

The Art of Interrogation – For Better Requirements Capture

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SUMMARY

Good requirements capture is well known to be critical to the success of a rail systems project. This paper takes a different approach to the typical guidance for requirements capture provided for engineers, bringing multiple tools of interrogation from disciplines outside rail, and using complex system change techniques including appreciative Enquiry and Interventive Interviewing to crack a real-world complex problem: external cable routes in Melbourne.

This paper has unconventional two-column formatting to assist the reader in aligning the theoretical frameworks or techniques of interrogation (left hand column) with the corresponding steps of the supporting practical example (right hand column). Each page covers a key conceptual step or technique in its entirety.

1 THE IMPORTANCE OF ORGANISATIONAL IDENTITY

Each person comes into a project with their own biases, perspectives and frameworks – and each team or organisation provides its own overlay of explicit and implicit incentives and priorities, culture and identity, perception of time, and prioritisation system of criticality and urgency.

Requirements capture is a standard step in systems engineering on a project. The systems engineering guidance [1] has been shifting from a traditional hardware-oriented approach (sequential processes to specify all requirements up front prior to the project starting; focus on specifying component, subsystem and system architecture and function) to a Soft Systems approach (iterative process, working concurrently on requirements and solutions, user focused, delivering for today's requirements & also preparing the system to adapt & evolve in the future).

The soft systems approach incorporates social identity theory to explain how people, as providers and users of a system, alter their perception and priorities around the organisation that they feel part of. The four principles of social identity are [2]:

1. A person's organisational identification is a cognitive framing independent of that person's feelings (e.g. loyalty) or behaviours (e.g. effort) for the organisation;
2. A person who identifies as in an organisation will personally feel its successes and failures;
3. A person who feels part of an organisation does not necessarily agree with the prevailing values, attitudes or strategy of the organisation;
4. A person can form a relationship with their organisation as if it were another person; and act according to the relative roles in that relationship.

This theory goes part way to explain how the organisational context is important to requirements.

1.1 Current Victorian Rail organisational context

The "Big Build" is a decade-long program of transport infrastructure projects across the state of Victoria, Australia. Over 100 projects have kicked off, including brownfields upgrades, line renewal, and greenfields extension projects on the metropolitan and regional rail networks: Approved scope includes:

- Grade separation of 75 level crossings in metropolitan Melbourne
- Upgrade of the regional passenger network, including new stations, junction modifications and active level crossings
- Large scale metro tunnel construction under the city and modern high capacity trains
- Refresh of technology (power, signalling and communications) on aging parts of the network
- Four elevated railway sections, 23 new stations.

Unlike other places, Victoria does not have a single rail authority. Rail projects rely on cooperation between more than 30 separate organisations. These include the following (also see Figure 1):

Governments: Federal, State, and local councils;

Asset owners: the publicly-owned corporations that own the state railway assets and major road assets;

Asset operators: The Metro and regional railways are operated under two separate franchise contracts;

Construction authorities: set up to oversee the projects on behalf of the Victorian State Government;

Delivery Alliances: Nine separate organisations comprising government and corporate participants, each delivering a suite of projects, with engineering services from two consultancy joint ventures;

Sub-contractors & suppliers: providing specialist expertise across multiple projects/asset managers.

2 PROBLEMATIC REQUIREMENTS

A project requires a single, clear set of requirements to set the scope, trace achievement of that scope throughout the project lifecycle, and deliver an asset or outcome that is fit for purpose for the users. The quality of requirements capture is well established as being critical to the success of a project [3] but in a context of many organisational identities, good requirements capture can be difficult.

Requirements capture seeks to distil complex rail operations and systems behaviours, each originally in the different languages and mental frameworks of the team it comes from, into a single set of written-down project requirements for the project delivery entity. Often this information is in story form, raw digital data, or written into the physical asset.

The translation of performance-based requirements (what the asset does) into prescriptive requirements (needed to perform the design) is very important. If a performance based requirement is made prescriptive without capturing the rationale, it may become an artefact of a past context carried forward into inappropriate future contexts.

