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Modern approach for integrating safety events in a risk management process

ABSTRACT: Safety events offer an apparent opportunity to learn about the operational reality and contribute to risk management. Intensive focus on events has also been criticized, as managing safety events does not seem to correlate with avoiding major accidents. The paper presents a new approach for integrating safety event data in the risk management process by introducing an event risk assessment method and a framework for so-called safety factors. Consequently, event data can be turned into risk data and aggregated presentations of cumulative risk can be created. Safety factors allow capturing negative and positive aspects of safety in line with safety-II principles. The methods are discussed both from the perspective of the underlying safety science and the practical constraints when one has to deal with a constant flow of events. Both methods produce immediate results but also integrate well in the overall risk management process.

1 INTRODUCTION

Real operational events have an interesting role in risk management programs. On one hand they are factual and should provide an opportunity to know what is really going on in the operation. The long-time assumption has been that safety incidents warn about problems which could later lead to accidents. This approach has led to systematic collection of safety events and often to a relatively intensive activity related to analyzing and treating the related issues. As the systems have become safer they have been faced with one of the paradoxes of ultra-safe systems: there are less events to work on. This again has led to moving from reporting incidents to reporting also precursors and precursors to incidents (Amalberti 2001, p. 113).

On the other hand, this classic approach of processing events has been criticized. It is being questioned whether safety incidents actually predict accidents - either through the causal factors they may highlight, or through the increasing number of events. (Hale 2001, Amalberti 2001, p. 123, Dekker 2014, p. 351).

Furthermore, the approach promoted by resilience engineering and safety-II is that the focus should not be on things that go wrong but rather on learning positive lessons about resilience in the normal operation (Hollnagel 2014). It is true, that especially in safe systems (e.g. mass transport) safety events are the exception, not the rule.

In many industries (e.g. aviation, nuclear operation), reporting systems have had the time to establish themselves and organizations may receive hundreds or even thousands of safety reports every month. As safety reports typically include narratives, processing such events introduces a considerable resource requirement. The classic way has been to categorize events using various taxonomies. In light of modern understanding of complex systems it is easy to agree that such reductionism-based approaches have severe limitations in today’s operational complexity. One can ask, is the resource well used?
Another, more recent use of event data has been the creation of safety indicators. However, safety indicators are typically based on counting events without opening the internal dynamics of the events. Therefore, it can be argued that the value of such indicators in reflecting operational safety levels is again very limited (Nisula 2014).

It is therefore justified to ask: how should safety events be utilized within a risk management process? The current paper approaches this question through two sub-questions:

1. How to transform event data into knowledge on risks? This requires being able to deal with events both in terms of severity and probability, and being able to aggregate the results in some meaningful way. Simply counting events does not contribute much to a risk management program.

2. How to start a movement away from the reductionism-based taxonomies towards methods which support modern views on safety management, such as safety-II?

2 CLASSIC METHODS

2.1 Event data

Typically, the event flow reaching the safety analysts consists of different types of events in different formats. For example, airlines may receive air safety reports, ground safety reports, investigation reports and flight data events to name but a few. They all reflect operational events that have been defined important enough to be looked at. The different formats allow different types of analyses and are associated with different resource requirements. In particular, narratives are rich in information and contain interesting details about the dynamics and interactions related to the events. At the same time, a narrative is slow to process because a human analyst needs to read it.

In addition to this diversity of event data, there are two aspects that are significant in the context of risk management. First, the quantity of event data can be so large that the initial analysis applied to all events must be a quick one. Complicated and slow methods can only be applied on some chosen events. Secondly, whatever the data source, event data is always incomplete and biased. Every data source has its strengths and its problems (IATA 2014, p. 21-82).

2.2 Classic ways to treat event data

The classic way to process event data is characterized by three aspects: use of categories and/or descriptors, construction of safety indicators and a flawed method for assessing event risk. Each of these aspects is discussed below.

