Chapter 5: Case Study: Actions & Findings

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This Chapter explains the whole case study research procedures & the *case study protocol* employed in this research on the selected sample, the actions including the *modes* of collected data, three levels of *case study questions* as well as the *findings* from the study.

5.1 Case Study Protocol

The case study protocol employed in this research has been detailed in the following paragraphs. It is to be noted here that this *Section 5.1 describes the case study protocol that has been employed in doing the case study research* and not the research design strategies & rationale that have been designed (in line with the research objectives) as chronicled in the anteceding chapters.

5.1.1 Introduction to Case Study and Purpose of Protocol

As per the earlier chronicles, an extensive review of existing literatures has shown that there has been no research on engineering design management in India. The objectives of this research project have been:

(Continues in next page)

(i) *To Study the Existing Practices/Models* of Piping Engineering Design Management that are being used in oil & gas industry in India, and

(ii) *To Identify the Areas of Improvements* in order to develop a Model of Piping Engineering Design Management for the oil & gas industry in India.

This has been achieved through a qualitative descriptive case study by mapping the existing piping design management practices in the design cell of India's largest oil & gas company (name of the Company has been kept confidential in order to guard against possible ignominious effects).

The Case Study Protocol is detailed in this document with the objective of providing guidelines to ensure that the data has been be *collected, presented and analyzed in a repeatable & reliable manner* by the researcher while minimizing interviewer bias.

5.1.2 Data Collection

The researcher has collected Explicit Primary & Ancillary Secondary Data from the company's unique & specialized design cell as antecedently discussed (case selection & unit of analysis have been chronicled in earlier Sections 4.1.5 & 4.16). In order to ensure validity & reliability of questions and answers (refer full Case-Study-Questionnaire, henceforth called C-S-Q), all data & findings have been verified through a number of tactics discussed in earlier Section 4.1.3. The substantiations are referenced in Appendix A. It may be noted here that Interviews & Interactions with team members have been done at individual members' convenient time, so as to ensure no disturbance to their official work. Also, the researcher has not divulged the names of the persons observed/interviewed/interacted with, without their written permission, in the case study report. Further the researcher has not used the data collected from this case study for any purpose other than the requirements of this research.

5.1.2.1 Explicit Primary Data Collection

The researcher, has *Interviewed, Observed & Interacted with the Team Members* to collect & document Primary Data (refer Appendix A for substantiation details) as answers to the research questions, in order to understand the activities of the holistic piping engineering design management cycle that are being practiced in the Indian oil & gas industry.

5.1.2.1.1 Interview Protocol

The researcher has interviewed the team members & recorded the interview audio/video for members who have consented to the live recording. For members who did not wish to be directly recorded, the relevant data has been written in the researcher's notebook.

5.1.2.1.2 Observation Protocol

The researcher has duly observed the activities in the team and sought answers to the research questions, while being with the piping engineering design management team. The researcher has documented the observations in his notebook.

5.1.2.1.3 Interaction Protocol

The researcher has interacted with the team members, collected relevant data as & when required and recorded the findings in his notebook.

5.1.2.2 Ancillary Secondary Data Collection

During data collection phase, as & when required, the researcher has collected Ancillary Secondary Data (Department Organogram, Direct Reporting Relationships, Job Descriptions, etc.) from the *Company's published Design Standards/Philosophies, Designs, Drawings, Reports, Policies, etc*. and has been used in this study with appropriate references. Ancillary Secondary data (refer Appendix A for substantiation details) also has been used for understanding a brief history of the department, its philosophies and functions at the start of the case study.

5.1.3 Case Study Interview/Interaction/Observation

Case Study Questions have been asked in order to collect Explicit Primary Data (discussed earlier) through Interview/Interaction/Observation. The rationale that drove the framing of the case study questions came from the objectives of this research; the research questions and the descriptive qualitative case study with grounded theory approach has been found to be an apt fit to this research (refer discussions in Sections 2.1, 3.6, 3.7, 4.1, 4.1.3 & 4.3).

The present research objectives (refer Section 3.7) have been to find facts about the present state of affairs in Piping Engineering Design Management (PEDM), the research objectives & research questions require to find the existing challenges and how to overcome those. Since the objectives of this research have been to find ***what are being done, what are the areas of improvements & how to improve those***, the researcher has done textual data analysis using Grounded Theory approach (Charmaz, 2006) through the descriptive qualitative case study as discussed in earlier sections. Data analyses through grounded theory approach involves process iterations connecting movements between existing theory and the interview data, observation data & interaction data (Charmaz, 2006). Grounded theory approach is a systematic generation of theory from data that contains both inductive and deductive thinking & is most applicable when the researcher wants to - ***formulate hypotheses based on conceptual ideas, to discover the main issues and how to resolve them***. The questions the researcher repeatedly asks in grounded theory are **–** ***what is going on, what are the main problems & how these can be resolved***. These questions get answered by the core issues & their properties in due course of the research (Charmaz, 2006). Since in this research, the researcher has wanted to know, what are the existing practices that are going on, what are the issues & how these can be improved, ***hence, this grounded theory approach is best suited in this case***. Accordingly and inline with the reasearch questions discussed earlier, the ***case study questions have been derived*** *on* **what** *is going on,* **how** *that is going on &* **when**, **how** *the activities are connected,* **what** *are the problem areas,* **why** *do the respondents consider that as a problem area,* **how** *these can be improved, etc.* In line with this discussion the ***case study questionnaire (refer C-S-Q) has been arrived at through a 3 step philosophy – first***, the information required from the team members (Design Engineers/Managers) of the company's piping engineering design management team have been first grouped under the following *9 basic head-inquests* (refer **Table 5.1**): these are the preliminary/basic information-to-be-taken that the researcher kept in his mind during data collection); then in the ***second*** step, ***each of these 9 head-inquests had further multiple basic as well as further in-depth probing-inquests*** (refer **Table 5.2**); finally in the ***third*** step, ***multiple case study questions*** (refer ***C-S-Q*)**, the individual conversations led to ask more questions) have been used till the objective information (*minimum limit*: answers to the research questions & *maximum limit*: as much as practically possible to get), could be obtained from each of the sources. It may be noted here that due to the natural human tendency to differ from each other, the details of the required information that emanated from the responses, are varied and as such the multiple case study questions (refer full Case-Study-Questionnaire, named C-S-Q) have been suitably modified (while maintaining relevancy) corresponding to the individual responses; the answers to the questionnaire satisfied the present research questions given in Section 3.5 and thus helped to fulfill the research objectives.

