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System Dynamic Modeling on Tuberculosis Case Findings in Jember District

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Abstract
Tuberculosis (TB) is a contagious infectious disease caused by Mycobacterium tuberculosis. Five countries in Southeast Asia are among the 22 countries with the highest number of TB cases in the world and Indonesia is ranked fifth. East Java is the province with the second highest number of TB cases after West Java. Jember became the district with the second highest number of tuberculosis sufferers in East Java, so prevention efforts are needed through a system approach that could establish the number of TB cases. This study used a system dynamic modeling to see the variables that could be suppressed to control TB case finding in Jember District. The initial modeling results had a MAPE validation value of less than 10%, so the model could be continued on the development model. Modeling development showed that reducing the number of new sufferers and preventing recurrence could reduce the number of TB cases in Jember District. The application of policies to improve new sufferers discovery for treatment as early as possible to thoroughly could improved TB cure rates and reduced recurrence rates. Improving environmental conditions would reduce the risk of contagion and incident of TB. TB control and eradication programs could be done through cross-program and cross-sectors cooperation and also community empowerment in environmental improvement efforts that would reduce the risk of TB transmission.
Keywords*: tuberculosis, system dynamic modeling, Jember district*

I. INTRODUCTION

Tuberculosis (TB) is a contagious infectious disease caused by *Mycobacterium tuberculosis*. The bacteria could attack various organs, especially the lungs. Through Sustainable Development Goals (SDG's), Indonesia was committed to implementing 17 development goals. One of the development goals is to ensure a healthy life and promote well-being for all people of all ages. At that goal, there are 13 targets, one of them is the eradication of tuberculosis (Hoelman et al., 2015).

In 2000 to 2014, it was estimated there are about 43 million people with TB in the world. Five countries in Southeast Asia are among the 22 countries with the highest number of TB cases in the world (WHO, 2015). Indonesia is ranked fifth. TB prevalence estimation of all cases amounted to 660,000 cases and Incidents estimation amounted to 430,000 new cases each year (WHO, 2017). East Java is the province with the second highest number of TB cases after West Java. Jember became the second highest number of TB sufferers in East Java. By 2015, there were 3,126 TB case findings. The case increased in 2016 to 3,445 cases (Jember District Health Office, 2016).

Prevention of TB disease spreading could be done in various ways. A method that could be used is to know tuberculosis disease spreading with system dynamic modeling. System dynamic modeling is an approach to understanding the behavioral movement and its mechanism. The purpose of the dynamic system model is forecasting and policy planning (Richardson and Pugh, 1986).

Based on the background, the purpose of this research was to identify the system dynamic modeling of TB case findings in Jember District.

II. METHODS

This research was conducted in Jember Regency. The relevant offices in providing data needed in this research were Jember District Health Office, Disease Prevention and Eradication Section (P2P) of Jember District.

In terms of data collection and analysis, this type of research was a nonreactive research study using previously collected data or secondary data. Nonreactive measurement is a study in which the targeted individuals of the study were unaware if they were part of the study. Nonreactive measurement is also called unobtrusive measurement (Kuntoro, 2011).

Secondary data were obtained from data on the number of TB sufferers in Jember District recorded in Jember District Health Office, Disease Prevention and Eradication Section (P2P) and population data recorded in Indonesian Statistics Center. The data was from TB data for five years, especially in 2012-2016.

Data were analyzed by system dynamic modeling using powersim program. Time estimation was done for 2012 until 2030. Modeling system dynamic began with building a causal loop and stock flow diagram of TB case finding in Jember District. Model validation obtained from MAPE value. MAPE is a deviation between the average values of the simulation of the actual data. Limit allowed deviation maximum 10%. Model validation test using MAPE for actual data and simulation result data with the following formula:

$$MAPE = \frac{1}{T}\sum \frac{|A_t - F_t|}{A_t} x100\%$$

Information:
At = *Actual Value* in t-year
Ft = *Forcast Valu*e in t-year
T = number of years

III. RESULTS AND DISCUSSION

A. Development of Causal Loops

Causal Loop Diagrams were made to represent, understand, and analyze the effects and feedback structures of TB case findings in Jember District

