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COMPETITIVE ADVANTAGE AND FUEL EFFICIENCY IN AVIATION

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ABSTRACT

This paper builds upon a resource based view of competitive advantage under a dynamic capabilities construct. Fuel efficiency measurement in the aviation industry can be incorporated into dynamic capabilities such as strategic decision making and alliancing. These dynamic capabilities can drive operational cost reductions, which in-turn can enhance profitability and establish a competitive advantage. To further this advantage, fuel efficiency can be embedded inside an organizational culture. A fuel efficiency focused organizational culture can be a valuable, rare, inimitable and non-substitutable resource. This paper proposes a model to merge the dynamic capabilities of strategic decision making and alliancing with organizational culture under fuel efficiency. Under this model, a fuel efficiency index is introduced to drive behavior and provide accountability. Effective use of the index has profit potential.

INTRODUCTION

A firm's efficient utilization of resources can be a source of competitive advantage. For the aviation industry, the resource that makes up the largest component of total cost is fuel. Aviation industry fuel encompassed 20% of total costs in 2007 and United Airlines saw their cost of fuel, as a percentage of total cost, vary between 10% and 25% from 1973 to 2006 (Mazraati, 2010). A dynamic capability to obtain the efficient use of fuel and reduce those costs could lead to a sustained competitive advantage.

Barney (1991) suggests a rationale for a resource based view of sustained competitive advantage. The two main assumptions of this view are that a firm's resources are heterogeneous and that those resources may be immobile across firms. In addition, resources that provide for a sustained competitive advantage must be valuable, rare, inimitable and non-substitutable. Fuel is not rare or inimitable. Fuel as a resource therefore will not provide for a sustained competitive advantage. Yet, a firm's dynamic capabilities properly applied to fuel efficiency can achieve that advantage. Eisenhardt and Martin (2000) expanded upon Barney's resource based view model by adding dynamic capabilities as potential sources of sustained competitive advantage.

AVIATION FUEL EFFICIENCY AND DYNAMIC CAPABILITIES

Dynamic capabilities as defined by Eisenhardt and Martin are those "organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve and die." Some examples given of dynamic capabilities include alliancing, product development and strategic decision making. Eisenhardt and Martin suggest that dynamic capabilities can be a source of competitive advantage by altering a firm's resource base. The efficient utilization of fuel in the aviation industry is dependent upon alliancing, product development and strategic decision making. A model for implementation of a fuel efficiency strategy can be seen in Figure 1.

The model's three elements — strategic decision making, supply chain fuel efficiency and an organizational culture of fuel efficiency directly impact a firm's operational fuel efficiency. Strategic decision making concerning fuel efficiency involves strategic investment and strategic planning. Strategic investment

FIGURE 1
AVIATION INDUSTRY FUEL EFFICIENCY MODEL

involves the acquisition of aircraft, software, ground equipment and infrastructure improvements. Examples of each of these categories can be seen in Table 1. The critical factor in all of these strategic elements is to consider their fuel efficiency impact on operations. This impact is associated with a purchased item's fuel efficiency and weight. Strategic investments need to consider weight minimization as an important requirement. Strategic planning involves location management and process decisions. Location management decisions include the basing of aircraft, ground equipment, facilities and maintenance repair capability. The goal of location management is to optimize requirement flow with minimum fuel usage. Process decisions include initial process design for fuel efficiency, process redesign for fuel efficiency and accountability for fuel efficiency. Metrics need to be designed to drive behaviors that increase fuel efficiency in these strategic areas.

Supply chain fuel efficiency involves alliancing. Partnering with other firms in the supply chain can result in significant fuel efficiency enhancements. Examples include information technology collaboration that shares aircraft schedules and loads with cargo distribution centers to optimize load factors. Another potential improvement area in alliancing fuel efficiency comes from the increased load factors associated with pooling. Pooling involves sharing requirements to optimize load factors. Gagnepain and Marin (2007) conclude that airline alliances are able to lower prices because they result in lower costs.

Organizational culture is not a dynamic capability, but meets the valuable, rare, inimitable and non-substitutable requirements of a resource based view. Barney (1986) suggests that organizational culture may be a source for sustained competitive advantage. Achieving a fuel efficiency focused organizational culture involves the integration of the importance of fuel efficiency as a core ingredient to the success of the organization. Embedding fuel efficiency into an organizational culture is difficult (Hatch, 1993).

TABLE 1
AVIATION INDUSTRY STRATEGIC DECISION MAKING FOR FUEL EFFICIENCY

Strategic Decision Making					
Strategic Investment				Strategic Planning	
Aircraft Acquisition	Automation and Optimization Software Acquisition	Ground Equipment Acquisition	Infrastructure Improvements	Location Management	Process
More Fuel Efficient Engines	Route and Schedule Optimization for Enterprise Requirements at Minimum Cost of Fuel and Assets	Mission Handling Equipment Fuel Efficiency	Strengthening a Runway to Increase Load Factors	Aircraft Basing	Initial Process Design for Fuel Efficiency
Lighter Materials and Components				Ground Equipment Locations	
Enhanced Aerodynamics		Mission Support Equipment Fuel Efficiency	Lengthening a Runway to Increase Load Factors	Facility Locations	Process Redesign for Fuel Efficiency
Optimal Fleet Mix for Fuel Efficiency				Maintenance Repai	Accountability for Fuel Efficiency

Schein (1984) stressed the importance of the structure of the firm and the firm's reward system during the development of organizational culture. The process to embed fuel efficiency into the culture requires measuring individual contribution to fuel efficiency and then establishing mechanisms that utilize that contribution element as an important consideration for promotion/reward. Leadership involvement is also critical toward embedding fuel efficiency in the organizational culture. Fuel efficiency should be incorporated into leadership communications to employees. Organizationally, a top executive can be assigned to oversee a firm's overall fuel efficiency effort. A committee can also be established among top executives to discuss strategic fuel efficiency opportunities.

