Research Article

Can the decision ladder framework help inform industry risk assessment processes?

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Abstract

Background: The decision ladder framework is a diagrammatic template that can be used to identify a range of different ways a task might be performed which could make it useful in industry risk assessment processes. However, there seem to be no studies on practitioners' perceptions when trying to apply the decision ladder framework. **Aim:** The aim of this study was to gain insights into participants' perceptions of the understandability, usability, and usefulness of the decision ladder framework after they had tried to use it in a risk assessment process. **Method:** The study involved participants from industry and from a university. Working in pairs, participants used the decision ladder framework to identify the range of ways operators might perform a prescribed task as part of a risk assessment processes. Participant comments were recorded and analysed to extract insights relating to their use of decision ladder framework. **Results:** Feedback from participants suggests that more could be done to make the decision ladder framework more understandable and usable. The feedback also indicates that using decision ladder framework may be useful because it helps people think more deeply about the range of ways humans can perform tasks. **Conclusions:** The study results indicate that the decision ladder framework might help people think more about the range of ways humans can perform work in industrial contexts. However, further work is required to improve the understandability and usability of the decision ladder and to determine whether its use might add value to industry risk assessments processes.

Background

Workers can usually use a range of strategies to perform their work. Accordingly, a Strategies Analysis for Enhancing Resilience (SAfER) method has been developed to help industry practitioners identify system design changes that might guide workers to effective strategies for managing expected, unexpected, and unprecedented operating situations (9). The SAfER method incorporates Rasmussen's decision ladder framework and a set of predetermined categories of strategies to help practitioners identify the range of strategies that workers might use.

The decision ladder was developed by Rasmussen and colleagues at the Risø National Laboratory in Denmark in the 1970s (1, 2). It was developed from "analyses of verbal protocols taken during actual work in different work domains that identified the different categories of statements made by the actors about their knowledge, their questions regarding their task, and their past and intended acts" (3). The decision ladder framework is a template that allows analysts to represent diagrammatically a range of possible reasoning processes that people could use and knowledge states they could achieve when performing a task.

Since its inception, the terminology and methodology associated with using the decision ladder has been defined by a number of researchers including Rasmussen et al. (3), Vicente (4), Naikar et al. (5) and Lintern (6). The decision ladder and associated terminology used for this study is shown in Figure 1. The decision ladder consists of a series of ovals and rectangles. The ovals represent states of knowledge. The rectangles represent the cognitive processes a person can use to move from one state of knowledge to another state of knowledge. The decision ladder has three main parts.

- The left leg contains the cognitive elements involved in identifying the current system state.
- The top of the decision ladder contains the cognitive elements involved in evaluation options.
- The right leg contains the cognitive elements involved in formulating and planning the execution of the task.

Arrows are used to represent how people might mentally move from a cognitive process or state to another state of knowledge. Some arrows show the leaps and shortcuts that people can take from one part of the decision ladder to another part of the decision ladder, often as a result of experience.

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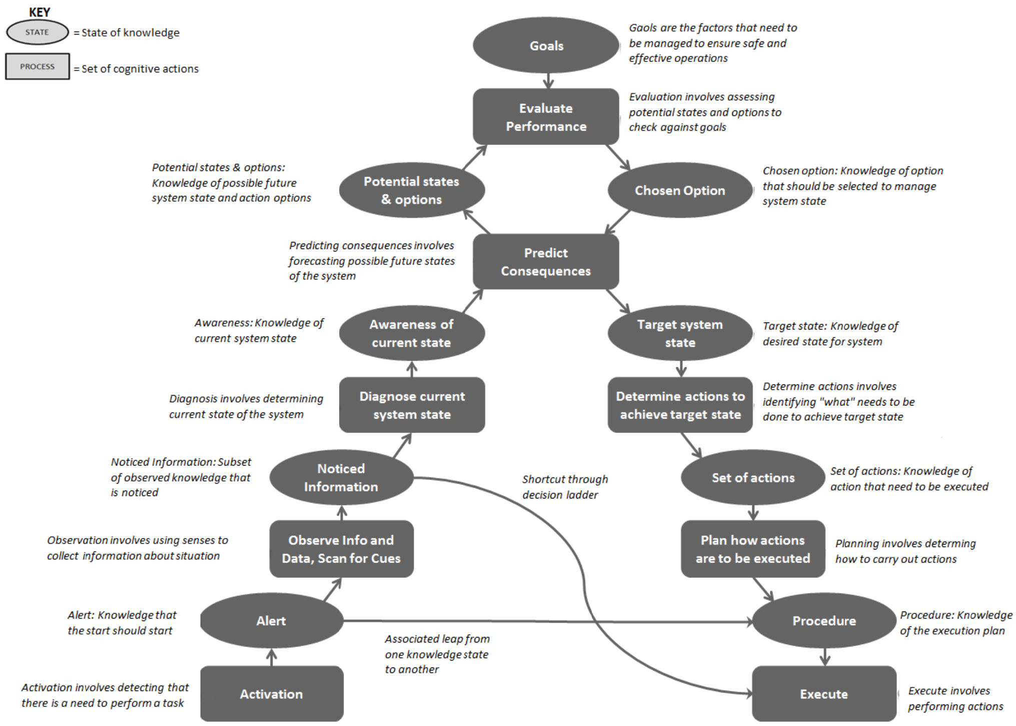

