7th USA/Europe Air Traffic Management R&D Seminar, Barcelona, Spain, July 02-05, 2007

A PSYCHOSOCIAL APPROACH TO UNDERSTANDING PILOT AND CONTROLLER ACCEPTANCE OF CHANGE IN ATM, BASED ON THREE CDA CASE STUDIES

Andrew Cook, Graham Tanner, University of Westminster, London, UK

Nadine Pilon, Tony Joyce, EUROCONTROL Experimental Centre, Brétigny s/Orge, France

Abstract

Next generation ATM systems cannot be implemented in a technological vacuum. The further ahead we look, the greater the likely impact of societal factors on such changes, and how they are prioritised and promoted. The equitable sustainability of travel behaviour is rising on the political agenda in Europe in an unprecedented manner.

This paper examines pilot and controller attitudes towards Continuous Descent Approaches (CDAs). It aims to promote a better understanding of acceptance of change in ATM. The focus is on the psychosocial context and the relationships between perceived societal and system benefits. Behavioural change appeared more correlated with such benefit perceptions in the case of the pilots.

For the first time in the study of ATM implementation, and acceptance of change, this paper incorporates the Seven Stages of Change model, based on the constructs of the Theory of Planned Behaviour. It employs a principal components (factor) analysis, and further explores the intercorrelations of benefit perceptions, known in psychology as the 'halo effect'. Disbenefit perceptions may break down this effect, it appears.

For implementers of change, this evidence suggests an approach in terms of reinforcing the dominant benefit(s) perceived, for sub-groups within which a halo effect is evident. In the absence of such an effect, perceived disbenefits, such as with respect to workload and capacity, should be off-set against specific, perceived benefits of the change, as far as possible.

This methodology could be equally applied to other stakeholders, from strategic planners to the public. The set of three case studies will be extended beyond CDA trials. A set of concise guidelines will be published with a strong focus on practical advice, in addition to continued work enabling a better understanding of the expected, increasing psychosocial contributions to successful and unsuccessful efforts at ATM innovation and change.

1. Introduction

1.1 The Emerging Mindset of ATM

This paper aims to promote a better understanding of acceptance of change in ATM. Taking three case studies, it examines pilot and controller attitudes towards Continuous Descent Approaches (CDAs), considered in a societal context. Compared with conventional, stepped descents, CDAs keep aircraft higher for longer and reduce thrust transients, and are thus not only an important noise abatement technique, but represent a type of ATM change with a particular societal component. In contrast to human factors, the methodology of this paper is to examine the process of behavioural change, specifically through understanding pilot and controller perception and evaluation of associated (dis)benefits. It will examine the psychological processes determining such behaviour, as set in the societal context, for which the term 'psychosocial' is used.

The relationships between what might be broadly termed 'societal' and 'system' benefits will be examined, recognising that there is often a trade-off between them (e.g. with CDAs, between controller flexibility and noise abatement). The 'societal' context is defined in the broad sense, encompassing not only 'society' in terms of the public, but also with regard to the wider political, environmental, and legislative framework, and not least the media. The boundary between 'societal' and 'system' contexts is a blurred one. From the pilot's perspective, for example, 'societal' could be extended to the airport and the ANSP, but this might be more technically referred to as the 'system'.

Bolic and Hansen [1], in their paper with the objective "to investigate how air traffic controllers adopt and adapt new technologies", point out that "individual centers can be considered as separate social systems". Indeed, they further cite human factors research which found that controller preferences even changed with the group of controllers. This was witnessed to some extent during our interviews, whereby the propensity of controllers to offer a CDA could be affected to some (small) degree by the interactions between those on shift. It should also be borne in mind that CDAs often depend on coordination between adjacent sectors, and the ATC offer of a CDA to a pilot may very well not be determined by just one controller, or sector.

Next generation ATM systems cannot be implemented in a technological vacuum, but increasingly need to pay attention to the balance between societal and system benefits, and how this perceived balance motivates behavioural change. The further ahead we look, the greater the likely impact of societal factors on such changes, and how they are prioritised and promoted.

The societal context in which change in ATM is taking place is already growing at an accelerating rate. The sustainability of travel behaviour is rising on the political agenda in Europe, particularly in certain states, in an unprecedented manner, as society feels its way forward in its attempts to balance demand for travel against environmental impact. Privatisation within the industry, shareholder responsiveness, increased legislative exposure, not to mention developments in the EU emissions trading scheme, will continue to propel a previously 'behind the scenes' process into the public arena. The societal context of change in ATM is thus growing in weight alongside the more system-driven platforms such as ACARE, SESAR and NGATS. Such initiatives already refer to the 'needs of society', but these needs are not only demand-based and are presenting the industry with a growing challenge in terms of how it is viewed with regard to its environmental impact, and how it satisfies demand in an equitable manner – even within national social strata, let alone across EU states, and beyond.

Motivation and decision-making within the industry, both at the tactical and strategic levels, and the perceived benefits and disbenefits of options available, will be increasingly coloured by this societal context.

