

# A tool application model for Root Cause Analysis

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## Abstract

*Purpose.* The purpose of this paper is to present the results of a research study investigating the use of root cause analysis (RCA) in embedding and sustaining a culture of continuous improvement and the development of an approach model (Tool Application Model TAM).

*Methodology.* Using a case study approach the use of RCA tools and how they are perceived by the participants in problem solving in small groups were investigated with the aim of finding a more robust problem solving approach for reducing or eliminating recurring errors in a complex manufacturing environment. The RCA tools used as part of the investigation were Ishikawa's cause-and-effect (CED) method along with 5 Why's analysis.

*Findings.* The initial findings show that to embed a culture of continuous improvement within the scope of problem solving methods a structured approach which encourages participation, engages stakeholders, enables group decision making, promotes learning, and empowers individuals to bring about cultural change must be used.

*Practical implications.* The proposed Tool Application Model (TAM) to explore the 'human element' of root cause analysis can be used in conjunction with other quality tools and techniques to provide a structured approach in problem solving.

*Originality/value.* This paper is of value in that it proposes a Tool Application Model to assist those undertaking root cause analysis as part of a continuous improvement programme.

## Keywords

Root Cause Analysis (RCA); Continuous Improvement; Culture Change; problem solving; Cause and Effect Diagram (CED)

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\* This paper presents the research findings carried out by Iain Muir as part of his MSc in Quality Management.

## 1. Introduction

The subject of root cause analysis (RCA) is a challenge for those wishing to undertake any problem solving activity due to the heterogeneity of each problem situation. This is heightened when those wishing to enter into the RCA process are inexperienced and need training in a structured approach. The overarching role of RCA is to allow teams to identify the root cause of the problem situation and to generate solutions that will prevent recurrence.

Despite many studies exploring the implementation of root cause analysis, few studies look to how they are perceived by the participants, the impact of following a structured approach, and how it influences organisational culture. This paper presents the result of a research study into the impact of RCA on the culture with the aim of developing a tool to support the training of new and inexperienced staff in RCA. This paper also highlights the benefit of not only conducting the actual problem solving scenario, but also provides an assessment of the group outputs, group interaction, group behaviours, and the participants perception of RCA. The usefulness of the Tool Application Model (TAM) is the assessment of the tool itself and its inter-changeability with other tools and techniques.

This paper also presents an argument that incomplete or poorly executed root-cause-analysis affects the ability to accurately provide corrective and / or preventative measures that reduce or eliminate re-occurrence of quality escapes. The study explored how the RCA investigations are perceived by the participants within the organisation and how a structured approach impacts the solutions generated. The overarching research questions informed the individual case studies as the participants sought to conduct RCA investigations and generate solutions. Root Cause Analysis (RCA) will generally be defined as a method of problem solving used for identifying the root causes of faults or problems.

## 2. Research Design & Literature

The research followed a constructivist paradigm using a multiple case study approach (Yin, 2013) and sought to use qualitative methods (Creswell, 2013) to develop and analyse the research findings. In line with the research purpose statement the participants heuristically explored the application of Ishikawa's cause-and-effect diagram (Ishikawa, 1986) and 5 Why's analysis (Ohno, 1988) within Root Cause Analysis. The data collection and analysis was undertaken using a qualitative assessment through direct observation of groups, focus groups and interviews. The individual case studies explored the how and whys of the problem situation and informed the overarching research questions.

The Cause-and-Effect Diagram (CED) commonly known as the Fishbone or Ishikawa diagram was developed by Kaoru Ishikawa (Ishikawa, 1986). CED has been developed and incorporated into many other RCA methodologies and fields. Using a taxonomy of classes to group the identified causes of the effect seen. i.e. Equipment (machines), Process (methods), People, Materials, Environment, Management.

Three types of cause-and-effect diagrams can also be used (Ishikawa, 1986, p 21):

1. Dispersion analysis type
2. Production process classification type
3. Cause enumeration type

For the purpose of this research, the production process classification type was used within the case studies to identify the causes that affect quality during the production process. These causes can come from variance in materials, equipment, method undertaken, measurement, but also from deviation from the planned route, management, external influences, mistaken interventions, etc.. As such, the taxonomy of classes is based around those commonly seen in

a manufacturing setting. Once a non-conformance has been highlighted to the Inspection Department the following steps were implemented to conduct RCA:

1. A cross functional team was gathered who had either particular skills or exposure to the process. First of all a problem statement was agreed upon and placed in the effect box, allowing the investigation to focus on the particular problem. The team then sought to brainstorm the possible causes and to arrange them taxonomically. Once the branches were populated with causes and sub-clauses the group then looked to identify which were likely, very likely or not applicable (n/a) for the given situation.
2. Once the most likely causes relating to the stated problem have been identified the team conducted 5 Why's analysis (Ohno, 1988) to funnel down to the root-cause. Five Why's analysis (Ohno, 1988) originally came from the questioning intellect and the habit of watching. The concept was developed within the Toyota Production System along with other methods such as *kanban* and just-in-time, which form the base of 'lean' methods (Womack et al., 2007), (Ohno, 2012).
3. The 5 Why's may go through further iterations where more than one likely cause were identified during the brainstorming phase. Once the root cause(s) has been identified the group then sought to develop corrective measures that would fix the immediate concern, and preventative measures that would seek to mitigate or eliminate re-occurrence of the effect.
4. A review of the corrective and preventative measures was undertaken to ascertain whether the solutions were appropriate and effective.

Not only can the CED method be used for any problem, but can be used as an effective continuous improvement tool i.e. to brainstorm causes that will bring about a proposed future state. This flexibility in the method is arguably one of reasons that it has been incorporated into a vast array of industries and methodologies.

The CED and the 5 Why's method is not without critics, (Finlow-Bates, 1998) introduces the root cause myth, where the tools are seen as weak and confusing, that it is difficult to separate assumptions from genuine issues, and that seeking an absolute root is to be avoided. Other shortcomings can be in regards to understanding why the causes occurred, lacking a systems perspective, tackling complex system-wide problems, taking a holistic view (Yuniarto, 2012). Yet others criticise the method when it not applied in conjunction with critical thinking (Ayad, 2010), limiting the query to the why aspect, leaves other avenues of questioning unexplored.

The selection of case study research approach was to explore the how and why of the problem situation and to explore the problem situation in its real world setting (Yin, 2013, Dasgupta, 2015). An in-depth study of each case allows us to provide a narrative of the event (Neale et al., 2006), Wood et al., (1994), as cited in (Labib, 2014):

*"We most fully integrate that which is told as a tale."*

According to Flyvberg (2006 p 237), case studies provide an element of narrative:

*"Good narratives typically approach the complexities and contradictions of real life."*

Care was taken on the part of the researchers to ensure that narrative fallacy (Labib, 2014) and bias were not introduced to the body of the research. Dooley (2002) notes; that the researcher is normally interested in completely understanding to phenomena, by observing all facets and relationships within the data.

The individual cases for root cause analysis were selected from the production manufacturing area of the plant as most of the problem situations arise from the machining of complex and highly technical specifications. The cases were strategically selected (Flyvbjerg, 2006) by those which commonly occur or most likely occur rather than 'special' cases, as these can offer a greater impact in taking the 'lessons learned' (Neale et al., 2006), from each situation.

The constructivist paradigm was chosen as the participants will be enabled to build knowledge and learning from the interaction with their experience and their ideas, patterns of behaviour. Creswell (2013) notes:

*"The goal of the research is to rely as much as possible on the participants' views of the situation being studied."*(p 8).

Greenwood & Levin (2007) comment that the constructivist approach brings the views of the problem owners to the fore, as they are the key to understanding and making sense of the situation being evaluated (p 188). The interpretivism / constructivism approach assumes that there are multiple realities, that knowledge is subjective, and experienced differently by different people (Dasgupta, 2015), this being compatible with our RCA methods.

The qualitative method (Creswell, 2013) was used within the research as this supported the research structure, in terms of the data being collected within the participants' setting , inductively building to form themes, which then allows meaning to be derived (p 4). The approach allows consolidation of the subjective outputs of the RCA sessions, focus groups, observations, and interaction seen within the groups. qualitative method supports the constructivist philosophy and narrative form of case study research. Ellis (2003) as cited in (Anaf et al., 2007) notes:

*"Thus, the application of case strategies within a qualitative framework facilitates a flexible mode of inquiry."*

The chosen paradigm and methods were based on the congruence between exploring and conducting RCA, to supporting the data collection, drawing the findings from multiple cases while answering the overall research questions. The case study approach, constructivist outlook, qualitative methods i.e. focus groups, observations, interactions, interviews, etc., along with the application of CED and 5 why's seemed to bring the best fit for the research.