Due to the large quantity of event data there is a natural need to make sense of it, and using categories and descriptors is probably the most intuitive way of trying to do that. For examples from the maritime and aviation domains, see Landre et Hänninen (2012) and ECCAIRS (2010). As Nisula (2014) argues, such taxonomies (and derived indicators) could work well in a system where the main safety driver is unreliable technology. Statistics on failures by different categories would then show which technical aspects need to be improved. However, today’s systems are characterized by complexity, emergent and transient phenomena, interactions within the sociotechnical system and extremely reliable technology. Therefore, outcome indicators do not seem like an ideal tool for risk assessment. Furthermore, the underlying reliance on reductionism often self-destructs elaborate taxonomies. Trying to be more and more “precise” with the categories leads to a situation where data is spread so thin that the operational usefulness of the system collapses. Lee and De Landre (2000, p. 10) provide a delicious example of this:

“A review of the usage of the existing OASIS events and descriptive factors was completed using data from 1993 to 1995. This revealed that of the 1400 descriptive factors available in OASIS, only 50% were used on average in a year, and that 29% were not used at all. It was further found that if 75% of the least used descriptive factors were removed, it would impact on only 0.5% of occurrences.”

Event categories can also be used as Safety Performance Indicators (SPI). The aim is to make safety performance measurable and make comparisons between different times and regions. Organizations such as the International Civil Aviation Organization (ICAO) are strongly promoting the use of SPIs (ICAO 2010). Almost all current SPIs are measuring outcomes. Consequently, they are more useful for making statistics of yesterday’s safety performance than for predicting tomorrow’s risks. There is a conscious attempt to link some SPIs to lower-severity events in the hope that these could predict risks of accidents. However, as mentioned above, the relationship between lower-severity events and accidents is unclear, and it does not help that indicators merely count how many times certain kinds of events occur - remaining completely insensitive to the content of the event (Nisula 2014).

The notion of event risk is conceptually challenging. First software tools which were created for managing safety events - such as BASIS (British Airways Safety Information System) - missed this challenge. As there was a practical need to prioritize events, a simple risk matrix was introduced. The two dimensions in the matrix were “severity” and “likelihood of recurrence”. The problem was, that the latter is not a feature of a single event. It is a feature of an event family. This conceptual flaw haunted event
risk assessment in aviation until the development of the ARMS methodology in 2010 (ARMS working group 2010). ARMS addressed a number of important issues, for example:

1. In the definition of risk "likelihood x severity", the two questions "likelihood of what?" and "severity of what?" need an absolutely clear answer. Are we talking about real outcomes of events or also potential outcomes? In terms of severity, is the reference the most probable potential outcome, is it the worst-case scenario, or something else?
2. ARMS defined a concept of event risk which truly depends only on the single event in question. The old question on "likelihood of recurrence" implied dependence on other "similar" events. This referred to a vague event family where the meaning of "similar" was not defined. This was a serious trap which often went unnoticed.
3. The previous point also means that event risk values can be summed together to obtain cumulative values, for example for a specific month or a specific place. If risk values had been obtained in the old way and summed together, the result would have been incorrect.

3 THE PROPOSED APPROACH

The new proposed approach consists of two methods:

- To obtain risk information, event risk assessment is performed on all events. This offers a view to the potential severity of events instead of just counting them.
- To be able to process safety on a positive scale, the so-called safety factors are introduced. They offer an alternative to the reductionism-driven taxonomies.

These methods are discussed below, first separately and then in combination to highlight their synergy.

As stated above, the methods must cope with the quantity of event data and with the fact that events will always provide only a partial view to operational risks. Therefore, it must be easy to combine the results with other information on risks including other types of safety information such as observational data.

