On Using AcciMap to Support Judgements of Risk During System Development

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SUMMARY

AcciMap is a tool developed for the investigation of system failures during past events. This empirical study on the judgements of 12 specialists investigated judgements of potential failure associated with system development using the AcciMap technique. The system development studied was a radar centre for the defence of London in the late 1930s. The results showed that system development experts make consistent judgements on some AcciMap characteristics but not others including external influences and some job designs.

KEYWORDS

System development, risk assessment, AcciMap

General Introduction and Aim

System development teams are keen to mitigate risks during the development process, so that the product has well founded characteristics when "in service". One ergonomics/human factors technique in support of this aim is Early Human Factors Analysis (EHFA) to identify risks with a view to mitigation. This use of EHFA has been central to the application of ergonomics/human factors as required by the UK Ministry of Defence (2016) over at least the past two decades. The judgements of risk involve estimates of both likelihood and impact of design characteristics. However, little is known about how well these judgements are made during system development.

Ergonomics specialists have known for many years that people can be poor in making judgements of risk (Cohen, 1960) and that these judgements can be easily influenced by a variety of circumstances. Further, these judgements can be influenced during group decision making (Kogan and Wallach 1967) when group influences can increase the likelihood of making risky judgments. However, in a system development context, we have no empirical evidence to indicate how good or bad, systems development specialists may be in making judgements that underpin the assessment of risk. Further, many of these judgements are made in a team context.

This investigation set out to survey the judgements of system development specialists with a view to gaining a better understanding of their strengths and weaknesses when makings judgments of likelihood and impact. These judgements underpin the assessment of risk.

One technique employed to understand the characteristics of past failures is "AcciMap". However, in this case, the AcciMap technique was used to look forward into the future deployment of a system rather than backward to understand failings as exemplified by Waterson (2023). Further the technique needed to be linked to a task involving judgements that might be undertaken during system development where there is a need to avoid failure. Hence, it was recognised from the start that a characterisation scheme was required that supported the study of judgements about the future.

Waterson (2023) summarised his approach to AcciMap using five categories which support the characterisation of failures:

- external influencers,
- organisational issues,
- workplace constraints,
- physical constraints and
- outcomes.

These categories may be considered in terms of a set of layered descriptions that can be traced from one to another and be functionally decomposed from the highest to lowest levels. The linkages between the layers give traceability within the development process.

Firstly, the external issues in system development are the system goal and associated conditions which must be specifically defined to ensure that its functional decomposition yields specific criteria at each layer. Secondly the organisational layer provides a description of the operation/business which determines the functions which the system must perform. Thirdly, the workplace must be described as they determine the conditions and constraints which are a result of the equipment characteristics and the tasks which must be performed to ensure effective and safe operation. The final two layers describe the tasks for the users within the system and their individual and personnel characteristics.

The Technique

The AcciMap categories are given in the left hand column of Table 1. These categories have to be mapped onto system characteristics which are relevant to system development.

The system characteristics relevant to the user are given in Table 1. The mapping is made to characteristics used to describe a User System Architecture (USA) as described in earlier studies (Tainsh, 2018).

The USA forms part of the total system architecture for the capability. However, to understand the risks within the design, it is necessary to understand the possible causes of failures that may occur over the anticipated lifetime of the system. This is true for equipment as well as organisation development, or combinations of the two. Once the possible causes of failure are identified then mitigation can be put into position.

An understanding of the extent of the risk is important to support studies of their mitigation as these will help identify the likelihood and impact of adverse events occurring. The case for mitigation will depend on judgements of these two factors.

Table 1 uses the concept of Layers. The USA is understood to be open to functional decomposition where each layer is available for decomposition into the layer below. The exact process of decomposition will depend on the specific layers under consideration. The Layer number is a shorthand means of reference.