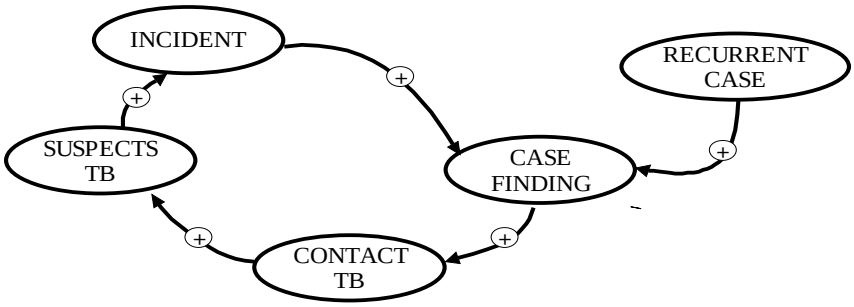

Figure 1. Causal Loop Diagram of The First Scenario Model

TB findings might increase if there was a TB contact reach, so the tuberculosis suspects and Incident might also increase. Improper treatment might also lead to recurrent cases, which would also increase TB findings.

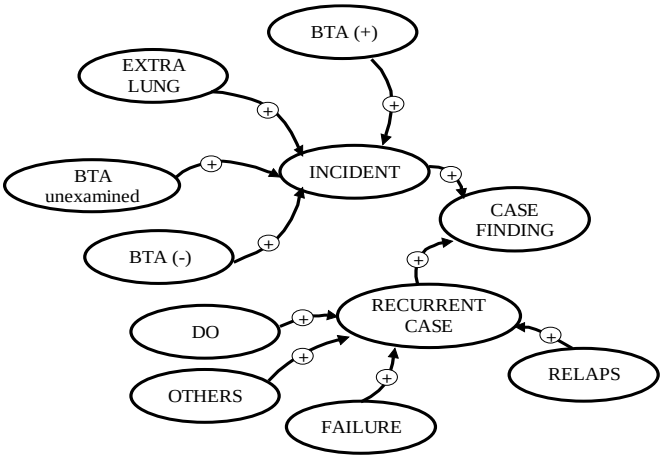

Figure 2. Causal Loop Diagram of Changed Scenario Model

Causal loop changing scenario was obtained based on data in Health Office of Jember district. New TB cases data were obtained from new BTA (+), Extras Lung (EL), BTA unexamined and new BTA (-). TB reccuring data were obtained from DO, others, new failed, and relapsed.

