OPERATIONS AND SUPPLY CHAIN MANAGEMENT
Vol. 15, No. 1, 2022, pp. 69 – 78
ISSN 1979-3561 | EISSN 2759-9363

A Proposed Model for Drug Demand Forecasting and Ordering Inventory System for Dengue Endemic

Irwan Syahrir
Department of Industrial Engineering
Muhammadiyah University of Surabaya, Surabaya, 60113, Indonesia
irwan.syahrir@ft.um-surabaya.ac.id (*Corresponding Author*)

Suparno
Department of Industrial and Systems Engineering
Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia
suparno@ie.its.ac.id

Iwan Vanany
Department of Industrial and Systems Engineering
Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia
vanany@ie.its.ac.id

ABSTRACT

In a tropical country such as Indonesia, dengue fever has become an endemic outbreak because it occurs almost every year, especially in the beginning and towards the end of the rainy season. Districts affected by dengue fever need accuracy in predicting the number of patients and drugs. Hospitals need a suitable drug order inventory system to treat dengue patients. The objective of this paper is to develop a model with higher accuracy and suitability. We propose a two-phase model with several steps and methods to fulfill the objective of each phase. In first phase, we determine a drug forecasting method to predict the number of patients and drug demand. In the second phase, we determine the drug order system (continuous review and periodic review) including the optimal quantities, frequencies, safety stock, and reorder point. The proposed model was then applied in a hospital in Sidoarjo. The results show that the proposed model can be applied in the district and the hospital; and the drug demand forecasting and ordering system resulted in optimal inventory and costs. This study proposed a new multi-phased model that can be used in drug demand forecasting and ordering system, with practical benefits for hospitals and the healthcare systems.

Keywords: *drug demand forecasting, ordering system, dengue endemic, drugs, hospital, SEIR model*

1. INTRODUCTION

Endemic disease outbreak is usually related to the local climate, population density and urbanization. According to McMichael (2003), climate change has a crucial role in the emergence and transmission of certain diseases. Some endemic disease outbreak that can arise due to climate change are yellow fever, influenza cholera, and dengue fever (Shope, 1991). Endemic disease outbreak can spread very quickly and cause large casualties. Dengue fever outbreak was an immediate concern for both healthcare and economic systems in most tropical countries in the world (WHO, 2012). In many Asian countries, dengue fever is endemic in a three- to five-year cycles with a large number of casualties inflicted in tropical and sub-tropical countries (Myat *et al*., 2016). It is an acute infectious disease caused by the dengue virus carried by aedes aegypti mosquitoes with clinical manifestations ranging from influenza-like symptoms to high-heat symptoms that can be life-threatening (WHO, 2012).

The cases of dengue fever worldwide have increased sharply in the past few decades. An estimated of 390 million people were infected with dengue, with 96 million being severely ill (Bhatt *et al*., 2013). Another study estimated that 3.9 billion people in 128 countries were at risk of being infected with dengue fever (Brady *et al*., 2012). In Indonesia, dengue fever risk is high and the spread is rapid (Directorate General of Disease Control and Environmental Health, 2020).

In recent years, a lot of research that considers disaster and pandemic situations has been carried out. John (2021) had explored the relationship of agility dimension i.e flexibility and responsiveness in humanitarian response operations using special reference to water-based disasters such as cyclones and floods. Pujawan & Bah (2021) reviewed a number of articles discussing supply chain management strategies in the face of disruption due to the coronavirus pandemic. Sumarliah *et al*. (2021) propose strategies that companies can implement to manage clothing supply chain risks during the Covid-19 pandemic.

To treat hospitalized patients, drugs are essential but there is often uncertainty in the demand. As such, there is imbalanced between available supply and the number of patients in need of medication (Mohanty, 2013). He and Liu (2015) forecasted drug demand with an epidemic mathematical model and its distribution logistics network, as well as the time needed to distribute the drugs from hospitals to health services in affected areas. Demand forecasting for predicting the number of patients and drugs becomes a major challenge for academics in the healthcare planning (Saedi, Kundakcioglu, & Henry, 2016).

The Susceptible-Infectious-Removed SIR and Susceptible-Exposed-Infectious-Recovered (SEIR) model are predictive models that are commonly used by the academics and practitioners (Al-sheikh, 2012; Li, Graef, & Wang, 1999; Lunelli, Pugliese, & Rizzo, 2009; Saito *et al*., 2013). The SEIR model is an extension of the SIR model (Ergen, Çilli, & Yahnioglu, 2015; Kermack & McKendrick, 1927). The SEIR model has been widely used in previous studies. Al-sheikh (2012) simulates resources management due to limited bed capacity. Hurint, Ndii and Lobo (2017) analyzed the sensitivity of SEIR model to determine the effect of changing parameter values on the basic reproduction numbers and endemic fixed points, especially in the exposed and infectious classes. Lunelli, Pugliese and Rizzo (2009) predicted the transmission of influenza in Italy by looking at the age of the disease sufferers. Noorani (2012) simulated the spread of dengue fever in Malaysia. Despite the wide range of application, the SEIR model is only able to predict the spread of disease in an area in a short period of about two to three months (Handayani, 2020). Therefore, the level of accuracy tends to be low if it is applied for a longer period of observation. In addition, this model has not covered the need for an order inventory system for hospitals. That said, this method is able to provide reasonable forecasts of epidemic impact using simulation techniques and varying the length of the early epidemic growth phase (Smirnova & Chowell, 2019).

Considering the shortcomings of the existing models, the current research aims to create a model that can be used to predict dengue patients and the demand for drugs more accurately, and an effective drug order system that can estimate optimal order quantities, frequencies, safety. Stock and reorder point. The practical implication is to help hospitals tackle problems pertinent to dengue fever influx of patients and manage the related costs more efficiently.