Those who hold the operationally critical requirements - the actual operators and maintainers - are not typically skilled at writing these down in a form compatible with projects. The important details may be:

- Tacit – the critical detail is so automatic or that the user may not be aware of it, or may not mention it: *“Of course we need to get a truck in there! That’s obvious!”*
- Hidden in the team’s daily practices – where there may or may not be an opportunity to change or improve; *“That’s the way we’ve always done it!”*
- Lost or twisted – e.g. through a management chain, in the different published documents and knowledge frameworks, or one person’s habit or mental short-cut being cast in stone into (or out of) the requirements.
- Context-specific – where the limits of application may not be fully understood.

Markers of a problematic or incomplete requirements capture process may be:

- Contradictions: e.g. a feature is both mandatory (*“You must do it this way!”*) and prohibited (*“You must absolutely not do it this way!”*) at the same time;
- Underground practice: *“Yes, [that] is what is written down... but people in the game just know to do [this]”*
- Vastly different practice in this context compared to best or normal practice: doing or building ‘weird’ things
- Habits: process elements that do not seem to map to any requirements, but do not shift using conventional continuous improvement (e.g. Lean or Six-Sigma).

2.1 The Combined Services Route: an example of problematic requirements

A wayside cable route is typically a straightforward element of the railway, but In Melbourne, Victoria it is not. The Combined Services Route (CSR) is a bewildering phenomenon for engineers new to the network, and a cause of much design consternation and some conflict between organisations.

For the Big Build, the task of establishing a single, clear set of requirements for cable route construction was identified as a high-value initiative, but it has been a long process and thus a superb case study for the art of interrogation.

On many other railways worldwide, cables are typically contained in ground level troughing, or cable ladders on wayside mounting or structures such as cuttings, tunnels or viaduct walls. Design is simple: only a small engineering effort is required to keep the signalling, power and communications cables appropriately separated from each other and the public. Standard designs and products ensure a low risk of connected systems malfunctioning. Construction efficiencies have been achieved by specialised hi-rails with mass construction attachments.

For these railways, formal requirements for cable route construction are provided by written Standards, augmented with or tailored to project or site-specific requirements.

In Victoria, cable route standards are not straightforward.

Three different company standards typically apply to each CSR: the rail operators maintain separate standards for high voltage and signalling cable routes, and the telecommunications operator maintains a third cable route standard for communications services. These were written for the past context of small-scale or greenfields projects. Each group is reluctant to fully align with the others – for valid engineering & compliance reasons, and for reasons of identity and minimising disruption to their practices

The standards specify cable route elements appropriate for existing cable-intensive signalling and communications technology, e.g. comfortable spares allowance. This ignores the shift towards less cable-intensive emerging signalling technologies, and improved efficiencies of maintenance practices over time.

The result is that a fully compliant CSR is typically a trench with conduits (“pit & pipe”): depth ranges from 1200mm to 1500mm: width from 650mm to 2100mm. Pit clusters of 5 or more cable pits are placed at regular intervals, providing separate inspection, cable pulling and joint access points for different maintenance teams. Refer to Figures 2 & 3.

Extensive spare conduits are provided: specifications are slightly different for each service, but typically, less than 30% of the conduits will contain cables on the day of project completion.