B. Development of Stock Flow Diagrams

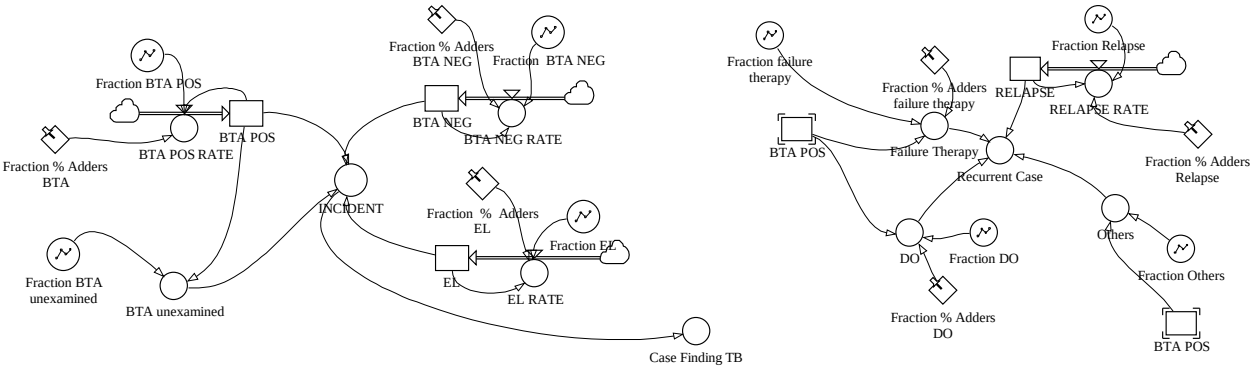

Figure 3. Stock Flow Diagram of TB Case Findings

Incident of TB were the result from addition of Positive BTA, Negative BTA, unexamined BTA, and EL. The formula of incident was 'BTA NEG'+'EL'+'BTA POS'+'BTA NON'. Stock Flow of Positive BTA rate was obtained from the sum of increasing rate fraction of Positive BTA cases during 2012 until 2015 with the adder fraction, and then multiplied with Positive BTA. Stock Flow of Negative BTA rate was obtained from the sum of increasing rate fraction of the Negative BTA cases during 2012 until 2015 with the adder fraction, and then multiplied with Negative BTA. Stock Flow of EL rate was obtained from the sum of the increasing rate fraction of EL cases during 2012 until 2015 with the adder fraction, and then multiplied with EL. The values of Positive BTA, Negative BTA, and EL contained the first time data based on time series data of variables stock. BTA unexamined was an initial case for a unexamined BTA that obtained from the fraction value of BTA unexamined percentage to Positive BTA (BTA unexamined Fraction) multiplied by Positive BTA. The formula that made was 'F BTA NON'*'BTA POS'

Recurrent cases were the sum of failure therapy, relapse, DO, and others. The formula was DO+'FailureTherapy'+RELAPSE+Others. Failure therapy was obtained from the fraction of percentage of Positive BTA multiplied by BTA. The formula was 'BTA POS'*('Fraction failure therapy'+'Fraction % Adders failure therapy'). The DO case was formulated with 'BTA POS'*('Fraction DO'+'Fraction % Adders DO'). The DO fraction represented the percentage of DO cases against Positive BTA. 'Others' fractions were formulated with 'BTA POS'*'F Others'. 'Other' fraction was the percentage of DO cases against Positive BTA. Stock Flow of Relapse rate was obtained from the increasing rate fraction of recurrence case during 2012 until 2015 with the adder fraction, and then multiplied with relapse. The value in the relapse stock contained the first time obtained data based on time series data of variables stock. The finding of TB cases was the sum of Incident TB cases and reccurence TB cases.

C. Validity

1. Validation Results using MAPE for the New TB Cases Amount in Jember District

Table 1. Validation Test Result of New TB Cases Amount in Jember District

Year	Actual Value (A_t)	Forecast Value (F_t)	MAPE
2012	3,225	3,225.00	0.000
2013	3,018	3,017.88	0.004
2014	3,061	3,060.96	0.001
2015	3,054	3,053.91	0.003
2016	3,231	3,230.80	0.006
Mean Absolute Percent Error (MAPE)			**0.003**

Validity test results was less than 10%, so the model could be accepted and proceed to the development scenario.

2. Validation Results using MAPE for The Reccurence of TB Cases in Jember District

Table 2. Test Result of Reccuring TB Cases Validation in Jember District

Year	Actual Value (A_t)	Forcast Value (F_t)	MAPE
2012	84	84.04	0.05
2013	86	85.98	0.02
2014	80	79.99	0.01
2015	72	72.00	0.00
2016	84	84.01	0.01
Mean Absolute Percent Error (MAPE)			**0.02**

Validity test results was less than 10%, so the model can be accepted and proceed to the development scenario.

3. Validation Results using MAPE for TB Case Findings in Jember District

Table 3. Validation Test Result of TB Case Findings in Jember District

Year	Actual Value (A_t)	Forcast Value (F_t)	MAPE
2012	3,309	3,309.03	0.001
2013	3,104	3,103.87	0.004
2014	3,141	3,140.95	0.002
2015	3,126	3,125.91	0.003
2016	3,315	3,314.81	0.006
Mean Absolute Percent Error (MAPE)			**0,003**

Test result validity was less than 10%, so the model can be accepted and proceed to the development scenario.