Table 1: AcciMap summary as applied to USA within investigation (Waterson et al 2017)

Layer number	AcciMap Categories	USA Layer Name	The features of Biggin Hill air defence capability at RAF Biggin Hill
1	External influences – System goal and capability	User goal, scenario/ context and constraints	Defend London Air Defence Area (LADA).
2	Organisational issues	Business/operational description	Conduct coordinated Air Defence from Biggin Hill to counter the threat through the use of a

			three layered system of assets (an outer layer of guns, middle layer fighters and an inner layer of balloons and barrages).
3	Workplace constraints, Physical constraints	A technical description of the system's equipment including user aspect	Use of radar, plotting tables and secure telephony with specialist military teams.
4	Team /task issues	Users' roles and team organisation	Use of standalone radars by specialist RAF teams to plot aircraft movements and intelligence, to feed information to asset controllers.
5	Work personnel issues	Individual User's characteristics and tasks	Air defence picture compilers/plotters Asset managers

The Capability of Air Defence of London in the late 1930s

The example of capability development used here is Air Defence at RAF Command at Biggin Hill (Zimmerman, 20024). This development was undertaken in highest secrecy during the late 1930s.

The air defence capability for London was achieved, in part, through a radar system with the user architectural characteristics shown in Table 1. This formed part of the total system architecture for the capability which in turn linked into the overall defence capability of the UK. Clearly the radar system is part of a larger defence system including air and other assets.

The development intention is to have requirements that result in performance effectiveness that satisfied criteria of RAOAL (Risks At Operationally Acceptable Levels). These criteria address the lifecycle of the system.

The RAOAL assessment criterion is associated with an appropriate risk assessment matrix. In this context "highly unlikely" may be quantified as not expected to change within the next year but maybe within two-to three years, "unlikely" as potentially could happen within the year but not expected, "likely" means that an impact could be expected within the first two quarters of the year. Guidance on the meaning of the impact assessment was provided to the participants for each judgement.

The impacts are quantified dependent on the characteristics of the system. The evaluation of the combination of impact a likelihood is given in Figure 1 which uses a set of categories ranging from trivial, tolerable, moderate, substantial up to intolerable. Clearly the latter two categories are the most severe and to be avoided. All categories of risk should be addressed proportionately i.e. with project effort matching risk severity as part of the mitigation process.

		Potential degree of impact/performance loss		
		Systems experiences slight performance loss	Systems experiences minor loss of performance	Systems involves major loss of performance
Likelihood of loss occurring	Highly unlikely	Trivial	Tolerable	Moderate
	Unlikely	Tolerable	Moderate	Substantial
	Likely	Moderate	Substantial	Intolerable

Figure 1: Applicable Risk Matrix with outcome evaluations

The Study

A study was conducted with participants who were all employees of BAES with substantial experience of system development. It was not a homogeneous group - all had varied backgrounds as users, engineers, managers and ergonomics specialists.

Each participant was given a 14 page proforma which described the development of radar as taken from Zimmerman (2004) and described each of the USA layers with a description of the impacts as shown in Table 2.

Method

The investigation was conducted by the author. It included describing the radar development process which was detailed within the proformas to each participant. The proformas included a figure for recording the risk decisions. It was also explained that the task of making the judgements should be carried out under calm conditions that enabled each participant to take full account of all the information that was provided in the proformas. The participants carried out this task away from the workplace.

The means of categorising likelihood was explained along with the specification of categories of impact for each layer.

It was explained that a single cell of the risk matrix had to be selected as this was the risk that was to be used for developing the radar system. Mitigation would depend on the evaluation associated with it.

The participants completed the task independently but were able to ask for advice to clarify information and ensure their understanding. The data from all the twelve participants was tabulated in histograms and each histogram was compared to a random distribution using a chi-squared technique to assess whether there was consistency in the judgements.

The results

The results are given in full in Table 3. In summary:

- The judgements on external influence (Layer 1) showed no consistency.
- The judgements on the design of the operational system (Layer 2) showed a high degree of consistency with a moderate risk.
- The judgements on the design of the technical system (Layer 3) showed a high degree of consistency with a moderate risk.
- The judgements on the design of the team organisation (Layer 4.1) showed a significant degree of consistency with a moderate risk.
- The judgements on the design of the Duty Officer's job (Layer 4.2) showed no consistency.
- The judgements on the design of the Plotters' jobs (Layer 4.3) showed a significant degree of consistency with a substantial risk.
- The judgements on recruitment and training (Layer 5) showed a high degree of consistency with intolerable risk.