2. PROPOSED MODEL

There are two main phases in proposed model that are needed to achieve the research objective:

Phase 1: Predicting the number of patients and drugs demand

The objective of this phase is to determine the number of patients in each hospital by using SEIR model. The SEIR model is a mathematical model for an endemic disease with an incubation period (the time interval between exposure to disease and an individual showing the symptoms). Three steps are needed to achieve the objective of this phase, namely:

Step 1: Predicting the number of dengue patients and total drugs costs

The number of dengue patients in a district and the total drugs costs are determined by using SEIR model, with a formula following Hurint *et al*. (2017) as follows:

$$\frac{dS}{dt} = \mu N - \frac{\beta I_j S_j}{N} - \mu S_j \tag{1}$$

$$\frac{dE}{dt} = \frac{\beta I_j S_j}{N} - \alpha E_j - \mu E_j \tag{2}$$

$$\frac{dI}{dt} = \alpha E_j - \mu I_j - \gamma I_j \tag{3}$$

$$\frac{dR}{dt} = \gamma I_i - \mu R_j \tag{4}$$

Where:
N = The population
S_j = The number of susceptible patients in district j
E_j = The number of exposed patients in district j
I_j = The number of infectious patients in district j
R_j = The number of recovered patients in district j
β = The transmission rate class S to E
Υ = The recovery rate
μ = The natural death
α = The transmission rate from class E to I

The population is assumed to be constant $N = S + E + I + R$, so that the rate of birth and death is assumed to be constant. According to He and Liu (2015), a slight modification for time discrete is needed in determining the number of patients in the affected district, as follows :

$$D_{jt}^{p} = \begin{cases} \theta_k \int_{t_0}^{t_0+L} \left[S_j(t) + E_j(t) + (1-\gamma) I_j(t)\right] dt - Inv_{jt}^{p}, & p \in M_p \\ \theta_k \int_{t_0}^{t_0+L} \gamma_j I_j(t) dt - Inv_{jt}^{p}, & p \in M_t \end{cases} \tag{5}$$

where:
θ = The number of drug k
t_0 = The beginning of the period t
L = The length of period
M_p and $M_{t\,c}$ = The set of medical reliefs
t_o = The beginning of the period (t)

The parameter values of the SEIR model use those from Keeling & Rohani (2007) i.e., population (N), natural death (μ), transmission rate (β), the number of susceptible (S_0), the number of exposed (E_0), the number of infected I_0, the rate of transition from class E to I (α), and recovery rate (Y).

After the forecast numbers of dengue patients in the affected district and hospital are calculated using the SEIR model, the hospital managers in the affected district can determine the amount of drug needed and also the budget. As such, the district government will be able to provide the demand more effectively.

Step 2: Determining the appropriate forecasting method

Before determining the appropriate forecasting method, understanding whether the data has a trend or seasonality is necessary. This is done by collecting and summarizing sufficient data of the number of patients treated for dengue fever; and the using them to forecast the number of patients in the following year. However, the weakness of forecasting patients and drugs using the SEIR model is that it only has one forecast period (a year). Meanwhile, monthly forecast is necessary for dengue cases because the fluctuation of number of dengue patients is high.

Several forecasting methods are used in the proposed model such as Single Exponential Smoothing (SES), Double Exponential Smoothing (DES), linear regression, quadratic regression, Bayesian regression, winters method, ARIMA, and SIER model. Three types of accuracy of forecasting methods such as Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Mean Squared Deviation (MSD) are compared to determine the accuracy of the forecasting.

Step 3: Forecasting drug demand and selecting forecasting method (SEIR model modified)

The drug inventory costs for dengue fever are calculated by using the hospital inventory model by Uthayakumar and Priyan (2013). The expected total cost per unit time for drugs *i* is as follows :

$$\begin{aligned} ETC_{hi}(Q_i,L) = {} & \frac{D_{jt}^p}{Q_i}(A_i+F+R(L)) + \frac{(Q_i-D_{jt}^p t_c)^2 p_i I_c}{2Q_i} + \frac{h_{bi}Q_i}{2} \\ & + (h_{bi}+p_i I_c)k_i\sigma_i\sqrt{L} + \frac{D_{jt}^p}{Q_i}(d_i C_{di}(L)+\upsilon_i) \\ & - \frac{D_{jt}^{p\,2} t_c^2 s_i I_d}{2Q_i} - \frac{s_i t_c I_d D_{jt}^p}{Q_i}E(X_i-r_i)^+ \end{aligned} \tag{6}$$

Where:

Q_i	=	Number of orders for drug i $(i = 1, 2, 3, \dots M)$
L	=	Lead time (days) for all drugs
D_i	=	Average demand for drugs products per year
d_i	=	Expiry rate for the i^{th} drug
$R(L)$	=	Crash lead time costs per order for all drug products
h_{bi}	=	Holding costs per unit per year excluding interest charges for i^{th} drugs
A_i	=	Ordering cost per order for the i^{th} drugs
t_c	=	The period of general trade credit for all drug products offered by pharmaceutical companies in years
I_d	=	General deposit rates for all products per year
I_c	=	Interest costs paid to the bank for all medical products per year
p_i	=	Purchase price per unit for the i^{th} drug
s_i	=	Selling price per unit for the i^{th} drug
r_i	=	The point of ordering for types of drugs
$E(Xi-ri)+$	=	Estimated shortage of demand for the i^{th} drug at the end of the production cycle
υ_i	=	Labor costs for ordering and receiving types of drugs i
C_{di}	=	Expired costs for the i^{th} drug
F	=	Fixed transportation costs for all products per shipment

The parameter and the equation of type of hospital inventory costs is shown in **Table 1**:

Table 1. Parameter and equation of the drugs inventory costs by (Uthayakumar & Priyan, 2013)

Equation inventory costs	Type of Drug Inventory Cost	Parameter
$\frac{D_i}{Q_i}(A_i+F+R(L))$	: The ordering cost per unit time for drug i	X_1
$\frac{(Q_i-D_i t_c)^2 p_i I_c}{2Q_i}$	: The opportunity interest cost per unit time for unsold units of drugs i	X_2
$\frac{h_{bi}Q_i}{2}$	: The holding cost per unit time for the cycle stock of i	X_3
$\frac{D_i}{Q_i}(d_i C_{di}(L)+\upsilon_i)$	: The expected expiry cost	X_4
$(h_{bi}+p_i I_c)k_i\sigma_i\sqrt{L}$	: The total cost of the safety stock per unit time.	X_5
$\frac{D_i^2 t_c^2 s_i I_d}{2Q_i}$	: The interest earned by hospital per unit time for drug i	X_6
$\frac{s_i t_c I_d D_i}{Q_i}E(X_i-r_i)^+$	: The hospital earns interest unit time during the credit period	X_7