1.2 Three CDA Case Studies

Notwithstanding a lack of robust definitions for the different types of CDA, the preferred nomenclature of this paper is to refer to 'vectored CDAs' (often referred to as 'Basic' CDAs, or 'B-CDAs') and 'STAR-CDAs'. The former rely on ATC issuing vector headings and distance-to-go updates to aircraft, are simpler to implement in many respects, and have found widespread use [2], whilst the latter are based on published STARs and may be programmed into the aircraft's Flight Management System (FMS).

For the three airlines participating in the trial at Manchester, vectored CDAs were assumed as standard during the period 2200 – 0600. At Bucharest (Henri Coanda International – henceforth "Bucharest"), TAROM was the sole participating airline in the trial: STAR-CDAs were initiated by pilot request at all times, with three entry points per STAR, each feeding onto runway 08L or 08R, making six distinct profiles in all (each using additional, 'company', waypoints).

SAS was the sole airline participating in the CDA trials at Stockholm-Arlanda (henceforth "Stockholm"). Four STAR-CDAs were operated onto each of the runways (19R, 01L and 26), making twelve continuous descent approaches in total. These could be flown as STAR-CDAs (P-RNAV only) or as 4D, P-RNAV trajectories managed from Top of Descent – which were referred to as "Green Approaches". All were flown on ATC offer, in low traffic.

The "Green Approaches" aimed at achieving a continuous descent approach from Top of Descent (ToD) to the runway. This involved 4D-trajectory management, using Required Times of Arrival, managed through an ACARS dialogue with the appropriately equipped (B737) aircraft, initiated from any time just after take-off at the origin airport, through to three or four minutes before ToD. These were designed to operate without controller intervention, being managed wholly by the FMS.

Pilot and controller interviews were conducted on-site in Manchester (07-09 March 2005), Bucharest (21-24 March 2006) and Stockholm (15-17 November 2006), on ANSP premises and at airline bases. Most interviews were conducted face-to-face, lasting typically 20 minutes (but up to 50 minutes). Other questionnaires were posted back to the University of Westminster. All interviews were anonymous. Although not used in the quantitative analysis *per se*, supporting interviews were undertaken with airline management and training captains, ANSP managers and controller supervisors, CDA designers, and senior representatives of the airport authority, to establish a broader context of the introduction of the CDA trial. The distribution of interviews contributing to the dataset used for the current analysis was as follows:

Table 1. Response Distribution

Location	Pilots	Controllers	Total
Manchester	21	10	31
Bucharest	10	14	24
Stockholm	13	14	27
Total	44	38	82

2. Understanding Change in ATM

2.1 Case Study Societal Context

In response to open-ended questions regarding the motivation for the trials, and the potential benefits and disbenefits, fuel savings and reduced environmental impacts were widely quoted by pilots and controllers. From a system perspective, controllers cited traffic and sequencing considerations above all others, with pilots more often focusing on other technical issues (in addition to fuel savings), such as FMS capabilities and Rate of Descent calculations.

In terms of the societal contexts for the three case studies, there was a clear public complaints culture about noise at Manchester and Stockholm (reflecting broader national traits in the UK and Sweden), which was markedly absent in Bucharest. Nevertheless, the CDA Working Group at Bucharest was chaired by the Airport Authority, which demonstrated a clear desire to be pro-active and anticipate such future pressure (be it through legislation and/or societal pressure).

Neither the Manchester nor Bucharest trials were introduced in the context of any increase in noise complaints, i.e. were not driven by societal pressure *per se*. However, the STAR-CDAs at Stockholm were introduced mainly to tackle the large number of noise complaints which resulted from the use of the third runway (01R/19L) from early Spring, 2002. It was one of twelve measures investigated to deal with this problem, and each controller was briefed by the Airport Authority on the issue of noise in 2005, as an important part of the trial implementation and education process. However, the noise issue cannot be said to have persisted in controllers' minds, based on their feedback in the interviews, and this may well be attributable to a greater focus, particularly in the media, on the "Green Approaches".

The "Green Approaches" were not primarily motivated by noise complaints (despite much the same noise reduction benefits as the STAR-CDAs), but were focused more on arrival time management, integration with CDM, plus reduced emissions and fuel consumption. This also fitted in with Luftfartsverket's (formally "The LFV Group" – the Swedish ANSP and operator of Stockholm-Arlanda Airport) strong environmental policy: it was the first major Swedish business group to become climate neutral.

SAS reported considerable positive media coverage as a result of the "Green Approaches". Comments were even received during the interviews from SAS pilots that the trial "showed a belief in the future" at a time when the airline was in financial difficulty, sending out a "positive company signal".

When asked about 'the possibility of noise complaints from the public, if CDAs were generally not being used', levels of concern (from pilots and controllers combined, to make suitably sized sample sizes) ran in the order: Bucharest > Stockholm > Manchester, with no statistically significant difference between Stockholm and either of the other two, but with concern at Bucharest significantly higher than at Manchester (Mann-Whitney U test, $p=0.03$). Overall, pilots ($n=44$) showed somewhat greater concern than controllers ($n=38$) in this respect (Mann-Whitney U test, $p=0.04$). It is worth noting in passing, that some controllers across the sites (more so than pilots, but not a marked trait) expressed some annoyance about the attention paid to noise, especially since some residents had moved to live near airports 'in full knowledge of the consequences'. Some pilots devolved responsibility for environmental impact to 'the system' (most notably the airport authority).

