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Modelling of air traffic demand forecasting using a dynamic systems for assesment of readiness on the development of Indonesian airports

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Abstract

The growth of air passengers has increased in line with the population and economic growth of the country. Currently the Indonesian government has obstacles in the provision of funding the development of airport infrastructure. Certainty of return on airport investment is a big question, to answer these doubts, one attempt is to estimate the potential demand of air passengers. Forecasting of air passenger demand is important inputs for a wide variety of any decisions not limited to research and development, airplane design and production planning but including for airport infrastructure development. This paper addresses analysing and forecasting air passenger demand, provide a better understanding in developing model and validating the model using system dynamics approach. The advantage of demand forecasting model using dynamic systems approach is the variables to measure the potential demand is determined through a process of thinking system that considers the causality relationship inter variables with dynamic, systematic, logical and realistic. The robust model of demand forecasting could support to analyze a decision making for investment and as integral part of airport's strategy that reflects the capacity utilization which will be considered on airport infrastructure development.

Keywords: Air passenger demand, Airport infrastructure, System Dynamics.

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1. Introduction

The growth of air passengers is increasing in line with population and economic growth in a nation. The growth of air transportation in Indonesia by the number of air passengers reached 72.4 million in 2012, including the best 10 of the world and the highest in Asia Pacific region [1]. The increasing of air passenger growth rate would require an increase in airport capacity. Currently the development of airports in Indonesia is still a burden, therefore, the goverment should create some the policy instrument to support the development of the airport infrastructure. The government needs information on the price sensitivity of passengers in order to be able to estimate the likely policy effects or to justify noise annoyance policy [2]. It is a consideration to predict the potential demand of air passenger on the airport that will be developed. Forecasts of air travel demand are important inputs for a wide variety of economic decisions, including, but not limited to, research and development, airplane design and production planning [3].

The growth of revenue passenger kilometers (RPK) around the world during the past 10 years (2000-2010) grew an average of 4.7% per year, and in Southeast Asian region, RPK’s growth in the same period was 6.6% per year [4]. It showed that the rate of traffic growth in Southeast Asia exceeds the growth rate of the world. The potential of this market became the foundation for the airline to compete globally by working to improve services continuously. Changes in technology and industry practices have resulted in substantially enhanced price transparency and more time efficient flight option. Changes in the airline industry have numerous important implications for consumer travel decision making [5].

Transportation services demand has nature "derived demand" arising as impact of the demand for commodities or other services. It means the transportation service demand occurs if there is a reason to create a trip. There are several factors affecting air travel demand, each factor is composed of elements which can stimulate or constrain air travel growth [6].

Factors affecting demand for the air travel demand are GDP, population, price expectations and passenger characteristics. While motivation becomes a driving force in deciding to make the trip. Motivators are factors which make the consumer willing to travel and these will be related to personality traits and attitudes, and may be influenced by the promotional activities of the providers [7].

The growth of air transportation passenger in very rapid course must be balanced with the provision of air transportation infrastructure, while the government budget in transportation infrastructure sector has a constraint. Budgeting for the airport infrastructure sector, the government only allocates 19.5 trillion/ 5 years while the necessary budget for the development of 233 airports amounted to Rp.54 trillion / 5 years hence a financing gap amounting to Rp. 34, 5 trillion or 63 % of the budget requirements [8]. Development of airports in Indonesia is still a burden. For this reason, it needs the government's policy instruments if they want to involve the role of private sector in the airport development. The one of policy istruments is defining a model of air passenger demand forecasting using a dynamic systems approach to support financial analysis in the development of airport infrastructure.

The advantage of demand forecasting model using dynamic systems approach is the variables to measure the potential demand that is determined through a process of systems of thinking, namely the determination of the variable with the mental model that considers the causality relationship inter dynamic, systematic, logical and realistic variables [9]. The robust model of demand forecasting could support to analyze a decision making on an airport development that involves the participation of private investment.