Operational fuel efficiency can be greatly enhanced by fuel efficiency strategic decision making, supply chain fuel efficiency and an organizational culture committed to fuel efficiency. To align all of these sources of competitive advantage together requires fuel efficiency metrics. These metrics need to be measured, analyzed and reported to key decision makers. Accountability for metric performance must be established in terms of both individual promotion/reward and fuel efficiency trends needing management attention. The metrics should be designed to influence positive behaviors and issues where negative behaviors, can positively impact a metric should be highlighted and widely acknowledged.

FUEL EFFICIENCY INDEX

Fuel efficiency metrics in the transportation industry are based upon several aggregate measures of output. In the aviation industry, the Bureau of Transportation Statistics includes air revenue ton miles and air revenue passenger miles (Lahiri et al, 2003). Internationally, revenue ton kilometers and revenue passenger kilometers are used (Owen, 2008). Assuming an increase in these metrics is positive then increasing revenues, distances and load factors would result in a positive trend. The desired objective of fuel efficiency is to move the greatest quantity of cargo and passengers at the least cost of fuel for a given distance, set of assets and unit of time.

Ton miles and passenger miles should measure the Great Circle Distance (GCD) between cargo and passenger onload and offload as established in Federal Regulations (Code of Federal Regulations, 2010). Including GCD in the metric would allow the flight of more miles to save fuel overall. Flying greater distances can save fuel. Examples include flying farther to find more favorable winds or flying farther to obtain an Air Traffic Control routing that allows for a higher, more fuel efficient altitude. Ton miles and passenger miles still fail to take into account fuel, so those metrics should be divided by fuel used. The literature includes many examples where fuel is incorporated with passenger distance and cargo weight distance (Lee et al, 2004; Hileman et al, 2008; Owen, 2008; Rutherford and Zeinali, 2009). Ton miles per lbs of fuel consumed and passenger miles per lbs of fuel consumed consider fuel and mass transported over a given distance.

Hileman et al (2008) labeled these metrics Payload Fuel Energy Efficiency (PFEE), but uses fuel energy consumed instead of lbs of fuel consumed. This metric excels as an aggregate measure, but fails to take into account how an increasing quantity of sorties can tend to increase the measure of efficiency. For example, if two sorties are performed exactly the same, then the aggregate PFEE of both sorties is twice the size for the PFEE of one sortie. The reason for this is that both variables in Hileman et al's metric numerator are doubled while only one term in the denominator is doubled. This effect of increasing efficiency by increasing sorties is eliminated by obtaining the sortie average. Including the number of sorties n in the denominator of PFEE operationalizes the Fuel Efficiency Index (FEI) metric as seen in equations (1) and (2).

$$Cargo\ FEI = \frac{\sum_{i=1}^{n} \frac{Tons_i * Miles(GCD)_i}{KLbs\ of\ Fuel\ Burned_i}}{n}, where\ n = \#\ of\ sorties \quad (1)$$

$$Passenger\ FEI = \frac{\sum_{i=1}^{n} \frac{Passengers_i * Miles(GCD)_i}{KLbs\ of\ Fuel\ Burned_i}}{n}, where\ n = \#\ of\ sorties \quad (2)$$

TABLE 2
AIR MOBILITY COMMAND FEI BY MDS NOVEMBER 2010

	Sorties	Great Circle Distance (Nautical Miles)	Cargo (Tons)	Fuel Consumed (1000 lbs)	Fuel Efficiency Index: (GCD*Cargo)/(FC*Sorties)
C-17A	3110	4471385	54406.05	220724	354
C-5A	74	133192	1781.5	8141	394
C-5B	251	542520	7494.2	31936	507
C-5M	4	10375	116.25	549	550
C-130E	317	64456	860.55	1661	105
C-130H	675	280850	2562.7	6492	164
C-130J	188	145918	831.45	2587	249
KC-10A	107	186420	288.95	14955	34
KC-135R	358	494280	459.05	26663	24
KC-135T	60	74927	49.1	5265	12
Total	5144	6404322.45	68849.8	318971	269

THE DATA

Babikian et al. (2001) demonstrated that efficiency differences between regional and large aircraft can be affected by sortie length. As the proportion of large and small aircraft changes over time, the overall FEI can be biased. To remove this bias, the FEI in equations (1) and (2) can be calculated on an aircraft type basis to remove the bias of different aircraft type ratios impacting the overall efficiency metric. To obtain a better understanding of the fuel efficiency index, 5,144 Air Mobility Command military airlift sorties from November 2010 were analyzed with respect to the proposed index. Only channel, contingency or special assignment airlift mission sorties were selected. A summary of the index numbers broken down by aircraft Mission Design Series (MDS) can be seen in Table 2.

Note how the larger aircraft tend to have on average better FEI scores with the C-5M scoring highest. This trend for larger aircraft matches Babikian et al's results. Tanker aircraft (KC-10 and KC-135) tend to have very low FEI scores due to the limited cargo they carry and also due to the fact that airlift is ancillary to their primary mission of air refueling. The overall efficiency numbers are at the lower end of their range due to the prevalence of sorties with no cargo. Of all the sorties observed, 22% had no cargo. Sorties at the top of the efficiency range had FEI measuring in the thousands. Table 3 includes the descriptive statistics for all of the FEIs.

From the descriptive statistics, note that the standard deviation is larger than the mean. This suggests a large dispersal of the data. There are a few outliers at the top of the range that are associated with bad data. A couple of cases included diverts back to the origin, but failed to change the city pair. This resulted in extremely low fuel usage for a long distance resulting in a false FEI. In the cases of diverts, it is important to record the destination as the same as the origin. Finally, the mean is much larger than the median suggesting influence by a few outliers at the top of the range.

