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Knowledge Elicitation in Reliability

Management in the Airline Industry

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CERTIFICATE OF ORIGINALITY

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ABSTRACT

Aircraft reliability is a very important issue for an airline. Once there is an accident, the airline will suffer financially. Passengers' confidence in the airplane may also be shaken to a degree beyond recovery. Considerations of reliability management are different from traditional failure prevention or failure analysis. Aircraft components are expensive, and there are complicated procedures for aircraft surveillance, replacement of parts and periodic maintenance. In reliability management, the main task is to arrive at optimal maintenance decisions, processes and policies to ensure the safety criteria are met while at the same time the solution will not have burdensome and unrealistic financial implications for the profitability of the business.

Knowledge elicitation is a very important process in Knowledge Management and it is useful in helping to retain knowledge within an organization. Knowledge can be captured through the means of surveys, and interviews and ethnography etc. After analyzing the information obtained, it can be organized and presented in different ways. For example, knowledge can be stored in a database or in a document management system, presented in semantic nets, concept maps, etc. In this research, cognitive mapping is chosen for making visible the mental models of the staff in the Engineering Division of Dragonair who handle reliability issues.

The cognitive maps are constructed from the narrative data collected from a particular group who share the same concerns, by asking participants to tell their

stories. This technique is simple yet effective in stimulating people to reflect on their intuitive thinking, to capture and to organize their experiences. With a sufficient number of cognitive maps elicited from each individual member of staff, the reasoning patterns are revealed and then combined to form an aggregate cognitive map. This aggregate cognitive map represents the collective knowledge and insights of the whole reliability group about handling reliability issues. Such a combined map is similar to the construction of a taxonomy of knowledge required for handling their daily operations. The map can help make their thinking process explicit when they need to handle new cases which are similar to those that they have handled in the past. It can also help trigger their thoughts when they face new situations.

Team learning is achieved through the process of constructing and validating the aggregate cognitive map constructed from individual narratives. Such a map will make sense to the staff as it helps users to reflect on what they have done in the past and what others have done. Extracting learning points and identifying thinking processes from narratives provide a natural and useful way of revealing and sharing the staff's group mental model for working on a common task. This thesis is a demonstration of how to elicit tacit knowledge from individuals and make it available to a team and then elicit it from the team and make it available to the whole organization.

ACKNOWLEDGEMENTS

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CHAPTER 1   INTRODUCTION

1.1   MOTIVATION FOR THE PROJECT

This is a joint project between The Hong Kong Polytechnic University and Hong Kong Dragon Airlines Limited (Dragonair). Dragonair started its first knowledge management project in the Engineering Division in the year 2002. At that time, a cultural survey was conducted in order to see whether Dragonair was ready to launch a knowledge management project. After the survey, a division-wide knowledge audit was performed. First of all, a questionnaire was administered to all staff in the division in order to identify the processes in which critical knowledge was embedded, and key knowledge holders were identified. Following that, in-depth interviews were conducted with the 21 key knowledge holders so as to build up the knowledge inventory. With the results of the interviews, a social network analysis and a taxonomy of the knowledge inventory was developed.

Dragonair then identified several initiatives to start her KM journey. Firstly, a Technical Information Centre was developed and all the technical manuals were stored in this centralized repository. This Centre is a virtual library which is maintained by a document management system. Manuals are stored in a systematic way where staff can retrieve the manuals effectively and efficiently. Storing them in this way can prevent confusion arising between the obsolete and the latest manuals. Since knowledge management should not focus only on technology, a

people-based project was also proposed in order to capture the knowledge and skills of experienced staff. A Teaching Company Scheme between Dragonair and The Hong Kong Polytechnic was launched in which the author was the principal investigator. The Reliability Management Unit of the Engineering Division was chosen as the trial case.

1.2   BACKGROUND TO THE STUDY

Dragonair was founded in 1985. It serves 29 passenger destinations across Asia with one of the youngest and most advanced aircraft fleets in the region. Its catchment area spans half of the world's population and includes places such as Beijing, Shanghai, and Tokyo, among others.

Dragonair's fleet of modern, passenger-pleasing Airbus aircraft comprises single-aisle A320 and A321 and A330 wide-body jets. Its cargo service which comprises three Boeing 747-300SF freighters, one Boeing 747-200F freighter and one Airbus A300B4, extends to cities in Europe, the Middle East, Japan, Southeast Asia and mainland China, connecting exporters and importers directly to Dragonair's extensive mainland and regional network. With its international flight crew, and traditional Asian hospitality on the ground and in the air, Dragonair is aiming to provide a pleasurable and comfortable flying experience.

This project was performed in the Engineering Division of Dragonair. The structure of the whole Engineering Division is a kind of lean matrix organization (Figure 1.1). A matrix organization is a pure project

organization overlaid on the functional divisions of the parent firm. At the top management level, there is a General Manager. Then, two Assistant General Managers act as the assistants to the General Manager. Under them, there are seven departments. They are: Planning, Fleet Team, Purchasing, Maintenance Operations, Engineering Service, Line Maintenance and Quality Assurance. Staff in each department have different mixes of project and functional responsibilities as several functional specialists work on a number of projects.
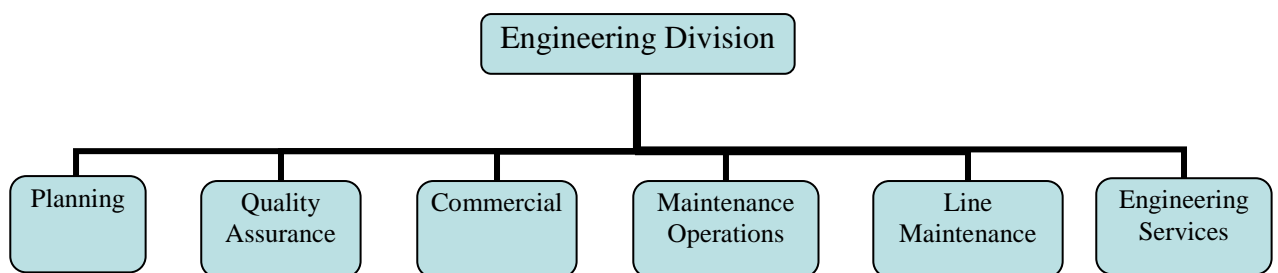
Figure 1.1 Departmental Chart of the Engineering Division

The Engineering Division performs a lot of knowledge-based work everyday. For example, they have to plan flight schedules, purchase parts, negotiate contracts, and manage outsourced maintenance tasks. The work is very knowledge intensive and no single department can master all the knowledge needed to perform the job. Therefore, senior management wishes to have a systematic way to organize the company's know-how, and to facilitate the retrieval and sharing of this know-how among staff in the Engineering Division.

The Division uses an operations model named a virtual airline in its daily operations. It is a virtual airline not because of its online reservation

system, but due to its extensive outsourcing of works to outside companies. As a young Airline, the company tries to outsource the non-core activities to third party service providers in order to reduce the cost and time needed to start up its operations. Parties providing outsourced services to Dragonair include Hong Kong Aircraft Engineering Company (HAECo), China Airlines (CAL), SR Technics (SRT) and Singapore Engineering Company (SIAEC) where SRT and SIAEC make up the Fleet Technical Management (FTM) team which provides most of the technical advice to Dragonair. Nevertheless, Dragonair needs its own highly competent staff to understand the outsourcing business and monitor the performance of the service providers to ensure that it meets both the required safety as well as efficiency standards. There is a need to retain the critical know-how among its staff and train new recruits in running this complex engineering business.

1.3   PURPOSE OF STUDY

1.3.1   "Reliability Management" in the Airline Industry

Reliability engineering normally focuses on the identification of the root cause of a problem and tackles the problem by altering the design and process to improve product reliability or reduce the occurrence of failure. However, airline reliability management is different from that. Airline reliability management seldom exercises the Failure Mode or Effect Analysis (FMEA) or Fault Tree analysis types of technique which are performed by manufacturers/OEMs to identify the root cause

or potential cause of failure. Airline reliability management is more about approaching the problem from the angle of how to protect the airline from disruption of its operations and at the same time how to maintain the service level to its passengers with high quality services. Airline reliability management takes a systems approach to considering different ways on how to maintain safe operations and help reduce the operating costs. The issue is both technical and non-technical. For example, the staff in an airline needs to explain to the public the cause of an incident in order to maintain the reputation of the airline. In case of suspected failure of components, which may affect safety, they have to assess the degree of the impact of such failures on flight safety, make decisions about the level and scale of inspection and maintenance to be done and the timing to ensure that the safety standard is not compromised. On the other hand, they have to minimize the effects of maintenance on flight schedules and resource allocations.

Aircraft reliability plays a very important role in building up the overall reputation of an airline. In order to fulfil the business needs, it is important to maintain the reliability of aircraft. The airline business needs are as follows:

a) Reputation

Reputation is very important for an airline. In order to build up their reputation, it is important for an airline to comply

with the safety and airworthiness standards since this is the most important factor for an airline, and one that cannot be jeopardized. Also, in-flight returns (when an aircraft returns to base instead of going to its destination), flight delays or flight cancellations affect the reputation greatly. Therefore, an airline has to ensure that all flights fly on time and keep the number of acceptable defects to the minimum.

b) Cost management

Aircraft Utilization – In order to maximize the profitability of an airline, its aircraft has to be fully utilized and time on the ground should be minimized. Flight delays, cancellations and additional maintenance ground time to rectify aircraft defects will all mean minimizing aircraft utilization. To achieve a high utilization rate, an airline has to maintain its fleet up to a highly reliable standard and with minimum disruptions to its operations.

Maintenance Cost – Aircraft maintenance is one of the greatest sources of expenditure for an airline. Normally, it will be account for nearly 18-20% of the whole operating cost of the airline. Poor reliability will result in unnecessary maintenance works which imply a higher maintenance cost than normal.

Maintenance Burden – Poor aircraft reliability requires many resources to troubleshoot and rectify the defects. This maintenance work will also lead to the reduction of effective ground time (the time spent in checking and cleaning the aircraft and replenishing it with fuel, food and sanitary materials).

c) Quality Services

The quality of services is the most important thing to attract new customers and maintain customer loyalty. This is the way how the profit of an airline is generated. Quality services include the performance of the aircraft. Whether the flight is on time and reliable enough is very important and affects how passengers judge the service quality of Dragonair.

In general, airline reliability management focuses on how to manage the manufacturers/OEMs and on how to implement a practical improvement plan instead of identifying the root causes of failures. An airline should also consider how to cope with reliability problems as good coping procedures can always protect the airline, streamline its operations, provide quality services and minimize the operating cost. There are strict aviation safety procedures that airlines need to comply with. Poor reliability may cause incidents which may be sensitive to the image of an airline and sometimes it may also attract attention from the media. Very often it may affect the public image or reputation of the

airline. Therefore, it is important to have a good reliability management programme in an airline.

1.3.2   *Current Issues in Reliability Management*

Aircraft defects due to reliability problems will result in a heavy maintenance burden on trying to rectify the problem, sometimes the problem may end up with an In-Flight Return (IFR), flight delay or flight cancellation. Therefore, a good reliability programme is crucial to an airline. A reliability monitoring programme is a mandatory requirement by the Hong Kong Civil Aviation Department as per Hong Kong Airworthiness Requirement (HKAR) 1.6-2 Appendix 1, since the public will suffer if the aircraft is unreliable. It may lead to adverse incidents, accidents or even deaths if the safety of the operating fleet of an airline is below standard.

There is no doubt that Dragonair has its own reliability programme. However, the responsibility of Dragonair is limited. The Maintenance Operations Department (MOD) will be the first group of people who handle the problem in order to ensure that aircraft will operate within the acceptable levels of airworthiness and reliability. They will alert the FTM team once they find any issues that they suspect may affect reliability. MOD will not be capture nor analyze any reliability data. They will only highlight suspected reliability issues. Whenever there is a problem related to reliability, the FTM team will take over the ownership of the

problem and appoint an engineer to be responsible for solving it. The engineer will tackle the problem and develop the appropriate corrective action programme by looking at the problem from the technical perspective and providing recommendations strictly from the technical point of view. Most of Dragonair's FTM works are outsourced to external parties who may not have the same sense of understanding as members of staff of the airline and may not provide a solution or recommendation that can fulfill the needs of the airline.

The responsibility of FTM is to conduct statistical analyses and preliminary investigations to detect and verify adverse trends and set alert levels based on a pre-defined trigger, for Dragonair. On a monthly basis, Dragonair's FTMs will generate a reliability report for each aircraft fleet. During the monthly Reliability Control Board (RCB) meeting, the report will be presented to Dragonair Engineering Division (Fleet Team and Quality Assurance Department) and The Hong Kong Civil Aviation Department. However, it is identified that the report generated is mainly focused on analyzing data and to trigger alerts or to generate solutions to the problem following a straightforward technical approach. Not much effort has been put by the FTM into providing recommendations on how to handle failure situations with respect to Dragonair's operating environment and commercial considerations, according to Dragonair's needs.

Dragonair has to build up its own knowledge pool to manage the reliability issues and not depend on outsiders.

1.3.3 Problem Definition

The vision of Dragonair's Engineering Division is to create an environment to sustain the highest operational integrity with superior services and safety standards, through teamwork. In order to maintain its low cost strategy which is good enough to support their daily operations, it has adopted an outsourcing model where most of the operations are outsourced to external parties. It is the business direction of Dragonair Engineering Division to maintain a lean organization structure and to reduce its overhead costs. This business direction has driven the Engineering Division in the past not to have too many staff. The Dragonair Engineering Fleet Team staff mainly fulfil management roles to oversee the overall operation, and take responsibility for reliability in the Dragonair Engineering Division. Due to the lack of a focal point and lack of expertise during the early stage of development of the division and due to the requirement to support the operation, staff have relied heavily on FTM teams for technical recommendations.

In the past, Dragonair did not have sufficient resources or manpower to focus on reliability management, and hence there are no staff designated for this purpose at the current stage. The only thing that Dragonair can do is to rely heavily on FTM teams

to manage most of the reliability issues on Dragonair's behalf. However, FTM's approach is mainly concerned with tackling the reliability problem from the technical point of view and without deeply considering the commercial and other needs of the airline. FTM will mainly approach the problem by exercising the conventional reliability analysis techniques or coordinating with manufacturers/OEMs to find out the root cause of the problem and rectify the problem from a strictly technical point of view. Only very severe problems that may impact the operation of the fleet or affect the corporate images will be alerted to Dragonair management or get Dragonair management involved. Dragonair Engineering will then try to react to the problem by using a "damage recovery" approach. Very often, using a damage recovery approach means extra resources are required where damage has already been developed, reputation may have been affected and poor customer perception has been established. The problem in using this outsourcing model is that, the FTM providers are not the operators of the airline. They may not have much commercial consideration nor have the viewpoints of the airlines in mind when they make decisions and handle problems. If the problem is not tackled using the correct approach, the same problem may occur again either in the same manner or in another form. In the worst case, if the problem is not handled properly, disasters or fatal accidents may occur and the destruction will be too permanent for recovery.

1.4   OBJECTIVES OF THE STUDY

A good reliability programme is crucial to an airline since aircraft/engine system or component failure may sometimes occur. A reliability control programme is therefore necessary to continuously monitor and manage these failures and to strive for continuous improvement as necessary. All aircraft components are high cost items and any component replacement or failure rectification will imply an increase in maintenance cost for the airline. All airline operators wish to reduce its maintenance cost and improve its operational efficiency. An adequate reliability management programme will be able to highlight the high failure rate or non-performing systems/components such that adequate improvement or modification can be accomplished in order to prevent the same problem from happening again. Also, improving reliability implies reducing system failures, and thus, reducing the maintenance cost. A good reliability programme can help reduce the defect handling administrative workload and reduce the maintenance time required to carry out failure rectification work. Moreover, it can improve the utilization of effective ground time due to the reduction of resources/manpower needed for rectifying failures. This in turn can help an airline to put more effort into preventive or routine maintenance. Also, good reliability can improve operational performance as there will be fewer occurrences of ad-hoc defects which will reduce the chance of grounding the aircraft for rectification of the defects. That means it can help to improve

operational punctuality, performance and even reputation which will bring a good return to an airline.

A knowledge repository related to all the reliability related cases will be valuable to Dragonair. Staff can reduce the chance of reinventing the wheel by reusing past knowledge or by taking past experience as a reference for decision making and much time will be saved in handling frequently occurring cases. It can further help improve the efficiency with which staff perform their daily work. From the perspective of Dragonair's Quality Assurance Department, there is a need for knowledge management to capture knowledge and know–how in the form of records and procedures. Dragonair has to establish a whole new reliability procedure in order to obtain the E2 Design Approval. E2 Design Approval allows airlines to do modifications to aircraft, systems and equipment in both the avionic and structural fields. Airlines can design modifications from changing the seating layout and installing photoluminescent floorpath lighting, to installing TCAS and RVSM avionic systems. It gives the airline greater flexibility. This flexibility can further minimize airline operation distractions since the airline has the right to do modifications without strictly following the manuals and it can save some expense as well. In order to build up Dragonair's capability and reduce maintenance and operating costs, a knowledge management project is proposed where the valuable experience of staff in handling reliability cases is captured and guidelines will be established according to their experience.

The overall objectives in the project are:

i.   To build up a knowledge repository in reliability management in order to facilitate knowledge retrieval and reuse

ii.   To retain valuable experience or knowledge from existing staff

iii. To help the members to reflect on their experiences

iv.   To shorten the learning cycle for new employees

v.   To promote a positive knowledge sharing culture and team work among employees

1.5   LAYOUT OF THESIS

There are six chapters in this report. First of all, an introduction to the motivation for the study and project objectives is presented in Chapter One. Next, the underlying assumptions of knowledge, the methods and problems in knowledge elicitation, how knowledge can be organized and represented are introduced in Chapter Two. In addition, the methodology of implementing this project in Dragonair, the approaches for collecting narratives and how to stimulate the thoughts of participants are discussed in Chapter Three. After that, the construction of cognitive maps and the consolidation of an aggregate cognitive map are presented in Chapter Four. The application of team and organizational learning, the process of knowledge elicitation and the areas of improvement are discussed in Chapter Five.   Finally, Chapter Six gives the conclusion, addresses

significant findings of the project and discusses the possible future work that can be further explored in Dragonair.

CHAPTER 2   LITERATURE REVIEW

In this chapter, the common underlying assumptions about knowledge and the problem of knowledge capture are introduced. Related theories, methodologies and tools supporting this project are reviewed.

2.1   COMMON UNDERLYING ASSUMPTIONS OF KNOWLEDGE

There are many different definitions of knowledge and it appears that in defining knowledge, individuals have shaped their definitions to suit their particular problems (Probst et al, 1999).

2.1.1   What is Knowledge?

From the "Knowledge Management Forum, KM Forum Archives -- The Early Days," the author discusses Denham's research on knowledge and knowledge management. Denham defines knowledge as the full utilization of information and data, coupled with the potential of people's skills, competencies, ideas, intuitions, commitments and motivations. It is a fluid mix of framed expertise, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. According to Davenport and Prusak (1998), it originates from and is applied in the mind of the knower.

Figure 2.1 shows the conventional view that data in context becomes information, and information in context becomes knowledge which generates decisions.

According to the definition by Suresh (1996), data is the basic element of information in an organization. Organizations collect, summarize and analyze data to identify patterns and trends. Most of the data thus collected are associated with the functional processes of the organization.

Each data element is a component of a transaction and does not provide much information unless they are presented in conjunction with other data elements. The accumulation of data into a meaningful context provides information.

Knowledge is different from data or information in that it can be created from any one of those layers or from existing knowledge using logical inferences.
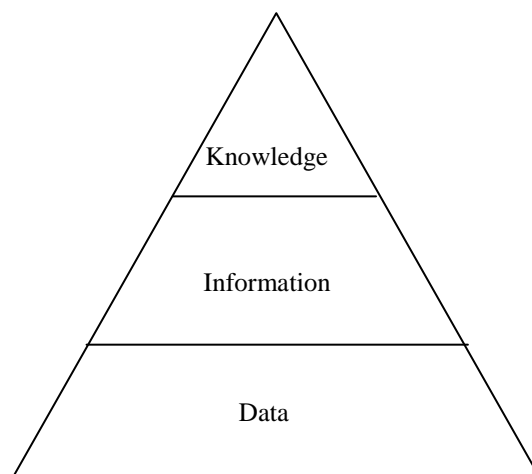
Figure 2.1 A Conventional View of the Knowledge Pyramid

Knowledge can never be complete and is only partially true since it is normally extracted from human practices and disseminated throughout the organization. Knowledge is not only embedded in a document or repository, but also can be generated from routines, processes, practices and norms (Davenport and Prusak, 1998). However, people have to process all these in order to turn them into knowledge since they comprise only information. Therefore, knowledge should be something actionable and stay within personal level where individuals will create and articulate knowledge to make decisions. It is sometimes difficult to codify and cannot be shared easily as most knowledge is embedded in the mind but not elicited. In fact, there is no knowledge at organizational level in the sense that what can be kept within the organization is only data and information. It has no value if no one acts upon it. Thus, managing knowledge at organizational level should also relate to trust building and sense-making among individuals and employees of an organization (Grant, 1996).

The reason why knowledge is so important is that, it is the key to success and competitive advantage for every organization. It can facilitate people to make better decisions through the effective sharing of information. Therefore, the elicitation of knowledge, that is, implicit knowledge not yet been codified is important in every organization. However, how can such knowledge be elicited from people's mind and transformed into useful

information for future use? Many organizations would ideally like to transform into learning organizations through acquiring and transferring knowledge, and modifying the behaviour of individuals to reflect new knowledge and insights (Garvin, 1993). In order to develop into a learning organization, knowledge that is still tacit or implicit in the minds of employees needs to be elicited, disseminated and then turned into use.

2.1.2 Acquisition of Knowledge

According to Huber (1991), knowledge can be acquired through five means: congenital learning, experiential learning, vicarious learning, grafting, and searching and noticing. Congenital learning refers to knowledge that is acquired by any person from his or her past organizations and which is brought to the present organization. Experiential learning means knowledge that is acquired through direct experience. This kind of learning may occur intentionally or unintentionally. Sometimes, there are some second-hand experiences which have been acquired through vicarious learning. Vicarious learning occurs when an organization learns from other organizations. Grafting occurs when an organization increases its store of knowledge through acquiring or grafting on new members who possess knowledge not previously available from within the organization. This method allows new knowledge to be gained more quickly. Lastly, searching and noticing can occur in three forms: scanning,

focused search and performance monitoring. Scanning occurs when an organization senses external information. Focused search refers to knowledge which the organization searches purposely in order to tackle specific problems. Performance monitoring means that an organization searches for information in order to fulfil its pre-defined goals. Noticing, relates to the unintentional acquisition of knowledge.

All the channels and sources described by Huber (1991) are important in acquiring knowledge. However, the process and mechanism of eliciting knowledge has not been addressed in detail. To get a better insight, it is necessary to understand the taxonomy of knowledge, and the cognition and social processes used in eliciting them. In the literature, there is no lack of theoretical models on knowledge elicitation. However, very few actual industrial cases with field data have been reported. The methodology for knowledge extraction is either too brief or too abstract.

2.1.3 *Classification of Knowledge*

Knowledge can be mainly classified into three categories – explicit, tacit and implicit as shown in Figure 2.2. Nickols (2000) stated that explicit knowledge refers to the knowledge that has been codified or expressed in words, numbers and pictures and shared in the form of data and manuals. However, knowledge must be generated through people's minds since what they can

read is only information. They have to process the information and transform it into knowledge. Tacit knowledge refers to knowledge that resides in the heads of individuals with or without their knowing. It is not easily visible or expressible, and usually requires joint, shared activities in order to transmit it such as experiences, insights and intuitions (Prusak, 1998). Finally, implicit knowledge refers to knowledge that has not been codified but is presumed to exist. It is also known as informal knowledge. Its existence is implied by or inferred from observable behaviour or performance. This is the kind of knowledge that can often be teased out of a competent performer by a task analyst, knowledge engineer or someone skilled in identifying the kind of knowledge that can be codified. (Nickols, 2000) The distinction between tacit and explicit knowledge determines who owns the knowledge. Explicit knowledge can be institutionalized and become the property of the firm in the form of either data or a work product. Both tacit and implicit knowledge effectively remain the property of the knowledge worker. That means, if that person leaves the company, the knowledge will leave the company with that person as well.

