ISSN 2250-3153

Developing an Instrument to Understand Impact of Knowledge Management on Equipment Reliability

Tarapada Pyne*, Utpal Baul, Radhey Shyam Jangid****

* JSW-ISPAT Steel Ltd, Dolvi, Raigad, Maharashtra,India.
** Department of Management, Birla Institute of Technology Mesra, Ranchi, India.
**Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai, India.

Abstract- The previous research in Knowledge Management (KM) concentrated on the development of the subject of Knowledge, the creation of the maturity models, the process of implementation etc. as evident in the literature. The related past instruments are not applicable for evaluating the relationship of KM with industrial equipment reliability. The purpose of this paper is to develop a validated instrument to prove the relationship of organization-wide 'failure factors (FF) of KM' with 'equipment performance'. A survey among the expert professionals attached to the inter-disciplinary tasks of managing assets' reliability reveals that 116 items in 4 constructs suit this core specific purpose. The empirical results had provided the strong support for the models. It is expected that the proposed model would help in any future study on the 'impact of KM' on 'asset management'.

The various 'factors of equipment's failure' as commonly encountered and applicable in any sector of industry were adopted and then these factors were validated with the responses from the industrial and specialized workforce either working on or associated with the equipments' mal-functions. The responses from experienced 'reliability experts' had been statistically validated for consistency and reliability. The interplay and the inter-dependence of the failure factors are analyzed along-with the various 'independent factors' those have bearing on the equipments' failure. The relationship of these independent factors with associated Knowledge Gap (K-Gap) and/or Knowledge Risk (K-Risk) and/or Knowledge Strength (K-Strength) may guide then to formulate the equipment-oriented KM strategy.

Index Terms- Knowledge Management, Equipment Reliability, Failure Factors, Knowledge Gap, Knowledge Risk, Knowledge Strength.

I. Introduction

The review of previous research literature indicates that the major thrust of KM was either as an 'academic study' or the more specific to 'Information Technology (IT) and enabling technology' in order to relate the overall organizational perspective and goal. The effort was not fully intended to look for a related instrument that would fit and can be used in 'equipment oriented KM'. The purpose of the current instrument was to capture expert views on equipment's performance reflecting cultural, human, process aspects of the organisation. The failure factors listed by Weber [1] have been widely used. Knowledge concept as defined by Gordon [2] is applied in order to get feedback from participants on their understanding of equipment's operational knowledge. The questionnaire then formed to have a feel on the impact of both the 'macro level' and 'micro level' factors [3] on reliability.

A. Objectives

The objective of this exercise was whether or not an effective instrument could be developed to capture expert's attitude towards equipment reliability and the reasons behind non-performance of equipment. The proposed instrument was expected to be statistically valid and consistent. The responses must give an indication of impact of knowledge management on equipment reliability.

B. Motivation of this Study

The process industry's main value-adding production entities are the critical process equipment, through which the input-resources (with low value) are transformed to the output products (with higher value). Any break of this process of value-adding chain due to the malfunction of assets/equipments ultimately affects the production-volume and the production-quality due to the disturbed process in case of breakdown and/or unhealthy running of equipment beyond/below the designed specification.

The causes of these malfunctions may be any or more of the reasons e.g. the deficiency in engineering, variation in manufacturing process, the environment not conducive to the production and assembly process, the flaws in commissioning and installation etc. and the 'human unreliability' in each stage. Among the total 'human errors', 'human unreliability' in the operation and maintenance stage occur in significantly large proportions due to the knowledge 'gap' and/or due to the knowledge 'risk' of the demotivated employees [3]. The human unreliability plays an important role since there is a direct correlation between the 'equipment reliability' and the equipment-specific 'skills and knowledge' of equipment operators. The positive attitudes of employees lead to more reliable equipment [4].

With this background, an attempt had been made here to study whether or not there is any possible link between equipment reliability and management of knowledge through empirical study formulating specific sets of questionnaire, shown in annexure-A.

II. PROPOSED INSTRUMENT AND TARGET FIELD OF STUDY

The tool to improve organizational performance, to understand the ‘overall success and benefits’, the ‘organizational readiness’ to adopt KM , the various knowledge maturity models, the SECI (Socialization, Externalization, Combination and Internalization) model, the instrument to evaluate KM projects etc. are the most accepted latest matured models [3]. Davenport and Prusak provided a balanced perspective of social, political, and technological issues in successful implementation of organizational knowledge initiatives. The need of leadership to champion the successful adoption of KM and the right organizational culture was propagated by Davenport and Prusak [5].

The current study is more specific and related to value-adding production process equipment. It is important to briefly explain here the span of the business process being discussed with a focus on the current area of study. It is illustrated in the sketch given in figure 1.

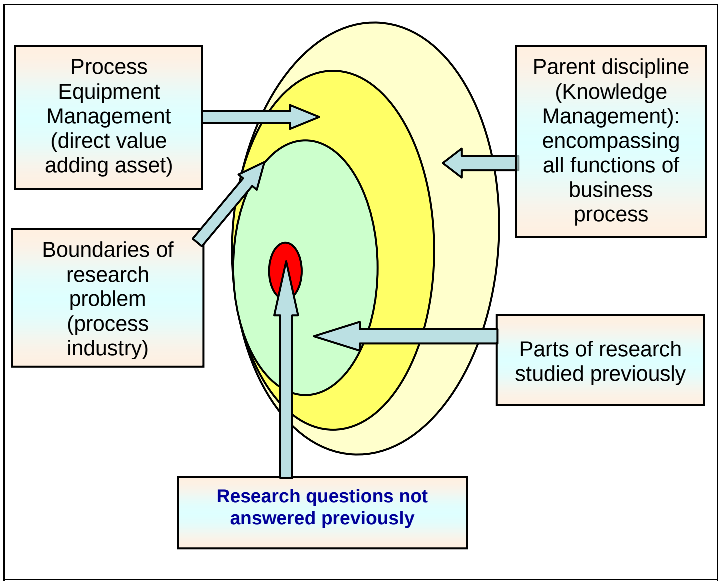

Figure 1: Subject Area of Study

III. KNOWLEDGE ‘GAP’, ‘RISK’, ‘STRENGTH’

Understanding the concepts of knowledge gap, risk and strength is vital as the entire study moves around these fundamentals. The characteristics, as first conceived by Gordon [2] and team in AKRI (Applied Knowledge Research and Innovation), are explained below.

A. Knowledge ‘Risk’

Change of technology, HR issues, changes in organization culture etc. may create knowledge risk. The important characteristics [3], [2] related to the knowledge ‘risk’ are:

1) Certain knowledge items need early attention as, if delayed the organization may either lose those or knowledge may become obsolete.
2) Risk may continue to change over time and not a constant phenomenon, restricting firms thus to mitigate risk with the similar approach and methodology.
3) Changes in technology may either increases risk as the special type of knowledge is required for mitigation or decreases risk as some pieces of knowledge become less important putting existing knowledge into risk.
4) Removal and recruitment of employees may lower risk, but the reduction of staff may increase risk.
5) New projects, plant expansion etc. may demand new knowledge.