4. Modeling

a. The Results of The First Scenario Based on Stock Flow Diagram

Table 4. Simulation of TB Sufferers Amount in Jember District

Year	Positive BTA	Negative BTA	BTA unexamined	Extra Lung	New Cases
2012	2,202.00	827.00	0.00	196.00	3,225.00
2013	1,995.89	784.99	0.00	237.00	3,017.88
2014	2,071.94	790.01	0.00	199.01	3,060.96
2015	2,120.83	604.99	89.08	239.01	3,053.91
2016	2,144.80	699.98	92.01	294.01	3,230.80
2017	2,169.04	809.97	93.05	361.66	3,433.62
2018	2,193.55	937.02	94.10	441.88	3,669.55
2019	2,218.33	1,084.13	95.17	547.25	3,944.88
2020	2,243.40	1,254.34	96.24	673.17	4,267.15
2021	2,268.75	1,451.27	97.33	828.06	4,645.42
2022	2,294.39	1,679.12	98.43	1,018.60	5,090.54
2023	2,320.31	1,942.75	99.54	1,252.98	5,615.58
2024	2,346.53	2,247.76	100.67	1,541.29	6,236.25
2025	2,373.05	2,600.66	101.80	1,895.94	6,971.45
2026	2,399.86	3,008.96	102.95	2,332.20	7,843.98
2027	2,426.98	3,481.36	104.12	2,868.84	8,881.31
2028	2,454.41	4,027.94	105.29	3,528.96	10,116.60
2029	2,482.14	4,660.33	106.48	4,340.97	11,589.93
2030	2,510.19	5,392.00	107.69	5,339.83	13,349.71

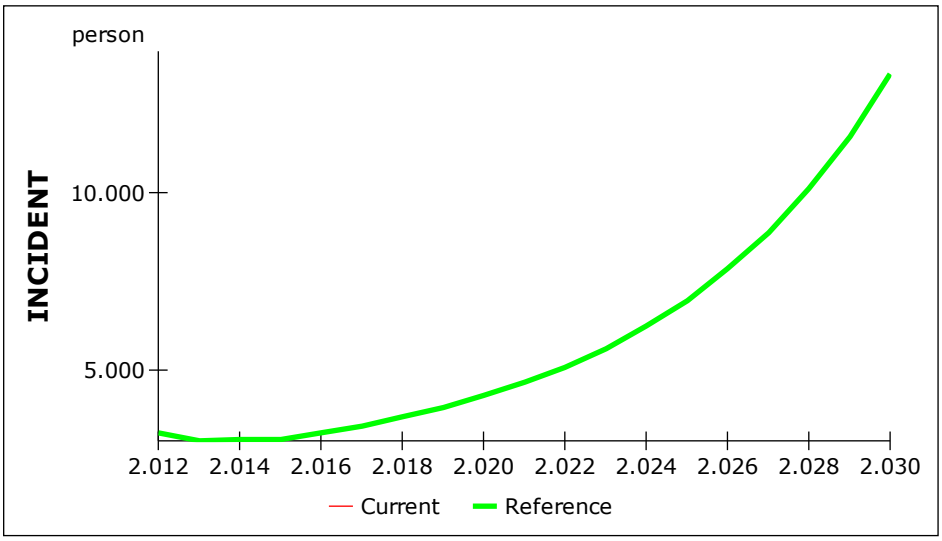

Figure 4. Projection Graph of Incident TB Case

The projection of new TB sufferers were obtained from the addition from incident of Positive BTA, Negative BTA, Extra Lung, and BTA unexamined. The first simulation projection results showed that the number of new TB sufferers since 2016 to 2030 would continue to increase in every year.

Table 5. Simulation of Reccurence TB Cases in Jember District

Year	Drop Out	Failure Therapy	Others	Relapse	Recurrent Case
2012	0.00	5.06	3.96	75.00	84.03
2013	1.00	4.99	2.99	77.00	85.98
2014	2.07	4.97	9.95	63.00	79.99
2015	2.97	2.97	1.06	65.00	72.00
2016	4.93	7.08	3.00	69.00	84.01
2017	4.99	7.16	3.04	73.24	88.42
2018	5.05	7.24	3.07	77.75	93.10
2019	5.10	7.32	3.11	82.53	98.06
2020	5.16	7.40	3.14	87.60	103.31
2021	5.22	7.49	3.18	92.99	108.87
2022	5.28	7.57	3.21	98.71	114.77
2023	5.34	7.66	3.25	104.78	121.02
2024	5.40	7.74	3.29	111.22	127.65
2025	5.46	7.83	3.32	118.06	134.68
2026	5.52	7.92	3.36	125.33	142.12
2027	5.58	8.01	3.40	133.03	150.02
2028	5.65	8.10	3.44	141.21	158.39
2029	5.71	8.19	3.48	149.90	167.27
2030	5.77	8.28	3.51	159.12	176.69