2. Introduction

Theory and method are developed using the system dynamics which aim to define the model for airport infrastructure delivery. The model using system dynamics tools could capture the feedback loops and delay that occur in the actual complex systems, as we know the air travel demand has volatile and cyclical characteristics, and hence it is important for doing the forecast demand in air transportation. The method used in this paper is based on the assumption that it is useful to consider investments in airport infrastructure and provide the options to accommodate the future growth scenarios. For more detail, the theory and method background of the paper is presented as follows:

2.1. Structure

The rapid growth of air transportation in the world has attracted the researchers to consider study on air travel demand. Many studies have emerged to explain some factors that influence it. Important studies in this field include among others:

Bafail et.al. (2000) have developed a model for forecasting of the long-term demand for domestic air travel in Saudi Arabia. They utilized several explanatory variables such as total expenditures and population to generate model formulation [10]. *Abed et.al. (2001*) proposed econometric model of demand derived for Saudi Arabia international air travel. Population and expenditures were found to be the primary determinants of international air travel in Saudi Arabia [11]. *Brons et al. (2002) c*ollected 204 estimations of price elasticities of demand for air travel and conducted a meta-analysis on these previous estimations. The finding of study was the long-run price elasticities were higher in absolute value; passengers became more price sensitive over time while the business passengers were less sensitive to price [12]. *Castelli, Pesenti, Ukovich (2003) i*nvestigated the price elasticity of a specific airline (Air Dolimiti – the largest Italian regional carrier). Nine routes were examined, price elasticity was found to vary significantly across the various routes – from -0.75 to -1.62 [13]. *Rubin and Joy (2005) p*ostulated that demand for air travel has become more elastic with the advent of online purchasing making prices more transparent – heightened competition and increased awareness. Due to the high price elasticity for leisure travel, airlines pass these charges forward as surcharges to consumers [5]. *Njegovan (2006)* analized the leisure travel demand elasticities in the United Kingdom. It is Estimated that domestic leisure market has income elasticity of 0.6. Elasticity with respect to air fare changes is inelastic. The cross-price elasticities in the air travel equation were relatively large compared to the value of the own-price elasticity [14]. *Grosche, Rothlauf, and Heinzl (2007)* According to their research, there are some variables that can affect the air travel demand, including population, GDP and buying power index. The authors considered GDP as a representative variable for the level of economic activity [15]. *Goolsbee and Syverson (2008)* in their paper shows that the threat of Southwest entering a market was sufficient to encouraging incumbents to lower their prices – this was also said to cause an increase in demand prior to Southwest beginning service. The fare and quantity changes from this period implies a demand elasticity between -0.64 and -1.12 [16]. *Oum et al. (2009)* develop a set of forecasts for both intra and inter regional travel. Their model is based on measured impacts of GDP, liberalization and exogenous events (e.g. wars) on air travel growth in the past [17].

2.2. System Dynamic Proposed Model

System dynamics approach is an approach to understanding the behavior of complex system over time. System dynamics was developed by Jay Forrester (1961) in Massachusetts Institute of Technology (MIT) with the aim of improving the decision making process. It is one of the suitable approaches of the complex system of behavior. According Niles and Nelson (2001), the mobility and dynamism of transportation system is noticeable but the decision makers still utilise static models to produce the demand forecasting for transportation projects [18]. In general the affected factors are grouped into two factors, those are external and internal factors. The interaction factors of each subsystems are shown as followed:

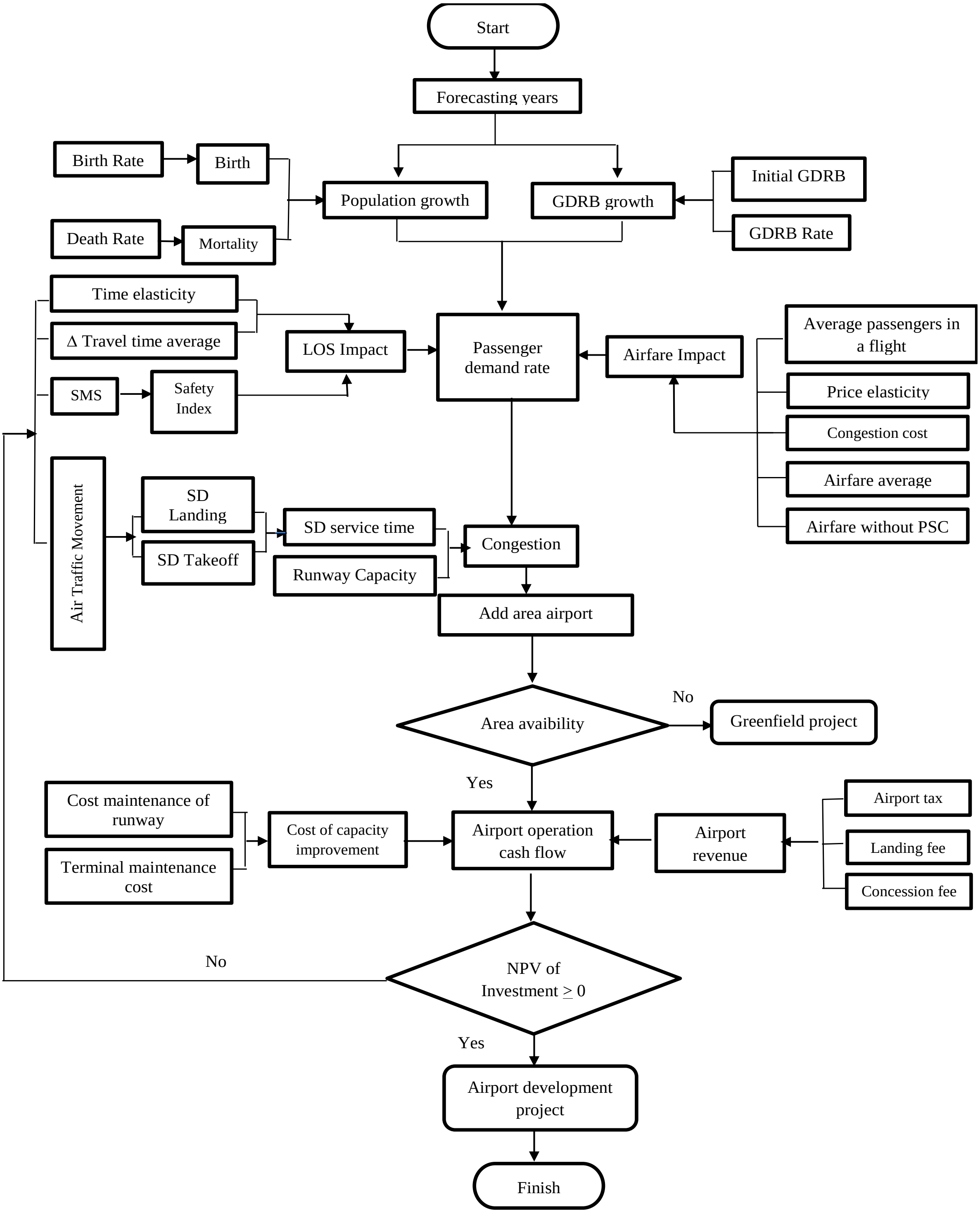

Fig.1. Flow chart the development of model

Fig. 1 shows that the system dynamic model is based on external and internal factor that have affect the air passenger demand. The external factors consider the macro economic such as demographic factor (population) and gross domestic regional product (GDRB).

The internal factors that affect the passenger demand rate are the level of services (travel time and safety index) and airfare impact. Passenger demand rate is sensitive to changes airfare but the degree of sensitivity is vary depend on the different situations (price elasticity). The airfares increase due to the impact of the higher of airline operating cost. Congestion decreases will reduce airfare increases, congestion occurs as the runway capacity is held constant when aircraft movement increases. Furthermore if the airport want to expand must be review of the airport operation cash flow. Airport operation cash flow represent of airport revenue and cost of capacity improvement, by discounting the difference between them, can be decided it is possible or not if the airport will be developed by investor. If the NPV investment is not possible, will be reviewed the internal factor which is the determinant to support the increasing of passenger demand rate, so that will be boosting the airport revenue.

There are several subsystems of demand forecasting model in building the airport infrastructure development, they are the subsystem of economic and demographic, subsystem level of service, subsystem of airfares, subsystem of air traffic demand, sub system of air traffic congestion, subsystem of airport infrastructure investment and subsystem evaluation benefits and cost.