The approach described below was developed for the Finnish Transport Safety Agency, Trafi in 2013-2015. Trafi covers four modes of transport: aviation, maritime, railway and road transport. This is a demanding context for safety management methods. For example, the severity scale would range from minor injuries to several thousand fatalities as there are daily operations of huge passenger ships between Finland, Sweden and Estonia. In addition, there was a desire to measure risk in three dimensions:

![Figure 1. Event risk assessment table for fatalities and injuries.](image)

<table>
<thead>
<tr>
<th>Event Risk Classification (ERC)</th>
<th>Zero-Accident materialized</th>
<th>Marginal</th>
<th>Weak</th>
<th>Medium</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>A150</td>
<td>B150</td>
<td>C150</td>
<td>D150</td>
<td>E150</td>
</tr>
<tr>
<td>5-99</td>
<td>A52</td>
<td>B52</td>
<td>C52</td>
<td>D52</td>
<td>E52</td>
</tr>
<tr>
<td>1-4</td>
<td>A2</td>
<td>B2</td>
<td>C2</td>
<td>D2</td>
<td>E2</td>
</tr>
</tbody>
</table>

- Loss of human life and injuries
- Environmental damages
- Material losses and damages

To make sense of the whole, a common risk currency for these three dimensions was a necessity.

3.1 Event risk assessment

In an operational environment, the first question concerning a new event is: does the event highlight something that requires urgent action? This explains why some kind of event risk classification is required rapidly once the event has occurred. In addition to addressing the urgency issue, event risk assessment produces a numerical value of (relative) risk for each event. This produces a new useful risk currency for all types of desired analyses. One can now look for patterns guided by risk, instead of just event count. This is why event risk assessment is desirable also at the level of safety agencies who don’t need to control operations directly.

The proposed event risk assessment method is based on the ARMS methodology but highly customized. The description of the original ARMS methodology can be found in ARMS Working Group (2010) and a discussion of the benefits of such an approach compared to the use of safety indicators in Nisula (2014).

The ARMS Event Risk Classification (ERC) is based on two components:

- If the experienced event had escalated in an accident outcome, how severe would the most credible accident scenario have been?
- How probable would this escalation have been? This can also be expressed in terms of barriers: what was the combined effectiveness of the remaining barriers?

The original ARMS methodology stresses the importance of this conceptual framework. The actual practical application can be done in many ways. The example application within the original development was a 4×4 matrix where each square contained a
color of the urgency and a risk index number that gave the relative risk value of the event.

The customized event risk assessment method accommodates any value of potential severity and any probability value for the outcome. The primary assessment is done in terms of risk of fatalities and injuries. A combination of a matrix (Fig.1) and the possibility for direct entry of values provides a solution which is fast for typical cases while still allowing exceptional values to be entered manually. Severity is assessed in terms of points, and probability is logically a number between zero and one. These are multiplied to obtain the event risk value.

Severity points in terms of environmental damages are obtained from a separate table which is based on the so-called Polscale table. The number of points corresponding to one fatality was fixed to 10,000. Based on literature (Vanem 2012) and experience on costs of severe injuries in Finland, it was decided that a severe injury would also be worth 10,000p and a minor injury worth 100p. Finally, a simple formula was created to calculate severity points corresponding to different levels of material damage.

But how were the different types of risks calibrated in relation to each other? What kind of environmental damage would be worth 10,000p which again corresponds to one fatality? A specific questionnaire was created where the respondents were asked to position different kinds of environmental and material damages on a scale of human lives. The questionnaire was given to 22 people in Trafi and results from this sample indicated that there was a clear agreement about the relatively small importance of material damages compared to fatalities. However, for large environmental damages the results were completely dispersed. Enlarging the sample size might or might not create more clarity on the issue. Furthermore, it is obvious that this kind of questionnaires suffer greatly from framing issues, i.e. how the matter is presented may have a huge impact on the results. For example, if the material loss is a ship or a boat, who owns it? The state? A foreign millionaire? If the loss is two human lives, who are they? Two 8-year-old girls walking to school? Or two drunk drivers in their 60s having already been convicted of driving drunk several times? However, the difficulty of calibrating the different risk dimensions is more a detail than a major problem. This is because:

- Whatever calibration values are selected initially, can be changed later. Tools can be built in such a way that all the results get instantly updated in line with the new calibration.
- Calibration issue is only applicable on combined results from different risk dimensions.
- Even mixed results are usually driven by fatalities and injuries. The only major exception would be environmental damages in the maritime domain.