The root cause investigations were conducted by the research participants, with the researcher observing the small groups of between 4 - 7 individuals. Feedback from the researcher highlighted any salient points in order to generate solutions for the problem situation, and in developing the problem solving skills of the participants. The researcher conducted focus groups and interviews (Interview protocol - *Appendix*) with cross-functional departments to gain a holistic view of the research

The researcher, in contrast to the research itself, takes a rather pragmatic worldview in seeing the strength of various methods and traditions, and is happy to draw on these to address the matter at hand (Easterby-Smith et al., 2002, Greenwood and Levin, 2007, Creswell, 2013). The focus of taking a holistic view of the business, being a facilitator and guide (Avouris et al., 2003, Doggett, 2004b, Healy, 2013); rather than being prescriptive in numerous tools and techniques is a deeply held core value as a quality professional. This is echoed by Sun Tzu (1988) as cited in (Bamford and Greatbanks, 2005):

*"A warrior should never have a favourite weapon."*

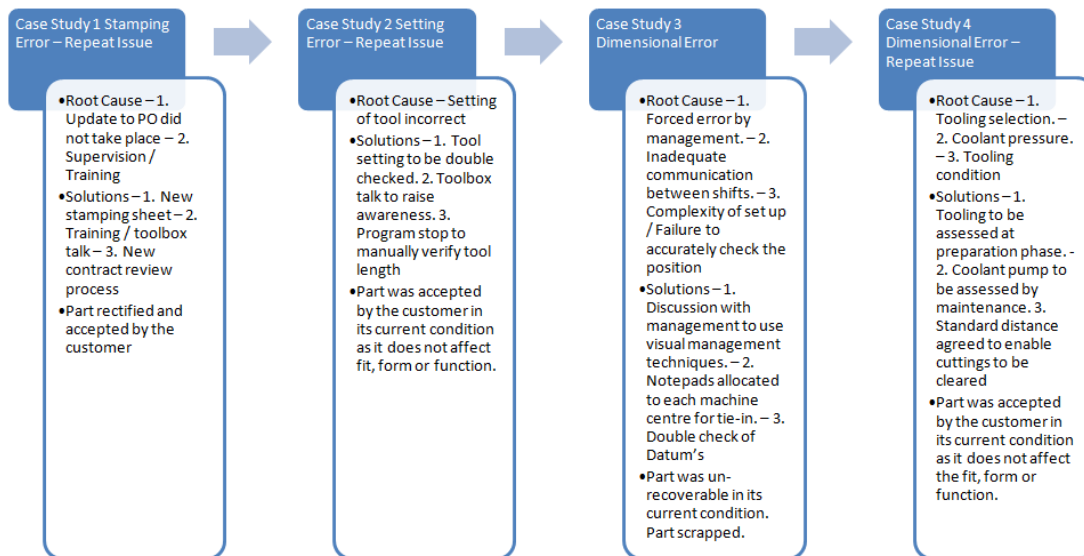
### **3. Root Cause Analysis Findings**

The exploration of each case study sought to bring together cross-functional teams who followed a structured format in conducting the RCA to (Doggett, 2004b), describe the issue, follow the sequence of events (Healy, 2013, Labib, 2014), identify underlying and root cause/s (Mahto and Kumar, 2008), generate solutions (Iedema et al., 2008, Rooney and Heuvel, 2004), implement and follow up (Otegui, 2014). This leading to improvement in processes, procedures, working practices, behaviours and organisational learning (Arnheiter and Greenland, 2008, Labib, 2014). The case studies followed the how and why of the

problem situations (Yin, 2013), one customer complaint and three internal rejects with origins on the production shop-floor.

The following figure (Figure 1) displays the RCA findings for each investigation; the first case followed a customer complaint in relation to incorrect part marking on a manufactured component, the second case explored a machine setting error by the operator, the third and fourth cases followed internal escapes with a dimensional error on a specified machined feature; each column summarises the root cause/s, selected solutions and the final disposition of the component.

**Figure 1 Root Cause Findings**



Source: Author compilation

While the research sought to explore the experience of the participants in regard to RCA, it also provided an opportunity for less experienced interviewers to lead the RCA session. The findings for each case were based on the outputs of the original RCA sessions; however the researcher offered some alternative options and recommendations in each case study report.

### 3.1 RCA Focus Group Responses

The focus group provided some themes and responses in relation to RCA. These have been aligned with the literature review to inform the research. The focus groups were analysed for the themes and ranked according to the coding for each session (4 in total). The themes which appeared on all four occasions were regarded as very strong, three as strong, two as moderate, and one as weak.

The figure 2 below depicts the responses from the RCA focus groups with strong themes which support continuous improvement, participation, following a structured approach, empowers group decision making, engages stakeholders, and promote learning to bring about lasting cultural change. The themes also explored some of the constraints and negative aspects that can be seen when RCA is carried out following an unstructured or undisciplined approach.