Besides that, there are other ways of classifying knowledge. Knowledge can also be classified as structured or unstructured, formal or informal, declarative, procedural or strategic. Structured knowledge is knowledge that is manageable and can

be quantified, counted and organized and measured (Glazer, 1998). It usually refers to knowledge that is captured, codified and stored with the use of technology. The most common use of technology in knowledge management is to create a repository of so called "structured knowledge" (Davenport and Prusak, 1998). On the other hand, unstructured knowledge is the knowledge of "what people know" which cannot be articulated, abstracted, codified, captured or stored (Hildreth and Kimble, 2002).
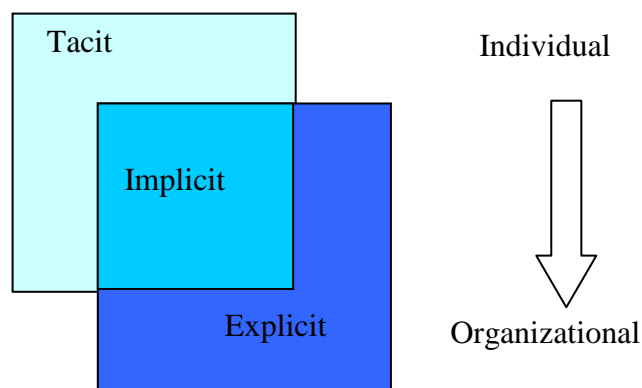
Figure 2.2 Explicit, Implicit and Tacit Knowledge

Conklin (1996) described formal knowledge as that which is found in books, manuals and documents, and which can be easily shared in training courses; while informal knowledge is the knowledge that is applied in the process of creating formal knowledge.

Other than that, some researchers such as Nickols (2000) classified knowledge as declarative, procedural and strategic. Declarative knowledge consists of descriptions of facts and things

or of methods and procedures that have much in common with explicit knowledge. It is concerned with facts in a domain (Hogeveen et al, 1994). Procedural knowledge refers to the know-how for performing some tasks. It is a list of instructions like a recipe or a computer programme that explains the step-by-step process of how to do something. Finally, strategic knowledge refers to what might be termed the know-when and know-why. Specifically, it may refer to knowledge that is conceived as the aspect of describing but not doing. It is probably best thought of as a subset of declarative knowledge instead of being in its own category.

In this thesis, the focus is on the elicitation of procedural and formal knowledge that is implicit and not codified in relation to reliability management in the Engineering Division of Dragonair.

2.2   WHAT IS KNOWLEDGE MANAGEMENT

Knowledge management (KM) is the process of systematically and actively managing and leveraging the stores of knowledge in an organization (UniSA, 2005). The major principle of knowledge management is "to provide the right knowledge to the right person at the right time with the right context". It focuses on capturing, storing, retrieving and reusing knowledge and experiences of individuals and groups within an organization and making this knowledge, best practices and lessons learnt, readily accessible to a wide audience internally and externally and empowering knowledge generation and learning

(Pasquariella, 2003). In this thesis, the process approach is adopted to demonstrate how knowledge can be elicited, codified and shared among employees so as to gradually build up a knowledge sharing and organizational learning culture.

KM can benefit an organization in a number of ways, including leverage "lessons learnt" to lower expenses, share information to generate new ideas, increase revenue and decrease expenses, improve the corporation's ability to adapt to change and to opportunities in the market, and foster innovation through the sharing of past solutions and collective ideas (Hough, 2002). The beauty of KM is that, not only usable or explicit knowledge (to know what we know) can be captured and knowledge gaps or needs (to know what we do not know) can be identified, but it can also help to elicit hidden knowledge (do not know what we know) and unknown gaps (do not know what we do not know) which may create future opportunities or threats (Stewart, 1997) (Figure 2.3).

	Know	**Don't Know**
Know	*Knowledge that you know you have* Explicit knowledge	*Knowledge that you know you don't have* Knowledge gaps
Don't know	*Knowledge that you don't know you have* Tacit knowledge	*Knowledge that you don't know that you don't have* Unknown gaps

Source: Intellectual Capital by Stewart

Figure 2.3 Self Knowledge versus Knowledge Domains

2.2.1 Evolution of Knowledge Management

There are three generations of KM. The first generation mainly focused on information technology. At that time, KM was over-hyped and misunderstood (Mullins, 2003). Most of the people were focusing on information management only. They tried to use technology such as document management system, content management system, expert systems, search engines, etc. to structure the flow of information to decision makers and support their decision making. However, technology cannot help creating knowledge. It can only manipulate explicit knowledge that is already known. Knowledge should come from people, but unfortunately managers at that time were unaware of the people dimension and many talented and experienced people were being laid off which resulted in loss of knowledge.

Therefore, it led to the second generation of Knowledge Management. Knowledge was regarded as either tacit or explicit according to the SECI model (Fig. 2.4) developed by Nonaka Takeuchi (1995). This SECI model was developed based on the distinction stated by Polanyi (1983) between tacit and explicit knowledge. It creates knowledge on the platform named "Ba" (Nonaka and Konno, 1988) which advanced individual and collective knowledge. There are four types of "Ba" that correspond to the four stages of the SECI model which focus on the movement of knowledge between tacit and explicit. They are

internalization, socialization, externalization and combination. According to Nonaka (1994), socialization refers to the sharing of tacit knowledge through face-to-face communications. Externalization refers to how tacit knowledge can be codified into explicit knowledge. Combination refers to the process of explicit knowledge capturing such as building a prototype and internalization refers to the process of learning where explicit knowledge becomes part of an individual's knowledge base.
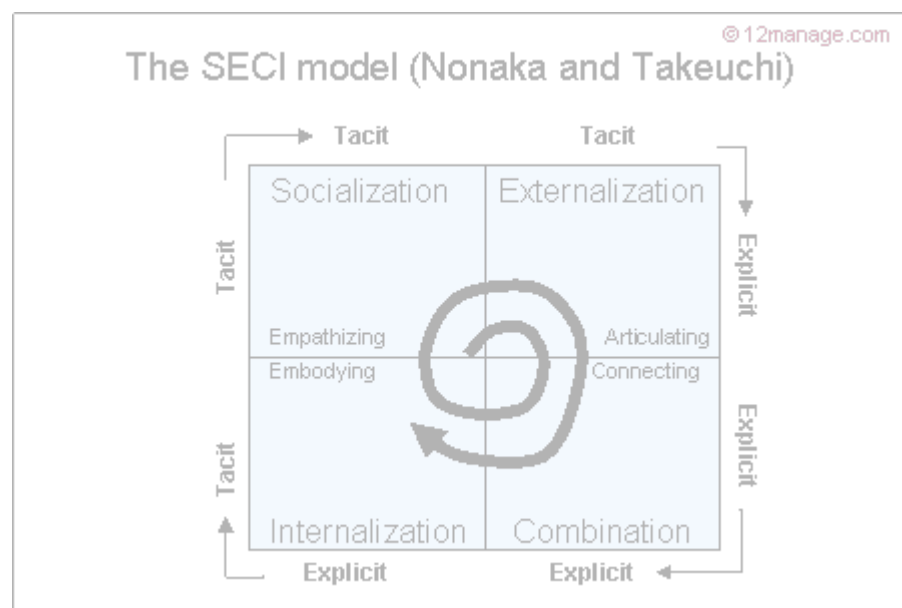
Source: 12manage by Geytere
Figure 2.4 The SECI Model

Although this model has been criticized for not recognizing that the conversion of tacit to explicit knowledge fundamentally changes the nature of the knowledge itself (Snowden, 2000), there is clear recognition of the social and human aspects that are involved. The fact that three out of the four quadrants are actually people-centric proves this point. However, this model

can only categorize the "social" process of conversion between different categories but does not explain how tacit knowledge can be elicited and made explicit.

Due to these pitfalls, the third generation of KM has been developed where people and culture are the main focus. Koenig (2002) mentioned that the third generation of KM is the stage of the arrangement and management of content through taxonomy construction and use which is something like the first generation where it is heavily biased towards information technology. However, Snowden (2002) claimed that knowledge is never wholly tacit or explicit and so only taxonomy may not be enough to deal with it. It is important to build strong boundaries between formal and informal communities. It focuses on effectiveness rather than efficiency and it is a more people-centric approach to KM with consideration given to social and human aspects. Knowledge is not something static like an object that can be transferred form one person to another. According to Snowden (2000), knowledge has the following characteristics:

(i)   It can only be volunteered, it cannot be conscripted.

(ii)   I only know what I know when I need to know it. Human knowledge requires contextual stimulation and the way that we know things is not the way that we say we know them, and that goes for decision making too.

(iii)   We always know more than we can say, and we will always say more than we can write down.

This is opposite to the traditional approach of classifying and storing knowledge and treating knowledge as an object. There is an opinion that once knowledge is captured, it is dead. Some researchers believe that it is difficult to capture knowledge since there are no common cause-and-effect relationships in solving a complex problem. Issues are seldom retrospectively coherent and repeat themselves in the same context. Therefore, there is no definite answer for each problem. The use of existing knowledge may limit creativity and innovation. Therefore, the re-use of existing knowledge should mainly be for routine processes and works that are similar. The validity of the captured knowledge to cover new circumstances should always be checked and cautioned, otherwise this would curtail innovation in an organization. Therefore, the elicitation, classification and introspection of knowledge should be of a continuous process. Having taken into consideration of the complexity of knowledge, the importance of capturing past experience and to build a knowledge repository should not be omitted as long as its undesirable effects have to be tackled and eliminated.

Another concern in performing KM is cost, since knowledge is something that can be very abstract (Snowden, 1999). According to Snowden (2003) as shown in Figure 2.5, the abstraction of

knowledge is inversely proportional to cost. At the level of highest abstraction, for example, when one person shares his experience with others, there is only a minor cost incurred. At the other extreme, if people want knowledge to be widely spread, cost becomes high, such as educating people to learn and to gain experience in a structured manner. Narrative is intermediate in the level of abstraction. It avoids the task of abstracting knowledge in formulating a receipt but conveys sufficient context to the receiving end than the ad hoc experience sharing among individuals.
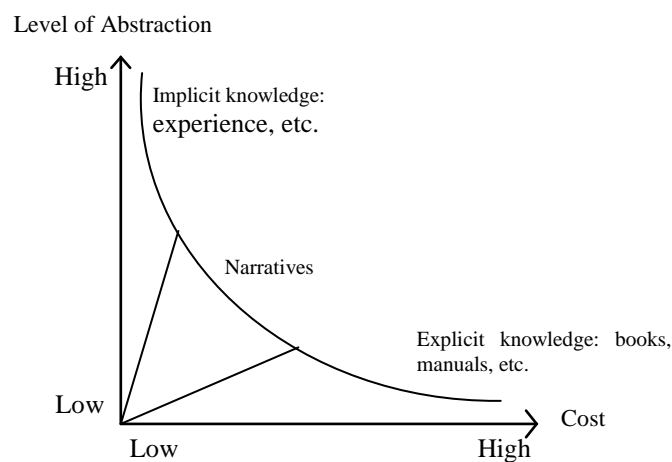
Figure 2.5 Level of Abstraction versus Cost

In addition to that, one obstacle in performing knowledge management is that people are afraid of sharing. At present, many people still perceive that knowledge is power (Skyrme, 1997). If knowledge is shared, power will be lost. Therefore, people resist sharing information and knowledge freely. Another problem is that it takes time to capture knowledge. People may

put knowledge management in a very low priority when compared with their daily work and they may not be willing to share even when they have time. Moreover, it is difficult to measure the return on investments of a knowledge management project. The outcome from a knowledge management project is not something that can be quantified easily. Therefore, it may be difficult to start a knowledge management project in an organization and there are many challenges in eliciting and capturing knowledge, and so a good sharing culture has to be promoted. It is recommended that every KM project should start on a small scale with clear objectives and deliverables that can be visualized and participated in by the people concerned. Culture is the key to the flow of knowledge in the organization (Snowden, 2003). Therefore, in order to minimize the cost, sharing knowledge or transferring knowledge to new members is critical to compensate for the cost incurred during knowledge creation and dissemination.

The first KM project started at Dragonair was on the coding of the business processes and the building of the Technical Information Centre (TIC). In this project, we tried to elicit the tacit knowledge of the staff in the Engineering Company involved in the handling of quality and reliability issues in aircraft maintenance. We did this through the application of narrative techniques and concept mapping.

2.2.2 *Learning Organization*

Learning takes place everyday everywhere, but in the past, people might only focus on individual learning and overlook the concept of organizational learning. Individual learning is only a prerequisite to organizational learning. Since 1975, March and Olsen have tried to link individual learning and organizational learning. In their model, individual beliefs lead to individual action. It in turn may lead to an organizational action and a response from the environment which may induce improved individual beliefs. This cycle will then be repeated. Organizational learning is the process by which an organization acquires the knowledge necessary to survive and compete in its environment. This includes the development of knowledge and understanding, shared among organizational employees, that leads to effective action (Bennet, 2005). Apart from that, Argyris and Schon (1978) defined organizational learning as "the detection and correction of error". They addressed the distinction between single and double loop learning (Figure 2.6). In single-loop learning, individuals, groups or organizations modify their actions according to the difference between expected and obtained outcomes; whereas in double-loop learning, different parties question the values, assumptions and policies that led to the actions in the first place. If they are able to view and modify those actions, then double-loop learning is said to have occurred.

Governing variable → Action strategy → Consequences

Single loop
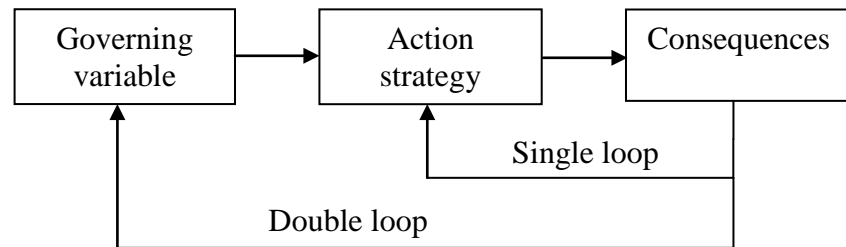
Double loop

Figure 2.6 Single and Double Loop Learning

Since the key concept of organizational learning is the interaction that takes place among individuals, it can facilitate an organization to become a learning organization.

A "Learning Organization" is one in which people at all levels, individually and collectively, are continually increasing their capacity to produce results they really care about (Karash, 2002). According to Senge (1990), learning organizations are those where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to see the whole together. In order to improve performance level, learning is the essential element to achieving it since learning is a systems-level phenomenon. It stays within the organization even if individuals change.

Being a learning organization can help maintaining and improving the performance of an organization. It can provide a harmonious environment for employees to work in which will

bring fulfilment and satisfaction to them in the end. From this, people can then generate their own creative and innovative ideas which lead to a happy life for them. It can further develop the core competencies of the organization by enhancing the knowledge base which in turn provides a win-win situation for every organization.

Culture is an important issue for an organization to become a learning organization. It is the main challenge in building a learning organization as organizations need to get the commitment of people and see how it can help them to learn. Culture helps to build the learning processes to ensure an institutionalized reality. Having a good sharing and learning culture can ensure knowledge transfer between people and this is a critical step in starting a knowledge management programme in an organization.

2.3   METHODS AND PROBLEMS IN KNOWLEDGE ELICITATION

The process of knowledge elicitation involves various activities including task identification, the selection of elicitation techniques with the corresponding selection criteria, the analysis, representation of the knowledge being mapped and its integration from the individual to the team level. The whole process is shown in Figure 2.7.

Traditionally, knowledge is captured by questionnaire surveys and structured interviews. Sometimes, knowledge may be captured through

methods known as ethnography and phenomenology. However, there are many limitations in each of the above formats. As mentioned previously, we may not even know what we know. Therefore it is difficult to use a structured way to elicit the knowledge needed.
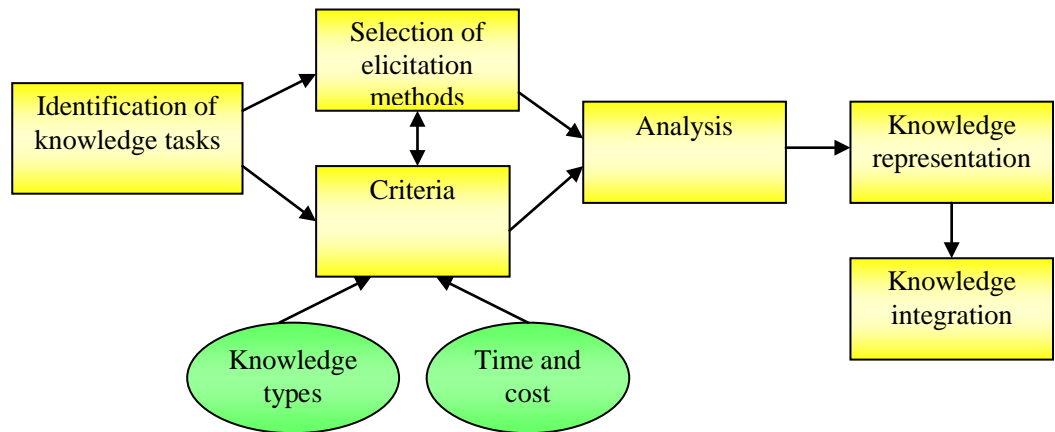
Figure 2.7 Knowledge Elicitation Framework

2.3.1 *Selection of Elicitation Methods*

Knowledge elicitation is the process of extracting information, through in-depth interviews and observations, about cognitive events, structures, or models. Often, the people who provide this information are *subject matter experts* (SMEs) - people who have demonstrated high levels of skill and knowledge in the domain of interest (Klein Associates, 2000). Nordlander (2005) has a similar interpretation of knowledge elicitation. He claimed that knowledge elicitation is a sub-set of knowledge acquisition that specifically refers to retrieving knowledge from a human expert(s) using a range of strategies.

Most critically, knowledge elicitation is a process of eliciting tacit knowledge, that is bringing out the knowledge present in the conscious and sub-conscious mind or helping the expert in recalling and redefining their rules of thumb, work practices, processes, etc. with the help of a knowledge engineer (Songar, 2007; Morecroft and Heijden, 1994).

There are many different elicitation techniques (Cooke, 1994) and selecting the "right" technique in a particular situation is important. Moreover, knowledge elicitation involves skilled people and this makes it an important cost-determining factor.

There are two important factors to consider (Martinez-Bejar et al, 1996):

(i) the kind of knowledge to be elicited

(ii) the time and cost involved in the elicitation process

One of the methods in eliciting knowledge is using questionnaire surveys. Using questionnaire surveys is an efficient and easy way in collecting and administering a large amount of information from a large number of subjects. One main advantage is that responses are gathered in a standardized way, so it will be easier for researchers to analyze the data. Generally questionnaire surveys are relatively quick to collect information. However, in some situations they can take a long time not only to design but also to apply and analyze. Also, the return rate of using

questionnaire surveys may be low. The main disadvantage of using questionnaire surveys is the inability to probe responses. Most of the time only areas of interests will be asked, recorded, codified and analyzed where some of the useful information may not have been noticed. According to Walonick (1997), questionnaire surveys allow little flexibility to the respondent with respect to response format. In essence, they often lose the "flavour of the response" (i.e. respondents often want to qualify their answers) since there may not be enough space for respondents to express their feelings and comments. Comments are among the most helpful of all the information on the questionnaire, and they usually provide insightful information that would have otherwise been lost. However, subjects always leave the comments section blank. Therefore, conducting interviews may be more suitable for capturing knowledge and experiences. In general, questionnaire surveys are mainly used to seek opinions from a large volume of subjects. They are inappropriate for eliciting procedural and experiential knowledge.

Another method in capturing knowledge is ethnography which is more focused on qualitative information. It is used by cultural anthropologists when studying groups of people. It involves four key tenets as stated by Schensul (2005): (i) ethnographers spend time with people as they go about their daily lives, learning how they live by actually doing what they do; (ii) it is conducted in the

space where participants actually live, work and play, not in a separate research facility; (iii) findings are delivered in the words of the participants, using their language and intonation; (iv) actions and thoughts of people are influenced, directly or indirectly, by absolutely everything in their lives. Ethnographers stay open to all potential connections.

This method can be useful to understand the real situation that people come across, but it may take a long time for researchers to obtain enough information or there may be difficulties for researchers to obtain information that they want. Also, after collecting the information, there may be difficulties in presenting the knowledge to others in an appropriate way.

Phenomenology is another qualitative method to capture knowledge. Phenomenology is the study of structures of consciousness as experienced from the first-person point of view (Smith, 2005). It studies the appearances of events as they appear in the experience of one person or the way that a person experiences events. It is suitable for understanding social processes (Olukunle, 2006), but it is a time consuming process. Also, it is difficult to do data analysis, as in the case of ethnography, as clear patterns may not emerge.

Interviews are widely used to capture knowledge from experts. There are still some techniques which may enhance the data collection process where people may not have noticed. As stated

by Bright (1991), interviews can be used as a means of sampling the knowledge, opinions and thoughts of interviewees. It is mainly used to focus on areas of expertise. The success of an interview relies heavily on the questions asked and also how the interviewees articulate their knowledge. The advantage of using interviews is that it allows greater depth and flexibility in gathering knowledge because it enables interviewees to elaborate and explain complex issues. "The spoken or written word has always a residue of ambiguity, no matter how carefully we report or code the answer". (Fontana and Frey, 2000) Also, the interviewing technique can be invaluable because if the interviewee answers the question wrongly due to his or her understanding of the wording, the interviewer can easily rephrase the question to put the answer back on track (Milne, 1999).

There are different types of interviews: structured, semi-structured and unstructured (Turban and Frenzel, 1992). Questions for structured interviews are set in advance just like an oral presentation of a questionnaire where interactions are kept to minimal. For this kind of interviews, the questions are quick and easy to answer and the inquiry is clear. However, structured interviews are quite inflexible. Interviewees may be forced to give an answer which is not according to their will, thus the number of responses is limited and it is not appropriate for capturing knowledge related to complex issues. For semi-

structured interviews, a series of questions are used very much like a questionnaire, but the questions are usually open-ended and personal opinions should be avoided. For unstructured interviews, only a few themes are identified and interviewees are allowed to express themselves freely. All the questions are open-ended. Interviewers must be trained to have good interpersonal skills, listening skills and interviewing techniques. This kind of interviews is good for revealing particular experience of interviewees. It is possible to capture complex issues using the narrative technique as a form of unstructured interview. It allows free flow of information where hidden assumptions and knowledge in people's minds can be captured. More details will be discussed in the next section.

2.3.2   Narrative Technique

"Knowledge elicitation compromises a set of techniques and methods that attempt to elicit knowledge of a domain specialist through some form of interaction with that expert" (Schreiber et al, 2000). One of the techniques is the use of narratives.

The word 'narrative' is derived from the Latin word "gnarus" and the Proto-Indo-European root gnu, "to know", it came into English via the French language and it is used in a number of specialised applications. It is an interpretation of some aspect of the world that is historically and culturally grounded and shaped by human personality (Walter, 1984). Narrative is an account of

a sequence of events. It is a story describing situations and characters according to a timeline in text which can either be fictional or non-fictional.

Narrative can be a story or an anecdote. According to dictionary.com, a story is an account or recital of an event or a series of events, either true or fictitious. It refers to a retelling of events that led to an outcome which is of value to certain audiences (MSDN Academic Alliance Developer Centre, 2005); while an anecdote is a brief tale which narrates an interesting or amusing incident. It is always based on real life, an incident involving actual persons in real places. It can be a story of personal experience. However, over time, modification in reuse may convert a particular anecdote to a fictional piece. The word anecdote ("unpublished", literally "not given out") comes from Procopius of Caesarea, the biographer of Justinian I, who produced a work entitled Ανεκδοτα (Anekdota, variously translated as Unpublished Memoirs or Secret History), which is primarily a collection of short incidents from the private life of the Byzantine court. Gradually, the term anecdote came to be applied to any short tale utilized to emphasize or illustrate whatever point the author wished to make.

According to Snowden (1999) and Gabriel (2000), anecdotes are typically oral and ephemeral. They are just one of the many types of stories told in organizations and the collection of anecdotes

from people in an organization can be used to better understand its organisational culture.

Narrative technique is a traditional way for humans to share and affirm ideas, issues, and values. It is an informal way in capturing and organizing the experience of individuals or a particular group of people. Sometimes, hidden agenda in people's mind can be surfaced since it provides an opportunity for participants to think and reflect on themselves. It acts as a means for knowledge disclosure. It is suggested that narrative technique be applied in complex situations where the outcome is dynamic with many possibilities. There are always non-linear interactions since it involves human perceptions and cause-and-effect relationships are clear in retrospect. Generally, narratives are defined as stories with a patterned series of episodes including a beginning, middle and end, and told in particular situations for particular purposes (Magoulick, 2003). Narratives can be faction or fiction, good practices or even bad practices depending on the nature of the project, but the piece of information should be contextual. The most important aspect of using narratives is that they can really help individuals to grasp ideas and values from the events being told. In addition, trust and respect between people is very important, without which, knowledge may not be shared in an effective manner.