B. Knowledge ‘Strength’

The amount of knowledge of a subject a person can possess is the ‘Strength’ of knowledge. For a certain task, a common person knows something, but an expert may be required for any difficult situation. The important characteristics [3], [2] related to the knowledge ‘Strength’ are:

1) The knowledge ‘Strength’ is something like someone knows the answer but does not have the knowledge to derive the answer.
2) The ‘Strength’ of knowledge is needed to estimate correctly the knowledge ‘gap’.

C. Knowledge ‘Gap’

The knowledge ‘Gap’ is the difference between the ‘knowledge needs’ and the ‘knowledge already in possession’. Gap is unwanted and needs to be bridged through effective KM process. The important characteristics [3], [2] related to the knowledge ‘gap’ are:

1) The organizations may itself be responsible for creating the knowledge gaps. Employees’ promotion, redeployment to other assignment can make specific knowledge related to current assignment inactive.
2) Gap may be created in case of any new expansion, technological upgrades.
3) Employee’s ignorance to the enabling technology, the ego, the resistant to change etc. may create undesired gaps.

IV. SOURCE OF EQUIPMENT UNRELIABILITY AND THE IMPORTANCE OF KNOWLEDGE

The focused areas [6] of equipment reliability issue in any organization are:

1) Management Systems (include areas like performance, inspection, maintenance standards, workflows, KPIs (Key Performance Indicators), audits, skills improvement and training, employee recognition etc.).
2) Management Support (should be continuous, consistent, at the highest and all levels, management understands the importance of KM and Reliability).
3) Design and Engineering Practices (should follow global engineering standards, OEM master databases, should practice design for operability and maintainability).

4) Operation and Maintenance Practices (to focus on reliability improvement programs e.g. Risk Based Inspection (RBI), Reliability Centered Maintenance (RCM), Root Cause Analysis (RCA) etc; on right maintenance strategy e.g. Preventive Maintenance (PM), Predictive Maintenance (PdM); failure reporting, aging and wear management, spare management, Standard Operating Procedure (SOP) and Standard Maintenance Procedure (SMP) etc.).

Process industries various functions including design, engineering, operation, maintenance, human resources and various other support functions if not managed in the right way then there would be a room for equipment unreliability. The most unquestionable reality is that these functional areas are to be effectively manned and jobs are to be performed by employees only. Here comes the importance of employee's knowledge.

V. DEVELOPMENT OF INSTRUMENT

In order to develop an instrument, it is imperative to explain in brief the ideas behind the preparation of questionnaire since the study is intended to find out whether or not there is a relationship between equipment reliability and knowledge management. Reliability (Q) is a function of equipment Failures (F) which is again a function of either Gap (G), or Strength (S), or Risk (R). Due to the independent variables [3] like 'motivation level', 'organizational culture', 'basic knowledge' etc., there is a possibility of either Knowledge 'Gap' or 'Risk' or 'Strength'. Due to the Knowledge 'Gap' or 'Risk' or 'Strength', there is possibility of equipment 'Failure' and due to the 'Failure', there is every possibility of equipment's 'Unreliable' performance.

VI. PARTICIPANTS

The target focused group was Operation and Maintenance Managers, Reliability Engineers and HRD/HRM Experts both from industry as well as from academics. Companies include various sectors like refinery, petrochemicals, steel and OEM for process industries. The participants are expected to have good exposure in operation and maintenance of equipment, reliability and training needs. The table-1 below gives an indication of categories and sources of feedback recorded.

Table 1: Summary of Target Group and their Background

Sample Size: 113			
S.No.	**Data Grouping**	**Sub-Grouping**	**%**
1	Industry type	Academics/ Institutes	5.32
		Consulting	19.15
		Energy	2.13
		Petrochemical/ Refinery/ Oil and gas	26.60
		R&D and Engg.	4.26
		Steel and Metals	42.55
2	Functions	Academics	5.32
		Consulting	19.15
		Industry	54.26
		Reliability Managers - interdisciplinary	21.28
3	Experience	< 5 years	22.34
		5-15 years	22.34
		> 15 years	55.32

VII. PROCEDURE

The data was collected from May 2010 to December 2010 using emails, through a dedicated web-site [7]. The intention of this survey was conveyed by email as well as reflected in web-site before starting the web-based questionnaire, with specific hints to participants on the subject-topic. Participants were able to open the questionnaire in web-site itself (the majority of the feedback) and then complete the same. The data automatically got saved in a report file, which later on exported to an excel sheet. Responses in hard copy were taken in related research conferences and collected on the spot.

VIII. MEASURES

The measurement scale is 5 point Likert-type scale ranging from 1 (= strongly agree) to 5 (= strongly disagree). The instrument is presented in annexure–A. Participants were asked to respond against each statement using this scale.

This study developed a preliminary scale consisting of 116 items. Four sub-constructs, one for macro level factor items, and another three each one for knowledge 'gap', knowledge risk, and knowledge 'strength' are formed. First construct consists of 15 factor items; the second construct is based on the 'knowledge gap' and contains 16 items; the third construct is based on the 'knowledge risk' and contains 44 items; and the forth construct is based on the 'knowledge strength' and contains 41 items.

In statistical analysis, from 'Strongly Agree' to 'Strongly Disagree' range has been considered varying from +2 (Strongly Agree) to -2 (Strongly Disagree).

IX. QUESTIONNAIRE OBJECTIVES

Literature survey reveals that the available tools are on the overall organizational general KM perspective and no tool can be taken to directly apply in this study. This specific instrument is developed in order to tap the right response related to 'macro' and 'micro' level failure factors since the current study is intended to explore the relationship, if any, between employee's knowledge on process equipment and the failure factors of KM. The aim was to get feedback on the factors responsible for either the knowledge 'gap' or 'risk' or 'strength' specific to equipment's performance. The intention was not only to extract the failure causes related to the operation and maintenance issues, but also from the other support functions of the organization in order to understand the extent of those functions' involvement in failure of the industrial value-adding production equipment.

The instrument is applied to get right responses related to the 'equipment knowledge' from the experts in the field. The KM failure factors (FF) as listed out by Weber [1] had assisted to form base work. The core 'conceptual' approach of KM by Gordon [2] is applied to the various failure factors of KM to understand the impact on knowledge gap, risk and strength related to 'equipment operational knowledge'. The separate responses have been captured to get a feel on the impact of 'macro' level factors [1] on the manufacturing equipment's

ISSN 2250-3153

failures. The dependency on 'micro' level factors and their influence on equipment knowledge 'gap', 'risk' and 'strength' had been asked separately to understand the participants' general opinions of knowledge-related issues on the performance of manufacturing assets.

