SUSTAINABLE GROWTH OF THE COMMERCIAL AVIATION INDUSTRY IN MALAYSIA USING A SYSTEM DYNAMICS APPROACH

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Abstract

The environmental impact of the commercial aviation industry for an emerging economy like Malaysia is under-studied. The focus on the subject has thus far concentrated either on non-geographical performance of the aviation industry or technical performance of aircrafts and that leaves the sustainability of the commercial aviation industry for an economy, or more specifically, an emerging economy least understood. Hence, this paper aims to investigate the sustainability of the growth of the commercial aviation industry in Malaysia and its impact upon the environment using a system dynamics approach. VENSIM is employed to model the commercial aviation industry in Malaysia as a dynamic system to evaluate the CO_2 emitted from each component within the industry in order to forecast its overall CO_2 emission. Results from the analysis show that sustainable growth can be affected by adopting short and long term strategies identified in this study.

Keywords: System dynamics, Commercial aviation, Malaysia, Aircraft design.

1. Introduction

The growth of Malaysia's commercial aviation industry is significant and has undergone rapid development since its early stage, which has seen sustained growth in its domestic and international services. Rapid progress of the industry has resulted in the need to study the impact of the industry upon existing support infrastructures and the impact of support infrastructures upon the environment. All these support infrastructures are interconnected and affecting each other, thus their impacts cannot be considered in silo when viewing the aviation industry.

Abbreviations	
CLD	Causal Loop Diagram
EU	European Union
FFP	Frequent Flyer Program
IATA	International Air Transport Association
IPCC	Inter-governmental Panel on Climate Change
KLIA2	Kuala Lumpur International Airport 2
RVSM	Reduced Vertical Separation Minimum
SFD	Stock and Flow Diagram

Most of the previous researches focused on total CO_2 emission from aircrafts and their impacts upon the environment where it was commonly found that the overall CO_2 emission from the aviation industry has a huge impact upon the environment. IPCC Special Report stated that CO_2 emission from the industry contributes approximately 3.5% of global warming [1, 2]. Besides, the impact of an aircraft's CO_2 emission when airborne at high altitude upon the environment is estimated to be 2 – 4 times greater than grounded due to a series of chemical reactions whilst in operation [3].

Although previous research has explored the emission of carbon dioxide (CO_2) from aircrafts and fuel consumption rate [4], and the impact of emission upon the environment is well understood [5]; the knowledge gap on determining CO_2 emission's dominating factor within the commercial aviation industry is limited. Besides, there is also limited number of researches regarding new aircraft design, performance, and alternative fuels which plays an important role in the future of the aviation industry.

The aim of this paper is, hence, to study the impact of the growth of the commercial aviation industry in Malaysia by predicting its total CO_2 emission over a period of 20 years. Total flight CO_2 emissions from Malaysia's international and domestic airports are estimated using a simulated model of the country's commercial aviation industry on VENSIM (Ventana Systems Inc.), a system dynamics software with known capability to simulate real world problems using the concept of causal-loop and stock and flow. This has enabled the simulation of the entire aviation industry in Malaysia as a dynamic system consisting of all contributing components in a single model. Potential and foreseeable scenarios, e.g., carbon taxing is also included in the scope of modelling. Discussions will focus on CO_2 emission from each contributing factor and the impact of penalty imposed for total CO_2 emission when exceeding the limit, if and when, Malaysia implements carbon taxing.

2. Malaysia's Aviation Industry

In general, aviation is any activity related to aircraft. Commercial aviation in Malaysia is a vital and blooming industry despite being monopolised by two companies – Malaysia Airlines and AirAsia. Malaysia Airlines has a total of 112 aircrafts in its fleet whilst AirAsia has a total of 72 aircrafts in theirs [6]. Aircrafts generate emission during operation and the amount of emission is significant.

Malaysia's commercial aviation industry is inter-related with existing support infrastructures and it is estimated to grow along with an increase in air transport

demand especially as a result of the country's growing tourism industry. The International Air Transport Association (IATA) has announced that the global aviation industry is growing at a healthy rate where the overall demand has grown 5.6% from 2012 for the total market [7].

In Southeast Asia, the demand for international air travel has also shown a healthy growth rate of 20% in only 18 months, where Malaysia has a 25% seat capacity growth for the period April 2012 to October 2013 [8]. Seat per week of air travel in Malaysia has also increased by approximately 205,000 seats compared to the previous year [8].