Using narratives is a low cost but effective tool that can stimulate people to think and reflect on themselves so that knowledge can be shared, captured and transferred. This technique can enhance knowledge sharing since effective communication needs a story to be told in a convincing and attention catching way. This tool has been used in many organizations such as the World Bank (Denning, 2000), the British Council (Cheuk, 2003), Scottish Enterprise (Perkinton, 2003), etc. This kind of exercise should be conducted through an open discussion on a pre-defined topic. In stories circles (Donaldson, 2005), a large number of anecdotes and stories can be created and shared. Participants will be given a chance to tell their stories or anecdotes on a particular event while others will be able to listen and learn from them.

According to Jonassen (2006), experiential knowledge representations in the form of stories are the most natural, comprehensible, and memorable representations of knowledge. Stories can be used to solicit opinion, experience or know how. The ASHEN model is proposed by Snowden (1998) to help practitioners identify the elements to be extracted from stories during the elicitation process and capture the knowledge of experts.

2.3.3 ASHEN Model

Before collecting stories, a set of questions should be prepared to arouse people's interest and stimulate them to tell different

narratives. Stringer (1996) suggested that questions should be carefully formulated to ensure that participants are given maximum opportunity to present events and phenomena in their own terms and to follow agendas of their own choosing. The process of formulating the questions can start the learning process. It can be done by giving the questions some serious collective thought before asking. Often the questions will be modified to more accurately capture the disjuncture or part of the reality that is really stimulating the group. Also, direct questions should not be asked and those asked should provide a focus to participants to ensure that the responses are useful and related to the scope of the project.

The ASHEN model is one of the methods for facilitating the framing of questions. It was advocated by Snowden in 1998 to help to identify what knowledge needs to be captured, shared and transferred. It can be used in building context in the narratives which would be collected through the application of narrative technique. ASHEN refers to Artefacts, Skills, Heuristics, Experience and Natural Talents. A description is given by Cheuk (2005) as follow:

- ARTEFACTS - anything made by people to hold knowledge independently of those people, e.g. documents, databases, tools, etc.

- SKILLS - something we know how to do and which can be measured absolutely i.e. the skill of using a computer or riding a horse.

- HEURISTICS - simple rules which can make a project work, i.e. rules of thumb

- EXPERIENCE - things that can only be learnt or fully understood if one has experienced them

- NATURAL TALENTS - some people are simply better at doing things than others e.g. singing or playing a musical instrument.

The ASHEN Model provides a linguistic framework both to help organizations to identify what they know and to move directly to action as a result of the meaning provided by the language (Snowden, 2000). Knowledge can be elicited in an effective way with the use of this anthropological technique. It is a conduit to elicit knowledge from people through combining the narrative technique and the ASHEN model. After collecting the narratives, relevant information and knowledge need to be extracted, represented and organized for future use.

2.4   ORGANIZATION OF KNOWLEDGE

After collecting sufficient data or information, it is important to organize it to help people share and retrieve it for generating new knowledge.

Knowledge organization requires optimizing the organization of knowledge repositories in order to support easier retrieval, creation and sharing of knowledge for user communities (Sigel, 2000). Also, it can simplify the problem solving process by an appropriate choice of knowledge representation. Therefore, knowledge organization is vital in performing a knowledge management project as it can ensure all important knowledge assets are fully utilized and enhanced with respect to the business value of an organization.

2.4.1 Knowledge Representation

Knowledge representation is concerned with how people store and process information. It includes a variety of schemes that organize, manage and retrieve data and information (Hodge, 2000). It appears in different kinds of forms such as databases, portals and libraries, and ranges from general classification schemes, for example from organizing books on a shelf, to taxonomies, semantic networks and even ontologies. They are all powerful and intuitive philosophy, methodology and framework that can be used to leverage existing data, resources and knowledge that will allow systems to evolve with the business.

To be more systematic and combine knowledge with the use of information technology, some organizations may use knowledge-based systems, such as document management systems, to organize their data in a convenient and efficient way. These are typically computer systems that can imitate human problem

solving through programming. It is a form of artificial intelligence and uses a database of knowledge on a particular subject. The main purpose of these systems is to centralize data or information and further categorized data in a meaningful way for users so that data or information can be readily retrieved.

According to Davis et al (1993), knowledge representation is fundamentally a surrogate or a substitute for the knowledge itself, used to enable an entity to determine a sequence by reasoning about the world. There is a variety of knowledge representation tools available such as logic, rules, frames, and semantics nets. Semantic nets allow people to define relations between objects. They were developed by Quillian (1986) as a model for human memory and the relationships can be arbitrarily defined by knowledge workers. Inheritance is one of the main kinds of reasoning employed in semantic nets (Konev, 2004). However, it may cause problems since no one has validated the data. Facts placed inappropriately will also cause problems as there is no standard about the values between the relationships. Therefore, validating the data is very important when using semantic nets.

In today's ever-changing world, there is no universal way in organizing and representing data or information since there is no standardized cause-and-effect relationship between an action and its possible consequences. Business is only possible when there is an expectation of shared meaning between parties. As long as

the expectations are congruent, and the eventuality agrees with the expectation, business continues. Therefore, in order to cope with this ever-changing world, it is suggested to compare new objects or experiences that users are familiar with and then identify patterns and group them into the existing categories. Cognitive mapping is one of the solutions for transferring knowledge in a dynamic way.

2.4.2 Cognitive Mapping

Generally, a map can be defined as a visual representation. It can establish a landscape or a domain for people to find locations. It further names the most important entities that exist within that domain and simultaneously places them within two or more relationships. In more complex applications, maps can facilitate the images of being "within" the established domain and encourage mentally moving entities. A map does not exist without establishing a 'domain' although everything should be defined by context (Huff and Jenkins, 2002). Thus, a map highlights this critical aspect of knowledge. The word "cognitive" in cognitive science is used for any kind of mental operation or structure that can be studied in precise terms (Lakoff and Johnson, 1999) where cognitive science refers to the action or process of knowing and it is the interdisciplinary study of mind and intelligence (Thagard, 2004). Cognitive mapping is a type of mental processing, or cognition, composed of a series of

psychological transformations by which an individual can acquire code, store, recall, and decode information about the relative locations and attributes of phenomena in their everyday or metaphorical spatial environment (Downs and Stea, 1973). Cognitive maps, as shown in Figure 2.8, in cognitive psychology are considered as dynamical schemes inside human mind (Tolman, 1948). This is why cognitive mapping can help visualize the relationships between entities and assist decision making since it combines the concept of a map and presents the mental processes of perception, memory, judgment, and reasoning of people, as contrasted with emotional and volitional processes.

Cognitive mapping can connect and organize dispersed organizational knowledge, and so it is a valuable technique for improving the quality of the decision process by producing a representation of the thinking process about a particular issue or situation. Therefore, it has gained prominence as a way of visually presenting the mental models of how organizational members see their worlds based on their everyday experiences. Mental models are the basic structure of cognition (Johnson-Laird, 1983) and they are the basis for all reasoning processes (Holland et al, 1986).

Cognitive mapping can measure the human mental representations by structuring data in a contextual way in order to encode knowledge and information and link objects together

through relations. It helps to make inter-relationships and inter-dependencies explicit. It has the capacity not only to catalogue but also to generate knowledge. This can be done by presenting information to people through the use of cognitive maps, and they will make decisions based on the information. This is how knowledge can be generated. Axelrod (1976) stated that cognitive mapping can help evaluate the reasoning of people and avoid over simplification of complex decision environments. It can facilitate organizational activities by simplifying inevitably complex domains as they can present information in a simplified but systematic way. They can even surface and organize concepts and relationships that are normally taken for granted. In order to allow decision-makers to examine their reasoning, practitioners can lay bare the structure of their thoughts and the connections between their beliefs by the use of cognitive maps since such maps can harness the power of vision to understand complex information "at-a-glance" (Dillard, 1999).

Other than that, cognitive mapping is a technique that has been developed over a period of time that can serve a variety of purposes such as helping to structure, analyze and make sense of messy or complex data for problem solving. It can also be applied when conducting interviews by visualizing the mental models of interviewees. According to Ackermann et al (1993), cognitive mapping can be used as a note-taking method during

interviews or acts as an effective interview device to structure a complex problem. Alternatively, it can be used to record transcripts of interviews or other documentary data in a way that promotes analysis, questioning and understanding of the data. Whilst cognitive mapping is often carried out with individuals on a one-to-one basis, it can be used with groups to support them in problem solving. However, it may be a challenge for the practitioner to listen and understand what the interviewee is telling at the same time. The practitioner may end up either abandoning the map and making straightforward notes, or missing important points of view.

Cognitive maps are directed graphs and thus they have their historical origins in graph theory, which was formulated by Euler in 1736 (Biggs et al, 1976). In each link connection between variables has a direction (Harary et al, 1965). This direction will show users how information will flow from one entity to another. Axelrod (1976) was the first to use cognitive mapping to show the causal relationships among variables as defined and described by other people, rather than by the researcher. Many studies have used cognitive mapping to look at decision-making as well as to examine people's perceptions of complex social systems (Axelrod, 1976).
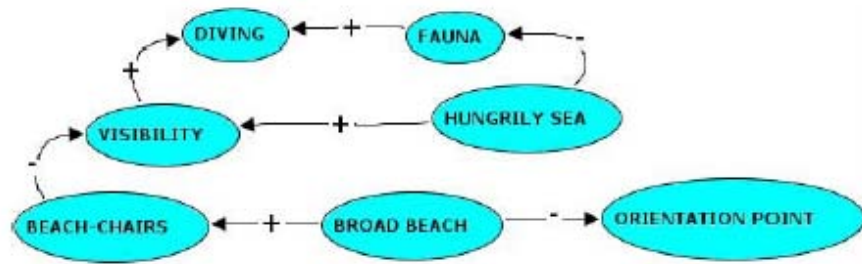
Source: From Cognitive Mapping to Qualitative Modeling in Cognitive Research
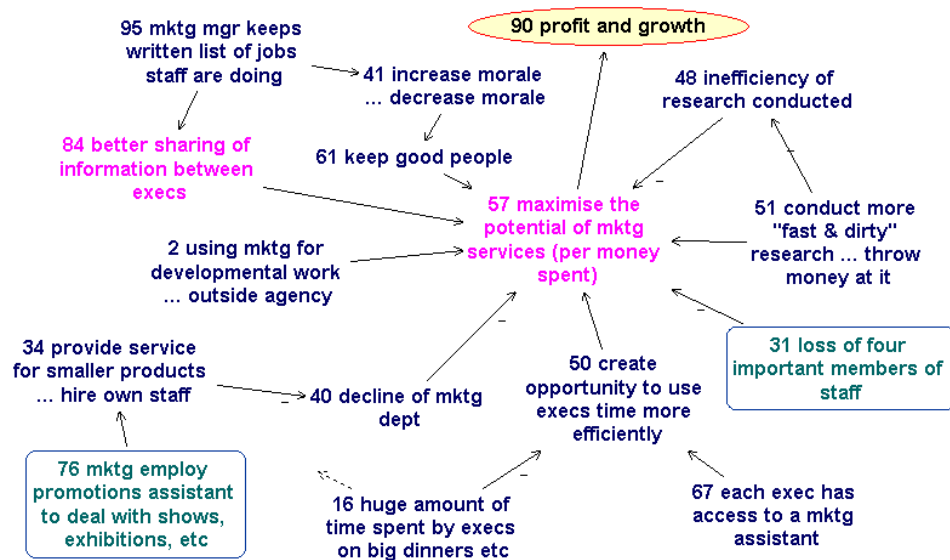
Source: www.banxia.com

Figure 2.8 Samples of Cognitive Maps

According to Senge (1992), "Systems Thinking" is a discipline for seeing wholes. Cognitive mapping can help present a case as a whole. It helps by presenting interrelationships rather than individual events and by showing patterns of change rather than static snapshots. A cognitive map is a network of casual relationships between options and objectives that one can safely trust, if not always, at least most of the time. It provides a better

semantic interoperability for organizing data and information. The cognitive map of a company entails the options that it envisions, the objectives that it wants to pursue, and a network of casual links from options to objectives along paths that represent available strategies (Minati et al, 2006). Also, it has the capacity to represent knowledge at various levels of abstraction, therefore, it is useful for presenting information that are obtained from the narratives as they are of different levels of abstraction. Moreover, it is vital in sharing knowledge by presenting the mental model of people in knowledge organization since they are mapped through different labels, and the names of labels found on the map deserve explication. The mapmaker is typically well advised to use some well-known names as an orienting device, even if the map is a private thinking tool.

According to Huff and Jenkins (2002), the most distinctive attribute of a cognitive map is that it establishes relationships. It is important to relate map entities. Design, colour, sound cues, computer links and other options can be used for clarity and to add additional categorization schemes. Also, cognitive maps can facilitate the making of images. The visual form of cognitive maps makes it easier to consider the implications of 'standing' at different points on the map. They have the ability to facilitate the communication in group settings and help aggregate opinions within a group. As such, cognitive maps are highly suitable as

measures of mental models, and they can be represented and assessed on paper or screen through a concept map.

2.4.3   Concept Maps

Concept maps are one of the methods that can be used to represent knowledge as shown in Figure 2.9. Concept mapping is a type of cognitive map, in a sense that it represents a structured process, focused on a topic or construct of interest. It involves input from one or more participants that produces an interpretable pictorial view, or a map of their ideas and concepts and how these are interrelated (Trochim, 2006). A concept map is "a schematic device for representing a set of concept meanings embedded in a framework of propositions" (Novak and Gowin, 1984). Concept maps, sometimes called mind maps, are used to stimulate the generation of ideas, and are believed to aid creativity (Novak and Canas, 2006). They are sometimes used for brainstorming and are used to form knowledge models by placing them in a hierarchical organization and appending elaborating media onto the nodes within each map (Coffey et al, 2002). According to Lanzing (1997), concept mapping can be used for several purposes. For example, it can be used to generate ideas, design a complex structure such as hypermedia, large web sites, communicate complex ideas, learn by explicitly integrating new and old knowledge and to assess understanding or diagnose misunderstanding.

Source:

http://cmap.ihmc.us/Publications/ResearchPapers/TheoryCmaps/Fig1CmapAboutCmap
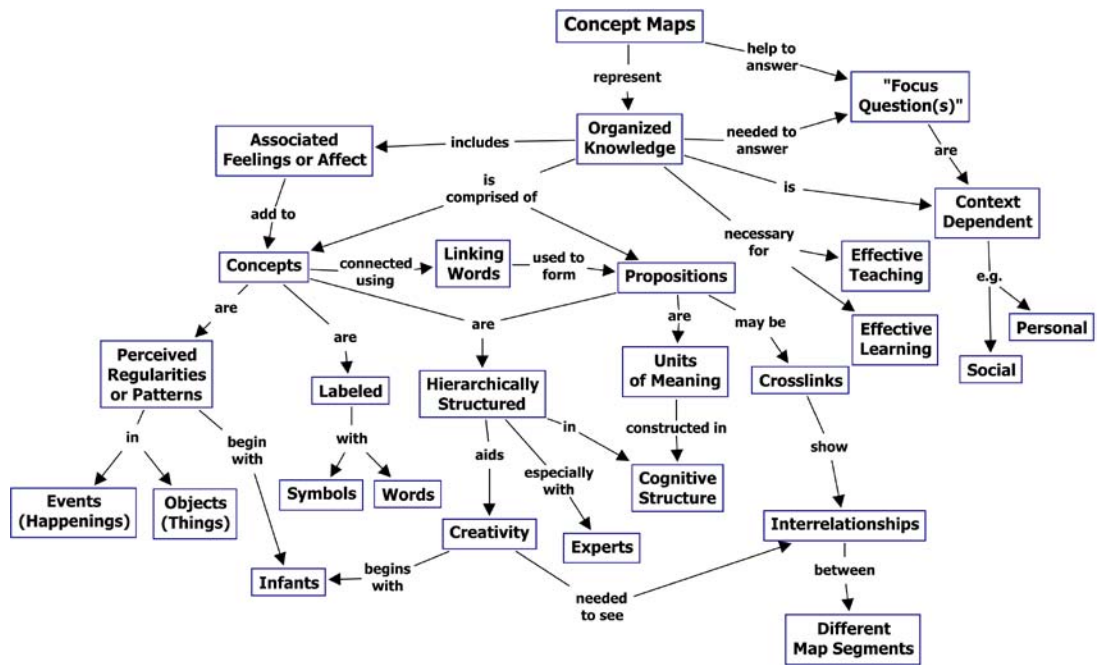
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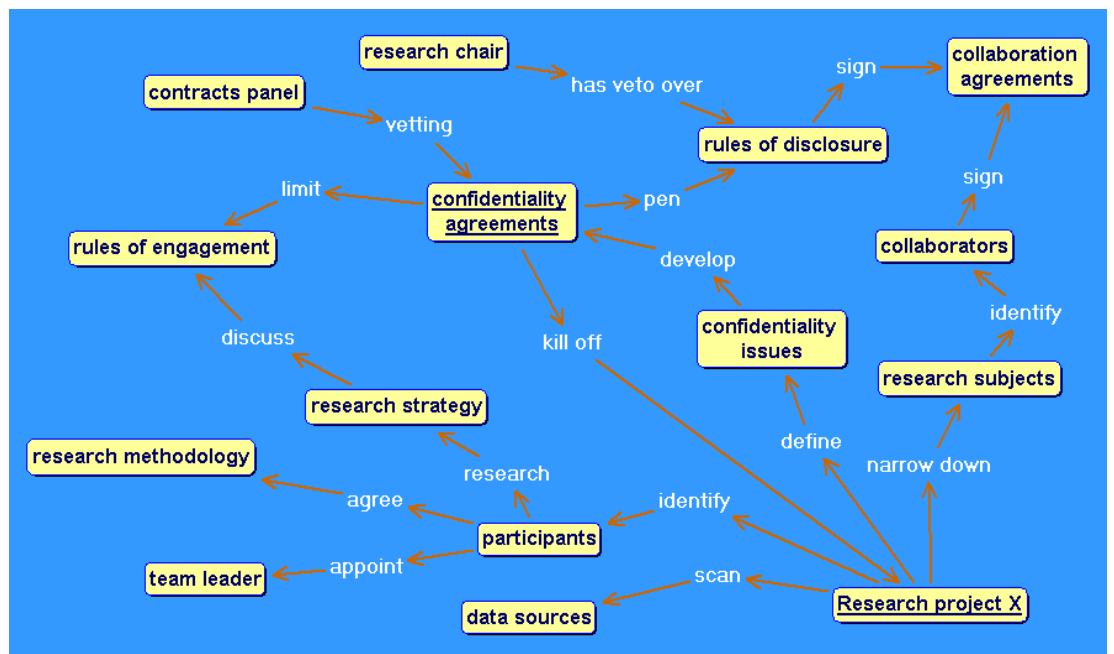
Source: www.banxia.com

Figure 2.9 Samples of Concept Maps

As described by Plotnick (1997), a concept map is a graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts. The concepts, and sometimes the links, are labelled on the concept map. The links between the concepts can be one-way, two-way, or non-directional. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts.

Concept maps and cognitive maps look very similar, but they represent knowledge in different ways as shown in Table 2.1. Both concept maps and cognitive maps allow people to see the connections between ideas and organize them in a logical but flexible structure, and both are applicable to complex issues. However, the difference between the methods is that cognitive mapping is a causal based mapping technique. It is based on Personal Construct Theory (Kelly, 1955) that can visualize the mental model of an individual, a team or an organization. It is in general an individual's internal representation of the concepts and relations among concepts that the individual uses to understand their environment (Swan, 1995). At the simplest level, cognitive maps can be expressed as concepts that are associated in a network in one's mind (Ward & Reingen, 1990). A cognitive map is traditionally represented by a signed directed graph, where concepts correspond to nodes of the graph and causal

relationships correspond to arcs oriented from the cause concepts to the effect concepts. In contrast to relationships in concept map, the sign and strength of causality in cognitive map are expressed by evaluating the arcs with numerical values. The ideas in concept maps are often single words. The links between nodes in concept maps are labeled with descriptions, defining the association between concepts and expressing a relationship type.

In this project, the cognitive maps of individuals are visualized in the form of concept maps. Cognitive maps are constructed to present the flow of the decision making process of staff. Making the cognitive maps of staff explicit can help them to re-use past information and generate new knowledge for better decision making in the future. Also, it helps staff to share their mental model among themselves which can promote the culture of organization learning.

Table 2.1 Comparison between Cognitive Map and Concept Map

Cognitive Map	Concept Map
Cognitive mapping is a type of mental processing, or cognition, composed of a series of psychological transformations by which an individual can acquire code, store, recall, and decode information about the relative locations and attributes of phenomena in their everyday or metaphorical spatial environment (Downs and Stea, 1973)	Concept mapping is a type of cognitive map, in a sense that represents a structured process, focused on a topic or construct of interest, involving input from one or more participants, that produces an interpretable pictorial view called a concept map of their ideas and concepts and how these are interrelated (Trochim, 2006)
Cognitive maps in cognitive psychology are considered as dynamical schemes inside human mind (Tolman, 1948). Cognitive mapping is a causal based mapping technique. It is based on Personal Construct Theory (Kelly, 1955) that can visualize the mental model of an individual, a team or an organization. It is in general an individual's internal representation of the concepts and relations among concepts that the individual uses to understand their environment (Swan, 1995). Cognitive maps can be expressed as concepts that are associated in a network in one's mind (Ward & Reingen, 1990)	A concept map is "a schematic device for representing a set of concept meanings embedded in a framework of propositions" (Novak and Gowin, 1984)
Cognitive map combines the concept of a map and presents the mental processes of perception, memory, judgment, and reasoning of people, as contrasted with emotional and volitional processes. A cognitive map is a mental representation of the layout of one's environment. It seems that many animals, not just humans, are able to form a mental representation of an environment that they have been in or are currently in. For example, when a friend asks you for directions to your house,	A concept map is a visual representation of an individual's knowledge structure on a particular topic as constructed by the individual. It represents an individual's own understanding of specific material. Concept maps bring to light individual differences in learning; different people will have different types of concept maps, even on the same content. (http://www.ttuhsc.edu/SOM/success/DHPS/Concept%20Map%20

you are able to create an image in your mind of the roads, places to turn, landmarks, etc., along the way to your house from your friend's starting point. This representation is the cognitive map. (http://www.alleydog.com)	Module.htm)
Cognitive mapping can connect and organize dispersed organizational knowledge, and so it is a valuable technique for improving the quality of the decision process by producing a representation of the thinking process of people about a particular issue or situation. Axelrod (1976) stated that cognitive mapping can help evaluating the reasoning of people and avoid unnecessary simplification of complex decision environments. It can facilitate organizational activities by simplifying inevitably complex domains as they can present information in a simplified but systematic way. They can even surface and organize concepts and relationships that are normally taken for granted.	Concept maps are used to evaluate how people organize their knowledge of a particular topic. Concept maps are useful for several reasons: they give an observable record of an individual's understanding; they demonstrate how information is meaningful; they force an individual to think about his/her own thought processes and knowledge structure; and they are helpful in problem solving, application, and integration. (http://www.ttuhsc.edu/SOM/success/DHPS/Concept%20Map%20Module.htm)
In order to allow decision-makers to examine their reasoning, practitioners can lay bare the structure of their thoughts and the connections between their beliefs by the use of cognitive maps since cognitive maps can harness the power of vision to understand complex information "at-a-glance" (Dillard, 1999)	Concept maps harness the power of our vision to understand complex information "at-a-glance." The primary function of the brain is to interpret incoming information to create meaning. It is easier for the brain to do so when information is presented in visual formats. It is essential to one's studies and career so that one can handle complex information; concept maps offer one method to do this. (http://classes.aces.uiuc.edu/ACES100/Mind/CMap.html)
According to Ackermann et al (1993), cognitive mapping can be used as a note-taking method during interviews or acts as an effective interview device to structure a complex problem.	Concept maps, sometimes called mind maps, are used to stimulate the generation of ideas, and are believed to aid creativity (Novak and Canas, 2006). They are sometimes used for brainstorming and are

	used to form knowledge models by placing them in a hierarchical organization and appending elaborating media onto the nodes within each map (Coffey et al, 2002). According to Lanzing (1997), concept mapping can be done for several purposes. It can be used to generate ideas to design a complex structure such as hypermedia, large web sites, etc., to communicate complex ideas, to learning by explicitly integrating new and old knowledge and to assess understanding or diagnose misunderstanding.
Cognitive maps are directed graphs and have their historical origins in graph theory, formulated by Euler in 1736 (Biggs et al, 1976). In each link connection between variables has a direction (Harary et al, 1965). This direction will show users how information will flow from one entity to another. A cognitive map is traditionally represented by a signed directed graph, where concepts of the cognitive map correspond to nodes of the graph and causal relationships correspond to arcs oriented from the cause concepts to the effect concepts. In contrast to relationships in concept map, the sign and strength of causality in cognitive map are expressed by evaluating the arcs with numerical values. Cognitive mapping encourages people to look for a "hierarchy" in the ideas that they are mapping. The hierarchy is one of cause and effect, means/ ends, how/ why, working towards identifying desired and (as a consequence undesirable) outcomes. In cognitive mapping, as with the other forms of mapping, the full meaning of the ideas is given by the "whole picture". Links between ideas add further	The ideas in concept maps are often single words. The links between nodes in concept maps are labeled with descriptions, defining the association between concepts and expressing a relationship type. As described by Plotnick (1997), a concept map is a graphical representation where nodes (points or vertices) represent concepts, and links (arcs or lines) represent the relationships between concepts. The concepts, and sometimes the links, are labeled on the concept map. The links between the concepts can be one-way, two-way, or non-directional. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts.