After the most accurate forecasting method is selected, we modified the SEIR model based on the expected costs. The expected costs from hospital inventory model by Uthayakumar and Priyan (2013) are used in the proposed model. The modified SEIR model uses the index of the forecasting method, with an index value obtained from the value of the proportion each month from the forecasting results. The SEIR model is modified slightly because it needs to be contextualized into a monthly basis because, as mentioned previously, it is the most popular forecasting method to be applied in endemic cases, but only for a short period of observation time (e.g. ,Noorani, 2012; Saito *et al.*, 2013; Annas *et al.*, 2020)

Phase 2: Determining a suitable drugs order inventory system

The objective of this phase is to determine the drug order system based on using hospital inventory costs by Uthayakumar and Priyan (2013). One hospital case is selected to determine the drugs order system including the order optimal quantities, safety stock, and reorder point, with the following steps:

Step 1: Determining the order review systems

There are two types of order systems that are selected based on the hospital inventory costs, namely continuous review (s, S) and periodic review (R, S) because these two order systems have different approaches and are also most often used in hospitals in Indonesia (Hafnika, Farmaciawaty, Adhiutama, & Basri, 2016; Setyaningsih & Basri, 2013). The continuous review (s, S) method, often called the min-max system, is an inventory review that is carried out without considering the position of the purchase time interval. The expected inventory position is between the minimum point (s) and the maximum point (S)(Silver, Pyke, & Thomas, 2017). Periodic review is an inventory policy that considers a certain time interval when an order has reached a reorder point (Silver *et al*., 2017). Determination of the optimal order quantity, safety stock, and reorder point for dengue fever drugs are determined for the two inventory policies and which method to choose based on the least cost.

Based on the hospital inventory costs calculation by Uthayakumar and Priyan (2013), optimal Q_i will be obtained if $\frac{dETC_{hi}(Q_i,L)}{dQ_i}=0$, then the differentiation of the equation becomes:

$$\frac{dETC_{hi}(Q_i,L)}{dQ_i}=0 \tag{7}$$

$$-\frac{D_{jt}^{p}}{Q_i^2}(A_i+F+R(L))+\left[\frac{2\left(Q_i-D_{jt}^{p}t_c\right)2Q_i-2\left(Q_i-D_{jt}^{p}t_c\right)^2}{4Q_i^2}\right]p_iI_c$$

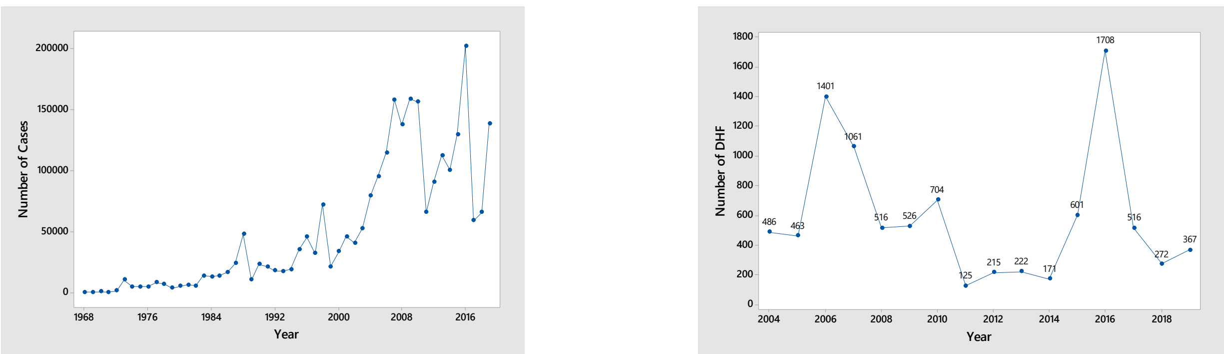
$$+\frac{h_{bi}}{2}+\frac{\left(D_{jt}^{p2}t_c^2s_iI_d\right)}{4Q_i^2}+\frac{s_it_cI_dD_{jt}^{p}}{Q_i^2}E\left(X_i-r_i\right)^+=0$$

so it obtains:

$$Q_i=\sqrt{\frac{D_{jt}^{p2}t_c^{\,2}p_iI_c+2D_{jt}^{p}(A_i+F+R(L))-\left(D_{jt}^{p2}t_c^2s_iI_d\right)-2s_it_cI_dD_{jt}^{p}E\left(X_i-r_i\right)^+}{\left[p_iI_c+h_{bi}\right]}} \tag{8}$$

3. DISTRICT AND HOSPITAL CASE

The proposed model for demand forecasting and drugs ordering system was applied in Sidoarjo, a district in East Java, Indonesia. Dengue fever threatens residents in Sidoarjo district almost every year. This is because the district has many shrimp and fish ponds and other bodies of water that can support mosquitoes' breeding. In addition to this is the poor environmental hygiene of the locals. **Figure 1** shows the number of cases of dengue fever endemic in Indonesia in 1968-2019 and the districts selected in this paper. The existing plotting data shows that there are fluctuating and exponential data patterns. The highest peak of dengue fever cases occurred in 2016. In the same year, it was the peak of the dengue fever endemic cases in Sidoarjo.



a b

Figure 1. (a) The number of dengue people infected in Indonesia (1968-2019) and (b) Number of fever incident in Sidoarjo district 2017-2019(month) (Sources: Ditjen PP dan PL Depkes RI, 2020)

One hospital case is selected to test the model. It is a middle class hospital in Sidoarjo established in 1967 with a capacity of 205 beds. Services are carried out for 24 hours with facilities such as emergency unit, intensive care unit, laboratory, pharmacy, operating room and isolation ambulance and other facilities. Procedures for dengue patients are: registration, temperature check, blood check, doctor decision (outpatient or inpatient), medical treatment (intravenous fluids, blood transfusions, heat-lowering drugs, and vitamins) and others. To support the treatment, hospital managers must plan their dengue fever drug's supply and inventory.