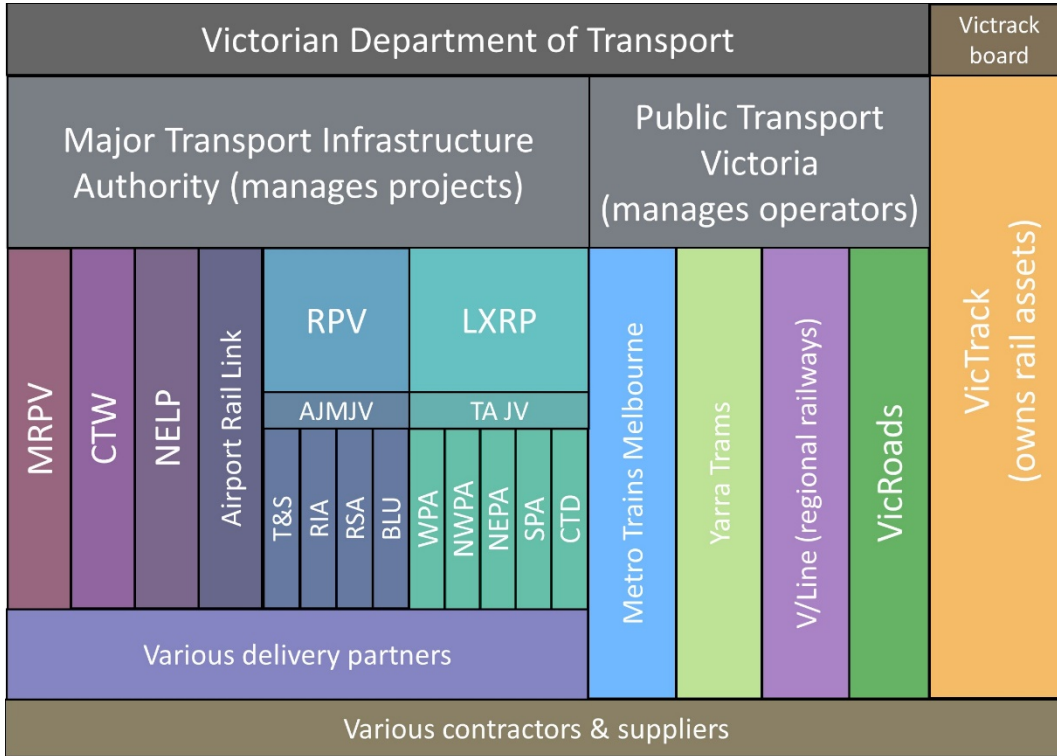


Figure 1: Organisations involved in the Victorian Big Build with lines of upward reporting/escalation



Figure 2a: Typical "Pit & Pipe" CSR during construction, and Figure 2b: typical CSR main route pit array with posts as errant vehicle protection – as adjacent to a suburban road.

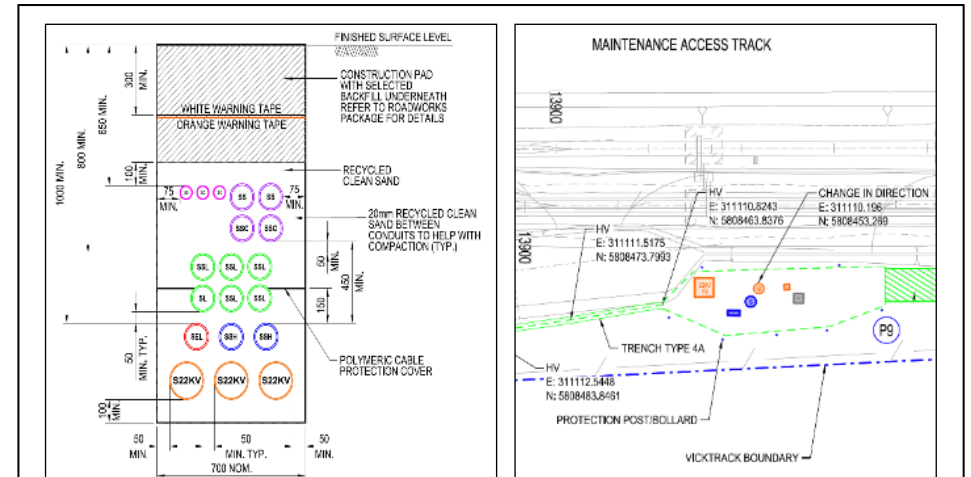


Figure 1a & 3b: Design documents for a trench cross-section and pit cluster of a fully compliant CSR. This one has 19 conduits, and only 5 hold cables on the day of commissioning.

