The effects of giving Captains feedback and targets on SOP fuel and carbon efficiency information: Results of the Virgin Atlantic University of Chicago and London School of Economics *Captains' Study*

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Executive Summary

Context: This study came about because of Virgin Atlantic Airways' (VAA) dual business drivers: 1) improving fuel and carbon efficiency – VAA's Change is in the Air[i] (CIITA) sustainability programme's number one environmental priority, and 2) reducing costs. As there is a direct relationship between aircraft fuel use, carbon emissions and costs, any improvements represent a double win for the company. Many teams at VAA have been focused on fuel- and carbon-efficiency measures for quite some time. This study represents the next step in this journey, in which the Fuel Efficiency and Sustainability teams at VAA partnered with academics from the University of Chicago (UC) and London School of Economics (LSE) to study the effectiveness of different strategies to deliver existing standard operational procedures (SOP) fuel and carbon efficiency information to Captains. The study was conducted day-to-day by the Fuel Efficiency team at VAA HQ UK, using data provided via its fuel monitoring systems, which they summarised and sent to Captains. Anonymised analysis and reporting was undertaken in full by the university team.[ii] This summary was written collaboratively by the VAA and university teams.

Main objectives: To evaluate the effectiveness of providing feedback, targets, and charitable incentives to Captains, on the implementation of fuel- and carbon-efficient procedures, as already approved for use in VAA's standard operational procedures (SOPs). A second objective was to investigate the effects of any behaviour changes on fuel use, carbon emissions and costs. Finally, Captains' satisfaction with the study was explored using a short (optional) online study debrief survey.

Study design: A four-arm randomised controlled trial (RCT)[iii], followed by anonymised satisfaction survey.

Participants: All eligible Captains (N=335) at VAA were notified of the study and randomised to one of the four groups below. There is normally one Captain on each VAA flight, each of whom works with one or more Senior First Officers (SFOs) or First Officers (FOs). The Captain retains overall responsibility for the flight, including following the SOPs that affect fuel and carbon efficiency. Hence, the Captain was chosen as the 'unit of randomisation' in the study. As there is usually only one Captain per flight, 'contamination' across groups was limited ('contamination' is the effect whereby Captains might talk directly with each other about their own intervention group, potentially watering down the observed differences across groups).

Interventions and comparisons: Captains were randomly allocated to one of four groups:

- **Group 1 – Control**: this group carried on with business-as-usual (BaU), with access only to information provided through VAA's SOPs documentation, which includes information on fuel efficiency procedures;
- **Group 2 – Information**: this group received monthly tailored feedback on their performance on the SOP behaviours described below;
- **Group 3 – Targets** (information + targets): this group received the same information as above, alongside information about their attainment of expected targets for that month;
- **Group 4 – Charity** (information + targets + charitable incentives): this group received the above information and targets plus a charitable donation incentive for each target met every month.

Targeted behaviours: The interventions aimed to improve Captains' implementation of three fuel-and carbon-efficient behaviours: (i) pre-flight Zero Fuel Weight adjustments (ZFW) for loaded weight, (ii) a range of in-flight Efficient Flight procedures (EF), and (iii) post-flight Reduced Engine Taxi-in (RET) to the gate. All information and targets applied to these three behaviours.

Procedures: Pilot unions, pilot managers and an experienced group of Captains were consulted during the design of the study. An initial study information sheet was sent to all VAA Captains prior to the study intervention period, which explained the aims and objectives and the RCT design. Once a month, over an eight-month period from Feb-Sep 2014, all Captains in Groups 2, 3, and 4 received personalised information by post. At the end of the intervention period, all Captains were sent a confidential follow-up study debrief questionnaire. Anonymised results were analysed by the university team.

Data and analysis: Thirteen months of pre-intervention data, eight months of intervention-phase data and six months of post-intervention data was collected, allowing for pre-post intervention analyses of the three target behaviours across all four groups. The study was designed (powered) to detect changes of approximately 3% in implementation of the above three behaviours with statistical significance (i.e. with a probability 'p-value' of 0.05, i.e. only 5% chance that any observed statistical differences were found by chance). Overall, over 40,000 unique flights and 110,000 Captain-level behavioural observations were analysed using econometric methods (regression analysis) that controlled for several individual- and flight-level variables — such as weather and aircraft flown — for each flight. This analysis compares differences across *changes* in captains' behaviour due to the intervention. For example, if Captains in the Control group increased implementation of ZFW by 5% of flights on a monthly basis, and Captains in the Information group increased implementation of ZFW by 12% of flights on a monthly basis, we would say the Information intervention had an 'intervention effect' on ZFW implementation of +7% of flights. This method allows for detection of intervention effects even when Captains in the Control group also change their behaviour. This is important since all Captains were aware their behaviours were being monitored and may have been more inclined to focus on those behaviours in their decision-making.