3.1 Phase 1: Predicting the number of patients and drugs demand

The following describes the results of phase 1 for the following three steps.

Step 1: Predicting the number of patients and total drugs costs

Secondary data collection for parameters i.e., natural death, the number of exposed, etc.; and hospitals i.e., inpatient capacity, were obtained from the Sidoarjo's Health Department and the hospitals. Interviews were also conducted to understand the types of drugs and the price needed for treatment. The parameters of SEIR model in Sidoarjo district were determined (see **Table 2**).

Table 2: Parameters used of SEIR model in Sidoarjo district

	Parameter	Value
Population	N	100,000
Natural death	μ	4.21E-05
Transmission rate	β	1.43
Individual	S_0	98,483
The number of exposed	E_0	163
The number of infected	I_0	16
The rate of transition from class E to I	α	0.12
Recovery rate	Y	0.14

The numbers in the parameters μ, β and α use the values used by Keeling and Rohani (2007). The graph of the SEIR simulation results is shown in **Figure 2**. The calculation of drugs needed is based on the prediction of the number of dengue patients.

The pattern of data of the numbers of dengue patients are shown in **Figure 2 (a)** and the actual distribution pattern is shown in **Figure 2 (b)**. The equilibrium point occurs when the values of S, E and I reach zero, where no disease is found in the population (the disease-free point). The peak of infected and infectious individuals (*I*) is used as a basis for predicting the number of dengue fever patients. Based on the calculation results, the peak point *I* occurred at 24,553 as shown in **Figure 2 (b)**. The balance point of parameter *I* occurs on day 130. So that the average daily number of dengue fever patients can be concluded as follows:

Predicted patients per day
= *I* max/ the number of days to the point in balance
= 24,553 infected individuals/130 days
= 189 infected individuals/day

Based on the prediction of dengue fever patients that can be handled by the hospital and the number of patients admitted per year, the number of each drug and the cost of drug required can be determined (see **Table 3**). For example, hospital case 2 will be able to handle 17 patients per day. With the assumption that each dengue fever patient gets an average inpatient service for four days, then the number of patients who can be treated in a year is 1,551 patients (17 patients/day x 365/4 days). The number of drugs A is 16,407 ampoules (12 x 1,551 patients) and the total drug cost in hospital case 2 is IDR 1,154,159,319. Meanwhile, the total drug cost for the whole Sidoarjo district is IDR 12,544,715,295.

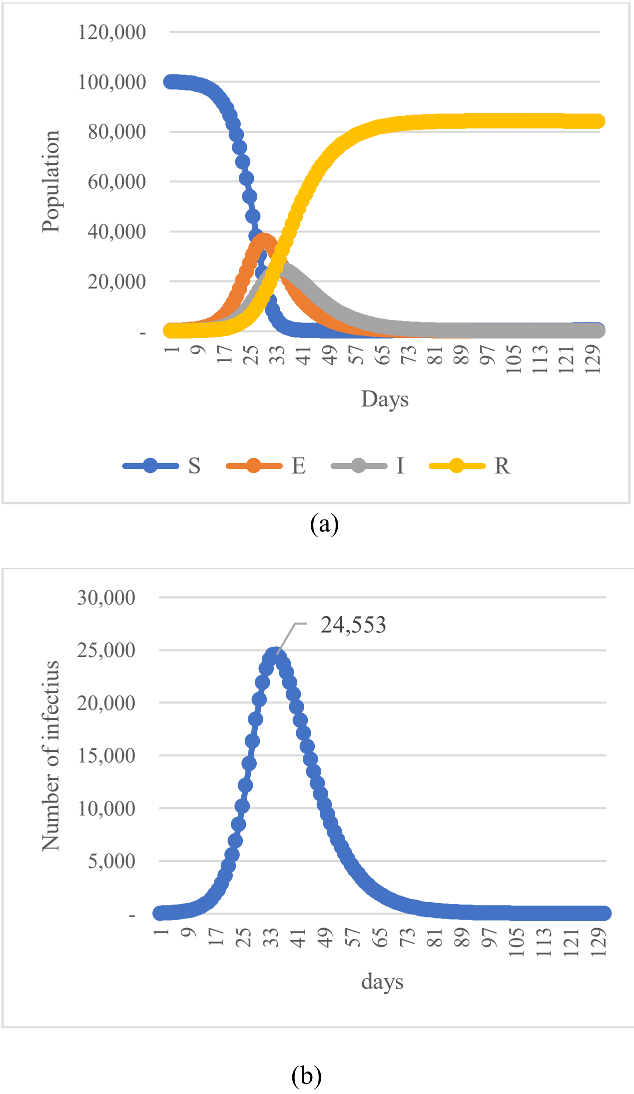


Figure 2. (a) Dengue people infected distribution in Sidoarjo using SEIR model
(b) The distribution of dengue people infected

Table 3. The number of dengue patients in Sidoarjo and total drugs costs in each hospital