It was indicated that Malaysia's commercial aviation industry has expanded from the previous years and similarly, it was also predicted that it will continue to expand for the coming years [8]. This prediction is further confirmed with the IATA Airline Industry Forecast for 2012–2016 which sees passenger number expanding at an average of 5.3% per annum from 2012 to 2016 or, in other words, a 28.5% increase of total passengers over four years [9].

The commercial aviation industry in general, and specifically in Malaysia, is growing fast and thus emission from the industry also will increase. From past researches, it can be seen that the total amount of CO_2 generated from the global aircraft fleet is in excess of 600 million tonnes/year [10]. Emission from Malaysia's commercial aviation industry can be predicted using the formula of total distance of flight travelled multiplied by carbon emission rate per km. Total distance travelled per annum can be obtained from the five international airports in Malaysia and CO_2 emission rate is taken as 114g/km CO_2 as this emission rate is for long distance flights. CO_2 emission rate is taken as 178g/km CO_2 for domestic long distance flights and 259g/km CO_2 for domestic short distance flights respectively [11].

3. Sustainability

The downside of an increasing demand for commercial air travel is an increase in CO_2 emission as a direct result of an increase in the number of flights. In this paper, CO_2 emission will be the focus of discussion. In the previous study, up to 3.5% of global warming is caused by air transportation and is predicted to increase in the next few years [11]. Pollution in a major airport by its air and ground transportation is almost equivalent to the pollution level in a metropolitan area [12]. Besides, emission from aircrafts will have bigger impact compared to the emission from ground due to chemical and physical processes when the emission is at an altitude from ground [13].

Pollution from the commercial aviation industry can be reduced by increasing aircraft fuel efficiency or reducing air travel demand. The implementation of Reduced Vertical Separation Minimum (RVSM) could potentially reduce emission of aircrafts by operating at their optimum level and thus reducing fuel usage [14] or in other term, an increase in fuel efficiency. Reducing or abolishing Frequent Flyer Program (FFP) will also have the same effect by reducing air travel demand at a rate of 20-35% per annum [15]. Using alternative fuels e.g. biofuel can also reduce emission at a rate of 2% per annum [16]. As the Kyoto Protocol fails to limit international aviation emission, the EU Emission Trading Scheme can be implemented. It was found that the schemed is more effective in

emission reduction and is forecasted to reduce CO_2 emission by 176 million tonnes per annum globally [17].

4. System Dynamics

System dynamics is a tool to understand the flow of a complex system. It can also be used to predict possible dynamic behaviour of that complex system. System dynamics is used in this study is to understand the commercial aviation industry system in Malaysia and to predict its future emission as a result of its continued growth.

System dynamics was invented by Professor Jay W. Forrester in mid 1950s [18]. Initially it was used in industrial processes but now it is widely used in every sector for solving vast and complex problems. System dynamics provides user with a clear system model after an issue is defined properly. In the model, any subsystems related to the subject at hand can be seen and thus further decision can be made from the investigated system.

4.1. Modelling philosophy

System dynamics modelling is a multi-disciplinary modelling platform suitable for most complex problems where robustness is a key criterion. This is usually considered as the first philosophy of modelling. In system dynamics modelling each problem is represented using causal loop diagrams (CLD) leading into stock and flow diagrams (SFD) for more in-depth analysis. These diagrams are suggested and used by Jay W. Forrester during his involvement with General Electric in 1950s [19].

The second philosophy of modelling is 'ontological problem of realism [20]' or in other term, the lack of realism. System dynamics model is generated to simulate current issue by relating all other related issues affected. In this study, modelling of Malaysia's commercial aviation industry's emission is generated by relating all current and existing issues.

The third philosophy of modelling is epistemological, that is the validation of knowledge claimed [20]. A system dynamics model is created using VENSIM where mathematical equations are applied whilst input parameters are taken from real data obtained. Results from the model are compared with current data again for validation. The model is validated whenever the result shows comparable trend within acceptable error levels.

4.2. Modelling methodology

In system dynamics modelling, there are four principal steps to build a model. These four steps are; identifying issue and objective, generating causal loop diagrams, generating stock and flow diagrams and lastly, validation of results.

Identification of the objective and issue studied is the most important part of modelling as this will lead to the creation of the desired model. The main objective for this study is to predict total aviation industry emission in Malaysia, thus any sector related to aviation emission is identified and then presented in causal loop diagrams.