(Table 5.1 follows in next page)

Table 5.1: Basic Information Required / Head-Inquests (Step 1)

H-I No.	Basic Information Required / Head-Inquests (H-I) [i to v]
1	The complete range of piping engineering design management activities typically done by the individual
2	The activities irregularly done by the individual & their linkups with the regular activities
3	Bottom-up managerial control
4	Top-down managerial control
5	Other input & output communications
6	Quality management approach & its associated activities
7	Areas of improvements
8	Inhibitors to improvements
9	Ways to improve

i. The H-Is in Table 5.1 have been the basic queries that needed answers. In many cases where the required information did emerge, but not fully from these basic Head-Inquests, additional Probing-Inquests (as depicted in Table 5.2) have been employed through even further Case Study Questions (refer C-S-Q).

ii. In order to ensure validity & reliability of questions and answers (refer C-S-Q), all data & findings have been verified through a number of tactics discussed in earlier Section 4.1.3. The substantiations are referenced in Appendix A.

iii. Interviews & Interactions with team members have been done at individual members' convenient time, so as to ensure no disturbance to their official work.

iv. The researcher has not divulged the names of the persons observed/interviewed/interacted with, without their written permission in the case study.

v. The researcher has not used the data collected from this case study for any purpose other than the requirements of this research.

Table 5.2: Probing-Inquests (Step 2)

H-I No.	***H-I to Further Multiple-Basic-Inquests (M-B-I)***	***M-B-I to Further In-depth Probing-Inquests (P-I)*** [i, ii]
1	What are all the different activities that you do on typical working days & why?	How & when do those activities start, flow through the links between the activities, and then end?, etc.
2	What are all the different activities that you do less frequently or are not typical & how?	Why & when are these less frequent activities required?, etc.
3	How frequently do you interact with your Boss & why?	How many Bosses you report to?, etc.
		What leads you to interact with your Boss & when?, etc.
4	What does your Subordinate report to you & why?	How many Subordinates report to you?, etc.
		What do you do with your Subordinate's report?, etc.
5	Apart from your Boss & Subordinate, who are the other people you communicate to & why?	How & when do you need to talk to them?, etc.
6	What do you do to check the quality of your output & when?	Do you do check it yourself or through some other person/agency & how?, etc.
		How frequently do you check the quality?, etc.
7	What are the challenges that you face in your work & how?	Why do you regard these as challenges?, etc.
		What do you do to counter these?, etc.
8	What leads to these challenges & how?	Why are the causes of these challenges not avoided/removed?, etc.
9	What do you think will help you to overcome these challenges & why?	How will those things help you overcome the challenges?, etc.

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i. These further probing-inquests have been suitably increased/customized depending on the responses till all required information, in line with this study's objectives, could be obtained as a minimum & in many cases exceeding the objectives, from each of the respondents (Appendix B); see C-S-Q (Section 5.1.3.1) for details on Case Study Questionnaire.

ii. In order to ensure validity & reliability of questions & answers (refer C-S-Q), all data and findings have been verified through a number of tactics discussed in earlier Section 4.1.3. All substantiations are referenced in Appendix A.

5.1.3.1 Case-Study-Questionnaire (C-S-Q, Step 3)

The *full set of questions* that have been asked to each of the team members, are referenced in this sub-section 5.1.3.1. As per the earlier discussed grounded theory approach, structured interviews have been carried out and each subsequent interview has been adjusted based on the findings and interpretations from each previous interview, with the purpose to develop general concepts or theories through data analyses. The answers to the present research questions (Section 3.5) emanated from these data collected and helped to *fulfill the research objectives* as detailed in subsequent Section 5.2. The case research has been printed in public domain (titled "Piping Engineering Design Management Scenario in a Top Oil & Gas Company") as one of the three research papers (refer Appendices E, F, G & H) of the researcher that have been published & presented to the world during the course of this research. All the case study questions that have been employed to obtain the explicit primary & ancillary secondary data are referenced in Appendix B. The case research including responses is referenced in Appendices E & G and the findings from the analysed data are detailed in Section 5.2. It may be noted that this particular company is named as "C" & the specific department as "D" here in order to guard against undesirable possible ignominious effects. All collected data including the questions and answers have been *recorded, transcribed and substantiated* (Appendix A). For ensuring the *validity & reliability* of questions & answers, all data and findings have been verified through a number of tactics discussed in earlier Section 4.1.3.

5.1.4 Data Analyses & Inference

This sub-section summarises the data analysis and inference process followed in this present case study.

The researcher has done Textual Data Analysis [1] using Grounded Theory approach on the answers to the research questions, as per the rationale earlier discussed in Section 4.1. Based on the findings, the researcher developed theory through induction from data in order to propose the model. The researcher has also cited limitations & further scope of research, if any. The collected data has been analysed (open coding, focussed coding, networks, families, links, dependencies, in-depth analyses, etc.) with the help of Atlas.ti software [2] as one of the means for improving reliability (Section 4.1.3) as detailed in the subsequent Sections. Constructivist grounded theory methodology, as discussed in earlier Sections 4.1 & 4.3, have been employed. Let us take a little further look into the analysing process.

The data analyses in Atlas.ti has been done using Codes. “Coding means categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data” (Charmaz, 2006). Grounded theory coding involves “two main phases: 1) an initial phase involving naming each word, line, or segment of data followed by 2) a focused, selective phase that uses the most significant or frequent initial codes to sort, synthesize, integrate, and organize large amounts of data” (Charmaz, 2006). During “initial coding, the goal is to remain open to all possible theoretical directions indicated by” (Charmaz, 2006) the researcher’s understanding of the data. Then later, focused coding is used “to pinpoint and develop the most salient categories in large batches of data” (Charmaz, 2006). A common terminology of coding may be define here as *In Vivo Codes*; these are codes of participants' terms, codified in the participants’ used words that may convey a meaning/dimension in terms of the research objectives and as such, in vivo coding can be employed in both open as well as focussed coding (Charmaz, 2006).

1: Textual data analysis refers to profoundly investigating each word, line or segment of data in tune with the research objectives; coding of data using textual data analysis is an integral part of grounded theory approach that has been employed throughout the entire process of this study.

2: Atlas.ti is a renowned data analysis software tool that is mostly used in qualitative researches around the world; it may be noted that this software only acts as a tool to segregate, categorise and link data, thus helping to managing data effectively but does not give the inductive solutions which can only emanate from the researcher.

The first phase is the *Open Coding that has been done by coding parts of text, sentences & paragraphs of the collected data, in Atlas.ti*. In the second phase *Focussed Coding has been done from the perspectives of the theoretical framework/lens, the existing constructs and search for any new finding* (Section 4.4). *Code Families* and *Code Networks* have been developed from the codes and their inter/intra/contra/cross-relationships [1]. It may be noted here that a few glimpses from the in-action coding are given in Appendix C for reference and the full Atlas.ti work record has been archived as substantiation.

There is a variety of schools of thought on the phases of grounded theory coding technique, however, Open Coding & Focussed Coding are generally accepted worldwide and therefore the present research followed Open Coding & Focussed Coding. Some other school of researchers call *Focussed Coding* as *Selective Coding* and some also sub-categorise *Focussed Coding* into *Axial Coding which is further sub-categorised into specialised Theoretical Coding* (Strauss, 1987; Strauss & Corbin, 1990, 1998). *Axial Coding* is for assigning categories/concepts to subcategories, with properties & dimensions (Charmaz, 2006). A "dense texture of relationships around the axis of a category" can also be called axial coding (Strauss, 1987; Charmaz, 2006). *Theoretical Coding* is a sophisticated/specialised focussed coding to specify relationships between categories (Charmaz, 2006).

