# Evaluating Actions Towards Sustainable Aviation

## A Case Study using Action Interdependence and Multiple Criteria Decision Making

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## Sustainability:

Sustainability is the ability to satisfy the needs of the present without compromising the ability to satisfy the needs of the future.

## Introduction:

The use of aircraft in a rapidly expanding market produces an increasing amount of $CO_2$ and other greenhouse gases, which contributes to climate change. The commercial aviation industry is growing at a rate of 5% a year, and is responsible for 2 – 5% of global $CO_2$ emissions. This growth leads to an increased amount of $CO_2$ from engine exhaust and contrails, which trap heat in the atmosphere by reflecting it back towards Earth. As petroleum is a finite resource, it is in the industry's interest to investigate options to reduce fuel usage and reduce $CO_2$ emissions.

## Possible Actions:

Eleven possible actions to the industry are identified. They are organized into four action groups.

| Action Group | Actions |
|---|---|
| Biofuels | Corn fuels,<br>Algae. |
| Advanced aircraft design | High bypass turbofans,<br>Blended or closed wing designs with ducted engines. |
| Standards of practice and flight parameters | Reduce altitude and cruise speed,<br>Formation flying,<br>Constant descent air traffic control,<br>Electrical tow cars and other ground vehicles. |
| Market driven actions | Retire aging aircraft,<br>Carbon trading,<br>High speed trains to reduce short haul flights. |

However, the implementation of one action can affect another action which is known as **action interdependence**. For example, the biofuels action group is interdependent with the advanced aircraft design action group because high bypass turbofan engines can be designed to specifically burn biofuels in the most efficient way.

The actions will be judged using four criteria. While these criteria are valued, they are not considered of equal importance. They are:

- Return on Investment (ROI)
- Reduction in $CO_2$ emissions
- Minimal disruptions to normal business
- Popularity with customers and stakeholders

## Analysis Method:

The first step in analyzing the problem is for the decision maker to determine its preferences for each criterion, which is called a weight and expressed as a percentage. In this case, there have been public statements from several key members of the industry expressing their preferences. The estimations are:

40% — **ROI:** This criterion is ranked the highest because the industry must stay in business by investing in efficiencies to reduce costs.

30% — **$CO_2$ Emissions:** By reducing emissions, the industry can move towards its goals from the Kyoto Accord and reduce fuel use.

20% — **Minimal Disruption:** Avoiding disruption to flight schedules and downtime for aircraft saves the aviation industry money.

10% — **Popularity:** This is the least important criterion because the implementation of any actions is unlikely to be unpopular and it is necessary to give customers a voice.

The next step is to evaluate each action with respect for each criterion. For example, if the aging aircraft in a fleet are replaced with new and more efficient aircraft, there would be a 10.4% reduction in fuel burned per aircraft. This can be considered as the evaluation of this action on the criterion ROI if the other action evaluations are represented in fuel reduction per aircraft. This process is repeated to give each action an action value for each criterion, represented below.

$$v(a) = \sum_{p=1}^{n} w_p c_p(a)$$

where *v(a)* is the action value, *n* is the number of actions, $w_p$ is the criterion weight, and $c_p(a)$ is the evaluation of the action for the criterion.

To include action interdependence in the analysis, a rating scale is introduced and ranges from -1 to 1, where 0 indicates no interdependence, -1 a negative interdependence and 1 a positive interdependence. A positive interdependence describes a situation where the combination of two actions produces a more positive result than if the actions were implemented separately and in terms of the criterion for which they are being evaluated. For example, the interdependence between corn biofuels and high bypass turbofans is slightly positive (0.2) with respect to the ROI criterion because the engines can be designed to burn biofuels more efficiently.

## Applying Action Interdependence:

The interdependences between all non-repetitive actions must be evaluated for each criterion. Once the interdependencies are determined, a score for each combination of two actions is created by multiplying the action value for the set by their interdependence value (I). Once a score is found for all sets of actions with respect to each criterion, the scores for each set of actions per criterion are added together to create the total score.

$$TS = I_{ROI}TS_{ROI} + I_{CO2}TS_{CO2} + I_{MD}TS_{MD} + I_{Pop}TS_{Pop}$$

## Results:

The top five scores for the combination of two actions are listed in the table below.

| Rank | Action 1 | Action 2 | Total Score |
|---|---|---|---|
| 1 | algae | high bypass engines | 1.8536 |
| 2 | corn | high bypass engines | 1.5028 |
| 3 | corn | algae | 1.4950 |
| 4 | high bypass engines | blended wing | 1.0570 |
| 5 | algae | high speed trains | 1.0450 |

A sensitivity analysis was conducted to see if changing a small detail would have a large effect on the model. An interdependence was increased slightly which did not alter the options chosen or their order, but changed the top total score by 3%. Because the percentage was so small, the model is considered stable.

## Conclusions:

The similarity between the top three results indicate that the industry would prefer to invest in a biofuel and high bypass engines, a position which is supported by public releases from large members of the industry. An area for further study would be to determine if the chosen option would be able to meet the goals agreed to by the industry by the ICAO of reducing $CO_2$ emissions by 50% by 2050.

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