The main purpose of a causal loop diagram is to relate any side (or sub-) systems that will give rise to positive or negative impact to the issue at hand, in this case, CO_2 emission from commercial aviation industry in Malaysia. Once developed, the causal loop diagram shown in Fig. 1 is then further developed into stock and flow diagram for detailed analysis.
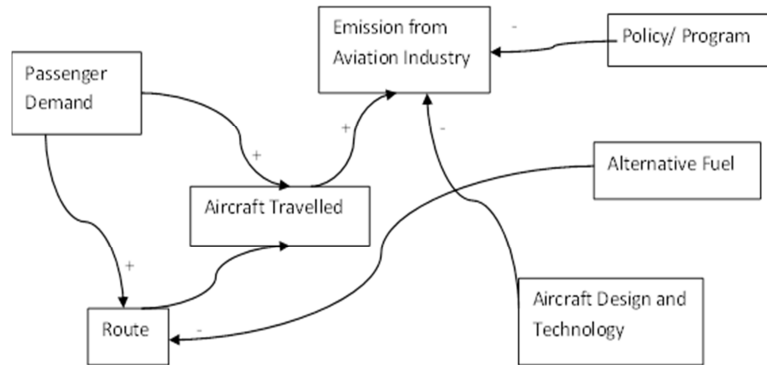

Fig. 1. Causal loop diagram of emission from a commercial aviation industry.

Stock and flow can then be modelled by defining the relationship for all variables in the model. First of all, the backbone of the model is generated such that the objective of the model can be clarified. Figure 2 shows the backbone of the entire model. From the backbone, other variables will be added to further complete the functional model.
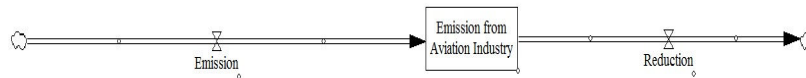

Fig. 2. Backbone of the emission model.

Prior to that, equations applicable to the model will be applied in the 'Emission from Aviation Industry', which means emission minus reduction. After setting up the backbone, reduction variables, emission variables and CO_2 penalty are also added to further complete the model.

The last step in modelling is to validate the model by comparing the results obtained with the actual data. The results generated from the model are compared and classified as valid whenever the results obtained follows the trend of previous data regardless of slight difference in value. All data used for modelling and validation were obtained from various governmental and private entities predominantly available on public domains.

In this study, four scenarios will be created using the model to predict the future impact of Malaysia's commercial aviation industry. It should be noted that this study works on the premise and assumption that there is a time-halt at the time of modelling and has not taken into account the effects of recent events involving Malaysia Airline's MH 370 and MH 17 upon the country's commercial

aviation industry. The inclusion of these events into the model will require a drastic expansion of scope.

Scenario One investigates the impact of additional airport(s) upon the environment. New airport(s) with estimated data will be added into the model to estimate the increase in CO_2 emission. This model is essential as Malaysia has had a new airport in 2014 due to insufficient capacity of current airports.

Scenario Two will investigate the effect of using alternative method to reduce CO_2 emission. There is a plethora of reduction solutions and yet using alternative fuel is considered the most practical method. Changing an aircraft's fuel from kerosene to biofuel is one of the solutions suggested by Airbus Competition and this suggestion is also supported by the IATA that biofuels could potentially reduce CO_2 emission approximately 2% [16, 21]. In Malaysia, the Airbus fleet is dominating compared to other makes and hence implementing biofuels in each Airbus aircraft could potentially affect CO_2 emission and operating costs for commercial aircrafts in Malaysia. [6].

Scenario Three will investigate the impact of Malaysia's airlines expansion upon CO_2 emission. AirAsia planned to expand its business by increasing international route as mentioned in its new business strategy [22]. Thus, all additional flight distances are used as input in the model.

Scenario Four investigates the combination of the previous three scenarios. This combination is considered valid as it represents a very likely future scenario. This scenario allows for future total CO_2 emission and potential carbon tax imposed after reduction methods are predicted. This scenario will also determine the feasibility of reduction method proposed in Scenario Two.

