Validation Exercise Excerpts from Interviews

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1 | CHALLENGES IN EVALUATING SYSTEM COMPLEXITY

The first question asked to all participants was; "What challenges did you find when trying to evaluate the complexity of the system?".

1.1 | Challenges related to the scenario

Unsurprisingly, given the nature of the study, participants generally reported challenges relating to the scenario such as; not having enough time to assimilate all of the information available, not having access to the required stakeholders to discuss concerns or to gain further information, not having previous working relationships with other participants, etc.

"I think that understanding the stakeholders. Obviously, in a real situation I would know which company actually bidding for the rest of the systems, but without knowing that, you don't know the culture and I think as much as the technical bit can be quite challenging. The integration between the stakeholders is very key. [VA]"

> *"Most importantly, were the constraints of time available, as well as the limited amount of information available. And lastly, access to the stakeholders that we know that we wanted to, you know, ask the right questions in the context of [inaudible], you know, so the people in the field really know what the reason for the project, what the drivers are. [VK]"*

> *" So in general it was assembling the information in a way that lent itself well to a structured assessment of the complexity and an I, I guess that's the point. It's always that way, the information doesn't nicely line itself up in a way that patterns become abundantly clear immediately...And then the third bit was about how we did it. Absolutely, doing it collaboratively is the right thing to do. Doing it collaboratively, over Skype, with people that you don't know, and understand their background and where they're coming from. So the fact that [REDACTED] and I had never worked together before made that harder than it would be in a real life situation where you'd be part of a bid team or part of a project team, and you know each other and have a report. [VG]"*

> *"From the basic aspects of the lack of the knowledge and the little bit information we had and the short amount of time to read into it if I'm honest, but then also trying to use the tool so trying to make sure we didn't just use our own opinions and own experiences and actually use the tool as an approach and I did*

find the aide-memoire bit we did at the end quite useful. [VF]"

"kind of procedural challenges in terms of that storming, norming, forming new group dynamics, who's actually leading, how are we doing this? And it ended up being a bit of a rambling discussion, half using the tool half, not using the tool, rather then being organized and going like this is how we're going to approach it. This person is leading it, let's make sure actually ticking off the various different things as we go through. However, I do think that we talked about a lot of things and got into a lot of detail and maybe that was a good way to approach it to the start. And if we've been doing this for real, we then might have gone right we had a good brainstorming session, let's actually now look at it from a little bit more organized perspective and go through see what we've missed and try and try and be a bit more quantitative about what we think the complexity is rather than just a qualitative discussion...[VJ]"

1.2 | Challenges related to the complexity assessment tools used

Challenges in complexity evaluation were also related to the task of evaluating system complexity (i.e. what the term means), and related the specific tool used by participants.

"Challenges I think came into two phases, so the first phase was what I kind of expected to happen when we started with a group that I haven't worked with before was which is what is complexity and agreeing on that common definition. Hence, I was really keen to ask that question and try and have that conversation right at the start of what is complexity? What do we mean by complexity? What do we think a complex versus a complicated system was? And happily we came to an answer very quickly on it, but there was some slight difference of opinion of what it was or maybe lack of knowledge from it. [VJ]"

"I think the big one really was the same one that always comes up. What's complexity and what is complication. And I think what you find is that there's things that are on the border of complex and complicated. Actually, I think thinking back to that system architecture that was put together [in the scenario], that was a sort of thing that was right on the border of it. You know where one person might say 'well, there's nothing complex about it, it's just a number of things that work together and you just have to do the slog of putting it together' and another person would say, 'Oh no, that's very complicated. I expect to see all sorts of weird stuff happening across that.' So I guess for me that was challenge number one. [VH]"

"The challenges I found was, something that [REDACTED] brought up, what people define as something complex and complicated, so having a common lexicon, a common understanding what you mean by complex and complicated, but once those ground rules, I suppose, were established it made things easier. And then once you established, you know what was complicated, complicated, or complex, again, people's perceptions of what is complicated and complex again, so some people focused a lot more on the technology side of a complex system as opposed to people, processes and technology. So again, it is that balance of what people from their previous life experiences, what is complex? But we spent a lot of time talking about those sort of things. Yeah, so that was the key issue to start with.[VL]"

One participant using the "Complexity Profiler" reported challenges around ambiguous definitions of the system complexity factors and their scoring criteria; "...some of the guidance around the different levels wasn't as clear as it

could have been, and trying to understand exactly what information fits into which category wasn't always clear...[VE]"

One participant from groups that used the "Complexity Register" reported challenges around whether system complexity evaluation should be qualitative or quantitative and establishing the level of abstraction that the system should be considered at for the evaluation.

> *"In terms of examining the complexity of a system, I think I mentioned this at the time, is it's really hard to come up with a quantitative assessment of complexity, like what is complexity? What is good enough? And I think we discussed a lot about where system boundaries are or the environmental impacts are on the SoI is as you start to include those, the environment and environment affects, complexity is going to increase. And it depends how much that you take into account and how much you include time and money and a simple system, if you go all, everything's going to change in 10 years time, we don't quite know how, could be complex or have complex variables acting on it. [VJ]"*

2 | SELF-REPORTED CONFIDENCE IN SYSTEM COMPLEXITY EVALUATION

We asked every participant "How confident did you feel after the exercise that you had effectively evaluated the complexity of the system?".

