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COLLABORATION ACROSS THE EXTENDED ENTREPRISE: BARRIER OR OPPORTUNITY TO DEVELOP YOUR KNOWLEDGE ASSETS?

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ABSTRACT

Europe's Aeronautical industry operates as a highly complex and dynamic relationship between a vast number of specialist companies. Current aircraft design and manufacturing processes involve 40 to 50 different companies in a tiered supply chain. In this context, it's becoming more and more difficult to make sure that product quality is maintained and that delivery schedules are met. Successful collaboration requires an understanding of, and support for, the interaction and interdependencies between communication, culture, exploitation and dispersed team working. in the continual drive for competitivenes. Knowledge Management (KM) has been identified as a key enabler in reducing costs, improving quality and helping to ensure safe and correct products (Brimble, R, Longueville, B, Sellini, F, 2004).

The European project VIVACE (FP6, 2004-2007) aims at improving the capability to design and build an aircraft in such a context, and moreover to doing it ever faster. VIVACE proposes to define a Knowledge Enabled Engineering (KEE) environment, whereby knowledge is managed not only within individual companies but across supply chain relationships. The challenge is to provide solutions that span long product lifecycles within multi-disciplinary, multi-company and multi-cultural environments. VIVACE will take the lead in driving these solutions into the extended enterprise and contribute to Europe's aim of becoming the world's leading knowledge-based economy.

The VIVACE research work is driven by real business cases to understand the knowledge challenges and to identify effective solutions deployable into future Aircraft programmes. The work presented in this paper relates to a Wing Engineering Use Case (KEWE).

KEYWORDS

Knowledge management, concept phase, collaborative design, extended enterprise, aircraft design

1. INTRODUCTION

The European research VIVACE project (FP6, 2004-2007) aims at delivering an improved Aeronautical Collaborative Design Environment with associated Processes, Models and Methods to design an aircraft and its engines as a whole, providing virtual products with all requested functionality and components in each phase of the product engineering life cycle. The

VIVACE approach is to develop advanced capabilities such as Knowledge Enabled Engineering, (KEE), Multi-disciplinary Optimisation (MDO), Design To Decision Objective (DtDO), EDM, IT Infrastructures applied on real case engineering and business scenarios from the aircraft and engine sectors. The KEE advanced capability is of interest for this paper as the work presented here is from the Wing Engineering business case, which has identified key challenges related to Knowledge Management in the extended enterprise context.

In order to better understand the key elements associated with these KM challenges, several semi-structured interviews were conducted with different stakeholders from both the prime and supply chain contractors for a typical wing design activity. The interviews covered issues of collaboration, communication, knowledge capture sharing and re-use, risks relating to organisational structure and the dispersed nature of the team as well as how lessons learned are captured and implemented across projects or within new projects.

Several analysis frameworks were used to identify the gaps between the 'as-is' knowledge practices and the desired 'to-be' vision as defined by the supply chain stakeholders. These included a "Strengths, Weaknesses, Opportunities, and Threats" analysis (SWOT), as well as using part of the Relationship Evaluation Tool (RET) provided by the UK *Supply Chain Research In Action* (SCRIA) organisation (Lamming, Cousins and Hogan, 1998) and the use of IDEFØ formalism (www.idef.com) to provide a visual output.

Section 2 & 3 of the paper will focus on the scenario that formed the base of the wing business case used for the VIVACE project and the methodology used to conduct the assessment and analysis. In section 4, the paper will present the findings and functional requirements that will drive the selection and deployment of appropriate Knowledge Management Solutions to the business.

2. USE CASE SCENARIO

2.1. Business requirements

In the extended enterprise context, preliminary knowledge challenges or business requirements were identified and rated as high priority.

