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Low Cost Airlines Operating in the Ghanaian Airspace

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Abstract

We develop a mathematical model to determine the quantum of adjustment to existing airfares when there is jet fuel adjustment incorporating the hard currency dependency of the air industry. We state that any adjustment to existing airfares should be exactly the loading and that any additional amount to the existing airfares differing from the loading leads to either overcharging or undercharging of domestic air travellers. Also, we show that any negotiation about the quantum of adjustment to existing airfares reduces to proper assignment of the number of passengers aboard an aircraft and the exchange rate of the currencies of interest. We tested our models on privately operated domestic airlines in Ghana, using data obtained from the headquarters of these airlines, Ghana Civil Aviation Authority, which is the umbrella institution that oversees airlines operations in Ghana, and the National Petroleum Authority. The result indicates that some routes are profitable while others are not for these domestic airlines. The models should be useful to any businessman/investor interested in entering the airline industry. Furthermore, it would assist transport planners, coordinators and administrators in setting and adjusting airfares. It should also help settle disputes about new airfares between domestic air travellers and air transport administrators that arise any time there is adjustment in jet fuel prices.

Keywords— Asset Replacement Cost, Destination Distance, Loading, Optimization, Viability Condition, Yield.

Introduction

Air transport has many benefits for any country and Ghana is no exception. The industry provides employment for people, generate revenue for governments and reduce the pressure on other means of transport such as road, rail and water. In addition, it transports goods and services faster than any form of transport today. Consequently, it is a time saver, which makes it the preferred mode of transport among businesspersons, middle and upper income earners in Ghana. Thus air transport has become an integral part of domestic travelling in Ghana. Notwithstanding the benefits and importance of air transport to domestic travelers, a worrying trend prevails in the industry in that regular increase in domestic airline fares that do not seem commensurate with the jet fuel price adjustments thus short-changing travellers.

If Ghanaian domestic air travellers are ever to pay realistic fares for each adjustment in jet fuel price then it is essential that a framework is put in place that determines what constitutes a fair price for domestic air travellers per each aviation fuel increase or decrease. Moreover, majority of operational costs of the airline industry in Ghana are hard currency dependent (mainly US dollars). Operational cost such as aircraft lease charge, spare parts, Ghana Civil Aviation charges, aircraft insurance, system charges, aircraft major checks, cost of crew and training are all based on the US dollars. Consequently, even though the cost of jet fuel may decline or even stay the same, the operators of these airlines may have to adjust fares to reflect the depreciation cedi to enable the payment of these expenses in US dollars. Currently, Ghana has two domestic airlines and these airlines ply four domestic routes, Accra-Kumasi, Accra-Sunyani, Accra-Tamale and Accra-Takoradi. Airline fare increases are rampant in Ghana’s transportation sector largely due to the unstable nature of the cedi (domestic currency). Any change in oil price at the global level is accompanied by airline price adjustment to reflect the prevailing prices on the world market. Airline price adjustment was uncommon in Ghana until 2014 when the Ghana government removed its subsidy of aviation fuel as result of its inability to shoulder the increasing cost of subsidy. By an act of Parliament (Act 691), the National Petroleum Authority (NPA) was mandated to regulate the downstream sector of the petroleum industry. By this, the NPA adjusts prices of petroleum products every two weeks to reflect recurrent global market prices of the commodity. Minimal increases in global oil price thus leads to aviation fuel price increases in Ghana, which in-turn leads to airline fare increases. Largely, the increases are triggered by the depreciation of the local currency, the Ghana cedi (GHS), to the United States Dollar (USD), which is the currency Ghana uses for its oil payments. Thus in 2014, exchange losses were estimated to be about US$2million for each domestic operator in Ghana (Andoh, 2015). Currently, Ghana’s

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aviation fuel is about the highest in the West African region. Specialised fuel is sold for about US56 cents per litre in Nigeria and about US90 cents per litre in Ghana (Andoh, 2015). The regular adjustment in jet fuel prices coupled with the depreciating domestic currency has imposed a corresponding pattern of increase in domestic airline fares that does not seem commensurate with the jet fuel price adjustments. In 2015 alone, domestic airline prices have increased by 17.5 percent (Andoh, 2015). Thus Ghanaian domestic airline passengers feel they are paying unrealistic transport fares and therefore being cheated.

The purpose of the research is to develop mathematical models for the management of low cost carriers that operate in the Ghanaian airspace. There are several important questions that domestic air travellers, airline operators, Ghana Airports Company Limited and the Ministry of Transport are awaiting answers to. What is the fair price that domestic air travellers have to pay anytime there is adjustment in jet fuel price considering the dollar dependency of the industry? Is there a model that can be employed by the airline industry to minimise the frequency of adjustments in airfares? What is the minimum number of trips that airline operators have to make on a specified route to ensure profitable of their operations? How does an airliner know that a particular routes operation is unprofitable? How does an investor know that the air transport business is a good place to commit a substantial amount of funds?

Thus there is the need to have a model that airline planners, coordinators and administrators can employ to automatically adjust airline fares to correspond with jet fuel price increases incorporating the dollar dependency of the industry. In addition, there is the need to have a model that can be employed to minimize the frequency of adjustment in airline pricing thus assisting airline operators plan budgets. An investor interested in the air transport business will like to know the likelihood that the estimated profit will be realized before committing substantial amount typical of the air transport business. In this study, we develop a model that guarantees fair airline price adjustment, after each fuel price adjustment, and establish a model for assessing the number of trips an airline must make on a designated route to ensure the viability of the operation on that route. Furthermore, we develop a model to assess the viability of operations of all routes that an airline plies together with the likelihood that estimated profit will be realized.