2.1 | Control group with no complexity assessment tool

The control group, who were given no complexity assessment tool, reported mixed confidence in their assessment where one was not very confident and the other was reasonably confidence, as both said they needed additional information (e.g., from finance, supply chain, human resources):

> *"I think there's a lot of information … in the normal world you will have whole pack of documentation come with it and obviously, without the presence of the supply chain, the HR to making sure the resource you need, …with finance, you know the sorts of risks and the margins that we're looking at… but also involving with procurement and legal to making sure that you know all those little things. [VA]"*

2.2 | Group given the "Complexity Profiler"

The group who used the "Complexity Profiler" generally reported confidence in their assessment:

"I would say our assessment, where we positioned the system, our assessment was, I feel confident in our assessment, it effectively shows there is a lot of uncertainty around the system. [VE]"

"...I thought we did fairly well...I think pretty much all the areas considered, because it was a large system of systems really and because of that, for me it was complex. So I thought that a three was, overall, if you wanted to summarise it, you know, grouping them all together a three out of four would probably be, you know, straightforward. [VD]"

> *"I think more or less when we do such exercise in real life, you should feel more comfortable because you will have on the paper what you probably had already in mind so you will probably discover not so much, but at least it will help to put on the paper a global vision that you can share, the important thing there*

is to make explicit some of the topics. What I have seen in projects many, many times from the very beginning you already know what will be the main [inaudible] that you have to solve, [inaudible], so at least you don't address really the topic and you don't find a solution. So it is important to make explicit and to share that with the team and to find the appropriate answer. So you should more comfortable except if you discover something which is completely new. Or you discovery an area that you are not comfortable with. So let's say for example, you discover that you have very high issue of ergonomics or human factors and you have nobody in your team that is able to do that you would probably have to contract to find the right resources outside, so it may bring difficulties but then at least you manage [the challenge]. [VC]"

2.3 | Group given the "Complexity Register"

The intervention groups who used the "Complexity Register" generally reported that they were fairly confident, and would have been even more confident if they were given additional time and access to subject matter experts:

"Not in its totality, however, I think that was largely due to time constraints. I feel had we kept going for another hour, actually, from the level of information and the level of complexity in that system architecture as it were, I think I would come away feeling like we've done a good, if I had I really been a peer reviewer. I think I'd come away feeling like I've done a pretty good job. [VG]"

"Caveat that by the time we had and the information we had, I think we did OK actually. I think it did start to open up avenues of where we would quite happily carry on, you know, [REDACTED] joking said "we could spend an hour on interfaces", well, quite easily an hour on interfaces. It was only the tip of the iceberg really, but I don't think that's necessary with tool, I think it was just a time frame. I do question how detailed you could go with that level of tool as well. I think it might be good for capturing the high level, and maybe the non-technical aspects of what we're complexity is. But being able to drive it down to the technical "ones and naughts" levels, I think then it would start to struggle. [VF]"

"[And how confident did you feel after the exercise that you had effectively evaluated the complexity of the system?] Oh well, it's a bit like that old joke, isn't it? How do you know an engineer is finished designing something? 'cause he's dead. But yeah, I think, I keep coming back to design reviews, but I think as you move through the maturity of your product, I think you'd be going back and back to that Complexity Register saying I'm confident I've addressed these issues. Or 'Oh crap, something else has arisen' or and I'm in the middle of this problem, I've done something…" [VH]

" So I feel we'd identified a number of different sources of potential complexity, evaluated what the complexity level of the MASSS system was, not that confident, but yes, we said there are potential sources of complexity in the system, we had a number of ways that we thought we could reduce the complexity of it, but maybe this is my lack of experience with trying to assess and quantify what complexity is and I don't know where this as an engineering discipline of trying to assigned whether this system is complex or not. So I don't know, and that might be down to my lack of experience, rather than anything else…The exercise we did, I think I would have had a better handle of the complexity of the system if we had more time, as we got into that, ok we've done that brainstorming phase which is effectively what we did, and lets try and think how complex this system is. And I think rather than going, overall this system is this level of complex,

thinking about it now, I could have been happier to go right, this system is complex in these areas, and then you can assign something to go right we think the system is particularly complex in its use cases with users and interactions with users but its technical aspects are not complex, I'm not saying that's true for the system we did, but you could break it into different areas of complexity. Which, yeah I suppose we did as we were going through the areas as identifying the areas of complexity [VJ]"

"I believe in given one hour we had for the team and the time we had to prepare then, I know I had probably even lesser time, apologies for the delay, but I think at least, if not almost all the so called surprises where already considered in the complexity register. So I think it was very effective and I believe it can be made more effective by giving some clear, shall we say, objectives as examples, so that we don't limit the scope. So what is going to help in defining the project scope? What is going to help in defining the resources available? What is going to be available in ensuring that the requirements are technically feasible for implementation and you know what is going to be available that the requirements are not conflicting? Have we addressed the safety and security of the system up front...Given the time constraints, I think we did very well. We knew most of the surprises and most of the things that came up would have been already known before, so not being a surprise if the mitigation actions had been incorporated, and possibly some of it may not have been captured in writing, but in terms of what we had discussed as a team, I don't believe we would have had new surprises. [VK]"

3 | FEEDBACK ON THE THALES GROUP "COMPLEXITY PROFILER"

3.1 | Aims of the tool

The aim of "Complexity Profiler" was described variously but fundamentally as a way to promote consideration of if an undertaking is likely to be particularly challenging and to document a rationale and action plan to mitigate this. One respondent described the aim as capturing a broad summary of the complexity of the system to assess "at a high level" if an undertaking is likely to be particularly difficult and their rationale, with another participant having a similar view. Another participant described that the tool is "used to surface risks, quite similar to risk management".