1. How can we ensure that knowledge is up to date and consistent? How can we be sure that different mediums, applications, and models are all in alignment? For example, if I have a knowledge base, a CAD model, and / or an application, how do I know they are up to date, at a local level as well as at a distributed level? How can we provide visibility of context and provenance of information to support individuals in deciding the degree to which they should trust, accept and re-use information.
2. How can we enable people to share knowledge and information across the extended enterprise with confidence? This includes exchange of technical as well as process information, formal and informal information (through interpersonal communications, sharing personal notes and so on), as well as lessons learned and good practice. It is anticipated that success will be highly dependant on the relationships within the enterprise within the technical teams, as well as the contractual environment within which the team is working.
3. How can we find knowledge through people within the extended enterprise across cultural (including discipline, organisational, and national) boundaries? This means taking a network approach to develop organisational awareness through knowledge networks – enabling individuals to both push and pull information and knowledge.
4. How can we mitigate risk in the extended enterprise? By avoiding the negative impacts and delays, extra costs and rework due to confusions and misunderstandings, access to the right information or access to the right skill.

The ultimate aim of the VIVACE project and particularly the KEE advanced capability is to deliver Knowledge Enabled Solutions to respond to these challenges. The future work section will describe how the survey findings will provide functional requirements to define the appropriate Knowledge Solutions.

2.2. Specific business context

For the purpose of the study, the business scenario dealt with the design of a wing tip, which is part of the wing structure design in the aircraft development process. For a new derivative of an Aircraft, a revised wing tip is required resulting in a longer span, and a simple winglet. The change requires a new structure outboard of the current wing tip

support rib, and revisions to the rib interface in order to take the new wing tip. Because the derivative activity occurs when the prime contractor's capability is utilized elsewhere, the third tier supply chain will be engaged to support the prime contractor engineering team. The scenario context is the need for a prime contractor to outsource design and associated technical analysis work on a winglet within an outsourced work package and where considerable collaboration between the prime contractor and suppliers is required to support an integrated operation. To ensure the task is completed successfully, both prime contractor and the supplier need to ensure the task can be completed to the required standard.

Within this scenario activity it was required to evaluate and understand the knowledge issues raised. Knowledge Requirements (KR) from both prime contractor and supplier perspectives are identified as follows:

- How much knowledge (for both product and process) has to be transferred to the supplier to enable the tasks to be completed using the latest techniques?
- How can we build a sharing culture?
- How might a shared data environment support the collaborative process?
- How can we create knowledge from this aircraft programme to be used in the future in order to strengthen the relationship within the supply chain?
- How can we integrate other knowledge associated with the product or materials which is gained in the broader domain, with the knowledge gained from this programme, through a recognised capture and categorisation process?
- How can we retain the knowledge in a format that can be applied in the future?
- How can we capture lessons learned alongside any knowledge gained so that the knowledge can be used more effectively and efficiently?
- How can we ensure personnel are willing to share the knowledge gained, and create 'recognition and reward' for sharing?

The scenario and these KR have been used to conduct the survey presented extensively in the following sections.

3. EXPERIMENTATION METHOD AND TOOLS

Following the KR presented in the previous section, good KM practice is recognised as key to improve operations within the supply chain. Therefore the present study aimed at achieving a description of the AS-IS situation, create a TO-BE vision and generate a list of Functional Requirements for necessary KM solutions.

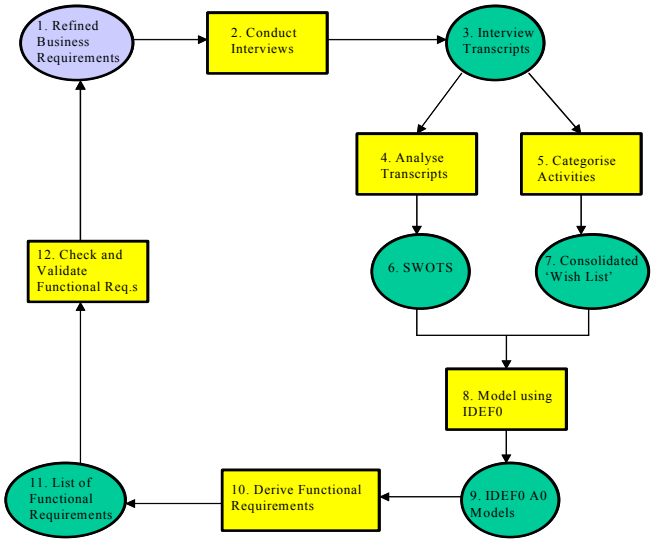


Figure 1: process for the study

Figure1 describes the process followed during the study which included tasks such as:-