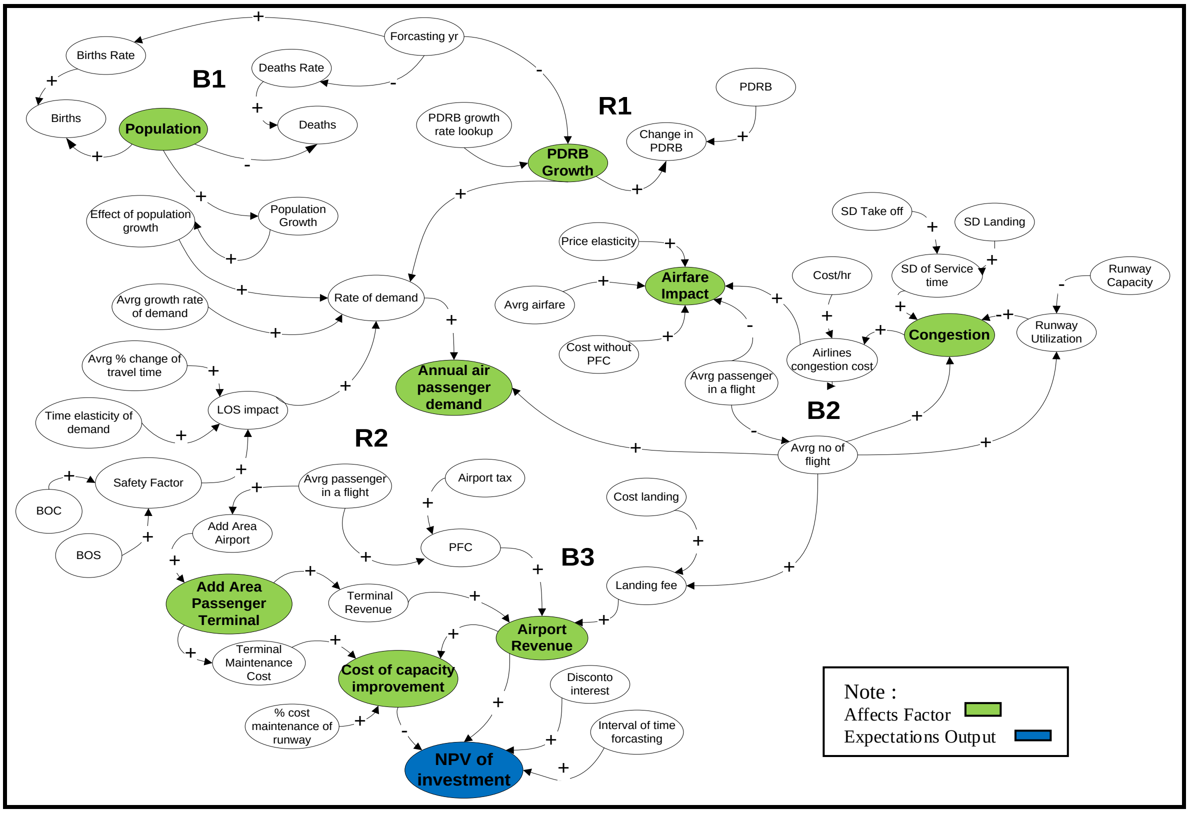

Fig. 2. Causal-effect diagram of the air traffic demand forecasting model

The development of Indonesian airport within the framework of Public Private Partnerships has increased the number of players in the decision-making process for infrastructure investment decisions. The Uncertainty in the future needs the approaches before making decision to invest, one of them is by doing the demand forecast, it means to pay attention to risks when the project is going on and assist to design the better policies for airport infrastructure delivery.

The next step is building simulation model through "stock flow diagrams" so that the behavior of all the variables that form the subsystem can be measured and observed with inter interactions variables and intra subsystems in the model. The model can represent the system in real conditions so that the results of simulation models can then be used as consideration in policy decision-making steps.

Figure 2 is representing the proposed model with the causal loop diagrams. Cause-effect or causal loop diagrams are a visual representation of the interactions and feedback loops between different variables affecting air passenger demand rate. Causal loop diagrams identify variables that will be used on the stock flow diagrams and illustrate how each variable can affect the outcome directly or through other intermediate variables. The feedback loop on the CLDs can be positive or negative. The meaning of symbol R is variables in positive or reinforcing loops that can be increased or decreased and symbol B means the variables in negative or balancing loops, stabilise over time.

