

# Critical Success Factors of Root Cause Failure Analysis

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## Abstract

**Background/Objectives:** Failure causes huge loss to oil and gas industries in context of operations stoppage, human injury, equipment and assets damage. RCFA process is commonly used to control these failures. Nevertheless, RCFA goes ineffective and unsuccessful due to various reasons. Objective of this study is to highlight existing shortcomings and identify critical factors of RCFA crucial for effective failure investigation. **Methods/Statistical Analysis:** To achieve the objectives of this study, various literatures will be reviewed related to RCFA to identify existing weaknesses and flaws in the process. Recognise important elements of RCFA and analyse them to find critical factors of RCFA necessary to be considered to perform effective and successful failure investigation. **Findings:** After extensive literature review, study highlighted various shortcomings of existing process and identified multiple factors crucial to be considered while carrying out RCFA. These factors have been categorized under resources, management support, data and information, technical factors and failure data management system/database. Each identified factor is significant and has key importance for successful implementation of RCFA. **Application/Improvements:** Study will support failure investigation team to understand and consider critical factors necessary for conducting effective RCFA. Study will also enhance accuracy of investigation in controlling future failure recurrences.

**Keywords:** Critical, Equipment, Factors, Oil and Gas, RCFA, Root Cause Failure Analysis

## 1. Introduction

Failure analysis is critical in oil and gas industries due to different factors like mechanical, chemical, environmental, technical and physical factors could be involved in a failure<sup>1</sup>. These failures causes huge losses and pose economic impact to the industries in context of operations stoppage, human injury, fatality, parts damage, production loss, equipment and assets damage<sup>2,3</sup>. The main challenge of plant management is to select most suitable and effective method to control failure and avoid further

losses<sup>4,5</sup>. Root Cause Failure Analysis (RCFA) is widely used method in industries to control recurrence of these failures. It is a failure analysis method focus to detect underlying causes of failure and control similar failure in future by identifying and eliminating those causes<sup>6-9</sup>. Practicing RCFA required in-depth understanding of the process to get effective results. Various definitions can be found in literature given by many authors to describe RCFA. Some of them are:

RCFA is a disciplined problem solving methodology, used to determine root causes of specific failure events<sup>10</sup>.

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Root Cause Failure Analysis is a class of problem solving methods using a step-by-step method to discover the basic causes of failure<sup>11</sup>.

It is a process for identifying the true root cause of a particular failure and using that information to set a course for corrective/preventive action<sup>12</sup>.

RCFA required initial investigation to analyze nature and frequency of failure to decide whether to conduct RCFA or not. Once it is decided, then process starts with comprehensive data gathering regarding failure including physical and technical evidences, continues with analysis of gathered data, finding root cause of the failure and ends with offering solutions to prevent recurrence. RCFA supports incident investigators to designate what happened during a particular incident, find how it happened and to know why it happened. It develops cause and effect relationship between failure and its cause to identify the root cause of failure<sup>13</sup>.

Emphasized that problem must be analyzed accurately for getting effective solution to the failure and there should be the importance of solution<sup>8</sup>. RCFA also required great support from management and commitment from everyone involved in the process, skilled multidisciplinary team, availability of adequate data, information and evidences to achieve desired results of investigation<sup>14</sup>. Besides root cause finding, RCFA is also a source of cost saving by controlling failures, maximizing profit, improving effectiveness and smooth operation<sup>15</sup>.

Goal of RCFA is to avoid and control recurrence of failures by eliminating root causes but sometimes it goes unsuccessful, incomplete or ineffective due to various reasons. List of issues has been identified and underlined related to unsuccessful RCFA, these issues are:

- Problem is not understood and defined properly<sup>16</sup>.
- Inappropriate, insufficient and irrelevant data or information available<sup>14,17,18</sup>.
- Inadequate or poor failure analysis<sup>17,18</sup>.
- Poor implementation and execution of RCFA process<sup>17-19</sup>.
- Improper implementation of recommendation/corrective actions.
- Lack of communication<sup>20</sup>.
- Management do not buy-in or support proposed action<sup>21</sup>.
- Improper tracking or follow up of solutions<sup>16,18</sup>.