The next section begins the description of the evaluation framework used to understand pilot and controller behavioural motivation.

2.2 Theory of Planned Behaviour

The Theory of Planned Behaviour is used widely in the health sector, dating from 1985 [3], but is far less common in other fields of research. It was developed at this time from the Theory of Reasoned Action [4], which is a much older theory, dating back to the late 1960s [5].

The key difference between the two theories is that the Theory of Planned Behaviour takes specific account of *perceived* behavioural control, in addition to *actual* behavioural control [6]. It has been used to develop questionnaires in the health sector, for example by the University of Newcastle [7], and, after further development, in the transport sector, to evaluate behavioural change in sustainable travel choices ('mobility management'), by the University of Westminster [8].

The Theory of Planned Behaviour aims to predict deliberated behaviour in the context of (perceived) control. In the ATM (and ATC) context, behaviour is particularly (and desirably) subject to the external constraints of operating procedures. Neither the pilot nor controller has autonomy of action, but is subject to the evolving constraints of the strategic and tactical control environment.

The Theory of Planned Behaviour uses three basic constructs as 'predictors' of the intention of an individual carrying out a desired action:

‘attitude’ (a favourable disposition towards the action), ‘subjective norm’ (perceived social pressure to take the action), and ‘perceived behavioural control’ (whether the individual feels in control of the process of action). Across the three sites, there was no evidence of undue management pressure on pilots or controllers to perform CDAs. Managerial support was perceived as ranging from ‘just positive’ to ‘firmly positive’, but never extending to a blame culture in cases of non-execution of a CDA. Pilots and controllers qualitatively reported feeling appropriate levels of decision autonomy within the prescribed conditions for carrying out CDAs. Societal pressure in terms of concern about noise complaints has been discussed already, and will be referred to again in Section 3.2.2.

2.3 Seven Stages of Change Model

The University of Westminster has integrated the Theory of Planned Behaviour constructs into its Seven Stages of Change model, under funding from the EU’s TAPESTRY project [8]. These stages (see Figure 1) represent the theoretical, cognitive and conative ‘process’ through which an individual may move, from one type of behaviour (e.g. not performing CDAs) to another type (e.g. habitually performing CDAs). The process through the seven stages may be viewed as a successful implementation of change.

In order to successfully implement change in ATM, it is necessary to appreciate that all types of change require some type of ‘buy-in’ in order to work. This does not just mean accepting that a change needs to take place, or accepting some responsibility, or recognising some benefits, as these alone are insufficient. At the tactical level, in a CDA trial, for example, the accomplishment of the continuous descent approach requires a pilot and controller(s) to cooperate, and this cooperation is more likely if both feel fully motivated towards the new process.

The stages depicted are not necessarily followed sequentially, but nevertheless constitute a valuable framework for developing an understanding of attitudes and beliefs which determine behavioural change. A certain degree of ‘post rationalisation’ might come into effect – i.e. a pilot or controller might have their awareness of an issue increased, or their willingness to accept responsibility for contributing to change, *driven ‘after the fact’* by their perception of the corresponding benefits, although it is obviously difficult to establish any directionality in these relationships (a vertical panel survey might contribute to such an understanding). Only two respondents across all three trials indicated reduced support as the trial progressed.

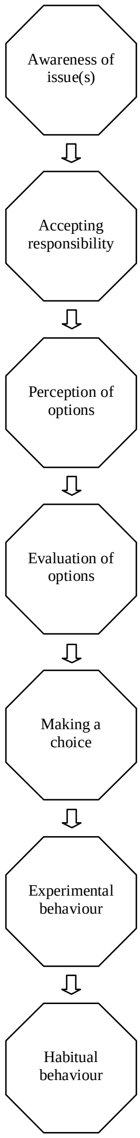

Figure 1. Seven Stages of Change Model

In implementation research, by measuring maturation on each of these stages, and understanding the relationships between them, it is possible to gain valuable insights into behavioural motivation. Moreover, such understanding can give implementers of change insights into the likelihood of successful and unsuccessful strategies, highlighting perceptual barriers to change, and drivers of change. Part of this on-going work with EUROCONTROL seeks to develop a library of questions which can be used to measure these seven constructs in generic cases of ATM change, initially testing this model in three CDA case studies.

Table 2 shows how three of the Seven Stages of Change constructs were estimated in the survey questionnaire. These have been selected for exploration in this paper partly for simplicity, as they were more flexible in their interpretation by respondents, and were thus more independent of respondent ‘bias’ on the perceived, primary motivation of the trial (e.g. fuel savings or noise reduction). Propensity to recommend is often used as a proxy measure for net 'buy-in' (or repeat purchase intention in commercial market research). It may only be used as a weaker behavioural proxy of intent, or for 'making a choice', in the ATM context – here, such choices cannot be based on personal motivation alone. Each controller, for example, within the prescribed parameters of operating procedures, will determine, at any given time, by 'gut feeling', when they are no longer at ease accepting another continuous descent approach under their control (limits of 3 – 5 were sometimes quoted).