3 MAPPING A PROBLEM SPACE COLLABORATIVELY

The performance requirements for any asset are derived from user requirements of that component and the interface requirements of connected systems (human and technical). Where there is a problematic requirements space, the requirements engineer can use both one on one conversations and group workshops to map the multiple perspectives on the task or problem. The conflicting or nonsensical requirements may make better sense from a point of view other than the project view. This is known to social constructionism as a curious and dialogic stance.

The appreciative enquiry framework [4] follows four steps:

- 1) Investigation into the “best of what is” – believing that in general, people behave according to their best definition of “doing their job right”.
- 2) Imagining better ways of working in the future – using conversations to identify improvements
- 3) Planning and prioritising changes – according to common or mutually agreed priority frameworks
- 4) Deploying those changes – potentially requiring concurrent changes across multiple stakeholders. A requirements specification can be a vehicle for this.

The full framework of Appreciative Enquiry is very powerful but can be quite daunting. As a starting point, the author suggests the following:

- Map your stakeholder organisations and seek to meet a key person from all of them.
- Do not avoid hostile or belligerent stakeholders – the hostility can be a marker of someone who has a very different perspective and is under attack (though not necessarily by you), and belligerence can be a marker of someone who feels they are the last line of defence against catastrophe, chaos and darkness.
- Use a mixture of one-on-one interviews and facilitated workshops. If inexperienced in either one, seek mentoring, formal training, or expert support.
- Ask good questions (Section 4). Let people speak without contradicting or interrupting the flow.
- Feel free to move into the “what if” space to trigger appreciative change. You might use the “magic wand or “deep sleep” question: “If we imagine 10 years from now, and let’s say some powerful and positive changes have taken place, what would you see that is new changed, more effective? How did we get there?”
- Cross check “facts” against data – using whatever data sources you can access yourself or with permission from the owner. Understand the limits of the data set.

In a hostile requirements space, running effective collaborative workshops is an expert skill and a novice interviewer might use a professional workshop facilitator.

3.1 Mapping the CSR problem

From a project perspective, cable protection is normally straightforward, and the cable routes that projects had put in are “clearly overbuild”, with “ludicrous spares” and “ridiculous land requirements”. A single project would seek to negotiate a reduced site-specific design primarily to reduce cost. Non-compliant proposals were met with resistance, hostility and stonewalling from other stakeholders. Ultimately the project timeline required a scope decision at the point where delay was more costly than the CSR. Thus each project would have the same battles against both asset maintenance acceptance and the clock, while being accused of seeking to build a “cheap and nasty asset”, and “rushing through the review too fast”.

Key complaints from projects about a compliant CSR are the cost and delay to construction, critical-path impact, insufficient space in the rail corridor, and construction risk to both buried assets and workers. Urban outcomes had been compromised: pits had been placed in bike paths and station forecourts, and geotechnical & hydrology impacts have been observed.

Hostility and stonewalling are not typical professional behaviours, and noticing this, the author sought out alternative views from multiple levels of each stakeholder organisation, focusing on the point of agreement: that CSRs are not satisfactory.

A facilitated workshop brought to light the different perspectives. The CSR is at the interface point between commercial and government organisations, project management, asset management, and multiple disciplines of engineering, design and construction. The CSR standard driving “overbuild” was one stable solution to four separate organisations trying to satisfy their legal responsibilities in five separate legal frameworks (also see Figure 3 on the next page). The task in common was to collectively do better. The workshop then had “multi-voting” to agree the next steps, and working groups were formed to tackle a few priority issues (Figure 4 below)