The rest of the study is organized as follow: section 2 deals with literature review. Here, we review literature available on air transportation in the public domain. In section 3, we develop the mathematical models for managing the pricing of airfares. Towards achieving this objective, we develop the pricing model for fuel price adjustments and give conditions under which airline operations will be viable. In addition, we provide criteria for assessing the viability of the air transport business and propose a model that can be employed to minimise the frequency of fuel price adjustments. The empirical results and discussion are contained in section 4 where we tested our models on domestic airlines. Section 5 summaries, concludes and give recommendations of the study.

Literature Review

Scant research exists in this area. In fact, hardly any research could be utilized by this study within the Ghanaian context on domestic airline operators in Ghana. Andoh and Quaye (2015) examined the interrelationship between fuel prices and travelling cost. However, their research focused on road transportation in Ghana. Consequently, this study had to source literature from outside Ghana. Thus Glab and Peterson (1994) argues that airlines price-discriminate between business and leisure travelers by offering unrestricted fares and tickets with restrictions such as cancellation fees and advance purchase requirements primarily for yield management. Deneckere and Peck (2012) views the airline industry as a market in which the primary goods offered (seats) have time and capacity limits with uncertain demand. According to Lazarev (2013) as early as 11 months before departure, seats can be sold for a scheduled flight and that the fare on any day is the result of the evaluations of the pricing department and the revenue management department. Jain and Cox (2011) added that the observed chaotic pricing in the airline industry is embedded in the exclusive monopolistic nature of the market with programs like frequent flier schemes that engenders brand loyalty. Bilotkach et al. (2010) investigated whether airline price-setting strategies were different by analyzing over 70,000 daily fare quotes. They found that the airlines use different pricing strategies and also fares tend to increase as the departure date approached. This position was confirmed by Pels and Rietveld (2004), when they observed that average price and average price dispersion increases with an increasing rate as the flight departure time approaches. Bilotkach et al. (2015) observed that the monotonic increase in fare prices as departure date draws near is as a result of active systematic yield management by airlines as fewer seats remain before departure but contend that there is also stochastic yield management that requires airlines to change pricing if unexpected situations arise or passenger estimates turn out to be imprecise such as may alter the pricing set under the systematic conditions and this then may engender a price drop. Mantin and Koo (2010) went further to argue that airlines tend to employ a weekend pricing discrimination but they also contended that for the airlines not to skew passenger demand to the weekend, the airlines employ a high-low strategy in their weekend pricing. Furthermore, Puller and Taylor (2012) found that tickets purchased on weekends were 5% lower than those purchased on week days. However, O'Connor (1995) indicated that the total costs of running an airline are made up almost entirely of fixed costs with the jet fuel cost, crew costs and passenger amenities costs being the major variable costs of operation. Plötner et al. (2015) observed that aircraft jet fuel burn can be reduced by cruising at lower speeds and employing varying technologies and thus reduce the jet fuel cost but this will affect the block times and airline networks and thus impact on the yield. Although this study has benefitted from the effort of the aforementioned studies to highlight challenges in the airline industry, there is a point of departure from this study in that this study goes further to develop a model that can be used to adjust airline fares to correspond with jet fuel price increases.

Model development

We write the profit function, p_{f_j}, of an airliner on route j, as

$$p_{f_j} = t_{r_j} - t_{c_j}, j = 1,2,\ldots, m$$

here t_{r_j} is the revenue generated on route j, t_{c_j}, is the cost of operations on route j and m is the number of routes operated by the airline. The total profit, P_F, emanating from all the routes operated by the airline within a given time horizon is

$$P_F = p_{f_1} + p_{f_2} + .. + p_{f_m}$$

The total cost of operations, T_c, of an airliner is given by

$$T_c = \sum_{j=1}^{m}(t_{f\,j} + V_{c_j}) + w_i AR_c (1+r)^i, i = 1,\ldots, n$$

t_{f_j} is the fixed cost of operations for route j, V_{c_j} is the variable cost of operation for route j, w_i is the fractional part of AR_c (the cost of aircraft, cost of tyres for aircraft that has to replaced every two months) that has to be paid in a given period on route j and satisfies $\sum_{i=1}^{n} w_i = 1, w_i \geq 0.$ r is the rate of interest at which AR_c was acquired and n is the life span of AR_c. Typically, the fixed cost of operations are the wages of staff, crew cost, insurance cost, rental of facilities, administrative overheads, Global Distribution Systems (GDS), navigation charges, maintenance and maintenance reserve, etc. The variable costs of operations are the commissions paid to agents, catering services, taxes paid to the government; ground handling charges and landing charges. Other variable costs are maintenance cost and the amount of jet fuel needed for the flight. These variable costs vary directly as the frequency of flights. The maintenance reserve are payments a lessee of an aircraft makes to a lessor toward the cost of major maintenance, such as airframe heavy structural inspections, landing gear overhauls, auxiliary power unit (APU) restoration, engine performance restoration, engine life limited parts, or other high-value items (Shuttle, 2013).

Remark 1:

GDS allows passengers anywhere in the world to make reservations on an airline but the airline operators pay for the services provided by the managers of the system. GDS can be fixed or variable depending on the arrangement an airliner has with the operators of the system.

The total revenue from all the m routes is given by

$$T_R = \sum_{j=1}^{m} N_{t_j} y_j d_j n_{p_j}$$

N_{t_j} is the number of trips an aircraft makes on route j within a specified time horizon, y_j is the yield (the price passengers pay per seat kilometre) and d_j the distance in kilometres of an aircraft on route j, that we call the destination distance. Thus $y_j d_j$ is the amount a passenger pays for getting to her destination on route j. n_{p_j} is the number of passengers an aircraft carry on route j, called the load. The loading factor is the proportion of seats available on an aircraft that are occupied by passengers.

Remark 2:

An aircraft may not fill all the seats available depending on the weight it carries on a particular route. Therefore the load is always less or equal to the number of seats available on the aircraft.