There are 5 loopings that are shown on the causal loop diagram in figure 2 where the loopings describe interaction of inter factors including population, GDP growth, annual air passenger demand, the impact of level of service, congestion, runway maintenance costs, and airport revenue. The loopings in the causal loop diagram are described as follows:

Looping B1 (Balancing) describes the condition of the population factor that is affected by birth and death rates. The equation for population factor [19] as followed:

$$\mathrm{PG_t} = \mathrm{P_t}\left[\left(\sum_{i=1}^{N} B_t\right) - \left(\sum_{i=1}^{N} M_t\right)\right] \quad (1)$$

The subsystem population on equation 1, PG is defined as a population growth, P as population, B is birth rate, M is mortality rate, N is forecasting year, i is initial year and t is time periode of forecasting.

Looping B2 (Balancing) describes the condition of air traffic congestion and airfare impacts that affect each other in the number of flights and air passenger demand.The congestion is defined as waiting time for every aircraft that use the runway. The equation of congestion [20] airfare impact and level of service [21] are described as follows:

$$Wq = \frac{\lambda.\left[\left[\frac{1}{\mu}\right]^2 + \sigma t^2\right]}{2.\langle 1-\rho\rangle} \quad (2)$$

$$\rho = \frac{\lambda}{\mu} \quad (3)$$

$$AI = \varepsilon_p \times \Delta T_c \quad (4)$$

$$LOS = \varepsilon_t \times \Delta T_t \quad (5)$$

On the model congestion is defined as Wq. Wq is waiting time for each aircraft that wants to landing or takeoff on the runway, where λ is the average number of flights, $\sigma t^2$is the standart deviation of service time, μ is runway capacity and ρ is the utilization ratio. Later on the next equation AI is defined as airfare impact, where ε_p is the price elasticity, ΔT_c is the percentage increase in travel cost as impact of the congestion cost. LOS is defined as level of service where ε_t is time elasticity and is ΔT_t change of travel time.

Looping B3 (Balancing) describes factors thatair passenger service charge, landing fee, runway maintenance cost, terminal maintenance cost that will affect the NPV of the airport infrastructure investment. The equation for looping B3 is described as followed:

$$NPV = \frac{AR_t - CCI_t}{\left[1+\left(\frac{r}{100}\right)^{ITF}\right]\times 100} \quad (6)$$

Equitation 5 NPV [22] is defined as net present value of airport investment, where AR is defined as airport revenue, CCI is defined as cost of capacity improvement, *t* is time periode, r is discount interest and ITF is defined as internal of time forecasting.

Looping R1 (Reinforcing) describes the condition of the gross regional domestic product (GDRB) factors that affect the number of air passengers per year. Looping R2 (*Reinforcing*) describes the condition number of annual air passenger demand that is influenced by the factors of population and GDP growth.

$$G_{(t)} = G_{(t-dt)} + (\Delta G) * t \quad (\mathbf{7})$$

$$\Delta G = \frac{Ggr}{100} \times G \quad (\mathbf{8})$$

The subsystem GDRB represented of gross regional domestic product of the review region (airport area). The equation 7 and 8 [19], G is defined GDRB Δ G is change of GDRB, Ggr is GDRB growth and t is defined as a time

3. Result and Discussion

3.1. Air Demand Characteristic in Tarakan Airport (Case Study of Indonesian Airport)

Indonesia is characterized by a high number of airports spread over the country and embedded in a particular institutional framework where many organizations (public and private) intervene and manage the different airport infrastructures.

Based on the Ministerial Decree PM No 69/2013 and the Indonesian aviation act, the number of public airports amounts to 299 in Indonesia (Figure 3). There are 273 airports managed by local government bodies (technical operation units) (TOU/UPT) for the Directorate General of Civil Aviation (DGCA), 13 airports managed by the Indonesian State Owned Enterprise (SOE/BUMN) PT. Angkasa Pura I and 13 airports managed by PT. Angkasa Pura II