"I think it's a way of capturing at a at a high level and in some sort of easy to understand and visualize way, with some fairly broad, broadly scoped categories to capture a summary of the complexity of the system...It's a good way of identifying probably a fairly broad brush view of 'Oh is this system or system of systems going to be very difficult'. Then from there maybe some more analysis needs to be done to look into why we think that. So it is a way of highlighting areas of concern. [VD]"

"I think the aim is to firstly to gain an understanding of the engineering risk or technical risk that's associated with the project. I don't see any, there's nothing in there about the project risk in terms of manpower and resources, it's very much about the delivered solution and the risks associated with that delivered solution because of it's complexity. [VE]"

"[the aim] is to understand if [you] will face something new and if you have to prepare for that. So it's really interesting to see in the Profiler that there is a first step about questioning, trying to understand what's new and what isn't. Then there is second stage about putting in place some action plan, of course to fill the

gaps between what you know and what you don't know" [VC]

3.2 | Positive features of the tool

We have already reported that several participants stated the value in complexity assessment tools is their ability to facilitate a discussion, with participants generally praising the "Complexity Profiler" ("I think it's quite good. I think that the process is a good one.[VD]") as it "drives discussions well [VE]", is easy to use and helps make explicit and shareable the observations of a project team. Further, one respondent praised the visual chart that is produced as part of the complexity assessment activity which "can be presented at gate reviews [VD]" and other milestones to additional stakeholders.

3.3 | Negative features of the tool and suggested improvements

However, criticism and suggestions to improve the tool included; providing additional guidance around definitions of system complexity factors and their scoring criteria, greater granularity on the scoring criteria, and the inclusion of additional factors (system integration challenge, the number and diversity of interfaces, defence lines of development, the complexity of enabling systems, Autonomous Systems and Artificial Intelligence, big data and data fusion considerations, service offering considerations).

"So it kind of goes back to what I was saying at the start, to get the granularity you know we could probably have rated a different system also a three and a significantly different system in terms of its architecture and is that a good thing or a normal thing? ...So it might be that the Complexity Profiler needs some other complexity factors added to it. So let's say start making the range extended. [VD]"

One respondent also suggested that the tool could prompt consideration of "best practice [VC]" as a way to mitigate system complexity issues. A further suggestion was that the produced "action plan [VC]" in the tool needed greater integration with other project management tools such as risk and issue registers and project plans.

This group also questioned whether the evaluations should use an "absolute or relative scale [VC]" as they suggested that the impact of system complexity also depends on the capabilities of the project team. They also stated that the evaluation reached depends on the skills of the individual or team conducting the exercise and noted that an assumption that personnel have competency in evaluating system complexity is sometimes not challenged. One respondent suggested that an improvement to the tool to tackle this challenge and ensure that the tool is delivering value, is to provide greater guidance in the instruction documentation on *how* complexity evaluation should be undertaken, including *who* is needed as part of the discussion and *what* should be documented in the tool. This respondent suggested other formal processes within Thales Group have clear guidance covering these kind of points and that the "Complexity Profiler" could be improved by bringing guidance material up to the same level.

3.3.1 | Feedback on the "Complexity Register"

3.4 | Aim of the tools

The aim of the "Complexity Register" was variously described as; "to elicit the complexity of a system by steering a thought process and providing a baseline for review [VF]", "straddle engineering management and project manage-

ment, a different approach to assess risk and understanding and impact and mitigations, a different language – a way to make risk and issue management something that feels like engineering [VG]", "a structured way of thinking about and recording discussions around system complexity [VL]", "...about identifying an issue and exploring it [VH]", "about identifying emergent properties [VK]", "provide a structure to allow teams to work through complexity issues [VI]", and "help organise thoughts, stop people jumping into 'solutioneering', and as a record of what has been decided and why...[VL]". From these responses it seems to participants that the aim of the tool is to provide a structured way of thinking about, and documenting, risks and issues that arise from the complexity of a system.

"It is to provide a structure so that teams can work through and gain a common understanding of why something is complex, I imagine. [VI]"

> *"[the Complexity Register] is a different approach to assessing the risk of the program and getting to what other right things to do to reduce the risk and uncertainty in a program. By using the different language and by using system complexity as the angle, I think it, or whether it was an aim, I think the aim is to make risk management and opportunity management something that feels like it's alive to us engineers and not something what project managers do. [VG]"*

> *"I guess we didn't really talk about it on the on the session, but it was a bit like a functional failure analysis or a functional failure description, kind of too, I don't know if you've used those before. Very much the same kind of idea where you identify an issue and explore it. So yeah, I thought it was really good for that because it kind of started to tease out 'oh yeah, right, well, I've got a rough feeling that there's going to be something odd here. Why do I think it's odd? What sort of questions am I asking myself about it and how am I going to communicate those to other people? [VH]"*

> *"It is to elicit the complexity of system, by either directing, not directing, but, maybe directing a little bit, the actual thought process of a person who's trying to analyze the system complexity. It should also give us a baseline which you can then go back and review and interesting enough, we actually did do that in the session we used the tool to go back and use the aide memoire to cross reference across ones we'd already assessed. So at least it gave you a baseline to work from, so I think that's one thing which I think the tool should be doing is capturing, the decision was made in gate one, right or wrong does matter, but then does that assessment stand up in gate two, well you can only do that if you've got almost a database of the decision. [VF]"*

