable that can be called pbesti (for "previous best"), to be compared with results of later iterations. The aim is to continue searching for better positions and updating $\vec{p_i}$,. and $pbest_i$. New points are chosen by adding $\vec{v_i}$ coordinates to $\vec{x_i}$, and the algorithm operates by adjusting $\vec{v_i}$, which can effectively be seen as a step size (Poli, Kennedy, & Blackwell, 2007).

MATERIALS AND METHODS

This study aims to optimise the BTSs in South West Java that suffer from inefficiency and location issues.

A preliminary study was carried out to analyse the development of telecommunications and the growth of the new BTSs in South West Java Province. Telecommunications companies must strive to meet the needs of their customers, by improving the quality of the network that can be achieved with the addition of BTSs.

The following are the methodology adopted in this study:

(1) Field Study

(2) Focus Group Discussion among operators

(3) Develop PSO Code Program

The objectives of the study are to optimise: a) the capacity of a BTS Tower (one tower can have more than one BTSs. b) the location The constraint: the BTSs within a 3-km radius will be in the same tower

(4) Data processing using PSO Code Program

(5) Analyse optimization result

(6) Propose the open access among operator

Coding of PSO is shown in Figure 4

```
function [ g ] = pso( g )
%% Generate Individual with Upper and Lower Position
Nvar = size(g.FieldDR,2);
Nind = g.MAXIND;

aux = rand(Nind,Nvar);
m=[-1 1]*g.FieldDR;
ublb=ones(Nind,1)*m;
lb=ones(Nind,1)*g.FieldDR(1,:);
ind=ceil(ublb.*aux+lb);

%% Optimize Looping
BestCost=inf;
BestSol=zeros(1,Nvar);

[B K] = size(ind);

C1 = 0.4;
C2 = 0.4;

%inisialisasi kecepatan partikel (velocity)
V=[];
 for j = 1:Nind
    for jj = 1:K
        V(j,jj)=0;
    end
 end

Z=[];
```

Figure 4. PSO code program

RESULTS AND DISCUSSIONS

Based on the Field Result and Data from the operator, we find 2967 BTS combinations for South West Java Province. MATLAB software and PSO code program was used to obtain the results shown in Figure 5:

1	TSEL_BDS2	-	3G2IP_JL_JAMII	-	257,992,920.00
2	TSEL_BDG8	XL_MC345:	3G2IP_SUKAJAD	H3I_100240	128,996,460.00
3	-	XL_351B02	U_PANGHEGAR	H3I_102609	171,995,280.00
4	TSEL_BDG5	XL_141	_DCS_BRAGA_C	H3I_103598	128,996,460.00
5	TSEL_BDK1	XL_351089	U_CIKUTRA_IM	H3I_103191	128,996,460.00
6	TSEL_BDG6	XL_2109	-	H3I_100524	171,995,280.00
7	TSEL_BDG1	XL_251337	DCS_CARINGIN-	H3I_105124	128,996,460.00
8	-	XL_1904	-	H3I_102527	257,992,920.00
9	TSEL_BDK2	XL_496	3G2IP_SARASA-	H3I_100517	128,996,460.00
10	TSEL_GRT2	XL_B126	RANCAMANYAF	H3I_103156	128,996,460.00
11	-	-	3GIP_PARONGF	H3I_105148	257,992,920.00
12	TSEL_CMI0	XL_251330	CIMINDI-ISAT83	H3I_102736	128,996,460.00
13	TSEL_BDK4	Axis_JBKB0	CIKIWUL_CLNG:	H3I_100268	128,996,460.00
14	TSEL_BDG8	XL_351PX1	CIUMBULEUIT-I	-	171,995,280.00
15	TSEL_BDG8	XL_351MC(	ANCOL-ISAT810	H3I_100482	128,996,460.00
16	-	XL_351056	-	H3I_105143	257,992,920.00
17	TSEL_BDG8	XL_MC346	PUNGKUR-ISAT:	H3I_103676	128,996,460.00
18	TSEL_BDG4	-	GND_AQUILA-IS	H3I_103831	171,995,280.00
19	TSEL_BDG2	XL_2041L1	U_SEKEJATI-ISA	-	171,995,280.00
20	TSEL_BDG4	XL_1925	MKRAMAT-ISAT	H3I_103398	128,996,460.00
21	TSEL_BDG0	XL_251C30	3G_CIKAWAO-I:	H3I_105002	128,996,460.00
22	TSEL_BDG9	XL_351EJ8	DCS_LUCKY_SQ	H3I_100483	128,996,460.00
23	TSEL_BDG3	XL_A935	SUKAMENAKINI	-	171,995,280.00
24	TSEL_SKB0:	XL_351PX0	3GIP_CIGEMBA	H3I_100534	128,996,460.00
25	TSEL_BDG4	XL_466	DCS_HOTEL_PE	H3I_101624	128,996,460.00
26	TSEL_BDG0	XL_3122	U_BRAGA-ISAT1	H3I_100266	128,996,460.00
2935	-	XL_BJ29	SUKAWENING-I	-	257,992,920.00
2936	TSEL_MJL1	XL_BJ43	-	-	257,992,920.00
2937	TSEL_KNG1	Axis_JBKNC	-	-	257,992,920.00
2938	TSEL_GRT1	-	MAROKO_TB-IS	-	257,992,920.00
2939	-	XL_1994	-	H3I_102565	257,992,920.00
2940	TSEL_CMI1	-	KOL_MASTURI_	-	257,992,920.00
2941	TSEL_MJL0	XL_251179	-	-	257,992,920.00
2942	TSEL_BDB0	XL_251056	-	-	257,992,920.00
2943	TSEL_SKB6:	XL_346417	-	-	257,992,920.00
2944	TSEL_SKB0:	-	DCS_CIBARENG	-	257,992,920.00
2945	TSEL_SMD1	-	-	H3I_100895	257,992,920.00
2946	-	Axis_JBSC0	CIJENGKOL-ISAT	-	257,992,920.00
2947	-	XL_251032	-	H3I_101409	257,992,920.00
2948	TSEL_GRT3	-	-	H3I_102852	257,992,920.00
2949	-	XL_251160	M_KUDUKERAS	-	257,992,920.00
2950	TSEL_CRB5	XL_2082	-	-	257,992,920.00
2951	TSEL_TSK69	XL_251080	-	-	257,992,920.00
2952	-	XL_346499	DCS_MANGGAH	-	257,992,920.00
2953	TSEL_BDS1	XL_B166	-	-	257,992,920.00
2954	TSEL_GRT0	XL_251001	-	-	257,992,920.00
2955	TSEL_CJR33	-	3GIP_CIBINONG	-	257,992,920.00
2956	TSEL_SMD(	XL_BJ42	-	-	257,992,920.00
2957	TSEL_GRT1	-	-	H3I_102771	257,992,920.00
2958	TSEL_BJR03	-	-	H3I_101150	257,992,920.00
2959	TSEL_SKB69	-	DCS_CIPELANG:	-	257,992,920.00
2960	TSEL_SKB0:	-	GUNUNG PADA	-	257,992,920.00
2961	-	XL_251174	-	H3I_103100	257,992,920.00
2962	TSEL_CRB5	XL_251156	-	-	257,992,920.00
2963	TSEL_GRT0	-	SANCANG-ISAT8	-	257,992,920.00
2964	TSEL_BDB0	-	DCS_UNJANI_PI	-	257,992,920.00
2965	TSEL_SKB69	XL_241252	-	-	257,992,920.00
2966					
2967				CAPEX	670,566,597,900.00