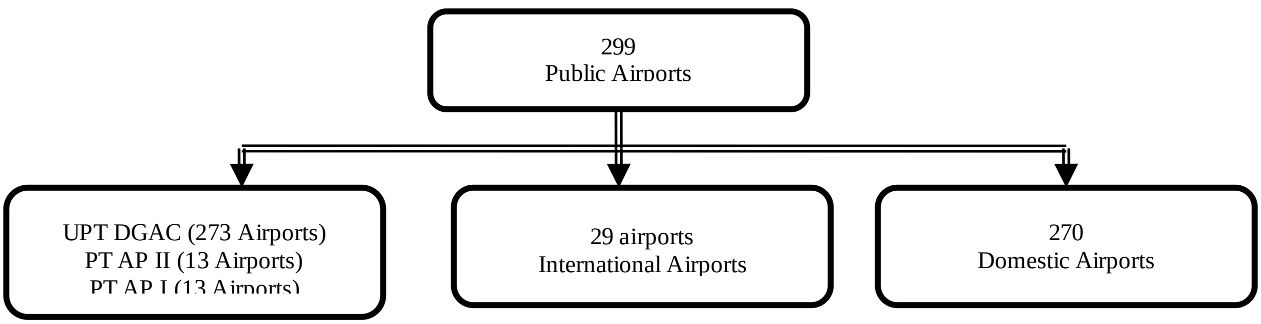

Fig.3. The different categories of airport in Indonesia

Tarakan Airport is one of the airports managed by Indonesian DGCA, with air freight traffic growth increasing every year. Population of Tarakan region reaches 212 100 people with the population density of 716 people / km2 and a population growth rate 7,17 per year. The GDP of Tarakan region from 2007 has increased three fold compared to 2000, which affects the growth of the transport sector up to 13, 46%. The development of air transportation demand in Indonesia has experienced changes quite volatile from period to period. The Passenger Demand of air transportation in 1998 decreased up to 41% compared to the number of air passengers in 1997. In 2000 there was a significant change. The number of air passenger demand began continuously increasing from year to year. The increase in the number of air transportation passenger demand in 2000 reached 18.8% and continued to increase until the year 2003, reaches above 30%. It is the impact for deregulation policy in the field of air transportation by the Indonesian Ministry of Transportation to remove the upper limit flight rates and ease licensing of airlines which in turn foster aviation firms "*low cost carrier*" (LCC) [23]. The competitive fare is very significant impact on the increase of the amount of demand for passenger air transportation.

3.2. Section headings

Forecasting is essential for business planning because it concerns with the future planning. Using the system of dynamic approach for forecasting the long term demand model can be easily for creating scenarios based on issuing different variables. Further to establish the confidence of the forecasting model relevant with its purpose could be done by validation. Validation is a process of evaluating simulation model to determine whether the model represent the real system or not. The validation of the model is conducted by comparing the historical data with the result of the simulation model. Model verification and validation conducted by comparing simulation results with various historical data, and continued with supplemental validation test [24]. According Quiggin (2004), demand risk as the possibility of unforeseen variation in the demand for service is generated by a project [25]. Bain (2009) forecast ratios is from 86 % below what was predicted to 51 % above what was predicted [26]. The study of Flyvbjerg et al. (2005) found that over 50 % average of transportation projects discrepancy between actual and forecasted infrastructure demand [27].

The error rates are smaller than 5 % .and all the error variances are less than 30 %. It means that the model is valid. The result of comparison between historical data traffic of flight and annual passenger is described as follows:

Table 1. The average of the simulation and actual data, standard deviation and error rate of air traffic flight and annual air passenger

Variable	Simulation	Actual data	Standart deviation of simulation	Standart deviation of actual data	Error rate (%)
Air traffic flight	16.482	16.778	12.674,49	9.781,33	1,80
Ann air passenger	947.094	973.134	735.120,62	655.715.58	2,75

The validation of air traffic flight describes whether the theories and assumptions underlying the conceptual model are correct and reasonable. Based on the above results (table 1) the error rates air traffic flight and annual air passenger are smaller than 5 % means the model is valid.

Demand for air passenger is very volatile, to capture the behavior we must do modeling by the advanced methods to achieve realistic demand forecasting. However, inaccuracy in demand forecasting model could be occurred, according (Quinet,1998) the sources of inaccuracy categorized as follows: inadequacy of the model structure, inaccuracy of the current data and uncertainty in prediction of the future value of exogenous variables [28].

Using system dynamics approach, we can represent the actual air transport system on the model. The advantage of demand forecasting using system dynamics, the variables to measure determined through a process of thinking system that considers the causality relationship inter variable with dynamic, systematic, logical and realistic. Based on the thinking system process then the model could capture the volatile behavior on air transport system. Figure 5 and 6 show the validation and forecasting purpose for 30 years addressed for air traffic flight and annual air passenger.