Data analyses through grounded theory approach involves process iterations connecting movements between existing theory and the interview data, observation data & interaction data (Charmaz, 2006) collected as described earlier. The present case data analysis can be represented in three steps or levels. The first step has been the open coding, followed by the second & third steps.

1: Refer to footnotes in Page 122 of 298.

Both the second and third steps are focussed/selective coding and used axial focussed as well as theoretical focussed coding techniques. In vivo coding has been used in all three steps to eliminate misinterpretations. While the first & second steps helped the researcher in exploring & understanding the existing practices of piping engineering design management and the challenges/issues by developing the codes, categories & concepts, the third step helped the researcher understand the relationships of the codes to the challenges/issues that affect the design management output in the existing practices. In the first step, open coding has been done in parts of text/words, sentences & paragraphs of the collected data illustrating evidence of any kind of relevance to the questions; the coded data has been assigned labels for easy retrieval and categorisation (Miles and Huberman, 1994) by using open coding technique (Strauss and Corbin, 1990; Charmaz, 2006).

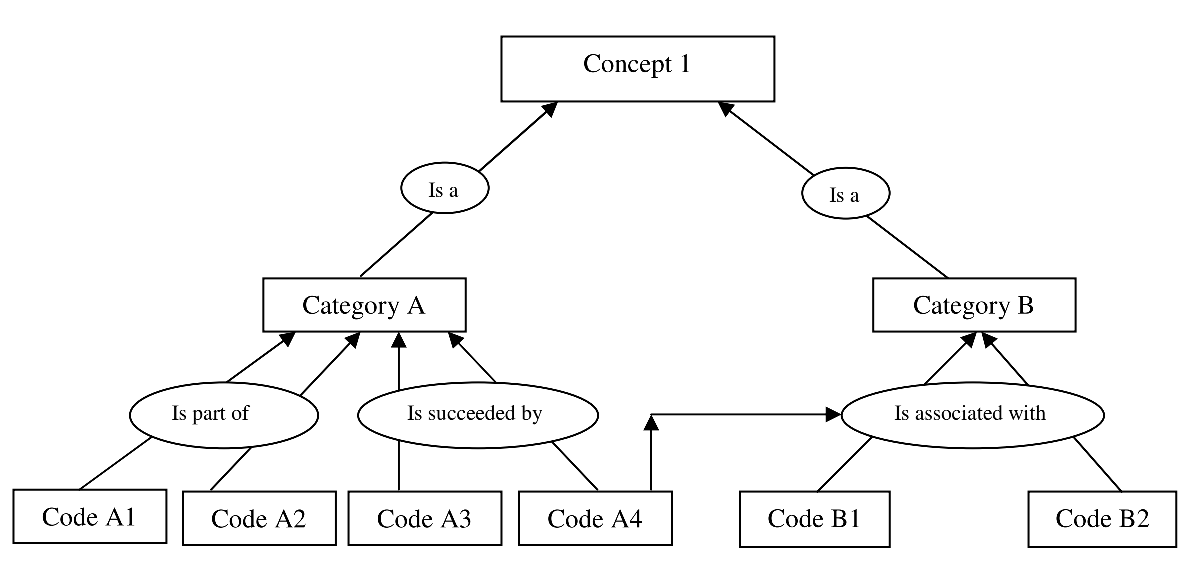
Data analyses has been done through grounded theory approach involving process iterations for movements between existing theory and the interview data, observation data & interaction data collected. The coding approach has involved perspectives of the theoretical framework/lens, the existing constructs and search for any new finding, in tune with the research objectives. The present case data analysis can be represented in three steps or levels. The first step has been open coding, followed by the second & third steps. Both the second and third steps have been focussed/selective coding and used axial focussed as well as theoretical focussed coding techniques. The third step differed from the second step by focussing deeper into the underlying relationships among the codes, categories & concepts; the identified inter-relationships, intra-relationships, contra-relationships and cross-relationships are linked as a pertinent root causal function. It may be noted that in vivo coding has been used in all three steps. While the first & second steps helped the researcher in exploring & understanding the existing practices of piping engineering design management and the challenges/issues by developing the codes, categories & concepts, the third step helped the researcher understand the relationships of the codes to the challenges/issues that affect the design management output in the existing practices.

Focussed/selective coding followed from the second step onwards. The focussed coding proceeded from perspectives of the theoretical framework/lens, the existing constructs and search for any new finding (Sections 3.2 & 4.4), in line with the research objectives. In this second step, similar codes having common attributes have been merged together to form conceptual categories & abstractions from the collected data (Strauss & Corbin, 1990). The codes have been categorised and linked as a 'belongs to' or definitional function of: *is a* [1] */ is part of* [2] */ is associated with* [3] */ is preceded by* [4] */ is succeeded by* [5] */ is property of* [6] */ etc.*; these case consolidations into code families enabled the reduction in the number of units working with (Strauss and Corbin, 1990) and thereby clarified the main themes emerging from the data. The codes have been grouped into categories using a bottom up approach as exemplified in Figure 5.1. It may be noted that the detailed discussions on what is coding, types of coding, etc. in the preceding paragraphs of this Section 5.1.4 are harbingers to the proceeding discussions.

The following retinues are the linking relations of codes as in software Atlas.ti; linking has been done in different dimensions as per suitability: inter-relation between objects, intra-relation within object, divergent cross-relation, antagonistic contra/clashing-relation, etc.; a specific relation can be of three formal properties/attributes–> transitive: able to take or be a direct object/code, symmetric: similar [sharing similar interest or comes/happens with] or asymmetric: non-similar [are different but may come/happen before or after or is integrated with the other object]:-

1. *is a = a transitive attribute link to signify: is itself a*
2. *is part of = a transitive attribute link to signify: is an element of a bigger object*
3. *is associated with = a symmetric attribute link to signify: is a concurrent companion of the other object*
4. *is preceded by = an asymmetric attribute link to signify: comes just after the other object*
5. *is succeeded by = an asymmetric attribute link to signify: comes just before the other object*
6. *is property of = an asymmetric attribute link to signify: is intrinsic to the other object*
7. *is cause of = a transitive attribute link to signify: is root causal producer of the other object*
8. *contradicts = a transitive attribute link to signify: opposes the other object*
9. *explains = a transitive attribute link to signify: analytically substantiates the other object's correctness*
10. *criticizes = an asymmetric attribute link to signify: analytically substantiates the other object's incorrectness*
11. *leads to = a transitive attribute link to signify: is intrinsic to & directs to the other object*

Figure 5.1: Code Categorisations



Terminologically, the categories as well as concepts are also codes and when a category is assigned, the reporting codes to that category become its sub-codes and this is same as when a concept code is created from two category codes, then the category codes become sub-codes or vice versa. For clarity of representation, codes / sub-codes / categories / concepts shall be henceforth called codes.

In the third step, efforts have been focussed in finding the underlying relationships among the codes, categories & concepts. Identified inter-relationships, intra-relationships, cross-relationships and contra/clashing-relationships are linked as a pertinent root causal function of *is a* [1] */ is part of* [2] */ is associated with* [3] */ is cause of* [7] */ contradicts* [8] */ explains* [9] */ criticizes* [10] */ leads to* [11] */ etc.* Comparing patterns and prospecting on other possible or rival explanations have been an intrinsic part of the analysing process. Code families have been linked and c*ode networks* have been developed based on the interrelationships as exemplified in Figure 5.2.

