

# D4D

## A process for distributed design

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Content from:

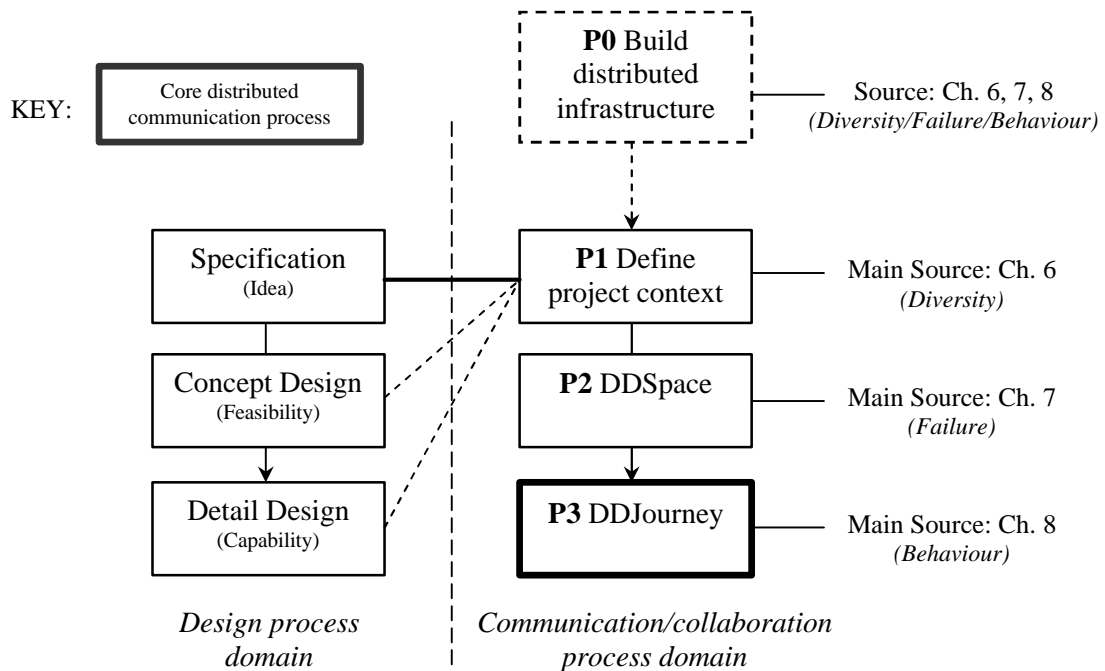
MacGregor, S. P., (2002) *Describing and Supporting the Distributed Workspace: Towards a Prescriptive Process for Design Teams*, PhD Thesis, DMEM, University of Strathclyde, Glasgow, Scotland. Details at: [www.design4distribution.com](http://www.design4distribution.com)

## D4D Framework

The main stages of the D4D framework are shown in figure 1. The design process domain is modelled on the left side of the figure representing any design process followed in a distributed organisation. The three main stages from the case studies are shown. The collaboration/communication process domain is represented on the right side of the figure. Process phases are created in response to the three distributed elements developed in part C. These do not change the core design process in any way but merely adds support, tweaking the core design process to make it suitable for distribution. It 'bolts-on' to a stage in the core design process. The point of connection depends on when distributed activity begins – the D4D phases should commence prior to distributed work and preferably at the beginning of the design process.

The main development source for each process phase is shown. However, a degree of overlap does exist – each phase sources elements of content and support from other chapters. Further, in addition to the core process phases developed respectively in chapters 6, 7 and 8 a pre-process phase is added which aims to build a general distributed infrastructure within an organisation. This pre-process phase gives the core process the best chance of success, drawing content from the whole thesis, to prescribe stages including training and activity modelling. Phase 3: DDJourney is also highlighted to signify its status as final vertical development – a core communication process identified as necessary in part A.

Sub-steps, actions and deliverables are now detailed for each phase, showing use of supporting tools and methods developed in part C.



**Figure 1 Main D4D elements**

**P0 Build distributed infrastructure:** This is a pre-process phase which should be completed in an organisation independent of a specific distributed project. However, the outputs from the phase are important to ensure the success of the core process. Sub-steps include *distributed training* and *modelling the current process*. Defining characteristics of

the organisation should be highlighted in terms of distributed work. Required organisational support should then be recommended in light of this analysis. Training should result in designers knowing better how to communicate *and* design at distance. The Distributed Design Workspace (*Workspace*) and Failure Modes & Effects Analysis (*FMEA*) are the primary supporting tools.

**P1 Define project context:** This phase commences the core D4D process and includes specifying the design project in terms of distribution. Sub-steps include the *definition of constrained and free conditions*, resulting in an overall distributed project strategy. Constraints should be defined first, leaving the specification of free conditions which should ensure minimum distributed difficulty and maximum performance. Constraints may include only the possibility of asynchronous communication in light of geographical time-zones with free conditions including involving only experienced personnel to counteract potential problems. The Matrix of Characteristics (*Matrix*) is the primary supporting tool – this should be divided into two separate matrices depending on the project context. P1 builds on the previous phase to *customise* the distributed infrastructure.