- The calibration only reflects subjective values given to different things by different people. There will never be one final answer.

In a typical case, the assessed event did not have any actual negative outcome but an escalation to an accident outcome could be imagined. If for example, the accident outcome involved 20 minor injuries and the escalation probability is estimated at 10% then the severity points would total 20x100p = 2000p and the total event risk would be 2000p x 10% = 200p. This risk value is now reflecting the potential harm this event could have caused and thus a more valuable piece of information than simply knowing that one of these events occurred (event count).

The first direct benefit is that all charts and graphs which used to reflect event counts can now be reproduced reflecting cumulated risk. It doesn’t take much time to notice that the picture drawn by risk is often different from the picture drawn by an event count. One of the first data sets which was analyzed in Trafi during an early experimental phase was a set of about 300 maritime safety reports from coastal pilots. In terms of event count, the biggest category was “technical failures” followed by events related to maneuvering the ship. When these two categories were compared using cumulative event risk as the unit of measurement, it turned out that the total risk of the maneuvering events was about twice as high as the cumulative risk of the technical events. Furthermore, there were some very-high-risk events among the maneuvering events, while there were none among the technical events. See also Figure 2 for an example from the railway domain.

The event risk concept also allows presenting events as an integral part of the total risk picture of the operation. For this, event risk needs to be presented as a vector instead of a number. As Abrahamsen et al (2004) point out, expected risk values do not provide a full picture of risk. It is useful to present events in a 2-dimensional risk picture through their event risk footprint, probability and severity being the components of the risk vector, in line with Johansen & Rausand (2014, p. 387). Two events having the same numerical event risk value may lie in two opposite corners of the 2D-presentation and this may imply important differences between the events in many aspects, e.g. in the level of associated uncertainty.

The risk picture can present various threats as rectangles in the two-dimensional risk space, the dimensions being severity and probability. Thanks to the event risk concept, experienced events can now be added to this risk picture. They provide more depth and an important link to reality. The overall risk management concept using this kind of risk picture is developed further in a dedicated paper (Nisula 2015).

As mentioned above, the event risk assessment method can also accommodate events with 100%
probability, i.e. losses which have already materialized, and ultimately even events which already caused some losses but where further escalation is possible. The coexistence of risks and already materialized losses in the same risk picture may be a surprising concept. From the risk management point of view, however, the concept is useful; one can focus on a single threat and visualize all related events and how far they escalated. Some remained close calls while some became actual losses.

As this kind of risk picture contains both risks and losses, the author would propose to call it a riss picture (risk + loss).

3.2 Safety factors

The idea behind safety factors was to create a modern alternative to the classic extensive reductionism-based taxonomies which typically catalogued the various ways things can fail. The key features of safety factors are the following:

- They are assumed positive prerequisites for safe operation. This means they can be used to capture both positive and negative aspects of safety in the operation.
- As much as possible, they are defined at the level of functions (such as controllability) instead of at the level of individual devices, procedures or other operational details.
- As a result of the first two points, the list of Safety Factors is short and compact, in contrast to many large taxonomies in use today – like ECCAIRS.

The safety factors aim at taking a step towards safety-II-thinking while trying to strike a balance between the precision and complexity of the model vs. the operational need for a relatively simple and fast method which can cope with the constant flow of events.

Safety-II focuses on the successful normal operation and tries to understand how operational resilience is maintained. It recognizes that human activities in sociotechnical systems are always underspecified and that such systems operate successfully thanks to the adaptability of humans. Accidents are not seen as consequences of failures but as emergent outcomes in the context of performance variability and functional resonance (Hollnagel 2014).

One particular application of safety-II is the so-called Functional Resonance Analysis Method (FRAM). In FRAM, an activity is analyzed and modelled based on its functions. Key focus is on interactions between functions (Hollnagel 2012). The resulting model can then be used to identify potential harmful functional resonances. Looking at practical applications of the FRAM method, such as Nouvel et al (2007), leaves no doubt that FRAM requires considerable investment of time and effort to study a single activity of a limited size - and therefore could not cope with a constant flow of hundreds of incoming safety events. Safety factors can meet this challenge thanks to the simplicity of the approach.