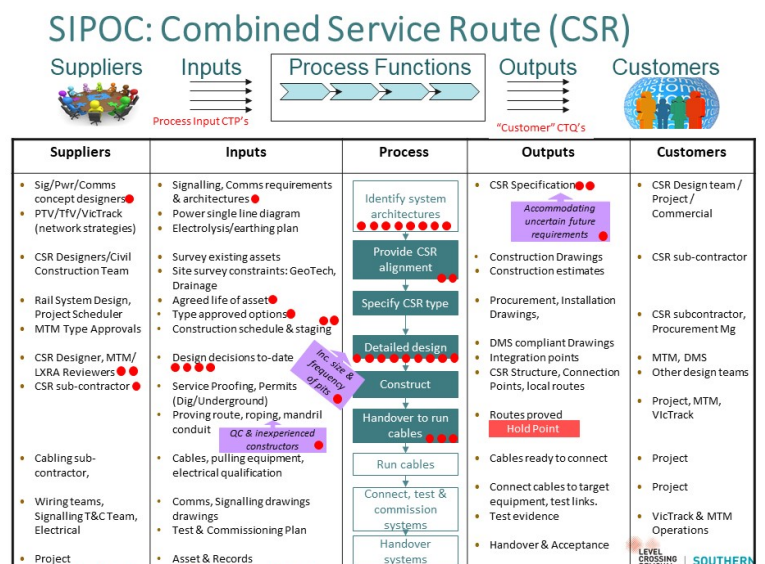


Figure 2: CSR workshop process map and multi-voting on the priority issues

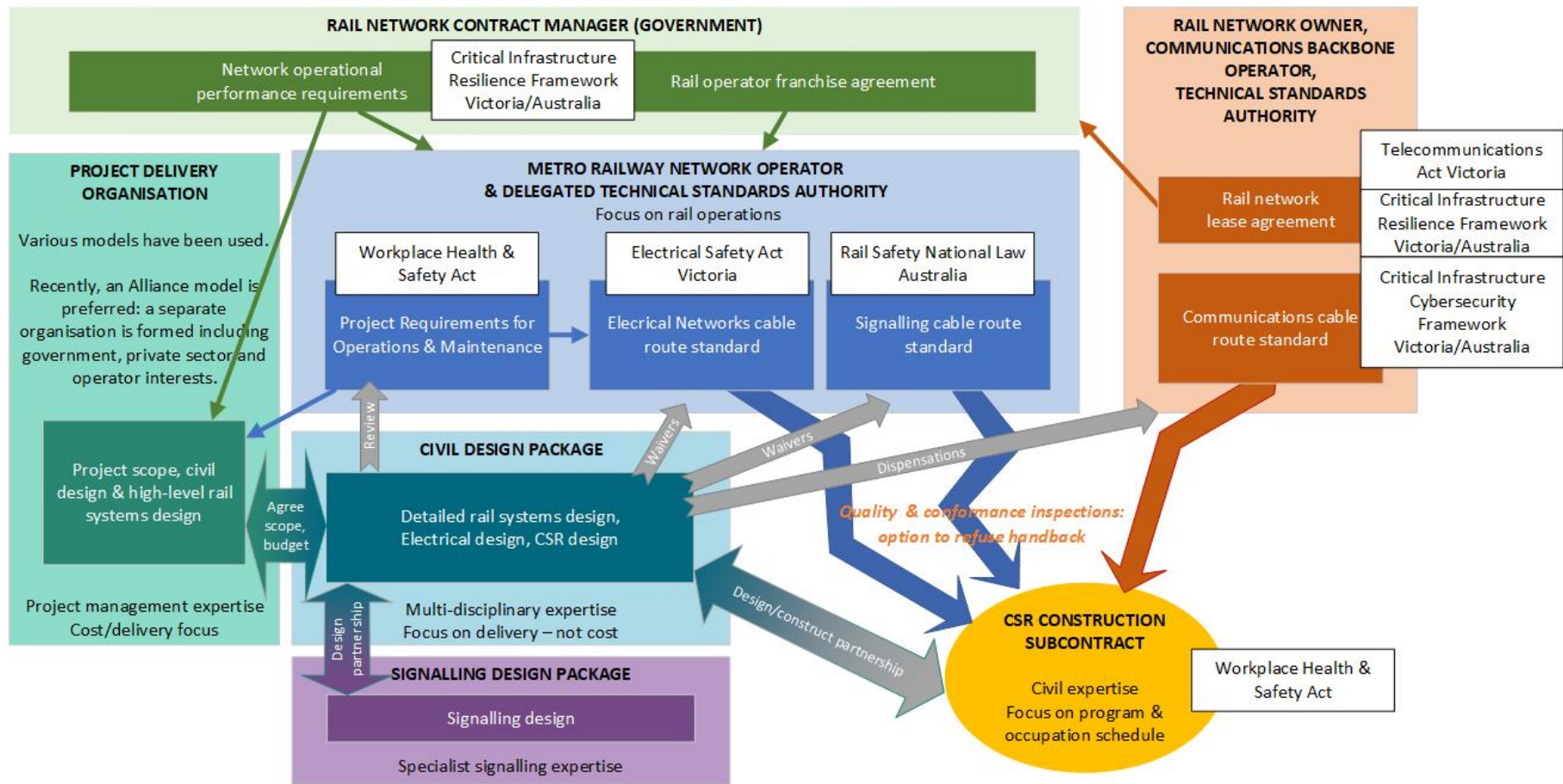


Figure 3: Organisational & legislative context for combined services route design & construction

Although drawn with the network owner at the top, there is no 'controller in charge of this system'. The key to understanding the asset is that the specification derives from three separate Standards, authored by two different asset operators who would understandably favour a minimum-maintenance asset. There are some key differences in the way different asset requirements flow down from legislation, so the built CSR must satisfy the most stringent cable route requirements of all connected systems. There is also no pathway for construction organisations to provide feedback into the specifications.

The large trenched CSRs are not overbuild – this is an adaptive system's response to achieve all requirements with minimum delivery risk.

4 ASKING GOOD QUESTIONS

Contradictions in a complex requirements space are generally adaptive: somewhere there is a story that supports each side. Journalism and marital & family therapy techniques can help ask the right questions in the right way.

Journalism provides a simple framework for successful information gathering [5]:

- **Prepare carefully**, familiarizing yourself with as much background as possible.
- **Establish a relationship with the interviewee conducive to obtaining information.** Arrange the interview to be convenient for the interviewee, e.g. a café close to their office. Buy cake and coffee: people talk more freely with free food.
- **Ask questions that are relevant to the interviewee.** Focus on their day to day practice, in the language that the interviewee is fluent. (There is no point asking a machinery operator about high theory, or a theoretician about machinery operation.)
- **Listen and watch attentively.** Write down what they say, even if you disagree. It is a powerful intervention in itself for the interviewee to feel 'listened-to', as well as a good record of the conversation.