Conclusion

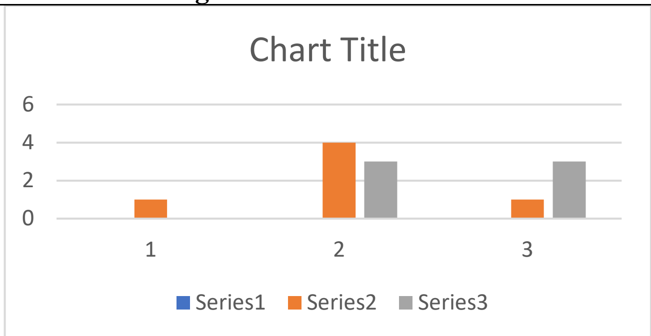
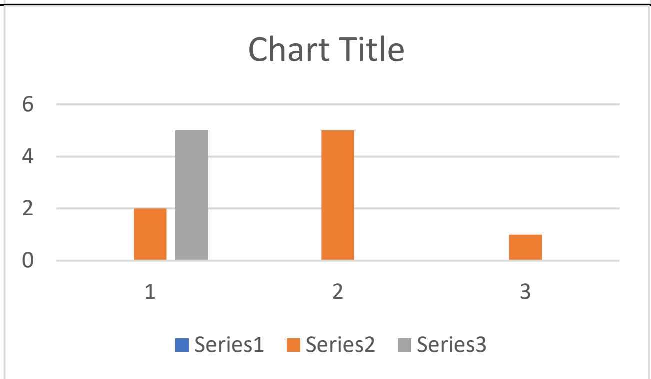
It was found that there was consistency in 5 out of the 7 sets of judgements.

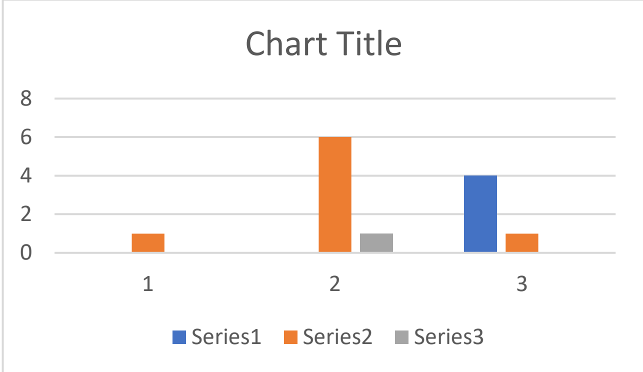
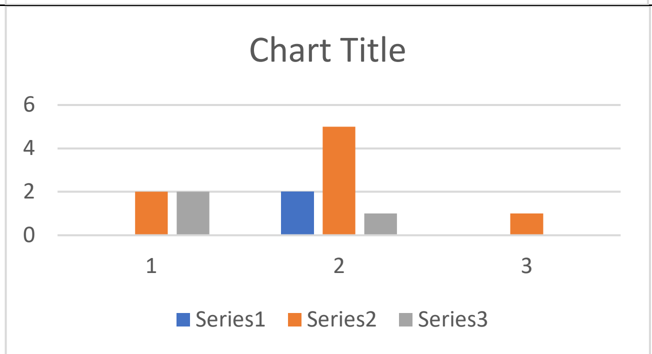
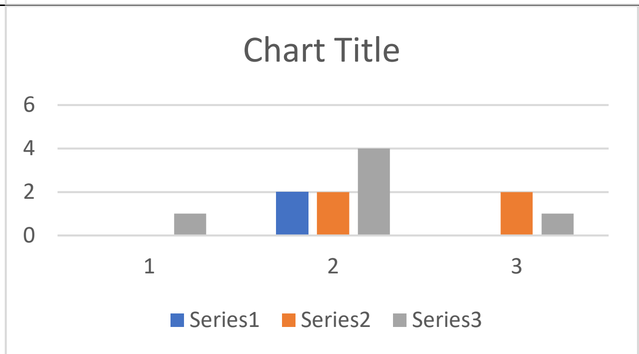
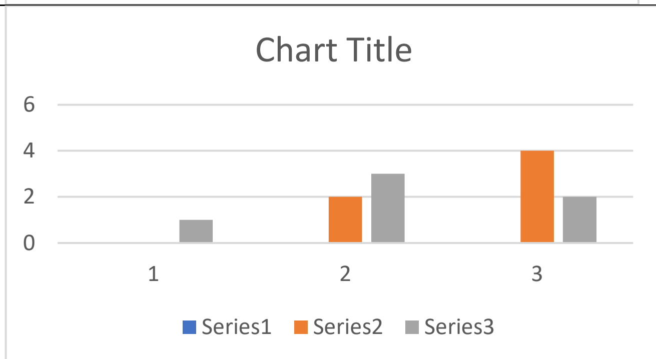
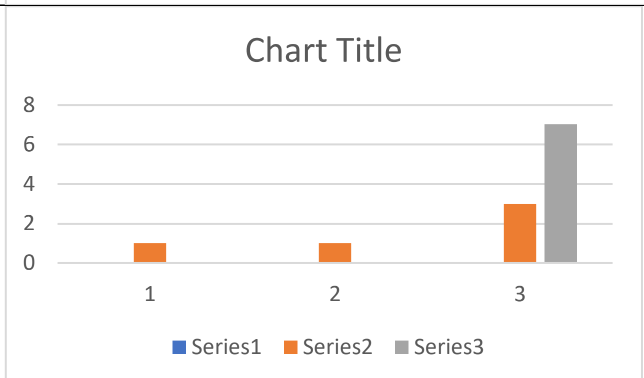
Table 2: Categories of Impact