The main analysis will explore the relationships between the variables of Table 2, and maturation on other stages, such as 'perception of options' (e.g. in terms of workload and capacity effects) and 'evaluation of options' (such as perceived benefits of CDAs to 'the public', 'the airline', 'the ANSP' and 'the airport').

Table 2. Overview of Three Key Variables

Variable	Question asked	Measure of
V_1	'Achieving CDAs at [airport] is not my responsibility'	acceptance of responsibility
V_2	'Achieving CDAs at [airport] is a serious contribution to positive change'	option evaluation (generic measure)
V_3	'I would recommend the way we do it at [airport], to a similar airport'	net 'buy-in' (proxy measure)
Likert (summated) attitudinal scale		

Specifically, relationships between these perceived societal and system benefits will be investigated in some detail. Before moving on to describe the analyses, it is to be noted that the Seven Stages of Change model also stresses the importance of asking questions relating to experiential cycles, e.g. how attitudes to particular changes (in ATM) are modified according to experience. For each of the three surveys relating to the CDA trials, the fieldwork took place after the trial had been well established, but the introduction thereof was still fresh in the memories of the respondents.

3. Data Analysis and Results

3.1 Methodological Overview

Factor analysis attempts to express a set of observed, independent variables, as a new set of independent variables – these 'factors' are always linear combinations of the original variable set [9]. The technique was originally developed in psychology to simplify the description of behavioural traits, for example.

Factor analysis shares its underlying principles with multivariate, linear regression. One of the key differences is that factor analysis tries to deal with the issue of multicollinearity associated with the independent variables. This is true especially of the technique known as principal components, usually considered a variant of factor analysis. In principal components analysis, there is zero correlation between the factors and it is hoped that the extracted factors can be interpreted in a meaningful, and reasonably simple, way. There cannot be more factors than there were variables in the original set, and it is obviously preferable that there will be rather fewer of them. A key indication of the quality of the solution, is the percentage of the original variance between the original variables, which is described by the (fewer) factors. It is not acceptable to obtain a purely 'mathematical' solution in the analysis, i.e. whereby the analyst is not able to assign real meaning to the factors. Where this presents difficulties, the analyst often 'rotates' the factors, to increase loadings on some of the original variables, and decrease them on others, in order to improve the interpretability and simplicity of the solution.

Table 3 and Table 4 show simplified elements from the questionnaires used. The benefit and disbenefit elements were included as a grid question, where the respondent was invited to indicate levels of agreement, or disagreement, with listed statements, on a Likert scale: "agree strongly", "agree", "neither agree nor disagree", "disagree", or "disagree strongly".

Even in cases where the interviews were conducted face-to-face, this question was presented to respondents for self-completion, as this promoted methodological standardisation. In the following analysis, it would have been interesting to explore responses comparing pilots and controllers at the case study level, but the relatively low sample sizes at this disaggregate level have largely precluded this possibility.

Table 3. Perceived Benefits Rated

Achieving CDAs at [location] …
… benefits people living under approach paths
… benefits the airline(s)
… benefits the ANSP
… benefits the airport
Likert (summated) attitudinal scale

Table 4. Perceived Disbenefits Rated

Achieving CDAs at [location] …
… significantly increases pilot workload
… significantly increases controller workload
… limits capacity
… less safe than stepped approach during LVP
… is too time consuming
Likert (summated) attitudinal scale

Apart from the measure of societal benefit expressed through responses to '… benefits people living under approach paths', these variables represent system benefits and disbenefits, and will form the core of the analysis.

3.2 Results of Data Analysis

3.2.1 Principal Components Extraction

Running a principal components analysis on the responses to these questions, for all 82 respondents, with (orthogonal) varimax rotation [10], produced two components (factors) from the nine original variables. These components were clearly and differentially loaded on the set of benefits (Table 3), and on the set of disbenefits (Table 4), explaining 55% of the original variance. (A non-rotated solution gave a similar result, but with less clear benefit-disbenefit differentiation).

As correlations between variables increase, the proportion of the variance explained by the first few components extracted also increases (if there is no correlation between any variables, no 'principal' component will be extracted – each will account for the same amount of variance).

This loading suggested that the perceptions of the benefits (and disbenefits) were intercorrelated – i.e. the perception of one benefit (e.g. to the airline) was likely to be associated with the perception of another (e.g. to the airport). These types of correlation are known as 'halo effects', and will be discussed later.

Looking at rotated solutions for the pilots (n=44) and controllers (n=38) *separately*, yielded similar results, but with a key difference for the controllers – giving an early insight into a developing hypothesis about the controller perceptions.

The analysis of pilot responses produced two components (factors), differentially loaded on the perceived benefits and disbenefits, of Table 3 and Table 4. These two components explained 63% of the original variance. Under the hitherto applied method for the extraction of components (i.e. extracting factors with eigenvalues greater than unity [10]), the controller analysis yielded four components. Whilst these explained 71% of the variance and could be relatively cleanly described as two 'benefit' and two 'disbenefit' components, the first two (one of each type) only explained 41% of the variance. Furthermore, although logically consistent descriptions of these components could be made, they were less well defined than the two pilot components, with the fourth controller component only being loaded with values above 0.70 on two original variables ('increases pilot workload' and 'less safe than stepped approach during LVP').