Objective of this study is to identify factors necessary to be considered while performing RCFA for identification of real root cause of the failure and successful implementation of RCFA process. Moreover, various shortcomings of RCFA process are also highlighted in this study.

## 1.1 Why do RCFA Fail?

Various resources are required to conduct RCFA effectively<sup>22</sup>, however, it can be ineffective due to unavailability of resources desirable to complete investigation. According to<sup>23</sup> issue was highlighted by various investigation teams about resources needed for effective execution of RCFA process, without required resources, it becomes difficult to achieve the objectives of failure analysis. Unavailability of competent team for conducting is another issue. They<sup>14</sup> underlined that multi-disciplinary team is one of the important resource required for RCFA. Formation of team by selecting competitive and experienced persons from different departments of the organization is recommended. Team can highlight different areas of problem according to individual's knowledge and experience.

Improper selection of tool, poor understanding of RCFA process and ignoring steps of the process may cause ineffective RCFA. They emphasized on selection of proper tools, having clear understanding of RCFA process and following all steps involved in the failure analysis process correctly to have more accurate identification of root cause<sup>24</sup>. It is important to have sound knowledge of process, ability of selecting suitable tool and expertise on using tool properly for valuable results. They further pointed out on commitment from each one involved in the team to achieve the objectives of RCFA investigation.

Some inadequacies of existing RCFA process are highlighted<sup>25</sup>. According to him, limitations of tool, ignorance of any issue (important or less important), lack of system perception and unavailability of sufficient data and information could be the causes of ineffective RCFA. While doing the RCFA, comprehensive and relevant data should be available in order to analyse the problem completely to highlight all possible causes of the failure. Further claimed that RCFA tools are not contributing to structure the problem, they are just limited to finding root cause of the problem and offering solution<sup>25</sup>. These tools ignore minor issues of problem and only focus on key issues. As a result it damages the ability of tool to outline underlying causes. Pointed out that people themselves are root cause of the problem. They don't agree on same concept, having

different views, perception, opinion and thoughts regarding RCFA<sup>26</sup>.

They also identified several shortcomings of RCFA. They argued that creating meaningful report is difficult due to random classification of causes. Consequences of failure are also not communicated properly to concerned departments of the organizations (lack of communication). Failure causes are mostly treated as technical whether these are organizational, managerial or human errors (always treated as technical fault). Further they highlighted that the preventive actions are not implemented and monitored properly to check the effectiveness of analysis that allows another failure to be happened<sup>20</sup> due to performance limitations and resistance to all failure modes does not appear practical<sup>27</sup>.

## 2. Critical Success Factors of RCFA

Extensive literature study is carried out to identify key elements of RCFA required to conduct fruitful RCFA. Based on literature findings and industrial inputs, several critical factors to perform successful RCFA are identified and these are classified and combined into five categories are discussed for further understandings.

- Management support.
- Resources.
- Data and information.
- Technical factors.
- Failure data management system/database.

Each factor has its own importance and influence and contributes an important role for meaningful RCFA. To conduct RCFA, these factors can lead to successful or failed analysis depends upon how these are considered.

### 2.1 Management Support

Preventing failures and their recurrence is the responsibility of each one in the organization from junior employee to management level<sup>2</sup>. Nevertheless, it is the ultimate responsibility of management to establish policies and assign budget and resources for failure prevention.

RCFA process needs strong support from management for its successful implementation. Management must be aware from every aspect of failure investigation project and allow investigation team to access all necessary

data and information, allocate sufficient time to complete investigation, encourage investigation team to implement corrective/preventive actions and follow up. All resources needed for execution of RCFA must be provided to the team for effective results. Management should authorize the RCFA team to take decisions in favour of preventing recurrence of similar failures in future<sup>14</sup>.

Commitment is an essential factor to achieve positive results of organizational project. While conducting RCFA, management should be committed to find valid and effective solution of failure. If management is not committed to support RCFA positively then the desired results cannot be achieved<sup>24</sup>. Team commitment is also required to accomplish goals of RCFA. Forming skilled, well trained and multi-disciplinary team is useless if the team is not committed to achieve RCFA investigation objectives. It is responsibility of every team member to perform task effectively and efficiently to accomplish worth full investigation.

