Descriptive models of how accidents occur are now commonplace in the aviation industry. These models are useful for guiding accident investigation teams and for helping to decide what changes need to be introduced to reduce the possibility of further accidents. However, from a psychological point of view, what is still lacking in the field is an empirical model that links organizational constructs such as safety climate with individual variables such as stress and fatigue and then shows how both of these combine to influence important outcome variables such as workplace violations, errors, and willingness to report incidents and near-misses.

The present paper reports on a series of studies conducted within aviation maintenance settings. The first study focussed on the link between safety climate, stress, and maintenance errors. The results suggested that safety climate does not have a direct effect on errors but has a strong indirect effect via psychological stress experienced by individual workers. A second study replicated this finding. A third study extended the model to include workplace violations and demonstrated the importance of measuring management attitudes and group norms when assessing intention to violate and actual violation behaviours. A fourth study has just been completed that introduced a variable labelled as willingness to report. Sections of the path model that were established in earlier studies received further support and a strong link was established between safety climate and willingness to report.

The paper concludes with recommendations as to how these empirical findings can be used to support ongoing initiatives in safety training.

Introduction

The increasingly sophisticated error classification schemes now in use in the aviation industry recognise the multiple causes of error by providing categories that capture the role of organizational, social, and individual variables. These categories embrace the roles of maintainers, operators, supervisors, as well as various levels of management (e.g., Shappell & Wiegman, 1997). The problem with classification schemes, however, is that there is no causal model embedded in the schemes to show how the linkages within the system operate. This is not to say that they are of no value. Classification schemes, provided they are backed by comprehensive investigation procedures, are very useful for identifying weak points in a system. What are needed in addition to the schemes are empirical models that illustrate how the parts of the system work to influence outcomes. The present research programme set out to develop such a causal model. The focal point of the programme has been maintenance performance in the aviation industry and it was within this context that the interaction between organizational, social, and individual variables was examined.

Study 1 (See 1999 ISAP Proceedings)

The first study was designed to explore the role of individual and organizational variables in maintenance performance in the aviation industry. Specifically, the objectives of the study were to: a) examine a number of organisational, job and individual factors that were considered likely to impact on maintenance performance; b) explore the relations among these variables; and c) develop a model for predicting important work outcome variables such as turnover intentions, psychological health, and self-reported maintenance errors.

A total of 240 maintenance engineers (232 males) working at the two main helicopter repair bases for the Australian Army responded to a safety climate survey constructed by the author and colleagues. Structural equation modeling was used to develop and test a model linking organizational and individual variables with self-reported maintenance errors and turnover intentions. A model which provided a good fit to the data is shown in Figure 1.
Errors, Violations, and Reporting Behavior in Aviation Maintenance  

Study 2 (See 2001 ASAP Proceedings)

The Fogarty et al. (1999) study provided strong empirical support for a model that that is implicit in the theories of Reason (1990, 1997) and embedded in a number of error taxonomies (e.g., HFACS: Shappell & Wiegmann, 1997). As such, the study represents an important contribution to the literature on human error. However, one limitation of the study by Fogarty and colleagues was the small number of items (4) used to construct the error scale. As the main outcome variable, it is essential that work continues on the improvement of the measurement properties of this key construct. It was also important that the structural model developed by Fogarty et al. (1999) be tested with a fresh sample of maintenance engineers.

Study 2 was essentially a validation study to test four hypotheses derived from the Fogarty et al. (1999) study. The four hypotheses were:

H1: That organizational factors would contribute to individual health.

H2: That organizational factors would contribute to individual morale.

H3: That organizational factors would not have a direct link with errors.

H4: That individual health and morale would have a direct effect on errors.

The Maintenance Environment Survey (MES) used in the first study was modified slightly and administered to 104 maintenance engineers working at the same Australian Army Aviation bases. The model is shown in Figure 2.

Figure 1. Explaining maintenance errors using workplace variables, morale, and health.

The main features of this model are that:

- Fit indices were acceptable (e.g., CFI = .99).
- Workplace variables accounted for 40% of the variance in Health.
- Workplace variables accounted for 58% of the variance in Morale.
- Health was the major predictor of maintenance errors, Morale a lesser contributor. Neither job intentions nor workplace variables exerted a direct influence on errors, although workplace variables had a significant indirect effect through Morale and Health.

Figure 2. Explaining maintenance errors: A replication with a more comprehensive error scale
The main features of this second model are that:

- Fit statistics were again within acceptable limits.
- The latent variable, Workplace, is now treated as a composite with formative rather than reflective indicators (MacCallum & Browne, 1993).
- The model once again showed that although workplace variables have a strong influence on health and morale of employees, the influence of these variables on errors is entirely indirect.
- The drop in variance explained in errors was probably due to the fact that this sample of maintenance engineers was more restricted, consisting mostly of newer recruits who had only recently completed basic theoretical training.