Constraining the solutions to two components for both the pilot and controller subsets, produced extractions which explained 63% (same component as before) and 46% of the original variances, respectively. The two pilot components were labelled ${}^{b}C_{P,2}$ (benefit) and ${}^{d}C_{P,2}$ (disbenefit). The higher value (63%) for the pilot variance is as expected from the foregoing discussion. Whilst all four components were rather cleanly loaded on benefits/disbenefits, the controller components (${}^{b}C_{C,2}$ and ${}^{d}C_{C,2}$) were thus weaker in terms of explained variance. Of all the loadings, the highest was in the pilot disbenefit component (${}^{d}C_{P,2}$), which loaded with a coefficient of 0.90 on 'increases *controller* workload' (more on which later).

3.2.2 Exploring the Components

These perceived benefit and disbenefit components, one constrained pair for both controllers and pilots, making four in all, were then generated as new, weighted variables (using the regression method), for further exploration of the dataset. ${}^{d}C_{P,2}$ and ${}^{b}C_{C,2}$ had weak but 'illogical' loadings on 'benefits people living under approach paths' (0.23) and 'limits capacity' (0.26), respectively. These original variables were retained in the solutions, however, since they each loaded strongly – and arguably more 'logically' – on ${}^{b}C_{P,2}$ (0.80) and ${}^{d}C_{C,2}$ (0.82).

Correlation matrices showed that for the pilots, all four benefit variables (see Table 3) were positively and mostly highly significantly intercorrelated ($p<0.01$ x5; $p=0.06$ x1). Furthermore, no benefit variable had a significant and positive coefficient on any disbenefit variable in Table 4 (20 coefficients: 9 negative with $p<0.05$). The corresponding controller correlation matrices showed similar, but weaker patterns, with no significant coefficient having an 'illogical' sign (such as a benefit loading positively on a disbenefit). The extracted components (as new, weighted variables) were next investigated in terms of their correlations with the key variables of Table 2 (V_1 … V_3), as discussed in Section 2.3.

The pilot benefit component ($^{b}C_{P,2}$) was significantly and positively, although not strongly, correlated with all three variables $V_1 \ldots V_3$ (correlation coefficients, respectively: 0.3, $p=0.03$; 0.4, $p<0.01$; 0.4, $p=0.02$). The controller benefit component was also positively correlated with V_1 and V_2 (0.4, $p=0.02$; 0.4, $p<0.01$; V_3, $p>0.10$). Both pilot and controller disbenefit components were negatively correlated, or uncorrelated, with all three variables (V_1, V_2 and V_3), with the pilot component ($^{d}C_{P,2}$) being somewhat more robust. In short, the components demonstrated 'logical' properties with respect to $V_1 \ldots V_3$, with the pilot benefit component ($^{b}C_{P,2}$) being the best 'predictor' (notwithstanding the relatively weak correlations) of $V_1 \ldots V_3$.

Given the intercorrelation of benefit variables discussed above, it is not surprising that, for the pilots, the four original benefit variables (Table 3) were also positively (and mostly significantly) correlated with the variables $V_1 \ldots V_3$. Similar results were obtained for the controllers, although with fewer correlations which were significant.

The extracted pilot benefit component ($^{b}C_{P,2}$) has thus been shown to be a plausibly good measure of net perceived benefit. As a weighted variable, it demonstrates consistently 'logical' behaviour with other variables from the questionnaire data.

Finally, building a weighted variable from an extraction constrained to one component, based on the variables of Table 3 and Table 4, but this time with the weakest loadings (on pilot and controller workload) removed, produced a pilot benefit component ($^{b}C_{P,1}$) which was positively loaded on all benefits, negatively loaded on all (remaining) disbenefits, and alone explained 49% of the original variance. This component was a better 'predictor' of $V_1 \ldots V_3$ (0.4, $p<0.01$; 0.5, $p<0.01$; 0.5, $p<0.01$) than either $^{b}C_{P,2}$, any variable in Table 3, or a derived variable which was the average of the variables in Table 3 (which itself outperformed $^{b}C_{P,2}$ in this respect). Again, qualitatively, concern about noise complaints cannot be said to have dominated the responses from any site during the interviews. Quantitatively, correlations with such concern were marginally higher with $^{b}C_{P,1}$ (and $^{b}C_{P,2}$) than with the original variables of Table 3. In summary, the best descriptor found of net perceived benefit thus also contained negative loadings on disbenefits, as opposed to being purely derived from benefit variables.

3.2.3 The 'Halo Effect'

The foregoing discussion introduces some of the advantages of using principal components analysis in exploring the relationships between perceived benefits and disbenefits, with other types of variables, giving the researcher valuable insights into the psychosocial composition of these constructs. It has also been made evident how benefits and disbenefits are correlated with each other. Such intercorrelation is not new to psychology, and is known as the 'halo effect', being originally proposed as long ago as 1920 by Thorndike, as a " …tendency to think of the person in general as rather good or rather inferior and to color the judgments of the qualities by this general feeling" [11]. Rooted in personnel appraisal, this principle may be applied equally to product, service, system or process evaluation, whenever the rating of one or more attributes is partially determined by the ratings of *other* attributes for whatever is being assessed. This is a much neglected effect in understanding perception and behaviour and has similarities with 'generalisation of response' described by learning theory [12].