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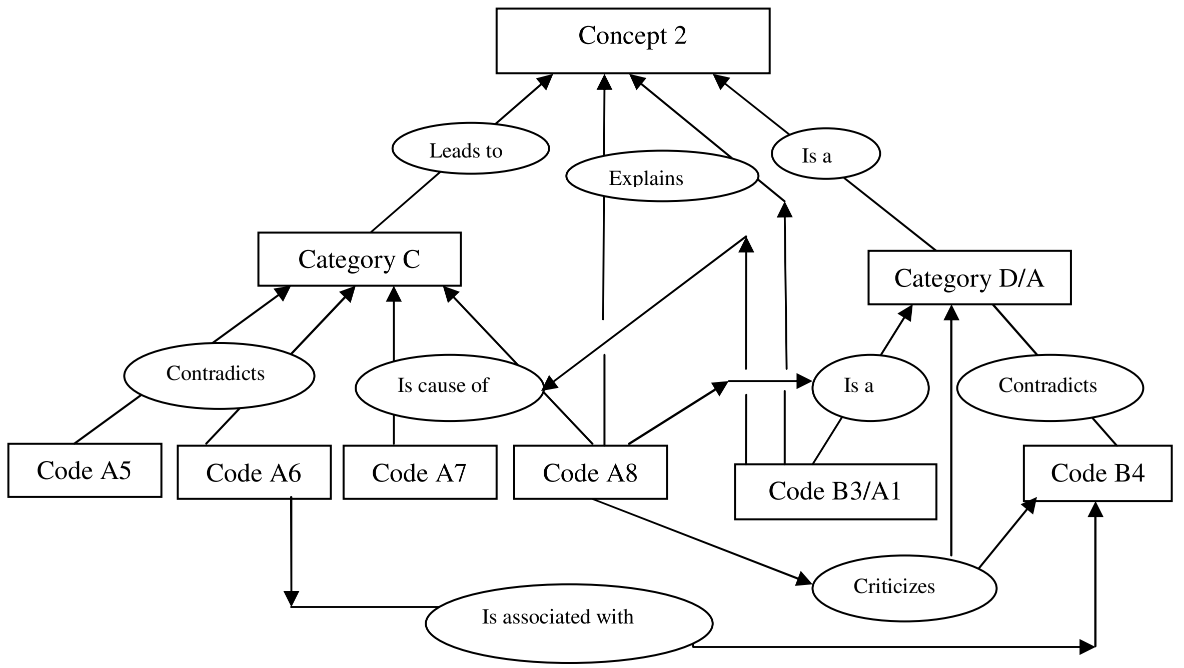
1 to 11: Refer to footnotes in Page 122 of 298.

Figure 5.2: Code Cognations



In the second and third steps, each category has been linked to the pertinent concept/s. If a category could not be associated with any of existing concepts or existing lens or existing constructs, then a new factor (new/additional concept) has been identified or thus emerged.

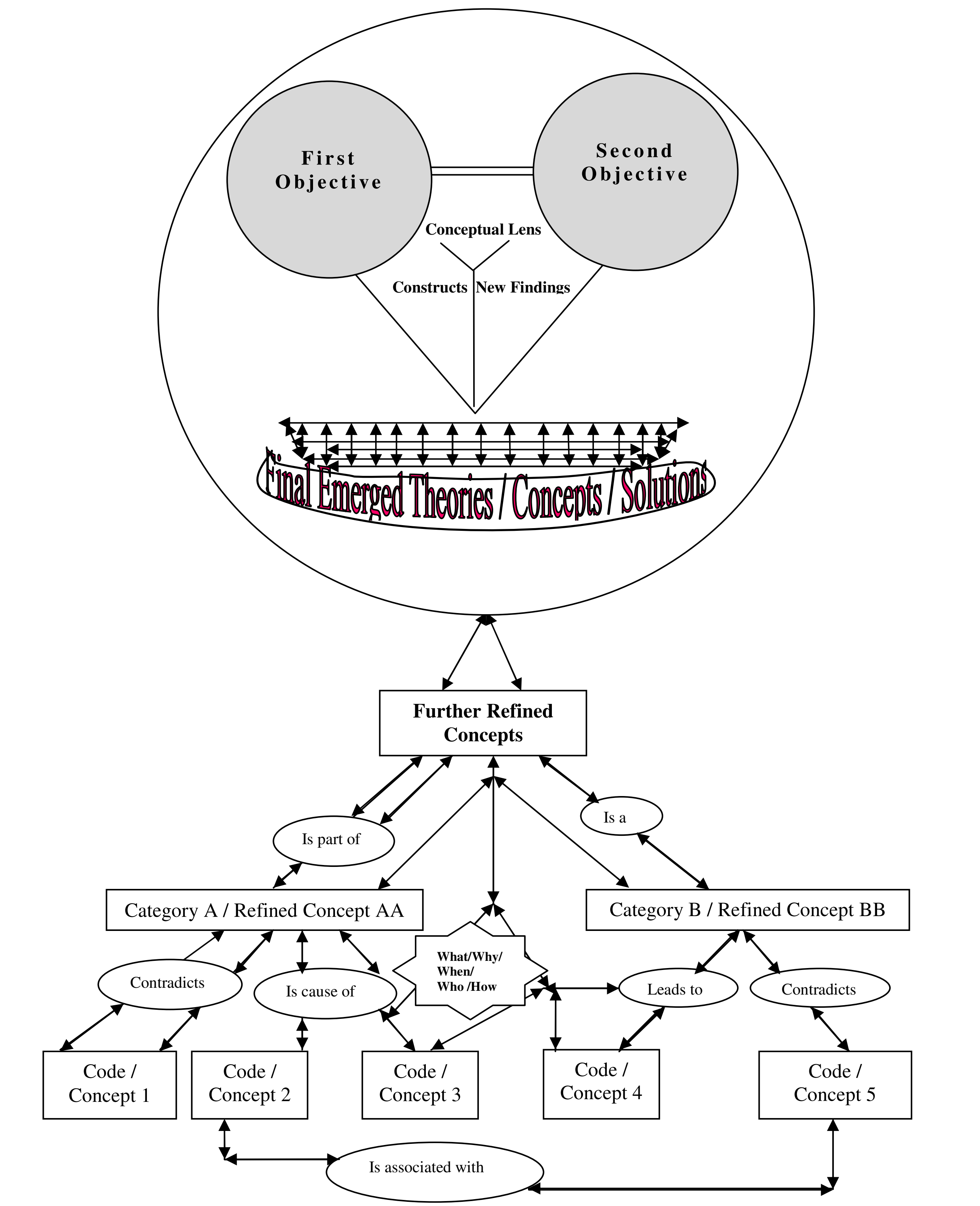
It may be noted here that while the second and third steps both involve focussed coding using axial as well as theoretical coding, the basic differences between them are in the different dimensional relationships (definitional function of: *is a / is part of / is associated with / is preceded by / etc.* in the second step versus root causal function of: *is a / is part of / is associated with / is cause of / contradicts / explains / criticizes / leads to / etc.* in the third step), depth of the relationships and the focus level (concepts in second step versus concepts as well as root causal relationships in the third step). For example: a particular statement "Gives non-technical non-piping related personal work to DE1 & DE2 in midst of their official work and then blames the SM due to delays in the work completion of DE1 & DE2" is open coded in the first step and is categorised as non-typical work and also a challenge in second step; in the third step, this code is found to be contradicting official work and is also found be a cause or an element causing a challenge to the overall time efficiency, thus affecting the desired output of the design management cycle, etc. As a result of the third step being so much more extensive, deep & root focussed than the other steps, any pertinent code or link that might have been missed in the earlier steps, is caught and integrated, thus rendering the iterative analyses cycles as fool-proof.