X. DATA ANALYSIS

The instrument was administered in a survey-field comprising of expert knowledge-source of 'equipment management' and then tested for validity and reliability to the extent to which the factors relate to the opinions of experts.

Statistical analysis of data reveals that the instrument is consistent and valid. Cronbach's α and item-to-total correlations are applied. The α coefficients for the four sub-constructs FF, G, R and S are found to be 0.800 (annexure-C), 0.854 (annexure-D), 0.929 (annexure-E) and 0.930 (annexure-F) respectively. The coefficients exceed the accepted threshold value of 0.70 [8]. Each sub-construct was also tested and good convergence and the internal consistency were found. The coefficients of the independent variables are also statistically significant.

A. Influences of K-Gap, K-Risk and K-Strength on Factors

The relationship of 'independent micro' factors along-with their influences with K-Gap, K-Risk and K-Strength is tabulated in annexure-B [3]. Responses have indicated that Managerial Responsibility (FF1) has a role on the issues of Motivation (IM), Organizational Culture (IC), Promotion (IP), Technology Improvement (ITI) and all have either contribution or influence on K-Gap, K-Risk and K-Strength. As an indication, the absence of 'Managerial Responsibility' has influence on 'Motivational' issue and the lack of motivation can increase K-Gap and decrease K-Strength.

B. Data Presentation

All the responses were analyzed here for their consistency, reliability and the response-dominance.

B.1 Macro Level Factors

B.1.1 Consistency and Reliability Analysis

The macro level failure factors (FF) from FF1 to FF15 are found to be completely consistent and reliable with Cronbach's alpha value 0.80 [3]. The importance of each question, the item to point correlation, is also checked with Alpha value showing very close to 0.80. These responses are based on the basic thought process of relating these factors on the equipment reliability i.e. whether these factors influence K-Gap, or K-Strength or K-Risk or not. Further whether these macro level factors also relate to individual question-item response or not, is also checked combining the items related to each FF and finding out Cronbach's Alpha where more than one item response is available. The consistency is found to be on positive side with values from 0.55 to 0.87 as shown in annexure-C.

B.1.2 Summarized Response Analysis

There is strong agreement that all the factors are equally responsible for influencing (creating) K-Gap or K-Risk and influencing K-Strength, each carrying average 65% positive response (with 'absence of manager's responsibility' as high as 80.5%, 'lack of knowledge specificity' as 78.8%, 'separation of human-process-technology' as 72.6%, 'barriers of knowledge transfer' 74.3%, 'lack of leadership support' 72.6%. Disagreement responses contribute to average 13% only and the rest 22% of responses are neutral.

B.2 Knowledge Gap

The 'Knowledge Gap' influencers can be referred to the questionnaire in annexure-A.

B.2.1 Consistency and Reliability Analysis

This construct is made to have the responses on how the 'independent' factors influence the 'Knowledge Gap'. The Cronbach's alpha value exceeds 0.854. The importance and the consistency of each item are also above 0.83 as shown in annexure-D.

B.2.2 Summarized Response Analysis

The construct is developed to study the influences of 'independent factors' like 'motivational issue', 'organizational culture', 'learning culture', 'fear of contribution'. There is a strong agreement as reflected in each item, carrying average 71.4 % positive responses and indicating the strong influence on K-Gap. Disagreement contributes to average 9.6 % only and the rest 19 % of responses are neutral.

B.3 Knowledge Risk

The 'Knowledge Risk' influencers can be referred to the questionnaire in annexure-A.

B.3.1 Consistency and Reliability

This construct is made to have the responses on how the 'independent factors' influence the 'Knowledge Risk'. The Cronbach's alpha value exceeds 0.93. The consistency of each item is also above 0.92 as shown in annexure-E.

B.3.2 Summarized Response Analysis

The construct is designed to study the influences of 'independent factors' like 'promotion and redeployment', 'lack of integration', 'knowledge transfer mechanism', 'perceptions on value', 'inadequate technology', 'absence of stake holder's inputs', 'lack of integration', 'experience', 'lack of inter-functions collaboration', 'centralized memory', 'fear of contribution'. There is a strong agreement as reflected in each item, carrying average 60.9 % positive responses and indicating the strong influence on K-Risk. Disagreement contributes to average 17.3 % only and the rest 21.8 % of responses are neutral.

B.4 Knowledge Strength

The 'Knowledge Strength' influencers can be referred to the questionnaire in annexure-A.

B.4.1 Consistency and Reliability

This construct is made to have the responses on how the 'independent factors' influence 'Knowledge Strength'. The Cronbach's alpha value exceeds 0.93. The consistency of each item is also above 0.92 as shown in annexure-F.

B.4.2 Summarized Response Analysis

The construct is designed to study the influences of 'independent factor's like 'motivational issue', 'grasping difficulty', 'experience', 'on-job exposer', 'basic knowledge', 'knowledge context', 'knowledge transfer mechanism', 'technology improvement', 'organizational culture', 'learning culture'. There is a strong agreement as reflected in each item, carrying average 64.7 % positive responses and indicating the strong influence on K-Strength. Disagreement contributes to average 14.2 % only and the rest 21 % of responses are neutral.

B.5 Independent Variables

The reliability and the internal consistency analysis of 'independent variables' are also carried out and found to be statistically significant and details available as annexure-G.

C. Discussion

The means, standard deviations, and Cronbach's alpha relationships among the study variables are shown in details as annexure-C to annexure-G. In this study, the relationships between the 'attitudes' toward KM and the macro factors, 'attitudes' towards micro level independent factors and the relationships of both macro and micro factors with equipment knowledge gap, risk and strength are described. There is an indication of strong relationships as exhibited.

XI. CONCLUSIONS

This study effort tries to explore an instrument and then validate the same for any influence of equipment oriented knowledge i.e. the impact of knowledge of employees (not necessarily KM process and related initiative in the organization) on the reliability. It appears that there is a strong relationship which is exhibited in models [3]. The organizational issues of 'people management' appeared to be the most important focused areas of 'equipment management'.

The instrument is tested statistically to establish high degree of confidence in the reliability and validity of scales. A new concept of KM, management of equipment knowledge, which has impact on or specific relation to equipment reliability is shown here. It is expected that the study would guide the enterprises to look equipment's 'imperfections', 'innovation' in operation, 'system'/ 'interfacing' issues of various business functions in an entirely different perspective and the company-wide management of knowledge in 'practical sense' of up-keeping of most value adding production entities, the equipment.