Correlation matrices show these relationships in detail. Correlations have been plotted in figures 2 – 5. The halo effects were stronger for the benefits, than the disbenefits, as reflected in the discussion on the principal components extracted, and the relative percentages of variance they explained, in both the pilot and controller cases. Benefit halo effects are thus chosen for illustration in the figures.

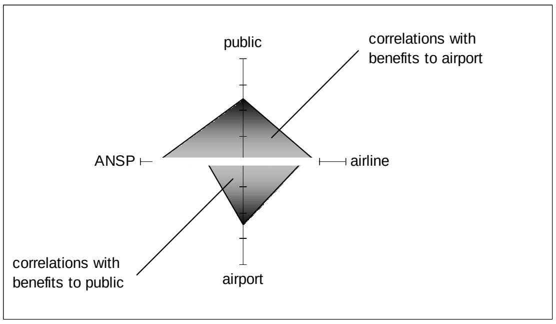

Figure 2. Pilot-perceived Airport and Public Benefit Correlations

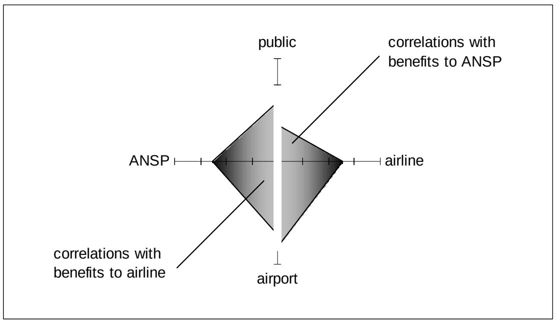

Figure 3. Pilot-perceived ANSP and Airline Benefit Correlation

The top-half of Figure 2 shows the correlations between responses to "benefits the airport" and the three other variables of Table 3 ("benefits people living under approach paths" – axis labelled "public"; "benefits the airline(s)" – axis labelled "airline", and "benefits the ANSP" – axis labelled "ANSP"). All the figures are drawn to the same scale, with correlation coefficients on the four axes running from 0.0 to 0.8. Figure 2 thus shows that for pilots, perceived benefit correlations (the 'halo effect') between the airport (represented by the triangle in the top-half of the diagram) and the ANSP, the public and the airline, were reasonably similar – i.e. the triangle extends along each of the three axes to 0.6 ± 0.1 (0.7, 0.5, 0.6; $p<0.01$ x3). The lower half of Figure 2 shows the correlations between "benefits people living under approach paths" (triangle labelled "correlations with benefits to public") and the other three variables of Table 3. Clearly, the figure is symmetrical about the origin along the y-axis by the nature of the plot. It also illustrates the coefficients for the 'public-airline' correlation (0.5, $p<0.01$) and for the rather weaker 'public-ANSP' correlation (0.3, $p=0.06$).

Figure 3 completes the picture for the pilot cases. It could, of course, have been plotted on the same axes as Figure 2, but this was difficult to render clearly, and separate plots were favoured despite some mutual redundancy. The halo effect was similar for the perceived airline and ANSP benefits, and all were (highly) significant.

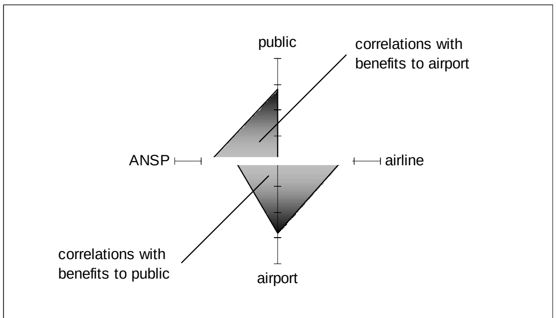

Figure 4. Controller-perceived Airport and Public Benefit Correlations

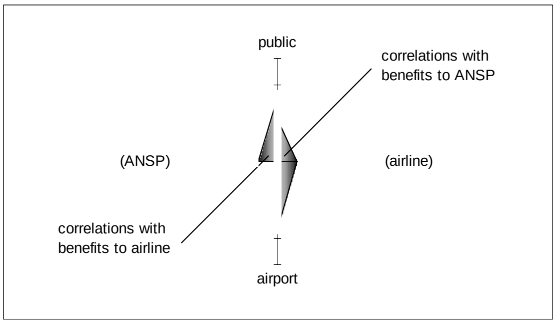

Figure 5. Controller-perceived ANSP and Airline Benefit Correlations

Figure 4 and Figure 5 illustrate (to the same scale) the mostly markedly lower halo effects for the controller-perceived benefits, compared with the pilots. In Figure 4, there was no significant 'airport-airline' correlation (hence no shading in the upper, right-hand quadrant) although the other correlations were all (highly) significant.

