TRANSFERING THE RETAIL OF HYDROGEN ECONOMY AND MISSING SAFETY ASSURANCE

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Abstract

Australian regional communities are moving ahead of governments. Enterprising individuals are pushing ahead to find global solutions to local issues that governments (local or state or federal) have abandoned, stalled, mothballed or failed to resolve. We are faced with a flaw in retail of hydrogen economy as fatal as Walgett running dry or a million fish killed in Murray-Darling. The challenge in Australian regional communities will be to interpret safety assurance requirements in an appropriate manner even in severe economic swings such as drought, bushfire, or floods. In this context, the efficacious cultural embrace by regional communities of three key program elements is essential - Australian Hydrogen Safety Panel, Hydrogen Safety Knowledge Tools and Dissemination, Hydrogen Safety First Responder Training. What are the odds of no accident in retailing hydrogen for examples, to vehicles? Place is everything in regional communities of Australia because in nature (as in the ocean) there is no spin. This paper examines the safety assurance issues associated with the cultural integration of Hydrogen's three key program elements in a country Australia that is fed-up with government.

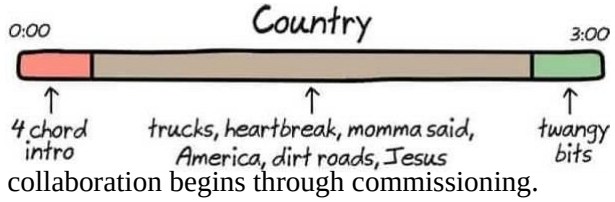
1.0 INTRODUCTION

1.1 Change: evolution or revolution

First of all, selection of best project delivery system for hydrogen retail infrastructure can reduce project's cost and time up to twelve and thirty percent respectively according to literature [13]. Commissioning, operation, and maintenance is commenced after an intentional stage of completing hydrogen retail infrastructure that is reasonably fit for purposes of hydrogen retail as specified by parties to the project delivery system. The main contribution of this paper is safety assurance for commissioning, operation, and maintenance notwithstanding minor defects not likely to affect usability of hydrogen retail infrastructure or, errors or omissions in project specification of hydrogen retail infrastructure. Code of Hammurabi provides for hydrogen retail infrastructure.

> *"If a builder has built a house for a man and his work is not strong and the house falls and kills the man, then that builder shall be slain."* - Code of Hammurabi, 2150 BC

Why is it that confidence in project delivery systems rarely fails? Why is it that, though tendering of project delivery seemingly occurs at random, clients know that project delivery systems assure that their hydrogen retail infrastructure will be delivered safely? Dominating economic paradigm underpins project delivery systems according to literature [13] and constantly infuses what funding is considered suitable, turning them to any economic purpose. The narrative of country (and its small towns) is done a disservice by lumping it all up into a single perspective e.g. its music. To be respectful is collaboration about understanding different places and what their challenges are, and being able to respond to those challenges. It is important to acknowledge evolution from project delivery to collaboration begins through commissioning.



1.2 Reverse Engineering or Engineer-in-Reverse

Scientific research is about a natural phenomenon; deconstructed to reveal its designs, architecture, or to extract knowledge. For example, "Push plays an obvious part in deep ocean circulation: if a deep, dense water reservoir grows in volume, its spread into all deep ocean basins will accelerate. But how does the water get from the surface to the depths? We began to see intriguing new direct measurements of vertical flows, capable of mixing fluid 'parcels' down to depths of 1 to 2 kilometres within a few hours, along with the first high-resolution computer models (basically upside-down cloud convection models) that could simulate this process in vivid detail." [14] To tell scientific research apart from reverse engineering; the latter is about man-made object.

> "*Fire is the test of gold; adversity of strong men.*" - Marcus Annaeus Seneca, 54BC-39AD

It makes sense to give people a boost by pushing them into university to increase social mobility and expand opportunities. But it pays to remember that not everyone wants to be a doctor, and we must not forget the kids who aren't interested in getting on the superhighway to university. And the difference between city's tradies versus farm hands is not merely an immigration visa. However all these are examples of "*Begin with the End in Mind (which) means to begin each day, task, or project with a clear vision of your desired direction and destination*." [18], that is to Engineer Forwards to a chosen End. Test result is passed or failed so "Engineer in Reverse" means Begin with not desired destination (Fail) then block access to pathways backwards from Fail to origin.

1.3 Contribution

The main contribution of this paper is to present the Engineer-in-Reverse methodology in a general purpose way to three key program elements - Australian Hydrogen Safety Panel, Hydrogen Safety Knowledge Tools and Dissemination, Hydrogen Safety First Responder Training. We discuss origin being commissioning, the fail categories of human error, the yardstick of operator's trust, and the hierarchy of error control. Although we demonstrate the methodology with Hydrogen, the methodology is applicable to any gas retail infrastructure in country NSW.