GREAT CIRCLE DISTANCE

After examining the descriptive statistics of FEI, the data was analyzed to assess the impact of great circle distance. If greater distances lead to better FEIs, than shifting the fleet to more long distance missions might improve the FEI measure. Increased distance tends to decrease payload capacity. This can be seen in Breguet Range equation (3) (Lee et al, 2004). V is the flight speed, L/D is the lift to drag ratio, g is the gravitational acceleration constant, SFC is specific fuel consumption and W is weight. The equation shows a tradeoff between fuel weight and payload weight.

$$R = \frac{V\left(\frac{L}{D}\right)}{g * SFC} * \ln\left(1 + \frac{W_{fuel}}{W_{payload} * W_{structure} * W_{reserve}}\right) \quad (3)$$

If Air Mobility Command aircraft were operating at maximum payload, then as distance increases, payload decreases counteracting the increase in FEI. When not operating at maximum payload, similar payloads will result in a higher FEI for aircraft that move the cargo farther. To isolate the bias of differing MDS aircraft, the

TABLE 3
DESCRIPTIVE STATISTICS FOR AIR MOBILITY COMMAND FEI NOVEMBER 2010

Mean FEI	267.41
Standard Deviation	332.32
Minimum	0
Maximum	5188.57
Count	5144

FIGURE 2
C-17 GREAT CIRCLE DISTANCE AND FEI

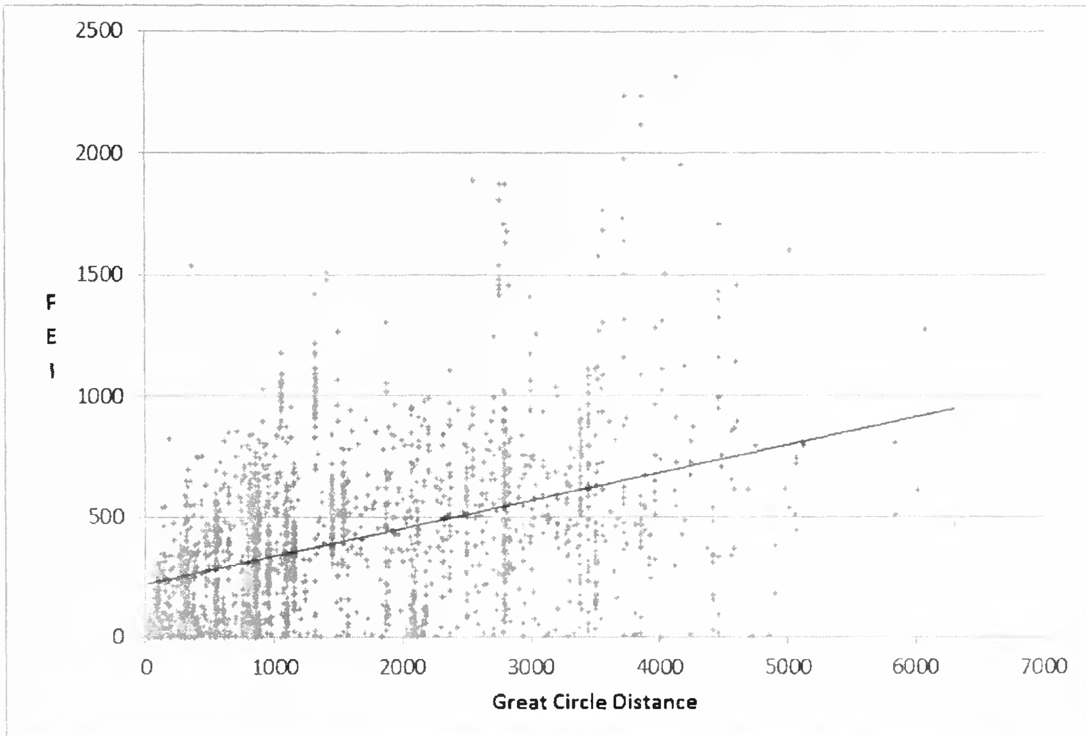
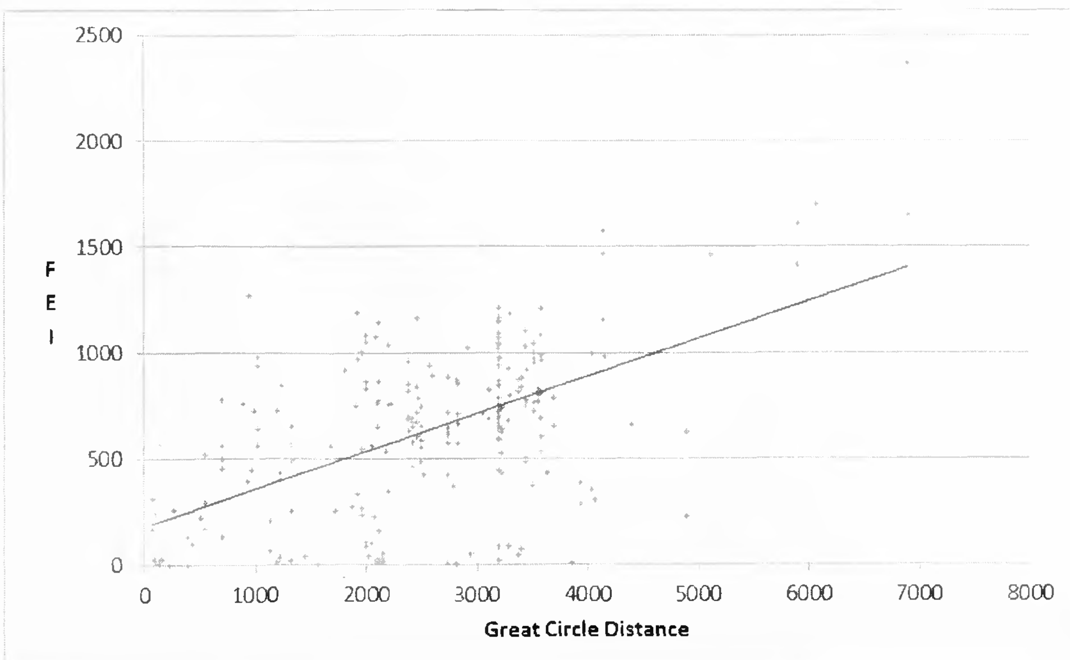


FIGURE 3
C-5 GREAT CIRCLE DISTANCE AND FEI



comparison of distance to FEI was made for the C-17 and the C-5. For the C-5, the A, B and M models were included together. The results were plotted in Figures 2 and 3.