The purpose query brought the following responses from the focus group sessions: this in terms of having a problem, wanting to fix it, and what can be put in place to stop it happening again (Yazdani and Tavakkoli-Moghaddam, 2012, Healy, 2013). One participant noted:

*"You have found a problem and want to make sure it doesn't happen again. You don't want to just fix the problem, but to fix what caused the problem."*

To do this the focus groups highlighted the importance of finding the real root cause (Dew, Mahto and Kumar, 2008), and what caused the issue in order to fix the problem. On exploring the root cause and fixing the problem one participant opined:

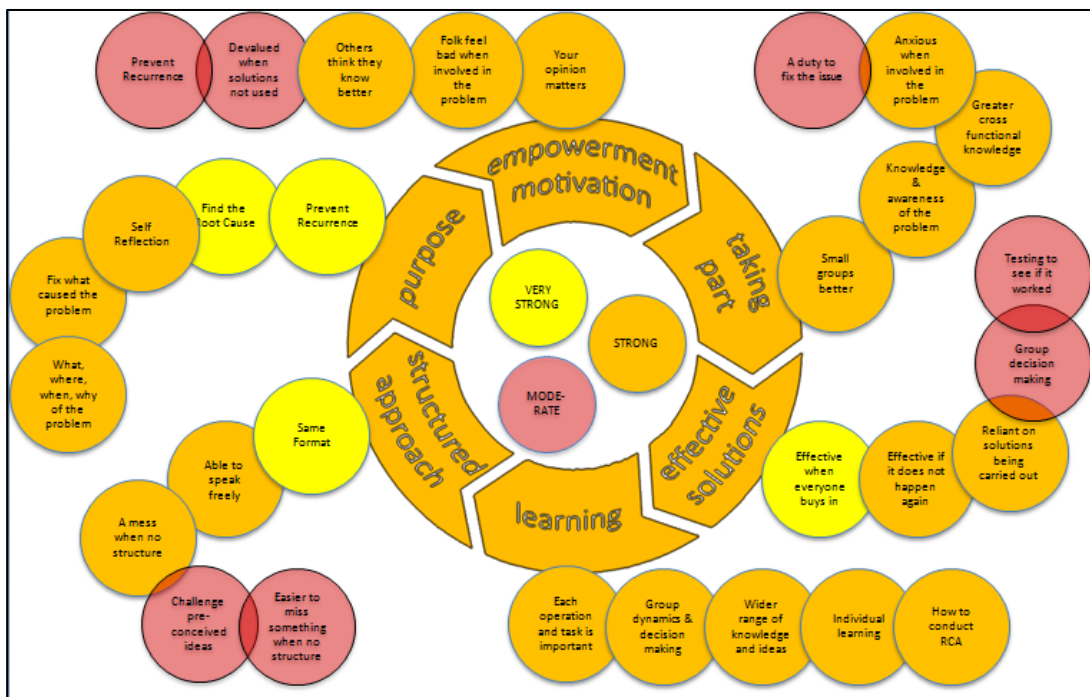
*"You don't want to just fix the problem, but to fix what caused the problem. If you just fixed the problem you would just be restarting it. You need to find the root cause of it. If you just fix the problem it will happen again - you need to find what caused the error."*

Dew, echoes the groups responses and explains the purpose of the root:

*"A root cause is the most basic causal factor, or factors, which, if corrected or removed, will prevent recurrence of the situation."*

Yuniarto (2009) follows this sentiment in the identification of the true root cause, and the need to eliminate the inherent root or 'common-cause' of the problem (Yuniarto, 2012).

**Figure 2 Summary of RCA themes**



Source: Author compilation

### 3.2 RCA observation discussion

The observed behaviours of the individuals ranged from indications being open and friendly; to somewhat reticent, not wholly uncommunicative, but showing some reserve. some participants almost went through the entire RCA session with their arms folded; this may just be a natural posture or indicate being closed to the discussions in some manner. While the participants' posture may have indicated some reticence, they contributed well to the group efforts.