> *"So the way I saw the complexity register and I'll include the associated aide memoire that went with it and using it as a tool. Is it provided some structure for way of thinking about complexity. I thought it provided a good place to capture various sources of complexity and also make people think about how you could handle and deal and come up with a plan for that complexity. So it did provide a good basis for bringing together all those areas, it introduced complexity and could cause, and in the scenario we're looking at is this effectively worthwhile bid? Is there too much complexity, allows us to analyze and workout is this worth doing, is it actually manageable. So in terms of complexity, it was a way of documenting and working out what activities you need to do to mitigate complexity or accept, well part of mitigation is accepting potentially so, although I think it was, I thought it was, as the description said, a bit like a risk register, but a way of documenting and potentially mitigating complexity. I don't think it was as good overall summarization, this is the amount of complexity in this project, but I thought it's a good way of looking at the individual*

things, but we have that problem in risk as well as complexity. [VF]"

"So the aims of it I would say would be to help organize thoughts, stop people jumping into solutioneering and we get that a lot don't we? And also then as a record of what was decided and why. So we do sometimes have it where you'll get, oh, we've always done it that way or you know, why are you doing that way, or we tried that in the past, and you've got a record of why you tried something, so you've got record of what's happened, helped clear peoples thoughts and processes and stops people going straight to the answer, because it might not be the answer especially on something that is by definition complex, you can't go for a simple answer straight away. [VL]"

"I think the aims of the complexity register are very wide, wider than it is suggesting or explicitly stated. The objective of the complexity register would be identify what are the emergent properties of the system at the time. I like the, I think [REDACTED]'s differentiation of complicated and complex, so if you focus on the emergent behavior is complex and not necessarily, too many interactions if they are well defined and not likely to change over time as complicated. So identify the emergent behaviors of the system. Identify the stakeholders, I mean the comprehensive list of stakeholders, it could be social, political, governmental as well, not just the engineering aspects of the system. Because they do influence significantly the scope of the system and how it will be measured. Then it also is about identifying the need of the project in the first place and what was the driver, the social, economic security, national security, or, you know, preventing smuggling, so really we really need to, if the Complexity Register has been done, then those questions should have either been answered or actions open actions identified to get those questions answered. So it goes a long way in having a clear understanding of stakeholder needs, making sure unambiguous and non-conflicting stakeholder requirements are identified which clearly define the scope of the project and its key success factors and who are going to be measuring the project success factors. I think the active learning aspects of the system are, you know, trivial in the sense that these are typically always taken into account, but the things which I mentioned until now are not necessarily always considered. [VK]"

3.5 | Positive features of the tool

Participants reported various positive features of the tool. These positive features include that the tool "is understandable with clear headings" and a "useful aide memoire" that "opened up areas we could dig into" and another praised the "simplicity of the spreadsheet". Another participant reported feeling "skeptical coming into this but [the Complexity Register] worked well. We nearly fell back into risk language but the tool kept us on track and it was easy to use. [VG]" The same participant went on to describe that risk management approaches can be "very prescriptive sometimes" and that conversely the tool "was not too prescriptive, it was good as a capture tool". Another participant reported; "I thought it was a really neat tool, I could see myself using it with project managers, commercial, or in a design review to flash up top three complexity issues [VH]". They want on to say that "the tool is good for helping people to have valuable discussions and take different perspectives", answering that the tool was easy to use with a sensible layout and sensible questions. One participant praised the tool's ability to "'cause it did draw out, especially at the beginning we had different people, with different views, because you weren't going straight for an answer, they did draw out some of the other conversations that you know people didn't think about [VL]". another participant added that they believed, that if the "Complexity Register" was used appropriately, that it would have enabled the pre-emptive mitigation of challenges later revealed in the scenario inject.

"Yes, so the user guide was particularly useful there as it gave you some focus to go through and ask questions. So I did see that, you know the checklist parts of the user guide, the team were using quite effectively at the end to say is there anything we have missed, so I think yes. [VI]"

"So I was a bit skeptical coming in when I first saw the spreadsheet in the pre-reading [REDACTED]. But I think in the former it worked really well. I think there were a couple of instances where [REDACTED] I and I both fell back into the risk language, and I think that's probably to be expected, People have been doing it for 20 years, but we didn't fall completely over that edge at all. We kept coming back and the language in the tool kept us I think from straying too far into that. And then into the latter, I think when you play pack the recording, it's pretty obvious that both [REDACTED] and I were pretty engaged in it and actually quite enjoying it, and probably could still be doing it now, if you let it run on that long. [VG]"

"It was the directed questions, you know, it made you think about, one of the ones I asked about was the legislation or regulatory aspects, and I hadn't even considered that. And then when it asked that question, then you start thinking about well hang on a minute what about the other items like the maintenance, like the user capability, the user training, all of these sort of things, then start building up in your mind. I actually found the aide memoire more useful than the spreadsheet. Because it asked you those sorts of questions to help to trigger the thoughts. [VF]"

"I think any tool is always as affective as the people using it, and the familiarity of the people using it, and the willingness to use it. And it comes back to my comment on the challenges we experienced. We are very much in a brainstorm thinking mode rather than a let's get this down in detail and fill out the forms so we've got something to present back. I think if I went back to that project in a week's time, it would be incredibly useful as a format for briefing someone else incredibly useful, and it's a good way of documenting and recording things. And that, is the plan worthwhile? Or is the planning process worthwhile? The planning process is fundamentally more important than the plan that you come over at the end, 'cause you spent time thinking about and analyzing these problems and working out what's important. [VJ]"