Both of the plots show an increase in FEI for longer distance city pairs. The overall correlation between GCD and FEI is 44%. The only method that a manager could use to increase GCD is to overfly an intermediate location or discover longer distance city pairs to replace city pairs currently being used. If these sorties were operating at maximum payload before the transition, than a payload penalty would exist for going to longer distances. Yet, if the sorties were flying with a suboptimal payload, then they could fly a longer range with the same payload and increase FEI.

LOAD FACTORS

To enhance the effectiveness of the FEI, it should be reported along with load factors. The benefit of the load factor is that it is a ratio of the actual load to the optimal load. This information provides important insight into how cargo loading efficiency influences FEI. Load factors can have two limiting factors. These factors include weight limitations and volume limitations. The volume limitation or cube is a matter of dimension. It is based on the surface area of the cargo floor and the height of the cargo door. It is often measured as a ratio of pallet positions used over pallet positions available. If a cargo compartment is cubed out (pallet positions used equals pallet positions available) and cargo of greater density is not available (assuming below payload maximum) then the horizontal optimal configuration was achieved. In order to achieve optimality for the vertical, a metric should be added for the load factor of the pallet. It should be noted that calculating pallet load factors could be complex if accuracy is a primary concern. To simplify pallet load factors, a ratio of the height of the pallet to the maximum allowable height might be preferable.

The weight limitation is more complex. Pallets and aircraft cargo floors have a weight limitation. The limits of these must be observed. The aircraft also has a maximum gross takeoff weight which is dependent upon several variables. The first constraint is an airframe limit. This airframe limit can be reduced based upon several variables. These variables include pavement strength, runway length, altitude, temperature, obstacles and runway winds. With the maximum gross weight for takeoff determined, cargo available equals maximum gross takeoff weight minus operating weight minus fuel on board. The fuel on board is a calculation based on many factors.

The primary factor is the distance to the next fueling point. Other considerations include icing, thunderstorms, weather at origin and destination, distance to alternate, airframe specific fuel degrade, cargo weight, routing, altitude and winds. Due to the complexity of all of these factors, determination of the exact maximum payload is extremely difficult and often requires iterative algorithms. Computer flight planning software can calculate the value of payload maximum (PMAX) and those values should be calculated and recorded for every sortie flown. For passengers, the load factor is based on percentage of seats filled. See equations (4), (5), (6), (7) and (8) for load factors. The behaviors desired from these metrics include maximizing the pallet loads and completely filling the aircraft.

$$Pallet\ Load\ Factor\ (Cube) = \frac{Actual\ Pallet\ Volume}{Maximum\ Pallet\ Volume}\ or\ \frac{Actual\ Pallet\ Height}{Maximum\ Pallet\ Height} \quad (4)$$

$$Pallet\ Load\ Factor\ (Weight) = \frac{Actual\ Pallet\ Weight}{Maximum\ Pallet\ Weight} \quad (5)$$

$$Load\ Factor\ (Cube) = \frac{Pallet\ Position\ Equivalents\ Used}{Pallet\ Positions\ Available\ (MDS\ Specific)} \quad (6)$$

$$Load\ Factor\ (Weight) = \frac{Actual\ Cargo\ Weight}{Computer\ Flight\ Plan\ computed\ Payload\ Maximum} \quad (7)$$

$$Passenger\ Load\ Factor = \frac{Actual\ Passengers}{Available\ Seats} \quad (8)$$

Load factors for passengers in the aviation industry grew from 60 to 80% from 1990 to 2008 and load factors for commercial cargo remained flat around 60% over the same time period (Hileman et al, 2008). To contrast against industry data, load factors for the Air Mobility Command data set were gathered. Payload maximum was determined using equation (9). Actual ramp fuel was used to aid in simplification, but operationally the load factors need to be determined before the ramp fuel is loaded. Payload maximum is not routinely used by Air Mobility Command's command and control staff, but its value is critical to accurate load factor determination during planning. Payload maximum is dependent on Maximum Gross Takeoff Weight. For the analysis, the Maximum Gross Takeoff Weight used was the maximum for the aircraft. Other variables that could further reduce Maximum Gross Takeoff Weight include airfield pavement strength limitations and departure obstacles. Their inclusion would serve to improve load factors. The cargo load factors for Air Mobility Command can be seen in Table 4. The Air Mobility Command cargo load factor is lower

$$Payload_{Max} = [Min(Payload_{Acft\ Max}, (W_{Max\ Gross\ Takeoff} - W_{Ramp\ Fuel} - W_{Operating}))] \quad (9)$$

TABLE 4
AIR MOBILITY COMMAND LOAD FACTOR NOVEMBER 2010

	Maximum Gross Takeoff Weight	Empty Weight	Load Factors
C-17A	585	282.5	23%
C-5A	769	380	23%
C-5B	769	380	31%
C-5M	769	380	28%
C-130E	155	90	15%
C-130H	155	90	21%
C-130J	155	90	27%
KC-10A	590	241	3%
KC-135R	322.5	119.23	3%
KC-135T	322.5	119.23	2%
Total			22%