We also explored the study effects on fuel consumption, CO_2 emissions and costs, using a data-driven approach. This approach takes account of fuel savings derived directly from the data, i.e. the effects of the study on Captains' actual fuel use in comparison to their pre-intervention use.[iv] Interestingly, we found that all Captains — including those in the Control group — increased their fuel efficiency due to awareness of the study (a well-known phenomenon known as the Hawthorne effect, where people change their behaviours because they know they are being observed). We determined these average savings per flight across all Captains, then identified those additional savings resulting directly from the interventions. Finally, we multiplied the total number of flights flown during intervention across all groups by the Hawthorne effect, and added the intervention-specific fuel savings to each respective study group. To calculate cost and environmental savings, we multiplied the calculated fuel savings by the price of fuel ($786/tonne, February 2014, IATA) and of CO_2 ($37/tonne, US EPA).

Finally, we investigated Captains' levels of satisfaction with the study by asking the standard job satisfaction question from the British and German Socioeconomic Panel surveys, which asked Captains to rank their overall satisfaction with their jobs on a scale from 0 to 10. We compared average job satisfaction across groups using standard t-tests for difference.

Outcomes: We found that all intervention groups implemented each fuel-efficient behaviour on a larger percentage of flights than the Control Group. Groups 3 (Targets) and 4 (Charity) were the most effective interventions, increasing implementation of EF (3-5%) and RET (8-10%) with high statistical confidence and a non-statistically significant change of 2-3% in ZFW.

We calculated that the study overall saved a substantial amount of fuel and CO_2. The calculated **fuel savings of approximately 6,828 tonnes**[v] correspond to a **value saving of £3,309,489 for VAA** at the time of the study (>£1 million at current fuel prices). They are also equivalent to environmental savings of **21,507 tonnes of CO_2** (independently valued at £490,739).[vi] Most of the fuel and carbon savings (6,123 tonnes and 19,287 tonnes respectively) can be attributed to Captains' awareness of being monitored (i.e. the Hawthorne effect). However, the interventions (Groups 2 – 4) resulted in additional savings of 704 tonnes of fuel and 2,218 tonnes of carbon dioxide (CO_2), i.e. beyond the Hawthorne effect.

This represents a marginal abatement cost (MAC) of *negative* \$250 per ton of CO_2 (i.e. \$250 savings per tonne CO_2 saved) from the interventions (Information, Targets, Charity) over the eight-month intervention period. This MAC of -\$250 per tonne of CO_2 *not emitted* is the lowest ever observed and twice as cost-effective as that reported as the most cost-effective way to reduce CO_2 (i.e. installing LED light bulbs in the residential sector). (N.B. This calculation does not include any of the business costs of setting up and running a study like this.)

These numbers also do not include any additional fuel savings that have resulted since the intervention period ended in October 2014 (although there certainly were positive long-term effects observed in the data).

Finally, 64% of Captains took part in the post-study satisfaction survey. Those in intervention Groups 2, 3, and 4 reported higher levels of job satisfaction, while 81% of those taking part in the survey said they'd like to receive more fuel and carbon efficiency information in future. This suggests that this study not only led to increased fuel efficiency, but also increased Captain satisfaction levels and willingness to be involved in this important issue.

Conclusion: Notifying Captains that fuel efficiency is being studied, as well as providing them with tailored information, targets and feedback, are highly cost-effective methods for changing behaviours and achieving fuel-, carbon-, and cost-savings. This represents a win for the triple bottom line: people, profit, and the environment.

Recommendations: Opportunities for reviewing and further capitalising on the carbon savings offered by this study are now being prioritised. Changes recently implemented by the VAA Flight Operations team (e.g. further upgrades to sophisticated Rolls Royce Controls and Data Services (CDS) fuel monitoring software, and a roll-out of iPads for flight deck teams) mean there are opportunities for even greater savings in terms providing pilots with 'real time' information that can aid their decision making.

The study in more detail

Virgin Atlantic context

Air travel is a fact of modern life connecting businesses, families, and communities. It is closely connected to economic development and brings huge socio-economic benefits. In 2011, an Oxford Economics report suggested that UK aviation alone contributed nearly £50 billion (3.6%) to UK GDP. In the last financial year (2015), Virgin Atlantic Airways' (VAA) own turnover was nearly £2.8 billion (profit £22.5 million), and the airline directly employs around 8,000 people. At the same time, air travel is clearly carbon-intensive, as such the aviation industry has been addressing its role in climate change for quite some time. In a ground-breaking move in 2009, airline industry body the International Air Transport Association (IATA) agreed carbon reduction targets among its diverse membership and intense international negotiations are currently underway to secure a global deal for carbon neutral growth (CNG), with UN body the International Civil Aviation Organization (ICAO) currently negotiating with national governments.

As for VAA, it was an early mover in aviation on environmental issues. In 2007, it launched its own 'Change is in the Air' (CIITA) sustainability programme, in which priorities and targets for CO_2 efficiencies and a range of other environmental and social issues were set out[vii]. It also was a founding member of the organisation Aviation Global Deal, an early advocate of a global carbon deal for the industry.

And as an airline, VAA is clear that its number one environmental priority is reducing carbon emissions, with an ambitious target to reduce its aircraft CO_2 per Revenue Tonne Kilometre[viii] (RTK) by 30% by 2020.