- Refining the list of Business Requirements generated in the Use Case Definition
- Conducting Interviews, using questions which were directly related to the Business Requirements
- The AS-IS description is being generated using transcript analysis; including categorisation of transcripts elements, producing SWOTs, filtering information using part of the SCRIA framework (Lamming, Cousins and Hogan, 1998) as well as building a graphical representation of the local contact network from the interviewee's perspective.
- Consolidation of a 'wish list' of user requirements, using the transcripts. This helped to describe the TO-BE vision.
- IDEFØ (A0) [high level] was used to model the KM activities. The Inputs from the SWOTs (constraints/enablers) and Wish List (activities) were used to define the activity inputs, mechanisms, controls and outputs.

- Generation of a list of Functional Requirements from the IDEFØ outputs

3.1. Collect / gathering material

To capture 'real life' experiences in sharing knowledge we wanted to engage with people who had previous experience in the supply chain relationship as a member of an IPT, with people who expressed an interest in the possibility of being involved as stakeholders and participating in the pilot phase, with individuals who could bring different experiences e.g. design or manufacturing, and Designers/Engineers from both the Prime Contractor and the Supplier.

Interviews were conducted and a questionnaire defined to capture the experience of these candidates. To be able to get 'real life' contributions semi-structured interviews were selected as the best way to meet our requirements. During the interview there is an option to probe a little deeper on some subjects in addition to the pre-defined set of questions. Interviews also allow the development of a good professional relationship, which can be particularly useful in future work.

The following 'Multi Faceted' model has been developed to support the definition of questions. Considering the various knowledge elements presented in Figure2 enabled us to consider the supply chain scenario from different perspectives.

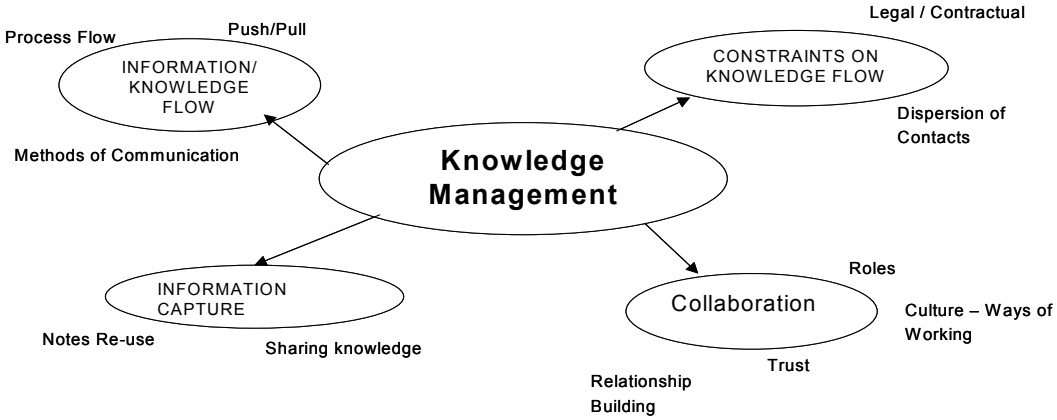


Figure 2: Elements that influence knowledge practices in a supply chain relationship

The core of the interview revolved around the following aspects:

- The role and responsibilities of the individual
- The collaboration across companies in the supply chain
- How information was exchanged, stored and managed (including quality aspects)
- How knowledge was retained and applied across projects or on to new projects
- The risks associated with the collaborative operation
- The harmonisation of processes between the organisations operating together
- The use and re-use of information and knowledge
- The capture, management and use of lessons learned

Eight people from both the prime contractor and supplier company took part in interviews. In addition to the list of predefined questions, each interviewee was asked to describe their position in the working network (Social Network Analysis – SNA in Conway, S., Fred, S., 1998) and to indicate on a modified Relationship Evaluation Tool (RET), their perception of the maturity of the supply chain relationship.