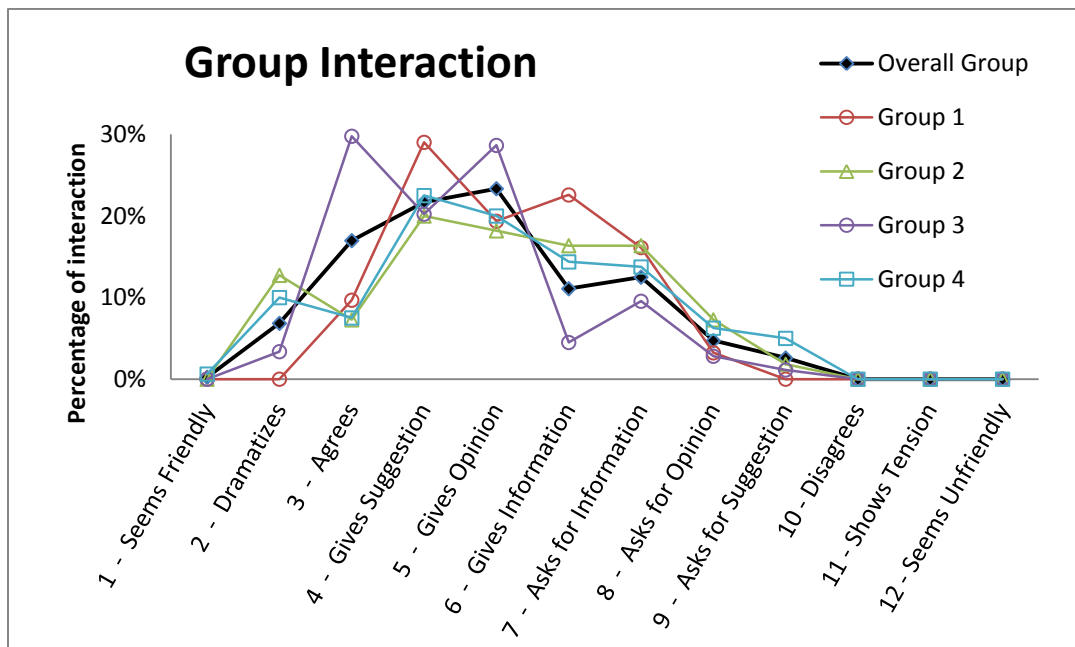
In comparing the group results it was noted that most sessions clustered around the yellow band of observations i.e. guidance, touching the face, hands on the table etc. The group findings may indicate the team exploring their options and then coming together, converging on agreed solutions. Not all sessions were plain sailing; however each was navigated well by the interviewers themselves, as they followed the structure and adapted where necessary.

In using the categories of interaction as a basis for the group observations Bales (1950, 1970), as cited in (Gorse and Emmitt, 2007) it was useful to code and analyse the observations. The observations were taken at a regular pace or when participants initiated dialogue.

Using the categories of interaction as a basis for the group observations Bales (1950, 1970), as cited in (Gorse and Emmitt, 2007), the findings were as follows: most of the interaction within the RCA session concentrated around section B (attempted answers), with 56 % of the responses. Section A (positive and mixed actions), made up a further 24 % of the responses.

In relation to RCA, the findings may support a heuristic type of learning as the group seek to identify possible causes, determine the root of the problem and then generate solutions. Some of the observed behaviour may indicate the group switching between analytical and creative thinking, normally marked by a brief quiet period.

Figure 3 RCA session interaction (after Bales, 19970) – data from 4 sessions.