Hospital	Inpatient Capacity (IC)	Proportion (P)	P x I (per day)	P x I (per year)	Drugs A (ampoule)	Drugs B (ampoule)	Drugs C (ampoule)	Drugs D (ampoule)	Drugs E (bottle)	Drugs F (vial)	Total drugs costs (IDR)
Case 1	500	0.35	67	6,114	73,232	48,822	73,232	48,822	73,232	24,411	4,439,035,844
Case 2	130	0.09	17	1,551	19,040	12,694	19,040	12,694	19,040	6,347	1,154,149,319
Case 3	99	0.07	13	1,186	14,500	9,667	14,500	9,667	14,500	4,833	878.929.097
Case 4	135	0.10	18	1,643	19,773	13,182	19,773	13,182	19,773	6,591	1.198.539.678
Case 5	136	0.10	18	1,643	19,919	13,279	19,919	13,279	19,919	6,640	1.207.417.750
Case 6	32	0.02	4	365	4,687	3,125	4,687	3,125	4,687	1,562	284,098,294
Case 7	81	0.06	11	1,004	11,864	7,909	11,864	7,909	11,864	3,955	719,123,807
Case 8	19	0.01	3	274	2,783	1,855	2,783	1,855	2,783	928	168,683,362
Case 9	36	0.03	5	456	5,273	3,515	5,273	3,515	5,273	1,758	319,610,581
Case 10	86	0.06	12	1,095	12,596	8,397	12,596	8,397	12,596	4,199	763,514,165
Case 11	109	0.08	15	1,369	15,965	10,643	15,965	10,643	15,965	5,322	967,709,814
Case 12	37	0.03	5	456	5,419	3,613	5,419	3,613	5,419	1,806	328,488,652
Case 13	13	0.01	2	183	1,904	1,269	1,904	1,269	1,904	635	115,414,932
Total	1,413	1.00	189	17,388	206,955	137,970	206,955	137,970	206,955	68,985	
Total drugs costs (IDR)											**12,544,715,295**

Step 2: Determining an appropriate forecasting method

In this step, hospital case 2 was selected, with data on dengue patients recorded properly for each month. Results data from the use of drugs needed are also recorded well. **Figure 2** shows the plot of hospitalized dengue fever patients in hospital case 2 in 2017-2019. The trend of dengue fever patients is fluctuating and tends to increase in May each year during the rainy season. This period is the best time for the aides mosquito to breed. The spread of the dengue virus becomes more widespread in the months of the rainy season every year. Meanwhile, the highest spike occurred in 2019, namely 466 patients.

In the second stage, the appropriate forecasting method is the Winter method ((α= 0.9; γ= 0.1; δ= 0.1) that is chosen based on the smallest MAPE, MAD and MSD values (see **Table 4**). The Winter method has the smallest error because it can capture seasonality of dengue fever patient's data in the hospital case 2. Although the SEIR model is often used in the case of an endemic (Annas *et al.*, 2020; Noorani, 2012; Saito *et al.*, 2013), but **Table 4** shows that the accuracy of the SEIR model forecasting is low.

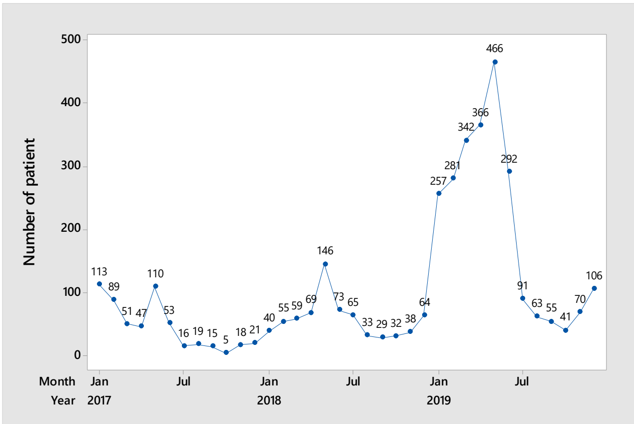


Figure 3. Plot of dengue fever patients in hospital case 2 (2017-2019)

Table 4. Determining an appropriate forecasting method in hospital case 2

Forecasting Method	MAPE	MAD	MSD	Rank
SES (α = 1.23)	47.5	38.0	3948.7	2
DES (α = 1.24 ; γ= 0.01)	47.2	40.2	4043.3	3
Linear regession	153.5	80.1	10453.8	6
Quadratic	153.7	80.1	10453.8	8
Winter Method (α= 0.9 ; γ= 0.1 ; δ= 0.1)	23.6	19.2	1123.1	1
ARIMA *	99.6	68.1	8199.1	4
Bayesian Regression	153.7	80.0	10453.8	7
SIER *	128.8	75.6	9196.1	5

Step 3: Forecasting drug demand and selecting a forecasting method (SEIR model modified)

In this stage, the Winter method is used to forecast the amount of 6 types of drugs needed to treat dengue fever patients. The SEIR model was modified by using the index of Winter forecasting results. Four days of treatment time was used based on the mean hospitalization time of dengue fever patients as confirmed by the hospital case 2 manager.

Table 5 shows the results six drugs forecast for hospital case 2 for the following year. The highest number of drugs is in May (period 41), in line with the forecast increase of the number of patients. The next step is to compare the Winter method and the modified SEIR model based on the minimum expected costs. **Table 6** shows the expected cost of each dengue drug in the Winter method and modified SEIR model. The SEIR method was selected for drug A (IDR 1,313,262), drug B (IDR 685,173), drug C (IDR 839,700), drug D (IDR 684,082) drug E (IDR 1,010,497) and drug F (IDR 1,010,497).

Table 5. The results of drugs demand forecasting using winter method and SIER Model

Method- drugs type	Demand forecasting each drugs in hospital case 2 in monthly												Total
	37	38	39	40	41	42	43	44	45	46	47	48	
Winter Method (patients)	241	251	265	286	437	252	105	71	62	48	80	121	2,219
Drug A (vial)	2,891	3,006	3,179	3,434	5,244	3,027	1,263	854	738	580	955	1,451	26,622
Drug B (ampoule)	1,927	2,004	2,119	2,289	3,496	2,018	842	570	492	386	637	967	17,748
Drug C (ampoule)	2,891	3,006	3,179	3,434	5,244	3,027	1,263	854	738	580	955	1,451	26,622
Drug D (ampoule)	1,927	2,004	2,119	2,289	3,496	2,018	842	570	492	386	637	967	17,748
Drug E (bottles)	2,891	3,006	3,179	3,434	5,244	3,027	1,263	854	738	580	955	1,451	26,622
Drug F (vial)	964	1,002	1,060	1,145	1,748	1,009	421	285	246	193	318	484	8,874
Method- drugs type	**Demand forecasting each drugs in hospital case 2 in monthly**												**Total**
	37	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	
SEIR Model	172	179	190	203	303	176	72	48	42	33	53	80	1,551
Drug A (vial)	2,068	2,144	2,280	2,431	3,642	2,108	868	580	499	393	636	963	18,612
Drug B (ampoule)	1,379	1,429	1.520	1,621	2,428	1,406	578	387	333	262	424	642	12,408
Drug C (ampoule)	2,068	2,144	2,280	2,431	3,642	2,108	868	580	499	393	636	963	18,612
Drug D (ampoule)	1,379	1,429	1,520	1,621	2,428	1,406	578	387	333	262	424	642	12,408
Drug E (bottle)	2,068	2,144	2,280	2,431	3,642	2,108	868	580	499	393	636	963	18,612
Drug F (vial)	689	715	760	810	1,214	703	289	193	166	131	212	321	6,204