ANNEXURE-A: Questionnaire

MANAGING KNOWLEDGE - MANUFACTURING PROCESS EQUIPMENT OPERATION						
Questionnaire						
Please rate each question from 1 to 5 scale, (where 1= Completely Agree, 2= Agree, 3= Neutral, 4= Disagree, 5= Completely Disagree)						
A	**Failure of Knowledge Management – Macro Level Issues**					
	Production Machineries / Systems often fail. Responsible factors are given below. Rating from you:					
		1	**2**	**3**	**4**	**5**
QA1	Absence of managerial responsibilities					
QA2	Ignorance to specificity of knowledge					
QA3	Knowledge not integrated to target process					
QA4	Separation of human, process and technology					
QA5	Indifferent perception on value of contribution					
QA6	Inadequate technology (Knowledge-based KM system)					
QA7	Absence of stakeholders inputs					
QA8	Lack of quality of knowledge					
QA9	Absence of collaborative approach					
QA10	Creation of monolithic memory (centralized store)					
QA11	Barriers of knowledge transfer					
QA12	knowledge (stored) difficult to interpret					
QA13	Lack of leadership support					
QA14	Fear of contributors, job security					
QA15	Absence of measurement of effectiveness of KM					
B	**Micro Level Issues Related to Knowledge Gap**	**1**	**2**	**3**	**4**	**5**
QB1	Employee motivation level has got direct link to equipment malfunction					
QB2	Gap widens for needed knowledge in operating or maintaining equipment due to de-motivated worker.					
QB3	Gap widens for needed knowledge in operating or maintaining equipment due to lack of supervisor's responsibility in engaging the operator.					
QB4	Gap widens for needed knowledge in operating or maintaining equipment due to ineffective strategic level issues in understanding importance of motivation in failure prevention.					
QB5	Unhealthy organizational culture creates knowledge gap.					
QB6	Depth of knowledge and specificity of knowledge has direct relation with employee's motivation level.					

QB7	Company's positive culture on productivity, people management, social responsibility greatly influence on bringing in quality knowledge.	**1**	**2**	**3**	**4**	**5**
QB8	Organization's culture on adoption of new technology of monitoring equipment can reduce the knowledge gap in changing scenario of modern machinery.					
QB9	Company culture (absence of collaborative / team approach) greatly influence the gap of knowledge between existing and required knowledge in managing equipment.					
QB10	Absence of knowledge collaboration exists between top level and bottom level, this influences motivation level and in turn has an impact on equipment health.					
QB11	Organizational culture may set a barrier to knowledge transfer					
QB12	De-motivated employees naturally become barriers and may increase the knowledge gap.					
QB13	Knowledge gap continues to widen on the existence of fear of losing job.					
QB14	Organization's positive culture on adopting latest tools and techniques can reduce the knowledge gap.					
QB15	Lack of effective leadership in managing knowledge widen the knowledge gap as it has effect on employee motivation					
QB16	Company's learning and managing knowledge culture from leaders reduce the gap					
C	**Micro Level Issues Related to Knowledge Risk**	**1**	**2**	**3**	**4**	**5**
QC1	When employee is promoted, certain specialized skills and knowledge get carried away to higher level creating risk at lower operator level.					
QC2	Equipment with advanced features of performance monitoring and controls brings new risk with it, creating current operating procedure at risk.					
QC3	Design/ expansion / technological upgrades bring in knowledge risk.					
QC4	Transfer on promotion to other function/ other site also brings risk to current function and hence knowledge is at risk.					
QC5	Specialized knowledge and skills become ineffective when employee promoted with other assignments.					
QC6	Specificity of knowledge often creates complexity and knowledge therefore is at risk.					
QC7	Knowledge transfer mechanism if inadequate, then equipment-specific knowledge and skills become a risk.					
QC8	Due to advent and inclusion of new technology into manufacturing process, there is lack of up-gradation of knowledge to fit the changed process.					
QC9	Knowledge not upgraded and not integrated to process is mainly due to improper knowledge transfer mechanism.					
QC10	Machinery failures occur often due to lack of integrated and coordinated approach between human, manufacturing process and available technological inputs.					
QC11	There is value-addition in contribution of skills and knowledge related to equipment, its operation and maintenance.					
QC12	People do not contribute to their full potentials because their jobs are not recognized.					
QC13	Low level of contribution is somewhat related to non-existence of a structured compensation, reward schemes.					
QC14	Current knowledge based solutions, IT and expert systems, are not adequate in narrowing down root cause of failure and often far from reality when compared between fault and symptoms.					
QC15	Expert knowledge-based rules often do not match with equipment fault-alarm.					
QC16	Rule based system is mostly automated and software is not user-friendly.					
QC17	Decision on start, run and stop the machines on/ after alarm/trip are taken based on guide-rules of Knowledge based automation system.					
QC18	Employee hardly face problem in automation and hardly have any learning problem.					
QC19	There is an urgent need to improve knowledge-base (rule-base) of automation in order to clearly indicate the root cause of the machinery failures.					
QC20	Equipment operational knowledge is not clearly mentioned in operation and maintenance manuals supplied by OEM.					
QC21	After sales interactions / knowledge sharing between equipment user and OEM is not a routine and mandatory process.					
QC22	Many failures can be avoided if failure cases are shared with designer/ supplier.					
QC23	Profit sharing/business tie-up with designer, supplier, equipment user, customer would reduce the breakdowns.					
QC24	Internal stake-holder's (management, plant maintenance, operation, Inspection) collaborative knowledge inputs can be a positive outcome in avoiding failures.					
QC25	Quality of knowledge is at risk when equipment and process with new technology is added/ upgraded, as new advanced tools/process brings new risk of unknown knowledge					
QC26	Redeploying an employee to another function while may add value to other business process may create a substantial risk in current tasks.					
QC27	Risk of losing knowledge for a particular equipment operational function may surface too on promoting an employee and assigning him with other tasks.					
QC28	Quality of knowledge is therefore a risk for current employees.					
QC29	Lack of minimum experience (for particular equipment) is a risk.					
QC30	Knowledge transfer mechanism if not effective, there is risk of knowledge needs.					
QC31	Collaboration with external customers/ vendors/ other stakeholders greatly improves desired equipment knowledge among employees and company's management and absence of these is big risk.					
QC32	Knowledge kept in centralized store is hardly accessed by equipment owner/ maintainer and itself a risky business process.					
QC33	Centralized knowledge store such as current day KM portals is less prescriptive in terms of enhancing equipment knowledge.					
QC34	Ineffective knowledge transfer mechanism is barrier and a great risk					
QC35	Fear of losing jobs (job security) is an important barrier to knowledge transfer.					
QC36	Risk of having the barrier of knowledge transfer is directly related to company culture.					
QC37	Job insecurity (barrier to knowledge transfer process) is due to low level of company's direction on reliability/ process experimentation.					
QC38	Tacit knowledge source is itself a big risk of knowledge transfer mechanism.					