3.2. Analysis tools

The interview data was considered from several viewpoints to do justice to the richness of the comments provided by interviewees. The following tools have been used to analyse and integrate the different outcomes:

(a)SWOT diagrams: SWOT analysis is a framework for analysing an organisation's or program's internal Strengths and Weaknesses, as well as the Opportunities and Threats that exist both within and outside the organization or program.

(b)Scales derived from the '*SCRIA Relationship Evaluation Tool''* (Lamming, Cousins and Hogan, 1998) and modified to reflect the specific

requirements. The SCRIA RET is a sophisticated and comprehensive tool to assess and diagnose problems with relationships between organisations, which are affecting performance. Only the section relating to collaboration and information and knowledge sharing was used here. Five areas have been used as a way of structuring the AS-IS view: Communication, Personal relations, Quality of communication, Information exchange, Problem notification and resolution, Trust.

(c)Social Network Analysis (SNA) (Conway, S., Fred, S., 1998): SNA analysis is the mapping of relationships and flows of information between entities in a process. The nodes in the network are the people while the links show relationships or flows between the people. Network Analysis is a good visual method of describing relationships in a supply chain context. A shortened version of network mapping was used to indicate the major links.

(d)IDEFØ (www.idef.com): process/activity modelling tool support. Used extensively in the engineering community, IDEFØ is very simple to comprehend and has been used for our particular objective of defining functional requirements.

This section introduced a range of techniques for analysing the information captured in the 'As-Is' interviews. The reasons as to why they may be useful are presented. We have used a range of these models to complete our analysis and this will be presented in the next section.

4. FINDINGS

4.1. "As-Is" description

SCRIA Scoring exercise

During the interviews we asked the interviewee's to score their perception of the maturity of the supply chain relationship for the six elements in the table. The scores can range from 1 to 5, 5 being the most mature level. The table shows the scores of interviewees in both the prime contractor and supplier. The letters 'a' to 'd' represent each interviewee for both supplier and prime contractor.

Prime Contractor

	a	b	c	d
Communication	1	4	5	4
Personal Relations	3	3	3	2
Quality of Communication	1	2	3.5	2.5
Information Exchange	2	4	2	2
Problem Notification and Resolution	1	3	2	2
Trust	2	1	1	1

Supplier

	a	b	c	d
Communication	5	5	1 & 4	1.5
Personal Relations	4	4	3	4
Quality of Communication	4	3	2	4
Information Exchange	4	4	4	3
Problem Notification and Resolution	4	4.5	2&3	2
Trust	3	3	3	3

Figure 3: Modified SCRIA scoring results tables

Some interesting comments were made in completing these scales, notably for prime contractor interviewee 'c', a high score was made for the frequency of communication exchanges with the supply chain. This can be viewed as part of a rich and collaborative relationship, but in fact in this case it was due to keeping the project on schedule and was key requirement. Significant amounts of travel and face-to-face meetings were also conducted in this case. The RET scales gave us an initial indication of the perception of people involved with the supply chain. Used in combination with further analysis, it enabled the team to understand better the 'AS-IS' situation and to develop the 'TO-BE' and functional requirements. Take for example the trust element. In the prime contractor view, lack of trust is an issue. It was highlighted as a weakness in the SWOT and as a need for improvement in the 'Wish List'

However it must be stated that we were working with a very small sample and it would be clearly unwise to extrapolate and use this table as a universal indication of the level of maturity of elements in the supply chain relationship.

SWOT Analysis

The SWOT analyses were useful in highlighting existing competences, which enabled the development of the TO-BE scenario. It also defined the risks and issues that require solutions.

STRENGTHS	WEAKNESSES
•'Man to man' marking •Efficient dissemination within prime contractor team •Regular project status meetings – drumbeats – improve communication & personal relations •Prime contractor teams are co-located •Personal networks •Prime contractor people working in the suppliers	•Project management issues – slipping programs, too much detail, fractured plans •Dissemination of information – delays and not done efficiently between supplier teams •Fire-fighting mode – resource issue •Not pro-active in problem resolution •Lessons learned shared in the prime contractor but too late – end of project •New tool sets are introduced after project begins, too late
OPPORTUNITIES	**THREATS**
•eRoom to share documents available but not used, training required •Prime contractor employees with expertise available to help suppliers •KM solutions – sharing experience/lesson learned tool •Other internal projects in prime contractor e.g. to ensure that suppliers have IT capability •Networking – *Socialising with Purpose*	•Trust – ' *I can't remember getting one thing that I wanted on the day that I wanted it on.*' •Contractual - 'Bickering' over what is in/out of contract •Some supplier teams are not co-located •Moving to a Critical Path plan but can important detail •'Time clocks' not synchronised •Moving people off projects – ramp down, rarely overlap period •Strategy in choosing suppliers not taking into account past performance