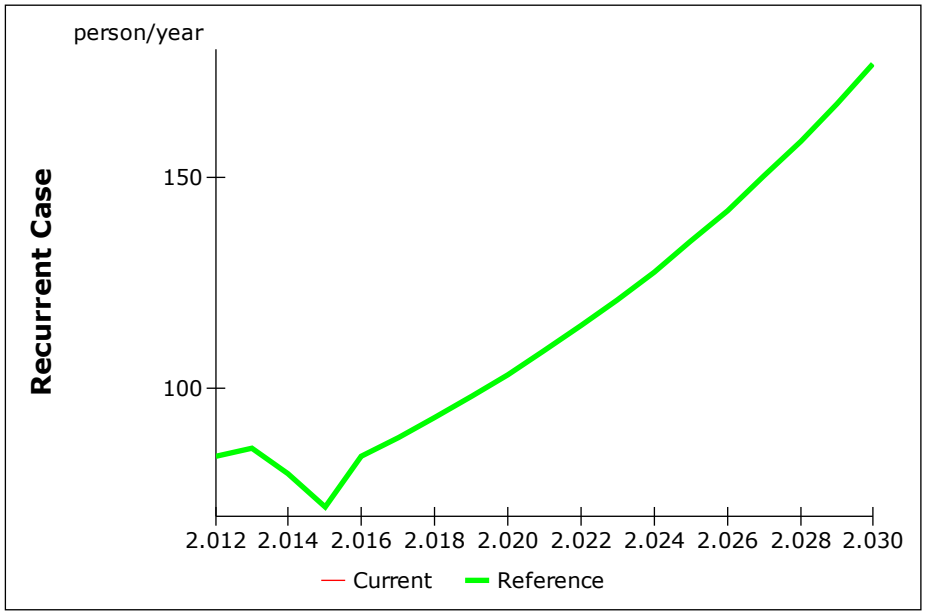

Figure 5. Projected Case Chart

The first simulation projection results showed that TB cases from 2016 to 2030 would continue to increase in every year.

Table 6. Simulation of The Invention of TB Cases in Jember District

Year	Incident	Recurrent Case	Case Findings
2012	3,225.00	84.03	3,309.03
2013	3,017.88	85.98	3,103.87
2014	3,060.96	79.99	3,140.95
2015	3,053.91	72.00	3,125.91
2016	3,230.80	84.01	3,314.81
2017	3,433.62	88.42	3,522.04
2018	3,669.55	93.10	3,762.65
2019	3,944.88	98.06	4,042.93
2020	4,267.15	103.31	4,370.46
2021	4,645.42	108.87	4,754.29
2022	5,090.54	114.77	5,205.31
2023	5,615.58	121.02	5,736.61
2024	6,236.25	127.65	6,363.90
2025	6,971.45	134.68	7,106.13
2026	7,843.98	142.12	7,986.10
2027	8,881.31	150.02	9,031.33
2028	10,116.60	158.39	10,275.00
2029	11,589.93	167.27	11,757.20
2030	13,349.71	176.69	13,526.40