2.0 HUMAN ERROR IDENTIFICATION

Sextus Roscius was accused of patricide (killing your father). This was the worst crime to commit in Rome and was punishable by death. Cicero suggested that Roscius neither wanted to nor had the opportunity to kill his father that Roscius did not have the depraved and vicious nature required to carry out such an act, that Roscius did not have the means to nor could get anyone else to kill his father. Cicero also used Erucius who could prove that Roscius was on good terms with his father who had never intended to disinherit him. Cicero then went on to pose the question 'cui bono?' or "who benefits?" This was Cicero altering the structure of the trial from Defence to Attack. Cicero then argued that country people were less likely to commit murder than city people.

> "*everything we hear is an opinion, not a fact. Everything we see is a perspective, not the truth."* - Marcus Aurelius, 121-180 AD

Right there is an agrarian ideology – a theme throughout human history – that the country is good and true (viz. Abraham), and the city is wicked and sinful (cf. Lot). In Australia, this country-city debate has been a running theme in national discussion since settlers crossed Great Dividing Range.

Senge [2] states that Systems Thinking is a discipline for seeing wholes. It is a framework for seeing relationships rather than things, for seeing patterns of change rather than snapshots. For example; understanding the life cycles of animals, seeing the patterns of seasons, identifying the hard edges of social strata in small communities, and much more is country-city educational divide yet we live alongside each other in country towns, we go to same post-office, we rub shoulders in so many other ways avoided in city social strata. The bottom-up design process is preferred for human error identification in country NSW towns, due to process synthesizing a new object out of a set of construction elements, such that this new object will provide the required service.

Every profession is based on a Body of Knowledge, and from our brief survey of a 30 year history of human error identification (Figure 1) after 1970, we understand how the human error identification Body of Knowledge developed. A representation of engineering out human error identification consists of two groups of activities (Experimentation + science, Design) and two

types of artefacts (Construction elements, Solutions). Therefore a solution emerging from the HyResponse project "*Mixed e-learning and virtual reality pedagogical approach for innovative hydrogen safety training of first responders*" [3] has crucial construction elements (e.g. virtual reality exercises). It is easy to overlook importance of standardisation and standardised construction elements and the role this has played, and is playing, in handling complexity within engineering out human error identification. For example, consider SHERPA in Figure 1 and as applied below.

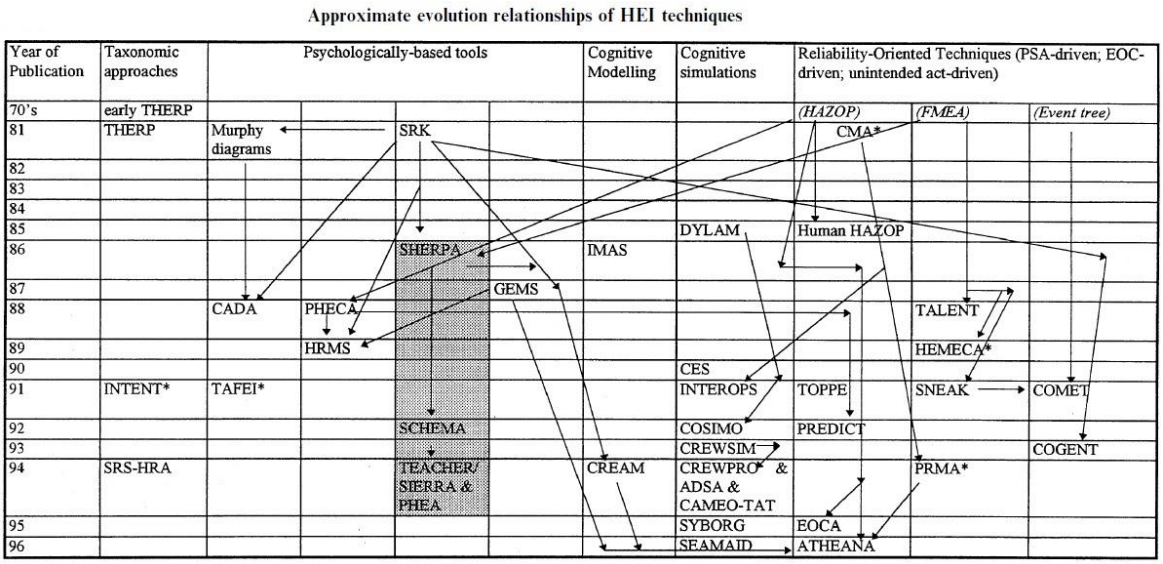


Figure 1. Human error identification techniques for risk assessment of high risk systems

If coastal or island ports prize interaction between human and machines like vessels at anchorages so much that, to prove their value, the International Journal on Marine Navigation and Safety of Sea Transportation of March 2018 has "Human Error in Pilotage Operations" article, is it any wonder that outback refuelling sites should want risk assessment in the same way of hydrogen-filled road tankers, given that country towns prize their refuelling sites much more highly? The maritime study deployed a systematic human error reduction and prediction approach (SHERPA) to shed light on error types and error remedies apparent in pilotage operations [6]. However if hydrogen-filled road tankers aren't needed (i.e. human error identification engineered out) by hydrogen manufactured on-site in country towns, how much more so on say Lord Howe Island?