**P2 Distributed Design Space (DDSpace):** DDSpace involves putting in place a supporting distributed infrastructure prior to distributed work. The relevant *Matrix* conditions should be examined in more detail, ideally as part of a collocated session by the main members of the distributed team. Sub-steps are *people space* and *product space* which include further actions: resource allocation and interaction design. Necessary deliverables are derived from people and product requirements specified in part C and include:

- Distributed responsibility documentation;
- Interaction map;
- Expertise directory;
- Identification of distributed champions and ‘learning loops’.

The awareness framework is used to identify and generate appropriate questions and is used in conjunction with the *Matrix* to provide necessary support. DDSpace focuses on two of the three critical *Workspace* actors – people and product while specifying ‘know-what’ or declarative knowledge.

**P3 Distributed Design Journey (DDJourney):** The final phase in the D4D process maps the specific distributed process and facilitates flexible action in response to problems. As such it develops proactive and reactive measures, using the awareness and switching framework as core support. Deliverables include a proactive process map comprised of switching actions and appropriate awareness elements at key stages. Encountered problems and reactive measures should be recorded in an experience database. The FMEA may also be used to better understand distributed problems. DDJourney focuses on the third critical *Workspace* ‘actor’ – process, and specifies procedural knowledge or ‘know-how’.

The complete D4D process is summarised in the appendix at the end of this report.. A summary and main benefits of each of the supporting methods is detailed below:

**Distributed Design Workspace (Theme generator: DIVERSITY)**

A descriptive summary of the main elements of distributed work. Can be used to identify and contextualise elements within a distributed organisation which affect the success of distributed work. Content also familiarises user with main elements of distributed design, serving as an introduction to distributed theory.

**Matrix of Characteristics (Theme generator: DIVERSITY)**

A descriptive or prescriptive tool which includes a variety of possible conditions for the main distributed characteristics, allowing a detailed illustration of different distributed

scenarios. This leads to the visualisation and evaluation of scenarios – highlighting relevant issues and detailing performance.

**Activity Modelling (Theme generators: DIVERSITY/FAILURE/BEHAVIOUR)**

Shows a procedure for highlighting important distributed behaviour and phenomena as well as highlighting applicable content within the distributed space.

**FMEA (Theme generator: FAILURE)**

The analysis of main problems associated with distributed communication. Increases familiarity of common distributed failures and possible means of addressing them.

**Awareness and switching framework (Theme generator: BEHAVIOUR)**

Identifies new theory which constitutes behavioural needs for distributed success. Prescribes basic actions to satisfy appropriate needs at different times and in different situations. Focuses on improving communication and collaboration between distributed colleagues by formalising previously implicit behaviour, taking account of the difference between the collocated and the distributed space.

The original form of each of these methods is included in the appendix, together with notes on their use.

***Implementation issues***

In summary, the D4D process defines the distributed workspace and prescribes a means of successfully navigating it. It aims to leverage the value of the team through increasing a shared understanding and an awareness of common goals. The following sections should be considered in light of implementation.

**High focus design process stages – decomposition and reconstitution**

The relationship between the design process and distribution is the key factor at the very core of this thesis. Research has gauged the effects of distribution and prescribed support so that the design process can operate to its full potential in a distributed environment, while taking advantage of the opportunities that distribution affords. The general approach taken to support distribution in this thesis has been to focus on the role of communication and collaboration while keeping the core design process unchanged. However, there are elements of the design process which require to be highlighted in terms of distributed work.

The industrial studies showed that, ideally, the front end of the design process should be collocated. This is due to the uncertainty involved at the specification and conceptual design stage – distribution merely adds to this uncertainty, resulting in poor performance. Most distributed work, therefore, takes place in the latter stages of the design process when the design has matured and work can be divided between locations. However, problems then occur when attempting to integrate these separate locations. Two main areas of the design process are therefore important in distribution:

- The beginning of the conceptual design stage where the solution principle is established, and;
- The end of the detail design stage where sub-systems are integrated and interfaces reconciled.

In essence these are the **decomposition** and **reconstitution** stages in the process where sub-problems are generated before the overall solution is derived from the resultant sub-solutions. Decomposition occurs during the initial period of uncertainty. Distributed work can then proceed relatively smoothly until time for reconstitution. These are the highest periods of ‘turbulence’ in the distributed design process. Such periods of uncertainty should be catered for by the explicit and intentional nature of the D4D framework. Awareness

elements should be built into these phases while switching actions should be formalised and made visible to all members of the team.

Collocation is the ideal which should be considered as much a strategic decision of distributed work as using sophisticated communication technology. However, when impossible high levels of focus and formality should at least be applied. Initial conceptual design activities could also be merged with the collocated D4D session so that distributed factors are viewed in context. Ensuring that knowledge transfer is facilitated in all scenarios is key, especially at the beginning of the design process or distribution. In many cases, it is the significant 'start-up' effort which causes difficulty. If this can be surmounted, either by collocation or process support, distributed work has a better chance of success.