contextual information to the concepts themselves, and there is meaning through the content of the ideas - the way in which they are expressed as short phrases - and through the context within which they sit. (http://www.banxia.com/dexplore/whatsinaname.html)	
Axelrod (1976) was the first to use cognitive mapping to show the causal relationships among variables as defined and described by people, rather than by the researcher. Many studies have used cognitive mapping to look at decision-making as well as to examine people's perceptions of complex social systems (Axelrod, 1976).	Reader and Hammond (1994) suggested a simple definition for concept map as "a graphical representation of domain material generated by the learner in which nodes are used to represent domain key concepts, and links between them denote the relationship between these concepts"
The cognitive map of a company entails the options that it envisions, the objectives that it wants to pursue, and a network of casual links from options to objectives along paths that represent available strategies (Minati et al, 2006)	A concept map is a diagram showing the relationships between concepts. Concept maps graphically illustrate relationships between information. In a concept map, two or more concepts are linked by words that describe their relationship.
With respect to Huff and Jenkins (2002), the most distinctive attribute of a cognitive map is that it establishes relationships. It is important to relate map entities. Design, colour, sound cues, computer links and other options can be used for clarity and to add additional categorization schemes. Also, cognitive maps can facilitate the forming of images.	Concept mapping uses a top down approach, working from general to specific or use a free association approach by brainstorming nodes and then develop links and relationships. Use different colors and shapes for nodes & links to identify different types of information. Use different colored nodes to identify prior and new information. Use a cloud node to identify a question. (http://www.graphic.org/concept.html)

2.5   KNOWLEDGE INTEGRATION

After representing knowledge elicited from individuals, knowledge integration is useful for providing an overview of knowledge of the whole process for sharing among the group of people. Knowledge integration consists of combining knowledge which is fragmented and dispersed among individuals in order to solve a problem or make a decision (Okhuysen and Eisenhardt, 2002). Clemens (2004) states that knowledge integration is the process of fitting ideas of people, that is the theories of how-the-world-works, together into a coherent structure. The goal of knowledge integration is to weave diverse ideas together into coherent networks. That coherent structure, and the process of bringing knowledge together, have a number of critically important uses:

- For expanding the scope of thinking when people come across just the idea, or combination of ideas that enables progress to be made on the seemingly intractable problems that people face

- Reconciling conflicting ideas by forcing into the open hidden assumptions and logical inconsistencies

- Clarifying thinking and highlighting areas of incoherence, disagreement or uncertainty by synthesizing diverse perspectives.

- Creating a whole by connecting ideas together that is greater than the sum of its parts

Moreover, the differentiation of knowledge creates a need for knowledge integration. No one can be an expert in all areas. Therefore, knowledge integration makes use of the specialized knowledge from each expert to come up with a broader perspective on how to solve a problem. It helps in solving complex problems by getting a grasp of the whole, and can prevent specialized knowledge from becoming dispersed too widely over organization members (Tsoukas, 1996). Also, individuals have restricted learning capacities (Simon, 1991). They cannot have the breadth and depth of knowledge required to solve all the problems. Therefore, knowledge has to be integrated in order to provide a general idea on how to tackle a problem. From this integrated body of knowledge individuals can learn more and get guidelines to solve a problem, based on others' ideas. Thus, the aim of team sharing can be achieved.

Cohen (1997) claims that many people use a database management system to integrate knowledge by identifying a common set of terms in a set of documents and selectively integrate them together. This is also called semantic heterogeneity. Decision support systems are another mechanism to integrate knowledge. Knowledge is codified and embedded in the system. The original specialist knowledge of people can be integrated in the practices of a wide range of other members of the organization (Davenport and Glaser, 2002). Group problem solving is also a way to integrate knowledge. This mechanism consists of the direct combination of knowledge previously dispersed among

individuals in order to solve a problem (Okhuysen and Eisenhardt, 2002). This method involves the active use of knowledge and the generation of new ideas aided by the combination of knowledge.

In this project, knowledge integration refers to the congregating of the cognitive maps of individual members of staff to form an overall map that combines all the major features of the decision making process of individual staff in handling reliability issues in aircraft maintenance in Dragonair. Although the combining process is done by the author, the overall map needs to be discussed and validated by all staff members concerned who contributed to the map to make sure there has been no distortion or mis-interpretation of the data in the combination process.

CHAPTER 3   PROJECT PLAN AND SCOPE

This chapter addresses the selection of a project on knowledge elicitation, the process and the methodology involved.

3.1   OVERVIEW OF PROJECT

The main focus of this project is on how to elicit knowledge from the experience of the staff in the Engineering Division of Dragonair. The process of knowledge elicitation is shown in Figure 3.1. A project theme has to be identified at the very beginning. This is a very important step since it may affect the success of the project. It is crucial to identify a business task that involves decisions to be made by various parties. After that, the objectives have to be defined. The objectives can provide directions in framing the stimulating questions that help participants to trigger their thoughts in later stages. Following that, the scope of the project has to be identified. A scope is a boundary or a breakdown structure with descriptions that are needed to complete the project so that it will be easier to control. Once the scope has been defined, stimulating questions can be set. Although a free flow of information is allowed in the narrative technique for capturing knowledge, it is important to have a set of questions in order to guide and stimulate the participants to expose their experience. The questions are constructed on the basis of the ASHEN model. When the questions are ready narrative interviews are arranged with the chosen participants. Narratives will be recorded and transcribed into scripts. Following that, learning points will be extracted and they will

be shared among the staff through a document management system where they can retrieve detailed information about each narrative. After collecting a sufficient number of narratives (stories or anecdotes), cognitive maps will be drawn based on each narrative and each of them will be validated with the corresponding narrators. When a number of cognitive maps are available, patterns can be revealed and they can be combined to form a congregate cognitive map which can give a general idea for people when they face a new problem. Finally, a focus group exercise will be conducted in order to validate the data in the aggregate cognitive map. The map will be modified until it comes to a conclusion which makes sense to the participants.

3.2   SELECTION OF THE PILOT PROJECT

The first critical step for starting a project is to identify the project theme. Since this is a pilot run, it is important to identify an area that is crucial to the company, an area that contains complex and dynamic problems that require much experience to tackle.

In order to identify the project for knowledge elicitation in Dragonair, a brainstorming section was carried out among the departmental management staff within the Engineering Division. This allowed them to identify the areas that need to make use of knowledge management techniques to help them capture and retain their existing knowledge. After that, they had to identify an area in which the experience captured would be most crucial and critical to its business. All department

managers were invited to identify projects in which they expected

knowledge management would be able to help them to fulfill their needs
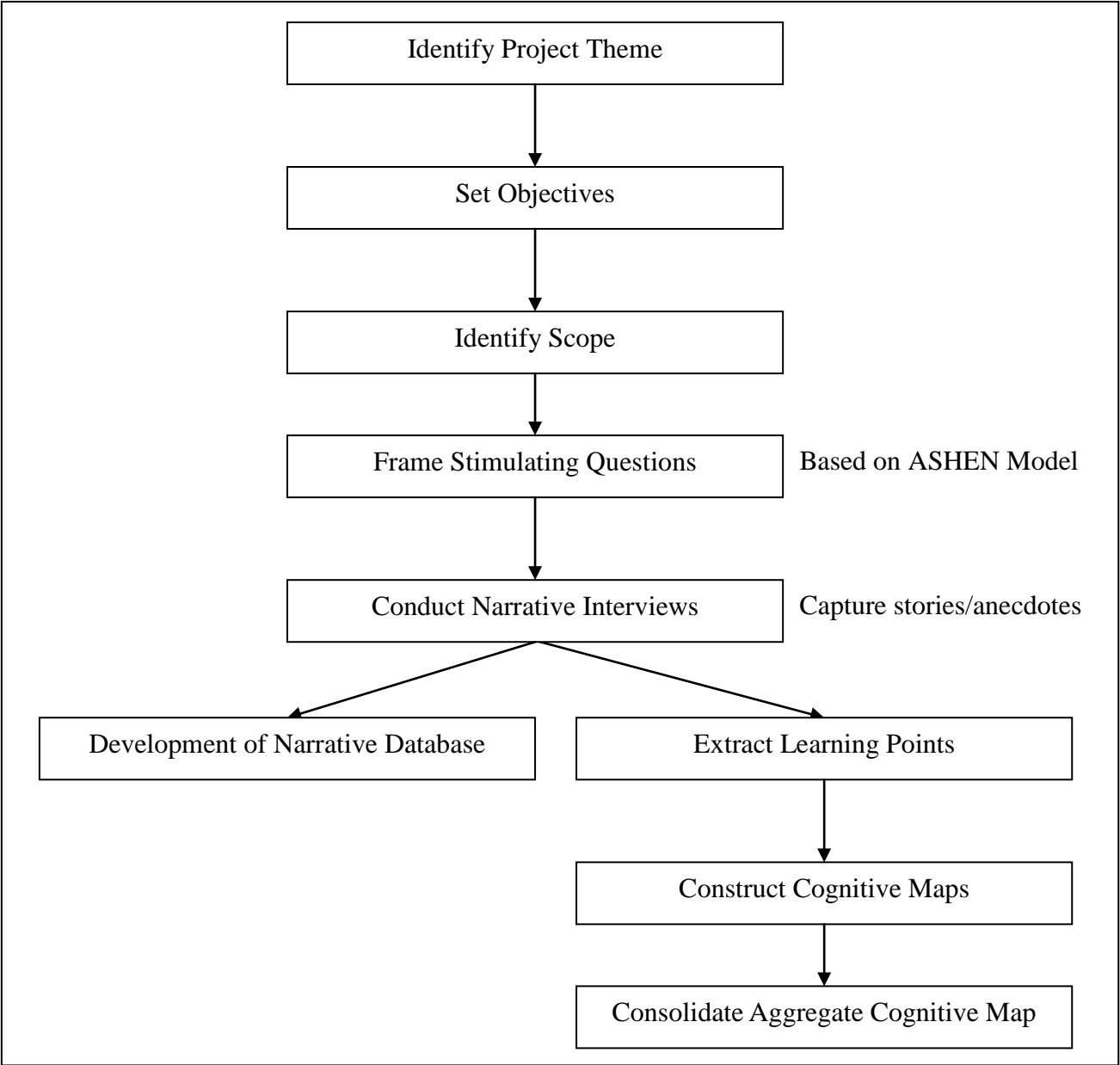
(Table 3.1).

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┌─────────────────────────────────────────────────────────────────────────┐
│                    ┌─────────────────────────────┐                        │
│                    │   Identify Project Theme     │                        │
│                    └─────────────────────────────┘                        │
│                                  │                                         │
│                                  ▼                                         │
│                    ┌─────────────────────────────┐                        │
│                    │       Set Objectives         │                        │
│                    └─────────────────────────────┘                        │
│                                  │                                         │
│                                  ▼                                         │
│                    ┌─────────────────────────────┐                        │
│                    │       Identify Scope         │                        │
│                    └─────────────────────────────┘                        │
│                                  │                                         │
│                                  ▼                                         │
│                    ┌─────────────────────────────┐                        │
│                    │  Frame Stimulating Questions │   Based on ASHEN Model │
│                    └─────────────────────────────┘                        │
│                                  │                                         │
│                                  ▼                                         │
│                    ┌─────────────────────────────┐                        │
│                    │  Conduct Narrative Interviews│   Capture stories/anecdotes│
│                    └─────────────────────────────┘                        │
│               ┌──────────────┴──────────────┐                             │
│               ▼                              ▼                             │
│  ┌───────────────────────────┐   ┌───────────────────────────┐            │
│  │ Development of Narrative  │   │   Extract Learning Points  │            │
│  │        Database           │   │                            │            │
│  └───────────────────────────┘   └───────────────────────────┘            │
│                                              │                             │
│                                              ▼                             │
│                                  ┌───────────────────────────┐            │
│                                  │  Construct Cognitive Maps  │            │
│                                  └───────────────────────────┘            │
│                                              │                             │
│                                              ▼                             │
│                             ┌───────────────────────────────────┐         │
│                             │ Consolidate Aggregate Cognitive Map│         │
│                             └───────────────────────────────────┘         │
└─────────────────────────────────────────────────────────────────────────┘
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Figure 3.1 The Knowledge Elicitation Process

After identifying the potential processes, they had to be prioritized in order to select the most important project to start the pilot run. To select the highest priority process, two major criteria were evaluated. They were the "impact to Dragonair if knowledge is lost" and the "need for knowledge retention".

Included in the "impact to Dragonair if knowledge is lost", is the amount of impact it will have on the aircraft reliability, daily operations, safety and airworthiness and operating costs if this special knowledge is lost. Secondly, the "need for knowledge retention", refers to the urgency for retaining specialist knowledge in Dragonair. The need for knowledge retention includes whether "the chance of losing the expertise is high", "difficulties in finding experts from the market" and "how long does it take to train a newcomer to pick up the job". With these criteria in mind, all the departmental managers were invited again to jointly score all the identified processes listed in Table 3.2 below. In order to select the pilot project, they were asked to rank all the items from one to five where one is the lowest in importance and five is the highest. After the evaluation the scores, we concluded that "Aircraft Reliability Management" (see Table 3.3) is the area of most importance and where this pilot project should start. After identifying the area, the objectives of the project had to be defined in order to set a scope for capturing the narratives from staff.

Table 3.1 Identified Knowledge Items

Department	Owner	Identified Projects
Eng Purchasing	AL	Performance Measurement System Implementation
Eng Purchasing	AL	Continuous Improvement Projects Facilitation & Implementation
Eng Purchasing	KH	Performance Measurement System (PMS) Development
Eng Purchasing	KH	Improvement of Project Coordination (Engine Reliability Management)
Tech Supplies & Contract	KT	Purchasing, Evaluation and Negotiation Process (Service)
Quality Assurance	SL	Company Maintenance Authorization
Quality Assurance	SL	Authorization of Flight Crew
Quality Assurance	SL	Updating and Distribution of Technical Manuals and Data
Quality Assurance	SL	Temporary Authorization
Quality Assurance	TO	Conducting a Quality Audit
Quality Assurance	TO	Review Procedure Manual
Eng Planning	FL	Man Hour Review
Eng Planning	FL	Work Order Coordination
Eng Planning	AF	Freighter Project from Acquisition to Aircraft in Service
Eng Planning	AF	Maintenance Planning
Eng Planning	TK	Coordinate between HX and KA Commercial
Eng Planning	TK	Short Term Maintenance Planning
Technical Services	SM	Fleet Configuration
Technical Services	SM	Fleet Performance Management
Technical Services	SM	Service Provider Performance Measurement
Technical Services	SM	Aircraft Reliability Management
Technical Services	SM	Financial Tracking
Technical Services	SM	Information Management and Tracking for Aircraft Delivery
Technical Services	SM	Budget Control
Technical Services	SM	Cost Control - Continuous Improvement
Technical Services	SM	Managing ADDs
Maint. Operation Dept	FT	Deferred Defects Expiration Monitoring
Maint. Operation Dept	FT	Providing Work Instruction to HX for DD Troubleshooting
Maint. Operation Dept	CC	Review Tech Log History and Propose Troubleshooting Procedures
Maint. Operation Dept	TB	Aircraft Delay Analysis - Root Cause
Maint. Operation Dept	TB	Deferred Defects Monitoring/Clearance
Maint. Operation Dept	TB	Aircraft Rotation & Task Planning
Maint. Operation Dept	KL	ADDM Coordination
Maint. Operation Dept	KL	Resolving Technical Delay Situation
Line Maintenance	BM	Liaising with CX/CASL for Riding Engineer
Line Maintenance	BM	OTP Preventing Unnecessary Delays
Line Maintenance	KC	Line Maintenance Staff Recruitment Process
Line Maintenance	KC	Line Maintenance Staff Training and Development Process (Technical Training)

Table 3.2 Scorecard on Identified Knowledge Items

Dept	Owner	Identified Knowledge items	Impact to KA if knowledge is lost (1 - 5, 5=Greatest impact)	Need for Knowledge Retention (1 - 5, 5=Highest Need)	Impact
Eng Purchasing	AL	Performance Measurement System Implementation	3	4	
Eng Purchasing	AL	Continuous Improvement Projects Facilitation & Implementation	3	4	
Eng Purchasing	KH	Performance Measurement System (PMS) Development	3	4	
Eng Purchasing	KH	Improvement Project Coordination (Engine Reliability Management)	3	4	
Tech Supplies & Contract	KT	Purchasing, Evaluation and Negotiation Process (Service)	5	5	
Quality Assurance	SL	Company Maintenance Authorization	5	5	
Quality Assurance	SL	Authorization of Flight Crew	5	5	
Quality Assurance	SL	Update and Distribution of Technical Manuals and Data	4	4	
Quality Assurance	SL	Temporary Authorization	4	4	
Quality Assurance	TO	Conduct Quality Audit	5	5	
Quality Assurance	TO	Review Procedure Manual	4	4	
Eng Planning	FL	Man Hour Review	4	4	
Eng Planning	FL	Work Order Coordination	3	2	
Eng Planning	AF	Freighter Project from Acquisition to Aircraft in Service	4	4	
Eng Planning	AF	Maintenance Planning	4	4	
Eng Planning	TK	Coordinate between HX and KA Commercial	3	2	
Eng Planning	TK	Short Term Maintenance Planning	3	2	
Technical Services	SM	Fleet Configuration	5	4	Incorrect configuration among the fleet
Technical Services	SM	Fleet Performance Management	5	5	Poor performance of the fleet
Technical Services	SM	Service Provider Performance Measurement	3	4	Inadequate support/Conflicts with Service Providers
Technical Services	SM	Aircraft Reliability Management	5	5	Poor operational performance among the whole fleet
Technical Services	SM	Financial Tracking	3	4	Over budget on projects

Department	Person	Task			Impact
Technical Services	SM	Information Management and Tracking for Aircraft Delivery	4	4	Poor handling on aircraft delivery
Technical Services	SM	Budget Control	5	5	Over spending for KA Engineering
Technical Services	SM	Cost Control - Continuous Improvement	5	5	Poor productivity/efficiency and end up spending more
Technical Services	SM	Managing ADDs	3	2	Poor performance of the whole fleet
Maint. Operation Dept	FT	Deferred Defects Expiration Monitoring	4	4	
Maint. Operation Dept	FT	Providing Work Instruction to HX for DD Troubleshooting	3	4	
Maint. Operation Dept	CC	Review Tech Log History and Propose Troubleshooting Procedures	4	4	
Maint. Operation Dept	TB	Aircraft Delay Analysis - Root Cause	3	4	
Maint. Operation Dept	TB	Deferred Defects Monitoring/Clearance	2	3	
Maint. Operation Dept	TB	Aircraft Rotation & Task Planning	5	3	
Maint. Operation Dept	KL	ADDM Coordination	5	3	
Maint. Operation Dept	KL	Resolving Technical Delay Situation	3	3	
Line Maintenance	BM	Liaising with CX/CASL for Riding Engineer	5	4	
Line Maintenance	BM	OTP Preventing Unnecessary Delays	5	4	
Line Maintenance	KC	Line Maintenance Staff Recruitment Process	3	4	
Line Maintenance	KC	Line Maintenance Staff Training and Development Process (Technical Training)	5	5	

Impact to KA if Knowledge is lost

    Affects aircraft reliability

    Affects daily operations

    Affects safety (which cause high consequential damages)

    Increase cost

Need for Knowledge Retention

    Chance of losing the expertise is high

    Difficult to find experts from market

    It takes a long time for a new comer to pick up the job

Table 3.3   Scorecard Evaluation Result

Dept	Owner	Identified Knowledge items	Impact to KA if knowledge is lost (1 - 5, 5=Greatest impact)	Need for Knowledge Retention (1 - 5, 5=Highest Need)			
			Cost	Chance of losing the expertise is high	Difficult to find experts from market	It takes a long time for a new comer to pick up the job	No. of stakeholders
Eng Purchasing	KT	Purchasing, Evaluation and Negotiation Process (Service)	4.25	4	4.25	4.5	20
Quality Assurance	SL	Company Maintenance Authorization	4	3.25	3.75	3.75	3
Quality Assurance	SL	Authorization of Flight Crew	3.25	2.5	3	2.75	2
Quality Assurance	TO	Conduct Quality Audit	3.25	3.25	4	3.5	8
Technical Services	SM	Fleet Performance Management	4	4	4.25	4.25	3
Technical Services	SM	Aircraft Reliability	4.25	3.5	4.25	4.75	9
Technical Services	SM	Budget Control	4	3	3.5	3.25	3
Technical Services	SM	Cost Control - Continuous Improvement	3.25	3	3.25	3.5	4
Line Maintenance	KC	Line Maintenance Staff Training and Development Process (Technical Training)	3.5	3.5	4	3.25	2

In this project, Aircraft Reliability Management was chosen as the theme. This is a unique area in the airline business and not many successful airlines in the world have captured the experience of staff and cases in handling reliability management, in a systematic manner.

3.3   SETTING THE OBJECTIVES

The reason for choosing reliability management is best illustrated in this way: imagine two Engineers, Engineer A and Engineer B, are working in the same department and they are both assigned to handle similar reliability cases. However, as we shall see the outcome may be different. Engineer A may work very hard and focus on how to tackle the problem from the technical point of view. He may tackle the problem by doing a detailed analysis of the problem in order to identify the root cause and communicate his findings with the manufacturer while trying to look for an improvement to prevent the same problem from occurring again. While Engineer B may not do anything by himself at all. He may just communicate with the manufacturer on the problem. He may put all his effort into coordinating with other team members and departments to manage this failure situation in order to prevent additional damage to the company due to this failure or performance degradation. From these two approaches, we can easily see the difference between these two Engineers, but "why is it that a similar problem/issue given to different people will result in different handling approaches?"

Different people handling the same reliability issues may end up with different results. They manage their work mainly based on their own knowledge of the task or of similar cases that they have handled on their own or they have heard about from their colleagues before. It means that the way how people react to or manage an issue will mainly depend on their own past experience or mental model. From the management point of view, both of them having their own experience and they are both of the same value to the company. From the efficiency and effectiveness point of view of the company, a task is seldom assigned to two engineers simultaneously. Therefore, there is a need to find out a way to capture, retain and share the knowledge of both Engineer A and Engineer B in such a way that they can learn from each other and enrich the decision making process without too many "blind spots".

From the Engineers A & B case mentioned above, it can be observed that different people will have different ways of looking at the same problem and how to resolve or handle it. These ways are affected by their own past experience. Therefore, Dragonair may need to consider capturing their individual experience and combining their knowledge together and preserving it so it can be shared with others who need to handle similar cases in the future.

With the objectives of the project defined, we can proceed to frame the stimulating questions for use during the narrative interviews. The objectives of this project are set out below:

- To develop a methodology of capturing airline reliability management knowledge

- To identify the decision making process in reliability management

- To provide guidelines for staff who need to handle cases of reliability

- To build up training materials based on the recorded stories

3.4   FRAMING STIMULATING QUESTIONS

Before the whole exercise starts, selected participants were told about the theme of the project and were asked to prepare the narratives that they would like to tell. They could also bring along related material with them in order to make the sharing more effective. Although they had already prepared before the session started, some stimulating questions were asked in order to build enough context for the narratives. Questions were framed according to the ASHEN model.