3.0 RURAL TOWNSHIP ECOSYSTEM – BACK TO THE FUTURE

Grid electricity systems have evolved from un-complex systems and loosely coupled transmission grids, up to the state of the art present-day as highly complex and tightly coupled infrastructures, greatly based on automation systems with various levels of reliability. Regional New South Wales' electricity ecosystem is lagging international norms and accelerating in terms of renewable energy penetration. The management of the Regional New South Wales' electricity infrastructure has become dependent on its information system infrastructure as automation continues to replace manual operations, and as market forces demand more accurate and suitable information as the power system equipment become older. Adapting Regional New South Wales' electricity grid [7] with Community Resilience Microgrids based on per community solar PV, residential solar PV and stored energy systems requires more complex monitoring and control of the electricity network. [5]

The concept of Township Hydrogen Platform is not akin to real "Digital Transformation" since a brownfield collective is the legacy infrastructure of dominant sunk-costs. Township Hydrogen Platform is akin to Heart Transplantation: the "gold standard" therapy of city-grade reliability & quality of supply, lower fair consumer price e.g. 10-15%, and emergency response backup power (e.g. 24 hours). Essence of Heart Transplantation approach is that hydrogen is manufactured on-site in country NSW towns where hydrogen fuelling occurs. By doing so, dealing with safety of hydrogen-filled road tankers is eliminated. Land is non-issue around country NSW towns, for Microgrid-scale hydrogen production. Road transport may bring water, or municipal waste, or forest trash, or industrial waste as inputs to produce hydrogen or natural gas for hydrogen co-firing

in gas turbines [15] but handling those materials is already enshrined in regulations and legislation.

Selection and delivery of Township Hydrogen Platform (c.f. Donor Heart) including hydrogen retail infrastructure is again by best project delivery system according to literature [1]. Installation onto a site (c.f. Heart Transplantation Surgery) concludes with energisation onto grid electricity systems and hydrogen retail commissioning which is also origin for Engineer-in-Reverse methodology that is main contribution of this paper.