FIGURE 4
C-17 LOAD FACTOR AND FEI

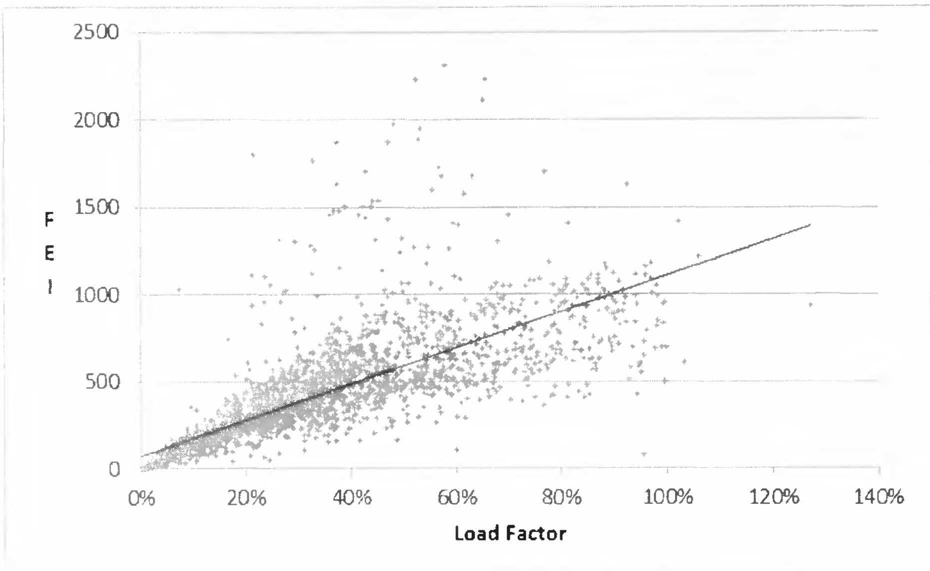
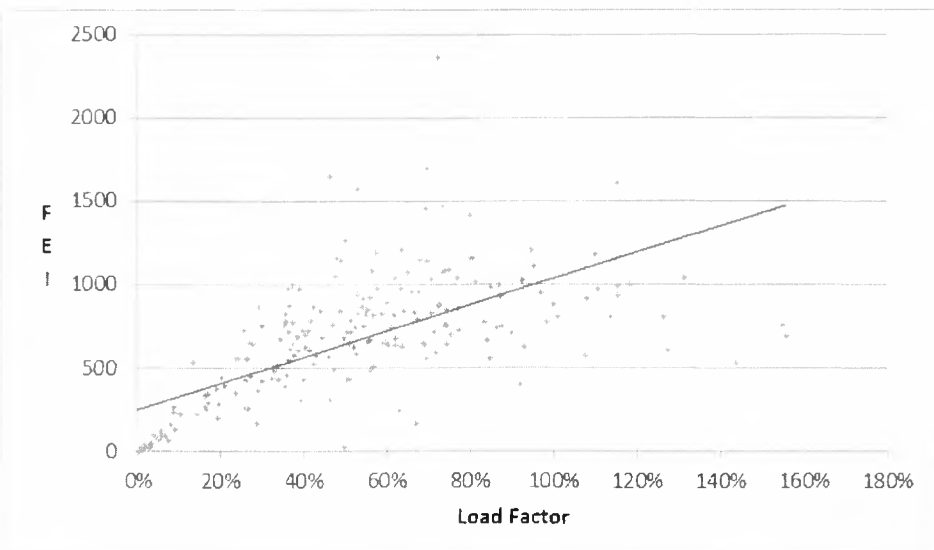


FIGURE 5
C-5 LOAD FACTOR AND FEI



than industry by a factor of 3. This illustrates the need for the operationalization of the load factor metric into Air Mobility Command planning, command and control. Each sortie's load factor needs to be highlighted when the value falls below a firm's specific threshold. Load factor feedback control systems can have a positive impact on the fuel efficient operation of the enterprise.

Strategic airlift airframes were selected from the data for more detailed analysis. To better understand the impact of load factors on FEI, load factors were plotted against FEI for both the C-17 and the C-5 as seen in Figures 4 and 5. In both cases, a positive correlation is seen between increasing load factors and the FEI. Overall, there exists a 74% correlation between load factor and FEI. This is almost twice as large as the 44% correlation with GCD. There are several data points outside 100% load factors. These are suspected to be due to waivers that allow for loading more cargo than Maximum Gross Takeoff Weight. One other item of note is the increasing variance of FEI as load factors increase. This was also apparent in the analysis of GCD.

INACTIVE SORTIES

Aircraft often need to reposition to pick up cargo and deposition after delivering cargo. This reduces load factors by driving up the number of no cargo sorties. It also reduces FEI due to the zeroing of the numerator. Inactive sorties drive the desire to either stage aircraft out of heavy cargo and passenger requirement locations or to select aircraft that are nearest to the cargo and passenger requirement onload or offload locations. A metric that is proposed to handle the efficiency of aircraft selection to meet this requirement is inactive miles per inactive sortie as seen in equation (10). An inactive mile is defined as a mile flown to position an aircraft at a cargo onload location or to deposition an aircraft from a cargo offload location. An inactive sortie is a sortie composed of inactive miles. The behavior desired is to drive aircraft staging to where the cargo is located or to select an aircraft for a mission that is closest to the cargo onload and offload.

TABLE 5
AIR MOBILITY COMMAND INACTIVE MILES PER SORTIE NOVEMBER 2010

	Inactive Sorties	Inactive Miles	Inactive Miles Per Sortie
C-17A	960	1186113	1236
C-5A	33	27453	832
C-5B	98	129808	1325
C-5M	2	5188	2594
C-130E	40	18876	472
C-130H	49	47441	968
C-130J	31	29748	960
KC-10A	37	88638	2396
KC-135R	77	163989	2130
KC-135T	7	7493	1070
Average			1398