Further references on the coding part including operational definitions and a few glimpses of coding in-action can be glanced in Appendix C.

"Theoretical integration begins with focused coding and proceeds through all subsequent analytic steps" (Charmaz, 2006) & as such the concepts have naturally emerged and that is how the gradual theoretical build-up has been accomplished through those steps. The concepts themselves are the theory built-ups from the analysis. For example: many concepts emerged like the Concept 1 through the built-up approach in Figure 5.1 that are pertinent to the existing practices of piping engineering design management and the challenges/issues; further, in the third step many concepts emerged like the Concept 2 through the built-up approach in Figure 5.2 that are also pertinent to the existing practices of piping engineering design management and the existing/new/additional challenges/issues at the same or differing depths or relationships. These refined concepts/solutions are then again iteratively integrated to synthesise the final refined concepts/theory/solutions. Further, within case analysis has been performed for each step in two phases: conceptual & detailed, as one of the methods employed to improve quality (refer Chapter 4) by triangulation of perspectives on the same set of data (Patton, 1990) as discussed earlier. The conceptual analysis findings are intrinsically descriptive whereas the detailed analysis findings are naturally prescriptive (Tsang, 1997) through the multidimensional causal relations, from which the results/theory/solutions naturally emerged. The theory triangulation approach of two phases employed in each step is represented along with the gradual & iterative theory built-up process in exemplified Figure 5.3. Based on all of these preceding discussions, further detailed results of the case research are presented in the pertinent Sections 5.2, 6.1 & 7.1.

(Figure 5.3 follows in next page)

Figure 5.3: Phases & Emerging Concepts / Solutions



As discussed earlier, this interpretive study (basis clarified in Section 4.1.2) tries to understand phenomenon through the meanings that the people assign to that and the interpretive research methods are "aimed at producing an understanding of the context of the problem, and the process whereby the problem influences and is influenced by the context" (Walsham, 1995). Furthermore, the research study adopts a social constructivist point of view for reality, which implies that reality is socially constructed by the observer (Berger and Luckmann, 1967). Specifically, the research study employs an adapted version of the grounded theory (Glaser and Strauss, 1967), also referred to as the constructivist grounded theory (Charmaz, 2006). Its two processes, discovering and emerging, are understood as covering a meticulous interpretative process in which the resulting concepts eventually theory is constructed. This approach does not seek the truth as universal and lasting, but the research product is seen as a rendering or one interpretation among multiple interpretations of a shared or individual reality (Charmaz, 2006).

5.1.5 Quality Ensurance

The quality ensurance of this study in terms of construct validity, internal validity and reliability has been done as per the quality ensurance approach designed in earlier Section 4.1.3 of the Research Design Chapter. Further, in the preceding Section 5.1.4 it has been seen how the different levels of coding, within case analysis (conceptual & detailed – Section 5.1.4), theory triangulation (Section 5.1.4), employment of case study protocol (Section 5.1), use of software Atlas.ti (Sections 4.1, 5.1 & Appendix-C), archival of all evidences (Sections 4.1, 5.1 & Appendix-A), etc. have been carried out to ensure high quality (construct validity, internal validity & reliability) of the study. However, a brief on the quality measures are summarized in this section for ligature continuum.

Construct Validity:

Construct validity refers to establishing the correct or apt measures for concepts that are being studied (Yin, 2003). The constructs as well as all data & new findings have been analysed through the conceptual lens (discussed earlier in literature review Section 3.8). To ensure construct validity, two tactics are employed. First, two levels of analyses are undertaken during data analysis – conceptual and detailed, by triangulation of perspectives (also called theory triangulation) on the same set of data (Patton, 1990). The conceptual analysis findings are intrinsically descriptive whereas the detailed analysis findings are naturally prescriptive leading to solutions (Tsang, 1997) through the multidimensional causal relations, from which the results/theory/solutions naturally emerged. Secondly, the case study reports are reviewed by key informants as advocated by Yin (2003) and their feedbacks have been incorporated in the final research.

Internal Validity:

Internal validity is obtained by "establishing a causal relationship, wherein certain conditions are found to lead to other conditions, as distinguished from spurious relationships" (Yin, 2003). Internal validity includes interpretive and causal validity apart from the validity of other aspects (methods, data transcription, etc.). The problem associated with internal validity is that of spurious effects when there may be other determinative factors apart from those identified in this particular research design. In order to overcome this problem & improve internal validity, a number of tactics have been employed as discussed in the preceding Section 5.1.4. First, during case analysis the same data set has been analysed from different perspectives/phases – on conceptual as well as detailed levels. This is done as one of the methods to improve quality by triangulation of perspectives (also called theory triangulation) on the same set of data (Patton, 1990) through the multidimensional causal relations, from which the results/theory/solutions naturally emerged. The conceptual analysis findings are intrinsically descriptive whereas the detailed analysis findings are naturally prescriptive leading to solutions (Tsang, 1997). Secondly, the key participants have been requested to appraise, review & comment on the case reports and their comments are incorporated in the final research. All these steps ensured the identification & assessment of alternative explanations in order to ensure the causal validity. To ensure internal validity the researcher has been focused on the understanding as well as the interpretation of the processes that can be represented as causal relationships between concepts: one concept (or a cause) leads to another concept (or an effect). Moreover, review by the respondents and incorporation of their comments ensure elimination of any flaws in the detection & analysis, thus upkeeping the interpretive validity.

External Validity:

External validity is the ability to extend the research findings to a more general Case (Yin, 2003). This present research is intended to provide an insight into the probable relationships suggested. As discussed in Section 4.1, a case study methodology is expected to provide depth and not external generalizability. This research should then lead to additional valid research to confirm the relationships using measures that provide the necessary confidence in the results for generalizing. As discussed in Section 4.1, a case study methodology is expected to provide depth and not external generalizability. Therefore to generalize beyond this particular research area would require additional confirmation of results that is beyond the scope of this particular research and has been included as a further research scope in the concluding chapter. As such, external validity is beyond the scope of this particular research and is a future research arena.