3.4.1   ASHEN Model

The ASHEN model refers to **a**rtefacts, **s**kills, **h**euristics, **e**xperience and **n**atural talents. These are the elements that should be included in the questions set in order to stimulate participants to tell their narratives.

- "A" refers to artifacts. Questions such as "What do you need in order to get your work done?", "What tools/resources did

you use?", "What are the documents needed to support the decision made?", "What was the most useful tool you had to work with? Why was that?"

- "S" refers to skills. Questions included: "What kind of skills are needed to solve the problem?", "How did you find out what was wrong?", "What were your questions at that stage?"

- "H" refers to heuristics. Questions like "If you have another chance to handle the case again, what is the thing you most regret or would most like to "undo"?", "If you have another chance to handle the case again, what is the most important aspect of your work that you would want to continue with?", "How was the decision made?"

- "E" refers to experience. Questions included "What were the immediate actions taken?", "What are the long term improvements?", "What action was taken to prevent future occurrence?"

- "N" refers to natural talents. Questions are "Were you able to take advantage of any good luck during the project?"

Applying these five elements in framing questions can help to add context to the narratives told by participants. Therefore, it is always a good practice to design a set of questions based on the ASHEN model before interviewing the participants.

3.4.2 Other Suggested Questions to Stimulate Thoughts

Apart from using the ASHEN framework, another essential point is to stir up the interest of the interviewees to recall their memories. In order to achieve this, the questions constructed should be open-ended. This can allow participants to tell more and elaborate in greater detail. Probing questions may include some emotional words such as 'frustrating' and 'enjoy', so that it will stimulate their thoughts and allow them to tell more of their experience and make the narratives more contextual. Also, during the interview, it is suggested that the practitioner should try not to interrupt the participant as this may distract the narrator from the original idea that he/she wants to talk about. Sometimes, questions that include some emotional terms can trigger the participants to tell more. These include:

- What did you find to be most frustrating?

- Who was the person you went to most for assistance?

- What opportunities were missed on this issue?

- What have been the most valuable experiences?

- What have been the most unexpected developments?

- What were the most difficult parts in handling the case/identifying the problem?

- What did you enjoy most (least) about the XYZ project?

- What was the best moment for you during the project?

These kind of questions can help participants to say what made the case so successful or what make the case fail, which is the main thing that we want to obtain from them. This is the knowledge or decision point we would like to capture. Sometimes, we may try to put participants into situations or allow participants to answer in a 3rd party's identity. This can help them to express their experience in a more effective way and they will not be afraid of telling others about what they did wrong before. Most importantly, never ask a direct question since asking a direct question will limit the answer that the participants can give**.**

3.5 CONDUCTING NARRATIVE INTERVIEWS

One of the most difficult tasks in this project is how to capture a sufficient number of narratives from the group of participants. Narratives are collected by conducting individual, or focus group face-to-face interviews with selected participants. They are the staff of the company who are all experienced in handling reliability cases. The narrative interview is chosen because sometimes staff may not be able to tell their experience to others since we do not know what we know until we need to know it, but through this exercise, this kind of knowledge that they may not be aware of, may also be revealed. Although it is called an interview, practitioners should

not treat it as a formal interview since it may give an impression to interviewees that the practitioner is trying to take their knowledge away. The narrative interviews should be done in an informal and relaxed manner to help them to reflect on their actions with a view to improving in the future. Before the interviews, the practitioner has to declare clearly to the participants the objectives and purposes of the interview in order to minimize any misunderstanding which make them reluctant to tell their narratives.

Conducting narrative interviews in a casual way can help break down the barrier between the practitioner and the participants. Refreshments can be provided if available so that a more relaxing and comfortable environment can be created and interviewees can share their narratives with the researcher just like talking to a friend. It may also be a good idea to do this kind of interview in the interviewees' own seats where people with the same expertise or interest surrounding them may voice out their opinions as well, since this may arouse the interest of others to share their own narratives as well. Also, their own seat is also a comfort zone for them to tell their narratives as it is their usual working place where they will feel safe and comfortable to speak.

During the interview, the practitioner has to take notes of what the participant says. It would be better if the narratives can be recorded on a tape recorder so that the researcher can transcribe them later. An example of a transcribed narrative is shown in the Table 3.4 below. However,

recording has to be agreed by the interviewees before hand. This can prevent the loss of important information in the narratives during the interviews. Also, it is important that the names of the interviewees are not recorded so that they will not be afraid of being blamed. In an exercise conducted in this way it is likely that the whole context of the narratives unfolded by participants would be captured. The narrative captured can be their own stories or from a third party which perhaps they will feel more comfortable telling. In addition to that, practitioner should try not to interrupt the participants while they are telling their stories so as to prevent affecting the context of the narratives. However, it is important to use the set of guidelines framed in the earlier stage in guiding the participants to tell narratives related to the theme of the project.

It took around five to ten minutes to capture one narrative and altogether eight members of staff were interviewed. After the interviews, information obtained has to be compiled, analyzed and delivered to end-users in a structured way. In this project, all the narratives are stored in a document management system which is explained in the following section.

3.6   NARRATIVE DATABASE

After collecting the narratives, they were stored in a centralized repository for ease of retrieval. This centralized repository is called a narrative database. The narrative database was built with the use of a document management system (Figure 3.3). For effective retrieval of narratives in the future, a set of attributes was defined before the narratives were

uploaded into the system, for case indexing. Indexing refers to assigning indexes to cases for future retrieval and comparison. The choice of indexes is important to enable retrieval of the right case at the right time. This is because the indexes of a case will determine in which context it will be retrieved in the future. Indexes must be predictive in a useful manner. This means that indexes should reflect the important features of a case and the attributes that influence the outcome of the case, and also describe the circumstances. Also, indexes should be abstract enough to allow retrieval in all circumstances in which a case will be useful. On the other hand, indexes cannot be too broad. If the indexes of a case are too broad, the case may be retrieved in too many situations or too much processing is required to match cases. Assigning indexes is still largely a manual process and relies on human experts. Therefore, it should be done by the narrative teller since they are expert in reliability management as well. Attributes can be defined based on features (e.g. types of failure, system types, etc.) and by dimensions (e.g. types of experience, detectability of the defect) that are predictive across the entire problem domain so that they can help case retrieval in the future and find out the most similar cases for users as a reference. The pre-defined set of attributes is shown in Figure 3.2.

After defining the attributes, learning points have to be extracted from each narrative. This can enhance learning for users since it will summarize the essential points, allowing them to read and understand the narratives faster. All the learning points should be extracted from the original script of the

narrative. They should not be refined otherwise it will affect the context of the narrative. This can be done by highlighting the key points from the original the narratives and key learning points will be documented in the form of word documents, after they have been validated by the corresponding narrative tellers.

The validation process will be done through the document management system by using the versioning control function. Documents will be hidden and only the narrative owner can have the right to view and edit it before it is published. The names of the narrative tellers will not be disclosed. Finally, in order to enhance searching and provide an easy way to retrieve the stories, meta-data will be entered according to the pre-defined set of attributes as shown in Table 3.4.

In order to make the narratives more interesting and easier to read, understand and interpret, related photos can be attached to the file so that the document will provide a clearer picture to users. Other documents such as meeting minutes, investigation reports, can also be attached since they can further help staff to better understand the problem situation and how the problem is resolved. For future analysis, reports can be designed and generated through gathering the data obtained from this meta-data.
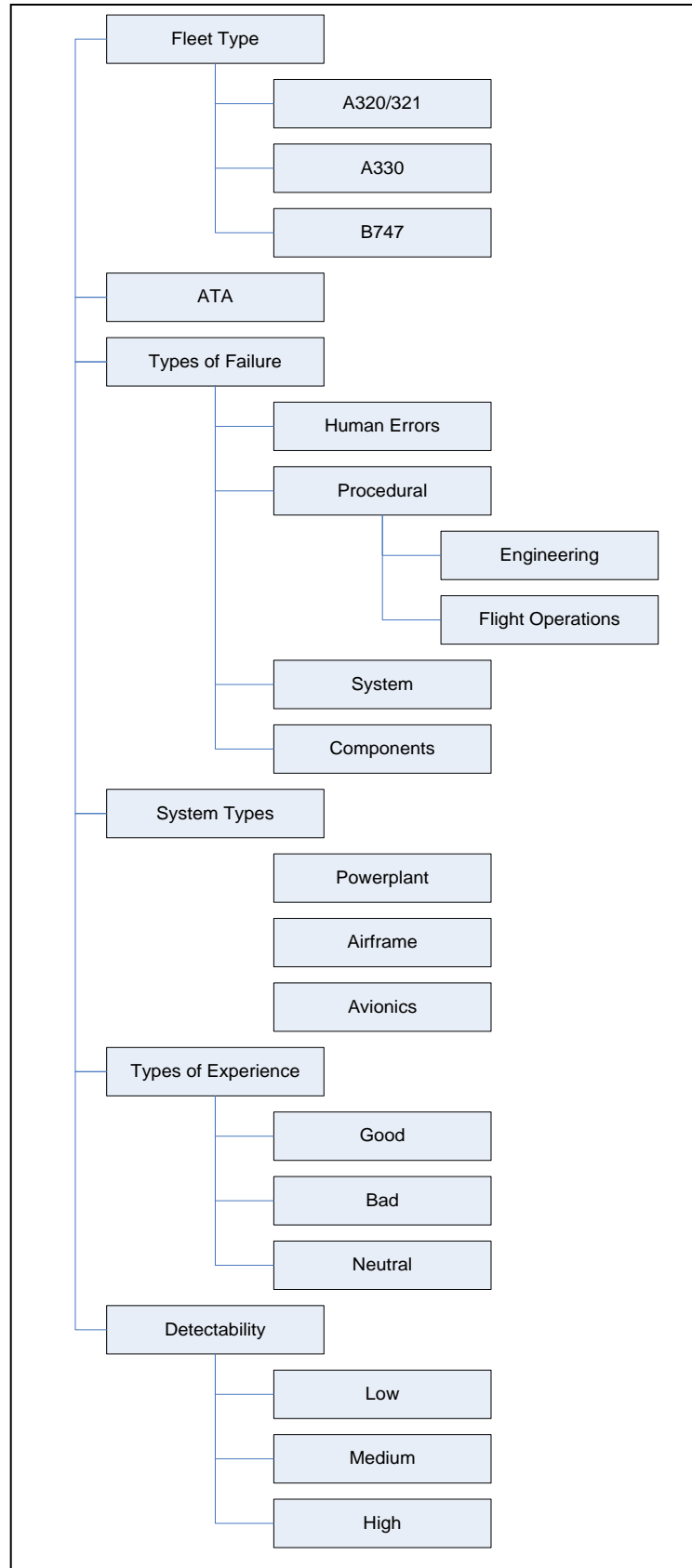
Figure 3.2 Pre-defined Set of Atributes
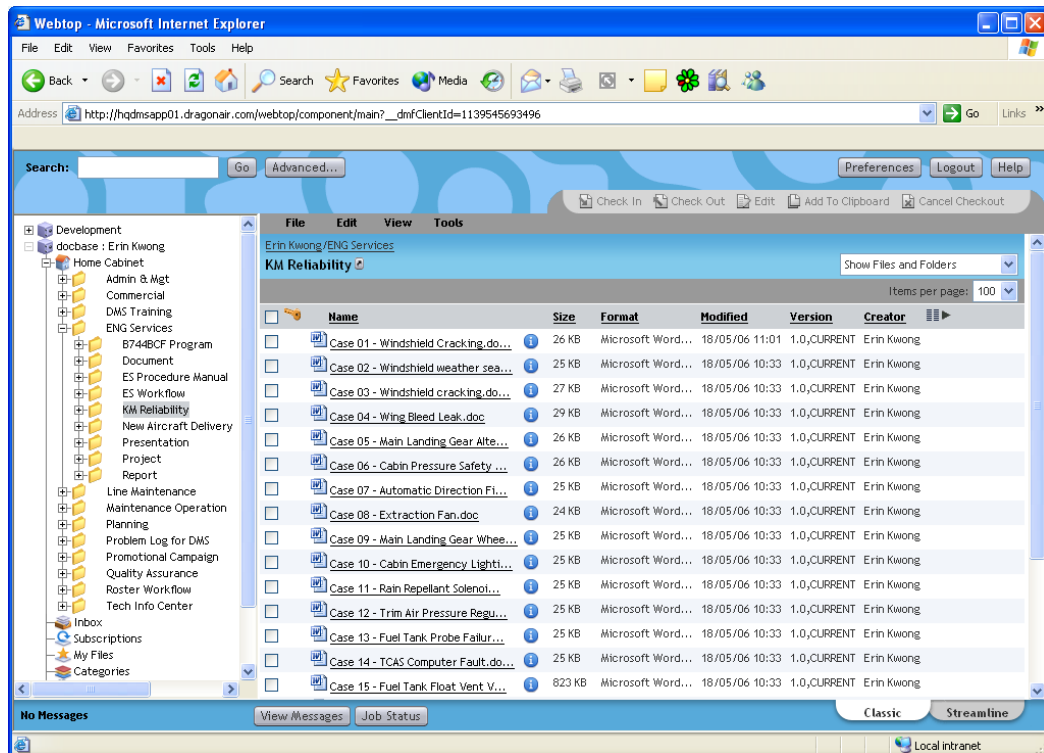
Figure 3.3 Document Management System by Documentum

Table 3.4 Sample Attributes

Defined Attribute	Data
Fleet Type	A320/321
ATA	56
Types of Failure	Component
System Types	Airframe
Types of Experience	Good
Detectability	High

CHAPTER 4   ANALYSIS AND RESULTS

The results and how they were obtained through the interviews are presented in this chapter.

4.1   EXTRACTING LEARNING POINTS

As mentioned previously, cognitive mapping is a tool for visualizing the mental processes that organize and give meaning to observable behaviour and to the cognitive skills needed to respond adeptly to complex situations. Before constructing a cognitive map, the key learning points need to be extracted from each narrative. The key learning points are the messages that have to be passed to users. They should be precise enough so that they do not affect the context of the narratives. The practitioner can use these points to create a hierarchy for the construction of a cognitive map.

It is generally helpful to first read through the entire transcribed narrative before starting to extract the key learning points so as to gain an overall understanding of the issue. A narrative of an incident is broken into its constituent elements – usually distinct phrases of 10 to 12 words which retain the original language of the person telling the narrative. Each phrase should be a single idea or concept. A pair of phrases may be combined into a single concept. One of the phrases provides a meaningful contrast to the other; i.e. where the contrast allows the user to make better sense of the other phrase. These phrases are constructs: meaning is retained through contrast. It is important that the meaning is retained through the context as

this can help users to make future decisions. These distinct concepts will be reconnected to represent the narrative in a graphical format, which is the cognitive map, in a later stage.

Before extracting the key points from the narratives and starting to draw the cogitative maps, the first two objectives of this project should be met.

The first objective of the project is to identify the decision making process regarding reliability management. The second objective is to provide guidelines on the type of thinking that staff need to use in order to handle the cases on reliability. In other words, our aim is to capture the reliability knowledge or the mental model of the engineers, their considerations and also their reasoning. In the following paragraphs, the process on how to identify key learning points will be demonstrated from a sample narrative. After identifying the learning points, a cognitive map is drawn.

To demonstrate with an example, the first narrative "Windshield cracking" is reviewed. First of all, the sentence with the same meaning is spaced with a stroke thus: '/' as shown in the following:

"Windshield Cracking

There was a crack discovered in the windshield in an A320 aircraft during flight resulting in an in-flight return. / Since it would be a media sensitive issue if it was made known to the public and would affect the reputation of Dragonair, the windshield was immediately replaced. / Through a detailed analysis of the stored life data of all previously failed windshields, we

came up with some expected life limits on the windshield which was much lower than the life limits claimed by the manufacturer for their products. / Investigation revealed that the failure was due to the moisture ingression into the windshield which caused arcing inside the windshield and resulted in the windshield shattering. / Immediate action was taken to identify the high-risk windshield according to the life limits of the windshield. / After negotiation with PPG, the windshield manufacturer, a replacement program was carried out to retrofit the high-risk windshield within 2 weeks time. /In addition, a long-term improvement action was adopted. We reviewed our windshield inspection frequency, / clarified the windshield inspection failure limits, / re-wrote the inspection job card contents to make it more easily understandable / and added color pictures   to help engineers easily recognize the windshield serviceability and failure standard. / Also, the communication and reviewing process of the inspection results were enhanced / and we reviewed the windshield design with PPG and Airbus to improve the product. / PPG finally came up with a modified windshield with improvement to prevent moisture ingression. / All inventories were purged and replaced with the modified windshields. / Now, all the windshields will undergo on-going monitoring based on this improvement in new product reliability.

During the whole process, PPG, SRT, Airbus, Prakash and Steve were involved and all the investigation reports were very important in resolving this issue."

After the sentences were segmented into spaced intervals, learning points were extracted (as shown in Table 4.1).

Table 4.1 Extracted Learning Points

"**Windshield Cracking**

Aircraft Type: A320

Failure:

- A crack in the windshield in an A320 aircraft was discovered during flight.

- Resulting in IFR

- Media sensitive when made known to public

- Would affect the reputation of the airline

- Windshield on that aircraft was immediately replaced

Investigation:

- Through detailed analysis of the life data (KA) of all previously failed windshields, we came up with some expected life limits on the windshield which were much lower than the manufacturer's claimed life limits on their products.

- Investigation revealed that the failure was due to the moisture ingression into the windshield which caused the arcing inside the windshield and resulting in windshield shattering

Solution:

- Immediate action was taken to identify the high-risk windshield according to the life limits of the windshield. After negotiation with PPG (windshield manufacturer) a replacement program was carried out to retrofit the high-risk windshield within 2 weeks time.

- Long term improvement action:

    i.   Reviewing our windshield inspection frequency

    ii.   Clarifying the windshield inspection failure limits

After the learning points were extracted, cognitive maps were drawn as described in the following section.

4.2   CONSTRUCTION OF COGNITIVE MAPS

The primary function of the brain is to interpret incoming information to make meaning. It is easier for the brain to make meaning when information is presented in visual format. Cognitive maps can harness the power of vision to help staff to understand complex information "at-a-glance". . .

Narratives allow people to accelerate the creation of common understanding and purpose in a non-directive and thereby more

sustainable and pervasive form. This can be enhanced by presenting them in the form of cognitive maps in order to visualize the patterns of information flow. Cognitive maps can help create, as quickly as possible, a wider understanding of the breadth and opportunities offered by the patterns revealed by narrative and the patterning capability of narrative interventions.

To translate a narrative into a cognitive map, first of all, it is necessary to place the topic or issue at a fixed location. The next stage is to start spreading out the map to other levels by connecting the decision points extracted from the previous stage. Then it will be easier to determine the hierarchical structure of the cognitive map based on those decision points. Cognitive maps can help users to perform self-analysis or better communicate with others and to conceptualize and analyze complex phenomena and knowledge in systematic ways for others to learn.

Constructing cognitive maps is a powerful technique used to structure, analyze and make sense of accounts of problems. It produces a representation of how a participant thinks about a particular issue or situation. Therefore, it is very useful to transform a situation into a graphical representation which can help users to understand the problem more easily and trigger their thoughts.

In the first stage in constructing the cognitive map, using the cracked windshield example (Dragonair), with the help from the reliability engineers, several actions, including the process of "analysis of the life

data", the "actual life limits" of the windshields, were identified. Then improvements were made accordingly to prevent them from cracking in future. The verbs in the sentences can also be identified as the process which leads to the determination of level one considerations, i.e. the actual on-wing service life limits of the windshields. Based on the identified process and the level one considerations, we can illustrate the first step in building the cogitative map as shown in Figure 4.1.
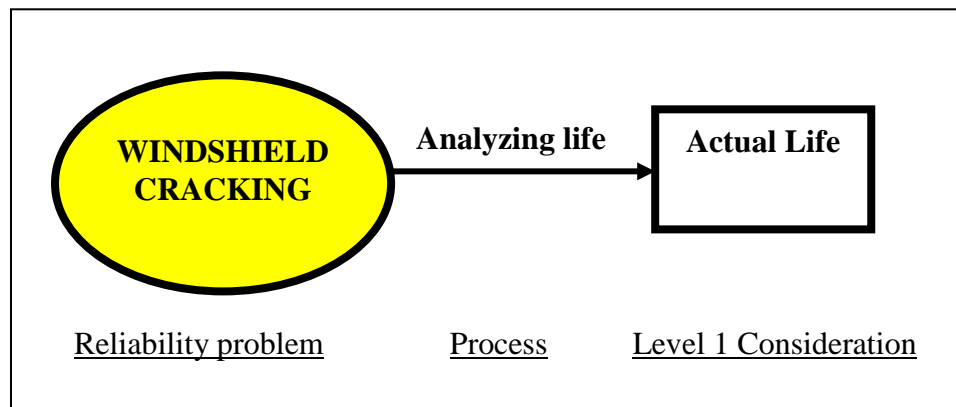

Figure 4.1 The First Stage in Constructing the Cognitive Map

As a consequence, after identifying the actual on-wing service life limits of the windshield, it is logical to review the installation life of the whole fleet. Therefore, "identifying" the "high-risk windshield" is the second step in our reliability management consideration and thinking process. A retrofit program was then developed by considering the material and spare-part support and also the availability of maintenance ground time. Sometimes the airlines may have to coordinate with the windshield manufacturer or even the aircraft manufacturer to retrieve the worldwide stock to support this retrofit programme. However, in the example,

complex procedures were involved in identifying the spare-part support and coordination with vendors and aircraft manufacturers. Therefore, the higher level triggering of identifying a "retrofit program" was selected as the knowledge point that a reliability engineer should consider when handling a reliability problem. The cognitive map could then be developed with level two and further steps of knowledge points as shown in Figure 4.2.
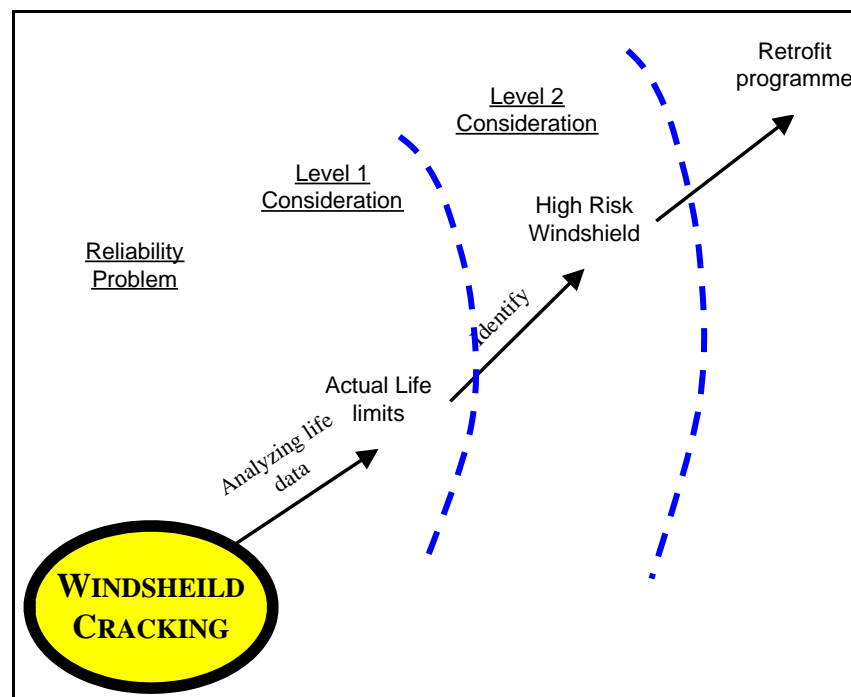
Figure 4.2 The Second Stage in Constructing the Cognitive Map

In the second stage in constructing the cognitive map, more level one, two and more knowledge points can be further expanded by using a "flowering-out technique" from the remaining narrative. For example, reviewing the windshield inspection frequency, i.e. "reviewing" the current "Aircraft Maintenance Programme", "reviewing" the "jobcard

contents", providing "clearer jobcard instructions" and with "colour picture", "clarifying the windshield inspection failure limits" can help to easily identify the serviceability of the windshield well in advance before its failure and its causing disruption to the operation of the airline. Through this exercise, all these fallback items were identified and the defective windshield, after the inspection findings, was "rectified". Following the identification of all these items, a better picture of the cogitative map is shown in Figure 4.3.
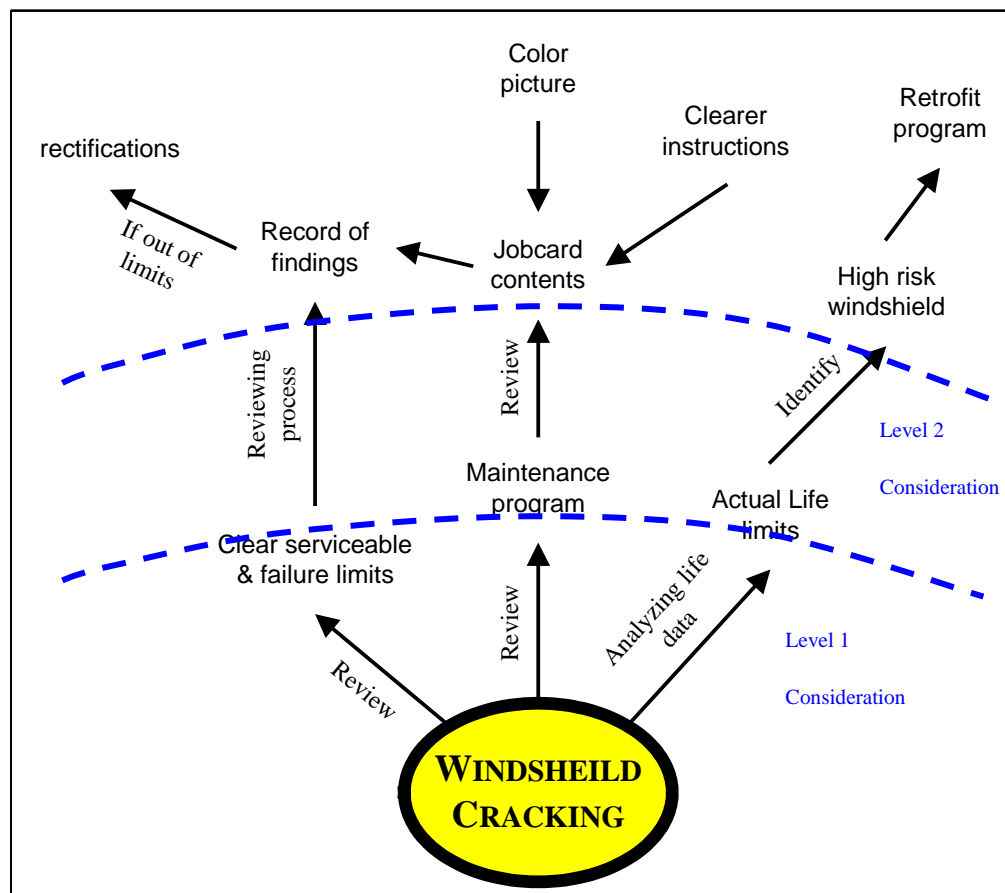
Figure 4.3 The Third Stage in Constructing the Cognitive Map

The narratives highlighted the need to seek "product improvement" from both the windshield manufacturer and Airbus. Finally a new type of windshield was introduced with several improvements or "modifications". This modified windshield was slowly retrofitted into the whole fleet. At the same time, the whole inventory store was "reviewed" in order to identify all pre-modification windshields which were "purged" and replenished with newly post modification type windshields. All newly installed post modification type windshield would undergo an "on-going monitoring" process to ensure that all newly installed windshields would not cause any further problems. All these steps have now been implemented into the final cognitive map (see Figure 4.4) to demonstrate the use of all the knowledge points that were gathered from this narrative.