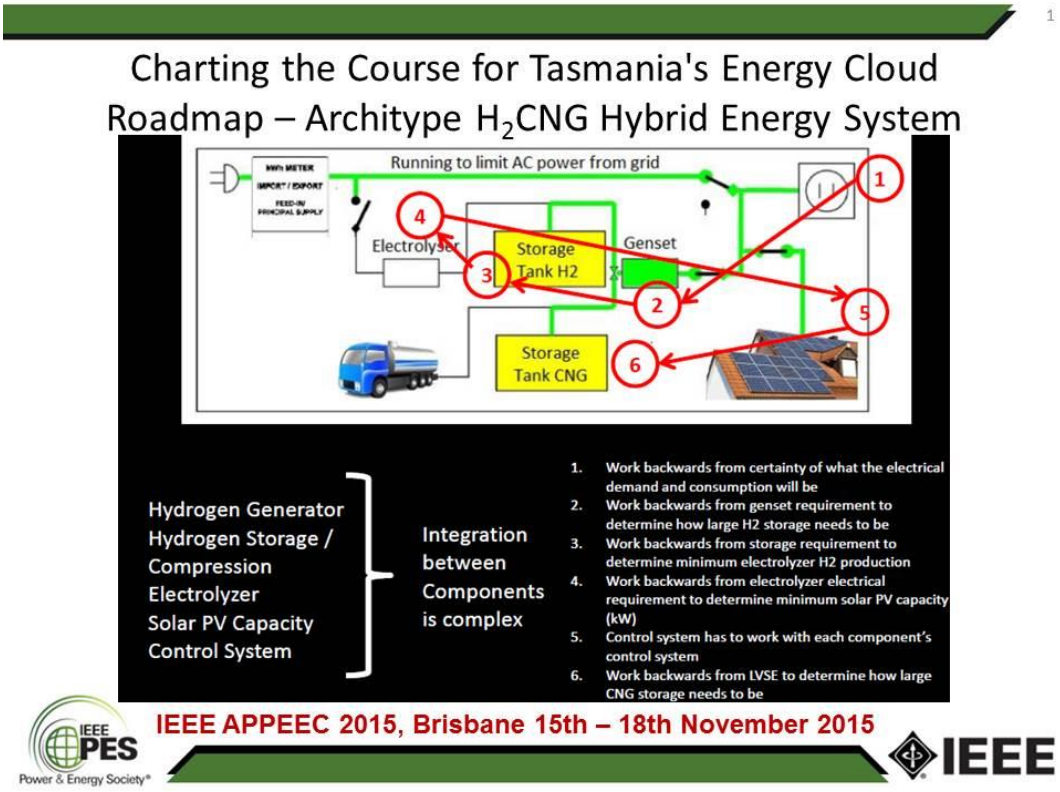


Figure 2. Architype hybrid energy system – hydrogen co-firing with natural gas

Glenk [4] analysed the economic prospects for renewable hydrogen through the lens of a potential corporate investor. The investor is presumed to choose the size of the renewable power source efficiently in relation to Power-to-gas facility, while taking advantage of real-time fluctuations in electricity prices and intermittent renewable power generation. It would be insightful to consider hybrid energy systems such that Power-to-gas facility can also source energy from external energy market e.g. natural gas. While the hydrogen produced would then no longer be 'renewable' due to the carbon emissions associated with external energy, such systems would achieve higher capacity utilization and thereby potentially result in substantially lower break-even prices for hydrogen Also since hydrogen is a form of electricity storage, hybrid energy systems may effectively compete with dispatchable power plants and other storage systems such as batteries in country NSW towns.

4.0 ON MAGICAL NUMBERS AND RUBIK'S CUBE

Government regulation in the form of red tape, form-filling and box-ticking sends blood pressure skyrocketing. And politicians of all levels pander to it. It all starts with a good idea – safety – but it ends with a government application process that begins three month in advance with twenty-eight days for a department to consider the application and if the date changes, the permit doesn't apply. Miller [2] concluded the span of absolute judgment and the span of immediate memory impose severe limitations on the amount of information that we are able to receive, process, and remember. By organizing the stimulus input simultaneously into several dimensions and successively into a sequence of *chunks*, we manage to break (or at least stretch) this informational bottleneck. But regulations resist *chunking* by depending on perfect behaviour of human beings beyond linguistic origins of regulations and so such government spending drives rural people to distraction.

Table 1. Nuberg's error spectrum [17]

Work free of mistake and error
Minor errors, mistakes and slight blemishes
Errors causing delay, seconds rework, rejects, waste
Damage to Property, Material Loss, Process Delay
Errors causing injury
Acts of negligence and deliberate destruction, Theft, Arson, Pollution

Safety posture for hydrogen in country NSW towns leans on a pharmaceutical manufacturing view, systems are inherently unsafe and people usually keep them running well. Miller's [2] the magical number minus one is suitable for Talsico human error reduction methodology utilized by many pharmaceutical companies categorize human error and develop effective strategies for prevention. Natural language (a.k.a. used in Table 1) is required for public Rubik's Cube (see Figure 3) to transfer the retail of hydrogen economy to operators in country NSW towns whereas the linguistic converse (that is the knowledge of the craftsman producing Contributing Factors Framework - CFF) is placed in a private structure such as this article (e.g. for review and maintenance of CFF).

