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Safety research during the past decade has increasingly emphasized the importance of understanding both positive and negative aspects of performance, rather than errors, risks, and accidents alone. As the aviation industry already enjoys such a low accident rate, safety managers are looking for predictive approaches in order to proactively monitor system behaviour. Expectations of the scope and complexity of models has also increased, trying to keep pace with the rapid evolution of the industry, and a systems view has now become the aspiration. A risk-management approach called the Safety Model Based Analysis (SaMBA) developed by Dédale attempts to meet these modern objectives. This paper describes and discusses the various challenges Dédale encountered during two attempts to apply SaMBA[2] at different organizations, only one of which was successful. The factors were manifold, among them certain challenges specific to safety interventions which raise questions about the industry's capacity for safety innovation.

Introduction

An approach called the Safety Model Based Analysis (SaMBA) developed by researchers at Dédale is an attempt to meet the needs of today's safety practitioners. SaMBA is a practical risk-management tool based on a predictive safety model. This analysis method creates and employs a "safety architecture" to capture a global view of how safety is created and maintained within a process or activity (e.g. a flight or a maintenance operation). The top-down safety model provides a picture of how the system is intended to be safe, which is used as a framework to make sense of bottom-up event data from daily operations. The comparison of empirical events with the safety architecture enables the maintenance of the model so that it stays relevant and informative, providing a way of monitoring practical drift towards the boundaries of safe practice.

SaMBA was developed over the past 8 years through a series of projects involving range of European commercial aviation activities: airline maintenance, aircraft manufacturing, air traffic management, civil aviation regulation, and accident investigation. The concept and principles were developed based on industry needs exposed during the earlier projects. Then two large-scale projects were conducted where a full version of the method was to be implemented to support operational safety management.

The basic principles behind the SaMBA approach are only described as required to give the necessary context (the approach is described in Bieder & Pariès 2003 and Pariès & Bieder 2003). The purpose of this paper is to describe the challenges Dédale encountered during the large-scale trials. Thus the discussion will focus on the factors which appeared to facilitate or hinder the success of implementing the SaMBA safety analysis method into the industrial workplace.

Closing the learning loop

Dédale is currently conducting a review of the facilitators and barriers to the application of SaMBA for the HILAS (Human Integration into the Lifecycle of Aviation Systems) project to ensure the smoothest possible implementation of any new tools and methods. The results and conclusions discussed here are based on interviews with Dédale staff only; the perspectives of the industrial partners will be discussed separately.

The retrospective observations of the participants themselves do not constitute 'hard scientific evidence'; nonetheless, there is value in the exercise of reflection and evaluation. It also provides feedback to the aviation safety community and initiates the opportunity to exchange ideas on the topic. In the hopes that the experiences and lessons-learned through these cases are externally valid, they have

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[2] The approach was given different names specific to the projects.

been generalized beyond their original context. This paper comprises a brief description of the attempted safety intervention and the features of the tool, the organizations, and the industry, which may have acted as barriers or facilitators to the change. There is more emphasis on hypothesized barriers which are specific to safety innovation, since understanding these problems is the first step towards solving them.

Changing safety management in the 'real world'

Two very different cases

The large-scale attempts to implement SaMBA differed in a variety of ways. Examples of the differences which appear relevant (at least in hindsight) to the outcome of the projects are briefly outlined in Table 1.

First of all, there was a fundamental difference between the objectives of the different organizations: in one case SaMBA was intended to fill an existing need, in the other improve an existing risk management system. The case where SaMBA was not adopted was a larger, more mature organisation with very high ambitions of using the approach throughout the entire company for the full range of their activities. This would have required significant restructuring of the company's safety management, information flow, and decision-making. The financial implications were within the means of the organization but nevertheless significant.

The company in the second case was much smaller and only wanted to adopt the approach for a relatively independent sub-unit, so the objectives were on a much more limited scale. This sub-unit was already undergoing changes at the time due to new regulatory requirements, resulting in extra flexibility. This company already had the appropriate personnel in a position to spear-head the change and act as process-owners, whereas the organization in case #1 needed to reassign their human resources to support the initiative.

The original plan, in case #1, was that SaMBA would be implemented during a period of reorganization, there were slips in the schedule which resulted in it being too late to realize this. The role of external consultant in this first case brought with it the typical political paradox where the advice of outsiders may be considered by some employees as a helpful voice, more likely to be heard by decision-makers, while others may view it as unnecessary or inappropriate interference, possibly even resenting the implication that outside expertise is required.

In case #2 the application of SaMBA was in the context of a European research project. As the company had an existing need for the tool, the timing was less of an issue and the political and economic context was more favourable to putting SaMBA into practice.