Table 6. Determining winter or SEIR - seasonal index method selected based on expected cost

Forecasting Method - Drug Inventory costs	Drug A	Drug B	Drug C	Drug D	Drug E	Drug F
Winter methods						
Ordering costs (X1)	631,809	425,192	613,659	497,211	628,783	582,373
Opportunity interest costs (X2)	8,784	22,827	549	12,668	3,679	1,742
Holding costs (X3)	253,241	250,867	260,731	214,530	254,460	91,579
Total cost of the safety stock (X4)	1,330,308	91,123	380,580	131,605	727,454	459,294
Expected expire costs (X5)	73,588	49,523	71,474	57,911	73,236	67,830
Interest earned per unit time for product i (X6)	719,267	40,180	399,591	145,364	529,207	363,740
Interest earned per unit time during the credit period (X7)	10,807	906	6,004	3,276	7,951	16,396
Expected cost (IDR)	1,567,657	798,446	921,399	765,286	1,150,453	822,683
Total Expected Cost (IDR)						**6,025,924**

Table 6. Determining winter or SEIR - seasonal index method selected based on expected cost (Con't)

Forecasting Method - Drug Inventory costs	Drug A	Drug B	Drug C	Drug D	Drug E	Drug F
SIER - Seasonal index						
Ordering costs (X1)	609,563	365,571	566,218	430,729	590,146	548,366
Opportunity interest costs (X2)	492	33,285	3,140	27,515	418	10,326
Holding costs (X3)	183,506	203,988	197,553	173,130	189,543	67,995
Total cost of the safety stock (X4)	944,274	64,680	270,142	93,416	516,358	326,015
Expected expire costs (X5)	70,997	42,579	65,949	50,168	68,736	63,870
Interest earned per unit time for product i (X6)	485,143	24,152	257,762	88,037	347,241	239,446
Interest earned per unit time during the credit period (X7)	10,426	779	5,540	2,838	7,463	15,438
Expected cost (IDR)	1,313,262	685,173	839,700	684,082	1,010,497	761,686
Total Expected Cost (IDR)						5,294,400
Decision based on Total cost (Min. cost)	**SEIR**	**SEIR**	**SEIR**	**SEIR**	**SEIR**	**SEIR**

3.2 Phase 2: Determining the drug order system

In phase 2, we determine the appropriate drugs order system based on the drugs inventory costs. Two types of drugs order system i.e., continuous review (s. S) and periodic review (R, S) were used in this proposed model. Continuous review policy is a continuous inventory checking policy, the ordering Q amount is performed when the inventory level has reached the reorder point (Hung, 2011; Rizkya *et al.*, 2018). The periodic review policy is the inventory management policies that review the physical availability of inventories at specified time intervals and place orders for a maximum level of inventory (Wisner, Tan, & Leong, 2019).

Table 7 shows the results of a selection of the types of drugs order system based on the minimum expected inventory costs. All types of dengue drugs (drug A-drug F) uses a continuous review system because the expected inventory costs in continuous review policy are lower than the periodic review. The total estimated costs of all dengue drugs in hospital case 2 using continous review is IDR 4,609,943. The total cost of drug inventory using continuous review (s. S) is lower than using the periodic inventory review system which results in a total cost of IDR 6,273,988. **Table 7** also shows the optimal order quantities, safety stock, and reorder points to support the management of drugs inventory in hospital case 2. For example, for drug A, the values are for the optimal order quantities, frequencies, safety stock, and reorder point, respectively is 1803 , 11, 230 and 944.

Table 7. Determining an appropriate drugs order system in hospital case 2

Ordering system- Forecasting method	**Continous Review (s.S)**					
	Drug A	**Drug B**	**Drug A**	**Drug D**	**Drug A**	**Drug F**
Appropriate forecasting method	SEIR	SEIR	SEIR	SEIR	SEIR	SEIR
Q $_{Opt}$ (order quantities)	1803	1903	1900	1619	1838	660
Ordering frequency/year	11	7	11	8	11	10
safety stock	230	108	162	108	230	54
Re-order point	944	346	519	346	944	173
Expected cost each drug (IDR)	1,021,467	665.186	756,222	655,215	850,935	660,943
Expected cost (IDR) all drugs						4,609,967
Ordering system- Forecasting method	**Periodic Review (R.S)**					
	Drug A	**Drug B**	**Drug A**	**Drug D**	**Drug A**	**Drug F**
Appropriate forecasting method	WINTER	SEIR	SEIR	SEIR	SEIR	SEIR
Q $_{Opt}$ (order quantities)	3,285	1,108	1,663	1,108	2,319	555
Ordering frequency/year	11	7	11	8	11	10
safety stock	1,255	798	1,197	798	1,466	399
Re-order point	3,729	1,315	1,972	1,315	2,629	657
Expected cost each drug (IDR)	1,795,795	882,585	885,894	816,694	1,057,970	835,050
Expected cost (IDR) all drugs						6,273,988
Decision	Continous Review (s.S)	Continous Review (s.S)	Continous Review (s.S)	Continous Review (s.S)	Continous Review (s.S)	Continous Review (s.S)

4. DISCUSSION

Developing and applying a proposed model for drug demand forecasting and order inventory system will inform the hospital decision-making. The proposed model in phase 1 allows the local government to predict the number of dengue patients and the amount and costs of the drug needed. Based on **Table 3**, hospital case 1 was identified as the most intensive in treating dengue fever patients and requires the highest drug costs. Hospital managers in the infected district can also use an appropriate forecasting method that are more accurate.