Reliability:

Reliability test in a case study research implies that if any other research scholar does the same procedures, as employed by the previous researcher for conducting the same case study, he/she shall arrive at the same findings & conclusions (Yin, 2003). In this particular research a number of tactics have been employed to ensure consistency while applying the data collection & analyses procedures. First, the case study protocol has been used to guide the research process. The protocol is a major tactic in increasing reliability of a case study research and is intended to guide the researcher in the carrying out of the case study (Yin, 2003). The protocol comprised of instrument (i.e. the interview questions in line with the research objectives), as well as procedures and general rules that are followed. This ensured the consistency in the covered areas. Secondly, to reduce the likelihood of misunderstanding or forgetting the data and to allow independent analysis of data by other investigators, the interviews have been taped, transcribed and all original evidences are archived (refer Appendix A). Thirdly, the use of Atlas.ti qualitative analysis software allowed systematic and consistent analysis of qualitative data (Weitzman, 2000) that increased the reliability of research because the procedures can be repeated (Yin, 2003). Fourthly, the field notes that are taken by the research scholar have also been transcribed for future reference.

As discussed in earlier Section 4.1, it may be reiterated for clarity here that this present case (the employed Descriptive Qualitative Case Study with a Grounded Theory Approach) is for reaching the basic causal relations (Table 4.1 point-e: Case Study) leading to theory formulation only and is –

Neither: the verification or testing of generated theory/concepts to ascertain applicability (Table 4.1 point-d: Exploratory or point-h: Experimental),

Nor: 'sample to population' (Table 4.2 Purpose) or 'Testing of hypothesis' (Table 4.2 Research Questions) or 'External generalizability' (Table 4.2 External Validity).

The present study has involved identification of issues or challenges to engineering design management in the Indian oil & gas context and building of a new model catering to those issues (since previous researches have established that engineering design can be effectively managed if a model is built to cater to the identified issues); this study has verified that those seven issues (Table 3.1), that have been identified in other industries, are applicable to the Indian oil & gas context plus there are five additional challenges; the researcher has then built an integrated model to cater to all those identified twelve issues (Table 5.4), as described in the proceeding sections.

5.1.6 Data Archival

The evidential references to all collected original & raw data/records (in soft & hard forms), collected as part of this Case Study, have been archived as per date, time & source of collection, to serve as evidential references their original soft as well as hard forms – see Appendix A for details.

5.2 Data Analyses Findings

The preceding subsection 5.1.4 has explicitly detailed how the data has been analysed. This Section 5.2 summarises answers to the specific Case Study Questions (Section 5.1.3) in order to answer the Research Questions (Section 3.5) and as such, the research objective-wise findings are presented in sub-sections 5.2.1 & 5.2.4. As chronicled earlier, the analysis has been done in data analysis software Atlas.ti, initially with a grounded open coding approach followed by a focused thematic (research question specific) viewpoint. Referring discussions in Section 4.3, initially all collected data have been coded (lines as well as paragraphs have been coded) and then the codes have been categorised (sub-coded) as depicted in following Table 5.3. Apart from the detailed discussions on the analyses, codes, sub-codes, etc. in preceding Section 5.1.4, the operational definitions of all these codes and sub-codes alongwith a few glimpses of the in-action (Grounded as well as Focused) software Atlas.ti Codes, Sub-Codes, Networks & Families are given in Appendix C for reference. A few codes & sub-codes are shown here in Table 5.3 and a code with one sub-code in-action is presented in Figure 5.4 (it is noted that this Figure 5.4 has been taken from the Appendix C Figure C-17 where all other in-action analysis snapshots are given) as an example. *All details of codes, sub-codes, networks, families, dependencies, links, etc. have been referenced in Appendix C for further detailed insight into the analysis process through Atlas.ti software*.

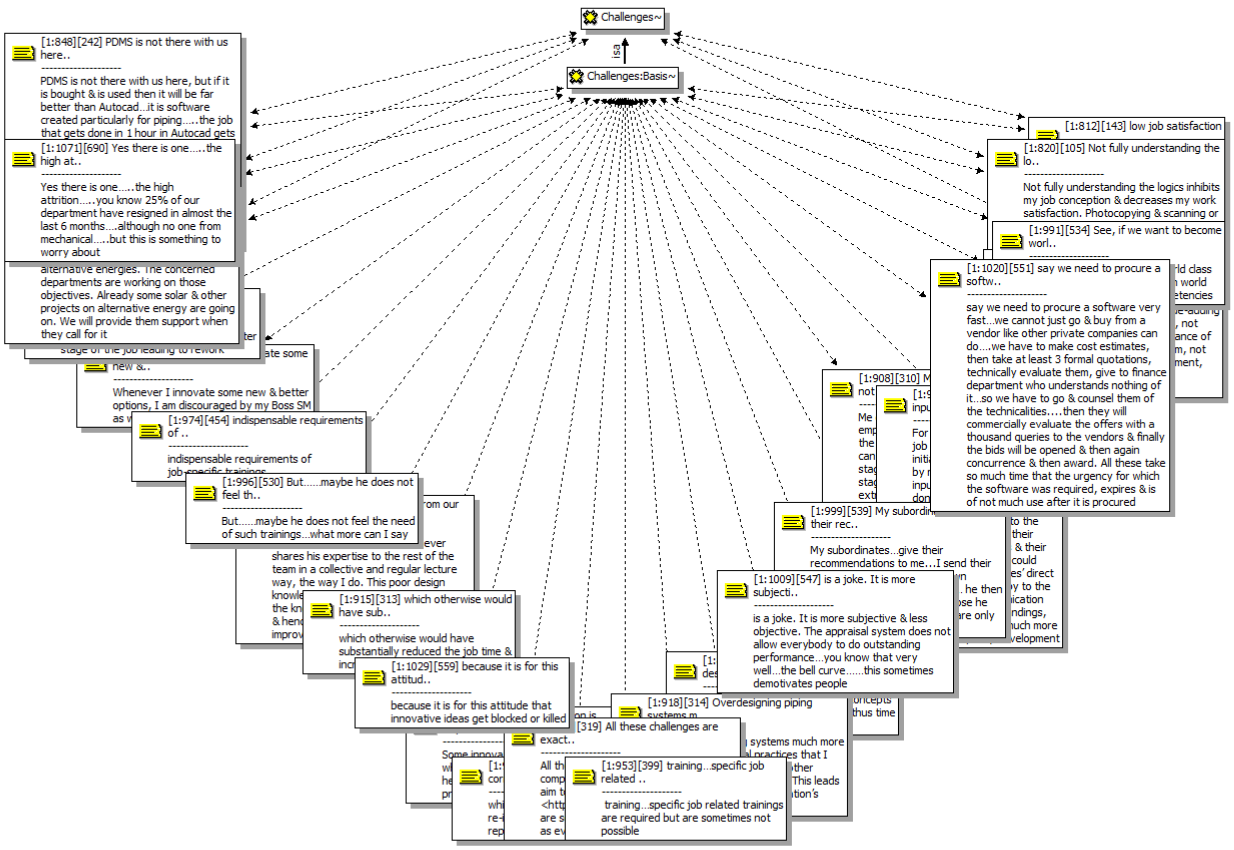
(Table 5.3 follows in next page)

Table 5.3: Few Codes & Sub-Codes employed through Atlas.ti Software
(Appendix C)

Code	**Sub-Code**
Work	Work:Typical
	Work:Non-Typical
Interaction	Interaction:Boss
	Interaction:Subordinate
	Interaction:Others
Quality	Quality:Process
	Quality:Depth
	Quality:Breadth
Challenges	Challenges:Elements
	Challenges:Basis
	Challenges:Countering
	Challenges:Barriers
	Challenges:Elimination

The focused approach of analysis elicited the existing practices specific to the piping engineering design management cycle being practiced in the company and also the areas of improvements in details. The existing challenges found, mostly matched with the seven issues of Table 3.1 that have been intriguing the PEDM cycle worldwide; additionally the focused approach yielded a few more (five) areas of improvements or challenges hindering the development through the PEDM business cycle and these additional challenges may be attributed to the unique Indian context of the subject. First the found existing practices of piping engineering design management are described. Secondly, the found areas of improvements are discussed alongwith inductive solutions. The interpreted *results are presented here, in a simplistic, condensed and easy to understand format*.