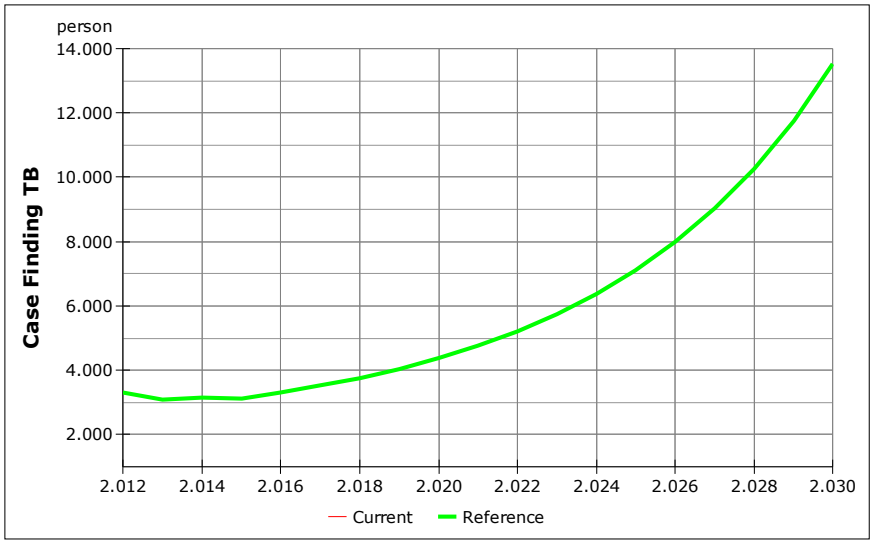

Figure 6. Graph of Projection The First Simulation of Case Findings

The projection results of the first simulation showed that case findings since 2016 to 2030 would continue to increase in every year. The TB case findings were obtained from the sum of relapse sufferers and new sufferers.

Modeling results showed that TB case findings were increased in every year and directly proportional to the increasing of population. The number of TB case findings since 2016 to 2030 was estimated increase in directly proportional with the increasing of population in Jember district. In 2016, it was projected that the number of TB case findings would reach 3,315 cases and continue to increase until 2030 that become 13,527 cases. Prevention of TB case should be done cooperatively by cross-programs and cross-sectors.

b. The Second Development Scenario of TB Cases in Jember District

In 2018, it was expected that there would be a reduction of TB relapse cases become 1.32%. After the increasing of case findings and adequate treatment in 2020, it is expected that there were decreasing of Positive BTA cases by 10%, EL by 10%, and new Negative BTA by 10%.

Table 7. Simulation of TB Case Findings in Jember District

Year	Incident	Recurrent case	Case Findings
2012	3,225.00	84.03	3,309.03
2013	3,017.88	85.98	3,103.87
2014	3,060.96	79.99	3,140.95
2015	3,053.91	72.00	3,125.91
2016	3,230.80	84.01	3,314.81
2017	3,433.62	88.42	3,522.04
2018	3,669.55	93.10	3,762.65
2019	3,944.88	97.03	4,041.91
2020	4,267.15	101.14	4,368.29
2021	4,218.70	103.88	4,322.58
2022	4,204.13	106.93	4,311.06
2023	4,223.52	110.31	4,333.83
2024	4,277.29	114.01	4,391.30
2025	4,366.26	118.03	4,484.29
2026	4,491.59	122.38	4,613.97
2027	4,654.88	127.06	4,781.94
2028	4,858.12	132.07	4,990.19
2029	5,103.80	137.43	5,241.23
2030	5,394.89	143.14	5,538.03