Figure 5. Results of BTS optimization

Based on Figure 5, for example, number 2935, we can see that 2 nearest BTSs can incorporate (XLB129 and SUKAWENING). Incorporating those BTSs reduces Capex by Rp257,992,920.00. For all combinations (until number 2967), we BTS Optimisation can reduce Rp 670,566,597,900 in Capex. A reduction of 72% in Capex can be achieved if we optimise the capacity of the tower and the location. Open access among operators must be mutually agreed upon. In Figure, the combination of 2 BTSs in one tower can save costs and other operators can share the existing tower. Figure is a blueprint for BTS optimisation:

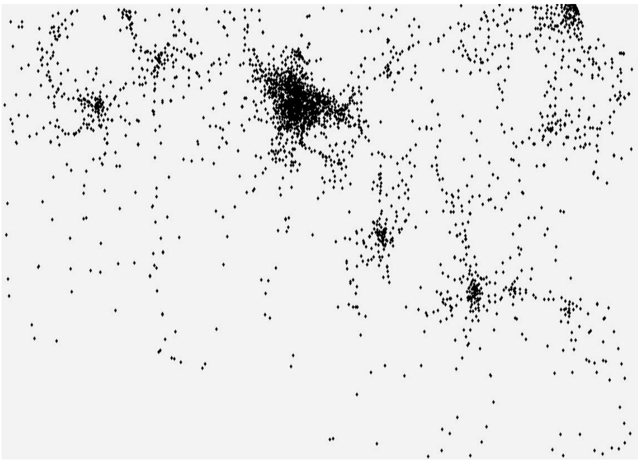

Figure 6. BTS optimisation blueprint

The map shows all of BTS combinations that occupy a tower, the combination solutions can be 1 BTS, 2 BTSs, 3 BTSs or 4 BTSs in a tower. The more BTSs in a tower, the lower the Capex.

CONCLUSION

The PSO approach allowed reduction of 72% y in CAPEX if infrastructure is shared among the operators. Therefore, government must encourage infrastructure sharing which results in cost efficiency. Low cost ensures the business is profitable. This study contributes to literature by proposing a new method using PSO to increase efficiency level. The infrastructure sharing has positive impact on the capex while optimising BTS capacity. Future research can look at different methods of optimisation, so that it can be proposed the best method to solve the infrastructure optimization.

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