Figure 5.4 (Figure C-17 from Appendix C): One of the Codes: Challenges and its one Sub-Code Challenges:Elimination with its Relevant Neighbours



5.2.1 The Practices of Piping Engineering Design Management

This subsection addresses the first research objective by answering the first research question, i.e. how piping engineering design is being managed at present (refer Sections 3.6 & 3.7), through the built-up conceptual lens (refer Section 4.4). How the answers have been arrived at, has already been explicitly chronicled in the earlier sections.

The case selection rationale given in Sections 4.1.5 & 4.1.6 has confirmed three governing levels of PEDM – Strategic Management, Tactical Management and Operational Management (refer Section 3.2 for details). From the analysis of the collected data it has been found that the General Manager (GM) is responsible for Strategic Management, the Chief Manager (CM) for Tactical Management and the Senior Manager (SM) & his subordinates for Operational Management, consistent with the theoretical framework/lens (refer Section 4.4).

The GM, as a strategic manager to ensure that the company's vision and mission are implemented, takes a stroll in the department at 9:45 am every day to identify his subordinates who are late by more than 10 minutes in any two consecutive days and orders those latecomers to take half-day leave. The GM personally interacts with the CM on a regular basis (every two days on an average) to take feedbacks on ongoing jobs and discuss execution action plans & time schedules for new jobs. With his other subordinates and other people he interacts as & when he feels necessary, mostly through telephone and emails. Apart from these work that he does regularly, he also checks and approves cost estimates for projects, performance appraisals, training proposals, software/Code/standard procurement and maintenance contracts, contributes in company standard design philosophies, attends business meetings with prospective Clients, interacts with his Boss the Executive Director for budget approvals beyond his authorized limits and his foreign trips, provides telephonic advice to refineries when called for and reviews designs with his team for any particular project that his engineering judgement makes him feel like reviewing. The GM also approves the yearly performance appraisal ratings of each member under him, after discussions with the SM & the CM.

The CM receives jobs (projects) from Chief Managers of the company's various refineries mostly and rarely from other companies, through emails. He then reads the documents and studies the requirements. He then forwards those to the SM with instructions on carrying out the job highlighting any critical/special engineering requirement and the time schedule. In case the SM and his team requires any additional resources like additional software, Codes/Standards, refinery data or clarifications then he arranges that from the relevant vendor/refineries' Chief Managers. He personally interacts with the GM regularly every two days on an average) to take the GM's directions in executing strategies and with his subordinates on a daily basis through emails/phone/physically to seek feedbacks on work progress and discuss further action plans. He also reviews the design output of the design team (drawings/documents) together with the SM & the MLE for every job, gives his comments based on the applicable Codes/Standards/project specifications, re-verifies that the comments are incorporated and then sends those final outputs to the respective Clients (Chief Managers of refineries or other departments/disciplines). Apart from all these typical work, he also drafts training proposals, software/code/standard procurement and maintenance contracts. The CM's work also involves reviewing yearly performance appraisal ratings of his subordinates given by the SM, before forwarding that to the GM.

The SM, being responsible for operational management of PEDM, receives the design engineering jobs from the CM and delegates that to the MLE with the special technical instructions, if any and the priority (time schedule). The SM acts as a link between the design engineers and the Client (refineries/other departments) through the CM on matters of input clarifications & output delivery. In case a clarification is needed from a Client, the SM first consults the CM and as per CM's directive, he sometimes seeks the clarifications directly from the Client through phone/email and sometimes through the CM. The SM acts as a guide to the design team members on technical issues and also facilitates the design process by raising new Code/standard/training/tour requirements of his team members by liaising with the CM on his team's behalf. The SM mainly interacts personally with his subordinates on a daily basis and with the CM when some clarifications are needed or when a product is ready to be final reviewed. To ensure product quality, the SM reviews the design outputs together with his lead the Lead Design Engineer (MLE), with respect to the code/standard/project specification requirements and ensures that any corrections, if necessary, are done before taking the output to the CM. The SM also judges and rates the yearly performance of his team members, before forwarding those to the CM and then revising the ratings as per the CM's recommendations. Besides these, the SM also takes quotes from vendors for Code/standard/software purchases, software annual maintenance contracts (AMC) before handing over to the CM for further action.

The MLE is the "SM's key to the operational management level of each phase in the cycle of piping engineering design management; he leads two design engineers on the jobs he gets from the SM. His daily activities are - going through his current work list to see what is pending, following up with Design Engineer 1 (DE1) & Design Engineer 2 (DE2) on the work delegated to them, resuming or starting to work on piping analyses jobs in Caesar II, updating SM & CM the status of the jobs as & when asked for, seeking clarifications from SM & CM or from Clients/Other Disciplines (Civil/Electrical/Instrumentation) through SM & CM as per need, reviewing & commenting on DE1 & DE2's outputs, providing clarifications to them, reviewing his work (DE1's output + DE2's work + MLE's output), reviewing his own work (stress analyses) & technical discussions alongwith SM, incorporating modifications, then emailing that output to CM, jointly reviewing that work finally with CM & SM, incorporating modifications (if any) & then finally emailing the output to CM. After that he seeks new assignment from SM. The MLE's non-typical or irregular work activities are giving short lectures on design subjects of his expertise to others in the team, performance plans & reviews, monitoring issues of latest applicable Codes & Standards and coordinating Code/standard purchase activities, from enquiries to getting the latest Codes, controlled by the SM, recommended by the CM and approved by the GM. Performance plans & reviews of himself and his subordinates are also coordinated by him. The MLE interacts with his Boss SM many a times regularly for seeking clarifications, status reporting, output reviews & further assignments. Although his official Boss is SM, he also sometimes interacts with CM as & when called for clarifications, reviews and status reporting, through personal contacts, phones & emails. He communicates with vendors for enquiries of latest Codes/Standards" through emails/phone as per need" (Dutta, 2013c).