In Figure 5, it should be noted that there was no significant 'airline-ANSP' correlation, but this was set to an arbitrary, low value, in order to produce a visible plot (otherwise a straight line would have been plotted along the y-axis). The x-axis dimension is thus not meaningful, and it has been removed. The vertical extent of the triangles, indicating 'airline-public' (upper left), 'ANSP-public' (upper right) and 'ANSP-airport' (lower right) correlations are still meaningful, demonstrating varied but (highly) significant correlations.

Some of these patterns may be partly explained in terms of perceived workload, in that controller halo effects may be dampened by the fact that at the STAR-CDA sites (Bucharest and Stockholm), controllers were more likely to declare that CDAs increased their own workload, than pilot workload. Reynolds *et al* [2] comment that "the controller's ability to clarify aircraft intent through control commands appears to be diminished" in both types of CDA procedure. These authors go on to suggest that "in procedures that require precise trajectories and many constraints, it may be best to delegate fine control of the trajectory and tactical separation assurance to the pilot". This concept received mixed support from interviewees at the three case study sites, some controllers being apprehensive of a step towards reduced intervention as a norm. Again, at the STAR-CDA sites, controllers were highly significantly more likely to agree that the procedure "reduces flexibility too much, due to increased procedural standardisation", compared with the pilot responses ($p<0.01$; Mann-Whitney U test).

In each case study, whilst it seemed that pilots were at least marginally more inclined to express the view that CDAs increased controller workload, rather than their own, this was a weaker effect. Whilst these effects cannot be tested statistically for pilots and controllers at the case study level, the overall difference was significant for both the controllers (Wilcoxon Signed Ranks test, $p<0.01$) *and* the pilots ($p=0.01$).

The weakest halo effects for pilots and controllers were both with 'benefits the ANSP' (on 'benefits people living under approach paths' and 'benefits the airline(s)', respectively). As mentioned, of all the loadings, the highest was in the pilot disbenefit component (${}^{d}C_{P,2}$), which loaded with a coefficient of 0.90 on ‘increases *controller* workload’. It may thus be speculated that this observation for pilots is partly due to their perception that controller workload is increased by CDAs – whereas many pilots cited decreased pilot workload with CDAs, subject to FMS functionality. Further explanation may be found in that controllers at Stockholm and Bucharest highly significantly ($p<0.01$; Mann-Whitney U test) believed that CDAs limited capacity, more than did their pilot counterparts. At Manchester, this perception was clearly the same (although the sample size was too small to test statistically on Manchester alone).

The theory of this paper concurs with the observations from Bolic and Hansen (2005) that adoption “is faster when advantage of use is perceived” and “slows when adopters need to change their set of values in order to use the innovation”. Investigating this through the proxy measure for net ‘buy-in’ (or weaker behavioural proxy of intent, or for ‘making a choice’), V_3 was significantly ($p<0.05$ x2) correlated with two of the variables of Table 3 for pilots (the ‘public’ and ANSP dimensions), but for controllers, with *none* of the variables of Table 3. Indeed, for controllers, $V_1 \ldots V_3$ were not significantly correlated with either ‘benefits people living under approach paths’ or ‘benefits the airline(s)’. Of note was the fact that for neither controllers nor pilots, was V_3 (‘I would recommend the way we do it at [airport], to a similar airport’), significantly correlated with ‘benefits the airport’.

Examining further the issue of the balance between societal and system benefits, it is to be noted that the ‘public’ benefit of CDAs demonstrated a similar halo effect with controllers and pilots (c.f. Figure 4 with Figure 2). Indeed, there was no significant difference across the sample as a whole between pilots and controllers with regard to these absolute ratings. This was true of all the variables in Table 3, except ‘benefits ANSP’, which was rated higher by the pilots (Mann-Whitney U test, $p<0.01$). Of further note was that of these four variables, the highest net rating was for the airline benefit perceived by pilots; the lowest was the ANSP benefit perceived by controllers. These observations are consistent with the system perceptions already discussed, i.e. relating to workload and capacity.

It is noted in closing, that whilst principal components analysis, and correlation matrices, are able to indicate the strength of the packaging effects observed, they do not explain directionality or causality. Indeed, the independent variable(s) driving the observed packaging effects with pilots might be one(s) as yet not directly measured, such as the perception of fuel saved.

4. Conclusions

Within the context of these three CDA case studies, whereas pilots tended to ‘package’ together perceived benefits of the new process, controllers were less prone to this.

The relative predisposition of controllers and pilots towards this ‘halo effect’ may have been determined in part by their relative perception of the associated workload and capacity implications of this particular ATM change, i.e. (a) sufficiently strong disbenefit(s) may break down the benefit correlations. Looking at the relationships between perceived societal and system benefits, however, these particular aspects of the halo effect were fairly similar when comparing pilots with controllers, and there were few significant differences across the sample as a whole between pilots and controllers with regard to these absolute ratings. It would be of great interest in a future case study to look at an ATM change which reduced controller-perceived workload and increased pilot-perceived workload, for example, to see if the halo effect was then reversed.

Behavioural change appeared more correlated with such perceptions of benefits in the case of the pilots. This finding may be partly attributable to the greater external constraints on controller behaviour in the case of CDAs, in that they are less free to respond to perceived societal pressure: witness also the pilots’ somewhat greater concern expressed about public noise complaints.