The total profit, P_F, of an airliner operations is given by

$$P_F = \sum_{j=1}^{m} N_{t_j} y_j d_j n_{p_j} - \left[\sum_{j=1}^{m} (t_{f_j} + V_{c_j}) + w_i AR_c (1+r)^i \right], i = 1,\ldots,n$$

We split V_{c_j} into two parts: a part triggered by fluctuation in the jet fuel price, v_{c_j} and a part $\tilde{v}_{c_j}$ that change by some other source. Thus P_F can be written as

$$P_F = \sum_{j=1}^{m} N_{t_j} y_j d_j n_{p_j} - \sum_{j=1}^{m} v_{c_j} - \left[\sum_{j=1}^{m} (t_{f_j} + \tilde{v}_{c_j}) + w_i AR_c (1+r)^i \right], i = 1,\ldots,n$$

Decomposing the profits into the various routes we get

$$p_{f_1} = N_{t_1} y_1 d_1 n_{p_1} - v_{c_1} - W_1 [\sum_{j=1}^{m} (t_{f_j} + \tilde{v}_{c_j}) + w_i AR_c (1+r)^i], i = 1,\ldots,n$$

$$p_{f_2} = N_{t_2} y_2 d_2 n_{p_2} - v_{c_2} - W_2 [\sum_{j=1}^{m} (t_{f_j} + \tilde{v}_{c_j}) + w_i AR_c (1+r)^i], i = 1,\ldots,n$$

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$$p_{f_m} = N_{t_m} y_m d_m n_{p_m} - v_{c_m} - W_m [\sum_{j=1}^{m} (t_{f_j} + \tilde{v}_{c_j}) + w_i AR_c (1+r)^i], i = 1,\ldots,n$$

where $\sum_{i=1}^{m} W_i = 1, W_i \geq 0, i = 1,\ldots,m$ are the weights assigned to each route j. That is the portion of the cost of $w_i AR_c (1+r)^i$ assigned to route j. We compute W_j by

$$W_j = \frac{N_{t_j} d_j}{\sum_{j=1}^{m} N_{t_j} d_j}$$

and the reason is that the greater the frequency of flight on a given destination, the greater the pressure imposed on AR_c.

Assessing the Viability of Air Business Operations

For an airliner operations on route m to be profitable, the yield y_m must be set such that

$$y_m > \frac{v_{c_m} + W_m[\sum_{j=1}^{m}(t_{f\,j} + \tilde{v}_{c_j}) + w_i AR_c(1+r)^i]}{d_m n_{p_m} N_{t_m}}, i = 1,...,n$$

On the other hand if the yield y_m is set for route m then the number of trips should be such that

$$N_{t_m} > \frac{v_{c_m} + W_m[\sum_{j=1}^{m}(t_{f\,j} + \tilde{v}_{c_j}) + w_i AR_c(1+r)^i]}{d_m n_{p_m} y_m}, i = 1,...,n$$

For a fixed yield, the objective of an airliner on route j is

$$\max(p_{f_j})$$

$$\text{subject to } N_{t_j} y_j d_j n_{p_j} > v_{c_j} + W_j[\sum_{r=1}^{m}(t_{f\,r} + \tilde{v}_{c_r}) + w_i AR_c(1+r)^i], i = 1,...,n \quad (1)$$

$$\lambda_1 \le n_{p_m} \le \lambda_2$$

for some $\lambda_1, \lambda_2 \in Z^+$. On the other hand, if n_{p_m} is fixed then the objective of an airliner on route j is to

$$\max(p_{f_j})$$

$$\text{subject to } N_{t_j} y_j d_j n_{p_j} > v_{c_j} + W_j[\sum_{r=1}^{m}(t_{f\,r} + \tilde{v}_{c_r}) + w_i AR_c(1+r)^i], i = 1,...,n$$

$$\tilde{\lambda}_1 \le y_j \le \tilde{\lambda}_2$$

for some $\tilde{\lambda}_1, \tilde{\lambda}_2 \in Z^+$.

An investor interested in the air transport business will like to know the likelihood that the estimated profit will be realized before committing substantial amount typical of the air transport business. Let $p_{f_j}^{opt}$ be the optimal profit within a given time horizon on route j for model (1). Because the number of passengers that ply any route j in a given time horizon is random, $p_{f_j}^{opt}$ is random and for that matter the total optimal profit, P_F^{opt}, of all routes. Consequently, we can write

$$E(P_F^{opt}) = E(p_{f_1}^{opt}) + E(p_{f_2}^{opt}) + .. + E(p_{f_m}^{opt})$$

$$Var(P_F^{opt}) = \sum_{r=1}^{m}\sum_{t=1}^{m} Cov(p_{f_r}^{opt}, p_{f_t}^{opt})$$

From the Chebychev's inequality, for any $\varepsilon > 0$,

$$P\Big((E(P_F^{opt})-\varepsilon)\le P_F^{opt}\le (E(P_F^{opt})+\varepsilon)\Big)\le \frac{Var(P_F^{opt})}{\varepsilon^2}$$

(i.e. the smaller the variance of the optimal profit, the more likely that P_F^{opt} will be close to the expected optimal profit, see Promislow (2011) , pp 411).