Taken together, the findings from these two studies support the claims of other researchers who point to the role that social and organizational factors can have on human error (e.g., Reason, 1990). As these researchers assert, many errors result from interacting causes involving physical, cognitive, social, and organizational factors. To understand this interaction requires a model of how the components of the system work together to influence outcomes. We have provided such a model.

**Study 3**

Within the safety climate approach (see review by Flin et al., 2000), a number of researchers have attempted to categorise safety climate variables with the aim of constructing models to explain the interactions among the variables. The most common means of categorising variables is to organise them according to the level at which the variable exerts influence. That is, variables are classified at either the organisational, group, or individual level. The previous two studies fall into this category with the results suggesting that the effect of organisational level variables on errors is mediated by individual level factors, such as health and stress.

A similar study by Lawton (1998) examined the causes of violations among railway shunters working in the United Kingdom. Although the outcome variable was different in each case (errors versus violations), both models showed individual level variables mediating the relationship between organisational factors and measures of unsafe behaviour. Fogarty and Neal (2002) combined these two variables in their work on the causes of both violations and errors in the construction industry. The authors hypothesised that safety climate variables would predict violations, whereas individual level variables would predict errors. The relations among the variables used by Fogarty and Neal are modelled in Figure 3.

![Figure 3. Predicting violations and errors in the construction industry (Fogarty & Neal, 2002).](image-url)

As illustrated by the model, safety climate variables are seen as impacting directly on violations and the personal resources of employees. The employees’ resources influence the psychological strain they feel, which is directly responsible for the number of errors they make. According to Fogarty and Neal, there is also a causal link between violations and errors.

Study 3 built upon this earlier work by Fogarty and Neal and located it within Ajzen’s (1988) Theory of Planned Behaviour (TPB).

The main components of the TPB are a person’s own attitude, subjective norms, perceived behavioural control, intentions, and behaviour (Ajzen, 1988). Ajzen hypothesised that attitudes often fail to exhibit strong correlations with behaviour because of the large number of factors that potentially prevent the attitude from being converted to behaviour. Consequently, Ajzen introduced the concept of intention as a link between attitude and behaviour to strengthen the relationship. In this way, attitudes can be used to predict an individual’s intention to perform a behaviour, which in turn can be used to predict the occurrence of the actual behaviour. The incorporation of intention as a mediating variable has served to strengthen the relationship between attitudes and behaviour in the application of the TPB across a variety of settings (e.g., Conner, Warren, Close, & Sparks, 1999). The concept of subjective norms is more complex. Subjective norms refer to the beliefs and behaviours of people who are likely to influence the view of the individual. In a work situation, this is likely to include both managers and those coworkers who are closely associated with the individual. For
example, if an employee does not believe that management or colleagues are concerned with safety, then they are less likely to consider safety as important. The third predictor of intention and also a direct predictor of behaviour is the component of perceived behavioural control. According to Ajzen, perceived behavioural control strengthens the relationship between intentions and behaviour. Ajzen argued that people often intend to perform certain behaviours, yet fail because of factors which fall outside their control.

To a large extent, the constructs included in the TPB mirror the individual, group, and organisational level variables measured by Fogarty and Neal (2002) in their study of violations in the construction industry. Consequently, it was felt that the TPB could be used to provide a theoretical foundation for the prediction of violations in aviation maintenance. Specifically, we hypothesized that management attitudes would exert an indirect influence on violation behaviour via own attitudes, group norms, and perceived control. We also hypothesised that group norms would have a direct effect on own attitudes.

Some components of the MES from the earlier studies were included in the survey but, for the most part, the scales were new and developed for the purpose of this study. Factorial validity and reliability estimates were checked using SPSS. All scales were satisfactory.

Participants in Study 3 included 312 aircraft maintenance personnel from the Australian Army (N = 105), Navy (N = 86), and Air Force (N = 116), plus 6 civilian maintainers. The majority of the participants were aircraft maintainers (52%) or avionics maintainers (39%), while the remaining nine percent were involved in other maintenance support roles. The survey was distributed by staff working for the Directorate of Flying Safety and returned to the author for analysis. It is not certain exactly how the sample was chosen but these figures represent less than 20% of the total population of maintainers in the three branches of the Australian Defence Force (ADF).

Amos 4.01 (Arbuckle, 1999) was used to test the fit of the path model shown in Figure 4 to the covariance matrix generated from the safety climate variables.