"I think fairly well, the tool itself did do that, but what I think was the benefit was having different people looking at the same tool, that was more of a vehicle of getting that discussion and those thoughts down. So it's a good vehicle to getting answers down but you then still need it sent to different types of people ...And what I liked about it, was the actual simplicity of the spreadsheet. It wasn't 20 pages, I mean, I managed to look at it and interact with it on my little iPad tablet screen which is a bit tricky, but it was only an 8 inch window, if I had my proper monitor this information would have been really easy. It wasn't an overly onerous task filling it in which I thought it will make people more willing to fill it in and complete, if it's just tables on tables when you spend time in moving it around and you can't see it all on one screen, that sometimes puts people off. So I like the fact you could get it on one screen and then it was easy to fill in [VL]"

"you know, to me, if the complexity register was then with the correct stakeholders with a reasonable amount of time, none of what you explained [in the scenario inject] would have come as a surprise and they would have been potentially captured mitigating actions already, or triggered to revise the complexity register if those kind of change request came in. And, I further believe, that it would have also pre-empted

the situation we were presented in the scenario because a lot of these questions would have been asked upfront, clarified up front, and either the stakeholder expectations would have been clarified or the system scope would have been updated and the preparation for CDR [Critical Design Review] have been done appropriately and clearly stating what aspects of the system would not be feasible in the time frame that was originally requested, given that it was only TRL 7 and not TRL 8 let alone TRL 9. [VK]"

3.6 | Negative features of the tool and suggested improvements

Another participant identified particular usefulness for "bridging" communications between the technical and non-technical community, claiming the tool was "very very powerful, to communicate complexity with stakeholders... [VF]". However this participant went on to clarify that the tool is "not used for deep and dedicated analysis but rather a high level view [VF]". While most participants praised the content of the tool and associated documentation, one participant said that the "aide memoire could be more comprehensive [VK]". One participant suggested the inclusion of complexity issues relating to the Defence Lines of Development in the aide memoire would bolster the usefulness of the tool. Two participants suggested the tool could be further improved through integration with other tools such as enterprise architecting tools and risk and issue management tools.

"And like you said in the aide memoire, some kind a little bit a more exhaustive list, just kind of, you know, pointers. 'Have you considered ABCDEFH?' It's already there, but maybe it can be made more comprehensive. [VK]"

"Yeah, I mean I would like to explore it further, certainly, but what we did find in the session was that actually it gave us a lot of valuable discussion. And again, something you find as you get more into systems engineering is people have got particular interests that they like to tease out, quite kind of you know soon into the process so you know, clearly we had a couple of guys on the call who are big into safety and security. Obviously I'm interested in those, but less interested than I am in sort of system architecture and behavior, but they are all issues that can have complexity around them. So yeah, I would really sort of promote it as a useful communication tool, get everybody talking about all the complex issues and how we start going about them. And it's one of those things you know, a bit like, I don't have done much functional modeling, a bit like, you want a lot of perspectives on it before you really start exploring some of the depth. So yeah, brilliant tool for doing exactly that. [VH]"

"[And so how easy did you find the Complexity Register to use?] It was simply laid out. It was sensible questions. I think there were no questions on it where I looked at it and I went 'What on earth is this bloke trying to say with this question?' So, yeah, I mean obviously if I explored it further I might start to want to tailor it or look at more specific things. But now I thought it was neat and easy to use. Clearly it's sort of optimized for tabletop reviews or printing out in a design review or something, passing around the table to look at. Yeah, as I say, if I if I were presenting a design review with that, I probably have a slide with my top three on it. And talk about some of the complexities and what we're doing to overcome them. And you did have that sort of proposed mitigation which always makes people happy. [VH]"

One participant was reserved in their judgement of the effectiveness of the tool, saying that they did not have enough time to do a thorough assessment and that operating in a virtual team was challenging. However, they went on to say that they believed the tool, user guide and aide memoire were "good", and that they would use the tool in the future, giving an example of using the tool "as part of a systematic design review". Another respondent was

keen to highlight that the tool is only as good as the people that use it but that , it depends on how it is approached, however, [Complexity Register] is a good way to document and record this [VJ]" and reiterating that it is the planning process, not the plan, that is of most importance. Another participant shared this view, saying that the effectiveness of the tool "depends on the team you have, the knowledge they have and when you do [the complexity assessment] [VF]", similarly another participant answered that "[the] tool is a good a good vehicle, but it still depends on the people using it [VL]".

While most participants answered that the tool was simply and easy to use ("Yeah, its clear and understandable, headings with goods. And then the subsequent rows, we did find a bit of repetition between the rows, but that's probably understandable. Yeah, easy to use but that's because I think it's a relatively easy tool as well. [VF]"), one respondent answered that "[the Complexity Register] took some explaining... and seeing it talked through for it to click, but once that happened it was fine [VL]". Another participant suggested that the three perspectives on system complexity suggested in the aide memoire could be entered onto the Complexity Register template to help with initially starting the activity, "as opposed to staring at a blank form [VJ]".