To get an estimate of $Var(P_F^{opt})=\sigma^2_{P_F^{opt}}$, for a given period $\tilde{n}$ of airline business we set

$$\hat{S}^2_{P_F^{opt}} = Var(\hat{P}_F^{opt}) = \frac{1}{\tilde{n}-1}\sum_{r=1}^{\tilde{n}}\left(P_{F^r}^{opt}-E(P_F^{opt})\right)^2$$

$\hat{S}_{P_F^{opt}}$ give the risk of the optimal profit for a given period of interest. To get an estimate of the true risk, $\hat{\sigma}_{P_F^{opt}}$ for a fixed yield, we solve the optimization problem (1) for all possible number of passengers that use all routes and get the optimal profits $P_F^{opt(m)}, m=1,2,\ldots,M\in Z^+$ and calculate $Var(\hat{P}_F^{opt(m)}), m=1,2,\ldots,M$ for each optimal profit. Then the expected average variance, $E[Var(P_F^{opt})]$ for the period $\tilde{n}$ of interest can be approximated by

$$\frac{1}{M}\sum_{m=1}^{M} Var(P_F^{opt}) \to E[Var((P_F^{opt})]$$

as $M\to\infty$ and $Var((P_F^{opt})$ is the variance of the optimal profit for path m . It can be shown that

$$E[Var((P_F^{opt})] = \sigma^2_{P_F^{opt}}$$

is the true variance of the optimal profit for path m (see Stock & Watson, 2007, pp 76).

The expected optimal profit can be estimated by

$$\frac{1}{M}\sum_{m=1}^{M} P_F^{opt(m)} \to E(P_F^{opt})$$

as $M\to\infty$.

Model for Airfare Adjustments

We split the variable cost of operations, V_{c_j} into two parts: a part triggered by fluctuation in the jet fuel price, v_{c_j} and a part $\tilde{v}_{c_j}$ that change by some other source. For example, $\tilde{v}_{c_j}$ can change when catering cost increase as a result of increase in the number of people who wish to travel during festive periods such as Christmas seasons or Muslim pilgrimage to Mecca when frequency of flight increase. v_{c_j} can be written as

$$v_{c_j} = n_{l_j} p_l \qquad (2)$$

where n_{l_j} is the number of litres of jet fuel required on route j and p_l is the price per litre of jet fuel. We denote the profit of old airline fares on route *j* by $p_{f_j^o}$ and that for new airline fares on route j any time there is adjustment in aviation fuel by $p_{f_j^n}$. Assuming the number of trips an airliner make on a specified route j do not change over time any time there an adjustment in jet fuel we get

$$p_{f_j^o} = N_{t_j} y_{oj} d_j n_{p_j} - n_{l_j} p_{l_o} - W_j [t_{f\,j} + +\tilde{v}_{c_j^o} + w_i AR_c (1+r)^i], i = 1,\dots,n \qquad (3)$$

y_{oj}, p_{l_o} and $\tilde{v}_{c_j^o}$ are the old yield, old price per litre of jet fuel and old variable cost that change by some other source. When there is adjustment in fuel price, we can write

$$p_{f_j^n} = N_{t_j} y_{nj} d_j n_{p_j} - n_{l_j} p_{l_n} - W_j [t_{f\,j} + +\tilde{v}_{c_j^n} + w_i AR_c (1+r)^i], i = 1,\dots,n \qquad (4)$$

where y_{nj}, p_{l_n} and $\tilde{v}_{c_j^n}$ are the new yield, new price per litre of jet fuel and new variable cost that change by some other source. Subtracting equation (3) from equation (4) and applying the viability condition, we get

$$y_{nj} \geq y_{oj} + \frac{n_{l_j}(p_{l_n} - p_{l_o}) + W_j(\tilde{v}_{c_j^n} - \tilde{v}_{c_j^o})}{N_{t_j} d_j n_{p_j}}$$

v_{c_j} is partly constant and varies directly as the destination distance d_j. For example irrespective of the destination of an aircraft the amount of jet fuel consumed is the same for take-offs and landing holding the weight fairly constant. Thus we can write

$$v_{c_j} = k_1 + k_2 d_j$$

for some constants k_1 and k_2. About 25% of jet fuel required for a destination is consumed in takes offs and landing and so we can write

$$v_{c_j} \approx \frac{1}{4} n_{l_j} + k_2 d_j$$

Hence from (2), k_2 can be approximated by

$$k_2 \approx \frac{4n_{l_j} p_l - n_{l_j}}{4d_j}$$

Airlines operations have many variables costs and we need to get a good estimate of the difference $\tilde{v}_{c_j^n} - \tilde{v}_{c_j^o}$ when there is adjustment in jet fuel. We do this via the following observations peculiar to the Ghanaian environment. Majority of operational costs of the airline industry in Ghana are hard currency dependent (mainly US dollars). Operational cost such as aircraft lease charge, spare parts, Ghana Civil Aviation charges, aircraft insurance, system charges, aircraft major checks, fuel, cost of crew and training are all based on the US dollars. Consequently, even though the cost of jet fuel may decline or even stay the same, the operators of these airlines may have to adjust fares to reflect the depreciation cedi to enable the payment of these expenses in US dollars. In addition, a reduction in jet fuel prices does not generally cause a reduction of goods and services. Consequently, we can write

$$(\tilde{v}_{c_j^n} - \tilde{v}_{c_j^o}) = k_3 + k_2 \mid p_{l_n} - p_{l_o} \mid$$

where k_3 is an exchange constant. k_3 is chosen as the difference in exchange rate (in GHS) at the time of the adjustment. For example, if $GHS4 = 1USD$ now and at the last adjustment $GHS3.7 = 1USD$, then $k_3 = 0.3$, but must be converted to the working currency. Hence

$$(\tilde{v}_{c_j^n} - \tilde{v}_{c_j^o}) = k_3 + k_2 \mid p_{l_n} - p_{l_o} \mid = k_3 + \frac{(4n_{l_j} p_{lA} - n_{l_j})}{4d_j} \mid p_{l_n} - p_{l_o} \mid, \; p_{lA} = \frac{p_{l_n} + p_{l_o}}{2}$$