$$Inactive\ Miles\ per\ Sortie = \frac{\sum_{i=1}^{n} Inactive\ Miles_i}{n},$$

$$where\ n = \#\ of\ inactive\ sorties \quad (10)$$

FIGURE 6
C-17 FUEL CONSUMED AND FEI

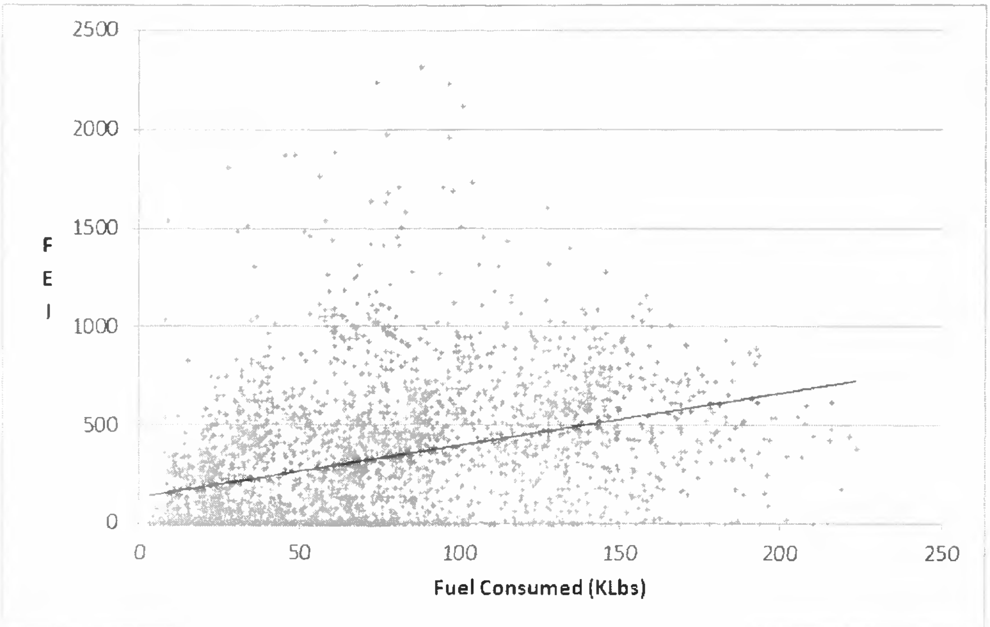
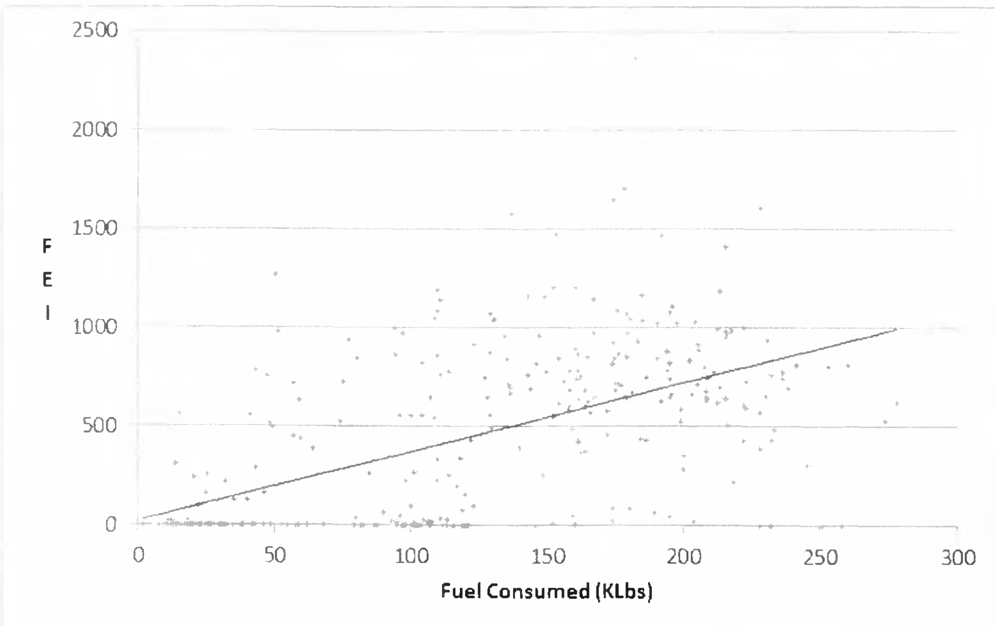


FIGURE 7
C-5 FUEL CONSUMED AND FEI



The results of the inactive miles per sortie analysis on an MDS basis for Air Mobility Command can be seen in Table 5. The tankers have to travel the longest to get their requirements. Inactive miles appear to decrease with aircraft size after that. Although this metric is broken down on a per MDS basis, it could be analyzed on a departure airfield basis to discover which units have the farthest to travel for positioning and depositioning. From these results, insights into potential staging opportunities could be an area for further research.

FUEL

After examination of the effects of Great Circle Distance and Load Factors on FEI, the final variable that is part of FEI is fuel consumed. An examination of fuel consumed against FEI was plotted in Figures 6 and 7. To aid in visibility for the C-17 plot, three outliers were removed. The expected behavior is that as fuel consumed increases, FEI should decrease. The opposite occurs in actuality. There are two suspected reasons for this. First, there is a 78% correlation between GCD and fuel consumed and the FEI increase associated with increasing GCD outweighs the additional fuel burned. Second, sorties with higher load factors burn more fuel. A potential solution to provide greater sensitivity to fuel consumed would be to square the fuel consumed in the denominator of the FEI equation.

When extra fuel is carried on board an aircraft, the added weight of that fuel burns additional fuel unnecessarily. Due to this cost of carrying additional fuel, it is often desired to ensure that no more fuel is added to a mission than planned. This illustrates the need for a metric that represents fueling accuracy as seen in equation (11). In addition to reducing the cost to carry fuel, it is often desired to have the aircraft fly the most fuel efficient flight profile. This is

$$Fueling\ Accuracy = Max\left(0, Min\left(1, 1 - \frac{actual\ fuel\ load - planned\ fuel\ load}{planned\ fuel\ load}\right)\right) \quad (11)$$

$$Fuel\ Burn\ Ratio = \frac{planned\ fuel\ burn}{actual\ fuel\ burn} \quad (12)$$

TABLE 6
FUELING ACCURACY AND FUEL BURN RATIO

	Average Fueling Accuracy	Average Fuel Burn Ratio
C-17A	97%	1.03
C-5A	95%	0.98
C-5B	98%	0.98
C-5M	100%	1.02
C-130E	100%	1.00
C-130H	99%	1.01
C-130J	93%	1.11
KC-10A	96%	0.98
KC-135R	92%	1.00
KC-135T	97%	1.00

complicated by load factors and distances involved. To remove these and other sortie specific factors, a contrast could be made between a planned fuel burn and the actual fuel burn. To drive this behavior, equation (12) measures a planned over actual fuel burn ratio. The goal of the metric is to maximize the ratio by minimizing actual fuel burn.