Family therapy has techniques of asking questions that can change dynamics in a complex relational system.

Empathy is critical: try to (at least temporarily) see through the interviewee's eyes, and feel some of their frustration.

Open questions (e.g. "Can you tell me about ...") are most useful to get an overview or general picture.

Closed questions (which have 'yes' or 'no' answers) can validate a point. Use sparingly: they can shut down sharing.

Clarifying Questions are used to confirm your understanding, or reveal specific details, e.g.:

- So am I right in summarising this as...? "
- Can you tell me the whole sequence of events?
- Can you give me an example?

Probing Questions drill deeper into the perspective of the interviewee and their organisation, e.g.:

- Why do you think this is the case?
- What do you think would happen if...?
- What sort of impact do you think this has?
- What is the connection between... and...?

Circular questioning is the practice of asking linked questions to multiple people, giving space for each to answer for themselves and reflect on others' answers, e.g.

- Who do you think should have responsibility for this?... What do you think they would say to you about that?
- How does your issue make life easier or harder for ...?
- Do you think this is improving or worsening over time?

4.1 Use of interviews to understand the CSR problem

One on one interviews with asset management staff were backed up with analysis of the network fault data. Both revealed that cable faults have caused a measurable increase in unscheduled signalling maintenance and train delays in the last 3 years. Signalling maintainers perceived the cables in the 1980's era galvanised steel troughing as more likely to fail – and thought of this as inadequacy of the original cable protection. They had been trying to prevent the future network from these problems going forward. New products such as composite troughing which are not type approved locally and are "unknown" and "risky", but underground CSR was perceived as maintenance-free, so had first become preferred in Standards, then mandatory.