***Figure 1:** Example of a decision ladder*

The decision ladder framework is linked with Rasmussen's (7) skills, rules and knowledge framework. Describing task performance using only the bottom parts of the decision ladder could provide insights into how the task might be performed using skill-based behaviour. Describing task performance using the bottom and middle parts of the decision ladder could provide insights into how the task might be performed using rule-based behaviour. Describing task performance using the top parts of the decision ladder indicates that knowledge-based reasoning, or reasoning from first principles, is needed. Figure 2 shows an example of a completed decision ladder illustrating the different ways the task of reversing a car onto a street can be done.

Since Rasmussen developed the skills, rules and knowledge framework, a significant amount of literature has emerged from different fields of research that has revealed additional insights into people's cognition and performance when controlling complex systems. Hassall and Sanderson (8) reviewed a range of the literature and derived eight categories of strategies that might be used by humans when performing a task. These categories of strategies are: (1) avoidance strategies, (2) intuitive strategies, (3) arbitrary-choice strategies, (4) imitation strategies, (5) option-based strategies, (6) cue-based strategies, (7) compliance strategies, and (8) analytical reasoning strategies. Hassall et al. (9) also show that the eight categories of strategies are related to using different parts of the decision ladder framework.

Describing task performance using the decision ladder framework in conjunction with the categories of strategies could help industry practitioners identify the range of ways a task can be done, and so better inform industrial risk analysis and system design processes. Some research has been conducted into the usefulness of the decision ladder for practitioners of different kinds. Naikar (10) and Lintern (6) compared the decision ladder to the recognition primed decision model and found that the two approaches provide different but complementary information for analysts designing decision support systems. Hoffman and McCloskey (11) explored using the decision ladder framework to practitioners macrocognitive work. However, there seem to be no research studies investigating how useful and usable analysts find the decision ladder framework when they are trying to identify the different ways in which people might perform some task. The research described in this paper was reported to begin the process of understanding how practitioners perceive the usefulness of decision ladder framework.

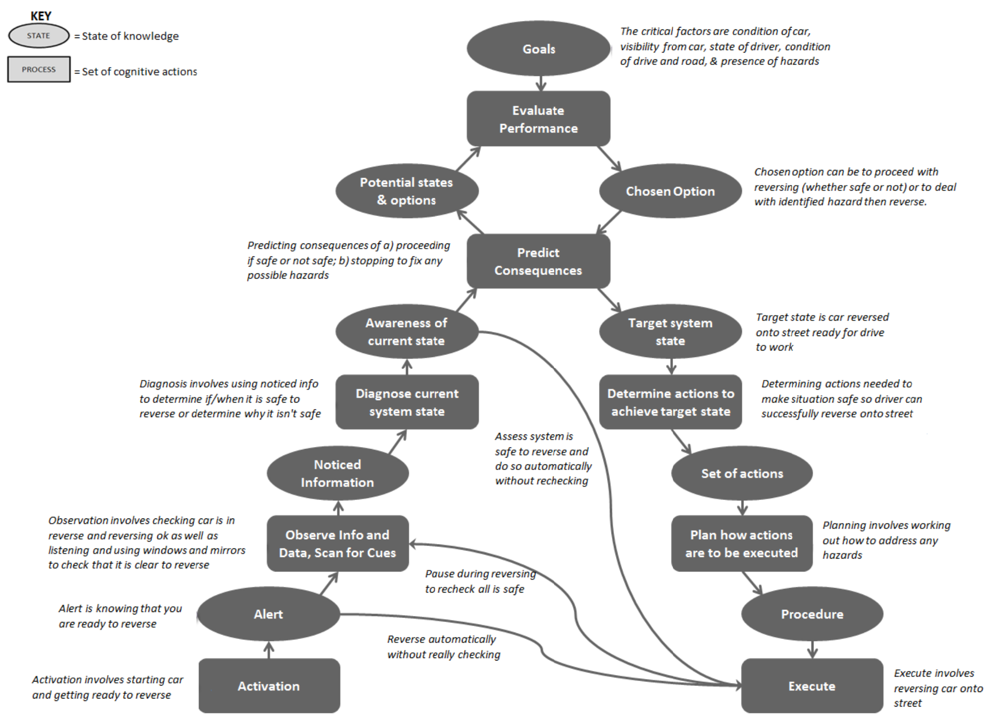

***Figure 2:** Decision ladder for the activity of reversing a car onto a street*

Aim

The aim of this study was to gain insights into people's perceptions of the understandability, usability, and usefulness of the decision ladder framework after they had used the decision ladder to identify the range of ways that human work might be performed in a particular context.