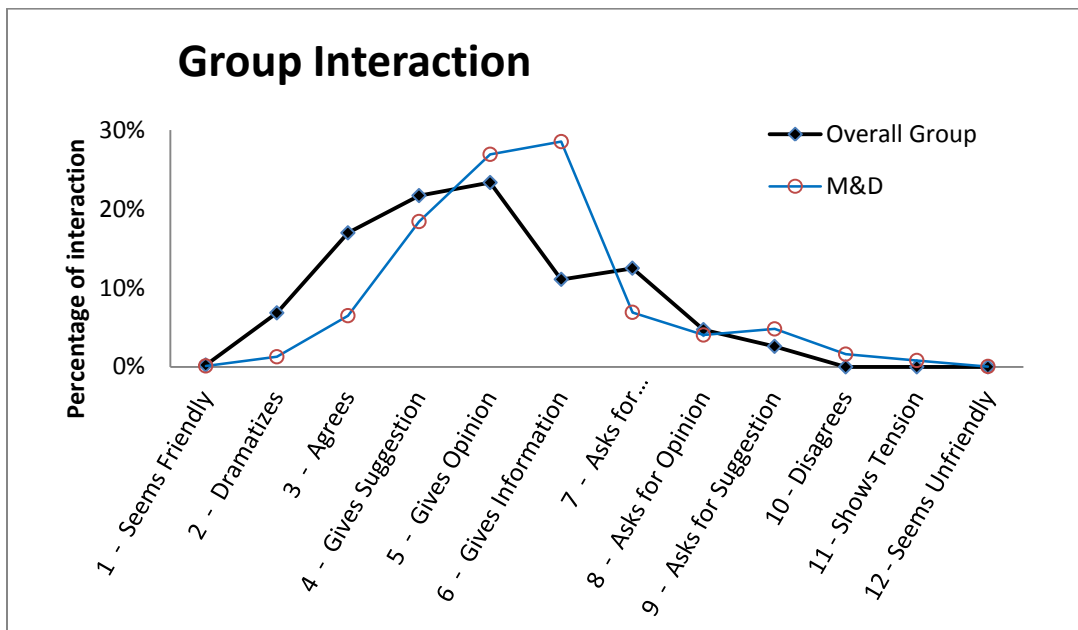


The findings for the RCA sessions cannot be regarded as statistically significant as they were only taken over four sessions. While the overall group results give an indication of the levels of interaction, each session itself shows wide variance even when taken in broad categories. Gorse and Emmitt (2007 p 1204) on following management and design team interaction note that:

*"The norms operating within the meeting result in the groups' use of giving task-based interaction being significantly higher than that of requesting task-based interaction."*

They go on to note that temporary teams do not tend to reach maturity in the group dynamics, and that they normally do not experience the extreme socio-emotional interaction (positive & negative).

Figure 4 RCA group comparison with M&D data



The comparison Figure 4, was taken, as the like the RCA sessions the project nature of construction industry offers teams temporarily being placed together. The RCA sessions may indicate more socio-emotional interaction due to the nature of RCA, these in terms of the participants being emotionally linked to the problem situation, or due to the need to converge on solutions. It would be interesting to see if further analysis and observation of the RCA sessions would bring the results more in line with those of the M&D groups (Gorse and Emmitt, 2007).

#### 4. Conclusions and future work

The aims of the research were to explore how we undertake RCA, to heuristically explore our problem solving provision (Simon and Newell, 1958, De Mast, 2004, De Mast and Bergman, 2006) through the use of a structured approach; namely CED (Ishikawa, 1986) and 5 Why's analysis (Ohno, 1988). The research sought to compare and contrast the findings from multiple case studies in order to develop our staff and to embed a culture of continuous improvement.

The problem situation for each case study was undertaken by the participants, in which they looked at the 'how & why' of the event (Yin, 2013). The CED and 5 Why steps were followed with one participant trained in problem solving leading each RCA session.

In all the sessions the groups demonstrated a lot of synergy in their discussions and decision making (Yazdani and Tavakkoli-Moghaddam, 2012). They were able to converge on solutions generated from the salient facts of the problem situation, rather than opinion based reasoning. No-one individual dominated or manipulated the decision making process (Dew), instead the team reached a consensus through group discussion (Doggett, 2004a, Yazdani and Tavakkoli-Moghaddam, 2012).

The results from the RCA sessions themselves found that all the corrective and preventative measures were completed and verified as successful. Case study three was the only investigation where the component itself was unrecoverable, as it could not be accepted



by the internal customer. While not all the outputs of the RCA were fully developed at the close of the RCA sessions, the subsequent recommendations by the researchers within the case studies were able to address some of the shortcomings. Allowing that the participants are mostly novices in conducting RCA, each case had to stand on its own, in order to address the specific problem situation.

The comparison of the focus group sessions brought very strong to moderate themes in relation to RCA, which laid the foundation for the Tool Application Model, the broad categories were in terms of:

- purpose - finding the root and prevent recurrence;
- taking part - small groups are better and gaining knowledge of the issue;
- learning - group decision making and each process having its importance;
- structured approach - has the same format and allows free speech;
- effective solutions - effective when you have buy in and the situation does not happen again;
- motivation / empowerment - my opinion matters and I feel bad when involved
- continuous improvement / business excellence - shows maturity to customer and helps improve the business

The strength of the themes generated allowed the 'human element' of the RCA tools to be explored. The use of feedback from multiple cases offers validity to the usefulness of the qualitative data.

Each individual case study was able to explore the how and why of the problem situation through the use of CED (Ishikawa, 1986), and 5 Why's analysis (Ohno, 1988) to identify possible causes and to generate viable solutions.

In terms of the research, the RCA provision was heuristically explored to answer the case study questions and overall aims:

*1. How do participants in root cause analysis describe their experience of problem solving in small groups?*

The focus groups indicated very strong themes that the purpose of the RCA sessions allowed the root cause to be identified (Ohno, 1988) and focussed on preventing recurrence of the problem (Healy, 2013). The effectiveness of the solutions and group recommendations are based on the buy in of the problem stakeholders.