Latest published figures (2014 data) show that VAA achieved a *10% reduction in CO_2 per RTK from 2007 to 2014,* and an *absolute reduction of 12% in CO_2e (all GHG) emissions from aircraft operations* during the same time period.[ix]

Many teams at VAA have been working hard on fuel and carbon efficiency measures for years, successfully implementing operational changes across the business, more recently using a sophisticated fuel monitoring system provided by Rolls Royce Controls and Data Services (CDS). This system has enabled VAA to more accurately calculate the savings from more efficient A330s and B787s coming into service. Combined with strategic route planning to maximise load factors, data suggests these are about 30% more efficient than the aircraft they have replaced on the same routes. The total savings are indicated in our headline CO_2 figures above. Additional savings are expected, as more 787s come into service and less-efficient aircraft are retired.

Because aircraft fuel use represents such a large part of an airline operational costs and CO_2 footprint, even fractions of a per cent savings can quickly add up to something significant. Optimising the way aircraft are flown can increase efficiencies, which is why VAA pilots routinely receive information on efficient operational techniques in their manuals, as part of their standard operating procedures (SOPs). In addition, for some time VAA had been exploring how to better engage with pilots on these measures, as it seemed likely not all opportunities had been fully explored.

VAA's Head of Sustainability, Emma Harvey, previously worked as an academic in evidence-based practice. In this discipline, evidence from medical and social sciences in the form of randomised controlled trials (RCTs) clearly shows that even expert practices can usually be improved by providing professionals with the best quality information, in the right way. Therefore, when approached by funded and experienced university researchers with a track record in evidence-based behavioural economics, she viewed it as an excellent opportunity to pursue the organisations' shared objectives around sustainability employee engagement.

Dr Robert Metcalfe (University of Chicago, UC), Professor John List (UC), and PhD researcher Greer Gosnell (London School of Economics, LSE) are economists experienced in the design, implementation, and analysis of RCTs to improve business practice.[x] After having secured academic research funding from the Templeton Foundation, they approached VAA in autumn 2012 seeking to collaborate on a joint undertaking to improve employee engagement on sustainability. Given VAA's environmental priority to improve fuel and carbon efficiency, and with awareness of other established initiatives, Dr Emma Harvey suggested that working more pro-actively with pilots could be the place to focus.

Next, a proposal was put to VAA's then Operations Director Corneel Koster and the VAA Fuel Efficiency Governance Group (FEGG) he Chaired, and together with a select internal team in Flight Operations (Dave Kistruck, General Manager Flight Operations; Claire Lambert, Fuel Efficiency Manager; and Paul Morris, Fuel Efficiency Analyst) an initial study of pilots' involvement in fuel and carbon efficiency was outlined. Following discussions and consultations with pilot managers and unions, a Captain consultation meeting was held in November 2013, in which a panel of experienced VAA Captains reviewed the initial study rationale, design, and materials and helped to make a number of improvements.

Claire Lambert and Paul Morris were responsible for working with the academic researchers during the study in order to ensure the highest standard of intervention and data fidelity. During the 8 month intervention period, the Fuel Efficiency Team supported the researchers as subject matter experts, managed the (anonymised) data flow between CDS and the researchers, manually distributed over 4,000 personalised reports and study details and provided detailed, timely feedback to all individual pilot queries.

Study overview

The main objective of the study was to evaluate the effectiveness of providing information, targets, and charitable incentives on changing (where possible) three sets of Captains' fuel- and carbon-efficient behaviours, in line with existing SOPs. A secondary objective was to explore the effects of any behaviour changes on fuel use, carbon emissions and costs. Finally, Captains' satisfaction with the study was explored.

To meet the objective, each eligible Captain on VAA's roster (N=335) in 2013 was randomly allocated into one of the four study groups outlined below. The interventions aimed to increase Captains' implementation of three fuel- and carbon-efficient behaviours: (i) pre-flight Zero Fuel Weight (ZFW) adjustments, i.e. final fuel calculations according to loaded weight, (ii) a range of in-flight Efficient Flight (EF) procedures, and (iii) post-flight Reduced Engine Taxi-in (RET) to the gate. All information and targets applied to these three behaviours.

The four groups to which Captains were randomly assigned were:

- **Study Group 1 – Control**: this group carried on with business-as-usual (BaU), i.e. access to information in VAA's SOPs documentation in pilot manuals, including that relating to fuel efficiency;
- **Study Group 2 – Information**: this group received monthly tailored feedback on their performance on the SOP behaviours described above;
- **Study Group 3 – Targets** (information + targets): this group received the same information as above, alongside information about their attainment of expected targets for that month;
- **Study Group 4 – Charity** (information + targets + charitable incentives): this group received the above information and targets plus a charitable donation incentive for each target met per month.[xi]

Captains were randomly allocated into these four groups such that each group comprised a similar composition of Captains in terms of pre-study fuel efficiency, aircraft flown, and demographics. All Captains were provided with summary information of the study in January 2014, and those in Study Group 1 (Control) received no further communication until after the study was complete. All other Captains received monthly personalised feedback reports, as letters to their home address, in accordance with the above, from February to September 2014.