After the first narrative was constructed into a cognitive map, the methodology was established and other narratives have now also been constructed into cognitive maps as shown in Table 4.2.

4.3   AGGREGATE COGNITIVE MAP

Although there is no standardized cause-and-effect relationship for complex situations, after constructing a number of cognitive maps, clear patterns would emerge. With these patterns, all the knowledge points can be combined together to form an aggregate cognitive map (Figure 4.5). The aggregate cognitive map will give a holistic view of all the decisions made in the process.
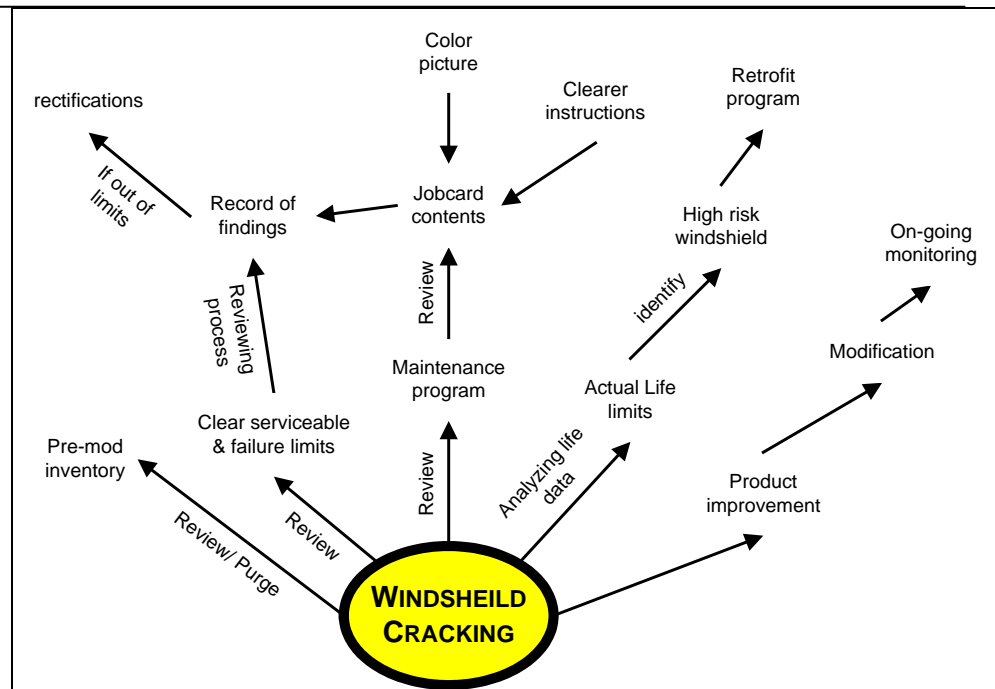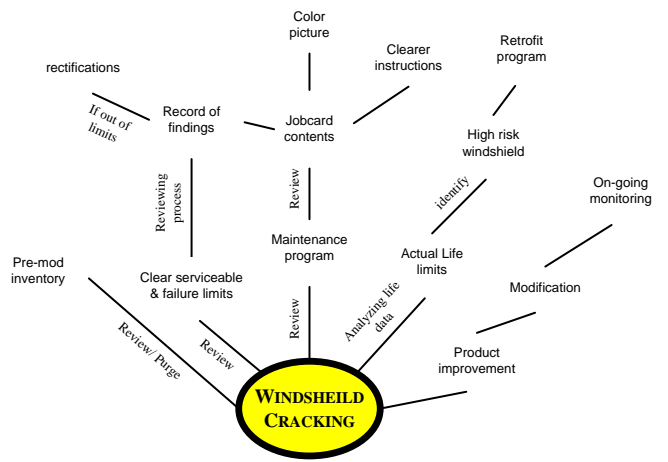
Figure 4.4 The Fourth Stage in Constructing the Cognitive Map

After repeating the above process a number of cognitive maps were drawn, and the knowledge points in handling various different reliability problems were identified. The aim of drawing the aggregated cognitive map is to group together all the knowledge points that were scattered around under various reliability cases. By grouping all knowledge points together, a generic knowledge base is formed for all reliability engineers who need to manage reliability issues in their daily work.

Before all the cognitive maps are combined together, the terminology and wordings have to be aligned in such a way that unclear terms that might create confusion in the future are eliminated.

Table 4.2 Cognitive Maps for Narratives

Narratives with Spaced Intervals	Learning Points	Cognitive Map
1. Windshield Cracking A crack in the windshield in an A320 aircraft was discovered during flight resulting in in-flight return. / Since it would be a media sensitive issue if made known to the public and would affect the reputation of Dragonair; therefore the windshield was immediately replaced. / Through detail analysis of the life data of all previously failed windshields, we came up with some expected life limits on the windshield which were much lower than the life limits claimed by the manufacturer on its products. / Investigation reviewed that the failure was due to the moisture ingression into the windshield which caused the arcing inside the windshield and resulting in windshield shattering. / Immediate action was taken to identify the high-risk windshield according to the life limits on the windshield. / After negotiation with PPG, the windshield manufacturer, a	**1. Windshield Cracking** Aircraft Type: A320 Failure: - A crack in the windshield in an A320 aircraft was discovered during flight. - Resulting in IFR - Media sensitive if made known to public - Would affect the reputation of the airline - Windshield on that aircraft was immediately replaced Investigation: - Through detailed analysis of the life data (KA) of all previously failed windshields, we came up with some expected life limits on the windshield which were much lower than the life limits claimed by the manufacturer on its products. - Investigation reviewed that the	

replacement program was carried out to retrofit the high-risk windshield within 2 weeks time. / Other than that, a long term improvement action was adopted. We reviewed our windshield inspection frequency, / clarified the windshield inspection failure limits, / re-wrote the inspection job card contents to make it more easily understandable / added color pictures to help engineers easily recognize the windshield serviceability and failure standard. / Also, the communication and reviewing process on the inspection results were to be enhanced / and we reviewed the windshield design with PPG and Airbus to seek product improvement. / PPG finally came up with a modified windshield with improvement to prevent moisture ingression. / All inventories were purged and replaced with the modified windshields. / Now, all the windshields would undergo on-going monitoring based on the result of new product reliability improvement in future. During the whole process, PPG, SRT, Airbus, Prakash and Steve were involved	failure was due to the moisture ingression into the windshield which caused arcing inside the windshield resulting in the windshield shattering
	
	Solution:
	- Immediate action taken to identify the high-risk windshield according to the life limits on the windshield. After negotiation with PPG (windshield manufacturer) a replacement program was carried out to retrofit the high-risk windshield within 2 weeks time.
	- Long term improvement action:
	  i. Reviewing our windshield inspection frequency
	  ii. Clarifying the windshield inspection failure limits
	  iii. Rewriting the inspection job card contents to make it more easily understandable and with color pictures to help engineer easily recognize the windshield serviceability and failure standard.
	  iv. Enhancing the communication and reviewing process on the inspection	

and all the investigation reports were very important to solving this issue.	result
	  v. Reviewing the windshield design with PPG and Airbus to seek for product improvement
	  vi. PPG finally came up with a modified windshield with improvement to prevent moisture ingression.
	  vii. All inventory was purged and replaced with modified windshields.
	- Still under on-going monitoring on the result of new product reliability improvement.
	
	- Involved parties: PPG, SRT, Prakash, Airbus, Steve
	- Documents: investigation reports	

2. Windshield weather seal deterioration The failure was due to prolonged operation of the windshield, leading to the deterioration and erosion of the weather seal. / The erosion was due to moisture ingression into the windshield and causing this windshield failure such as arcing, discoloration and delamination. / Also, the arcing of the windshield will	**2. Windshield weather seal deterioration** Failure: - after prolonged operation, deterioration + erosion - erosion -> moisture ingression into windshield and causing windshield failure e.g. arcing, discoloration, delamination - arcing – inflight returns, delays, cancellations -> sensitive to media, affect reputation	

cause inflight return, delays or even cancellations which are sensitive to media and will affect the reputation of Dragonair (KA).
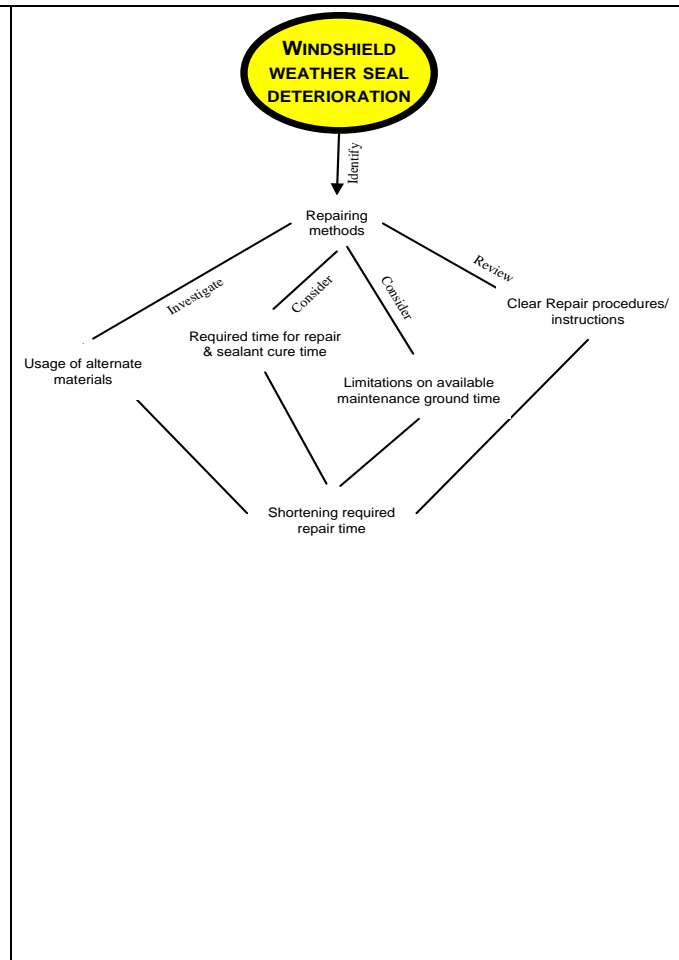
The material for the weather seal is a known problem which causes the erosion. / However, the material of the existing weather seal is already the best in resisting erosion and rapid weather change condition. / When a problem occurs, it takes a long repairing time for KA to repair it, but there is insufficient ground time according to KA's operating pattern. / To solve this problem, the manufacturer investigated and developed a new sealing material with the same specification and properties but with a shorter repair time. / The in-house interim solution was to identify a substitute sealing material with higher resistance to erosion and weather condition with a faster curing time through the experience on the sealing materials used in other areas of the fuselage and compare the specification of the sealing materials. / The advantage of this is that it can

Investigation:
- Material for weather seal is a known problem to have caused erosion
- Existing weather seal sealing material -> best to resist erosion and rapid weather change condition
- repair -> long repairing time -> insufficient ground time according to KA's operating pattern

Solution:
- Manufacturer investigated and developed a new sealing material with the same specification and properties with a shorter repair time; in-house (interim solution): identified a substitute sealing material (through experience on sealing material used in other area of the fuselage and comparing the specification of the seal materials) with less resistance to erosion and weather conditions with a faster curing time – advantage: can perform the required weather seal repair within the limited ground time – disadvantage: may require more maintenance work and more seal repair
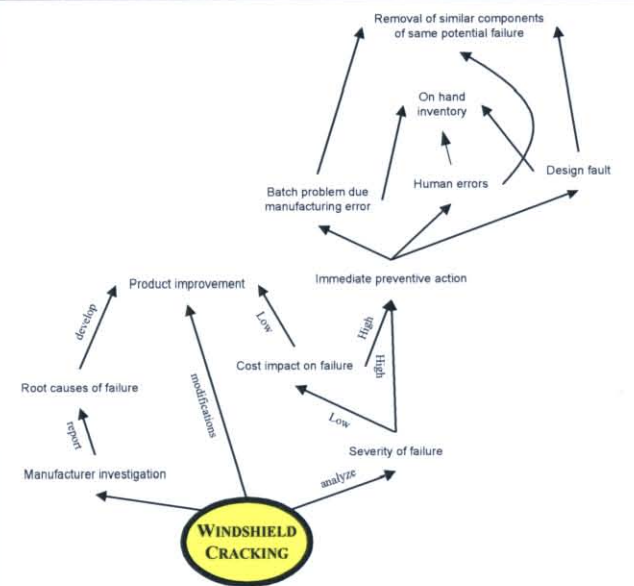
perform the required weather seal repair within the limited ground time / but the disadvantage is that it may require more maintenance work and seal repairs. / Therefore, a new repairing procedure was established for cleaning and removing the loose material. The parties involved in this case were the manufacturer (PPG), FTM (SRT), KA ENG (Prakash and Steve). The communication channel between them email. They focused mainly on the investigation report provided by the manufacturer.	Established a new repairing procedure for cleaning and removing loose material	
3. Windshield cracking A case of windshield cracking resulted in in-flight return recently. / Finally, the flight was cancelled. / After investigation, it was found that the windshield was installed 2 weeks ago during hangar inputs. / The failed windshield was a latest post-mod type windshield with improvement preventing moisture ingression. / The possible reasons for failure were identified. / The first one was maintenance induced human error during	**3. Windshield cracking** Failure: - A recent case of windshield cracking and resulting in in-flight return - Flight cancellation Investigation: - Windshield was newly installed 2 weeks ago during hangar inputs - Failed windshield was a latest post mod type windshield with improvement preventing moisture ingression	

windshield installation. / The second one was production error, / and a design fault on the post-mod type windshield. / During investigation, we found out that during the hangar input, 2 windshields were replaced on the same aircraft. / In order to prevent the potential problems of maintenance induced human error during windshield installation and to reduce the chance of another failure due to batch problems of manufacturing errors. / The immediate action taken was that the other windshield was also replaced as a precautionary action. / The damaged windshield was sent to PPG for investigation and analysis. / The other windshield was quarantined and is awaiting for investigation outcome on damaged windshield before the decision made on necessary action. / The outcome of the windshield investigation report shows that the root cause of the failure was an isolated case due to mishandling during the windshield manufacturing process. / The subject windshield exhibited a fractured center glass ply. /

- Initial reasons for the failure: (1) maintenance induced human error during windshield installation (2) production error (3) design fault on post mod type windshield
- Investigation revealed that during the hangar input, 2 windshields were replaced on the same aircraft

Solution:
- In order to prevent the potential problems of maintenance induced human error during the windshield installation and to reduce the chance of another failure due to batch problems of manufacturing errors
- Immediate action taken: the other windshield was also replaced as a precautionary action
- The damaged windshield was sent to PPG for investigation and analysis
- The other windshield was quarantined and is awaiting for investigation outcome on damaged windshield before the decision can be made on what action is necessary
- The windshield investigation report shows that the root cause of the failure was an

The fracture origin was located on the forward edge of the center glass ply. / The fracture originated from damage to the glass edge that occurred prior to casting the silicone gasket around the edge of the part in the manufacturing process. / The damage propagated after windshield installation due to cyclic stresses encountered in service, eventually causing spontaneous fracture of the center glass ply. / Investigation report concluded that the incident was an isolated case and the PPG confirmed that the same handling error had not happened on other windshields. / The quarantined windshield was then recertified and put back into service. Reference Doc: Windshield crack PPG investigation report_CA109118-SN04210H2048-JP Involved parties: PPG (manufacturer), Prakash, Steve, SRT, Airbus	isolated case due to mishandling during the windshield manufacturing process - The windshield exhibited a fractured center glass ply. The fracture origin was located on the forward edge of the center glass ply. The fracture originated from damage to the glass edge that occurred prior to casting the silicone gasket around the edge of the part in the manufacturing process. The damage propagated after windshield installation due to cyclic stresses encountered in service, eventually causing spontaneous fracture of the center glass ply. - Investigation report concluded that the incident was an isolated case and the PPG confirmed that the same handling error had not happened on other windshields - The quarantined windshield was then recertified and put back into service Reference Doc: Windshield crack PPG investigation report_CA109118-SN04210H2048-JP Involved parties: PPG (manufacturer), Prakash, Steve, SRT, Airbus	

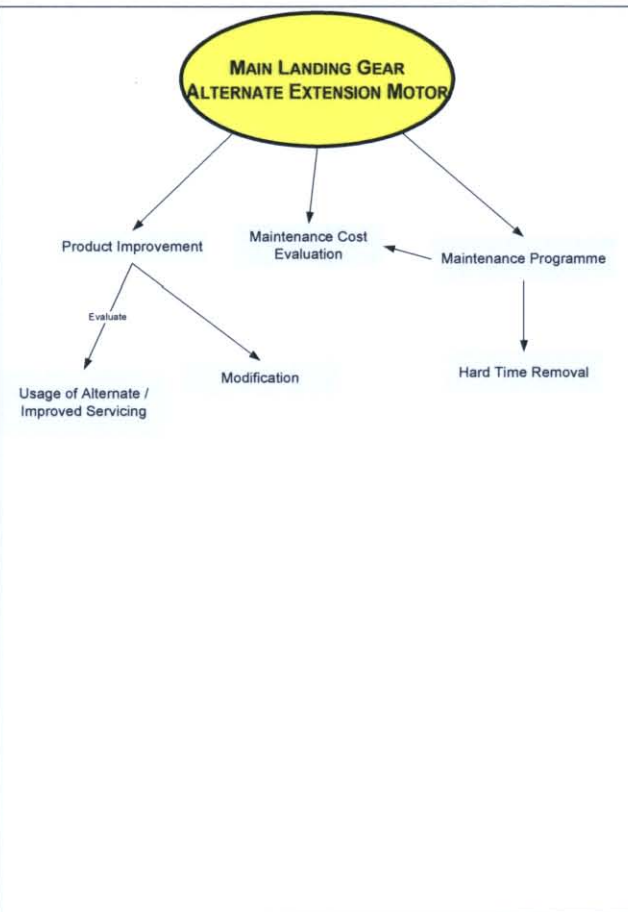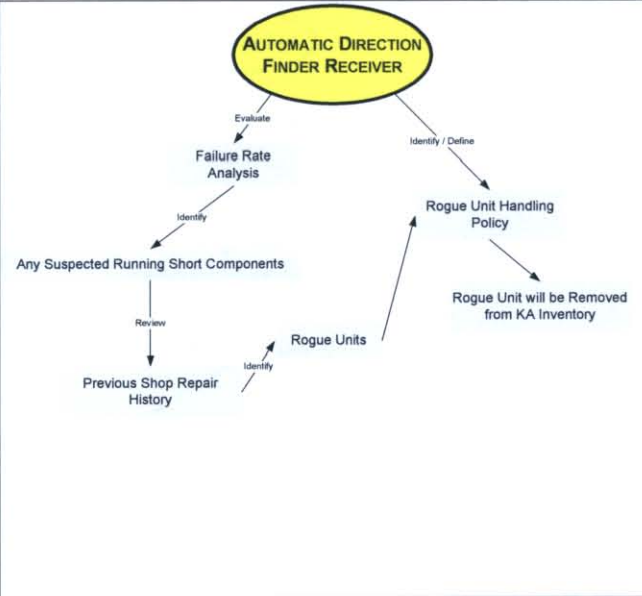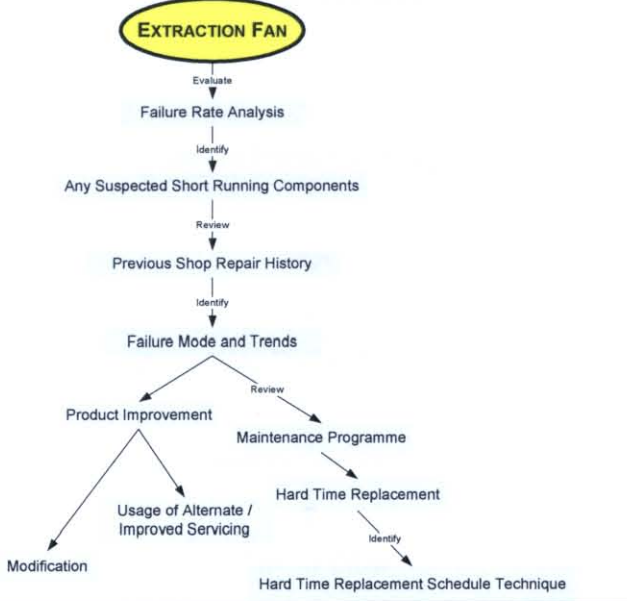|		
4. Main Landing Gear Alternate Extension Motor	**4. Main Landing Gear Alternate Extension Motor**	
It was a poor reliability handling case and it happened on a B747F. / The main landing gear alternate extension motor always failed during operation check. / First of all, we had to identify the root cause of failure. / Investigation revealed that the motor internal failure was due to the drying up of lubricant. / Since the motor was in the standby mode under normal operation and would only be selected to operate during emergency situation; therefore, from the component reliability figures, high MTBUR and MTBF figures were indicated. / Since the component was not used under normal situation, the MTBUR and MTBF figures could not truly reflect the reliability history. / In order to ensure the system availability in case of normal system failure, we have to ensure that the standby system functions normally to provide the backup function so as to maintain system availability in an emergency situation. / Current maintenance program was	A/C Type: B747F Bad reliability handling case Failure: - Main landing gear alternate extension always failed during operation check Investigation: - Identified the root cause of failure - Investigation revealed that the motor internal failure was due to the drying up of lubricant - Since the motor was in standby mode under normal operation and would only be selected to operate during an emergency situation - From the component reliability figures, high MTBUR and MTBF figures were indicated. Since the component was not used under normal situation, the MTBUR and MTBF figures could not truly reflect the reliability history - In order to ensure system availability in case of normal system failure, we have to ensure that the standby system functions	

reviewed and it was stated that only a routine system test of the alternate landing gear extension motor would be required and there would be no requirement for hard time replacement. / Discussion was also made with the manufacturer and they claimed that there were no complaints from other operators. / All component modifications were reviewed and the components that we had were already on the latest modification status. / In order to ensure system availability, a preventive maintenance was identified to implement hard time removal of this motor. / However, the disadvantage of this solution is that, the maintenance cost will increase. / Also, there is no systematic way of identifying the hard time removal interval, / and lastly, we still cannot confirm that no system failure will occur in the removal interval. / Therefore, final solution still needs to be implemented by rectifying the root causes and preventing the lubricant from drying up.	normally to provide the backup function so as to maintain system availability under emergency situation - Current maintenance programme had been reviewed and it stated that only a routine system test of the alternate landing gear extension motor would be required and there would be no requirement for hard time replacement - Discussion was also made with the manufacturer and they claimed that there were no complaints from other operators. All component modifications were reviewed and the components that we had were already on the latest modification status Solution: - To ensure system availability, preventive maintenance was identified to implement hard time removal of this motor - Disadvantage of this solution is that, (1) the maintenance cost will increase, (2) there is no systematic way of identifying the hard time removal interval, and (3) we still cannot confirm that no system failure	