*2. Does a structured approach to RCA bring about more robust solutions?*

Both the focus group and the interview sessions indicated very strongly that a structured approach was preferred and that it was important that it followed the same format. It was indicated that an unstructured approach would be 'messy' (Kotter, 1999).

*3. Does Root Cause Analysis embed a culture of Continuous Improvement / Business Excellence?*

It was also very strongly felt, that the RCA could improve the company culture as it allows the business to evolve, improve its processes and challenge customer perception as the teams demonstrate a mature approach to quality issues.

The research has allowed the organisation to learn in terms of developing the knowledge and skill of the individuals; group interaction and participation; inputs being valued and learning how to conduct RCA.

Concerns remain in terms of challenging hubristic behaviours (Dew) dispelling fear that can come from problem situations (Deming, 1986); again, the focus groups indicating that these practices no longer being the case. Other concerns are in having the resources and maturity to address the 'commonly occurring' problems and following up on the proposed recommendations. In light of the research outputs, it is the researchers hope that the improvement opportunities are embraced, as have some of the RCA findings, and that the tool application model can be further utilised.

### Tool Application Model

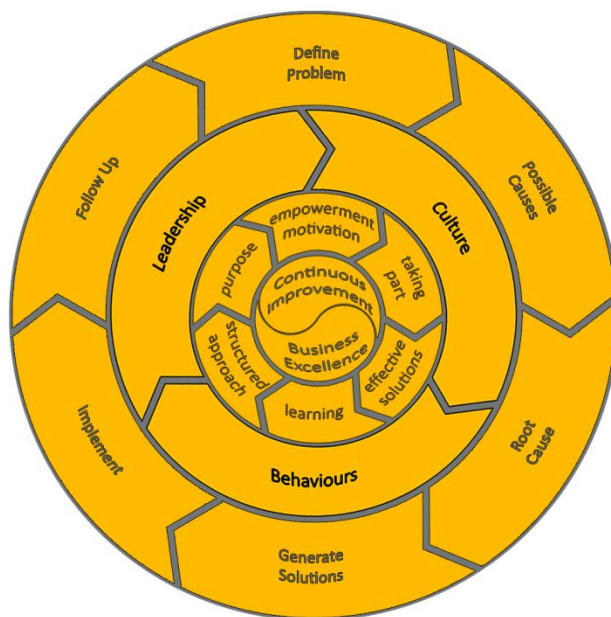
Outputs from the case studies, focus group, interviews and archival data suggest that further research is required to explore the common themes and root causes which recur in a complex manufacturing environment (Mahto and Kumar, 2008), namely:

- Dimensional compliance i.e. setting errors, tooling issues
- Leadership i.e. process correct but not followed, pressure
- Investment i.e. primary equipment, training

The categories of interaction can be deployed to other small groups and common meetings e.g. management review, business excellence, project teams etc., within the Proserv group to assess whether more formal teams are able to reach maturity in their levels of interaction (Gorse and Emmitt, 2007).

As the research progressed the initial assumptions and conceptual framework of RCA was explored by the researcher. This has been developed into the Tool Application Model (TAM) which can be used to assess the introduction of 'new' tools and techniques. The model developed during the research seeks to provide a mechanism to assess the broad aims of this study.

Figure 5 Tool Application Model



Source: Author compilation

The usefulness of the Tool Application Model (TAM) is the assessment of the tool itself and its inter-changeability with other tools and techniques, where the outer ring of the model can be replaced with an alternative tool i.e. 5S, DMAIC (1986), PDCA (Deming, 1986) etc. Researchers can conduct a similar study using the model as a framework to explore the 'human element' of the particular tool or technique while assessing the overall leadership, behaviours and culture of the organisation.