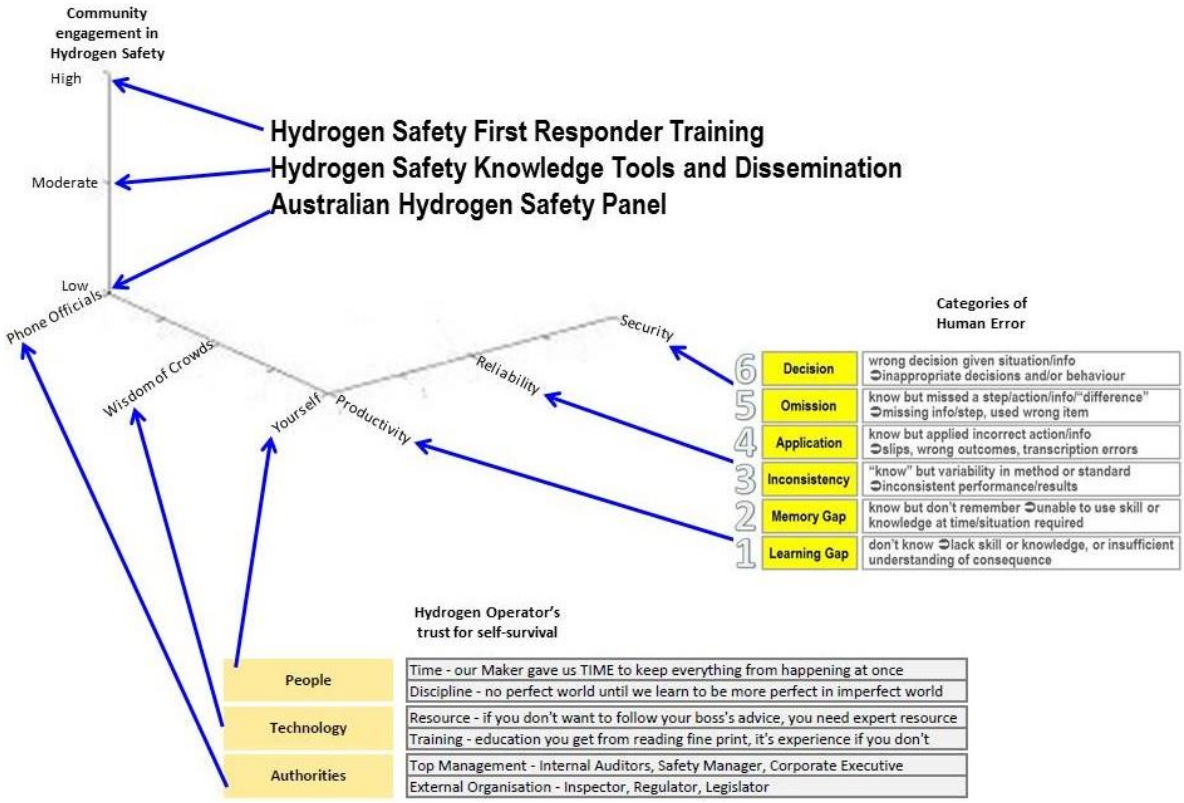


Figure 3. Properties of Rubik's Cube for Hydrogen in Country Towns

If you're stumped, who are you going to call? On 'Who Wants to be a Millionaire' popular wisdom is always ask the audience but for a hydrogen operator, Benjamin Franklin's grandfather's observation is worth adhering to here: *Let routine things be done in routine ways and let non-routine things be done in non-routine ways. Heaven help the one who insists on doing routine things in non-routine ways, for he will soon run out of the discretionary time necessary to give non-routine things the non-routine treatment they deserve*.

'If you want it done right, you've got to do it yourself.' – a management ethos from washing dishes to running an electric car corporation. I have now shifted from a hydrogen operator to manager or managing hierarchy. People, technology, and authorities (per Figure 3) are factors within bailiwick of manager controlling or under management control. Thus a hydrogen operator is subject to management modifying the factors in Figure 3 - people, or technology, or authorities - (or require

for this to occur automatically) upon the occurrence of a specified event. That happens to be among the most difficult of paradoxes, it can be taken that management is liable for the actions of its hydrogen operators provided hydrogen operators' actions are within course and scope of duties.

6.0 ERROR CONTROL IS POSSIBLE IN COUNTRY NSW TOWNS BUT ITS WORK

Plant and work are obviously tightly coupled, but they are of very different natures. The relationship is somewhat analogous to that of a glove and a hand; the size and shape of the glove is determined completely by the hand, but they are otherwise very different [16]. It is the authors' opinion that fitness trackers and other wearables (IoT) extract potential evidence about work that will be admissible in a court of law. Consider figure 4 used for a player's salary dispute.

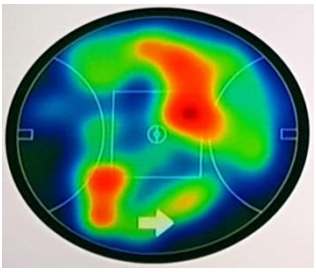


Figure 4. First Quarter Positional Heatmap of AFL player – Opening round of 2019 season

Facts about hydrogen operators can easily be detected with IoT-based sensors, and other useful information around these devices which can easily be extracted and preserved digitally. This will create new opportunities to hydrogen safety community by assisting Top Management or External Organisation (per Figure 3) to come up with new tools for IoT investigation so that hydrogen operators pattern or activity can be tracked. This is only a snapshot of current state of the art of IoT.

Concerning safety and profit; foremost principle, maturity of a hydrogen operator for country Australia is measured by ability to do the task without supervision and finish the task as well as its error control (see Figure 5) once the task has started. Then hydrogen operators contributing most of their personal productivity have the ability to get the plant working for them rather than visa-versa. Also the zone of work is specific domain within which error control is applied to plant and others.