> *"[So how easy did you find the complexity register to use?] Personally it took someone to explain it. I'm not always great at just reading instructions understanding. I like pictures and then someone explaining the pictures. So once, when you sent it through and I read it beforehand, that was good. But it wasn't until we actually walked and talked through an example that I actually understood it. I will put that more down to my learning style of how things, how I assimilate new information as opposed to the actual tool itself...We all like pictures and a verbal brief to go with it as opposed to lots of words. But once we had the pictures and a verbal brief it was fine and really useful. [VL]"*

> *"I think the structure that we struggled with and we jumped around a lot was, well, the way the a memoire broke into three steps and ways of thinking about it of the system itself, the system impacts. Now I cant remember the three things, but those three ways of looking at the system. Three perspectives. Maybe if we try to have those as reminders on the register, that might have helped in terms of going 'let's think about these bits first, these bits, then these bits' and breaking into those three sections might have been a better layout just to help 'cause when you started, presented with a big blank form at the start and get told off you go, it's always that, particularly having haven't used the tool before. Its always the joy of oh here is the tool let's just use It, you've all pre-read and understood how to use it, oh yes we have. And although I read it, you don't understand it until you've used it. [VJ]"*

Three participants suggested that the inclusion of suggested mitigating actions to potential system complexity issues would further improve the tool and associated documentation. Two of these participants also suggested that offering a clear definition of "system complexity" and related terms, and explaining what these terms mean in an engineered systems context, would further assist as "clarifying terminology and jargon is key", a sentiment also reported by another participant. The inclusion of a worked example in the documentation alongside figures explaining the intended use of the tool would also benefit the tool, as reported by another participant.

> *"Which is trying to come up with a common understanding of what complexity was, versus complicated versus chaotic versus complex adaptive versus simple. And also the fact that it does sit quite closely to a risk register, we never really explored how we think it would compare to a risk workshop, and I think that that prep part, I think would be quite important and the fact that there are no published mitigations yet for*

different sorts of complexity. [VI]"

"So you're asking is would that be a suggestion to include the definition of system complexity in the complexity list? [Yes.] Yes, my answer is yes. Because I think when you say Complexity Register, it could have a different meaning for different people and from the STAMP [Systems-Theoretic Accident Model and Processes] conference I recently had, safety analysis techniques, quite a few people said that the jargon or terminology was a big challenge and I'm also on the task groups, [inaudible], where again conflicting terminology of ISO 26262 and you know, [inaudible] comes up all the time, so I think the context needs to be clarified. If there's existing definition of system complexity that can be referenced to avoid creating new acronyms and new meanings, so probably existing INCOSE material can be referenced. I found something in, say, vocab, but that does not talk of the emergent nature of the behavior, so we should refer to what is available in INCOSE body of knowledge. Add the context if required, or you know if nothing is available then you know define it but, people need to know what, when we say Complexity Register, what do we mean by complexity? [VK]"

"So I think, improvement, I might have mentioned this earlier, that some specifics, so what does this mean to the project manager? What does this mean to the safety manager? What does this mean to the safety or security expert? What does this mean to the software, or algorithm development team? What does this mean to the data bandwidth analysis team? What does it mean to the software engineering team?...I think the tool support would be good, but it's easier said than done. The tool support would basically look at kind of potential conflicts in the entries in the complexity register which you know, if you forget about AI and machine learning, it's going to be hard and difficult, but the tool potentially could be saying that if you have adding something you know, can you bring up the related rows in the complexity register for the for the for the study team to look at so that they can ensure that these are not conflicting, complementary, and there is no ambiguity in them, but I don't know how the solution would be, but something like this would be useful. [VK]"

Several participants suggested that, in order to address the challenge of what level of abstraction the SoI is considered at, the tool could explicitly address different levels of abstraction (i.e., one "sheet" for a SoS perspective, one "sheet" for a system perspective, etc.). Another participant suggested that a better way to visualise or report the findings of the complexity evaluation process would benefit the tool, suggesting providing a prioritisation or scoring could be applied to "bring the problem children to the front [VF]", a suggestion echoed by another participant would have liked to see "a way to show the top three risks or issues say [VH]". That the Complexity Register prompts consideration of any compounding risks or issues was praised by several participants, and one participant suggested the tool could be further improved in this regard by presenting a further "sheet" containing an n by n matrix, where n is each raised complexity issue, to more readily evaluate the extant of compounding issues.

Another participant suggested a potential improvement to the tool is that, while the tool is useful for capturing issues related to complexity due to its structure, "[the Complexity Register] could be improved by providing a scoring or measure or metric of that complexity [VF]". This participant suggested that the Complexity Register is limited due to its subjectivity, and suggested that instead a risk register type quantitative approach would be more desirable, where impact, likelihood and proximity could be quantified. Interestingly, this participant stated that they preferred the Thales Group Complexity Profiler because it was seen to be more quantitative. Another participant also suggested that the Complexity Register could be improved if it was made more quantitative. However, another participant

reported challenges they could perceive with trying to provide an aggregate scoring.