Based on **Table 4**, the Winter method (α= 0.9; γ= 0.1; δ= 0.1) could be considered as an appropriate forecasting method to predict the number of dengue patients and drugs based on the smallest value of forecast error in three types of forecasting such as MAPE, MAD, and MSD. The Winter method is more suitable to be used in forecasting the number of dengue patients because the historical patient data contains seasonal elements. Dengue fever is a disease that depends on climate and will increase in the rainy season and end in the dry season.

Although SEIR is the most popular model, the value measure of forecasting error is high (rank 5, see **Table 4**). The large difference in the forecasting results shows that the SEIR model is not suitable for forecasting over a long period of time such as year or one-three short period such as one or three months. The SEIR model has its drawbacks when used with a deterministic approach, but it is a useful tool for modelling epidemic spread in an area (Teles, 2020). Meanwhile, the Winter method can also forecast epidemic diseases (diarrhea, acute respiratory infection, and malaria) with seasonality patterns. (Medina, Findley, Guindo, & Doumbia, 2007).

Phase 2 represents the suitable drugs order inventory system that are used for dengue drug in hospitals. The continuous review (s, S) was identified as suitable order inventory system based on the expected inventory costs by Uthayakumar and Priyan (2013). On the other hand, drug order optimal, order frequencies, safety stock and reorder point were also determined. Based on **Table 5**, the order optimal quantity for drug A-F is 1,803; 1,903 ; 1,900; 1,619; 1,838 and 895, order frequencies for drug A-F is 11, 7, 11, 8, 11 and 10, safety stock for drug A-F is 230, 108, 162, 108, 230 and 54, reorder point for drug A-F is 944, 346,519, 346, 944 and 173. Widyadana, Tanudireja and Teng (2017) investigated the performance of several inventory policies with stochastic and intermittent demand, showing that the performance of (Q, R) policy is better than (s, S) policy for inventory policy of all the products. They recommendation is to use a continuous review policy to reduce their inventory cost.

5. CONCLUSIONS

Endemic diseases in Indonesia such as dengue fever, influenza, yellow fever often occur every year which may result in death. Dealing with this needs an accurate prediction of the number of patients, the number of drugs needed and an order inventory system policy. The current study proposes a model for drugs demand forecasting and an order system. In phase 1, the Winter method can be considered as an effective forecasting method to predict the number of patients and drug demand. The final phase of proposed model determined a suitable order inventory system including quantity, frequencies, safety stock, and reorder point. The suitable order inventory system was determined to avoid shortages of dengue drugs and minimize the total inventory costs.

The pattern of influx of patients and drugs data play an important role in the forecasting. Endemic diseases that do not occur due to seasonality may require different methods of forecasting. There should be further research and testing of the proposed model with intermittent and lumpy patterns.

REFERENCES

Al-sheikh, B. S. A. (2012). Modeling and Analysis of an SEIR Epidemic Model with a Limited Resource for Treatment. *Global Journal of Science Frontier Research Mathematics and Decision Sciences*, *12*(14), 56–66.

Annas, S., Isbar, M., Rifandi, M., Sanusi, W., & Side, S. (2020). Stability analysis and numerical simulation of SEIR model for pandemic COVID-19 spread in Indonesia. *Chaos, Solitons and Fractals*, *139*(January).

Bhatt, S., Gething, P. W., Brady, O. J., Messina, J. P., Farlow, A. W., Moyes, C. L., … Hay, S. I. (2013). The global distribution and burden of dengue. *Nature*, *496*(7446), 504–507. https://doi.org/10.1038/nature12060

Brady, O. J., Gething, P. W., Bhatt, S., Messina, J. P., Brownstein, J. S., Hoen, A. G., … Hay, S. I. (2012). Refining the Global Spatial Limits of Dengue Virus Transmission by Evidence-Based Consensus. *PLoS Neglected Tropical Diseases*, *6*(8). https://doi.org/10.1371/journal.pntd.0001760

Ergen, K., Çilli, A., & Yahnioglu, N. (2015). Predicting epidemic diseases using mathematical modelling of SIR. *Acta Physica Polonica A*, *128*(2), 273–275. https://doi.org/10.12693/APhysPolA.128.B-273

Hafnika, F., Farmaciawaty, D. A., Adhiutama, A., & Basri, M. H. (2016). Improvement of Inventory Control Using Continuous Review Policy in A Local Hospital at Bandung City, Indonesia. *The Asian Journal of Technology Management (AJTM)*, *9*(2), 109–119. https://doi.org/10.12695/ajtm.2016.9.2.5

Handayani, L. (2020). The Ootbreak's Modeling of Coronavirus (Covid-19) Using The Modified SEIR Model In Indonesia. *SPEKTRA: Jurnal Fisika Dan Aplikasinya*, *5*(1), 61–68.

He, Y., & Liu, N. (2015). Methodology of emergency medical logistics for public health emergencies. *Transportation Research Part E*, *79*, 178–200. https://doi.org/10.1016/j.tre.2015.04.007

Hung, K. (2011). Continuous Review Inventory Model Under Time Value of Money and Crashhable Lead Time. *Yugoslav Journal of Operations Research*, *21*(2), 293–306. https://doi.org/10.2298/YJOR1102293H

Hurint, R. U., Ndii, M. Z., & Lobo, M. (2017). Analisis Sensitivitas Model Epidemi SEIR. *Journal of Natural Science*, *6*(March), 22–28. https://doi.org/10.22487/25411969.2017.v6.i1.8076

John, J. (2021). Agility in humanitarian response operations for water based disasters. *Operations and Supply Chain Management*, *14*(4), 564–575. https://doi.org/10.31387/oscm0470324

Keeling, M. J., & Rohani, P. (2007). *Modeling Infectious Diseases in Humans and Animals* (Fourth). Taylor & Francis Group.

Kermack, W. O., & McKendrick, A. G. (1927). A Contribution to the Mathematical Theory of Epidemics. In *Proceedings of The Royal Society* (pp. 700–721). https://doi.org/10.1098/rspa.1927.0118

Li, M. Y., Graef, J. R., & Wang, L. (1999). Global dynamics of a SEIR model with varying total population size. *Mathematical Biosciences*, *160*, 191–213.