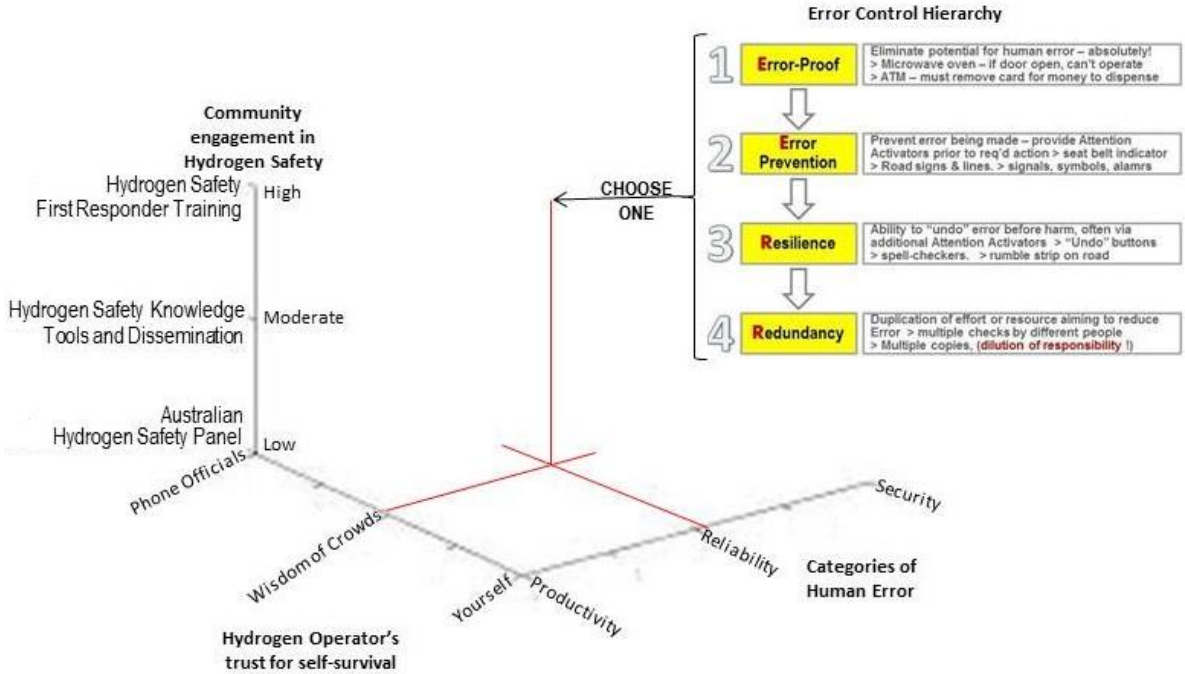


Figure 5. Interaction of Hydrogen Operator with Error Control

7.0 SAFETY ASSURANCE SYSTEM FOR HYDROGEN PLANT

The role of managing and locally coordinating safety sensor data for improving function decision support systems should fall to a device that we designate the Safety Data Aggregator (SDA). This device collects and aggregates data related to several towns in the same region to minimise OPEX costs for communications. Collectively SDA's provide a point of interface to the independent Systems Assurance Operator (iSAO) to facilitate the forensic investigation framework for the Plant (rather than the Work). Australian Hydrogen Safety Panel could be owner of iSAO and SDA whereas analytics based on safety sensor data is envisaged to provide knowledge for dissemination.