> *"I kept going back to being like a risk register approach and it was very much like that, you know, "there is a risk that" type of question and we the complexity register is built in that way, it was almost it is complex because. And with a justification list. But it didn't really as a tool, it didn't really help me understand the complexity system, all it allowed me to do is understand what complexity of the system captured when I did my review. It was really just a tool for capturing the complexity, rather than eliciting the complexity…It doesn't value, the complexity, it doesn't give you a magnitude or a significance to the business. I think that's what it is missing from to make it useful for measuring complexity and for evaluating complexity. It didn't really give you the tools to do that. I think if you went back and redid the complexity, you might come up with the same things, but you might score 'em differently because, time of day, how people are feeling, what they might read in the news so it didn't, it only captured the complexity, not actually made it a true baseline, actually. Yeah, initial judgements but it doesn't give you the magnitude of the complexity. You know there is no scoring approach, there is no, again, that might be more my mindset because it was phrased as risk register, I wanted to see something along the lines of a risk register, you know? Pre-mitigation, post-mitigation, scoring was it medium high or. Low. What was the impact to the project, was it cost time schedule. Start to quantify the complexity I suppose in the impact on the projects and it just missed that, it was almost no more than a log of the complexity. [VF]"*

> *"Yeah, I think it would be very difficult if you were doing a review to pull out which one of those complexities you actually have to do something about. So one of my recommendations would be either a prioritization or a scoring type criteria to better bring the problem child to the fore. That would be one recommendation, again that goes back to my initial comment. You know, we didn't score a problem, so it became very, very subjective, so if you have the scoring aspects, then you can then understand which areas should be considered for investigation. So that's the one thing I would say. [VF]"*

> *"…overall view, thinking about it more, I think it is hard to have an overall view of 'this gets a complexity of five' because it is complex by its nature isn't it where, that overall complexity value, if you break it into categories, like technical complexity, human complexity, decision making complexity, maybe, no idea what those buckets are and the reason that becomes useful is communicating to people that aren't intimately involved in that complexity decision, and helping you weigh one project complexity against another, or component, or subsystem against another so something that allows, even if it's a [REDACTED] highly likely, likely, wordage, value of complexity, it might be useful, its just something to help quantify that to others at the end. But that is kind of a secondary function, because what it did in terms of help you identify mitigations complexity I thought was good and I never really thought about, here's a source of complexity, what is the impact, how am I going to mitigate it? I never really thought about how am I going to mitigate it and I was a little bit skeptical and then I was like oh no its obvious it is quite straight forward, like, security, how secure does it have to be, those non-functional requirements, well actually you can say well define it and say what it is going to be and therefore reduce the complexity of that, because we can say it is this state, rather than it is secure enough, what is that? [VJ]"*

Another participant also drew a comparison with the Thales Group Complexity Profiler and suggested that the previous tool still "plays a role as something for a [Design Authority] to fill in on their own", but that the new tool is a

good way to get a collaborative understanding between key stakeholders.

> *"[And did you feel this is a potential improvement for you over the Complexity Profiler, the previous Thales tool?] I think so. But I think its not just about the tool. I think it was that the tool lends itself to having the right collaborative discussions, whereas the Thales Profiler is a bit more of a something that a Design Authority would sit down and fill in on his or her own. And so there is something in the way the tool is simple and asks some nice, open questions, that lends itself well to getting people collaborating to get the answer. [VG]"*

Another participant praised that the Complexity Profiler was not overly prescriptive and offered a suggested improvement in structure to more easily analyse compounding risks; "‘"‘[So some something that would help would be a way of being able to get the interrelationships between the issues somehow on the tool. The tool feels a bit one dimensional 'cause that's kind of how spreadsheets work. If you had separate tabs, maybe, that you could somehow interrelate the things to each other, or there was a separate one where you could.. lets say you got to 15 issues. That it was auto populate in another tab on the spreadsheet that had a matrix, a 15 by 15 matrix and you could say what where the interdependencies and where and whether they were strong or not. So it was missing that sort of level of richness for me. But In the way it did the job of the initial, let's capture the issues, let's capture them all flat and in a structured way that gets us to mitigation, but doesn't really, so it wasn't overly structured. So you know you know when we do, risk management is very prescriptive, right? How you write a risk, how you write a mitigation, how you write the impact and sometimes it becomes too prescriptive. I think this was a [inaudible]...Yeah, that's what I like was it wasn't too prescriptive but it did give some structure. And therefore we got to the mitigations and then we can come back to it. So I think as a capture tool it lends itself really well. It perhaps lacks a bit of richness around helping us through any analysis of what we captured.] [VG]"

3.7 | Willingness to use the tool in the future

The question of: Would you use the Complexity Register in the future was answered with mixed sentiments by participants; some said "I think, as long as you are happy, and I'd like to keep in touch with your study, I would like to take something like this into [REDATED], yes. [VG]" and "If I had your permission, yes...So if we were doing a design review, I would expect us to stay close to the design and assess the design in a systematic way rather than brainstorm which is more of what we did. [VI]"

> *"So yeah, I thought it was a neat tool actually, I could see myself using it. Not necessarily when I'm talking with the systems engineers 'cause you know you will have picked a lot of those things out already, but when you are talking with the PMs [Project Managers], the commercial, the management, senior management. Actually, or in a design review, something like that, I'd probably flash up, you know, like you flash up your top three risks, your top three issues, whatever else, top three complexities, yeah 100 percent. We would flash that up in the design review and say 'these are the things we identified and here's how we're working through them.' [VH] "*