QC39	Employee's fear of contribution in managing equipment's operation is a big risk of knowledge needed to enhance equipment reliability.	**1**	**2**	**3**	**4**	**5**
QC40	Open ideas, thoughts are not encouraged.					
QC41	There is tendency often noticed to create a gap in theory and practical part of equipment operation.					
QC42	Knowledge related to immediate practical solution to a failure issue does not demand theoretical explanation.					
QC43	Job security and fear of contributions of employee often get generated by misguided egoist experienced leaders.					
QC44	Way out of this menace is to change the company culture.					
D	**Micro Level Issues Related to Knowledge Strength**	**1**	**2**	**3**	**4**	**5**
QD1	Lack of motivation reduces the man-machine interactions, widens the knowledge gap and hence the employees knowledge strength diminishes.					
QD2	Motivation has close positive relation with structured HR issues like compensation, working environment, culture etc.					
QD3	Unhealthy culture reduces needed strength of knowledge of equipment operation					
QD4	Equipment-specific knowledge / specialized knowledge, at times, becomes difficult for employees due to the un-matching current potential and needed specialized complex knowledge. It is lack of knowledge strength.					
QD5	Employee's minimum experience is required in order to understand the specialized skills.					
QD6	Basic knowledge either by way of academic qualification or through training by employer or by association with peers is necessary for grasping equipment-specific specialized knowledge					
QD7	On-job exposure is must to understand and feel the equipment and operation.					
QD8	Improvement of employee's knowledge strength depends on effective knowledge transfer mechanism of the organization.					
QD9	Strength gets enhanced when knowledge is decoded and presented in easily grasping note/ lecture/ procedures/ visuals etc.					
QD10	Quality of knowledge is of prime importance in managing knowledge related to equipment function.					
QD11	Knowledge quality is strength to department owning the equipment.					
QD12	For quality knowledge, organization can bank only on motivated employees.					
QD13	Positive culture on equipment management is truly strength of the manufacturing business operation.					
QD14	Business ethics, operational strategy, HR philosophy etc. has direct link on failure-free operation of the equipment.					
QD15	Positive culture can only bring in the best available knowledge and helps in retaining and sustaining skills.					
QD16	Current skills become partially obsolete due to incoming technological improvement bringing in new knowledge requirement.					
QD17	Complex knowledge should be of such quality which can be easily understood by equipment operators, maintenance team.					
QD18	Knowledge strength in employee therefore has direct link to the form/state of knowledge items.					
QD19	Managing knowledge is easier for experienced employees due to his prior exposure to equipment/ similar equipment.					
QD20	Minimum experience truly adds on to current demand of strength of knowledge.					
QD21	Hands-on training enhances strength of knowledge.					
QD22	Knowledge strength reduces or remains stagnant in case knowledge transfer process is ineffective.					
QD23	Form of knowledge, whether in tacit or explicit, is a very important factor in attaining level of strength of knowledge.					
QD24	Organizational culture and values (in formation of team spirit) enhance employee's strength of knowledge/ skills.					
QD25	Knowledge collaboration is itself a great strength in equipment reliability.					
QD26	Absence of ethical values and superiority-ego influence de-motivation among operators and strength of knowledge suffers.					
QD27	Knowledge strength improves in ethical and value based business.					
QD28	Employee's knowledge strength can only be enhanced through right knowledge transfer mechanism.					
QD29	Motivated employee is strength.					
QD30	Employee not exposed to needed demand of new knowledge specific to equipment operation and process may delay the process of knowledge transfer.					
QD31	Employee not adequately qualified and lack of basic exposure of the equipment may be a barrier to knowledge transfer.					
QD32	Absence of knowledge items related to equipment, part, operation process needing physical contact for learning i.e. on-job practical, on-job controls, on-line maintenance etc. may create barrier.					
QD33	Form and state of knowledge items available in organization' store/ documentation are of complex nature and difficult to interpret.					
QD34	Prerequisite of increasing knowledge strength is to transform it to explicit and easy grasping language.					
QD35	Stored knowledge-context often less relevant in terms of repeated reference, understanding.					
QD36	Stored knowledge-context is often so complex that its retrieval becomes difficult when needed and references become cumbersome.					
QD37	Knowledge not easily decodable is almost like - not having knowledge and needed strength of knowledge becomes a casualty.					
QD38	Knowledge in tacit form is a barrier to strength of knowledge in on-job practical knowledge transfer.					
QD39	Complex knowledge is difficult to transfer and which affects process of transfer and in turn knowledge strength reduces.					
QD40	Employee knowledge strength often gets multiplied with caring, concerns and direction from the superiors who know the essence of knowledge management.					
QD41	Learning improves the strength of knowledge.					

Name:______________________________________ Experience (yrs.): ___________________

Organization:________________________________ Age (yrs.): ________________________

Function:___________________________________ Email ID:

Thank you for inputs !

ANNEXURE-B: Relationship between Macro and Micro level Factors [3]

Item code	Relation to Macro Failure-items	Independent Factors	Item code	Contributes/ Influences		
				G	R	S
FF1	Absence of managerial responsibilities	Motivation level	IM	√		√
		Organization Culture	IC	√		√
		Promotion	IP		√	
		Technology improvement	ITI		√	
FF2	Ignorance to specificity of knowledge	Basic knowledge	IBK			√
		Grasping difficulty	ID			√
		Experience	IE			√
		Knowledge transfer mechanism	ITM		√	√
		On-job exposer	IOJ			√
		Promotion	IP		√	
		Redeployment	IRD		√	
FF3	Knowledge not integrated to target process	Knowledge transfer mechanism	ITM		√	
		Technology improvement	ITI		√	
FF4	Separation of human, process and technology	Lack of integration	II		√	
FF5	Indifferent perception on value of contribution	Perception on values	IV		√	
FF6	Inadequate technology	Inadequate technology	IT		√	
FF7	Absence of stakeholders inputs	Stakeholders inputs	IS		√	
FF8	Lack of quality of knowledge	Motivation level	IM	√		√
		Grasping difficulty	ID			√
		Experience	IE		√	√
		Knowledge context	IKC			√
		Knowledge transfer mechanism	ITM		√	√
		On-job exposer	IOJ			√
		Organizational culture	IC	√		√
		Promotion	IP		√	
		Redeployment	IRD		√	
		Technology improvement	ITI		√	√
FF9	Absence of collaborative approach	Motivation level	IM	√		√
		Collaboration among stakeholders	ICS		√	
		Organizational culture	IC	√		√
FF10	Creation of monolithic memory	Creation monolithic memory	IMM		√	
FF11	Barriers of knowledge transfer	Basic knowledge	IBK			√
		Motivation level	IM	√		√
		Grasping difficulty	ID			√
		Fear of contribution	IFC	√	√	
		Knowledge transfer mechanism	ITM		√	√
		On-job exposer	IOJ			√
		Organization culture	IC	√		√
FF12	knowledge (stored) difficult to interpret	Basic knowledge	IBK			√
		Grasping difficulty	ID			√
		Knowledge context	IKC			√
		Knowledge transfer mechanism	ITM		√	√
		On-job exposer	IOJ			√
FF13	Lack of leadership support	Motivational level	IM	√		√
		Learning culture	ILC	√		√
FF14	Fear of contributors, job security	Fear of contribution	IFC		√	
FF15	Absence of measurement of effectiveness			**Not applicable**		