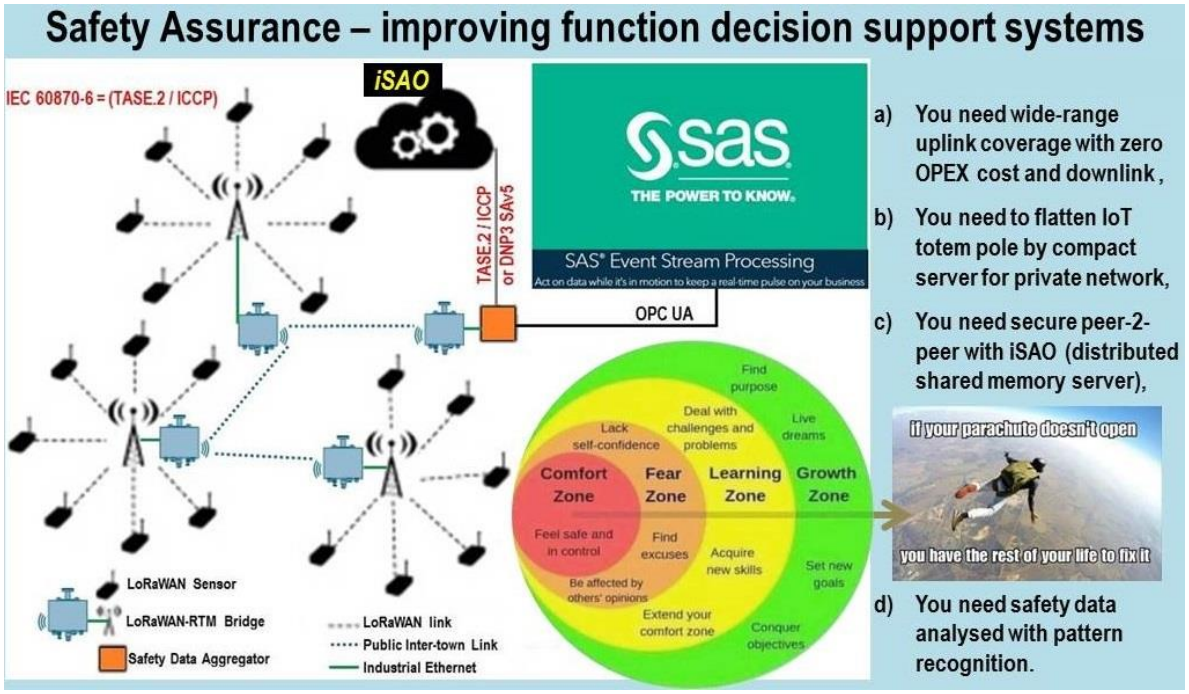


Figure 6. Architecture of Safety Assurance System for Hydrogen Plant

The Safety Data Aggregator (SDA) monitors timing-driven and unstructured safety sensor data and deploys a standard approach for translation to highly structured data suitable in rules-driven enterprise environments. The term "translation" is used to differentiate between translation software and the machine (virtual or physical) of the SDA and other functions the machine may be performing. Mixed-criticality workloads on a single physical machine can compromise the potential digital evidence transportation process unless its entire workload is safety-critical system. Cost-benefit analysis (CBA) can be used to determine the value of a project, program or policy. Table 2 shows the unit price estimate of each construction element for safety assurance system.

Table 2. Estimated Device Prices for Safety Assurance System.

Potential Digital Evidence [10]	Figure 6 acronym	Unit Price ($US)
Collection Identification Process	LoRaWAN Sensor	100-200 (CAPEX)
Township coverage	LoRaWAN link	0 (TOTEX)
Acquisition Process	LoRaWAN-RTM Bridge	1,000-2,000 (CAPEX)
3G/4G/5G subscription fee	Public Inter-town Link	Tender
Transportation Process	Safety Data Aggregator	10,000-20,000 (CAPEX)
Segregated traffic on grid backhaul	TASE.2 or DNP3 SAv5	Connection Agreement
Storage Process	iSAO	Tender
Broadband link connection fee	OPC-UA	Tender
Analysis and Interpretation	SAS	Tender

LoRa has long distance, low power, free license and much lower cost than its IoT alternatives. Cost-benefit analysis (CBA) principles and practices are well established - as evidenced by the abundant literature available from academics, CBA practitioners, and government agencies. CBA is a quantitative analysis tool to assist decision makers in efficient allocation of resources. It identifies and tries to measure the costs and benefits of Safety Assurance System for Hydrogen Plant. The strength of CBA method is to provide a framework for logical and consistent cost analysis [10].

8.0 ADDRESSING DEEP COMMUNITY-FOCUSED TRANSFORMATION

Heberlein [11] suggested that society has three fixes to reduce the probability of loss: technological, structural and cognitive. Consider emergence of wind and solar power:

- Cognitive fixes modify human behaviour by targeting the attitudes, beliefs, and values that affect those behaviours and cognitive glitches too.
- Structural fixes, such as renewable energy target regulations, try to modify human action by regulation of our social setting or "structures" in which these actions occur.
- Germany leads in technological fixes that try to bypass human element by modifying surroundings instead of people or social structures.

Virtual reality is being used in a unique project to check the driving skills of senior Australians (70-80 years) and improve road safety (courtesy of investment by the Australian Government) – Joint Media Release by Ken Wyatt AM, MP and Barnaby Joyce, MP. Roll-out of virtual reality was given a name "Hector" and prototype simulator developed by Deakin University was delivered to Inverell, NSW in December 2018 (publicised in Inverell Times). What's significant is how (Namoi Valley Independent (Gunnedah, NSW) publicised in March 2019. Inverell attitude and tone was about country "giving anything a go once" whereas after three months (including Christmas-New Year), Gunnedah attitude was "encouraging older drivers looking to polish their skills behind the wheel" – even though Hector was simulating Inverell streets. The author has driven both towns and their challenges are substantially similar with some sharp differences (e.g. rail level crossings).