RCFA is a systematic process of failure investigation and requires training for effective execution. Training is required to understand the basics of RCFA tool, method and process. While investigating the failure, team should be equipped with proper training and must be familiar with RCFA process properly to conduct effective investigation<sup>14</sup>. Trainings must be arranged by management for RCFA team to become more competent in failure investigation.

### 2.2 Resources

Resources are needed to complete RCFA investigation effectively<sup>22</sup>. According to<sup>23</sup> issue has been highlighted by many respondents that resources are required to accomplish RCFA. The main reason why organizations are willing to spend costly resources on RCFA is to avoid failures. Before conducting RCFA, it is necessary to ensure that all required resources like money, time and people are available.

Personal requirement is quite substantial element of failure investigation<sup>28</sup> as a multi-disciplinary expert team is required for successful RCFA<sup>1</sup>. Investigating team members must be skilled and trained in respective area as skilled professionals are desirable for RCFA process<sup>23</sup>. Formation of team by selecting competitive and experienced members from different departments of the organization is supportive for RCFA investigation<sup>16</sup>. The team can highlight different areas of problem according

to everyone's experience and skills, perform in-depth analysis, analyse failure from different point of views and offer effective solution<sup>14,29</sup>.

RCFA investigation requires enough time to be conducted effectively as data collection consumes more time for conducting interviews, preserving evidences, collection of accurate information and data related to the failure. Accuracy of data being collected is critical for analyzing causes of the failure correctly. Sufficient time is needed for data to be collected comprehensively.

### 2.3 Data and Information

RCFA requires sufficient data and information to analyse and investigate potential causes of the failure. Effectiveness of RCFA highly depends on availability of accurate and comprehensive data and ability of RCFA team to analyse the data properly<sup>30</sup>. Data and information help to analyse reasons why machine or equipment fail and to understand problem deeply. Data for any particular failure can be obtained from previous failure reports, equipment records, conducting interviews, observations, process data, environmental factors data, analysis reports, physical evidences and maintenance records. Insufficient information or data available can cause inadequate analysis on identifying underlying causes<sup>14</sup>. Proper guidelines and standards should be available to improve the quality and accuracy of data collection<sup>31</sup> being used for RCFA.

Documentation and reporting of each activity must be done by RCFA team and everyone involved in failure analysis process. All RCFA investigations activities need to be documented for future reference. Records like maintenance, engineering information, operating information and process safety information must be stored in soft/hard formats or any database management system. These records can be used for investigating similar type of failures, identifying root causes immediately and offering solution<sup>32</sup>.

Interview is critical element of RCFA process and essential part of data collection<sup>33</sup>. Interview is an effective way of gathering valuable information to establish facts of incident<sup>22,28,34</sup>. Initial interviews are conducted from different personal including those directly or indirectly involved and witness of failure. Data gathering may include information regarding nature of failure, place, plant, date, time and its impact on environment, human, operations, process, HSE and policies of organization.

Further detailed interviews are done for investigating potential causes of the failure deeply.

Interview may be conducted in different ways as Mobley<sup>28</sup> categorized them into following three types; 1. Individual interview, 2. Two-on-one interview and 3. Group interview. These methods of interview can be used for gathering information from people who are directly or indirectly involved in incident, witness of the incident and having knowledge of failure or incident like operator, supervisor, engineer, manager, worker, technicians, health and safety personal, compliance officer, experts, consultant and other people as required<sup>32</sup>. Interview can be initiated by taking interviewees into confidence that they are part of failure investigation and the purpose of interview is to collect and gather information to control future failure instead of punishing anyone<sup>28,32</sup>. To extract valuable information from people, following points should be considered by interviewer:

- Explain purpose of investigation, let interviewee feel calm and relax, don't interrupt by asking too many questions quickly, avoid threatening and built confidence not to punish<sup>34</sup>.
- Avoid blaming, ask open ended question and respect everyone involved in interview<sup>35</sup>.
- Consider on fact finding rather than fault finding.
- Interviews must be conducted immediately before the evidences are lost<sup>22</sup>.
- Don't conclude investigation based on blind guesses until all the investigation is done.

Another imperative factor of data and information is evidence collection. Evidences are required for investigating the failure deeply. These evidences are collected by visiting and inspecting the particular area/site where failure occurred. Evidences may include failed parts, failed equipment, photographs, videos, samples, analysis reports, process data, environmental conditions, materials and test reports etc. These evidences help investigator to analyse failure thoroughly to identify true causes of failure.