Differences between planned and actual fuel burn are subject to multiple variables. Many of these variables are outside of the pilot's control while some can be manipulated. Variables outside of the pilot's control include winds different than planned, achievable altitude below planned, icing/thunderstorms/turbulence altering routings and/or altitude and decreased engine performance. Variables within the pilot's control include throttle setting, not flying planned routings and altitudes (not influenced by external constraints) and climb/descent profiles. Since the ratio of planned fuel burn to actual fuel burn does not distinguish between aspects of fuel burn that are within the pilot's locus of control, the metric could be unjustly punitive. Despite this drawback, the metric does distinguish discrepancies from planned fuel burn and drives behavior to lower fuel burn. Air Mobility Command data for average fueling accuracy and average fuel burn by aircraft can be seen in Table 6.

From the table, note the high fueling accuracies. These high accuracies are due to the way the planned ramp fuel is calculated. The Air Mobility Command Fuel Data Tracker will set the planned ramp fuel equal to actual ramp fuel if the ramp fuel deviation reason was outside of the pilot's control. This aids in unjust attribution, but skews the data toward the high end of accuracy. The fuel burn ratio provides little information from an aircraft perspective. It might suggest something about the quality of the fuel planning or it could be a sign of something cultural in that aircraft's community. The fuel burn ratio could be more effectively used by comparing organizational units. It could also be used to compare pilots.

MANAGERIAL IMPLICATIONS FOR CITY PAIR ANALYSIS

FEI increased with GCD, load factor and fuel consumed. To get a better understanding of the sensitivity of FEI to load factor and fuel consumed, a specific city pair was selected.

FIGURE 8
KDOV-ETAR C-17 LOAD FACTORS AND FEI

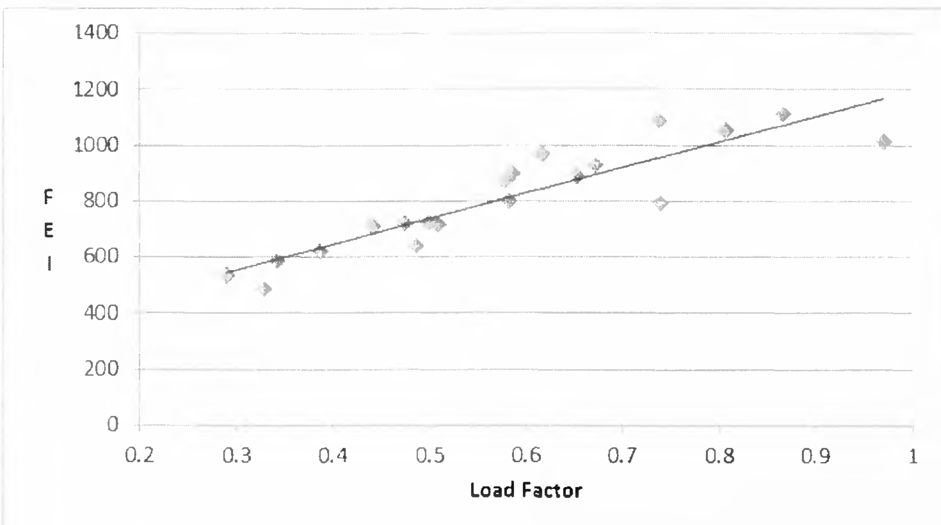
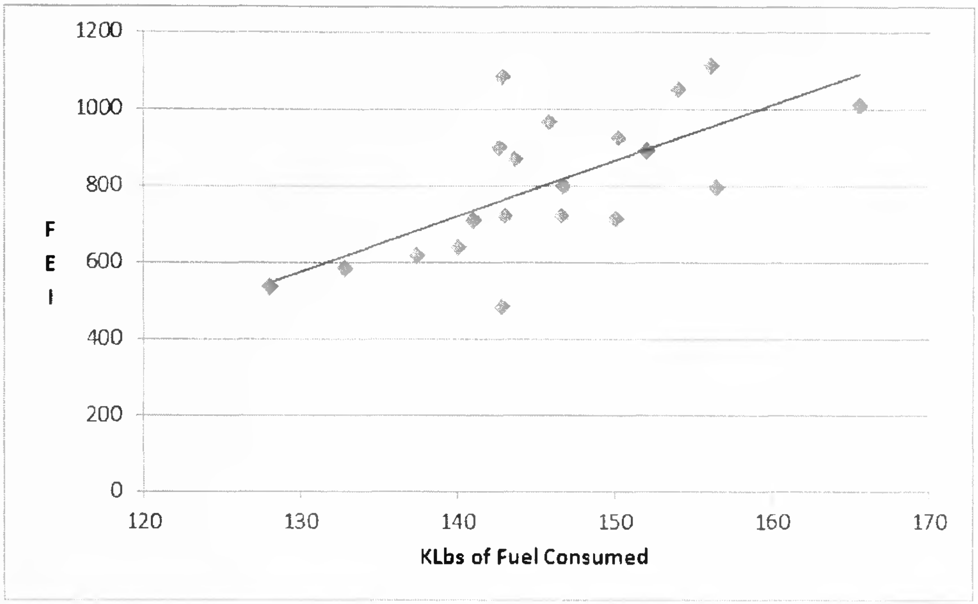


FIGURE 9
KDOV-ETAR C-17 FUEL CONSUMED AND FEI



This enabled distance to become constant leaving cargo and fuel as the remaining variables. Dover to Ramstein was a common city pair in the data set with 20 observations. Note that managing FEI by city pair might be time consuming and effort should be concentrated on frequent city pairs. C-17s were selected for the analysis to further constrain the variables by limiting aircraft type. The results can be seen in Figures 8 and 9.

Figure 8 shows how the amount of fuel consumed varies for a fixed distance and load factor, while Figure 9 shows how the amount of cargo varies for a fixed distance and fuel consumed. The Figure 8 relationship is useful for managers in that it identifies sorties that deviate from previous observations based on fuel efficiency. The ability to identify sorties that exceed a predetermined interval on the regression of that city pair could highlight outliers in both fuel efficiency and fuel inefficiency. In depth analysis of those outliers in terms of root cause could expose opportunities for greater fuel efficiency. Specific aircraft tails or aircrews might repeatedly occur outside the interval representing the need for possible remedial action.