Figure 4: example of SWOT result

Key outputs from the SWOTs include;

1. Professional networks i.e. connecting with people that you worked with on previous projects. This was particularly true for the prime contractor who actively managed the flow of people with particular project and product skills and knowledge to the next related project. The project network was highly valued by all. Drumbeat meetings (project status reviews) work generally well. Location and co-location is considered important, shared training courses would be beneficial, sharing across projects needs to be improved, knowledge gained through peer groups/mutual experience.
2. Personal relationships and networking are supported by the process of 'man to man' marking and by spending time with your partner company at the start of projects. Communications at this level are good. Local supply chain engineers and prime contractor engineers often had long standing relationships and in many cases had even gone to school together. Many of the supply chain engineers had previously worked for the prime contractor and hence had a) very good relationships, and b) had very good extant product and process knowledge. For the more dispersed supply chain, the relationships were not so close, although there was some movement of personnel between the companies just as there was for the local suppliers.
3. Structured folder systems enable sharing of data, such environments are available not always used efficiently. However, the lack of trust in project teams negatively impact the sharing of information. There was concern about sharing due to IPR type issues.
4. The quality function in the supply chain fulfilled a crucial role in logging good practice and recording decisions, but the benefits of this process were not necessarily realised by the prime contractor.
5. Capture and re-use of information not formalised. Lessons learned sometimes done, but the results are not necessarily used or formally embedded in the project review process.

Network analysis

During each interview we asked the interviewee to describe their position in the working network. It gave us an insight into information flows, the strength of the flow, how people communicated, if the process was formal and the degree of collaboration.

Some insights following the analysis were;

- Individual relationships between team members can be strong and are used to solve issues, level of trust between members differs within teams
- E Mail and face-to-face meetings are the main source of communication,
- The process for communication is a mix of informal and structured meetings,
- What was important to the interviewees was to connect with the right people, as opposed to the number of contacts that they had. The belief is that both personal level and professional level networks need to be developed to support KM activities.

Network analysis is a useful tool in mapping current and building future networks and can help to identify the strengths and weaknesses in the project network and hence allow support or mitigation of the negative impacts. A more in depth analysis should be part of future work.

4.2. "To-Be" description

High level vision

This use case aims at developing relevant capability relating to KM methodologies and technologies to assist participants in supply chain interfaces. This involves both commercial and technical personnel working across organisational, discipline and geographical boundaries that need to generate, share and re-use project knowledge, in order to facilitate effective working partnerships. The vision is for:

"Seamless teaming, where engineers of both organisations feel and are, part of both the local and the extended team"

The vision encompasses aspects relating to many interdependent factors, which need to be considered as a whole rather than individually. This means taking a systems view of the extended organisation. The following diagram gives a view of the interdependency between cultural factors, communication, geographic dispersal and enabling the flow of knowledge within the team/extended enterprise to achieve a truly collaborative team.