### 2.4 Technical Factors

Technical factors of RCFA are necessary to be considered while going for failure investigation. Team should focus all aspects of the failure including major and minor issues, having technical knowledge of using tools, aware

with all features of tool being used for investigation and proper understanding of the system.

Selection of proper or suitable tool is very important to conduct effective RCFA. Investigation team must be familiar with all aspects and features of RCFA tools desired to be used for investigation. Limited understanding of tools can lead to improper and RCFA. One of the common causes for ineffective implementation of RCFA

is using the tool inappropriately. Wrong adoption of tool, improper implementation and disregarding proper steps and procedures could affect entire RCFA investigation. There is variety of tools that can be used to perform RCFA<sup>36</sup> by selecting suitable one considering type of problem you are facing<sup>37</sup>. A comparison of selected RCFA tools has been presented as shown in Appendix 1. Comparison will assist investigation team to select suitable tool.

**Appendix 1.** Comparison of selected RCFA tools based on multiple criteria<sup>6,13,25,36,37</sup>

| RCFA Tool   | Define Problem | Define causal relationship | Provide causal path to root cause | Delineates evidence | Prevent failure | Easy to follow report | Level of difficulty | Creativity level | Software required |
|---|----------------|----------------------------|-----------------------------------|---------------------|-----------------|-----------------------|---------------------|------------------|-------------------|
| Events and Causal Factors (E and CF)                | Yes            | Limited                    | No                                | No                  | No              | No                    | High                | Medium           | No                |
| Tree Diagram  | Yes            | No                         | No                                | No                  | No              | No                    | Medium              | Medium           | No                |
| Fault Tree Analysis (FTA)                           | Yes            | Yes                        | Yes                               | No                  | Yes             | No                    | High                | Low              | No                |
| Fishbone Diagram (cause and effect analysis)        | Yes            | Limited                    | No                                | No                  | No              | No                    | High                | Low              | No                |
| 5-Whys (Why-Why)                                    | Yes            | No                         | Yes                               | No                  | No              | No                    | Low                 | Low              | No                |
| FMEA  | Yes            | No                         | Limited                           | No                  | Limited         | No                    | Medium              | Low              | No                |
| Task Analysis                                       | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |
| Control Barrier Analysis                            | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |
| Change Analysis                                     | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |
| Pareto chart (80/20)                                | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |
| Kepner – Tregoe problem solving and decision making | Yes            | Yes                        | Yes                               | No                  | Limited         | Yes                   | High                | -                | Yes               |
| Human performance evaluation                        | Yes            | Yes                        | Yes                               | No                  | Limited         | Yes                   | -                   | -                | -                 |
| Affinity Diagram                                    | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |
| MORT  | Yes            | Yes                        | Yes                               | No                  | Limited         | Yes                   | High                | Low              | Yes               |
| Interrelations Diagram                              | Yes            | No                         | No                                | No                  | No              | No                    | Low                 | Low              | No                |

Lack of system perception is also another significant factor of RCFA. It damages the ability of RCFA process to find multiple causes of the failures and their relationship. Lack of system perception limits to find exact root cause of failure and tends to improper investigation. Whoever concerned with process of failure investigation must have clear system perception to get the valuable results<sup>25</sup>.

Focusing on major issues, ignoring minor issues of failure, overlooking features of tools and lack of system perception can lead to weak failure analysis. Furthermore, successful RCFA required clear understanding of process to execute failure investigation effectively. Everyone involved in investigation must be able to understand the RCFA process for successful implementation. Unclear understanding of process moves the direction of investigation on wrong path which can lead to undesired results<sup>24</sup>.

## 2.5 Failure Data Management System/ Database

A solid failure data management/reporting system or failure database is highly desirable to record failures investigation and reporting data which can easily and quickly be accessed to avoid repetition of failure by reviewing previous failure/investigation reports and data from the database<sup>38</sup>. Failure database support investigator to access previous RCFA reports, failure details, identified root causes of any failure and tracking of implemented solution that would be supportive to analyse similar type of failures. Failure data management system is backbone of any failure analysis/performance improvement process<sup>39</sup>. It enables proper communication between failure investigation team and provide frequent status updates of the analysis at one place<sup>21</sup>. It also empowers quick root cause finding by reviewing previous failures reports and examples of similar failures instead of blind guesses based on personal opinions. Identifying root cause of failure and implementing corrective actions will not be successful without tracking implemented solutions.