Therefore,

$$y_{nj} \geq y_{oj} + \frac{n_{l_j}(p_{l_n} - p_{l_o}) + W_j\left[k_3 + \dfrac{(4n_{l_j} p_{lA} - n_l)}{4d_j} \mid p_{l_n} - p_{l_o} \mid\right]}{N_{t_j} d_j n_{p_j}}$$

$$y_{nj} \geq y_{oj} + \frac{4d_j n_{l_j}(p_{l_n} - p_{l_o}) + W_j \lfloor 4d_j k_3 + (4n_{l_j} p_{lA} - n_l) \mid p_{l_n} - p_{l_o} \mid \rfloor}{4d_j^2 N_{t_j} n_{p_j}}$$

with equality if, and only if, prices of jet fuel and exchange rate remain unaltered. The expression

$$\frac{4d_j n_{l_j}(p_{l^n} - p_{l^n}) + W_j \lfloor 4d_j k_3 + (4n_{l_j} p_{lA} - n_l) \mid p_{l_n} - p_{l_o} \mid \rfloor}{4d_j^2 N_{t_j} n_{p_j}}$$

is the amount each passenger pay per seat kilometer any time there is adjustment in jet fuel price (compare with Andoh & Quaye (2015)). Observe that the greater the value of N_{t_j} the smaller the amount that has to be added to the existing fares. As airline operators are generally interested in increasing their profits they will prefer n_{p_j} to be as small as possible. In any case, any addition to existing airfares should lie in

$$\left(0, \frac{4d_j n_{l_j}(p_{l^n} - p_{l^n}) + W_j \lfloor 4d_j k_3 + (4n_{l_j} p_{lA} - n_l) \mid p_{l_n} - p_{lo} \mid \rfloor}{4d_j^2 N_{t_j}}\right]$$

We can also write

$$y_{nj} d_j > y_{oj} d_j + \frac{n_{l_j}(p_{l^n} - p_{l^n}) + W_j k_3}{d_j N_{t_j} n_{p_j}} + \frac{W_j (4n_{l_j} p_{lA} - n_l) \mid p_{l_n} - p_{lo} \mid}{4d_j^2 N_{t_j} n_{p_j}}$$

where $y_{nj} d_j$ is the new airfare passengers pay for getting to their destination.

Stability Model for Air Transport

In this section, we develop a model for price setting that resist frequent adjustment to air transport fares when employed by airline operators. Suppose that one has at the disposal the history of prices of jet fuel up to a period T. Set

$$p_l^c = p_{l_n} - p_{l_o}$$

the difference between the old and the new price per litre of jet fuel. Then compute

$$\overline{P} = \frac{1}{T}\sum_{t=1}^{T} p_{l_t}^c$$

for a reasonable past data $p_{l_1}^c, p_{l_2}^c, \ldots, p_{l_T}^c$ and set

$$y_{nj}^* = y_{oj} + \frac{4d_j n_{l_j} \overline{P} + W_j \lfloor k_3 + (4n_{l_j} p_{lA} - n_{l_j}) \mid \overline{P} \rfloor}{4d_j^2 N_{t_j} n_{p_j}} \tag{5}$$

The absolute difference $\left| y_{nj}^{*} - y_{oj} \right|$ will be the gain or loss to the airliner anytime there is adjustment in jet fuel. We call (5) the stability model for air transport.

Empirical Results

We tested our models on the only two privately operated airlines (that we call Airline 1 and Airline 2) operating in the Ghanaian airspace.

Assumptions and Data Analysis

Historical prices of jet fuel for our analysis were obtained from the website of the National Petroleum Authority, the sole agency responsible for setting the prices of petroleum products in Ghana (http://npa.gov.gh/npa_new/index.php). Primary data of airline operational costs were also obtained from the headquarters of the two airlines currently operating in the Ghanaian airspace. Frequency of flight for each airline obtained from the headquarters was confirmed by agents located at the Kotoka International Airport in Accra, Ghana.

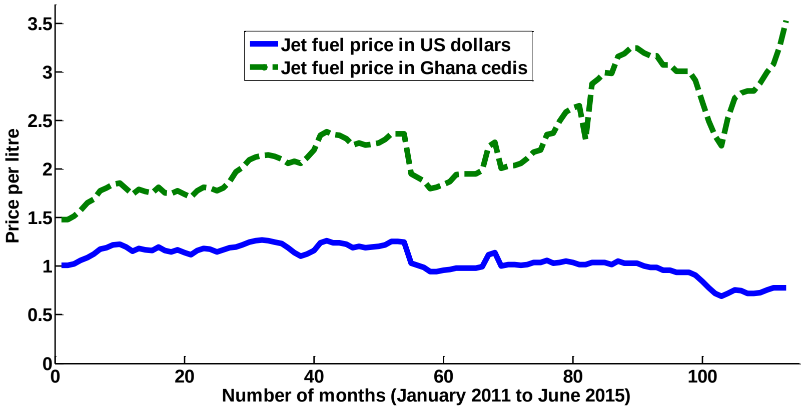

Figure 1: Comparison of jet fuel prices in Ghana cedis and US dollars.

Figure 1 shows a comparison of jet fuel prices in US dollars and Ghana cedis. As can be seen from the figure, from month 60 onwards, the there is general trend in the decline of jet fuel prices in US dollars but the same quantity of jet fuel prices in Ghana cedis keep rising. Consequently, airline operators need a greater amount of Ghana cedis to be able to stay in business. Thus the stabilization of the Ghana cedi is crucial for the stabilization of air transport fares.