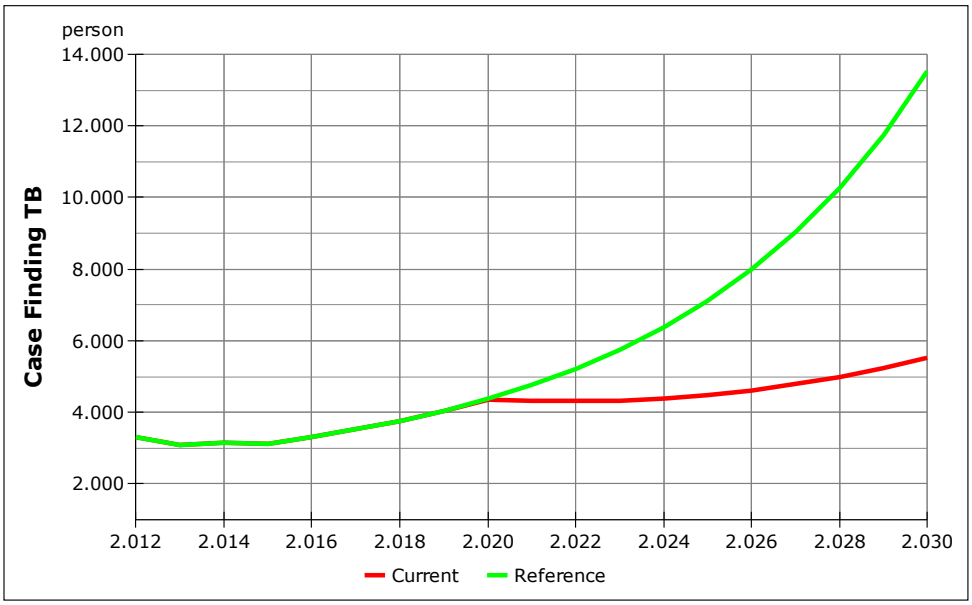

Figure 7. Projection Graph The Invention of Development Simulation Cases

One of TB program is finding of sufferers and adequate treatment as early as possible, so it will reduce the risk of relapses. Improving environmental conditions, which were a risk factor for TB, will reduce the risk of TB contagion, so new TB cases will be reduced. Reduced cases of recurrence and incident of TB will have an impact on decreasing TB findings. This will affect to the more controlled number of TB sufferers.

Integrated TB disease management in the source of the disease will be better if it use promotive and preventive efforts. Searching for cases actively and establishing cases with prompt and precise diagnosis and also treatment to cure will reduce the source of contagion. Promotional and preventive efforts for management of infectious diseases are to prevent the prevention of further contagion (Achmadi, 2014).

The main programs of pulmonary TB include the discovery of the sufferers, the treatment of the sufferers, and the tracking of defaulter cases and the default cases (DO). Case discovery strategy could be done by active counseling. Public health counseling is an activity of delivering message about health especially TB disease to one or a group of people, targeting all levels of society, sufferers, sufferers' family, public, and school children (MOH, 2009).

Based on the Jember District TB report, it was known that TB disease attacked all levels of society from various genders, occupation, and various age groups. So, health promotion messages should be made as easy as possible to reach all TB sufferers and all levels of society in Jember District. Public health counseling is a part of health effort activities to maintain and improve health by individual, group, community, government, and Non-Governmental Organization (NGO). Health efforts include promotive, preventive, curative, and rehabilitative aspects (Notoatmodjo, 2003).

Public health counseling on TB requires a strategic approach to discover TB sufferers effectively and efficiently. According to WHO (in Notoatmodjo, 2003), global strategies include advocacy, social support, and community movements. Advocacy is directed to decision makers or policy makers. The purpose of advocacy is for decision-makers to make policies in the form of laws and regulations. Social support aims to get health support from the community. Community movements are the activities carried out jointly by the community to achieve certain goals.

Jember District Health Office and all its networks had cooperated with cross-program and cross-sector in eradicating TB. Community Health Center (CHC), as the smallest unit of health service in a region, must implement socialization to get social support from community leaders in the concerned region, such as sub-district head, village head, community figure, and religious leader. Jember District Health Office also held TB cadre training. The goal of TB cadre formation was to assist officers in delivering information about TB and assisting officers in finding cases in

their area. Currently, Jember District has 10 pilots CHC in the formation of TB cadres who assisted officers in the finding of new TB cases. Ten CHC are in Tanggul, Patrang, Sumbersari, Pakusari, Puger, Rambipuji, Panti, Umbulsari, Bangsalsari, and Kalisat.

Activities to activate TB cadres at each health center in Jember District use Health Operational Fund as a source of cadre honorarium fund. Assistance from cadres, cross-sectors, and communities is expected to improve the findings of TB sufferers so they could get treatment early.

IV. CONCLUSION

The system dynamic modeling of TB case findings in Jember District was based on serial data since 2012 until 2016. The modeling was done from 2016 until 2030. Based on the identification of dynamic system model of TB case findings in Jember District, the initial simulation result without treatment showed that TB case findings continues to increase in line with the increasing population in Jember District. In the simulation of TB case findings, treatment was given by reducing factors in relapse cases and incident. Based on the simulation results, the decrease of TB case findings occurred due to the decrease of new cases and the decrease of case of relapse. Thus, it could be programmed related to the improvement of healing and reduction of new cases. Based on the validity test of system dynamic modeling of TB case findings in Jember District, MAPE value was less than 10%. This showed that the model had been in accordance with the real data.

ACKNOWLEDGMENTS

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