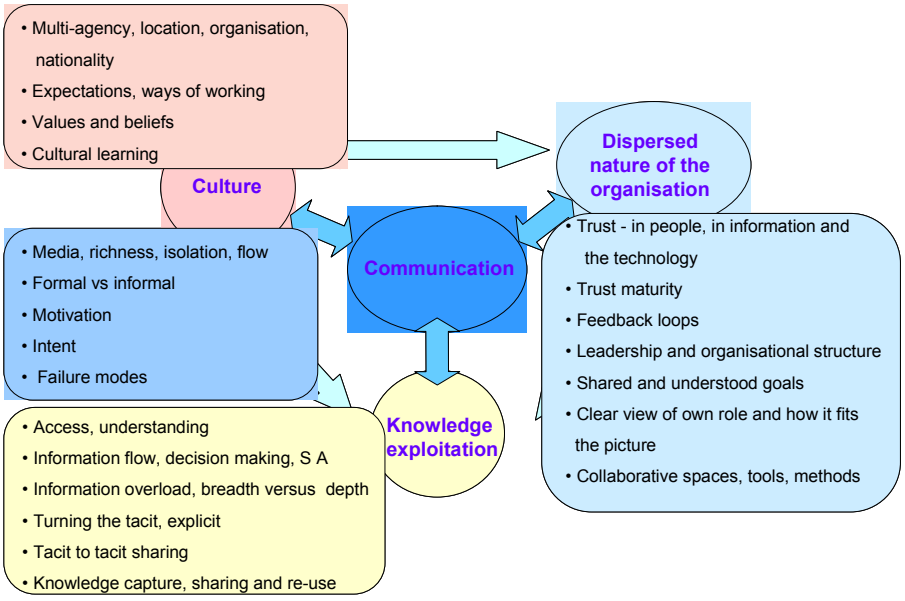


Figure 5: Factors affecting collaborative working in the extended enterprise (Carver, E., Monhsame, A., Khablouti, G., Walther, M., 2001)

Define the To-Be description

The process adopted in the KEWE use case has explicitly addressed communication, knowledge exploitation and also dispersal as key factors, and has inferred cultural factors and differences from the interview data. Research in the ENHANCE project (Carver, E., Monhsame, A., Khablouti, G., Walther, M., 2001) had identified the importance of partnerships both in the operation of teams and in effective collaboration across the extended enterprise. The 'Partnership triangles' model of Rosabeth Moss Kanter (Moss Kanter, R., 1994) describes well the multi-faceted challenges of working and partnering with other organisations in terms of cooperation, sharing, openness and trust, where balances need to be struck with respect to interdependency and integration.

The KEWE solution must address all these factors to enable exchange of information and knowledge across the supply chain where multiple organisations must share information and knowledge in order to be effective. This means that the technology, processes and behaviours must assist individuals in performing their tasks, and in their communication with other individuals, whether internal or external to their own organisation. All phases of the knowledge lifecycle must be considered and applied to project knowledge within the supply chain in order to enable all individuals within the multi-organisation team to access appropriate current and reliable information at the right time in the right format from the right person or from the right database.

Illustration with an example: lessons learnt

Improvement need	Lessons learned processes are applied, but generally only at a post project assessment stage.
Wish list	Need to have joint customer and supplier lessons learned activities, the knowledge gained should be mutual, and provide opportunities for more rapid improvement within the next phases, or in other projects. A structured process should be applied to support this

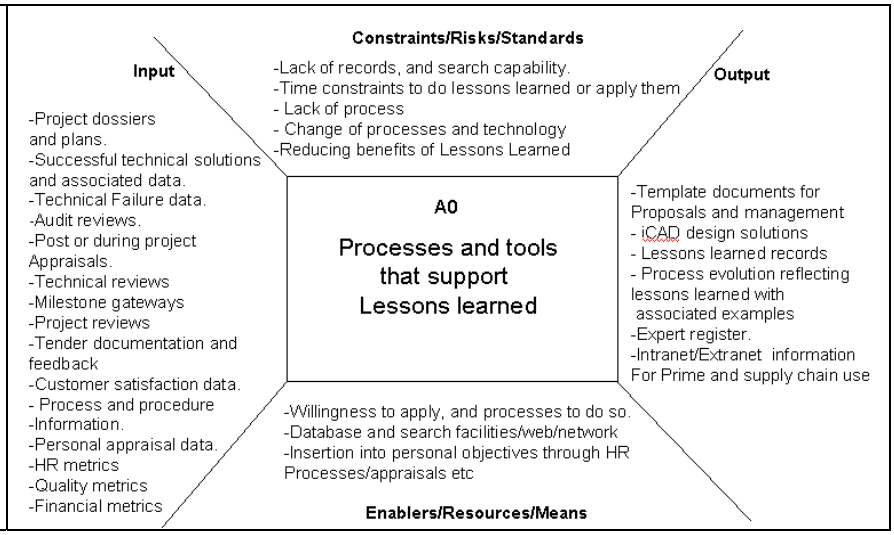
The IDEFØ modelling result This IDEFØ representation is used to refine the functional requirements for KM solutions.	