> *"[And if you were working on the development of a new system, would you use the Complexity Register?] Yeah yeah, probably up front. I mean, we saw in the study, that's where it's really handy where you know someone's come to you with the concept and you can refine it as you go. I come back to functional anal-*

ysis, in your first loop of it, your big handful kind of things, I've got system that's going to do navigation for me, I've got a system that's going to do detecting for me. And I have to talk to each other. Here's the complexity and then later down the line you are like yeah woah part of this system I'm hosting as a virtual machine somewhere and you know the rest of it I'm hosting is on processor cards somewhere and oh they've all gotta talk to each other. And by the way, every 10 seconds you're going to lose an in feed from this sensor so be ready for that. So yeah I'd expect to see it develop as you go through each sort of phase of your life cycle model, depends which one you using obviously, but something as simple as CADMID. I'd expect to see 6 iterations or 5 iterations of the complexity register to evolve with my ongoing maturity, my design review gates, that sort of thing…Yeah, yeah, definitely. I mean, the other place I might expect to or might consider using it, I don't know if you've come across the Ministry of Defence Lines of Development DLODs, [TEPIDOIL and all that?] All that yeah, yeah. I'd be straight into those with the Complexity Register, and I'd be saying right, well, is there any complexity that's going to arise around training, for example? Or is there anything that's going to rise around interoperability? Interoperability is almost a key one where you go, most people are going to say that's complicated. Think of all the emerging stuff again. So yeah, be straight into TEPIDOIL with it, and I'd be doing it early on. [VH]"

"I think broadly, as per the feedback, that I put in on Friday, I think it's a tool with a lot of potential. And while I might not necessarily use it for my deep and detailed engineering all the time, although obviously that is a good place to use it, but the place I see the real benefit is the stakeholder management piece and in particular, communicating what can be quite complex ideas, and there we go with that word complex again, meaning something else. Let's call it difficult ideas or perhaps things that the project or the program might find a little bit more unpalatable. Using it to communicate those sort of ideas I think would be really really quite powerful. I mean, I guess from your perspective, obviously you're doing PhD, right? With the, and I guess, the outcome of this is, you know, you're evaluating tools, toolsets and you'd like to see them, pushing into engineering practice going forward so you know I'd be really supportive of that. I think I'd like to see that that sort of complexity assessment start grabbing hold a bit more. I guess the interesting thing for me would be to think about is there an opportunity for me to sort of test it out, workwise, interesting one for me to take away I think? [VH]"

Another participant, however, preferred the previous Thales Group "Complexity Profiler":

"I wouldn't use that Complexity Register. I would still go back to the Complexity Profiler and the other works that I do with rich pictures and some causal diagrams, I'd bring my own personal experience into play on that one…Yes, although I do like the idea of having it as a more of a risk register type approach and scoring it whereas I think the Complexity Profiler doesn't really do that at the moment, ok it gives it a scoring, it gives you a polar graph, but it can go further on the scoring. But then you end up at the challenge of you only get out the quality of what you put in….I think the Complexity Profiler will probably draw out the same level of complexity as the Complexity Register, probably identify similar things. [VF]"

Others were uncommitted on whether they would use the "Complexity Profiler", while one participant stated that they would not use the tool as their current methodological approach would achieve the same aims.

"[if you were working on the development of a new system, would you use the complexity register?] Yeah.

Yeah, possibly could, I want to see how it would fit in with what we do, I've not done true requirements management before, I've received things in and different bits, so I'd have to double check and see the process that they use but I can't see why, if they got something on in process, you don't want to add too much to it, but it seems like a good tool to add to them. I can't see why it won't be used to assist, 'cause it did draw out, especially at the beginning we had different people, with different views, because you weren't going straight for an answer, they did draw out some of the other conversations that you know people didn't think about. [VL]"

"Don't know if it was a nice little tool, I don't know how often I'd use it or if I'd use it again and this might be one of your later questions. And I was chatting to a colleague about this this morning, in terms of would I use the complexity tool again? Maybe, not sure. I can think of some use cases why I said, oh, let's do a complexity analysis of this thing. A bunch of people are going to turn around and tell me [REDACTED] this is stupid, why are we doing this thing? Maybe if I did it in the background and had it to think about it, it could be useful, or maybe tweaked it. I'm not sure, don't know yet....[...would you use this tool again in the future if you were working on the development of a new system? You've previously said that you are not quite sure.]Yeah I think that is the blunt answer, yes, I'm not quite sure. I think, I might be tempted to use it if I suddenly picked up a project that I had an inkling or knew it would be complex; it was big, it was large, it had a large number of components, I might be tempted. Then again, how good are we at using tools? We are rubbish. Like how many people use the estimate in the military? Did you ever use it in your tour at [REDACTED] or the comms estimate? No, we had all these tools, and maybe it is not the planning tools that we learnt, it is the knowledge that the planning tools exist and we have to think about those factors. So might I think about going, what are the bits that are going to catch us out here, what is the impact going to be, what can we do to try to tighten the scope, I might do that process but whether I'd use that exact tool, I don't know, we will see, ask me in a years time. Notable, I am currently designing [REDACTED] to help people [REDACTED], there is a huge number of complexity in [REDACTED] when the ultimate thing is to protect peoples decision making or affect peoples decision making. We discussed how much people bring complexity to a system, because ultimately they are a bit of a black box, I'm not a psycologist and as much as I can do human factors and human decisions it is hard, so maybe using mental models or some stuff for it, but yeah, complexity by its nature is very hard to understand and get into the detail of, same as people. [VJ]"

"[And if you were working on the development of a new system, would you use the complexity register?] I definitely would use some form of what is known as impact analysis, requirements elicitation, which in my opinion, would have addressed the need or the what the intent of the Complexity Register was, so as long as, there needs to be some formalized method of an organization and if the people using it are not constrained to that specific description, then I'm ok with any method it really doesn't matter...Because I would have got those results whether I used the Complexity Register that I used in that exercise or not, I still would have got the same results but maybe in a different way in a different format, etc. [VK]"