From Figure 8, note the tight scatter of points about the simple linear regression. The R^2 for this regression is .82. This indicates that load factor when constricted by city pair explains most of the variability in FEI. Figure 8 also aids in understanding that to target an FEI near 1000 requires an 80% load factor. From Figure 9, note that the points have much greater variance about the line. The R^2 for this regression is .45. This indicates that fuel consumed when constricted by city pair explains only 45% of the variability in FEI. Taking a vertical slice of Figure 8 shows load factor replicates with the variance between the data points being explained by fuel consumed. Using a band about the regression line for a city pair in Figure 8 could highlight missions that consume too much or too little fuel contrasted against the aggregate. Further analysis into those missions could potentially highlight fuel savings opportunities.

INCORPORATING METRICS INTO THE AVIATION INDUSTRY FUEL EFFICIENCY MODEL

Application of FEI operationally can drive desired behaviors to increase load factors, reduce inactive miles and reduce fuel usage. Reducing fuel consumption might best be addressed through the banding method of the regression line in the Dover to Ramstein example. FEI has value beyond operational application. To obtain the optimal value from FEI, the metric should be applied to all of the components of the Aviation Industry Fuel Efficiency model. The first component of the model requiring the application of FEI is strategic decision making. FEI should be implemented in both the strategic investment and strategic planning components of strategic decision making,

From a strategic investment perspective, the FEI metric can drive aircraft acquisition requirements and allow for innovative paradigm shifts. The FEI minimum for several set distances can be specified as the requirement. Since FEI does not include time as a variable, that should be constrained to a set maximum when building the requirement to avoid solutions that are too slow. FEI also fails to address reliability. The C-5 has superior FEI on average, but suffers from reliability issues. This needs to be addressed when making strategic investments such as aircraft acquisition. Larger aircraft might be superior in terms of FEI, but might suffer mechanically due to their size and complexity. Infrastructure improvements enhancing load factor potential such as pavement strengthening can be assessed based upon FEI impact. Strategic airfield improvements could result in increased cargo flow and more efficient operations. Ranking airfield improvement projects by FEI impact can be an important factor when considering prioritization.

Beyond strategic investment, FEI could be extremely useful in strategic planning. FEI and inactive miles would be very useful for the determination of aircraft basing and staging locations. Those metrics would also be very useful from a theory of constraints perspective by highlighting the least efficient aircraft and mission pairings. Automatically calculating the FEI planning metric once an aircraft has been assigned to the mission and highlighting poor FEIs and inactive miles could provide planning and aircraft allocation functions immediate feedback for correction. Individual planners and aircraft allocators can be held accountable using FEI and inactive miles as performance metrics. Beyond individuals, organizational goals can be established regarding both the FEI and inactive miles.

Implementation of the FEI should extend beyond the firm when the FEI is dependent upon other firms in the supply chain. Suppliers performing functions such as warehousing and distribution that are tied to air mobility should be provided information on their FEI impact. In addition, strategic partnering should be encouraged to enhance load factors. Alliances should be examined that offer the greatest potential to increase the FEI. Shared investments on information technology, automated identification and tracking and cargo distribution equipment might offer FEI improvements that justify the acquisition. Suppliers need to be properly rewarded for their investments to enhance FEI.

Strategic decision making and supply chain fuel efficiency can be greatly improved through the use of the FEI. Yet, there are areas of improvement in FEI that can only be achieved by those operational workers executing the process. To reap those benefits, FEI needs to be embedded into organizational culture. Attempting to embed a metric into organizational culture and simultaneously using the metric as a tool for accountability is difficult. The problem is that individuals tend to rebel against punitive metrics. For acceptance, it is preferred to use the metric in a positive role until it becomes accepted as part of the organization. It is important to include the metric when measuring operations at every level. Obtaining leadership support for the metric is essential. FEI needs to be presented at senior level meetings and included in organizational goals. Finally, FEI should be part of the reward structure for promotion for factors within the individual's control. This could include individual awards for sustained high FEI performance to highlighting the metric during promotion discussions.

FINDINGS AND CONCLUSION

The Aviation Industry Fuel Efficiency model presents a framework for transforming fuel efficiency into a sustained competitive advantage. This is achieved through the use of the dynamic capabilities of strategic decision making and alliancing. In addition to those dynamic capabilities, the model recommends ingraining fuel efficiency into the organizational culture. To assist the manager in implementing the model, the FEI was introduced. The FEI drives desired behaviors to increase load factors, decrease inactive miles and reduce fuel consumed. Other metrics were suggested to further assist the manager in improving fuel efficiency behaviors to include load factors, inactive miles per sortie, fueling accuracy and fuel burn ratio. It is important to measure load factors from both a weight and cube perspective, to obtain a better understanding of the efficiency of operations.

Measuring FEI operationally can drive behaviors toward increased fuel efficiency, but application of the FEI to the model is where a firm can leverage much greater fuel efficiency benefits. Extending the FEI to strategic decision making, supply chain partners and the organizational culture will allow the firm's fuel efficiency focused resources to not be easily imitated. There are certain risks associated with greater fuel efficiency integration within the supply chain and strategic fuel efficiency investments. These risks need to be thoroughly analyzed. There are also risks to not integrating or not investing in an environment of rising fuel prices. Following a fuel efficiency strategy will make the firm and the firm's supply chain less susceptible to rising fuel prices. A fuel efficiency strategy will also increase a firm's ability to compete on price.

The FEI ties together all of the components of the model. It enables individual, organizational, corporate, supply chain and industry goals to align. This common sense of purpose can only be achieved if the metric is valued equally. FEI could support aircraft manufacturers, distribution centers, command information systems, planning systems and allocation. Much as a low cost retailer is less susceptible to economic downturns, a fuel efficient firm in the aviation industry is less susceptible to fuel price increases. A fuel efficiency strategy is a risk reduction strategy with opportunities for expert practitioners to obtain a sustained competitive advantage.

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