This study formed part of a larger research study to assess SAfER - a novel human factors risk assessment technique. Refer to Hassall and Sanderson (9) for more detail. The participants are the same participants as in (9) but the present paper covers aspects of their feedback that were not reported in the earlier paper.

Method

In industry, risk assessments are typically done by two or more people in a workshop. Because SAfER is intended to be used as an industrial risk assessment tool it was decided to test it using small groups of people from certain professional backgrounds. Industry participants from two industry sites were approached by managers known to the researchers and asked if they wanted to learn about and test SAfER. Students undergoing professional training at university were asked if they wanted to participate in a study about SAfER via a group email sent to a human factors/psychology mailing list and chemical engineering mailing lists.

A total of 24 people volunteered to participate in this study. Ten participants came from industry where they occupied a range of positions including operator, safety advisor, engineer and supervisor. Fourteen participants came from a university and were researchers and students from human factors/ psychology and engineering disciplines. In both cases specific ages were not collected from participants, but they ranged from the 20s to the 40s age range. More information on the participants is shown in Table 1.

Table 1: *Participant information*

	Industry		University		Total
Origin	Steel-making	Refining	Psychology/ Human Factor	Engineering	
Total participants	6	4	8	6	24
Training given	4 hrs	2 hrs	0 hrs	0 hrs	

As part of the larger research study (9) all participants were asked to trial the SAfER method and software tool, which included using the decision ladder template and predetermined set of strategies to describe the range of ways a task could be done. Participants underwent the following test process (9):

1. Participants were invited to attend a meeting to test and provide feedback on SAfER. For industry participants the meetings were held at their industrial site. For university participants the meetings were held at the university.
2. All participants were given an overview of the testing process and asked to provide written consent. All participants gave their consent.
3. The participants were divided into groups of two or three people and each group was given the electronic SAfER workbook. The grouping of industry participants was done by the researchers so that the groups had a mix of engineers and safety people. The grouping of university participants was done based on time availability.
4. The groups of participants were given a scenario to assess using the SAfER method and software tool. Industry participants chose the scenario they reviewed. Some industry participants reviewed an incident, whereas other industry participants reviewed a procedure. The incident involved an unwanted interaction between a suspended load and temporary structure. The procedure described the work required to perform functionality assurance testing on an emergency flare stack. The university participants were given a hypothetical case study which involved assessing the risks associated with installing a self-serve coffee machine on a tourist train. This scenario was selected for them by the authors.
5. Participants were then given instructions on how to proceed with their SAfER analysis (see Hassall et al (9) for detailed description of how to perform a SAfER analysis). Industry participants received several hours of training that was adjusted to fit within their time availability constraints. University participants received a user instruction manual and about 15 minutes of introductory information. University participants received no training on the SAfER method process because one of the test aims was to determine which aspects of the SAfER method and tool were self-explanatory and/or intuitive and which aspects might pose usability issues to novices.
6. Participants were then asked to work with their group members to try the SAfER tool on their scenario and to take as long as their availability permitted. Participants were encouraged to discuss aloud the SAfER process with their group members as they proceeded with their analysis. Audio or video was used to record participants' comments as they worked through the scenario using SAfER.
7. After using SAfER, each individual participant was asked to complete a confidential questionnaire within which they could provide free text responses to the following questions.

   Question 1. How easy was it to understand the SAfER process?

   Question 2. How easy was it to apply the SAfER process to the scenario?

   Question 3. How easy was it to use the SAfER workbook?

   Question 4. How effective is the SAfER process in identifying and assessing the range of strategies humans can use in performing an activity?

   Question 5. Overall how useful would the SAfER process be in improving the safety and resilience of a/your company if it was used to assess risky activities?
8. After the questionnaires were completed, a group debrief was conducted to obtain further feedback.

Information relating to the feedback on the overall SAfER process and workbook was extracted and has been reported elsewhere (9). The results relating to people's perceptions of the decision ladder framework were extracted, analysed and are reported below

Results

Most participants spent at about two hours trying the SAfER process after the training or introductory information was given. All participants tried to complete a decision ladder and use the predetermined strategies to identify the range of the work associated with their scenario might be performed. All responses on the decision ladder and its links to the predetermined categories of strategies were obtained from the free text and the video recordings of the debriefing sessions.