Lunelli, A., Pugliese, A., & Rizzo, C. (2009). Epidemic patch models applied to pandemic influenza: contact matrix, stochasticity, robustness of predictions. *Mathematical Biosciences*, *220*(1), 24–33. https://doi.org/10.1016/j.mbs.2009.03.008

McMichael, A. . (2003). Global climate change: will it affect vector-borne infectious diseases? *Internal Medicine Journal*, *33*, 554–552.

Medina, D. C., Findley, S. E., Guindo, B., & Doumbia, S. (2007). Forecasting Non-Stationary Diarrhea , Acute Respiratory Infection , and Malaria Time-Series in Niono , Mali. *PLoS ONE*, (11). https://doi.org/10.1371/journal.pone.0001181

Mohanty, A. (2013). An epidemiological study of common drugs in the health supply chain. *Journal of Humanitarian Logistics and Supply Chain Management*, *3*(1), 52–64. https://doi.org/10.1108/20426741311328510

Myat, M., Tun, N., Kyaw, A., Makki, N., Muthugala, R., Nabeshima, T., … Morita, K. (2016). Characterization of the 2013 dengue epidemic in Myanmar with dengue virus 1 as the dominant serotype. *MEEGID*, *43*, 31–37. https://doi.org/10.1016/j.meegid.2016.04.025

Noorani, M. S. M. (2012). SEIR Model For Transmission Of Dengue Fever In Selangor Malaysia. *International Journal of Modern Physics*, *9*, 380–389.

Pujawan, I. N., & Bah, A. U. (2021). Supply chains under COVID-19 disruptions: literature review and research agenda. *Supply Chain Forum*, . https://doi.org/10.1080/16258312.2021.1932568

Rizkya, I., Syahputr, K., Sari, R. M., Anizar, Siregar, I., Ginting, E., & Department. (2018). Comparison of Periodic Review Policy and Continuous Review Policy for the Automotive Industry Inventory System. In *IOP Conf. Series: Materials Science and Engineering 288 (2017) 012085* (pp. 0–6). https://doi.org/10.1088/1757-899X/288/1/012085

Saedi, S., Kundakcioglu, O. E., & Henry, A. C. (2016). Mitigating the Impact of Drug Shortages for a Healthcare Facility : An Inventory Management Approach. *European Journal of Operational Research*, *251*(1), 107–123. https://doi.org/10.1016/j.ejor.2015.11.017

Saito, M. M., Imoto, S., Yamaguchi, R., Sato, H., Nakada, H., Kami, M., … Higuchi, T. (2013). Extension and verification of the SEIR model on the 2009 influenza A (H1N1) pandemic in Japan. *Mathematical Biosciences*, *246*(1), 47–54. https://doi.org/10.1016/j.mbs.2013.08.009

Setyaningsih, S., & Basri, M. H. (2013). Comparison Continuous and Periodic Review Policy Inventory Management System Formula and Enteral Food Supply in Public Hospital Bandung. *International Journal of Innovation, Management and Technology*, *4*(2), 253–258. https://doi.org/10.7763/ijimt.2013.v4.401

Shope, R. (1991). Global Climate Change and Infectious Diseases. *Environmental Health Perspectives*, *96*, 171–174.

Silver, E., Pyke, D., & Thomas, D. (2017). *Inventory and Production Management in Supply Chains* (Fourth). Boca Raton,FL: Taylor & Francis Group.

Smirnova, A., & Chowell, G. (2019). Forecasting Epidemics Through Nonparametric Estimation of Time-Dependent Transmission Rates Using the SEIR Model. *Bulletin of Mathematical Biology*, *81*(11), 4343–4365. https://doi.org/10.1007/s11538-017-0284-3

Sumarliah, E., Usmanova, K., Fauziyah, F., & Mousa, K. (2021). Managing the risks in the clothing supply chain considering the coronavirus pandemic. *Operations and Supply Chain Management*, *14*(4), 576–587. https://doi.org/10.31387/oscm0470325

Teles, P. (2020). A time-dependent SEIR model to analyse the evolution of the SARS-covid-2 epidemic outbreak in Portugal. *Bulletin of the World Health Organization*, 1–13.

Uthayakumar, R., & Priyan, S. (2013). Pharmaceutical supply chain and inventory management strategies: Optimization for a pharmaceutical company and a hospital. *Operations Research for Health Care*, *2*(3), 52–64. https://doi.org/10.1016/j.orhc.2013.08.001

WHO. (2012). *Global Strategy for Dengue Prevention and Control 2012–2020*. *World Health Organization*. Geneva. https://doi.org//entity/denguecontrol/9789241504034/en/index.html

Widyadana, I. G. A., Tanudireja, A. D., & Teng, H. (2017). Optimal Inventory Policy for Stochastic Demand Using Monte Carlo Simulation and Evolutionary Algorithm. *International Journal of Industrial Research and Applied Engineering (JIRAE)*, *2*(1), 8–11. https://doi.org/10.9744/JIRAE.2.1.8-11

Wisner, J. D., Tan, K.-C., & Leong, G. K. (2019). *Principles of Supply Chain Management* (Fifth). Boston, MA: Cengage Learning.

Irwan Syahrir is doctoral student in Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember, Indonesia. He is a lecture at Department of Industrial Engineering, Universitas Muhammadiyah Surabaya, Indonesia. His research areas are industrial management , supply chain management and logistic management.

Suparno is a Professor in Department of Industrial Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. His research is around in the areas of operations research and logistics management.

Iwan Vanany is a Professor in the Department of Industrial Engineering at Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia. His research interests are in food supply chain management, business process management, operations management particularly in halal operations. He has published in International Journal of Information System and Supply Chain Management, Meiji Business Journal, Supply Chain Forum: An International Journal, International Journal Logistics Systems and Management, Journal of Islamic Marketing, and International Journal of Lean Six Sigma. He teaches business process reengineering, supply chain management, enterprise resources planning (ERP), system logistics, productions, and planning control, warehouse management, and purchasing management