Airline 1

This airline currently has 3 aircrafts, BA146, Q400 and ATR72500, in its fleet with seating capacities 94, 78 and 66. The routes currently plied are four routes: Accra-Takoradi, Accra-Kumasi, Accra-Tamale and Accra-Sunyani. The airline has 14 crews and the staff strength of the airline is 250 with 6 people in senior management positions, 8 in middle level management positions and the remainder, lower level positions. This airline pays respectively $7000, GHS2000 (1USD is about GHS4) and GHS1500 for workers in the senior management, middle level management and lower level positions respectively. Airline 1 pays a fixed amount of 30000 euros (about $32700) for signing on the Global Distribution Systems (GDS) and for any passenger that uses their service to make reservation, the airline must reimburse the operators of the GDS $10. We did not have a history of the number of passengers that used their service and so we excluded the number that signed on in our analysis. For each landing of BA146, Q400 and ATR72500, the Ghana Airport Authority charges $75, $45 and $45 respectively. Ground handling charges is $100 for each turn around. The amount of jet fuel required depends on the aircraft designated for a particular route. BA146 burns 2500 litres of jet fuel to Kumasi, whereas Q400 burns 1000 litres for the same destination. On the other hand, ATR72500 burns 900 litres to Kumasi. For our analysis, we fix an aircraft BA146 to Kumasi route and Q400 and ATR72500 to other routes. Thus estimates of jet fuel required for the various destinations are as indicated on table 3. For the maintenance reserve we use the middle point value of costs suggested by Shulte (2013) for each aircraft operated by airline 1. We also assume that the life span of BA146 that the airline owns is 10 years and used we the average load factors for the period January 2013 to May 2015 obtained from the airline to estimate revenue from operations. Details of the cost of operations, weights applied to each destination and estimated revenue from operations are all depicted in table 4, 1 and 2 respectively.

Table 1:
Weights Assigned to Each Destination For Airline 1

Route	Number of trips per week	Number of trips in a month (N_{t_j})	Destination distance, d_j , in km	$N_{t_j}\ d_j$	W_j
Accra-Takoradi	28	112	185	20720	0.1658
Accra-Kumasi	58	232	199	46168	0.3695
Accra-Tamale	28	112	431	48272	0.3863
Accra-Sunyani	8	32	306	9792	0.0784
Totals		488		124952	1

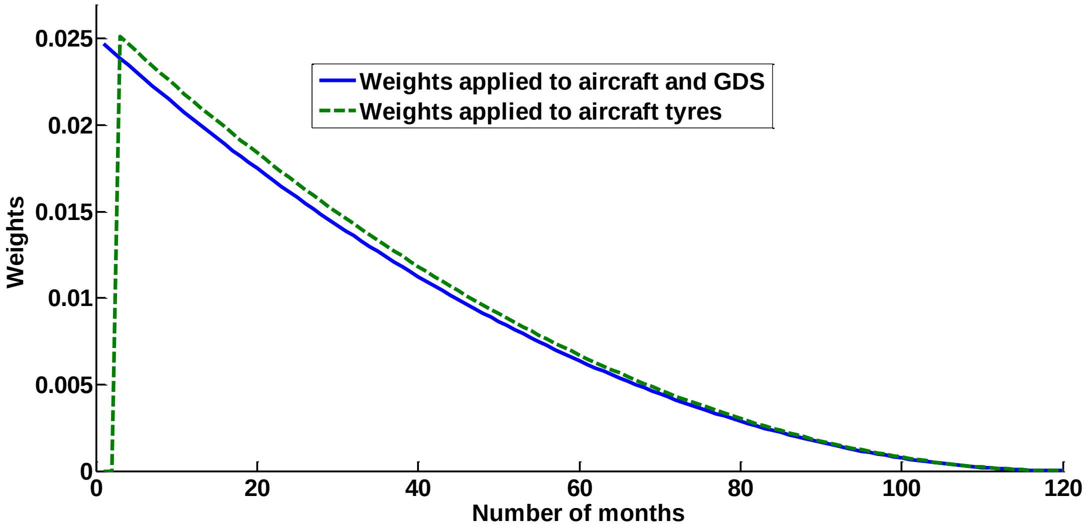

Figure 2: Weights applied to aircraft, aircraft tyres and GDS

The weights applied to the aircraft, aircraft tyres and GDS is as indicated in figure 2. We pay a greater portion of these costs in earlier years than later years when the craft is acquired anew. Observe that no tyre needs to be replaced in the first two months and so that account for the initial zero entries. We allow for funds for the entire 10 year period of projection and pay off a greater portion in the earlier years than later years at a low rate of interest of 1%. Because our computations are US dollars, the currency used in purchasing the tyres, we assume that there will not be a dramatic increase in the price of tyres for the 10 year period. Consequently, the allowance made for tyres should be sufficient to pay for the cost of tyres for these 10 years.

Table 2:
Estimated Revenue from Operations on all Routes

Route	Number of trips in month	Median load factors	Seating Capacity of aircraft	Number passengers aboard	Average ticket price to destination (in GHS)	Average revenue from destination (in GHS)	Estimated monthly revenue from luggage (GHS)
Accra-Takoradi	112	0.66	66	44	335	1650880	412.72
Accra-Kumasi	232	0.66	94	62	330	4746720	1186.68
Accra-Tamale	112	0.66	78	51	396	2261952	565.49
Accra-Sunyani	32	0.66	78	51	397.5	648720	162.18
Totals	488					9308272	2327.07
Total Revenue (USD)						2,327,649.77	

Table 3:
Estimated Cost of Jet Fuel Required for the Various Routes Plied by the Airline 1.