A total of 55 comments were received that related to the decision ladder framework – 52 were from the university participants and 3 were from the industry participants. There were 49 comments collected from the video and audio analysis and 6 comments collected from the questionnaires. A summary of these comments is in Table 2.

Table 2: *Summary of feedback from participants on the decision ladder (italics represent verbatim comments)*

Topic	Comment
Understandability (33 comments)	I found decision ladder complex/confusing (n = 14 including 2 from industry).
	Decision ladder terms not easy to understand (n = 9 including 1 from industry)
	Not sure how the decision ladder linked to the predetermined strategies (n = 6).
	Top of decision ladder, goals and target state does not make sense (n = 4).
Useability (11 comments)	The decision ladder process was okay and we could do it (n = 6).
	There were issues with arrows and textboxes (n = 3).
	"The DL is intense – I know a little about it but people who don't will get stuck there" (n = 1).
	"Working through DL took most time" (n = 1).
Usefulness (7 comments)	Doing the decision ladder helps people think more deeply (n = 5).
	The decision ladder can be useful if the activity has the complexity to warrant using it (n = 2).
Recommendations (4 comments)	More training is needed (n = 4).

Discussion

The results provide insights into the perception of participants with relatively low levels of familiarity with the decision ladder about the understandability, usability, and usefulness of the decision ladder as an element of a risk assessment process. Most comments reflected that there are challenges associated with understanding the decision ladder. Some comments also reflected challenges with its use. However, some of the comments on usability and all the comments on usefulness reflected that the decision ladder might have potential for use in industry risk assessment. Before interpreting the results any further, however, it is important to take into account the study limitations.

A first limitation of the study was the small sample size and limited sample demographic. The industry participants were limited to a small number of people from two industrial sites. The university participants were limited to people from one university campus. Any further testing on participants' perceptions of the decision ladder should seek to use a larger sample of participants from a wider range of demographic backgrounds.

A second limitation of the study was that it was a part of a larger study and did not explicitly ask for comments on the decision ladder. The comments may not provide a good representation of participant perceptions because a) only three comments were obtained from the 10 industry representatives whereas 52 comments were obtained from the 14 university participants and b) these comments may not reflect participants' views on all the strengths and weaknesses of the decision ladder framework.

A third limitation of the study is that most comments on the decision ladder came from the university participants and not the industry participants. This could reflect the influence of a number of factors. One influencing factor might be that the industry participants received training in how to use the decision ladder framework and the university participants did not. Another influencing factor might be the different focuses of the different groups. The feedback from the industry participants seemed to focus on how SAfER might be used in the industrial setting. The feedback from the university participants seemed to mostly focus on how easy or hard it was to do each step of the SAfER process. One reason for the difference in focus might be the perceived potential impact that SAfER could have on the participants' work and the relevance and lack of relevance of the case study to the participants. More comprehensive summative and empirical testing of the decision ladder with meaningful case studies is needed to 1) explore the impact that training has on peoples' ability to effectively use the decision ladder, and 2) to verify people's ability to understand and use the decision ladder in useful ways.

If the study limitations are taken into account, then the trial results can be used as insights into some of the perceptions that might be associated with the decision ladder framework. The trial results show that most of the comments made related to the understandability of the decision ladder framework. Participants commented that the decision ladder was complex and confusing and the terminology was difficult to understand. Participants also commented that the linkage between the decision ladder and predetermined strategies was not clear and the top section of the decision ladder was difficult to decipher. The "Understandability" comments combined with the "Recommendations" comments suggest that further work could be done to improve the descriptiveness of the terms used within the decision ladder and to improve training materials.

Any work done on decision ladder terminology should refer to the work done by Lintern (6) who has explored some alternate labels and meanings for some elements of the decision ladder. With respect to the comments about the linkages between the decision ladder and the predetermined strategies, a table highlighting these linkages has been published in Hassall et al., (9). However further test work is required to determine if this table helps clarify the linkages between the decision ladder and predetermined strategies.

The comments on usability and usefulness indicate that the decision ladder might help people think more deeply and gain new insights. However more summative testing is required to verify this finding and to determine if the deeper thinking and new insights actually lead to the identification of solutions that improve safety and risk management across different industries settings and for different types of industrial activity.

Conclusion

The study results indicate that without training, people may find it difficult to use the decision ladder to reason through the different strategies that may have contributed to incidents or that workers might use to perform procedures. Further clarification and training could help people understand the decision ladder framework better and use it more effectively. The results also suggest that the decision ladder framework might help people think more about the range of ways humans can perform work in industrial contexts. More summative and empirical research is required verify these results and to demonstrate whether using the decision ladder in conjunction with the predetermined categories of strategies leads to insights that can be used to inform risk assessments and improve safety across different industrial settings.

Acknowledgements

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