Table 1. *Comparing surface features of the cases*

	Case #1 **Unsuccessful**	Case #2 **Successful**
Goal	Improve/replace existing system	Create new system
Scope	All-encompassing	Limited to one activity
Org. Size	Large	Small
Org. Features	Mature	Undergoing change
Human Resources	No appropriate position existed	Dedicated task-owner existed
Timing	Out of synch with work plan	Newly created need
Context	Consulting project	Research project (partially funded)

Necessary but not sufficient?

While the circumstances of the cases illustrate some barriers to organizational change which may be common sense and are already well treated in management literature, it is not realistic to limit safety improvement efforts to small organizations or business units conveniently experiencing a phase of transition, etc. This would mean ignoring the players with the largest contributions to the industry.

The challenges faced in case #1 are daunting but not insurmountable if the organisation is sufficiently motivated. The fact that the company already had a well-established, compliant safety and risk management operation meant that there was no compelling, easily demonstrable need. In aviation, the rule-of-thumb is "if it's not broken, don't fix it" since the system is very complex and tightly coupled so any change can have multiple, far-reaching, and sometimes unanticipated consequences. It is prudent, therefore, not to make any changes unless the benefits are clear and unequivocal. There were internal stakeholders in case #1 who were convinced of the need for this change and the enormous potential benefit, but the onus was on them (and Dédale) to demonstrate a convincing case, that the benefits would justify potential negative effects.

Digging for deeper explanations

The surface features of the cases notwithstanding; Dédale hypothesizes three reasons for the lack of

success which specifically address the characteristics of safety management in aviation: (a) An unavoidable conflict of interest for those who should have been spearheading the project caused internal resistance; (b) The legal and legislative framework discourages organizations from exceeding the minimum safety requirements; (c) the fragmented structure of the industry means that some safety needs are structurally separate from the means to fulfill them, and the ambiguous commercial value of 'safety' does not naturally yield a supply-demand paradigm in response.

Conflict of interest

SaMBA integrates operational event data within the framework of a top-down safety architecture and highlights areas where the empirical data contradicts the theoretical safety model. It proposes ways of working, ways of thinking, information flows, decision-making, and organization of safety management activities which differ from the traditional approaches. SaMBA is a "revolution rather than an evolution" (Swuste & Arnoldy, 2003, p. 19), requiring major structural and paradigmatic changes. This is likely to be traumatic for any mature or traditional organization.

The SaMBA method relies heavily on the active engagement of employees throughout the organization, particularly operators and decision-makers. The flow of information is completely reorganized and becomes more direct, which breaks down the structural barriers between sub-units. The 'health status' of the system is rendered transparent so that everyone can see and understand it. In short, returning to the principle that "safety is everybody's job".

If there is an existing safety department, they will no longer act as the main conduit for certain types of safety information. They must transfer some of their responsibility and decision-making capacity to other departments, and as a result their role will be redefined. This does not imply that safety managers, risk analysts, or incident investigators are less important or out of a job, quite the contrary: as a major safety initiative it is imperative that these groups take on principal roles.

Implementing and using SaMBA requires the adoption of a non-traditional perspective of safety and risk. SaMBA attempts to consider the system as more of an ecological whole: The method involves describing *a priori* how the system maintains its functions, rather than 'calculating' safety quantitatively based on aggregations of component reliability and risk probability. Confronting the underlying assumptions about safety is further complicated due to the fact that they are rarely made explicit and they have likely been the status quo for decades. The system perspective taken by SaMBA is fundamentally at odds with the status quo in fact, thus accepting the new implies rejecting the old. This potentially creates cognitive tension and even defensive responses in individuals with a stake in the traditional approach.

Both of these structural and semantic adjustments put existing safety personnel in an uncomfortable position, and it is only natural for individuals to resist the change. These sources of individual resistance are covered in the management and sociology literature and it is not the objective of this paper to repeat that in detail.

Since it is these safety personnel critical to effecting the change who are likely to feel the most threatened, there is a conflict of interest. During the unsuccessful case, Dédale personnel claim to have seen evidence that people were threatened by these changes. The resulting conflict apparently created vigorous opposition to SaMBA in favour of the status quo or some other, less 'revolutionary' approach.

Be careful what you wish for

One of the key challenges facing safety researchers and practitioners is how to create a sense of urgency and reduce uncertainty about the need to act before an event or incident has occurred – in other words, how to create a proactive approach. One of the principle objectives of SaMBA is to make potential problems salient and unambiguous, in part through the creation of a more realistic picture of the gap between theory (what people say they do) and practice (what people do) but this creates a legal dilemma for the company since changes require resources and resources are limited. SaMBA is meant to support the prioritization of safety concerns, however, the company still much make choices.