In Trafi, a specific set of safety factors was created for each mode of transport. Most factors are actually identical or almost identical across at least three modes of transport. The maritime safety factors are given as an example below.

For each mode of transport, the development started with a draft which was put together by the author. A workshop was then organized with subject matter experts to develop the first version of the safety factors for that mode of transport. Using the safety factors in the analysis work with real safety events raised further points where refinement was needed. Clarifications and examples were created for each safety factor.

Conceptually speaking, the idea was to list all factors that were critical for safe operation. A good start was to think of functions whose failure alone could endanger the operation. Consequently, there are safety factors for technical functions (e.g. stability), crew competencies, the interface between the crew and the ship/vehicle, information, working practices and safety factors related to coping with external threats. As far as possible, the idea was to remain at the level of functions, and to avoid overlap between different safety factors. The result was a list of about 40 safety factors for each mode of transport.

The end result is undoubtedly colored by the views and experiences of the people involved. Many issues could be included at a more general level or at a more detailed level. There could be many different sets of safety factors which would all be equally useful for the intended purpose.

The most obvious use for safety factors is to link them with reported safety events. The idea is to identify which safety factors were instrumental in avoiding a dangerous escalation, and on the other hand identify the safety factors which failed. Obviously, it is not feasible to tick the box every time a certain basic function works successfully: this would only pollute the results, so judgment is necessary to pick positive experiences with safety factors when their role was significant.

There are many interesting areas for analysis beyond just looking for the “best” and the “worst” safety factors. For example, the safety factors start with the most critical and basic functions - these are called the fundamental safety functions. It may be very interesting to focus on these when trying to find solutions for the high-severity-high-uncertainty-threats, including the so-called black swans. For such threats, the exact scenarios will not be known and the solutions will have to have a broad bandwidth.
An existing list of safety factors is also an excellent starting point for continuing the safety-II journey and starting to make live observations of the real operational work. In that case, the safety factors provide a framework which helps the observer focus on the key functions and find out how practitioners have built resilience for these critical functions in the real operational context.

This section is closed by listing the maritime safety factors:

**Fundamental Safety Factors**
- Maneouvurability
- Availability of propulsion
- Controllability of ship stability
- Capability to stop ship and seakeeping ability
- Awareness of ship position in relation to the correct safe route
- Capability to maintain survivable conditions aboard ship
- Structural integrity and damage stability
- Capability to evacuate (escape routes, equipment, emergency communications)

**Competencies (for various crew categories)**
- Leadership and teamwork
- Communication
- Knowledge
- Application of procedures and knowledge
- Management of ship’s route and related automation/equipment
- Manual steering of ship
- Ship manoeuvring in port
- Situation awareness (including anticipation)
- Problem-solving and decision-making
- Workload management

**Fitness for work**
- Vigilance level
- Psycho-physical performance level

**Procedures, Practices and Culture**
- Adapted to real operational situations
- Quality and clarity
- Operational planning
- Anticipating demanding operations and situations
- Managing a multitude of cultures (and languages)
- Adequate focus on safety in the presence of commercial pressures

**Ergonomics and redundancy**
- Usability of bridge automation (ergonomics, HCI)
- Ergonomics in how information is presented
- Adequate redundancy within the crew (deck officers)

**Availability of timely and reliable information**
- Aboard ship
- Between the ship and the external world

**Knowing and respecting Operational Limitations**
- Shipload planning and loading: stowage, appreciation of cargo characteristics, volume.
- Limitations concerning the route, speeds, etc.