## References

1986. *Six Sigma Quality Process* [Online]. Available: [http://www.motorola.com/us/consumers/about-motorola-us/About\\_Motorola-History-Timeline/About\\_Motorola-History-Timeline.html](http://www.motorola.com/us/consumers/about-motorola-us/About_Motorola-History-Timeline/About_Motorola-History-Timeline.html) [Accessed 26/09/2015].
- Anaf, S., Drummond, C. & Sheppard, L. A. 2007. Combining Case Study Research and Systems Theory as a Heuristic Model. *Qualitative Health Research*, 17, 1309-1315.
- Arnheiter, E. D. & Greenland, J. E. 2008. Looking for root cause: a comparative analysis. *The TQM Journal*, 20, 18-30.
- Avouris, N., Dimitracopoulou, A. & Komis, V. 2003. On analysis of collaborative problem solving: An object-oriented approach. *Computers in Human Behavior*, 19, 147-167.
- Ayad, A. 2010. Critical thinking and business process improvement. *Journal of Management Development*, 29, 556-564.
- Bamford, D. R. & Greatbanks, R. W. 2005. The use of quality management tools and techniques: a study of application in everyday situations. *International Journal of Quality & Reliability Management*, 22, 376-392.
- Creswell, J. W. 2013. *Research design: Qualitative, quantitative, and mixed methods approaches*, London, Sage publications.
- Dasgupta, M. 2015. Exploring the Relevance of Case Study Research. *Vision - The Journal of Business Perspective*, 19, 147-160.
- De Mast, J. 2004. A methodological comparison of three strategies for quality improvement. *International Journal of Quality & Reliability Management*, 21, 198-213.
- De Mast, J. & Bergman, M. 2006. Hypothesis Generation in Quality Improvement Projects: Approaches for Exploratory Studies. *Quality and Reliability Engineering International*, 22, 839-850.
- Deming, W. E. 1986. *Out Of The Crisis*. Cambridge, MA: MIT.
- Dew, J. *Digging deeper for root causes* [Online]. Available: <http://bama.ua.edu/~st497/pdf/diggingdeeper.pdf> [Accessed 07/02/2014].
- Dogett, A. M. 2004a. Selected Collaborative Problem-Solving Methods for Industry.
- Dogett, A. M. 2004b. A statistical comparison of three root cause analysis tools. *Journal of Industrial Technology*, 20, 2-9.
- Easterby-Smith, M., Thorpe, R. & Lowe, A. 2002. *Management Research: An Introduction*. 2nd ed. London: Sage.
- Finlow-Bates, T. 1998. The Root Cause Myth. *The TQM Magazine*, 10, 10-15.
- Flyvbjerg, B. 2006. Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12, 219-245.
- Gorse, C. A. & Emmitt, S. 2007. Communication behaviour during management and design team meetings: a comparison of group interaction. *Construction Management and Economics*, 25, 1197-1213.
- Greenwood, D. J. & Levin, M. 2007. *Introduction to Action Research. Social Research for Social Change*. 2nd ed. London: Sage Publications.
- Healy, J. 2013. *Root Cause Analysis Considerations*.
- Iedema, R., Jorm, C. & Braithwaite, J. 2008. Managing the scope and impact of root cause analysis recommendations. *Journal of health organization and management*, 22, 569-585.
- Ishikawa, K. 1986. *Guide to Quality Control*. Tokyo: Asian Productivity Organization.
- Kotter, J. P. 1999. *John P. Kotter on what leaders really do*, Boston, Harvard Business School Press.
- Labib, A. 2014. *Learning from failures: decision analysis of major disasters*, Elsevier.
- Mahto, D. & Kumar, A. 2008. Application of root cause analysis in improvement of product quality and productivity. *Journal of Industrial Engineering and Management*, 1, 16-53.

- Neale, P., Thaoa, S. & Boyce, C. 2006. Preparing a Case Study: A Guide for Designing and Conducting a Case Study for Evaluation Input. *Pathfinder International: Writing a Case Study*.
- Ohno, T. 1988. *Toyota Production System: Beyond Large-Scale Production*. New York: Productivity Press.
- Ohno, T. 2012. *Taiichi Ohnos Workplace Management: Special 100th Birthday Edition*, New York, McGraw Hill Professional.
- Otegui, J. L. 2014. Root Cause Analyses. *Failure Analysis - Fundamentals and Applications in Mechanical Components*. Switzerland: Springer International Publishing.
- Rooney, J. J. & Heuvel, L. N. V. 2004. Root cause analysis for beginners. *Quality progress*, 37, 45-56.
- Simon, H. A. & Newell, A. 1958. Heuristic problem solving: The next advance in operations research. *Operations research*, 6, 1-10.
- Womack, J. P., Jones, D. T. & Roos, D. 2007. *The Machine That Changed The World*. New York: Free Press.
- Yazdani, A.-A. & Tavakkoli-Moghaddam, R. 2012. Integration of the fish bone diagram, brainstorming, and AHP method for problem solving and decision making—a case study. *The International Journal of Advanced Manufacturing Technology*, 63, 651-657.
- Yin, R. K. 2013. *Case Study Research: Design and Methods*. 5th ed. London: Sage Publications.
- Yuniarto, H. A. The Shortcomings of Existing Root Cause Analysis Tools. Proceedings of the World Congress on Engineering, July 4-6 2012 London, U.K.