1 User goal, scenario	Slight	A result of a change in German formations or aircraft weapons.
	Minor	A result of a change in German number of aircraft or means of protection.
	Major	A new class of weapons deployed or a major switch of resources within theatre
2 Organisat-ional/ Operational description	Slight	A result of poor operational practice within the operational system.
	Minor	A result of low capability in limited parts of the system.
	Major	A result of low capability in substantial portions of the system.

3 The system's equipment	Slight	A result of equipment sometimes being unreliable or failing.
	Minor	A result of parts of the equipment set failing but the remainder maintaining operational capability.
	Major	A result of substantial equipment failures.
4.1 Users' roles/ structure	Slight	A result of slight problems of communication or flow of information.
	Minor	A result of a problems of information flow and authorisations in a constrained part of the Command organisation.
	Major	A substantial failure in a pat of the organisation that put the operation at risk of complete failure,
4.2 Users' roles/tasks/ Duty Officer	Slight	A result of the Duty Officer experiencing difficulties in carrying out the task.
	Minor	A result of the Duty Officer experiencing acknowledged performance failures.
	Major	A result of the Duty Officer failing in an important part of his duties.
4.3 Users' roles/tasks/ Plotters	Slight	A result of the Plotters experiencing difficulties in carrying out the task.
	Minor	A result of the Plotters experiencing acknowledged performance failures.
	Major	A result of the Plotters failing in an important part of his duties.
5 Users' recruitment and training	Slight	A result of the Plotters experiencing difficulties in carrying out the task which could be linked to recruitment and training.
	Minor	A result of the Plotters experiencing acknowledged performance failures. which could be linked to recruitment and training?
	Major	A result of the Plotters failing in an important part of their duties which could be linked to recruitment and training.

Table 3: The results showing the raw data and statistical significance

Layer number	**Layer Name**	**Histogram of frequency of participants' judgements (total 12) for each risk matrix. Series 1, Series 2 and Series 3 show impact assessments in increasing magnitude and blue, orange and gray show decreasing likelihoods.**	**Chi-squared prob-ability**
1	User goal, scenario/ context and constraints.		Not significantly different from random
2	Organisational/operational description		Significance greater than 0.001

3	A technical description of the system's equipment including user aspect		Significance greater than 0.001
4.1	Users' roles and team organisation		Significance greater than 0.01
4.2	The Duty Officer		Not significantly different from random
4.3	The Plotters		Significance greater than 0.01
5	Individual User's characteristics and tasks – recruitment and training.		Significance greater than 0.001

Zimmerman does not state how the radar development team approached risk mitigation in the 1930s, but it is clear that an understanding of the external threat may have been difficult to take into account. It appears that some judgments were made consistently by the team but the system design depends on a judgement of external influences and here there was uncertainty. It suggests that the linking of development and external influences needs to be close or else the wrong system will be developed. Fortunately for the UK, in the 1930s, for radar, some good judgements were made by the UK.

AcciMap has helped characterise the USA development, and it appears that BAES employees can made consistent judgements on some development characteristics but have difficulty on two categories. The judgements on external influences are important because of their implications throughout the development. This indicates that engineering judgements as part of EHFA can be consistent but judgements of external events and job design may be less certain.

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