ANNEXURE-C: Macro level Failure Factors

Statistical Analysis (Cronbach's Alpha of these factors - 0.80)								
Item	**Code**	**Agree %**	**Disagree %**	**Mean**	**SD**	**item-total correlation**	**Cronbach's Alpha if Item Deleted**	**Dependency Test on G/S/R (Cronbach's Alpha)**
QA1	FF1	80.53	7.08	1.027	0.901	0.233	0.800	0.797
QA2	FF2	78.76	7.96	0.965	0.876	0.348	0.793	0.862
QA3	FF3	67.26	7.08	0.805	1.042	0.336	0.794	0.567
QA4	FF4	72.57	8.85	0.903	0.896	0.422	0.788	Question- only 1
QA5	FF5	58.41	14.16	0.619	0.994	0.478	0.783	0.571
QA6	FF6	61.06	17.70	0.690	1.070	0.492	0.782	0.738
QA7	FF7	53.10	26.55	0.363	1.134	0.470	0.783	0.705
QA8	FF8	63.72	15.93	0.717	1.106	0.532	0.778	0.866
QA9	FF9	70.80	8.85	0.938	0.994	0.342	0.793	0.668
QA10	FF10	55.75	16.81	0.531	1.044	0.355	0.793	0.756
QA11	FF11	74.34	5.31	0.938	0.816	0.456	0.786	0.821
QA12	FF12	59.29	15.04	0.593	0.951	0.349	0.793	0.818
QA13	FF13	72.57	15.04	0.929	1.091	0.475	0.783	0.548
QA14	FF14	53.10	18.58	0.504	1.078	0.393	0.790	0.739
QA15	FF15	55.75	10.62	0.681	1.002	0.428	0.787	Not separately influence G/S/R

ISSN 2250-3153

ANNEXURE-D: Knowledge Gap

Item-Total Statistics (Sixteen items with Cronbach's Alpha value - 0.854)							
Item	**Agree %**	**Disagree %**	**Neutral %**	**Mean**	**Std. Deviation**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
QB1	68.14	12.39	19.47	0.823	1.020	0.377	0.851
QB2	76.99	7.96	15.04	0.973	0.871	0.541	0.843
QB3	72.57	7.96	19.47	0.841	0.862	0.465	0.846
QB4	69.91	9.73	20.35	0.805	0.905	0.508	0.844
QB5	84.07	10.62	5.31	1.150	1.046	0.518	0.843
QB6	58.41	15.93	25.66	0.611	0.995	0.432	0.848
QB7	84.96	2.65	12.39	1.257	0.777	0.540	0.843
QB8	74.34	8.85	16.81	0.947	0.962	0.423	0.848
QB9	75.22	4.42	20.35	1.027	0.901	0.487	0.845
QB10	76.99	10.62	12.39	0.912	0.978	0.461	0.846
QB11	61.95	9.73	28.32	0.726	0.984	0.606	0.839
QB12	70.80	10.62	18.58	0.920	1.019	0.584	0.840
QB13	57.52	15.93	26.55	0.593	1.041	0.429	0.848
QB14	69.91	11.50	18.58	0.858	1.060	0.408	0.849
QB15	73.45	7.08	19.47	0.929	0.979	0.430	0.848
QB16	67.26	7.96	24.78	0.814	0.931	0.454	0.847

ANNEXURE-E: Knowledge Risk

Item-Total Statistics (Forty-four items with Cronbach's Alpha value - 0.929)							
Item	**Agree %**	**Disagree %**	**Neutral %**	**Mean**	**Std. Deviation**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
QC1	43.36	35.40	21.24	0.195	1.216	0.409	0.928
QC2	49.56	27.43	23.01	0.319	1.063	0.457	0.928
QC3	46.02	35.40	18.58	0.142	1.245	0.468	0.927
QC4	43.36	34.51	22.12	0.159	1.115	0.525	0.927
QC5	46.90	30.09	23.01	0.301	1.164	0.434	0.928
QC6	38.05	31.86	30.09	0.115	1.155	0.526	0.927
QC7	68.14	11.50	20.35	0.752	1.005	0.507	0.927
QC8	60.18	14.16	25.66	0.540	0.897	0.488	0.927
QC9	79.65	6.19	14.16	0.947	0.777	0.456	0.928
QC10	81.42	7.08	11.50	1.071	0.913	0.329	0.929
QC11	77.88	4.42	17.70	1.000	0.824	0.362	0.928
QC12	66.37	8.85	24.78	0.796	0.974	0.342	0.928
QC13	69.91	10.62	19.47	0.752	0.969	0.402	0.928
QC14	57.52	18.58	23.89	0.593	1.041	0.434	0.928
QC15	55.75	18.58	25.66	0.558	1.101	0.448	0.928
QC16	46.90	23.89	29.20	0.327	1.081	0.440	0.928
QC17	53.10	20.35	26.55	0.407	1.041	0.446	0.928
QC18	31.86	46.02	22.12	0.097	1.202	0.371	0.928
QC19	72.57	8.85	18.58	0.832	0.934	0.586	0.926
QC20	58.41	24.78	16.81	0.522	1.203	0.568	0.926
QC21	55.75	23.89	20.35	0.478	1.218	0.427	0.928
QC22	79.65	8.85	11.50	1.027	0.921	0.385	0.928
QC23	68.14	15.93	15.93	0.726	1.071	0.401	0.928
QC24	80.53	7.96	11.50	1.035	0.981	0.375	0.928
QC25	55.75	19.47	24.78	0.478	1.045	0.642	0.926
QC26	51.33	16.81	31.86	0.442	1.026	0.547	0.927
QC27	42.48	22.12	35.40	0.265	1.044	0.519	0.927
QC28	53.98	23.01	23.01	0.442	1.164	0.457	0.928
QC29	71.68	11.50	16.81	0.805	0.981	0.461	0.927
QC30	76.11	8.85	15.04	0.823	0.889	0.407	0.928
QC31	75.22	6.19	18.58	0.920	0.847	0.497	0.927
QC32	66.37	13.27	20.35	0.752	1.005	0.487	0.927
QC33	62.83	12.39	24.78	0.646	0.935	0.510	0.927
QC34	71.68	8.85	19.47	0.850	0.956	0.434	0.928
QC35	52.21	23.89	23.89	0.434	1.164	0.429	0.928
QC36	69.91	13.27	16.81	0.779	0.989	0.447	0.928
QC37	68.14	9.73	22.12	0.761	0.889	0.501	0.927
QC38	61.06	4.42	34.51	0.735	0.824	0.526	0.927
QC39	55.75	13.27	30.97	0.575	0.989	0.650	0.926