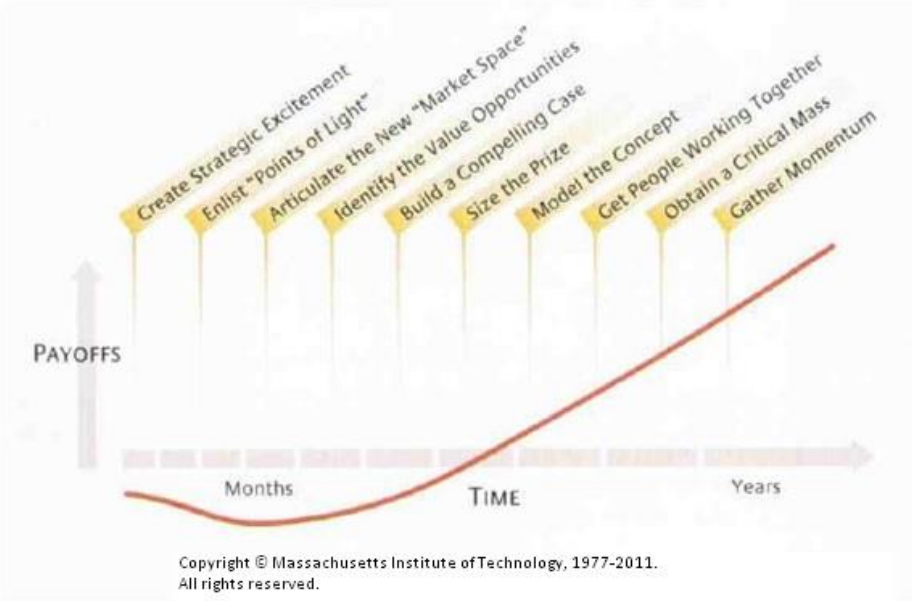


Figure 7. Addressing Deep Community-Focused Transformation

Country Australia has a strange interplay between three elements: the economic challenges in some areas, higher rates of self-reported well-being, and the lower levels of support for migration and cultural diversity. Social cohesion in country Australia relates to a shared vision and is an ongoing process rather than a destination. Place is everything in country Australia so factor in uniqueness.

Irrespective if it's logical or anecdotal, empirical evidence (although tiny publicity sample set then extrapolated in line with NSW election 2019 results) is that Hector will fail in country Australia if Hector's a one-town driving skills simulator. Logical evidence suggests every-town driving skills

simulator will fail in country Australia but for a different reason to hysterical overreaction; every-town won't check the driving skills of senior Australians. Three use cases should be explicitly considered in developing driving skills simulator for country NSW:

- Beginner: Bingara, Boggabri, Young, Wellington, Guyra, Glen Innes, Cookwell, Finley
- Intermediate: Gunnedah, Moree, Narribri, Tenterfield, Parks, Forbes, Cowra, Molong
- Highway: Dubbo, Bathurst, Armidale, Tamworth, Orange, Yass, Broken Hill, Wagga

The use cases in Safety Assurance (as well as suggest for driving skills simulator) are described in the context of Distribution Annual Planning Report for its electricity, which has a very common way of inputting to individual load forecasts for country NSW towns. Hence each name for three use cases can be selected to maximise community acceptance (e.g. publicity purposes) rather than internal development needs of virtual reality. Again, place is everything in country Australia so a hydrogen operator (or senior Australian) will need to select from profile of towns for Beginner, and Intermediate, and Highway. These ideas need to be exposed to analysis by towns for inclusiveness.

9.0 CONCLUSION

How mature is change within your community....

1. Initial - ad hoc process, chaotic, poor or non-existent resources
2. Repeatable - basic/ tactical management, using previous efforts as a template
3. Defined - some planning, some process but not an inbuilt KPI or aligned to core business
4. Planned - budding strategy, quality assurance & consistent management
5. Optimal - change integrated with biz strategy, continuous process improvement

Irrespective of your community's maturity, the solution framework discussed in this paper is focused on a specific combination of proven construction elements synthesized using a bottom-up design process into a comprehensive systems solution for transferring the retail of hydrogen economy to country NSW towns, without missing safety assurance. The second law of thermodynamics states that the entropy of any isolated system always increases and each country NSW town is best thought of as an isolated system with external stimuli tending to either decrease or increase entropy of a town's social cohesion.

Missing safety assurance is as easy as failing to entirely address deep community-focused transformation, or relying on a paper-based process for safety assurance system of hydrogen plant or hydrogen operator, or deploying Government regulation in the form of red tape, form-filling, and box-ticking. Prof. Miroslav M. Begovic observed at 2012 EEA Auckland New Zealand –

> "*Interactions are too complex to fully understand, model and account for*
> *Changes in patterns of use of resources are needed before they become irreversible*
> *Complexity of interactions and natural laws are forcing changes to be evolutionary...*
> *...but that attitude is revolutionary*!" [12].

Not only can we be blinded to things because of their ubiquity or obviousness, we can also be blind to critical information because of how powerfully our attention can focus in other directions. Social cohesion in country Australia relates to a shared vision and place is everything in country Australia. To avoid missing safety assurance in country NSW towns, the pragmatic theme this evolutionary change needs is "Do the doable"; focus on a specific combination of proven construction elements then synthesizing into a comprehensive systems solution using a bottom-up design process.

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