There are various failure data management systems/database present in industries that store information of an event or failure<sup>40</sup>. There are many databases that belong to different industries and organizations and consists variety of failure/incident investigation, case studies and reports<sup>2</sup>. These databases aim to share experiences and information that can be used for prevention of similar failures. Some of the databases are listed in Table 1.

**Table 1.** Various failure/incident reporting and investigation database

| Failure/Incident reporting and investigation database   |
|---|
| ✓ Failure Knowledge Database (FKD) <sup>41</sup> .  |
| ✓ ASM Failure Analysis Database <sup>43</sup> .   |
| ✓ Centre for Chemical Process Safety (CCPS).  |
| ✓ United States Chemical Safety and Hazard Investigation Board (CSB).   |
| ✓ United States Department of Energy (DOE).   |
| ✓ National Institute for Occupational Safety and Health (NIOSH).  |
| ✓ Occupational Safety and Health Administration (OSHA).   |
| ✓ National Transportation Safety Board (NTSB).  |
| ✓ Accident Investigation System (AIS)—occupational safety and health administration, US Department of Labour. |
| ✓ US DOT Integrated Pipeline Information System (IPIS) <sup>2</sup> .   |

These databases belong to different organizations and used to retrieve previous data and information for similar type of incidents. Some of the failure data management system/database discussed below which provide number of failure investigation reports that could be used as an example for similar failure/incidents.

- Failure Knowledge Database (FKD)<sup>41</sup>.
- Tango’s RCFA Information Management System<sup>42</sup>.
- ASM Failure Analysis Database<sup>43</sup>.
- Failure reporting, analysis and corrective action system (FRACAS)<sup>39</sup>.

Failure Knowledge Database (FKD) is an essential and useful resource<sup>44</sup> for carrying out RCFA by analysing similar incidents. Purpose of developing FKD was to share failure investigation experiences and lessons learned. FKD service was started on 23rd March 2005 and closed on 31<sup>st</sup> March 2011, now it is publically available on FKD website and can be seen at reference<sup>41</sup>. Thousands of incidents are available on FKD database under 16 categories such as oil, petro-chemistry, nuclear and aerospace. Various reports of failure analysis can be found in each category that enables investigator to find similar examples which can help to save time and resources.

Tango’s RCFA information management system supports investigator to perform RCFA, identify corrective actions and document report. It offers the user to initiate RCFA, record data and information in systematic way, facilitate tracking the progress of RCFA, find root causes, offering solution and track implemented solutions. Tango’s RCFA information management system is complete

application of RCFA from investigation to recording and also provide database of past failure investigations<sup>42</sup>.

ASM failure analysis database provides more than thousand failure analysis case studies from multiple journals and reports. It contains examples of different failures like process, corrosion and material failures to facilitate people involved in RCFA to get quick resolution of problem and improve effectiveness. ASM database include full description of failure and graphical representation to provide support for investigation of particular failure<sup>43</sup>.

FRACAS system provides opportunity for custom built database to be used in organizations. It can be incorporated in organizational maintenance management

system for failure investigation<sup>39</sup>. This database provides sufficient failure data and information to analyse the failure thoroughly by reviewing similar examples of failures analysis/investigation reports which can help to prevent recurrence of failures, save time, money and resources.

### 2.5.1 RCFA Knowledge Based Systems

It has been found that variety of RCFA knowledge based software is also available which facilitates industries to perform failure investigation. Some of the software offer complete solution from failure reporting to preventive actions while some of them support investigation. This software assists to identify root cause of failures, create