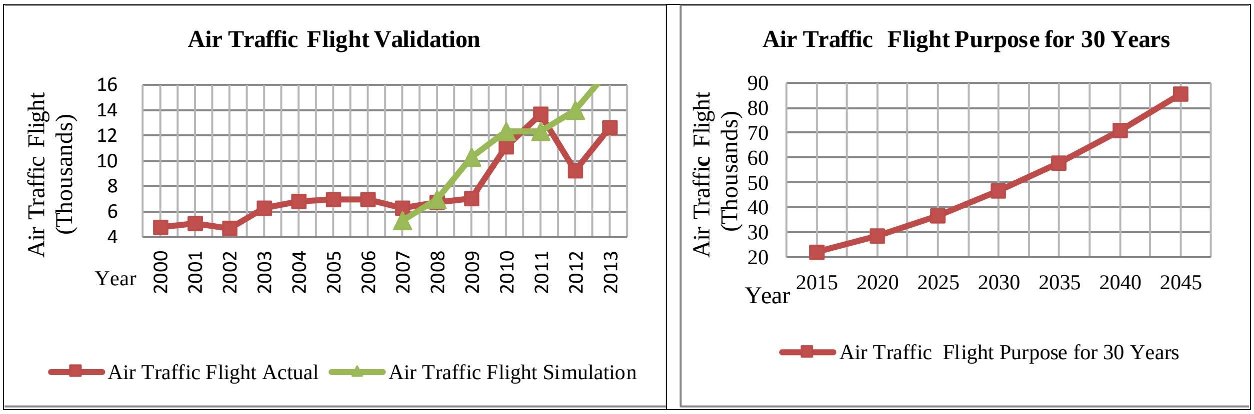

Fig.4. Air Traffic Flight Validation and Purpose for 30 Years

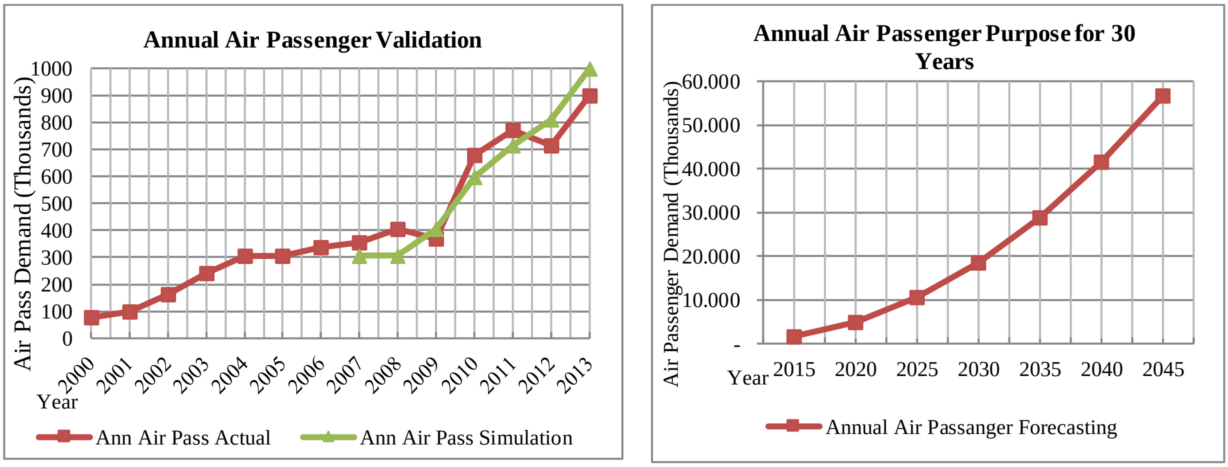

Fig.5. Annual Air Passenger Validation and Purpose for 30 Years

Further, graphs in figure 5 shows the data on the period 2000 to 2006 that is used to identify the variables that expected to affect the air passenger demand forecasting model, the data on period 2007 to 2013 are used to validate the model and later on period 2015-2045 is performed forecasting for 30 years. From the simulation results show that, when the demand of air passenger increases, the total number of air traffic flight also increases.