Although it is becoming gradually more acceptable to admit that procedures are not perfect and not all rules can be followed all of the time, there is still very little room for this grey area amid the blacks and whites of litigious Western society (Dekker, 2005). People are understandably fearful and reluctant to abandon the normative paradigm, at least when in comes to official company policy and written documentation. There is still little alternative available to management and regulators, "accountability" remains the name of the game.

So with increased knowledge comes the burden of increased (legal) responsibility. A method like SaMBA which makes the system's vulnerabilities more visible and compelling (and leaves a permanent written trace) is a mixed blessing given the realities of the modern judicial context (Anderson, 2004; Nørbjerg, n.d.) and intense commercial pressure. Along a similar vein, organizations required to demonstrate that they are 'safe' according to a rigid regulatory definition may also balk at tools which provide "too much of a good thing".

Structural divisions and supply vs. demand

If it does not pay to exceed the minimum requirements in the case of regulatory and judicial matters, then this may be even more true from an economic standpoint.

The SaMBA approach takes the process or activity as its unit of analysis so organizational boundaries are irrelevant. Speaking from an ecological perspective, the aviation system could be considered as a whole and in that case it seems illogical that the industry (design, manufacture, operation, training, maintenance, and infrastructure of air transport technology systems) does not share safety objectives or a model of successful performance, or even communicate easily and openly about safety concerns. This is not surprising, however, considering the commercially and structurally divisive configuration of the industry. Not only is the system not fully cooperative (although there are certainly exceptions), the industry is so fragmented that it is not rare to find that the inter-organizational relationship is adversarial. The intangible nature of "safety" is likely the main reason for this unfortunate situation.

Take the simple example of an airline and an aircraft manufacturer: suppose that an airline must choose whether to purchase one of two aircraft, each roughly equivalent from a technical standpoint. The airline could expect to experience fewer operational problems (which has both safety and economic implications) if they purchase the aircraft which has a superior HCI and human factors design concept. The manufacturer knows what these design features cost to realize, and could be expected to charge a higher price, but the airline may not have any way to ascertain the monetary value of this investment. The costs are immediate and always visible but traditional safety measures (i.e. lack of accidents or incidents) are based on very long-term statistics and are not easily seen or quantified; Cost-benefit analyses do not lend themselves readily to calculations of the economic savings of not having an accident.

And what of the even less tangible, cooperative endeavours, such as incident reporting systems? The airline may want to give feedback to a manufacturer so that they will improve the quality of their technology or procedures. These improvements would benefit both the airline and the manufacturer (presumably they would have increased sales), so who should cover the costs of running the reporting system?

While these are oversimplified examples of an extremely complex subject, the bottom line is that at industry level there exist both safety needs and the means to meet these needs, but these may not be collocated within the same organization. Thus one party may shoulder the (short-term) cost while the other enjoys the (long-term) benefits, and the ambiguous commercial value of safety means that no mutually satisfactory supply-demand framework emerges. In fact, it may be the inverse: a tendency towards the "tragedy of the commons" approach to safety (Ostrom (1990) in Woods, 2006, p. 303 and in Senge, 1990, p. 397). The main mediator is the regulator, however this does not fully replace the potential synergy of cooperation.

The experiences of Dédale confirm the claims of management literature: a clear understanding of the needs and benefits of the change is a key component for success. This does not bode well, then, for meeting the safety needs of a fragmented industry.

Conclusion

Factors influencing the success of making a new safety approach operational include the structural and semantic characteristics of the tool, the fit of the tool with the needs of the user, the commitment of the user to the cause, and the economic, political, and legislative environment. SMEs (subject matter experts) and academics are retained for research and consulting projects because of their expertise of the subject, thus important practicalities such as usability and organizational resistance run the risk of being neglected.

The creators of SaMBA recognized that developing the idea is only the first in a series of hurdles, but even when such matters are given sufficient attention success is not guaranteed. The organizational and industry-level barriers to innovation and change may be beyond the control of the individual researcher or safety department.

Some of the barriers described in this paper are not completely novel, however the fact remains that organizations and consultants often do not learn from the past. According to change management literature

the overwhelming majority of organizational changes do not achieve their objectives (Pfeffer & Suttion, 2000). The aviation system is mature and becoming increasingly standardized on a global scale, thus the limitations on innovation caused by organizational stiffness (Amalberti, 2006) and characteristics unique to aviation safety are increasingly apparent.

If there is any hope of making progress there must be a clear statement of the problem in order to unify aviation's global safety goals. This is the first step along a cooperative path towards a commercial regulatory environment in which organizations are not discouraged from surpassing the minimum safety standards and are free of the restrictions on safety innovations imposed by the current judicial and financially strained operational context.

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