During this time, Captains in Study Group 4 (Charity) were free to elect a charity from a shortlist, and £10 was donated to charity on their behalf, for each of the three target behaviours met in a given month. Over the course of the study, £12,265 was donated to charity, £6,670 of which went to Virgin Atlantic's charity partner, Free the Children. This money was distributed directly to the selected charities on behalf of the Captains from the university team's Templeton Foundation grant budget.

Data and analysis: During the study, the VAA Fuel Efficiency team were supported by Rolls Royce CDS who provided bespoke data downloads to VAA on a monthly basis. The complete dataset consists of 42,012 flights, and 110,489 observations of behaviour from January 2013 through March 2015 for the Captains sampled. However, a third of RET data (15,547 observations) was not captured by the system due to technical issues and is missing from the analysis for RET only. The reason for the missing data is entirely random and cannot be influenced by Captains, so this phenomenon should not affect the results beyond reducing the power of the estimates.

Among other variables, we observed fuel (kg) on-board the aircraft at four discrete points in time: departure from the outbound gate, take-off, landing, and arrival at the inbound gate. In addition, we observed fuel (kg) passing through each of the aircraft's engines during taxi, which provides a precise measure of fuel used while on the ground. We also observed flight duration, flight plan variables (i.e. expected fuel use and flight duration) and aircraft type. These were used as control variables in the econometric panel regression model, which constitutes a within-Captain analysis using several flight observations for each Captain.

To explore the relationships between pilots' assigned intervention group, fuel-efficient behaviours and fuel consumption, the university team used a statistical method called regression analysis. This method explores the relationships between 'independent variables' (here, the Captains' study group status, and a range of control variables such as weather, departure and arrival airports, day of the week, etc) and 'dependent variables' (in this case the fuel-efficient behaviours and the amount of fuel used). Flight-level data from January 2013 through January 2014 was used as the pre-intervention period, and February 2014 to September 2014 as the intervention period.

Two simultaneous comparisons were made in the analysis: (i) pre-intervention period versus intervention period (within-Captain comparison); (ii) control group versus study groups (between-Captain comparison). These two comparisons provide a standard 'difference-in-differences' estimation, which allows comparisons of each Captain's performance prior to intervention to his or her performance during intervention (within-Captain), and compares *changes* in performance of Captains in the control group to *changes* in performance of Captains in the active intervention groups.

Changes were observed across all three behaviours in all study groups, including the Control group, that is, substantial behaviour change resulting from a phenomenon well-documented in the social sciences, known as the Hawthorne effect – whereby people change their behaviours as a function of being observed. In addition, the analysis identified the incremental behaviour change in the active intervention groups (i.e. over and above this observed change in the Control group). For example, say Captains in the Control group increased implementation of ZFW by 5% of flights on a monthly basis and Captains in the Information group increased implementation of ZFW by 12% of flights on a monthly basis, it would be said the Information had an 'intervention effect' on ZFW implementation of +7% of flights. (A full account of the methods is provided in the academic paper and a review of the difference-in-differences estimation procedure is presented here: http://www.nber.org/papers/w22316).

The study effects on fuel consumption, CO_2 emissions and costs were also explored using a data-driven approach. This approach took account of fuel savings derived directly from the data, i.e. the effects of the study on Captains' actual fuel use in comparison to their pre-intervention use.[xii] Average savings per flight for all Captains within a given study group were determined, then multiplied by the number of flights flown during the intervention period, in each respective study group. To calculate cost and environmental savings, we multiplied these savings by the price of fuel ($786/tonne, February 2014, IATA) and of CO_2 ($37/tonne, US EPA).

Finally, Captains' levels of satisfaction with the study were investigated by the university team, by administering the standard job satisfaction question from the British and German Socioeconomic Panel surveys in which Captains were asked to rank their overall satisfaction with their jobs on a scale from 0 to 10. Average job satisfaction across groups was compared using standard t-tests for difference.

Results

i. Behaviour change

The interventions evaluated in Groups 2, 3, and 4 appear to have caused a clear improvement in the targeted behaviours, over and above those changes observed in the Control Group.

As shown in Figures 1-3 and Table 1, attainment of Captains in the Control Group is several percentage points below the least effective intervention group, for each of the three behaviours, with Captains in Study Groups 3 (Targets) and 4 (Charity) achieving the behaviours most frequently. Below, in Table 1 we provide the data used to generate Figures 1-3 for each of the behaviours, in each of the study groups, before, during, and after intervention. The orange brackets indicate standard errors of the means (a standard measure of statistical variability – the shorter the orange bracket, the higher degree of confidence we have in the presented mean of each respective bar).

Figures 1-3 and Table 1 highlight the large changes in behaviour during the intervention period. These changes appear to have some durability after the intervention phase ended. We see that under all circumstances, the 'during study' bars are higher than the 'before study' bars, indicating improvements in behaviour based on averages. Additionally, in almost all cases, the 'after study' bar exceeds the 'before study' bar, as well, though ZFW clearly proved to be the most difficult behaviour to influence.