QC40	60.18	18.58	21.24	0.602	1.074	0.581	0.926
QC41	67.26	12.39	20.35	0.717	0.977	0.487	0.927
QC42	46.90	33.63	19.47	0.212	1.176	0.345	0.929
QC43	66.37	9.73	23.89	0.770	0.886	0.422	0.928
QC44	72.57	6.19	21.24	0.920	0.908	0.515	0.927

ANNEXURE-F: Knowledge Strength

Item-Total Statistics (Forty-one items with Cronbach's Alpha value - 0.930)							
Item	**Agree %**	**Disagree %**	**Neutral %**	**Mean**	**Std. Deviation**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
QD1	55.75	25.66	18.58	0.487	1.189	0.388	0.929
QD2	61.06	19.47	19.47	0.628	1.104	0.496	0.928
QD3	56.64	23.01	20.35	0.496	1.211	0.491	0.928
QD4	48.67	26.55	24.78	0.372	1.135	0.492	0.928
QD5	53.98	24.78	21.24	0.442	1.149	0.442	0.929
QD6	46.90	25.66	27.43	0.363	1.196	0.510	0.928
QD7	75.22	7.08	17.70	0.938	0.966	0.504	0.928
QD8	63.72	10.62	25.66	0.708	0.913	0.535	0.928
QD9	83.19	6.19	10.62	1.018	0.845	0.399	0.929
QD10	83.19	5.31	11.50	1.150	0.826	0.351	0.929
QD11	75.22	2.65	22.12	1.080	0.825	0.324	0.930
QD12	65.49	8.85	25.66	0.779	0.914	0.345	0.930
QD13	69.91	10.62	19.47	0.814	1.014	0.446	0.929
QD14	59.29	15.04	25.66	0.664	1.014	0.441	0.929
QD15	63.72	15.93	20.35	0.717	1.106	0.442	0.929
QD16	50.44	21.24	28.32	0.389	1.089	0.399	0.929
QD17	61.95	15.04	23.01	0.619	1.055	0.597	0.927
QD18	41.59	29.20	29.20	0.168	1.068	0.544	0.928
QD19	75.22	8.85	15.93	0.858	0.925	0.539	0.928
QD20	63.72	16.81	19.47	0.681	1.096	0.556	0.928
QD21	75.22	15.93	8.85	0.912	1.169	0.512	0.928
QD22	77.88	8.85	13.27	1.035	0.944	0.423	0.929
QD23	70.80	13.27	15.93	0.743	1.007	0.516	0.928
QD24	79.65	5.31	15.04	1.062	0.919	0.401	0.929
QD25	62.83	15.04	22.12	0.664	1.057	0.624	0.927
QD26	54.87	15.04	30.09	0.540	1.053	0.563	0.928
QD27	50.44	16.81	32.74	0.469	1.061	0.485	0.928
QD28	60.18	18.58	21.24	0.558	1.060	0.446	0.929
QD29	74.34	9.73	15.93	0.956	1.012	0.457	0.929
QD30	72.57	9.73	17.70	0.770	0.906	0.422	0.929
QD31	74.34	7.08	18.58	0.947	0.895	0.456	0.929
QD32	64.60	12.39	23.01	0.735	0.991	0.493	0.928
QD33	61.95	14.16	23.89	0.619	0.985	0.450	0.929
QD34	69.03	10.62	20.35	0.796	0.956	0.482	0.928
QD35	53.10	19.47	27.43	0.442	1.060	0.586	0.927
QD36	66.37	15.93	17.70	0.690	1.010	0.447	0.929
QD37	68.14	7.96	23.89	0.814	0.892	0.487	0.928
QD38	61.95	7.08	30.97	0.726	0.899	0.497	0.928
QD39	55.75	16.81	27.43	0.549	1.061	0.576	0.927
QD40	66.37	15.04	18.58	0.726	1.046	0.554	0.928
QD41	76.99	7.96	15.04	0.982	0.935	0.440	0.929

ANNEXURE-G: Independent Variables [3]

Sl. No.	**Independent Factors**	**Influences in Gap/ Strength/ Risk**	**Related Questions (G)**	**Statistical Analysis**		
				Mean Response	**Standard Deviation**	**Cronbach's Alpha**
1	Absence of stakeholders inputs	Risk	R20	0.522	1.203	0.705
			R21	0.478	1.218	
			R22	1.027	0.921	
			R23	0.726	1.071	
			R24	1.035	0.981	

2	Basic knowledge	Strength	S6	0.363	1.196	0.598
			S31	0.947	0.895	
			S33	0.619	0.985	
			S34	0.796	0.956	
3	Creation of monolithic memory	Risk	R32	0.752	1.005	0.756
			R33	0.646	0.935	
4	Demotivation	Gap	G1	0.823	1.020	0.807
			G2	0.973	0.871	
			G3	0.841	0.862	
			G4	0.805	0.905	
			G6	0.611	0.995	
			G10	0.912	0.978	
			G12	0.920	1.019	
			G15	0.929	0.979	
		Strength	S1	0.487	1.189	
			S2	0.628	1.104	
			S10	1.150	0.826	
			S11	1.080	0.825	
			S12	0.779	0.914	
			S25	0.664	1.057	
			S26	0.540	1.053	
			S29	0.956	1.012	
			S40	0.726	1.046	
5	Difficult to grasp	Strength	S4	0.372	1.135	0.673
			S17	0.619	1.055	
			S18	0.168	1.068	
			S30	0.770	0.906	
			S39	0.549	1.061	
6	Experience	Risk	R29	0.805	0.981	0.550
		Strength	S5	0.442	1.149	
			S19	0.858	0.925	
			S20	0.681	1.096	
7	Fear of contribution	Gap	G13	0.593	1.041	0.784
			G14	0.858	1.060	
		Risk	R35	0.434	1.164	
			R36	0.779	0.989	
			R37	0.761	0.889	
			R39	0.575	0.989	
			R40	0.602	1.074	
			R41	0.717	0.977	
			R42	0.212	1.176	
			R43	0.770	0.886	
			R44	0.920	0.908	
8	Inadequate technology	Risk	R14	0.593	1.041	0.738
			R15	0.558	1.101	
			R16	0.327	1.081	
			R17	0.407	1.041	
			R18	-0.097	1.202	
			R19	0.832	0.934	
9	Knowledge context	Strength	S23	0.743	1.007	0.734
			S35	0.442	1.060	
			S36	0.690	1.010	
10	Knowledge transfer mechanism	Risk	R7	0.752	1.005	0.759
			R9	0.947	0.777	
			R30	0.823	0.889	
			R34	0.850	0.956	
			R38	0.735	0.824	
	Knowledge transfer mechanism	Strength	S8	0.708	0.913	
			S9	1.018	0.845	
			S22	1.035	0.944	
			S28	0.558	1.060	
			S37	0.814	0.892	
11	Lack of integration	Risk	R10	1.071	0.913	Q-item only 1
12	Learning culture	Gap	G16	0.814	0.931	0.245
		Strength	S41	0.982	0.935	
13	Non existence of inter-function	Risk	R31	0.920	0.847	Q-item only 1