**Appendix 2.** Comparison of some selected RCFA applications/software commercially exist

| S# | Criteria                              | TapRooT®  | Reality Charting®   | PROACT®   | REASON®   | XFRACAS   | NASA RCA Tool (RCAT)  | Cause Mapping   | Causelink®  |
|----|---------------------------------------|---|---|---|---|---|---|---|---|
| 1  | Define Problem                        | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   |
| 2  | Develop cause and effect relationship | Yes   | Yes   | Yes   | Yes   | No  | Yes   | Yes   | Yes   |
| 3  | Ability to find root cause            | Yes   | Yes   | Yes   | Yes   | No  | Yes   | Yes   | Yes   |
| 4  | Report generation                     | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | No  | Yes   |
| 5  | Provide database facility             | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | No  | Yes   |
| 6  | Track solution                        | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | No  | Yes   |
| 7  | Is Training required?                 | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   |
| 8  | Difficulty of use                     | High  | Medium  | High  | Medium  | Medium  | Medium  | Low   | High  |
| 9  | Single user/desktop                   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   |
| 10 | Enterprise                            | Yes   | Yes   | Yes   | Yes   | Yes   | Yes   | No  | Yes   |
| 11 | Organization/ Provider/               | System Improvements Inc.                                    | Reality Charting.   | Reliability Center, Inc.  | REASON® Root Cause Analysis system.                     | ReliaSoft Corporation.  | NASA  | ThinkReliability  | Sologic root cause analysis                                 |
| 12 | Website/Link                          | <a href="http://www.taproot.com">http://www.taproot.com</a> | <a href="http://www.realitycharting.com">http://www.realitycharting.com</a> | <a href="http://www.reliability.com">http://www.reliability.com</a> | <a href="http://rootcause.com">http://rootcause.com</a> | <a href="http://www.reliasoft.com">http://www.reliasoft.com</a> | <a href="https://nsc.nasa.gov/RCAT">https://nsc.nasa.gov/RCAT</a> | <a href="http://www.thinkreliability.com">http://www.thinkreliability.com</a> | <a href="http://www.sologic.com">http://www.sologic.com</a> |

cause and effects chart, generate failure report, graphical representation of results, offer preventive/corrective actions, document analysis and provide database facility as well to record and store the investigation for future reference. A number of RCFA software has been compared based on various criteria as shown in Appendix 2. This comparison will help investigation team for selecting appropriate software that can be used to support RCFA investigation.

### 3. Results and Discussion

This study has highlighted and identified various factors that must be considered while carrying out RCFA process. These factors have been categorized under resources, management support, data and information, technical factors and failure data management system/database as shown in Figure 1. Each identified factor is significant for RCFA in context of successful implementation.

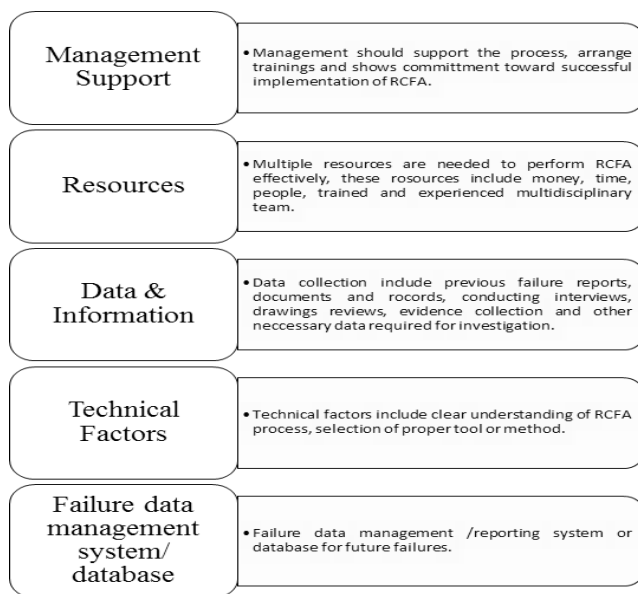


Figure 1. Critical success factors of RCFA,

### 4. Conclusion

As a conclusion for RCFA to be successful, the following elements must be addressed;

- Everyone involved in the team should have clear understanding of the RCFA process, methods and tools.

- Focus on both major and minor issues of the problem as well, not just focus on major issues.
- Availability of adequate, sufficient and relevant data and information to analyse the root cause of the failure completely.
- Selection of suitable tool is important to conduct effective RCFA, not same tool for all failures.
- Process should be followed step by step.
- Required resources must be available to conduct effective RCFA.
- Multi-disciplinary team is required to carry out the RCFA effectively.
- Training should be provided to the team.
- Team and management should be committed to achieve the objectives of RCFA investigation.

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