Electrical maintainers had a different issue. The Wiring Regulations had just changed, requiring them to comply with stringent work safety rules when accessing their cable assets. While cable faults in the power distribution network were rare, they were high-impact due to the old power system architectures between substations and lack of supply redundancy. Once again, network failure data validated the maintainers' perception.

An understanding emerged that the 'overbuilt' new cable route was repeatedly being used as a fix to pre-existing problems in the rail systems architectures:

Circular questioning on 'who had the responsibility to fix these cable asset issues?' identified that nobody did. There was a contractual gap in cable and CSR renewals, and work had lapsed for some years. Bringing this to light encouraged key organisations to act to close this gap.

"Since the workshop, Alex has drawn on the collective knowledge of the CSR community of practice to get a clear answer to the question, "Are cables part of the CSR?"

The answer has come back that cables are not part of the CSR. The CSR is a subassembly that contributes to cable management in other subsystems and the overall rail system. So it is interesting that the problem hot spots collected around the edges of the CSR process (in the context of the overall rail system).

So even though the working groups will focus on the CSR, we need to be aware that the root cause problems, and the improvements needed to properly fix them, might be on the other side of the fence."

Analysis of agreed waivers to the Standards revealed several cheaper non-compliant repeated solutions which could be generalised, specifically for temporary CSRs (within the life of a project) and reduced separation of redundant HV lines (in response to challenging excavation). It has also opened the conversation about other CSR options including modern troughing.

5 COORDINATING CHANGE ACROSS MULTIPLE ORGANISATIONS

When a change is contained in a single organisation, the task is to find the appropriate decision maker who has the accountability and responsibility over both sides of the problem, put forward the case to them, and seek a decision.

In a multiple-organisation or complex-organisation space, coordinated change may be needed in several places. In fact, top-down decision making can disrupt respectful collaboration already underway. 'Soft' coordination is key.

Three tools of multi-organisational coordination are interventive interviewing, reframing, and fast feedback.

Interventive interviewing [6] is the practice of asking questions that shape the intention or actions of the people that we engage with – i.e. asking questions that change the system. This social constructionist framework does not comfortably align with traditional linear requirements capture, but fits with Soft Systems requirements processes.

The intent is to use different question types to identify which person/organisation is actually responsible for what (co-clarifying intent) and which people/organisations can most usefully explain the past and map the possibilities going forward (co-constructing intent). Almost by magic, the problematic requirements space then becomes straightforward capture. Figure 5 below shows how specific types of questions can trigger a change of mindset that changes the system.

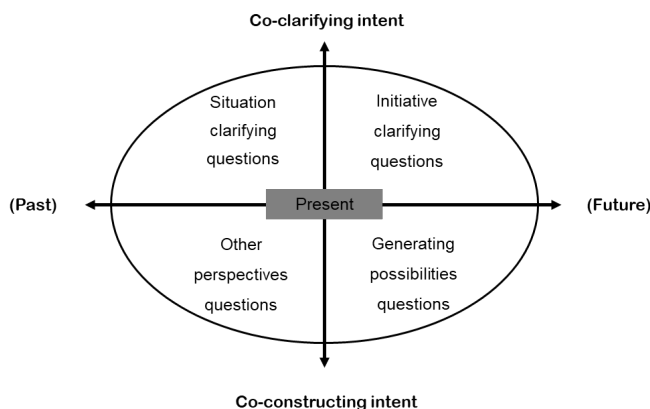


Figure 4: Interventive interviewing questions (from [6])

Reframing is the technique of re-telling a loss-focused story as a gain-focused story. Coordinated change requires joint effort towards a common goal: loss-focused stories can trigger defensiveness that impedes collaboration.

Fast feedback is the use of leading indicators, early data and case studies to identify *what is working* and *what is not working*. Collaborative working processes (e.g. Agile) all rely on small scale trials and fast feedback. In the multi-organisational context, feedback must be systematic: at small levels, e.g. weekly within a working group, as well as high levels, e.g. monthly summary to all organisations.