	- will occur during the removal period - Final solution still needs to be implemented by rectifying the root causes and preventing the lubricant from drying up	
5. Cabin Pressure Safety Valve This case happened in the A320/1 and A330 fleet. / The cabin pressure safety valve was a standby equipment installed on the aircraft for emergency use only. / It was designed to provide a backup for the cabin pressurization system in case of primary system failure. / Therefore, good reliability was required so as to ensure the availability of system backup in an emergency. / Under normal operation, we would not be able to detect any failure of this valve. / Therefore the removal rate of this unit was relatively low, together with high MTBUR and MTBF figures. / The only time that we would be able to detect the unit failure occurred would be during the system test or flight test period. / However, history indicated that the unit usually failed under the system test or flight-testing.	**5. Cabin Pressure Safety Valve** A/C Types: A320/1, A330 Failure: - The cabin pressure safety valve was a standby equipment installed on the aircraft for emergency use only. It was designed to provide a backup for the cabin pressurization system in case of primary system failure. Therefore, a good reliability was required so as to ensure the availability of system backup in an emergency - Under normal operation, we would not be able to detect any failure of this valve. Therefore the removal rate of this unit is relatively low, together with high MTBUR and MTBF figures - The only time that we would be able to detect that the unit failure occurred would be during the system test or flight test period	

An investigation was done with the manufacturer, but it did not indicate any industrial problem or trends. / Failure cases had rarely been reported by other operators. / After further investigation, suggestions were made and we carried out a hard life replacement of this component. / However, further operation checks revealed that failure still occurred during removal intervals. / Therefore, a further suggestion was made which was to reduce the operation check AMM allowable limitation in order to tighten the limits and prevent the failure before actual system malfunctioning. / This action had resulted in very high unscheduled removal rate of this component, but no further solution or suggestion could be provided by the operator. / Following that, we had further discussion with manufacturer and identified one of the possible causes was due to the pneumatic sensing bellow was too weak to drive the operation of the valve itself and the pressure setting of the bellow would easily be affected by the	- However, history indicated that the unit usually failed under the system test or flight-testing Investigation: - Investigation with manufacturer did not indicate an industrial problem or trends. Not many failure cases reported by other operators - After further investigation, suggestions were made to carry out hard life replacement of this component. However, further operation checks review that failure still occurs in between removal intervals - A further suggestion was to reduce the operation check AMM allowable limitation in order to tighten the limits and prevent the failure before actual system malfunctioning. This action has resulted in very high unscheduled removal rate of this component - No further solution or suggestion can be provided by the operator - Further discussion with manufacturer identified one of the possible causes was due to the pneumatic sensing bellow being

and the external environment. / Until this moment, this case is still under investigation and discussion with the manufacturer and Airbus.	too weak to drive the operation of the valve itself and the pressure setting of the bellow would easily be affected by the last operation and the external environment Solution: - This case is still under investigation and discussion with the manufacturer and Airbus	
6. Automatic Direction Finder Receiver The automatic direction finder receiver always failed in the A320/1 fleet. / To perform the investigation, firstly we reviewed the removal history of the component in order to analyze the S/N on/off record. / This was to identify particular S/N which always failed after a short installation period. / Also, we reviewed the shop repair record and no fault was found in the S/N. / We discussed with SRT component shop on how they repaired and tested the component, and the component was sent to vendor for shop check. / In order to identify the confirmed fault, we requested the vendor to review the past history of	**6. Automatic Direction Finder Receiver** A/C Types: A320/1 Failure: - Always fails Investigation: - Reviewed the removal history in order to analyze the S/N on/off record - Identified particular S/N which always failed after a short installation period - Reviewed shop repair record • Found S/N never any fault found - Discuss with SRT component shop on how they repaired and tested the component - Component was sent to vendor for shop check - Identify the confirmed fault	

the component during installation on other airlines. / Since this kind of information is proprietary, they cannot disclose the information unless there is a special request. / To solve this problem, that particular S/N was removed from KA inventory.	- Past history during installation on other airlines
	  • Proprietary information
	    ▪ Cannot disclose unless special request received
	
	Solution:
	- Particular S/N removed from KA inventory	

7. Extraction fan There was a high failure rate in the extraction fan of the A320/1 fleet. / From the shop reports, it was identified that most of the failures were due to the bearing failure. / A reliability statistics report indicated that the MTBUR figure for this fan was around 14,000 flying hours. / In order to prevent the in-service failure of this component, a scheduled removal (hard time) for this extraction fan would be incorporated at 12,000 flying hours.	**7. Extraction fan** A/C Types: A320/1 Failure: - High failure rate Investigation: - From the shop reports, it was identified that most of the failures were due to bearing failure - Reliability statistics report indicated that the MTBUR figure for this fan was around 14,000 flying hours Solution: - In order to prevent the in-service failure of this component, a scheduled removal (hard time) for this extraction fan would be incorporated at 12,000 flying hours	

8. Main Landing Gear Wheel Reliability

The whole Dragonair A320/1 fleet was modified with radial tyre in early 2005. / This new radial tyre was expected to have 10% improvement on the service life and wear resistance. / Because of this radial tyre installation, we had more replacements of MLG wheels due to shoulder wear. / Due to the design arrangement of the radial tyre, the shoulder wear was very sensitive to the tyre pressure variation. / During the investigation, it was revealed that there was a pressure difference between the old (bias) wheel and the new (radial) wheel. / It was suspected that the engineers were still using the old tyre pressure to service the new radial wheel. / Although during the Radial Wheel modification, a decal had been put on the landing gear to remind all engineers for the usage of the new tyre pressure. / However, the maintenance manual and all other associated paperwork might still be using the old tyre pressure. / Therefore, all

8. Main Landing Gear Wheel Reliability

A/C Types: A320/1

Failure:
- The whole Dragonair A320/1 fleet was modified with radial tyre in early 2005
- The new radial tyre was expected to have 10% improvement on the service life and wear resistance
- Since radial tyre installation we had more replacement of MLG wheels due to shoulder wear
- Due to the design arrangement of the radial tyre, the tyre shoulder wear was very sensitive to the tyre pressure variation

Investigation:
- It was revealed that there was a tyre pressure difference between the old (bias) wheel and the new (radial) wheel
- It was suspected that the engineers were still using the old tyre pressure to service the new radial wheel

Solution:
- A decal had been put on the landing gear to remind all engineers to use the new tyre

MAIN LANDING GEAR WHEEL

Severity of Failure

Low

Cost of Impact on Failure

High

Immediate Preventive Action

Preventive / Rectification

Human Error
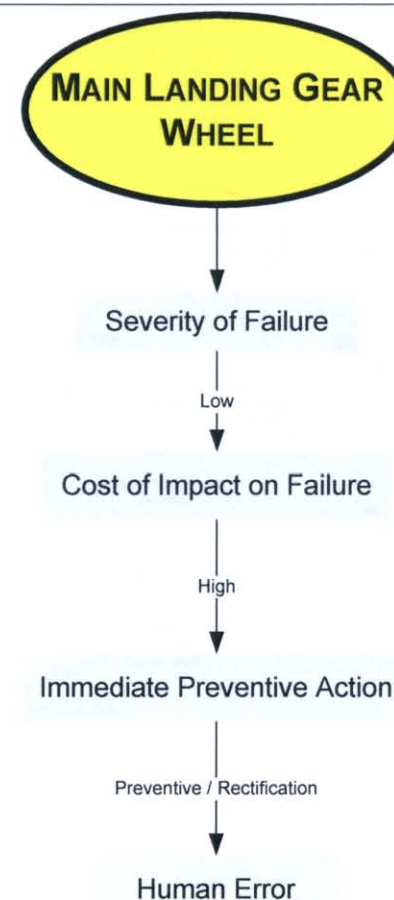
paperwork had to be reviewed and revised as necessary.	pressure. However, the maintenance manual and all other associated paperwork might still be using the old tyre pressure - Therefore all paperwork had to be reviewed and revised.	
9. Cabin Emergency Lighting Capacity Test On the A320/1, there were a lot of delays due to emergency light test failure before departure, during pre-departure check and maintenance check. / However, to carry out the thorough capacity test would take a long time. / In order to define the hard life intervals, KA and FTM had reviewed the previous removal history and utilization record of this component and identified the best removal time for this unit was at 2400 FH or 500 Days interval. / Since it would take a long maintenance ground time to replace all the affected EPSU (Emergency Power Supply Unit), the alignment with the 4A check interval was identified to be the most optimum time for this hard life interval. / To solve this issue, a hard life replacement program of the EPSU was suggested to be	**9. Cabin Emergency Lighting Capacity Test** A/C Types: A320/1 Failure: - A lot of delays were caused due to emergency light test failure before departure, during pre-departure check and maintenance check - However, to carry out a thorough capacity test would take a long time. Investigation: - In order to define the hard life intervals, KA and FTM had reviewed the previous removal history and utilization record of this component and identified the best removal time for this unit was at 2400 FH or 500 Days interval - Since it would take a long maintenance ground time to replace all the affected EPSU (Emergency Power Supply Unit), the alignment with the 4A check interval	

implemented in order to reduce the on-wing maintenance burden and keep up the on-time-departure rate for the whole fleet.	was identified to be the most optimum time for this hard life interval Solution: - It was suggested that a hard life replacement program of the EPSU be implemented in order to reduce the on-wing maintenance burden and keep up the on-time-departure rate for the whole fleet.	
10. Rain Repellant Solenoid Valve Seasonal defects normally occur during the period of spring and summer when there is heavy rainfall. / In this season, the rain repellant system in A320/1 is always reported by pilots as being inoperative. / Investigation revealed that system was inoperative was due to the blocking of the rain repellant tubing just downstream from the Solenoid Valve. / The rain repellant fluid had a sticky and hardening effect after exposure to air. / Therefore, the rain repellant fluid would remain in the repellant system tubing and would therefore be hardened when exposed to air and blocked the system. / In order to prevent system blockage, the system was	**10. Rain Repellant Solenoid Valve** A/C Type : A320/1 Failure: - Seasonal defects normally occur during the period of spring and summer when there is heavy rainfall - Inoperative rain repellant system is always reported by pilots Investigation: - Investigation revealed that the system was inoperative due to the blocking of the rain repellant tubing just downstream from the Solenoid Valve - The rain repellant fluid had a sticky and hardening effect after exposure to air - The rain repellant fluid would remain in	

designed to have an automatic air supply to blow into the tubing after each usage. / However, from the inside of the tubing and just downstream from the solenoid valve, there was a small portion inside the tubing, which was the stagnation point, where the cleaning air could not blow away the residual repellant fluid. The drying up of this stagnated repellant fluid would therefore block the solenoid valve and hinder its normal operation. Problem could not be rectified by the airlines due to the design deficiency inside the system. / Problem had been reported to Airbus for investigation and we are waiting for their advice.	the repellant system tubing and would therefore be hardened when exposed to air and blocked the system - In order to prevent the system blockage, the system was designed to have an automatic air supply to blow into the tubing after each usage - However, from inside the tubing and just downstream of the solenoid valve, there was a small portion inside the tubing, which was the stagnation point, where the cleaning air could not blow away the residue repellant fluid - The drying up of this stagnated repellant fluid would therefore block the solenoid valve and hinder its normal operation Solution: - Problem could not be rectified by the airlines due to the design deficiency inside the system - Problem had been reported to Airbus for investigation and we are awaiting their advice	

In order to build a knowledge base for a generic Reliability Management Process, the reliability knowledge points and handling process are commonly treated independently. In this way they can be applied or put into consideration as part of the thinking process and their applicability for reliability cases can be determined. To achieve this, the core of all reliability problems is replaced by using a generic wording of "Reliability Management Process".

A careful mapping process to identify all the common points in between various map locations is necessary to help to simplify the map. For example, in the maps of "Windshield Cracking", "Cabin Pressure Safety Valve" and Cabin "Emergency Lighting Capacity Test", all the Maintenance Programs need to be reviewed. After the reviews, then one "Maintenance Programme" block can be drawn and its entire subsequent works are linked to one block. By continuing to do this, a much-simplified version of aggregated cognitive map can be created. However, some of the knowledge points that may be useful and meaningful in their own narratives may not be plausible when they are joined to other narratives. This may affect the logic of the whole reliability management process. Therefore, some kind of reviewing process is necessary to construct a meaningful aggregate cognitive map. In order to achieve this, a validation process is required to filter out the illogical parts within the whole generic Reliability Management Process.

Figure 4.5 Putting all Cognitive Maps Together

The first level of the aggregate cognitive map (Figure 4.6) shows the first step that an engineer has to consider when he/she comes across a reliability related problem. After identifying the first step, the user can then follow the nodes in the map. Sometimes, the first step may trigger some new ideas for the user to solve the problem. Therefore, the information in this map has to be further validated by all participants and modified until they think it makes sense to all of them.

4.4   VALIDATION OF THE MAP

After consolidating all the cognitive maps together, a group validation session is conducted to review the data in the aggregate cognitive map. This group data validation is done in the format of a knowledge café. A Knowledge café provides a relaxing environment for participants, as a focus point, to discuss matters freely in an informal way. The purpose of conducting this is to validate the information in the aggregate cognitive map that has been developed by combining the individual cognitive maps that are drawn based on the narratives in the earlier stages.

The objectives of validating the aggregate cognitive map are as follows:

• To review, validate and refine the congregate cognitive map;

• To share the skill/technique and knowledge related to reliability management;

• To act as a means to align the skill of all staff on reliability management;

• To provide a sense of ownership to staff and get their buy-in.

During the session, participants are required to share their ideas on reliability management and modify the information in the aggregate cognitive map. Therefore, by reviewing the whole picture of reliability management, staff can link the fragments in the map together and understand areas that did not make sense to them previously. It is suggested that this kind of small group review session be done in groups of 6 to 8 and it should not take more than 60 minutes. The venue should be a meeting room or any relaxing environment where the participants will feel comfortable. Refreshments will be provided if available.

To start with, a copy of the aggregate cognitive map is distributed to all participants. They are given 10 minutes to study and understand the map. After that, there will be a 30 minutes free discussion session to review and modify the map if necessary. Finally, around 5 minutes are given to participants to sum up and finalize the map.

During the data validation session, the researcher acts as a facilitator in order to help the interviewees throughout the entire process to get the best information from the participants. The researcher has to offer input that triggers the interviewee's own memory search. During the session, it is important for the facilitator to manage the group dynamics and help interviewees make sense of the information that emerges. The facilitator has to take the group through a process of self-exploration and

Figure 4.6 First Level of the Aggregate Cognitive Map

understanding so as to create a meaningful and useful aggregate cognitive map. Also, during the data validation exercise, the facilitator has to discourage the participants from talking to one another. The following attributes and skills are required of a good facilitator. A good facilitator

- Is able to judiciously probe for details

- Maintains a relaxed manner – tension from the facilitator can be detrimental to the session

- Is able to show interest

- Has good questioning skills

- Can relish silence – lets it 'hang'

- Avoids asking too many questions and avoids turning it into an interview

- Is an active listener

After this exercise, the aggregate cognitive map should be finalized. This exercise has to be an interactive and on-going process since the data on the map may change. The narrative cycle in Figure 4.7 shows how the new procedures are developed through the application of this narrative exercise. Firstly, the method of thinking of staff is identified from the narratives collected. Then the thinking logics are figured out and the skill set will also be discovered. Following that, the information is documented to form a new procedure for staff to follow. With the trial of the new procedure, narratives will be modified in order to keep the information correct and up-to-date; and after that, the whole cycle will start all over again. This

exercise has to be conducted from time to time so as to keep the information up-to-date.

The post validation Reliability Management Process is the final step in the consolidation of the aggregate cognitive map (Figure 4.8). This process serves as a generic tool that can be applied to act as a checklist or reminder for the reliability engineers in their daily work. A detailed procedure manual can be developed based on the information shown on the map.
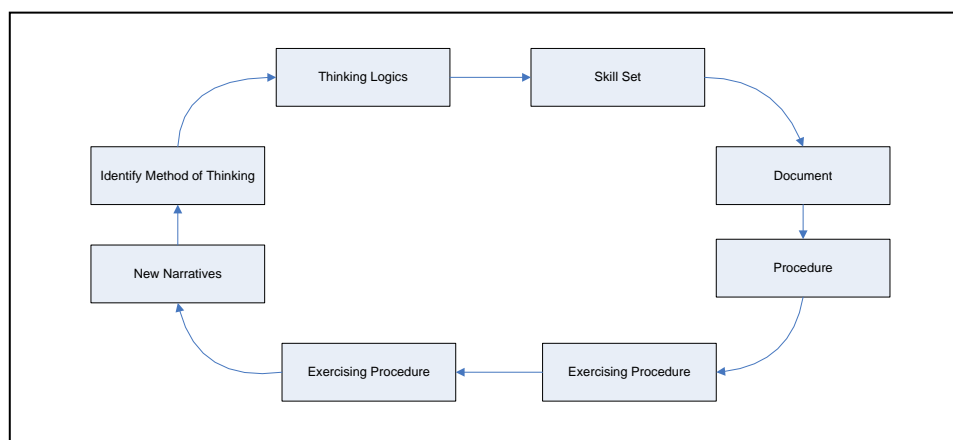
Figure 4.7 The Narrative Cycle
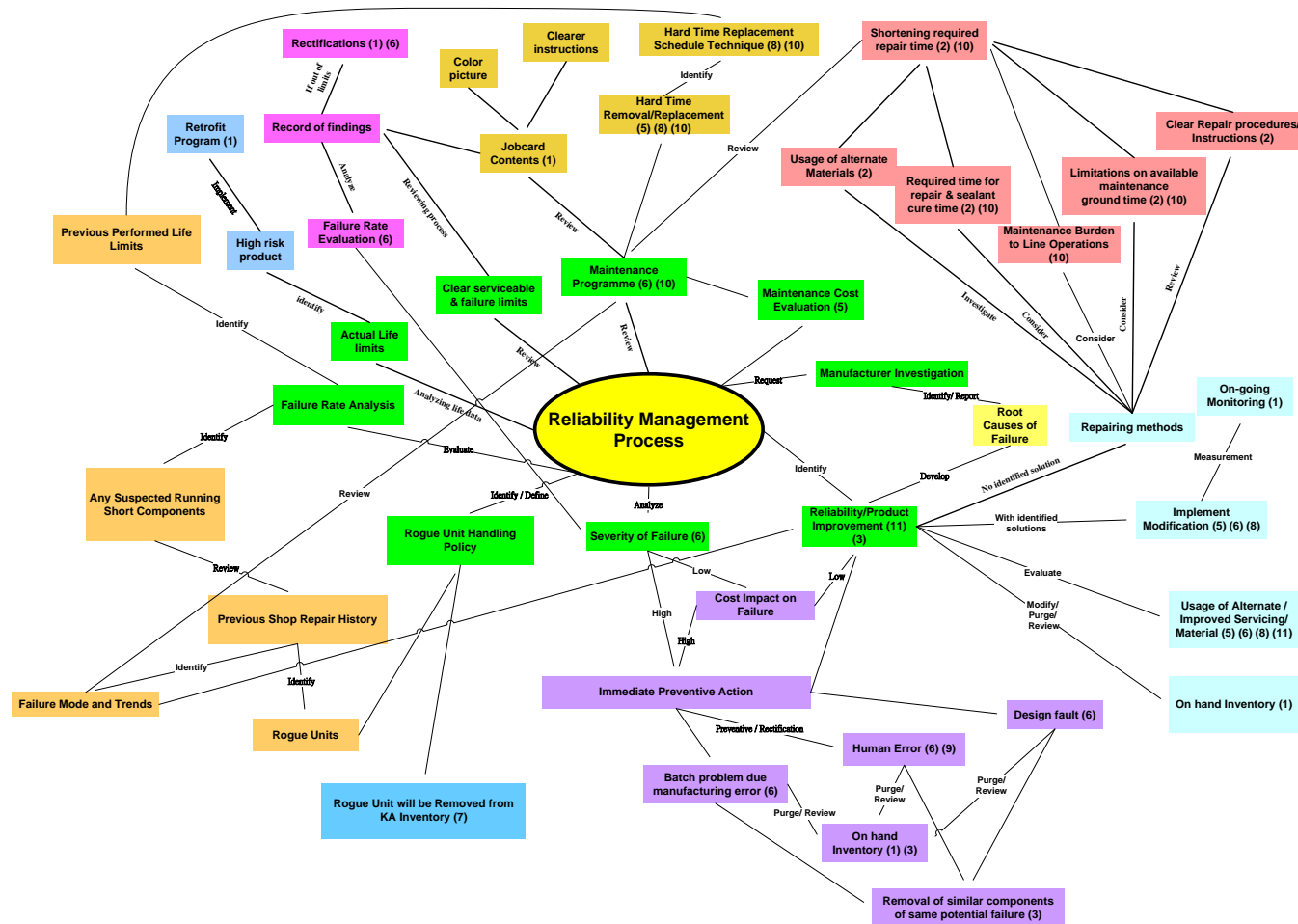
Figure 4.8 Post Validation Reliability Management Process

CHAPTER 5   DISCUSSION

In this chapter, the relevance of the work to team and organizational learning and the issues encountered in collecting narratives and constructing the cognitive maps in the Engineering Division of Dragonair, are addressed.

5.1   TEAM AND ORGANIZATIONAL LEARNING

Many knowledge management programmes fail due to various reasons. One common pitfall is that, they are either too ambitious or too vague in their scope, methodology or deliverables. To be successful, the project objectives should be linked to the business needs that lead to the solving of daily problems. The collecting and sharing of know-how of experience in reliability management in Dragonair serves as a good case in demonstrating how to build a corporate memory through team and organizational learning. This study not only illustrates how knowledge can be elicited through a combination of the narrative approach and the ASHEN model (Snowden, 1998), but also provides a good example which matches well with the stages of learning from individual, group to the organizational level as described in the 4 "I"s Framework of Crossan et al (1999), as well as the Senge's five disciplines (Senge, 1990) in the building of a team mental model and team learning.

5.1.1   The 4 "I"s Framework of Organizational Learning

As shown in the 4 "I"s framework defined by Crossan et al (1999), four associated processes link three levels of analysis and define learning within organizations: intuiting, interpreting,

integrating and institutionalizing. Intuiting and interpreting occur at the individual level; interpreting and integrating at the group level; with integrating and institutionalizing occur at the organizational level. Verbs are used to describe the four processes as they are intended to capture both a cognitive and behavioural perspective of learning.

Intuiting is the preconscious recognition of patterns and/or possibilities inherent in a personal stream of experience. This only affects the intuitive behaviour of individuals and will not affect others since they have not interacted with others yet. The second stage of the learning process is interpreting. It is the explaining of an insight or idea to one's self and to others. This process goes from the preverbal to the verbal and requires the involvement of language.