FIGURE 1: ZERO FUEL WEIGHT (ZFW) BY GROUP AND TIME PERIOD

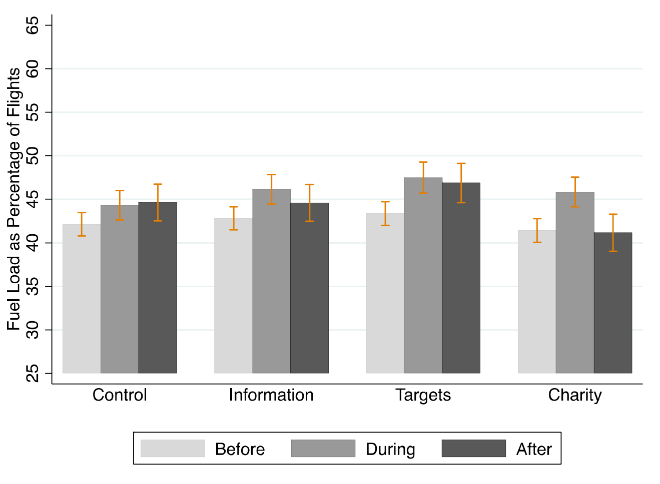


FIGURE 2: EFFICIENT FLIGHT (EF) BY GROUP AND TIME PERIOD

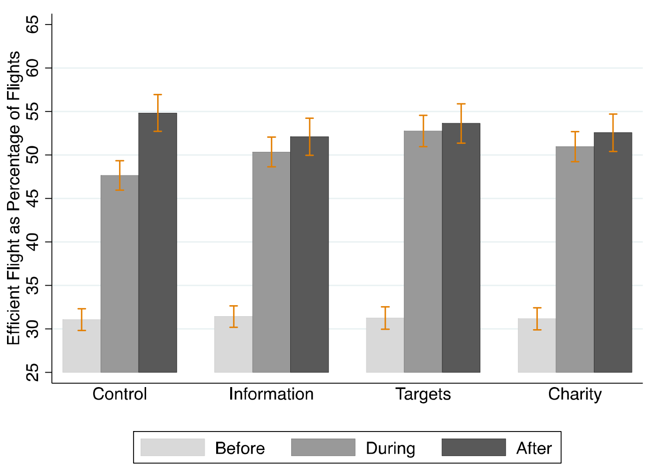


FIGURE 3: REDUCED ENGINE TAXI-IN (RET) BY GROUP AND TIME PERIOD

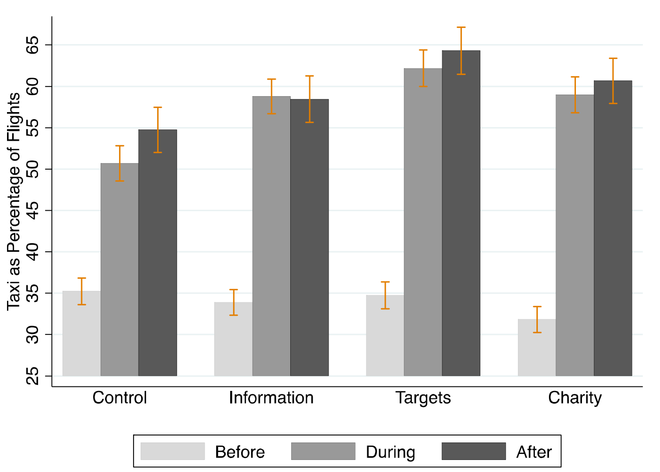


TABLE 1: TARGETED BEHAVIOUR IMPLEMENTATION BEFORE, DURING AND AFTER THE INTERVENTION PHASE

	Control Group	Information Group	Targets Group	Charity Group
ZFW				
Pre-intervention	42.1% [5,258]	42.8% [5,429]	43.4% [5,070]	41.4% [5,140]
Intervention period	44.3% [3,321]	46.2% [3,330]	47.5% [3,016]	45.8% [3,258]
After intervention	44.6% [2,140]	44.6% [2,120]	46.9% [1,867]	41.2% [2,063]
EF				
Pre-intervention	31.1% [5,258]	31.4% [5,429]	31.3% [5,070]	31.2% [5,140]
Intervention period	47.6% [3,321]	50.3% [3,330]	52.8% [3,016]	51.0% [3,258]
After intervention	54.8% [2,140]	52.1% [2,120]	53.6% [1,867]	52.5% [2,063]
RET				
Pre-intervention	35.2% [3,380]	33.9% [3,596]	34.8% [3,260]	31.8% [3,341]
Intervention period	50.7% [2,117]	58.8% [2,109]	62.2% [1,864]	59.0% [2,014]
After intervention	54.7% [1,277]	58.5% [1,201]	64.3% [1,090]	60.7% [1,218]

Notes: The total flight numbers for each group is in parentheses. No statistical analysis is provided on these numbers because they merely represent the proportion of flights for which each behaviour was met in each phase of the study. That is, they do not account for the correlation (relationship) between flight observations within a Captain, nor control for any potentially confounding variables that occur across the study phases (e.g. changes in weather or routes).