Route	Quantity of litres of jet fuel consumed	Cost per litre (USD)	Cost of jet fuel per trip (USD)	Number of trips in month	Total cost of jet fuel in a month (in USD)
Accra-Takoradi	938.08	0.78	731.70	112	81950.40
Accra-Kumasi (BA146)	2500	0.78	1950	232	452400
Accra-Tamale	1321.84	0.78	1031.04	112	115476.48
Accra-Sunyani	1129.96	0.78	881.37	32	28203.84
Totals					678030.72

Table 4:
Operational Cost Components of Airline 1

Costs	Airline 1 cost of operations	
	Components	Monthly amount in (USD)
Fixed cost	Insurance	$\frac{250000}{3} = 83333.33$
	Rentals of aircraft Q400	500000
	Rental of aircraft ATR72500	400000
	Rental of facilities, offices	5000
	Maintenance reserve	33900
	Administrative overheads, HR and IT	25000
	Wages (monthly)	
	Senior level	$7000 \times 6 = 42000$
	Middle level	4000
	Lower level	88500
	Crew cost	45000
	Maintenance	16950
Monthly total fixed cost		1243683.33
Variable costs ($\tilde{v}_c$)	Ground handling Charges	$\frac{488}{2} \times 100 = 24400$
	Landing charges	28920
	Commissions (6% to 8% of fare)	186165.44
	Catering (GHS3/per passenger)	19992
	Taxes (GHS5/passenger)	33320
	Value Added Tax (VAT) (17.5% of total fare)	407236.9
Monthly total fuel cost (v_c)	Fuel	678030.72
Monthly total variable costs ($\tilde{v}_c$)		700034.34
AR_c	Cost of Aircraft	
	BA 146	2050000

	Tyre cost	
	BA146	$1254 \times 10 = 12540$
	Q400	$1254 \times 6 = 7524$
	ATR72500	$1254 \times 6 = 7524$
		27588
	Cost of tyres for 9 years ten months	1627692
	GDS	32700

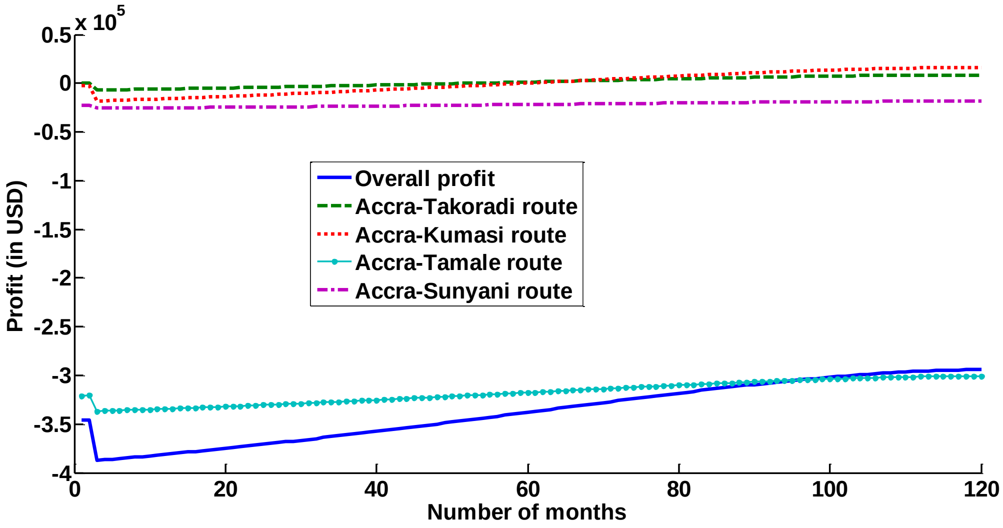

Figure 3: Overall profit of operations and profit for destination plied by airline 1

As can be seen from figure 3, the overall profit for airline 1 for the projected ten year period is negative. Accra-Tamale route is the most unprofitable route for the airline. Management can stop flight to Accra-Tamale route. A vigorous marketing and promotional campaign will have to be executed to induce greater number of people patronizing their flight.

Airline 2

Airline 2 currently has 3 aircrafts in its fleet all 50-seater aircrafts all of which are leased. The company currently has 216 employees, 2 in executive management positions, 9 in Senior Management, 21 in middle level position and the remainder lower level positions. The company has a pool of 20 pilots, 10 co-pilot and 22 flight attendance that it draws from. A pilot monthly remuneration is $6500 whereas the co-pilot earns $3000. The two flight attendants earn GHS700 each a month. The fuel capacity of the aircraft is 5117kg or 6396 litres of fuel and it takes 5 hours for tank to be exhausted when the tank is full. Each aircraft uses 6 tyres and each tyre cost $1254. Tyres have to be replaced every two months. Details for the operation costs, weights applied to the various destinations, revenue generated from each route and estimates of jet fuel required for each destination are depicted in tables 8, 5, 6 and 7 respectively.

Table 5:
Weights Assigned to Each Destination for Airline 2

Route	Number of trips per week	Number of trips in a month (N_{t_j})	Destination distance, d_j, in km	$N_{t_j} d_j$	W_j
Accra-Takoradi (Chartered flight only)	4	16	185	2960	0.0220
Accra-Kumasi	66	264	199	52536	0.3897
Accra-Tamale	38	152	431	65512	0.4860
Accra-Lagos	8	32	431	13792	0.1023
Totals				134800	1

Table 6:
Estimated revenue from operations on all routes for airline 2

Route	Number of trips in a month	Current load factors	Seating Capacity of aircraft	Number of passengers aboard	Average ticket price to destination (in GHS)	Monthly revenue for destination (in GHS)	Estimated monthly revenue from luggage (GHS)
Accra-Takoradi-Accra (Chartered flight only)	16		50	50		$211200	
Accra-Kumasi	264	0.7	50	35	349.50	3229380	8073.45
Accra-Tamale	152	0.7	50	35	408.50	2173220	5433.05
Accra-Lagos	32	0.5	50	25	479	383200	958
Totals	448					5785800 +$211000	14464.50
Total revenue in USD						1661266.13	

Table 7:
Estimated Cost of Jet Fuel Required for the Various Routes Plied by the Airline 2.