Figure 3 shows the causal loop diagram of Scenario One where the new Kuala Lumpur International Airport 2 (KLIA2) is added. This new variable is added in the grey "All International Airport Movement" shadow variable resulting in overall CO_2 emission using the previous model with the new shadow variable.
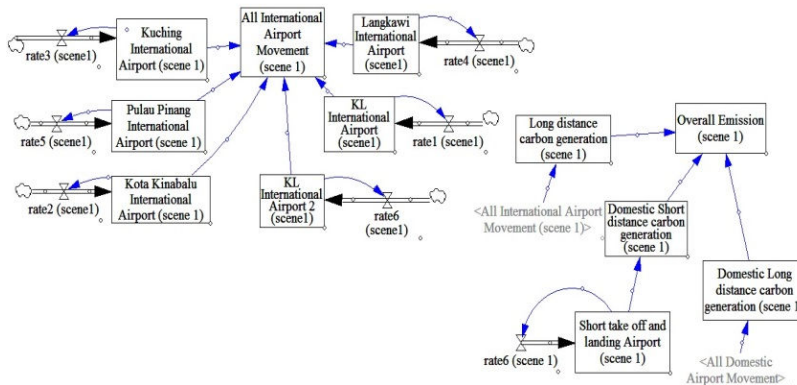

Fig. 3. Scenario One.

Figure 4 shows Scenario Two where biofuel is the suggested method for the reduction of CO_2 emission. Since biofuel is predicted as the future aircraft fuel,

the variable is linked to both international and domestic airport variables so that potential future emission reduction can be predicted.
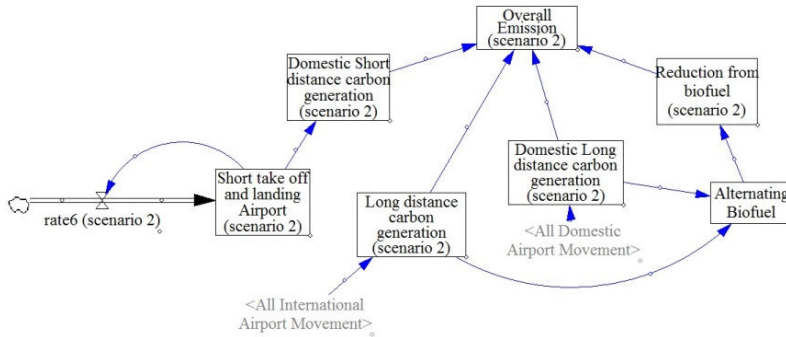

Fig. 4. Scenario Two.

Figure 5 shows Scenario Three where the expansion of airlines is depicted as increasing flight routes. Increasing flight routes will eventually increase the distance travelled and hence CO_2 emission will also increase. New flight routes' overall distances are summed and combined with the previous distance travelled forming a cumulative sum. In this scenario, new flight routes' distances are combined with the international airport movement as all the proposed flight routes are international routes. CO_2 emissions for international and domestic routes are different so it was suggested that new flight routes are classified separately for better prediction.
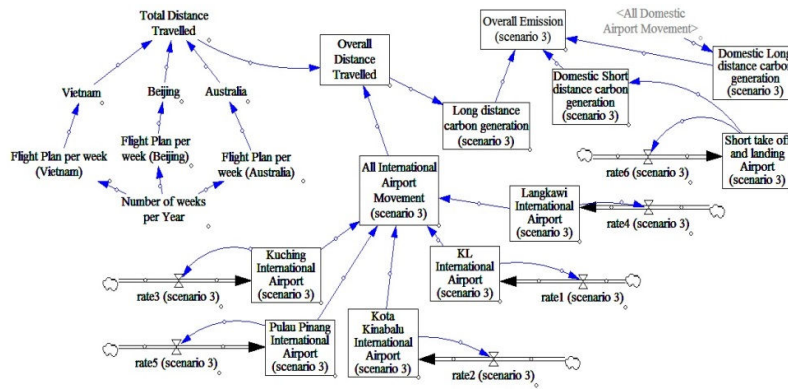

Fig. 5. Scenario Three.

Scenario Four investigates a likely future scenario in Malaysia's commercial aviation industry by combining all the previous scenarios. Basing upon these three factors where Malaysia has a new international airport opened in 2014, biofuels being a viable alternative fuel option and AirAsia's planned strategy to increase its international routes in their business plan, it would be plausible to predict a scenario combing all three scenarios. In this scenario, all new variables including CO_2 penalty variable and shadow variable are used. A better prediction of CO_2 emission and potential CO_2 penalty can also be obtained using this

scenario. Carbon trading cap allocated minus overall emission from the industry and multiplied by CO_2 cost will give the penalty cost to be paid or earned. Greece's carbon trading cap is referred to for Malaysia as both countries have demonstrated similar development in commercial aviation.