**External Safety Factors**
- Manageability of external threats (e.g. restricted waters, fairways, infrastructure)
- Manageability of threats related to conditions (e.g. weather, visibility, ice, currents)
- Manageability of threats caused by other vessels
- Manageability of exceptional phenomena and situations (icebergs, pirates)
- Pilotage
- Icebreaker assistance
- Towage
- VTS operations
- Port operations

3.3 Synergy between event risk assessment and safety factors

At the practical level, the most time-consuming part of event analysis is getting to know the event. This usually means reading through the narrative. Once this is done, the various analysis jobs are usually quite quick. In particular, in addition to the basic event analysis tasks, the analyst can perform the event risk assessment and link the event to safety factors without adding much time to the analysis process. In Trafi, the event risk assessment and safety factors are integrated in the same tool.

From the analysis perspective, the most obvious synergy is to assess the importance of various safety factors by using cumulative event risk as the currency. Such analysis may point to useful interventions at the level of individual safety factors. Figure 2 presents an example. It can be seen, that many safety factors were associated with events which were numerous, but generated very little risk (e.g. factors 1a, 16, 72, 25, 8C). In this example from the railway domain containing only the first-choice safety factors, the top two safety factors were situation awareness, and application of procedures and knowledge. The same chart can obviously be produced also for the positive safety factors (what “saved the day”).

An inverse analysis would be to focus on a particular group of events and to see if their safety factor footprints have any similarities. One such analysis would be to focus on events having a particularly high event risk.
find the use of points a good solution for being alert-
ed of any issues requiring urgent action, irrespective
of the other dimensions of event risk.

The presented method for event risk assessment is
based on a very simple linear model of event escal-
ation into an accident. Such a model makes no justice
to the complexity and dynamism of the real opera-
tional world. Furthermore, the assessment relies on
an accident scenario. This is problematic for events
which don’t offer an obvious escalation scenario. An
example could be a reported compromised emergen-
ocy exit: there is no immediate escalation scenario.
The condition would have a safety impact only if
there was an emergency and the need to evacuate.
There are probably millions of evacuation scenarios
but they all have very low probabilities. On the other
hand, Hale (2001, p. 14) also argues that risk as-
essment may be sensible only when the accident
scenario is easy to identify.

Another limitation is that the ARMS-based event
risk assessment deliberately focuses on the most
credible accident scenarios. This means that for in-
dividual events very unusual escalations would not
be considered.

The safety factors are a compromise between un-
derstanding the real work in detail and providing a
practical tool for capturing positive aspects of safety.
They provide a very compact and easy-to-use meth-
od for this. Thanks to their functional approach they
are much less reductionism-driven than typical safe-
ty taxonomies.

The safety factors introduce another route from
events to organizational risk management: they help
identify and work on the resilience in the operation.
The resilience in itself can be seen as an antidote for
risk and therefore links with the management aspect
of risk management. Their ability to capture both
positive and negative aspects resonates nicely with
remarks by Woods & Cook (2006) on incidents: “in-
cidents simultaneously show how the system in
question can stretch given disruptions and the limits
on that capacity to handle or buffer these challeng-
ges”.

The safety factors also open the door to new kinds
of observation methods which can be supported by
the framework. Such an idea was briefly tested on a
passenger ship and the experience was very promis-
ing: many positive aspects could be captured in a
short time through observation and discussion with
the crewmembers.

The fact that many safety factors are the same
across several modes of transport gives an oppor-
tunity to discover interesting similarities and differ-
ences between the different modes.

The simplicity of the safety factors method obvi-
ously has a downside: the safety factors are the as-
sumed prerequisites for safe operation but despite
expert involvement there is no guarantee that the
identified factors are the “correct ones”.

4 BENEFITS AND LIMITATIONS OF THE
PROPOSED METHODS

Both methods introduce advantages and according to
the experiences in Trafi are simple enough to be
used in the real operational context. The most obvi-
ous benefits of event risk assessment and its syner-
gies with the safety factors were already briefly dis-
cussed above.

From the risk management perspective, the most
valuable aspect is probably the fact that safety events
can be brought into the risk management process in
a meaningful way. First of all, the event risk value
gives an immediate idea of the urgency of treating
the related issues. Then, the events can be included
in the overall risk picture, like described above. It is
worth noting, that this way every single event con-
tributes to a better understanding of risks - unlike
with safety indicators where only a subset of events
contribute to the indicators.