Figure 6: Table showing an example of Analysis on Lessons Learnt topic

5. NEXT STEPS

To fulfil the To-Be vision a complementary mix of people and technology solutions are required. For example, to capture lessons learned, there is a need to motivate users to describe their experiences and a database to log these lessons. This consideration needs to be clear when developing the experimentation in future work. Following the example of lessons learnt, and from the result of the IDEFØ modelling, function requirements have emerged and been refined including:

- Create lessons learned records,
- Update members inside the functional expert register or Yellow Pages tool,
- Provide a central forum for the people network
- Provide an opportunity to discuss feedback on technical or management methods, or design approaches that were successful or not, to support future projects.

6. THE KNOWLEDGE ENABLED SOLUTION

The purpose of going through this process was to understand the challenges that the business use case had demonstrated and to address the requirements for improved knowledge management through a set of solutions. Given a number of constraints (including resources), the solutions are in part recommendations and in part proposals for trials of specific activities and technologies that will address the issues identified in the supply chain study. The next step is to develop the most appropriate solutions and to implement a trials plan to assess each in terms of the functionality and benefits for the solution itself, as well as how well it fits within the current process, the team and the organisations. This process has been done by using quality function deployment (QFD) to map requirements against solutions.

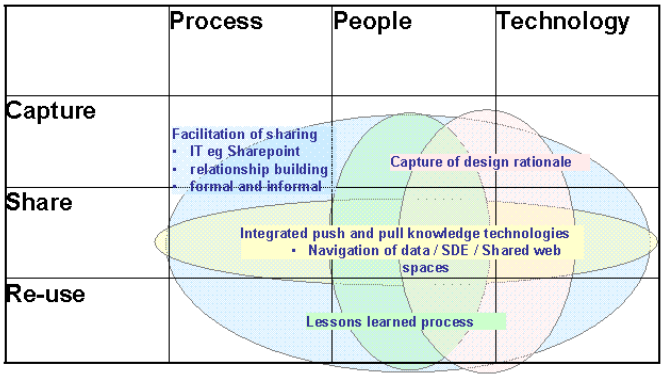


Figure 7 Areas where the pilot trials will be developed

Figure 7 shows the areas where pilot trials have been identified as being beneficial – they include:

- Facilitation of sharing across the extended enterprise - Achieving sharing across teams and organisations in a seamless fashion; through IT solutions, through relationship building, through both formal and informal mechanisms. Integrated push and pull knowledge technologies - Taking an integrated view across the enterprise looking a both push and pull and shared spaces.
- Lessons learned process - Capturing tacit knowledge in order to recreate success. Knowing what the barriers to success are will help in addressing issues of making time available, storing the lessons, and enabling re-use when

needed, as well as looking at how to embed this activity within the design process
- Capture of design rationale - Capturing experience for audit and certification

The figure maps the solutions against the knowledge lifecycle process as well as taking a systems view of the process, people and technology elements that contribute to a successful outcome. Participants are in the process of being identified and these trials will be rolled out in 2006.

7. CONCLUSION

The findings of the study map well on to other work in this area (e.g. Hoegl, M; Schulze, A., 2005; Liker, J.K; Choio, T.Y., 2004; Fagerström, B; Olsson, L-E., 2002) and give good pointers to where more in depth studies should concentrate. Through the analysis of the interviews conducted with people who have had active experience in interfacing with the supply chain relationship we have been able to:

- Describe the nature of different and similar supply chain relationships,
- Link the work with identified specific Knowledge Challenges, and
- Produce an output, which will go towards benefiting both the prime contractor design teams as well as the supply chain engineers as we move into the pilot phase.

These results have been achieved through a methodological approach in defining our strategy. Focusing on a single scenario enables us to expand on the previous Use Case work and confirm the identified knowledge challenges in a business environment.

8. ACKNOWLEDGEMENTS

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