If the capacity of runway constant, certainly appear the problems on services to users (airline) because there are queuing on the runway. The impact of queuing is congestion and congestion also give impact to the airfare as impact of increase of the airline cost. The congestion also decreases the level of service by lengthening travel time for air passenger. The level of service (travel time and safety index) will give impact to the passenger demand rate. To increase airport revenues in order to achieve the NPV > 0 it is necessary to increase the level of service, later on the equation model for the level of service is as follows:

$$\boldsymbol{LOS} = \left[\frac{(\boldsymbol{\varepsilon_t} \times \Delta \boldsymbol{T_t}) + \boldsymbol{S_i}}{\mathbf{2}}\right] \quad (9)$$

Where S_i :

$$\frac{1}{\left\{1+\left[e^{-\left(0.99\times(QC+QS)\right)}\right]\right\}} \quad \textbf{(10)}$$

On the model level of service, LOS is defined as level of service where ε_t is time elasticity and is ΔT_t change of travel time, S_i is safety index, $_{QC}$ is break of coordination and $_{QS}$ is break of separation. Safety index is....

By improving the safety management system (SMS) and the performance of runway (decrease the aircraft queuing on the runway), will be impact to reduce travel time and decrease the airfare impact, so that will increase the passenger demand rate. Furthermore, it is to create a design of scenario model that aims to determine the performance. The scenario of the model uses some parameters for example the growth rate of GDP, growth rate of air transportation, and some other parameters. The function of scenario is to check the existing capacity of terminal or runway whether the capacity is available for the future demand. The optimistic and pesimistic scenarios use the GDRB growth, the population growth, the air passenger growth and the air traffic growth.

Figure 8 shows the investment of the airport infrstructure based on the optimistic and pesimistic scenarios. The scenarios are made by incorporating some elements that are considered will affect the value of airport revenue and the cost of capacity improvement. These elements are the growth of air transport passengers, the growth of GDP, Inflation rate and average% change in travel time. The results of the simulation show different values between the optimistic scenario and pessimistic scenario. The difference in value occurred in the third year of running the simulation results.

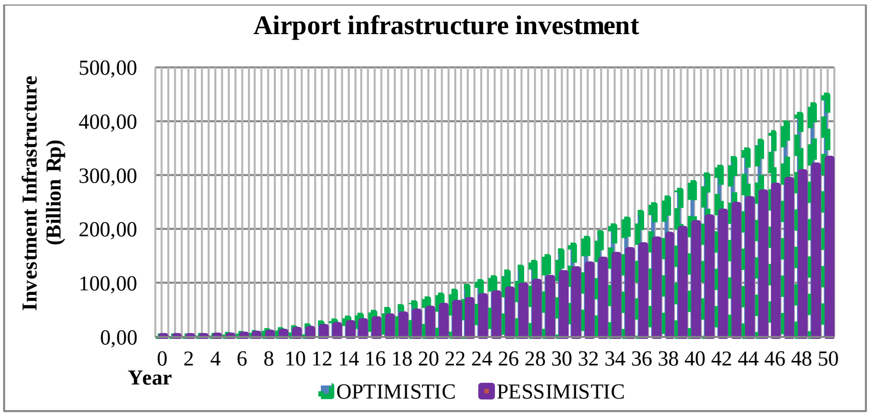

Fig. 8. Airport infrastructure investment in optimistic and pesimistic scenario

The subsystem of airport infrastructure investment illustrates the airport infrastructure development that will be done. The development of airport infrastructure will be done based on enhancement of air passenger demand. The subsystem of airport infrastructure investment also to determine whether the private sector can play a role in the development of airport infrastructure investment. Some of influential variables are airport revenue, airport expenditure and discount interest rate where the variables of airport revenue and airport expenditure are the result of the interaction of all subsystems built based on model of air passenger demand forecasting. Financial instruments taking into account that the NPV> 0 in order could involve the private role in the development of airport infrastructure investment. The model simulation of Tarakan airport investment shows that behavior over time for the variables have a tendency to increase airport revenue, so that the behaviors have a positive impact on supporting the behavior of the subsystem of airport infrastructure investment. Thus, Tarakan airport is possible to involve the private sector in the development of airport infrastructure.

Section headings should be left justified, bold, with the first letter capitalized and numbered consecutively, starting with the Introduction. Sub-section headings should be in capital and lower-case italic letters, numbered 1.1, 1.2, etc, and left justified, with second and subsequent lines indented. All headings should have a minimum of three text lines after them before a page or column break. Ensure the text area is not blank except for the last page.

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