Both the DE1 and DE2 have been found to be doing the similar Operational Management activities that are as follows. They start their day from any unfinished drawings of their last day in office. "They develop the piping plan, elevation, isometric drawings, bill of materials or technical notes from the sketches/documents given to them by the MLE. They seek clarifications from the MLE as per need. On completion, they show & get the drawing/document reviewed by the MLE. Then they incorporate the modifications/corrections directed by the MLE before finally emailing the drawing to him. After this, they await further direction & input for their next job. The different activities that they do less frequently are - Scanning (digitization) of engineering books & standards given to them by their seniors MLE/SM/CM/GM & giving them the soft copies, photocopying non-work related bills given to them by CM/GM & giving them back and sometimes the CM/GM send them to post their things, self-knowledge improvement like studying the different piping codes & standards, specifications, etc. as & when they get time between two job assignments. They interact personally with their immediate boss the MLE many times daily for job inputs, clarifications, output reviews & handing over of outputs. They also interact with the MLE's other seniors SM/CM/GM as & when they are called to help for those irregular works. The check the contents of their outputs as per the technical information & the hand sketches/documents given to them by MLE, before handing it over to the MLE for review. They also do their performance planning and self-appraisals yearly as per the directives of the MLE/SM" *(*Dutta, 2013c).

5.2.2 The Areas of Improvements and Inductive Solutions

This subsection addresses the second research objective by answering the second research question, i.e. what are the areas of improvements in order to develop a Model of Piping Engineering Design Management (refer Sections 3.6 & 3.7) through the viewpoints of theoretical framework/lens, the existing constructs and search for any new finding (as depicted in anteceding sections). How the answers have been arrived at, has already been discussed extensively in the earlier sections.

Plenty of improvement areas have been identified through the grounded open and focused coding approaches; some areas have scopes of improvements and some absolutely need immediate improvements which otherwise have tremendous potential to erode the competitive advantage of the company. All of these improvement areas have been inquired in details from the participants on the root causes, the existing countering measures, if any, the barriers to overcome and the best possible elimination methods; the biggest challenge identified by the majority is the lack of a well-defined & systematic design management system and they think it is only an integrated model that can counter/cater to those challenges, they also explained how they think the issues can be catered to through that integrated model, also consistent with the theoretical framework/lens (Section 4.4). Further, the case study has been validated through the respondents (as chronicled earlier). Most of the challenges are observed to be exactly similar to the issues found by other PEDM researchers through their independent researches worldwide as discussed earlier (Table 3.1) but a few (five) additional challenges are also found that may be unique to the Indian context. Table 5.4 presents these challenges and the best feasible solutions that are obtained from an in-depth inductive analyses of all challenges and their probable practical solutions, as extensively described earlier. The challenges and the solutions entail some key terms (the ***bold & italicised*** letters in the Solutions column of Table 5.4), named Owners and Operators respectively, that are depicted in Table 5.4 & further detailed in Sections 6.1 & 7.1 wherein the integrated model is described.

Table 5.4: Challenges & Solutions

Sl. No.	**Challenges/Issues**		**Solutions**
1	Design Product Engineering Side	Higher management (CM/GM) severely lack ***Objectivity*** in matters of technical decisions as well managerial decisions owing to their lack of managerial competence and absence of a well-defined PEDM system, thus affecting the **Aesthetics, Functionality, Buildability and Economics** of the PEDM product outputs as well the employees' efficiency and job-satisfaction.	A ***PEDM system*** with an ***Objectivity-Ensurer***
2		Exploitation of the ***Positive Side of Uncertainty*** is seldom practiced, thus losing potential competitive advantage.	A ***PEDM system*** with an ***Uncertainty-Positiviser***

Sl. No.	Challenges/Issues		Solutions
3		***Interdiscipline-Dependancy*** based Design Optimization is never done and hence combination of **more than one analysis type** like Hazard Identification & Operability (HAZOP) Studies and Mechanical Audits are out of question; this is affecting the economics of the design outputs and the profitability of the company.	A ***PEDM system*** with an ***Interdisciplinary-Optimizer***
4 (new)		Sometimes issuing Design Outputs without ***Checking*** at least once, owing to pressure from Client (other departments/refineries).	
5	Design Process Side	***Management** of **Design Knowledge*** is not at all **Transparent** , thus there is no **Balance between Top-Down & Bottom-Up** management grooming methods **in each of the Six Phases** of the design cycle, that could have easily being done **through Sequencing-Controlling-Monitoring**; this is resulting in poor succession planning that in turn is dooming the company's as well as the country's future.	A ***PEDM system*** with a ***Transknowledge-Balancer***

Sl. No.	**Challenges/Issues**		**Solutions**
6		There is no focused *or* ***Effective Communication*** for – Conflict Resolution by **Shared Understanding & treating Assertions as Facts** or **Dynamic Bi-Directional Feedback Integration**, or efforts for **Team Integration**; this is ensuring time loss, opportunity loss and revenue loss.	A ***PEDM system*** with a ***Multi-Integrative-Communicator***
7 (new)		**Very low *Accountability* in high level** of management, resulting in the strategic manager not formulating any development strategies and discouraging growth efforts.	
8		***Systematic Innovation Integration*** in the Three Governing Levels existing in each of the Six Phases **through Three Management Layers** – i. Enabling Technology Layer, ii. Solution Layer & iii. Interface Layer **by analysing Explicitness, Novelty, Importance & Usability** of each innovative suggestion/practice, is seldom encouraged, thus ensuring the erosion of the company's competitive design edge.	A ***PEDM system*** with an ***Innovation-Integrator***

Sl. No.	**Challenges/Issues**		**Solutions**
9		There is no effort towards Rework Minimization by ***Identification & Elimination of Non-value adding activities***, thus reducing the overall efficiency of the PEDM Cycle.	A ***PEDM system*** with a ***Rework-Minimizer***
10 (new)		There is no ***empowerment*** of junior employees, initially under supervision to move on the unsupervised authorities; this is affecting mutual trust & employee confidence besides eroding job satisfaction.	
11 (new)		***Lack of required Technical Competencies*** of the Engineers and ***Managerial Competencies*** of the Managers, affecting the Output Qualities, Reputation and misalignment of the department from the Company's vision and mission.	A ***PEDM system*** with a ***Professional-Developer***
12 (new)		***Subjective performance appraisal system*** that ensures that someone has to be axed in order for others to be benefitted.	

In tune with the philosophy, rationale & methodologies chronicled in earlier Section 4.1, this research is limited to only one organization that has been selected as a representative of the oil and gas industry in India based on the fact of that company being the largest (in terms of revenue, size as well as market share) among all oil & gas companies in India; however, a point to be noted here is - this research establishes that the challenges of design management outside India (seven) are applicable to the oil & gas industry in India plus there are some additional (five) challenges specific to the Indian oil & gas context and therefore, theoretically it can be inducted that most/all of the found out issues and their solution model proposed through this research shall be applicable to the other oil & gas companies as well (the researcher, through his previous work experiences, has also experientally observed these issues to be plaguing design management in some other oil & gas companies in India as well as abroad); further, as discussed in Sections 4.1.3 & 5.1.5, external validity is beyond the scope of this particular research and is a future research arena.

In this Chapter the actions and findings from the particular study have been discussed. The proceeding Chapter describes the modelling mechanism for gradually building up a new model from the findings and also depicts the fulfillment of the research objectives.