Table 2 shows the marginal impacts of the Information, Targets, and Charity groups in comparison to the Control group. It is clear that Information alone does not significantly change ZFW or EF (although they improved, we cannot be fully confident that the improvement was a result of the study). The improvements for Targets and Charity are much larger than those in the Control and Information groups. Therefore, while all intervention groups implemented each fuel-efficient behaviour on a larger percentage of flights than the Control Group, Groups 3 (Targets) and 4 (Charity) are the most effective interventions, increasing implementation of EF (3-5%) and RET (8-10%) with high degree of statistical confidence, and a non-statistically significant change of 2-3% in ZFW.

TABLE 2: INTERVENTION EFFECTS: INCREASES IN THE PERCENTAGE OF FLIGHTS ON WHICH EACH BEHAVIOUR WAS IMPLEMENTED (I.E. OVER AND ABOVE THE HAWTHORNE EFFECT) DURING THE INTERVENTION

	Information Group	Targets Group	Charity Group
ZFW	0.7%	2.1%	2.5%
EF	1.7%	3.7%**	4.7%***
RET	8.1%***	9.7%***	8.9%***

Notes: *,**,*** denote statistical significance at the 10%, 5%, and 1% levels, respectively. (A 10%, 5% and 1% level means there's a 10%, 5% or 1% chance of the statistical difference having been observed by chance. That is, all offer a reasonably high level of certainty, but the 1% level provides the most confidence in the results). The tests of statistical differences are between the pre-intervention period and the intervention period and between the control groups and the respective study groups. These differences were estimated whilst controlling for weather on departure and arrival, number of engines on the aircraft, aircraft type, ports of departure and arrival, aircraft maintenance, captains' contracted hours, and whether the captain has completed training.

i. Fuel savings

Calculations indicate that the study overall saved a substantial amount of fuel and CO_2. The calculated **fuel savings of approximately 6,828 tonnes**[xiii] also correspond to a **value savings of £3,309,489 for VAA** at the time of the study (still more than £1 million at current fuel prices). The fuel savings are equivalent to environmental savings of 21,507 tonnes of CO_2 (valued at £490,739).[xiv] Most of the savings (6,123 tonnes) can be attributed to Captains' awareness of being monitored, i.e. large fuel and carbon savings were observed in all four groups (i.e. the Hawthorne effect). However, the intervention groups (Groups 2 – 4) resulted in additional combined savings of 704 tonnes of fuel and 2,218 tonnes of carbon dioxide (CO_2), i.e. over and above the Hawthorne effect.

The data-driven estimates in Table 3 show the fuel savings during the intervention period, in each of the four groups, for each of the three behaviours, relative to fuel use before intervention. The university team used regression analysis to determine the amount of within-group fuel savings from ZFW (i.e. not *whether* captains met the ZFW requirement, but the actual *difference* in fuel uptake relative to 'ideal' uptake). To calculate fuel savings within each group, the savings from the Hawthorne effect were allocated according to the proportion of flights flown in each group, then added on the respective intervention group savings for Groups 2 – 4. Similar calculations were performed for EF and RET.

TABLE 3: DATA-DRIVEN ESTIMATES OF FUEL SAVINGS (IN TONNES) DURING THE INTERVENTION PHASE

	ZFW	EF	RET	Total	Per Flight
Group 1: Control	-425***	-1,146***	-1	-1,573	-0.474
Group 2: Information	-328***	-1,238***	-12	-1,579	-0.474
Group 3: Targets	-426***	-1,362***	-15	-1,803	-0.598
Group 4: Charity	-521***	-1,368***	16	-1,872	-0.575
TOTAL	-1,700	-5,115	-13	**-6,828**	-0.528

Notes: *** denotes statistical significance at the 1 per cent level. Tests for statistical differences in fuel use from the three behaviours between the pre-intervention period and the intervention period were undertaken. These differences were calculated whilst controlling for weather on departure and arrival, number of engines on the aircraft, aircraft type, ports of departure and arrival, aircraft maintenance, captains' contracted hours, and whether the captain had completed Ops Day training. The largest savings came from ZFW and EF since 99.5% of fuel use was influenced by these behaviours, whereas only 0.5% of fuel was used during taxi-in, on average.

In Table 3, the per flight calculation (right column) accounts for the number of flights flown in each study group (3321, 3330, 3016, and 3258 for the Control, Information, Targets, and Charity groups, respectively, i.e. a total of 12,925 flights). For reference, prior to the intervention period, an average of approximately 68 tonnes of fuel was used per flight. As shown in Table 3, the observed savings in the study groups range from 474 kg to 598 kg of fuel per flight, averaging 528 kg savings per flight.

The largest changes in fuel use came from Groups 3 and 4, though all groups demonstrated substantial savings (the Hawthorne effect). The Targets group demonstrated the highest per-flight savings, which were calculated as the total Group 3 savings divided by the number of flights flown in that group during the intervention phase.