For implementers of change, this evidence suggests an approach in terms of reinforcing the dominant benefit(s) perceived, for sub-groups within which a halo effect is evident. In the absence of such an effect, perceived disbenefits, such as with respect to workload and capacity, should be off-set against specific, perceived benefits of the change, as far as possible.

In terms of supporting the types of change required to successfully implement next generation ATM systems, it is hoped that this methodology will make a valuable contribution to understanding the associated complex psychological constructs, and their relationships: determining the perception of benefits, and how these are linked to behavioural change, through acceptance of change. In on-going work, the set of case studies will be extended to different types of ATM change. The library of questions will then be developed further and a set of concise guidelines will be published with a strong focus on practical advice, in addition to continued work enabling a better understanding of the expected, increasing psychosocial contributions to successful and unsuccessful efforts at ATM innovation and change.

Note

All analyses were carried out in SPSS. All p values are based on two-tailed tests. Non-principal components analysis coefficients are Spearman correlations.

Acknowledgement

The authors would like to express their appreciation to EUROCONTROL for not only funding this research, but for providing invaluable technical advice, and to extend sincere gratitude to all those across the three CDA trial sites who so generously gave of their time to facilitate and support these interviews. Further reporting will appear on the website of the EUROCONTROL Experimental Centre.

References

[1] Bolic, Tatjana, Mark Hansen, 2005, *User Request Evaluation Tool (URET) Adoption and Adaptation, Three Centre Case Study*, 6th USA/Europe Air Traffic Management R&D Seminar, Baltimore, USA.

[2] Reynolds, Hayley J. Davison, Tom G. Reynolds, R. John Hansman, 2006, *Human Factors Implications of Continuous Descent Approach Procedures for Noise Abatement*, Air Traffic Control Quarterly, Vol. 14(1), pp. 25-45.

[3] Schifter, Deborah E., Icek Ajzen, 1985, *Intention, perceived control, and weight loss: An application of the theory of planned behavior*, Journal of Personality and Social Psychology, Vol 49, No 3, pp. 843-851.

[4] Ajzen, Icek, Martin Fishbein, 1980, *Understanding attitudes and predicting social behaviour*, Englewood Cliffs, New Jersey: Prentice-Hall.

[5] Fishbein, Martin, 1967, *Attitude and the prediction of behaviour*, in M. Fishbein (Ed.), *Readings in attitude theory and measurement*, New York: Wiley, pp. 477-492.

[6] Ajzen, Icek, 1985, *From intentions to actions: A theory of planned behavior*, in J. Kuhl and J. Beckmann (Eds.), *Action control: From cognition to behavior*, Heidelberg, Germany: Springer, pp. 11- 39.

[7] Francis, Jillian J., Martin P. Eccles, Marie Johnston, *et al*, 2004, *Constructing questionnaires based on the theory of planned behaviour: A manual for health services researchers*, University of Newcastle: Centre for Health Services Research.

[8] Tyler, Sophie, Andrew Cook, 2004, *Measuring the effectiveness of campaigns: Lessons for mobility management from the EU TAPESTRY project*, 8th European Conference on Mobility Management, Lyon, European Platform on Mobility Management: http://www.epomm.org

[9] Stopher, Peter, Arnim Meyburg, 1979, *Survey Sampling and Multivariate Analysis for Social Scientists and Engineers*, Lexington Massachusetts: Lexington Books, pp. 237-261.

[10] Kim, Jae-On, Charles W. Mueller, 1978, *Factor Analysis – Statistical Methods and Practical Issues*, SAGE University Paper series on Quantitative Applications in the Social Sciences: 07-014, Newbury Park, California: SAGE Publications.

[11] Thorndike, Edward L., 1920, *A constant error on psychological ratings*, Journal of Applied Psychology, Vol IV, No 1, pp. 25-29.

[12] Bouton, Mark E., 2006, *Learning and Behavior: A Contemporary Synthesis*, Sunderland Massachusetts: Sinauer Associates, Chapter 8: *How Stimuli Guide Instrumental Action.*

Key Words

Workload, factor analysis, Continuous Descent Approach, psychosocial work environment, Theory of Planned Behaviour, halo effect, Seven Stages of Change model, acceptance of change.

Author Biographies

Andrew Cook is Senior Research Fellow at the University of Westminster, having previously obtained his DPhil Physiological Sciences (Sub-Faculty of Medical Sciences), at the University of Oxford (1993), and a BA (Hons), Natural Sciences, University of Oxford (1989).

Graham Tanner is Research Fellow at the University of Westminster, having previously obtained his MSc in Transport Studies at Cranfield University (1993), and a BA (Hons) in Government at UCE Birmingham (1992).

The research activities of this team over the last ten years at the Transport Studies Group, University of Westminster, both in ATM and ATC, and more widely in aviation and rail, have focused on Revealed Preference and Stated Preference studies, benchmarking, technical studies and behavioural research, for: the European Commission, EPSRC, the Department for Transport, the Energy Technology Support Unit, the airline industry, LVNL, NATS, the UK Department of Trade and Industry, and six studies for EUROCONTROL (two of which are on-going).