5. Results and Discussion

5.1. New KLIA2 airport

Figure 6 shows that CO_2 emission of Malaysia's commercial aviation industry increases compared to the current case as the number of international airport increases from five to six. The growth of the country's tourism industry and greater passenger volume has prompted Malaysia to invest in a new international airport for budget airlines e.g. AirAsia and Malindo Airways. As shown in Fig. 7, the Kuala Lumpur International Airport (KLIA) contributed the largest percentage of CO_2 emission for the period studied followed by Kuala Lumpur International Airport 2 (KLIA2). This is mainly due to their strategic location in Kuala Lumpur, which is the capital of Malaysia.
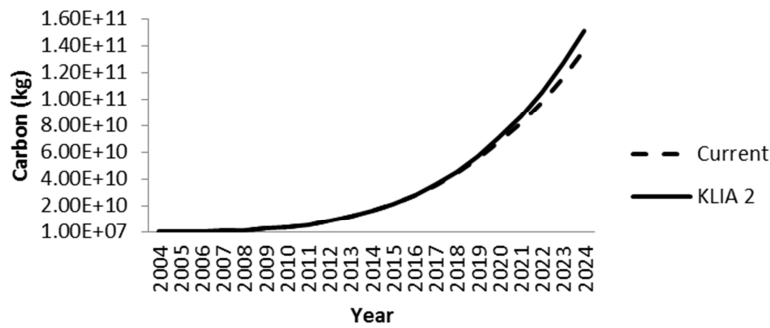

**Fig. 6. CO_2 emission of current airports
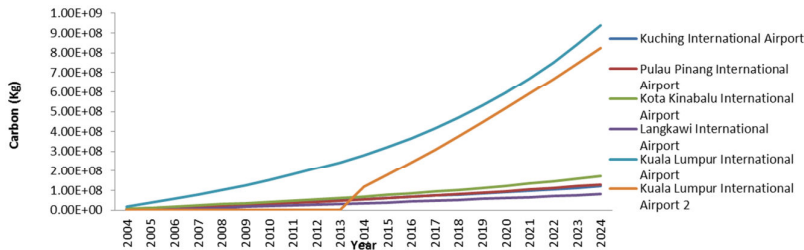increased emission incorporating KLIA2.**

Fig. 7. CO_2 emission from international airports in Malaysia.

5.2. Alternative fuel: Biofuel

Reducing flight routes is the most straightforward method to reduce emission but it may not be financially sustainable. Using alternative fuel such as biofuel and

implementing new aircraft designs are favourable as they are more practical given the appetite for increased passenger travel. New aircraft design technology is not discussed in this paper as the scope falls beyond the aim of this study. Most of the innovations conceived to date are either conceptual or in design phase whereas for alternative fuels such as biofuel, the results have been well tested and understood. Figure 8 shows the amount of reduction in CO_2 emission when using biofuel, indicating feasibility of its implementation.
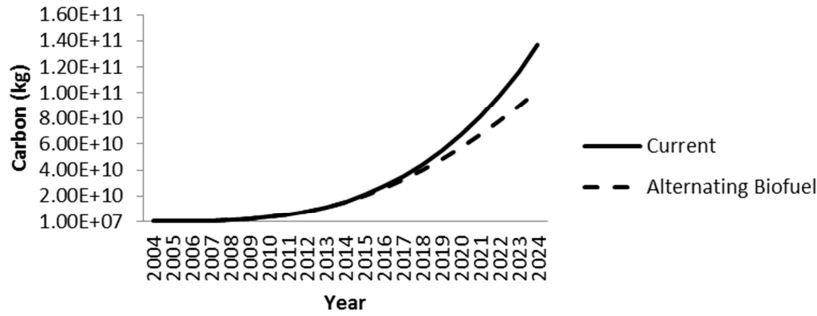

Fig. 8. CO_2 emission using fuel and alternative biofuel.

5.3. Increasing flight routes

Malaysia Airlines and AirAsia tend to increase their international flight routes especially to popular destinations such as Australia, China and Vietnam, thus leading to an increase in CO_2 emission significantly. Australia is a destination increasingly popular for travellers from Malaysia. Seeing this opportunity, flight routes to Australia have increased to 34 flights per week which also meant an increase of a total of 24 flights compared to 2012 [23]. From Fig. 9, it can be clearly seen that total CO_2 emission will be higher compared to a case where flight routes remained as they are (business as usual).
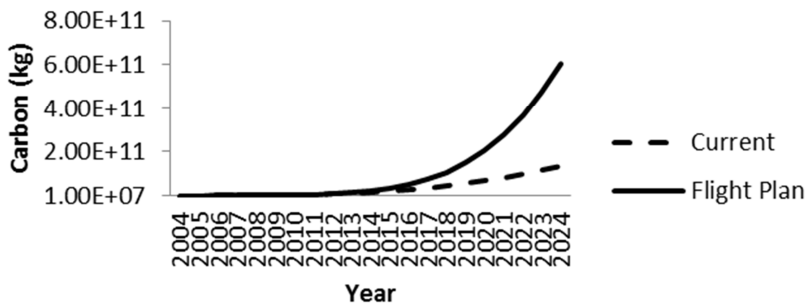

Fig. 9. CO_2 emission showing difference in increased flight routes.