Table 4 provides the breakdown of fuel savings between those resulting from the Hawthorne effect versus the additional effects of the interventions. It also shows the corresponding total fuel, monetary, and carbon savings.

TABLE 4: OVERALL SAVINGS OVER 8-MONTH ACTIVE INTERVENTION PERIOD

	Fuel (tonnes)	Fuel ($)	Fuel (£)	CO_2 (tonnes)	CO_2 ($)	CO_2 (£)
Combined Hawthorne effect (all groups)	6,123	4,813K	2,968K	19,287	714K	440K
Group 2. Information	1	1K	1K	3	0K	0K
Group 3. Targets	374	294K	181K	1,178	44K	27K
Group 4. Charity	329	259K	160K	1,036	38K	23K
Intervention savings	704	553K	341K	2,218	82K	51K
TOTAL SAVINGS	6,828	5,366K	3,309K	21,507	798K	491K

Notes: 6,123 is the combined savings observed across all groups from the Hawthorne effect. If equal numbers of flights had occurred in each group, this figure would be divided by 4 (groups) to get the Hawthorne effect saving per group. However, because there were 3321, 3330, 3016, and 3258 for the Control, Information, Targets, and Charity groups, respectively, the Hawthorne effect is distributed proportionately. The prices of fuel and CO_2 at the time of the study were used, at \$786/tonne and \$37/tonne respectively. 1 tonne of fuel emits 3.15 tonnes of CO_2, and the 30th September 2014 exchange rate of 1 USD = 0.6167 GBP was used.

These numbers do not include any additional fuel savings that have resulted since the intervention period ended in October 2014, although there certainly were positive long-term effects observed in the data.

These savings correspond to a marginal abatement cost (MAC) of *negative* \$250 per ton of CO_2 (i.e. \$250 savings per tonne CO_2 saved) from the interventions (Information, Targets, Charity) over the eight-month intervention period. This MAC is twice as cost-effective as the current most cost-effective means to reduce CO_2 (i.e. installing LED light bulbs in the residential sector).

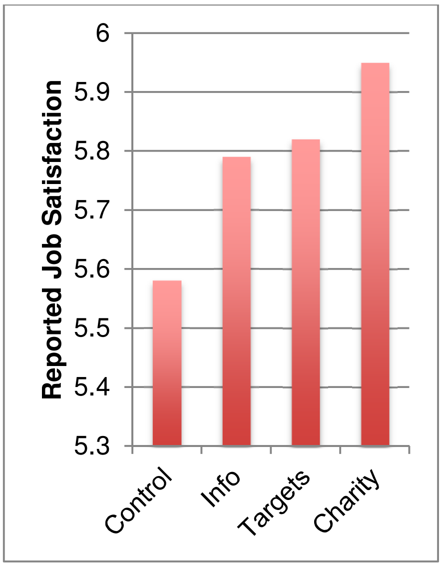
Job satisfaction and Captain feedback

In January 2015, all Captains were invited to participate in a five-minute online study debrief survey by the university team, via email. The purpose of this survey was to elicit feedback on the study, Captain-level information, and job satisfaction for further analysis.[xv] The Captains were offered up to £135 for taking part.[xvi] 189 complete and 27 partial survey responses were received, corresponding to a 64% response rate.

81% of Captains indicated wanting more fuel efficiency information in future. There was also a positive correlation between wanting more information and higher implementation of fuel-efficient behaviours. When asked how they can best improve fuel- and carbon-efficiency, the three study behaviours were among the top six responses cited by Captains, along with receipt of updated weather information, improved flight plans, and adherence to the flight plan.

Captains randomised to intervention Groups 2, 3 and 4 described being more satisfied with their jobs than those in Control Group 1 (see Figure 4). Captains in the charitable incentives (Charity) group reported the highest level of job satisfaction, exceeding that of the Control Group by 5%. This 5% difference is a large effect in terms of job satisfaction – it is equivalent to the effect on job satisfaction of moving from poor health to excellent health. Therefore, we believe the study improved satisfaction levels among Captains.

Figure 4: Post study self-reported Captain job satisfaction by study group



Summary and conclusions

1. Active engagement of Captains in SOP fuel efficiency information is an effective and cost-effective strategy

The study has shown that engaging pilots in an active way, over and above providing SOP information in manuals, is an effective way to change behaviours. First, notifying Captains they are to be included in a fuel and carbon efficiency study resulted in changes in their practices. Sending tailored information with targets and feedback (Group 3) proved to be the most effective strategy of the approaches tested, and highly cost-effective. Charity incentives for Captains didn't provide any additional change in behaviours, but may be helpful in terms of promoting job satisfaction.

Overall, the study resulted in bigger savings – and satisfaction levels – than anticipated, offering fantastic opportunities for further engagement of pilots on this key issue. These are currently being explored.

2. Consulting with Captains

We received a number of queries from Captains during the study and in several cases we sent additional data. Nevertheless, post-study satisfaction levels were high overall, and 81% of those who responded suggesting they'd like more fuel efficiency information. It's clear that Captains are happy to be involved in fuel efficiency if it's approached in the right way. Prior to this study, pilot managers, union representatives and a specialist group of experienced Captains were consulted, and took part in tailoring its design. Now the study analysis is complete, we will be exploring with pilots ways to build on these exciting results.