Route	Quantity of litres of jet fuel consumed	Current cost per litre (USD)	Cost of jet fuel per trip	Number of trips in a month	Total cost of jet fuel in a month
Accra-Takoradi (Chartered flight only)	938.08	0.78	731.70	16	11707.20
Accra-Kumasi	959.4	0.78	748.33	264	197559.12
Accra-Tamale	1321.84	0.78	1031.04	152	156718.08
Accra-Lagos	1321.84	0.78	1031.04	32	32993.28
Totals					398977.68

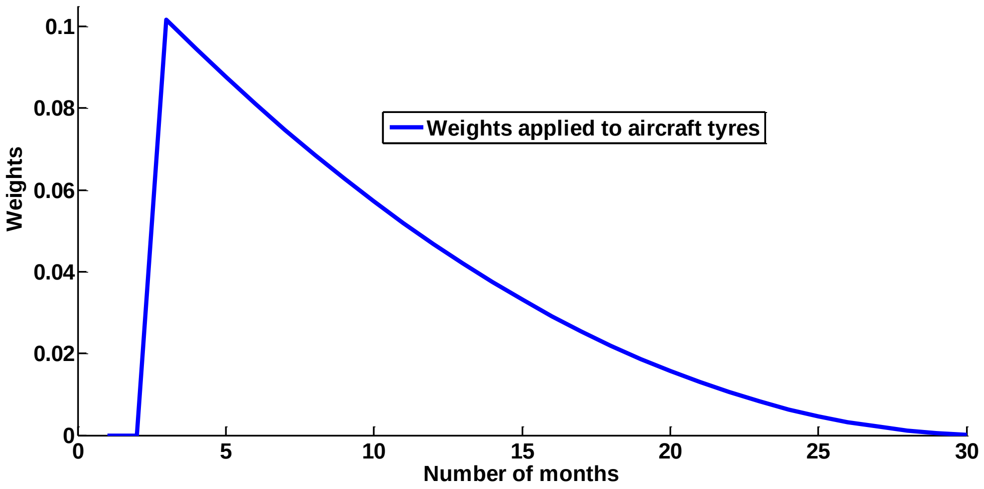

Figure 4: Weights applied to aircraft tyres for airline 2

Table 8:
Operational cost components of airline 2

Costs	Airline 2 cost of operations

	Components	Monthly amount in (USD)
Fixed cost	Insurance	$\frac{150000}{3}=50000$
	Rentals of aircraft (3 aircraft)	131250
	Rental of facilities, offices	20000
	Maintenance reserve	33900
	Administrative overheads, HR and IT	25000
	GDS	8000
	Wages (monthly)	
	Executive level	$7000\times 2=14000$
	Senior level	6750
	Middle level	6562.50
	Lower level	32200
	Crew cost	160000
	Maintenance	16950
Monthly total fixed cost		504612.50
Variable costs ($\tilde{v}_c$)	Ground handling Charges	$\frac{448}{2}\times 100=22400$
	Landing charges	11200
	Commissions (6% to 8% of fare)	115716
	Catering (GHS3/per passenger)	12120
	Taxes (GHS5/passenger)	20200
	Value Added Tax (VAT) (17.5% of total fare)	290053.75
Monthly total fuel cost (v_c)	Fuel	398977.68
Monthly total variable costs ($\tilde{v}_c$)		471689.80
AR_c	Tyre cost for five year lease	
	654588	

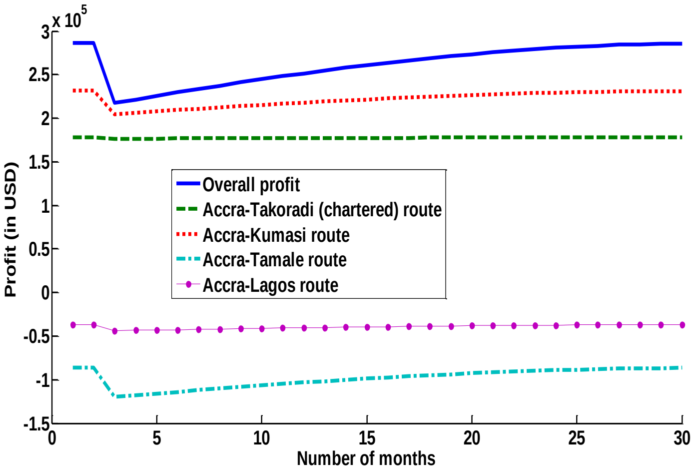

Figure 5: Overall profit of operations and profit for destination plied by airline 2.

As can be seen from the figure 4, although the overall operations of airline 2 are profitable, the Accra-Tamale and Accra-Lagos routes are unprofitable. A vigorous marketing and promotional campaign has to be embarked on by management to induce the travelling public to increase patronage.

Summaries, Conclusions and Recommendation

Summaries

In this study, we developed some mathematical models for management of air transport operations. Firstly, we have developed a model that will allow transport planners how much has to added or subtracted from existing fares any time there is adjustment in jet fuel prices and a model that can be employed to minimize the frequency of adjustment. Secondly, we provide models for determining the number of trips an airliner has to make to ensure that its operations are sustainable. Thirdly, we developed models that allow any businessman interested in entering air transport business assess the viability of the air transport business and to assess the likelihood that expected profit will be realized. Finally, we develop a model for determining the profitable routes plied by air business operator.

Conclusion

The models we have developed are useful decision tools for any airliner or businessman interested in entering the air transport sector. The models allows the air transport administrator determine at any time when their operations to a specified destination is profitable. The loading factor and the proportion of jet fuel consumed are central in the determination of new airfares when it is necessary to adjust air transport fares. The stabilization of the air transport fares in Ghana hinges on the stabilization of the Ghana cedi.

Recommendations

The government of Ghana recently introduced additional taxes on the operations of the local airline industry. This required all local airlines to pay 17.5% of total revenue as VAT (Value-Added-Tax). Already these operators are taxed a fixed amount for every passenger aboard the aircraft. We therefore call on the government to suspend the VAT it has currently imposed on the local carriers. Research has to be conducted on ways the government of Ghana can help the local airline operators to thrive.

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