The main findings from this model are that:
- Management attitudes have an effect – either directly or indirectly - on all other variables in the model.
- Group norms affect individual attitudes, workplace stressors, intention to violate, and actual violations.
- Workplace stress is not strongly associated with intention to violate and is not linked at all with actual violations when these other variables are included in the model.

The introduction of Ajzen’s TPB model helped to identify variables relevant to the prediction of violation behaviour, however the model does not cover errors, one of the key outcome variables in this programme of study, so the author reverted to the safety climate approach to develop a more extensive model linking errors, violations, and reporting behaviour. This work is described in Study 4.

**Study 4**

The three previous studies had all focused on explaining errors and violations. However, another key variable in aviation safety is the need to report violations and errors so that a comprehensive database on types of error/violation and their
associated causes can be compiled for system design and training purposes. The ADF has a well-established and well-promoted incident reporting system but is aware that many personnel do not use the reporting system at all. It was the author’s view that some of the reasons for non-use can be found among the safety climate variables used in earlier studies. Accordingly, the last study in this series was designed to integrate a variable called reporting behaviour into the model already developed in previous studies. For this purpose, a revised safety climate scale was developed and administered to 178 maintenance personnel responsible for servicing the Army Aviation helicopter fleet.

Results are summarised in Figure 5. Note that this model has been simplified for publication purposes and that the actual model contained both measurement and structural components. A brief description of the measurement components is given in the next paragraph.

The organisational factors variable was measured by five scales: supervision, commitment, communication, management support, and training. Workplace was a much narrower variable than in previous studies, comprising documentation (manuals, workcards, etc) and adequacy of resources. The stressors variable was measured by a range of items covering such issues as time pressures and work overload. All other variables in the path diagram shown in Figure 5 were formed from multiple-item aggregate scales.

The model shows that the organizational factors measured by the survey have a direct effect on the workplace environment and violations. The arrows indicate the direction of the effect. Workplace environment, in turn, has a direct effect on the stressors experienced by individual workers. Violations and individual health (which translates to strain in the present study) also have an effect on Errors.

As far as tendency to report is concerned, the expected links with errors and violations were noted (one has to make an error before one can report it). Organizational factors affected tendency to report, confirming that employees were more likely to report mistakes in situations where management is communicative, open, and committed to safety values.

R-square values were high for both the violations (62%) and errors (74%) outcome variables, reflecting the work that has already gone into determining the precursors to these behaviors in the earlier studies reported here. R-square for reporting behavior should improve as we get a better understanding of the motivators for this type of behavior.

Conclusions

There are many examples of safety climate surveys in the literature. When used in organizational settings, such surveys will demonstrate that short-cuts and work-arounds do occur in maintenance work and that supervisors and managers are aware of these deviations from set procedures. There are undoubtedly practical reasons (e.g., time pressures) for these short-cuts but statistical analyses of data collected from surveys such as the ones used in the present research programme repeatedly show that there are reliable links among violations and errors (e.g., Fogarty, Saunders, & Collyer, 1999, 2001) and organizational and individual variables.

These findings support the claims of other researchers who point to the role that social and organizational factors can have on human error (e.g., Reason, 1990). As these researchers assert, many errors result from interacting causes involving physical, cognitive, social, and organizational factors. To understand this interaction requires a model of how the components of the system work together to influence outcomes. We have provided such a model.

The first version of the model focused on the explanation of variance in self-reported errors.
Subsequent extensions of the model included other crucial safety outcomes such as violations and tendency to report safety incidents. The various models are conceptually driven and repeatedly validated on different datasets.

Continuing education is needed to improve awareness of these causal links. It will never be possible to completely eradicate errors, violations, or to achieve complete reporting of workplace incidents, but the process of validating influential but essentially descriptive models of safety behaviour will help to bring about attitude change at all levels of an organisation.

Where to from here?

Safety climate measures such as the ones used in these studies are very useful but they should be standardised so that the items and scales are basically the same across administrations, thus permitting the establishment of benchmarks on the various scales (Flin et al, 2000). We have not yet reached the point where we can standardise. The focus of the research up to this point has been the identification of key safety outcomes and defining the network of relationships among these variables and background climate variables. The next step will be to put together an instrument that is short enough for practical use but comprehensive enough to capture the constructs outlined in this paper.

A related aim is to link self-report measures with actual performance outcomes, rather than simply using self-report as the basis of measurement operations. The low base rates of incidents and errors suggests that this research will involve higher level modeling, but it is my expectation that the models developed to this point will prove useful in explaining safety data, whatever form it takes.

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The figures reproduced in this paper have not appeared elsewhere other than in the proceedings of the 1999 and 2001 International Symposiums on Aviation Psychology (Figs 1 & 2).

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