5.4. Lead scenario

With the total CO_2 emission predicted shown in Fig. 10, using alternative fuel such as biofuel yields positive changes due to its effectiveness in reducing CO_2 emission. Based upon the results shown in Table 1, increasing flight routes is the main cause for the significant amount of CO_2 generated and the most effective way of negating this effect is by changing the aircrafts' fuel into biofuel.
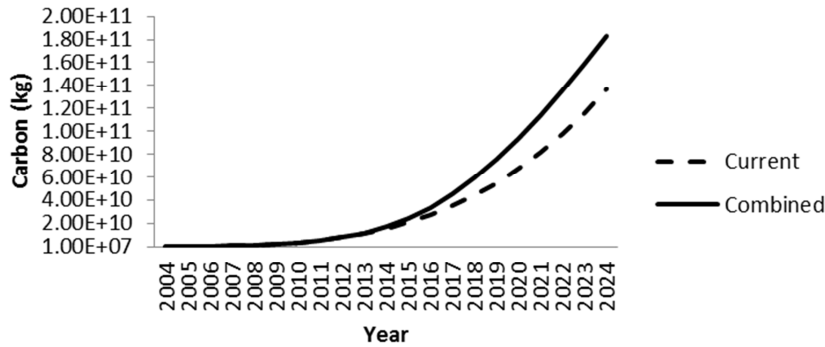

Fig. 10. CO_2 emission of a lead scenario compared to a business as usual case.

**Table 1. Percentage of CO_2 emission predicted
from each scenario at five years interval.**

Year/ Emission Increased (%)	2004	2009	2014	2019	2024
Scenario 1	0	0	0	3.83	10.22
Scenario 2	0	0	-0.64	-11.50	-26.28
Scenario 3	0	0	47.44	171.90	340.88
Scenario 4	0	0	7.05	37.96	33.58

Table 2 shows a hypothetical case indicating a possible carbon trading cost even it is not applicable in Malaysia as yet. A positive value indicates surplus CO_2 quota to be sold whereas a negative value indicates excessive CO_2 emission and therefore penalty or tax would apply. Results from Table 2 shows that a lead scenario (Scenario 4) presented a best case scenario for Malaysia, given the potential growth of its commercial aviation industry. Retarding the growth of an industry is hardly an option especially for a developing economy like Malaysia therefore having a portfolio of strategies to promote sustainable growth would be most desirable especially in the short and medium term.

**Table 2. Possible CO_2 emission trading predicted
from current and future scenario at five years interval.**

Year/ Carbon Trading (RM)	2004	2009	2014	2019	2024
Current Scene	6.74E9	6.54E9	5.22E9	1.40E9	-6.64E9
Future Scene	6.74E9	6.54E9	5.12E9	-6.39E8	-1.12E10
Percentage Difference (%)	0	0	-1.92	-54.36	-68.67

The period of this study is only set to 20 years from 2004 simply because a long period of study is not applicable. This is due to the fact that technological advancement occurs at a rapid rate that there may be key technological enablers, if and when they occur, which are very likely to change the ball game altogether.

6. Conclusions

To cope with the growth of the nation's economy, it is unavoidable that Malaysia has to grow its commercial aviation industry resulting in new airports and expansion of flight network and ultimately causing the rise of total CO_2 emission. Biofuel has shown its potentials for reducing CO_2 emission as a short and medium term solution especially with increased flight routes and airports for Malaysia. Whilst it is feasible to use alternative fuel such as biofuel in its aircrafts, at the same time the development of modern and efficient aircrafts giving lower CO_2 emission must also continue.

As a conclusion, this study has demonstrated that in order to sustain the growth of Malaysia's commercial aviation industry, biofuel could potentially play a key role as a short and medium term solution in driving down CO_2 emissions. However, this solution must be adopted whilst recognising a caveat that there must be a continued effort to develop modern and efficient aviation technology so that robust and continued CO_2 reduction from the industry can be affected instead of just concentrating on changing the type of aviation fuel used.

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