14	On job exposer	Strength	S7	0.938	0.966	0.510
			S21	0.912	1.169	
			S32	0.735	0.991	
			S38	0.726	0.899	
15	Organizational culture	Gap	G5	1.150	1.046	0.729
			G7	1.257	0.777	
			G8	0.947	0.962	
			G9	1.027	0.901	
			G11	0.726	0.984	
		Strength	S3	0.496	1.211	
			S13	0.814	1.014	
			S14	0.664	1.014	
			S15	0.717	1.106	
			S24	1.062	0.919	
			S27	0.469	1.061	
16	Perception on value	Risk	R11	1.000	0.824	0.571
			R12	0.796	0.974	
			R13	0.752	0.969	
17	Promotion	Risk	R1	0.195	1.216	0.710
			R5	0.301	1.164	
			R6	0.115	1.155	
			R27	0.265	1.044	
18	Redeployment	Risk	R4	0.159	1.115	0.665
			R26	0.442	1.026	
			R28	0.442	1.164	
19	Technology improvement	Risk	R2	0.319	1.063	0.696
			R3	0.142	1.245	
			R8	0.540	0.897	
			R25	0.478	1.045	
		Strength	S16	0.389	1.089	

ACKNOWLEDGMENT

The authors are truly indebted to Mr. Vinod Raj, M.Tech - Reliability Engineering, IIT, Kharagpur, India and Assistant Manager with JSW-ISPAT Steel Limited, Mumbai, India for assisting us in every aspect of collation and analysis. We are extremely thankful to all the expert professionals who had seriously responded the long questionnaire for the purpose. We are grateful to the management of M/S JSW-ISPAT Steel Limited and the Dept. of Management, BIT, Mesra, Ranchi, India and the Institute for Technology and Management, Navi Mumbai, India for all the supports.

REFERENCES

[1] R. O. Weber, "Addressing Failure Factors in Knowledge Management", Electronic Journal of Knowledge Management, 2007, vol 5, issue 3, pp. 333-346, ISSN 1479-4411.

[2] J. L. Gordon, I. M. Briar, C. Smith, G. Bain, P. Unsworth and S. Magraw, "Risk, Gap and Strength: Key Concept in Knowledge Management", Knowledge-Based Systems, 2003, vol 16, issue 1, pp. 29-36.

[3] T. Pyne, U. Baul and R. S. Jangid, "Knowledge Management and Equipment Reliability: Towards a Relationship Model", Int. J. Strategic Engineering Asset Management, Inderscience Publishing, 2012, vol 1, issue 2, pp. 193-223, ISSN 1759-9741.

[4] R. M. Williamson, "The Fuzzy Side of Equipment Reliability", Strategic Work Systems, Inc., Columbus, North Carolina, 1998, http://www.maintenanceworld.com/Articles/williamsonr/thefuzzy.html.

[5] T. Davenport and L. Prusak, "Working Knowledge: How Organizations Manage What They Know", Harvard Business School Press, ISBN 0-87584-655-6, Boston, MA, 1998.

[6] W. Pinto, "Excellence in Stationary Equipment Reliability", Lyondell Chemical Company, Houston Business Roundtable, Houston, Texas, 2007.

[7] Website - http://www.tarapadapyne.com/default.aspx.

[8] J. C. Nunnally, "Psychometric Theory", (2nd ed). McGraw-Hill, New York, 1978.

AUTHORS

First Author – **Tarapada Pyne** is a Mechanical Engineer from IE(I), Kolkata, 1985, with Post Graduate (M.Tech – Mech.) in 'Plant Engineering and Management', JNTU, Hyderabad, India, 1993 and has over 27 years of experience in defence services (IAF) and large process plants like petrochemical/ oil-refinery (Reliance Industries), chemical (Birla VXL), metal (Birla Copper, JSW-Ispat) industries in the field of Reliability Management, Machinery Diagnostics (Condition Monitoring, NDT), Rotary Equipment, Energy Management, Training etc. He is a Chartered Engineer (FIE) and Certified Reliability Professional (CFR, Chennai, India), Certified Reliability Professional (Reliasoft, USA), Certified Energy Auditor (BEE, Govt. of India), Vibration Specialist (Emerson), Certified in CBMS (IIPM, Rourkela), NDT (ASNT, UT-II). Currently, he heads the department of Reliability and Condition Monitoring of JSW-Ispat Steel Limited, Mumbai, India and is a doctoral research scholar (thesis submitted, 2011) of Department of Management, BIT, Mesra, Ranchi, India. He has 15 publications in journals/conferences and associated with professional bodies as Fellow/ Life Members.
Website: www.tarapadapyne.com.
E-mail- tarapada.pyne@gmail.com.

ISSN 2250-3153

Second Author – **Utpal Baul** is a Mechanical Engineer (BE-Mech) from Birla Institute of Technology, Mesra (1982), with Post Graduate in Management (MBA) from Birla Institute of Technology, Mesra (1984). He has completed his PhD in 'Business to Business Marketing' from Birla Institute of Technology, Mesra (2008). He has total 27 years of experience with 13 years in industry, 14 years in teaching and research. His areas of interest are Business to Business Marketing, Human Resource Management, Industrial and Quality Management. He is presently guiding 07 numbers of PhD scholars. Currently, he is a Professor in the Department of Management BIT, Mesra, Ranchi, India. He has a number of international and national publications to his credit. He is a life member of Indian Society for Technical Education and Institution of Engineers (India).
E-mail- utpalbaul@bitmesra.ac.in

Third Author – **Radhey Shyam Jangid** is a Civil Engineer (B.E.) from University of Jodhpur (1989) with Post Graduate (M.Tech. - Structural Engineering) (1991) and Ph.D (in Earthquake Engineering) from IIT Delhi (1993). He has more than 20 years of research and teaching experience and guided/guiding more than 20 PhD students and more than 50 M.Tech. projects. His areas of interest are - Earthquake-resistant Design, Vibration Control, Dynamic Analysis and Reliability. Currently, he is Professor in Dept of Civil Engineering, IIT Bombay, Mumbai, India. He has in his credit more than 130 publications in peer-reviewed international journals and presented paper in more than 50 conferences and authored two books. He was awarded BOYSCAST Fellowship of DST, INAE Young Engineer, DST Young Scientist, HOWE India fellowship at IIT Delhi. He is also associated with number of professional bodies and has provided services in consulting/ sponsored projects to large number of corporate.
Website: http://www.civil.iitb.ac.in/~rsjangid/.
E-mail- rsjangid@civil.iitb.ac.in

Correspondence Author – Tarapada Pyne, E-mail address-tarapada.pyne@gmail.com, contact number-+91-8805022148.