Integrating is the third stage of the learning process. It is the process of developing shared understanding amongst individuals and the taking of coordinated action through mutual adjustment. Dialogue and joint action are crucial to the development of shared understanding. The last step of institutionalizing is the process of ensuring that routinized actions occur. Tasks are defined, actions specified and organizational mechanisms put in place to ensure that certain actions occur. Institutionalizing is the process of embedding learning that has occurred by individuals and groups

into the institutions of the organization including systems, structures, procedures and strategy.

In this project, the process of eliciting knowledge from individuals through narrative telling involves the re-collection and invoking of a personal stream of experience which is the intuiting stage. The translation and extraction of the personal experience into meanings and insights involves the creation of concepts. The extraction of concepts and their inter-relationship through cognitive mapping of concepts, which can be termed interpreting, helps to make the ideas explicit and easily communicable to other people. No integration can occur unless the individual mental model is made explicit and shared by other team members. The consolidation of individual cognitive maps to aggregate maps helps to develop a shared understanding. Everyone can see their own contribution as well as the relationship of their reasoning to that of others, which gives a better overall picture of the problem concerned (reliability management in this case). The validation of the aggregate cognitive map through group discussion and arbitration enhances the integration process (the third stage in the 4 "I"s model). This enables all team members to see both the "trees" as well as the "forest" of the whole picture. According to Crossan (1999), this process of integrating is often ad hoc and done in an informal manner. However, the combining of individual maps into an

aggregate map provides a structured and systematic method of integrating individual experiences. The successful validation and endorsement of the aggregate cognitive map is built into the procedures and guidelines signifying the institutionalizing of the knowledge for re-use and training in the organization. The sequence of the 4 "I"s model is re-drawn in Figure 5.1 to illustrate the sequence of the learning process in knowledge elicitation from the individual, to the group and up to the organizational level. In the figure, it should be noted that the steps of learning from individual, group to organization is not a one way process. Individual experience will give rise to collective experience, which in turn can also affect the perception of individuals, as all effective learning process is always dynamic and non-linear in nature.

5.1.2   *Comparison with Senge's Model of Organizational Learning*

According to Senge (1990) personal mastery, systems thinking, mental models, shared vision and team learning are the five disciplines of a learning organization. Among these, team learning is critical to organizational learning for the following reasons:

- People learn more effectively when they interact with others and learn together as a team.

- Team learning is synergistic, so team learning is more important than individual learning.

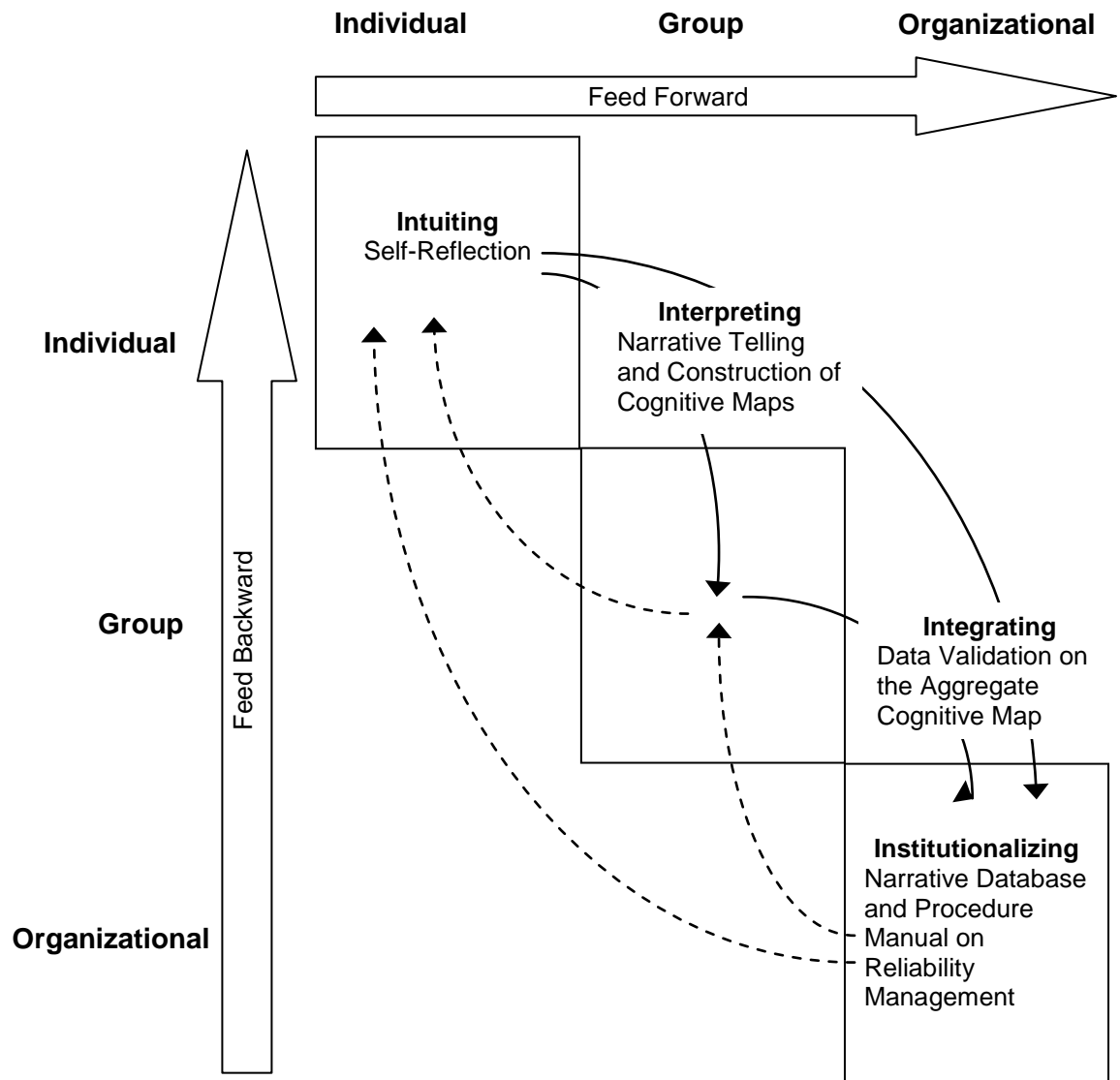**Figure 5.1 From an individual cognitive map to aggregate maps in the 4 "I"'s Learning Framework of Crosson (1999)**

Team learning does not mean that group members attend classes and seminars together, or receive the same instructional materials. One of the fundamental issues for effective team learning is enabling team members to share mental models. Without the sharing of ideas, thoughts, values, and assumptions among team

members, learning does not occur at the team level. This is the fundamental difference between team learning and individual learning. The making of mental models explicit among team members and the sharing of them is one of the most crucial processes to achieve team learning. Despite its wide acceptance, there have been relatively few cases reported in the published literature with detailed data and processes to illustrate how this model can be built and shared in a real industrial setting dealing with an industrial problem.

In Senge' work (1990), systems thinking is adopted to help individuals see how things are interrelated to each another, and promote mutual understanding among team members. In order words, systems thinking helps to build a "correct" mental model of the complex phenomenon under study. There are many ways of building mental models. Mental models are simplified representations in the mind (unspoken words) of real or imaginary situations that support understanding, reasoning, and prediction. A mental model is also sometimes referred to as a mental representation, a schema, a *cognitive map*, etc. A mental model is not necessarily associated with visual images. It can be the internal thought processes in the form of a set of condition-action rules that explain how the real world acts. Mental models are not values, beliefs or prior experience, but they are affected

by these factors, and play a significant role in bringing about thoughts and rules through reasoning.

Both systems thinking and cognitive mapping are different ways of constructing mental models. The cognitive map used in the Dragonair project provides a relatively low cost but effective tool to capture the reasoning among team members in handling reliability management issues. Therefore, in order to shorten the learning curve, visualizing the mental models of different people in the form of cognitive maps can help them to disseminate their implicit knowledge in an effective way. The subsequent building of the aggregate cognitive map enables the views and insights of individuals to be extracted and combined with others to form a whole picture. In the use of systems thinking to build a team mental model, all members participate simultaneously in brainstorming the factors involved and in examining their interconnectedness through the drawing of a causal loop diagram. Emphasis is on seeking and cultivating new insights into looking at things. In contrast to this, the methodology adopted in Dragonair is a balance between eliciting existing knowledge from individuals, sharing this knowledge through the aggregation of cognitive maps or group maps, and the generation of knowledge or insights through group activities in which team members discuss the validity of the aggregate cognitive map. Whether systems thinking or cognitive mapping should be adopted

depends on the nature of the problem. For the purpose of extracting and building on existing experiential and procedural knowledge, cognitive mapping is more appropriate than systems thinking to build the corporate memory. On the other hand, systems thinking will be a more powerful tool to model a phenomenon, understand its inter-relationships and then use it to construct new knowledge.

The be successful a learning organization must set up learning systems within an organization that will enable it to mobilize the talents in the organization and motivate people to contribute their knowledge to the corporate memory. The Dragonair case was a good example that demonstrated how such a learning system can be built in a real industrial setting.

5.2   ON KNOWLEDGE ELICITATION

5.2.1 The Process in Collecting Narratives

Staff in the Engineering Division of Dragonair are happy and willing to share ideas, despite the fact that their daily workload is very heavy. They are heavily engaged with their daily work with activities such as meetings and aircraft inspections. It is difficult for them to find time for the researcher to interview them. At the beginning, it was suggested that a focus group meeting be held to provide an interactive environment for the collection of narratives. However, it was very difficult to gather people together.

Therefore, individual interviews were conducted instead. There are both advantages and disadvantages of having individual interviews with staff. The advantages are that there is a chance for the researcher to clarify the points that they may not understand immediately and there is more time for interviewees to tell their own stories and their own thoughts without interruptions. If there are too much people sharing their stories together, there may be too much interference during the storytelling which may affect the flow of the narrative. Focus group can minimize the time spent in collecting narratives by collecting them all at one time. The team approach will allow more interactions among team members, and stimulate more input, insight and stories.

Contexts in the narratives are very important for understanding the stories. They help to create cognitive maps which make sense not only to the story tellers themselves, but also to others. However, there are difficulties in collecting narratives that are contextual during the interviews. Sometimes the narratives come in bits and pieces which are difficult to form into a meaningful story for outsiders. Therefore, researchers have to ask some stimulating questions which can help build a context into the narratives. It is suggested that the researcher should have some background knowledge of the operation, so that the researcher and the interviewees can communicate better and time spent in

seeking clarification can be saved. This is unlike the use of the naive interview (Snowden, 2003) which is best deployed to seek and detect signals that will not be captured in a structured interview as both the questions an answers are already bounded.

In order to encourage employees to talk about their experience, especially unpleasant episodes or failures, it is important to have a no-blame culture in the organization. If not, people will always try to hide things that they think are wrong and researchers will never be able to collect valuable learning points from mistakes. Trust is always the most important ingredient in collecting narratives. Therefore, building a good and close relationship between researchers and interviewees is important. When tape recording during the interviews for later transcription is required, it is necessary to get the consent from interviewees at the very beginning. If the interviewees do not allow the researcher to record the interview, controlling the speed of verbal information rather than being overwhelmed is vital. The researcher may ask the interviewees to speak a little bit slower so that he or she will not miss the point that the interviewee is making.

Also, the researcher should try the best to do a bit of alignment in the usage of words or terminology. Very often during various story tellings, interviewees may tend to use different terms, wording or jargon to express their viewpoints. With the help of and consent from interviewees, it will be easier to align various

bits of jargon that are used among various groups of specialists. An alignment on the usage of terminology can help to smooth out the development of cognitive maps especially in constructing a meaningful aggregate cognitive map. In addition, the interviewees should be briefed on the agenda of the interview before the interview starts. Interviewees must be briefed clearly on the purpose of the interview in order to remove hidden fears and ensure that they are willing to share their concerns with the researcher and are willing to cooperate.

5.2.2   The Mapping Process

The mapping process is the most critical part in making the experiential and procedural knowledge explicit. Mapping helps to extract the reasoning part embedded in the narratives and make the thinking process explicit. The most challenging part in constructing cognitive maps is how to visualize the thinking process in order to facilitate the development of the aggregate cognitive map. The revealing of patterns of reasoning from the cognitive maps is crucial to this project. If the patterns cannot be revealed, it is impossible to develop the aggregate cognitive map. This process involves extracting the decision making points or learning points from each narrative and linking them up in order to form a cognitive map. To facilitate this, the narratives should be broken down into smaller pieces with one main point in each, then it will be easier to connect them together to form a cognitive

map. The drawing of the reasoning process in the form of a concept map allows the expert to reflect on the representation and identify places that might be improved or corrected.

The cognitive mapping process helps to construct a holistic representation of the knowledge entailed in the reliability management process of the Engineering division. The aggregate map contains the thinking of many people and often includes different views on similar issues or even conflicting views on the same issue. After the first draft of the aggregate map is produced, meetings among all stakeholders are arranged for them to arbitrate, and negotiate the validity and accuracy of the reasoning process. The dialogue helps to reveal the values, assumptions and beliefs of the staff in their handling of reliability management issues, and provides an opportunity for reflection on procedures and practice currently enforced and on the need for re-examination and revision of existing policy, which will increase the likelihood of double loop learning (Argris, 1991).

The aggregate map is a kind of knowledge model that also requires frequent maintenance. If what is captured is mainly historical data, then the model can remain infinite. In the aviation industry, the regulations, technology, suppliers, sometimes change. The knowledge model thus built must be seen as a dynamic and iterative process so that change can be incorporated and disseminated.

5.3   AREAS FOR CONTINUOUS IMPROVEMENT AND DEVELOPMENT

This project is the first of its kind in Dragonair in the area of reliability management. In order to make this project run smoothly, there are a few areas that need to be improved.

 (i) Increase the Number of Narratives

To obtain a better result from the exercise, more narratives should be collected. The collection of narratives should be done continuously as the number of cases will increase as time goes by. The patterns revealed will be more accurate as the number of narratives increase. The accuracy of the analysis very much depends on the number of narratives collected.

(ii) The Use of Software

Software can be used to help in constructing the aggregate cognitive map once the number of narratives collected is large. In fact the researcher will need to use it when the number of narratives becomes very large. Also, the links in the concept map can be weighted by measuring their degree of importance in order to provide more guidance for staff to follow. A semantic network rather than a rigid tree structure might be needed to represent sophisticated reliability and maintenance knowledge in building terminologies in the field. The mapping of the expert knowledge into a semantic network is a challenging task.

(iii) Review Regularly

Regular reviews are vital to ensure the information in the aggregate cognitive map is always up-to-date and accurate. This should be done by collecting new narratives whenever there is a new case and by updating the existing narratives if necessary. Review meetings should also be held regularly in order to validate the information on the map and ensure the information is accurate. Modifications may be made from time to time due to changes in time and context.

(iv) Document the Procedures

Since this is a pilot programme deploying the narrative technique to capture airline reliability management experience, it is a good practice to document everything and set up a procedure in order to make this project ongoing. The experience should be shared with other departments outside the Engineering Division so that this technique can be applied in other areas. For the programme to continue and be sustainable using the existing Dragonair Engineering organizational structure, clear roles and responsibilities should be sestet out as below:

- Senior Management – Senior management has to buy in and accept the concept and understand the values of this exercise since they are the decision makers and the ones who can allocate resources to run this project. If this pilot run is successful senior

management may wish to consider promoting this methodology across different departments.

- Managers – They should be acting as project champions to facilitate this exercise. They are the drivers in asking their staff to participate in this project actively. Their support and participation are vital to this project as well since they can act as good models to demonstrate to staff the usefulness and importance of regular knowledge elicitation and the building up of corporate memory. They should also participate in the development of the cognitive maps and the aggregate cognitive map to contribute the management perspectives.

- Engineers – The continuous support and participation of every engineer and frontline staff is needed to maintain the system. Appropriate incentives should be considered to motivate them to identify and report stories. It is very important to make them understand how this project can help them to work more efficiently and effectively.

In the long run, the successful building of a knowledge team and its sustainability depends on the building of a trusting and a knowledge sharing culture in the organization.

CHAPTER 6   CONCLUSIONS AND FUTURE DEVELOPMENT

In this chapter, the significant findings in this project are discussed and the work that can be done in the future in order to improve the outcome is addressed.

6.1   SIGNIFICANCE OF FINDINGS

Knowledge loss is always a threat for an organization. It is a challenge for an organization to elicit knowledge from staff since it is difficult to ask people to relate their experience. This project, revealed some findings that will be useful to help the organization to undertake knowledge elicitation in the future.

6.1.1   The Power of Narratives

People always ask direct or close-ended questions to obtain information on how people manage a problem situation such as "What kind of knowledge did you use to solve the problem?" However, using this kind of question it is hard to obtain information about 'experience' since although most of the information collected is explicit, experience is usually a mixture of explicit and tacit knowledge. People will always unintentionally or even intentionally hide what they do not want to disclose and they will rarely elaborate on the points that they mention. However, people are more willing to share what they know if they are asked to tell the story about their experience.

When the experience is told in the form of a narrative they are willing to give more details as they have to tell the cause and effect of what happened in order to make the narrative complete. The power of narratives can never be imagined. They can sustain the interest of listener and also gain attention and illustrate the subject matter in a colourful and sometimes dramatic way. Hence, the learning process of the listener can be enhanced. Insights are gained by both teller and listener during the narrative capturing process. Narratives can arouse the interest and gain the attention of people listening to or reading them.

Since the world is dynamic and complex, it is very difficult to find out the causal relationships that occurred in different incidents. By using narratives, patterns can be revealed and so it can provide insight for users when a similar incident occurs again. Narratives can encode patterns and explanations, and can encode processes that are hard to explain. They can also reveal the hidden agenda that people may want to hide since explanations of processes are often untidy and do not always attempt to present universal causal claims. Also, narratives are a very good tool to explore the untidy, complex and controversial dynamics of organizational processes which may be difficult to observe or uncover. Also, they can encode processes which may be useful in providing guidelines for people to consider or follow in the future when similar cases appear again.

6.1.2 A New Methodology on Knowledge Elicitation

This project is a good example of eliciting knowledge through the application of narrative techniques based on the ASHEN model, construction of individual cognitive maps and the consolidation of the aggregate cognitive map. It is the first in the airline industry to adopt this methodology for developing its own procedure manuals. This model was implemented successfully in the Engineering Division of an airline business in order to handle their reliability management issues. Narratives related to the experience of reliability management handling are first collected, and then transformed into cognitive maps which can help to reveal the patterns involved in handling reliability management issues. The aggregate cognitive map can help to formalize the procedures and provide insights to staff when they come across similar cases again in the future.

6.1.3 Building a Good Sharing Culture

As a result of this project, a good sharing culture was built among staff. The aggregate cognitive map facilitated the solving of the complex reliability issues in a systematic manner. An example of this was the main landing gear alternate extension motor that always failed during the operation check. The reason behind this was that the lubricant of the motor always dried up. Before the

aggregate cognitive map was developed, this case could not be solved. The engineers could not find the root cause of this failure since there were no complaints from other operators. Therefore, they could only remove and replace the motor on a more frequent basis which increased the maintenance cost. After reviewing the aggregate cognitive map, the engineers thought of a new solution. They are now trying to find a new lubricant to replace the existing one which may prevent the lubricant from drying up in the Asia operating environment. Investigations are now going on to see whether this solution is appropriate.   From this case, it can be observed that the aggregate cognitive map triggered their thoughts and helped them to have a wider and more comprehensive scope of thinking. The map provided them with insights, which otherwise they may have missed, into how to solve complex issues.

6.1.4   Developing a Team Mental Model

This methodology helped the Engineering Division to prevent knowledge loss since it has built up a corporate memory where everyone shares the same mental model. Even when a member of staff leaves the organization, his or her knowledge still remains. This team mental model that is shared in the visualization of the aggregate cognitive map is comparable to the systems thinking idea put forward by Senge (1990) but with more focus on knowledge elicitation. It helps people to adapt to the changing

environment and influences people's sense-making and action by helping them to understand the interconnectedness, complexity and wholeness of a situation.

6.1.5 *The Application of the 4 "I"s Learning Framework*

This project was a good example of how an organization builds up its own corporate memory that matches well with the 4 "I"s learning framework in organizational learning. It incorporates individual learning through self-reflection (intuiting) and narrative telling (interpreting) and provides organizational learning by building the aggregate cognitive map and by encouraging team members to share the same mental model (integrating) and also through developing the procedure manuals (institutionalizing).

6.2 FUTURE WORK

6.2.1 *Capture more stories to reveal patterns for the sake of accuracy*

In order to make the aggregate cognitive map more complete and informative, it is important to gather more narratives. With more narratives, the patterns revealed will be more accurate since narratives can reveal embedded theories. Using the narrative technique can enrich the learning experience of people by providing more insightful information in every case which can better enhance the learning process. Also, it can help to expose new theoretical relationships between issues and establish more

meaningful questions for people to think about. This can help people to drill down into details in the cases so that they will have a better memory and will not commit the same fault again since this technique can help deepen and widen the coverage of every case which is quite different from just having review meetings and jotting down remarks in the minutes.

In order to collect more narratives, it is very important to establish a good social network between the people in the organization. Establishing trust is vital to the success of this project. Interviewees need to be assured that the narratives collected are not going to be misused, so they will be willing to relate their experiences to those collecting the narratives in a free and uninhibited manner. Therefore, staff who conduct such projects should always develop a good relationship with the participants so that he or she can get good results from the exercise.

6.2.2 *Case-Based Reasoning for Case Retrieval and Decision Support*

Case-based reasoning (CBR), an Artificial Intelligence tool which originated in the United States, is used for problem solving and support decision making. When faced with a complex problem, people often try to find possible solutions by looking at analogous problems (Aamodt and Plaza, 1994). CBR systems have been developed to support in this problem retrieval process, often at the level of document retrieval, to find relevant similar problems.

CBR is particularly good at querying structured, modular and non-homogeneous documents (Harrison, 1997). It is a methodology that supports human reasoning by collecting a large amount of data and then generates results through analyzing the relationships between the items of data.

CBR supports four main processes: retrieval, reuse, revision and retention.

(i) Retrieval refers to finding the most similar case(s) by comparing the past cases in the case library. Retrieving a case starts with an issue/problem description and ends when a best matching case has been found. Some systems retrieve cases based largely on superficial syntactic similarities among problem descriptors, while advanced systems use semantic similarities.

(ii) Reuse means using the retrieved case to try to solve the current problem. Reusing the retrieved case solution in the context of the new case focuses on: identifying the differences between the retrieved and the current case; and identifying the part of a retrieved case which can be transferred to the new case. Generally if the solution of the retrieved case is appropriate, it is transferred to the new case directly as its solution case.

(iii) Revision refers to revising and adapting the proposed solution if necessary. Revising the case solution generated by the reuse process is necessary when the solution proves incorrect. This provides an opportunity to learn from failure.

(iv) Retention means retaining the final solution as part of a new case. Retaining the case is the process of incorporating whatever is useful from the new case into the case library. This involves deciding what information to retain and in what form to retain it; how to index the case for future retrieval; and integrating the new case into the case library.

CBR is often used where experts find it hard to articulate or explain their thought processes when solving problems (Pal and Shiu, 2004). When using CBR, the need for knowledge acquisition can be limited to establishing how to characterize cases since CBR can help a user to retrieve and reuse past cases based on some criteria and propose a solution or trigger an idea for the user to consider (Bergmann et al., 1999). It will always provide the most similar case or cases so that users can adapt the solutions proposed by modifying them a bit. The solution will be retained as a new case for future use.

In this exercise, after collecting the narratives, relationships should be revealed. Then they will be centralized in a narrative database and CBR can then be applied. The reason why CBR should be applied in this exercise is that, CBR favours learning

from experience. It is usually easier to learn by retaining a concrete problem solving experience than by generalizing from it. In order for staff to learn effectively from CBR a well worked out set of methods is required in order to extract relevant knowledge from the experience, integrate a case into an existing knowledge structure, and index the case for later matching with similar cases (Aamodt and Plaza, 1994). However, it is often difficult to extract patterns and discover knowledge hidden in experience. If the staff can do this, it can always help the organization to perform smarter business since it can help people to save time in working and cost can also be lowered. Also, if people can learn from past experience this can help the organization to perform better business as staff will not fall into the same traps as they fell into previously. Nevertheless, one thing that has to be borne in mind is that case-based solutions are not ready-made solutions. Staff still have to analyze the retrieved solutions and see whether they can be reused, they can not simply apply them directly without analysis.

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