The event risk assessment starts by constructing a
scenario and then focuses on the severity of that sce-
nario. Whatever the probability, the high severity
value will always be visible in the 2D-risk picture.
This is an advantage because it reminds of the severity
of some threats that people are sometimes getting
too used to. This is in line with Hale (2001, p. 19)
who stresses the importance of focusing on clearly
articulated scenarios and especially on accident se-
quences leading to major harm.

The use of points (for severity and for event risk)
has several advantages that go beyond the possibility
to deal with different dimensions of risk. Larger risk
assessments which are beyond the scope of this pa-
er can use the same point system, so there is compa-
ratability between different levels of risk assess-
ments. Organizations with special sensitivities may

Figure 2. Railway safety factors (numbered on horiz-
onal axis) are compared by number of events where they failed (grey bars & left vertical axis) and the thus cumulated event risk (checker board bars & right vertical axis). N=533. Only top safety fac-
tors by event count presented here.
Furthermore, the reality is more complex than the list of safety factors may suggest. For example, many safety factors depend on each other and there are probably nonlinear relationships between them. To pick one example, a low vigilance level (fatigue) could undermine any competencies no matter how developed they are.

And finally, it is important to keep in mind that however seductive the resulting analysis may be, everything coming out from event data reflects a partial and biased view of the reality. To make things worse, in an operational environment the event risk assessment would often be done based on early incomplete information. One can also argue that in some sense event data presents a view to the past and provides very little material for assessing what could happen next.

5 DISCUSSION

The proposed approach for dealing with safety events presents a proper conceptual model for performing risk assessment on events. It also shows that the ARMS methodology which was originally developed for airline use can easily be extended and customized for more demanding contexts. The safety factors are a new interesting way to embrace the positive side of safety.

The event risk concept can be adopted by anyone who is dealing with safety events. In its simplest form the result is just one number. Therefore, using this concept does not require complicated tools. The safety factors now exist for the four modes of transport and such factors can be developed for virtually any activity.

From the risk management point of view, the two presented methods are a part of a larger process which is outside the scope of this paper but which is addressed in Nisula (in prep.). The event risk assessment helps integrate events into the larger risk picture. The safety factors help in analyzing the situation and finding promising avenues for positive interventions.

Throughout the discussion it must be remembered that analysis work on safety events typically takes place in a very specific context of high workload and the need to carry out the first risk assessment quickly once the events have been received. There are opportunities later in the risk management process to carry out more detailed risk analyses.

Another way to use event data which has not been discussed here is to use them for feeding more or less complex models that simulate the operation and assumably produce useful safety information. The experience of the author on such models is that in practice they are built for a specific purpose and cover only a small part of the operation. It is paradoxical that models easily become so complex that they become intractable but are still not complex enough compared to the real world. Once a model has been created, it is often opaque and it is difficult to judge how reliable the results are. The advantage of the 2D-risk picture is that event data can be combined with other types of safety information and the event data supports the analysis but is clearly distinguishable from other information elements.

6 CONCLUSIONS

The paper has introduced a new way to handle event data in the context of a risk management process. The two methods which were presented allow turning event data into risk data and create aggregated presentations of cumulative risk. In addition to measuring event counts, a risk currency is now available for all event-based charts and graphs. Both negative and positive aspects of safety can be tracked with safety factors which themselves can benefit from the risk currency as the unit of measurement and prioritization.

The paper has also established the links between the various aspects of the presented methods and the underlying safety science.

The experiences at the Finnish Transport Safety Agency Trafi during the past two years have shown that the described approach is both useful and feasible in the demanding context of a multimodal safety agency.

Event risk assessment and safety factors produce immediate results in themselves, but even more importantly they support an overall risk management process based on an integrated risk picture.

There is an exciting future ahead of us in terms of transitioning from the safety-I world to the safety-II world and one can hope that the current work on the safety factor framework has taken us a little bit closer to the goal.

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