5.1 A new story about CSRs that gives all stakeholders a collaborative way forward

The CSR has evolved over a number of years. Asset renewals funding is the main factor driving the incremental increases in this asset. The three key standards, written from the operators' view, have indeed become more onerous in the last 5 years, but this was a response to engineer out network vulnerabilities introduced from a gap in contracts going back 10 years or more which did not fund renewals of non-safety-critical items such as cable routes.

The pit and pipe CSR has become preferred because it gives the longest maintenance-free lifetime: this logic can also explain the high number of empty conduits specified:

There is wide acknowledgement that the pit and pipe by default CSR is causing problems. The fast-moving project delivery organisations which are now doing some of the cable route renewals need a cheaper option, and one which doesn't also potentially impact construction, corridor drainage, overhead electrification structures, cuttings, bridge ramps for elevated rail, land use and public amenity.

A re-write of the Standards is a complex task and will take some time. In the meantime, each stakeholder is working on their own priority issues.

Projects are working on:

- Temporary CSRs – we have feedback that this is already making a positive impact to projects
- Spares provision & pit separation for future projects
- Options for difficult sites (including elevated rail, cuttings, tight corridors and identified risk areas)
- Quantifying the cost and time impact on projects

Signalling asset management is working on:

- Faster turnaround on reviews & waivers (clear yes/no)
- Spares requirements for future projects into the specs
- Sharing best practice across organisations

Power asset management is working on:

- Network power reliability and line-specific upgrades
- High Voltage cable routes: cable separation, depth, alternative options for difficult sites

Communications asset management is working on:

- Trials of modern troughing products
- Phasing out copper in favour of fibre optic
- Temporary off-corridor comms links, e.g. diverse routes, microwave or radio links.

We now understand much better how a small change to specification can have a big impact on delivery, and a small change to delivered asset can have a big impact on the lifetime. The collaborative approach needs to be maintained, and we must commit to regular cross-organisation communication. .

6 CONCLUSION

This paper has covered a set of interrogation techniques to address a problematic requirements space or specification.

A problematic requirements space can be identified by looking for contradictions, a difference between the formal specification and actual practice, a difference between local practice and 'normal' practice elsewhere, or habits which do not change through conventional continuous improvement processes.

The problematic requirements space can be mapped through Appreciative Enquiry, which takes the view that individuals and organisations are mostly trying to do their best within their definition of 'what good looks like'. Structured interviews and collaborative workshops can be used to understand the different perspectives, objectives, incentives and constraints, share this understanding, and start to work towards a common picture of what 'good' will look like in the future.

Asking good questions is an important skill in requirements capture. The interviewer should prepare, and structure both the interview and the questions in a way that evokes information sharing. Attentive listening, and the act of taking written notes, can in themselves be an intervention and a way of de-escalating conflict or strong emotion. When an assertion is made which impacts the future requirements, the available data sets should be analysed to determine whether it is a fact or an unsupported opinion.

Top down decision making, which is the key mechanism for endorsing or scaling single-organisation change, tends to struggle to understand a problematic requirements space, and is not well suited to deliver coordinated, multi-organisational change that endures through time.

Multi-organisation change can be triggered by appreciative enquiry techniques such as Interventive Interviewing: a structure for asking questions which strategically re-shapes thinking about the system. The objective is to work through contradictions and collectively get a picture of the way forward – this then unlocks the ability to undertake straightforward requirements capture once again.

Reframing, or re-telling a story around the common potential for gain, is useful to keep participants collaborating across organisations and alongside their day-jobs. Fast feedback, and circulation of leading data indicators keeps all participants up to date with progress made and can fine-tune activity towards what is working and away from what is not working.

Taken as a comprehensive method, this structure allows repeatable and sustainable change in complex multi-organisation multi-discipline requirements space. For each step, an example is provided of the Combined Services Routes (CSR) apparent overbuild on construction projects in Melbourne.

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