3. Additional opportunities

- **Technology upgrades**
  At the time of the study, pilots received monthly feedback *by post*. Recent upgrades to RR CDS and the introduction of iPads to all of our pilots mean that going forwards, information can be made available in an even more timely and targeted way. Common sense (as well as good quality evidence from studies with other professional groups) suggests that reminders provided close to the point of decision-making (using computer-assisted calculations if appropriate) are highly effective in leading to changes in targeted practices.
- **Wider pilot implementation**
  The current study included only Captains, and only three SOP behaviour metrics. It's likely that rolling out the approach to all pilots and across a wider range of SOPs (that have an influence on fuel and CO_2 savings) could result in even more savings.
- **Other business teams**
  There is potential to explore the evidence-based approach in other areas of the business. This study showed that the scientific method was highly useful for VAA and this method may well be applied to other fuel, carbon and cost saving activities, as well as employee engagement and satisfaction or a whole host of challenges and proposed business strategies.

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Explanatory footnotes

[i] Full details and progress reports are provided annually via the online Change is in the Air (CIITA) reports available to download from: www.virginatlantic.com/changeisintheair. You can also check out our 3.5 minute animation for a light-hearted summary of what we do via the same CIITA site.

[ii] Gosnell, Greer K., John A. List, and Robert D. Metcalfe (2016). A New Approach to an Age-Old Problem: Solving Externalities by Incenting Workers Directly. NBER Working Paper: http://www.nber.org/papers/w22316.

[iii] Random allocation to study groups is the gold standard widely used in health and social sciences to determine which interventions work best in any given setting. Randomisation is an essential principle that means that the characteristics of participants in each study group are the same (equivalent) at baseline, *before* any interventions begin. Baseline equivalence ensures that any differences observed *after* an intervention can be attributed to the effects of the intervention/s and not to pre-intervention differences in groups.

[iv] See page 24 in the academic paper for full calculations (updated 04/04/16).

[v] The data-driven fuel savings estimates reported here stem from regression analysis on the average changes in fuel use from implementation of the targeted behaviours in the study on a per-flight basis. For instance, on average, *all* Captains used 345 kg less fuel in flight (relative to planned trip fuel) during the intervention period.* This saved an additional 26kg, 106kg, and 74kg per trip if they received information, targets, and charitable incentives (resp.). These per-flight savings were multiplied by the number of flights flown during intervention period: 345kg×(all flights) + 26kg×(Group 2 flights) + 106kg×(Group 3 flights) + 74kg×(Group 4 flights). In the academic paper, the university team also provide engineering estimates, which instead multiplied 'standard' per-flight fuel savings estimates for ZFW, EF, and RET provided by VAA, then multiplied these standard fuel savings by the increased number of flights on which the behaviours were implemented due to the study (see footnote ii. for citation). However, the data-driven estimates are more realistic since they used actual fuel data to identify savings. *Note that the study was not powered to detect fuel changes with statistical significance, though the (real) average fuel savings across groups from the study using regression analysis techniques have been determined.

[vi] Using the February 2014 U.S. Bureau of Transport Statistics jet fuel price of US$786 per tonne of fuel and the U.S. federal government social cost of carbon of US$37 per tonne of carbon (see https://www.whitehouse.gov/blog/2013/11/01/refining-estimates-social-cost-carbon.)

[vii] See footnote i.

[viii] RTK is one of the standard industry efficiency measures, based on the weight of passengers and cargo carried.

[ix] As above, all latest details and charts are available via the online CIITA reports.

[x] For an overview on field experiments in economics, see Levitt & List (2009) and List & Gneezy (2013). For an overview of the use of experiments related to employees within companies, see Levitt & Neckermann (2014) and Bandiera, et al. (2011).

- Bandiera, Oriana, Iwan Barankay, and Imran Rasul. "Field experiments with firms." *Journal of Economic Perspectives* (2011): 63-82.
- Levitt, Steven D., and John A. List. "Field experiments in economics: the past, the present, and the future." *European Economic Review* 53, no. 1 (2009): 1-18.
- Levitt, Steven D., and Susanne Neckermann. 2014. "What field experiments have and have not taught us about managing workers." *Oxford Review of Economic Policy* 30 (4): 639-657.
- List, John, and Uri Gneezy. *The why axis: hidden motives and the undiscovered economics of everyday life*. Random House, 2014.

[xi] The charitable incentive was £10 per target reached for each fuel-efficient behaviour per month. Over the course of the study a Captain receiving this intervention could donate £240 to a charity if he/she met all targets. The money for these incentives was kindly provided by the researchers through the Templeton Foundation.

[xii] See page 24 in the academic paper for full calculations (updated 04/04/16).

[xiii] See footnote v.

[xiv] See footnote vi.

[xv] The survey was administered by UC and LSE –individual-level responses have not been shared with VAA.

[xvi] All survey expenses were covered by the academic researchers.