### **Design activity**

Reliance on each of these phases will also depend on the context – design activity and product being designed. The cases have shown that original design projects have more reliance on the front end of the process and conceptual design stage. Variant and adaptive design projects re-use former work and normally begin at a relatively advanced stage of design embodiment and therefore involve higher levels of detail design. The main challenge in the adaptive/variant design environment was the complexity of the product. Such complexity adds to the significant challenges of distributed integration evident at the reconstitution stage.

The framework is perhaps best suited to non-original design work. The formality of the process lends itself to more procedural work where less uncertainties are likely. However, original design has much to benefit from the input of distributed designers, each adding their unique perspectives and backgrounds to the design of new products. It may be that such projects benefit from the general infrastructure of the D4D framework but not finer level constraints. This formality may aid in highly complex work allowing numerous sub-systems and interfaces to be tightly controlled.

### **Team architecture v team dynamics**

Team dynamics is a popular research stream which investigates how teams work together due to 'soft' issues including personalities and work setting. The D4D framework essentially establishes the *architecture* of the distributed workspace, including the team. In many cases, the architecture which includes resource allocation and interaction design is more important than team dynamics. Different stages of the design process may require different levels of architecture and dynamics focus.

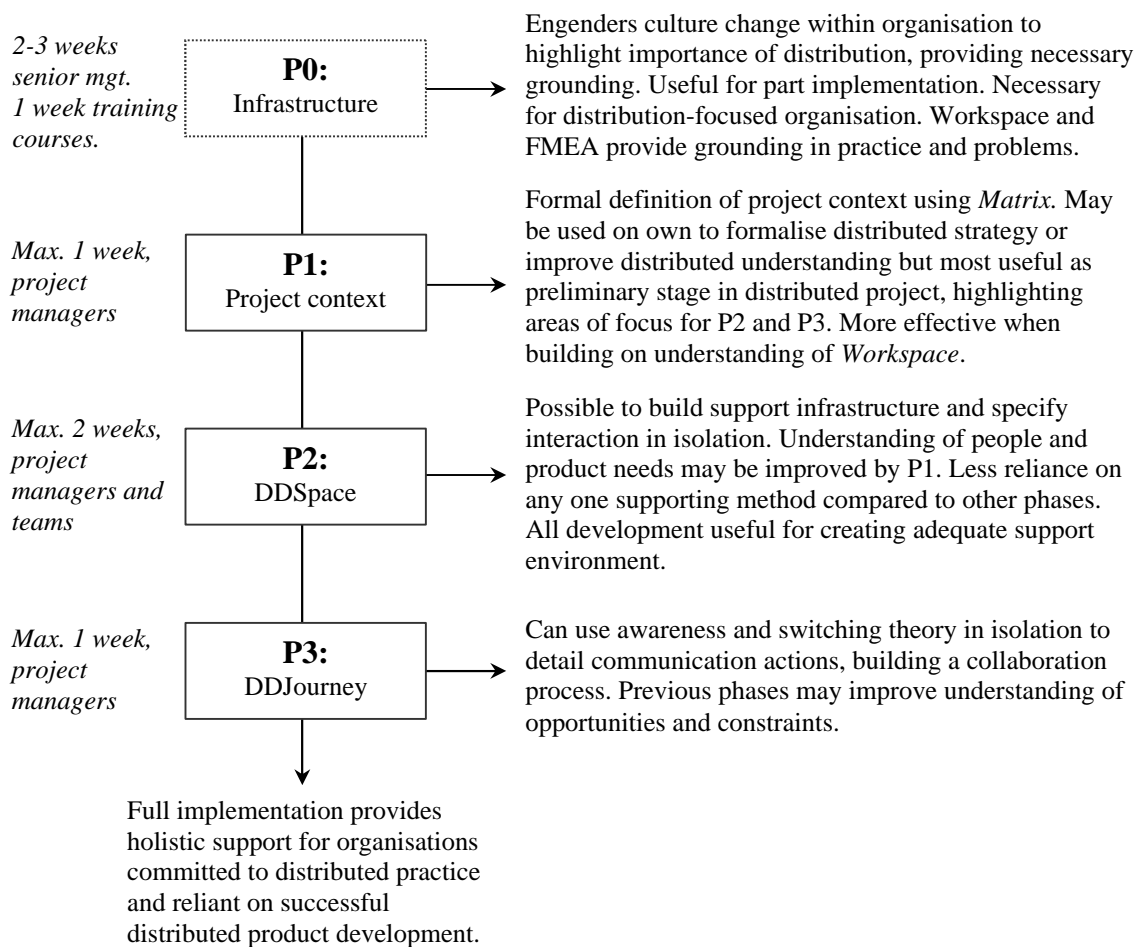
### **Training**

Training is crucial to efficient distributed work and exists on a variety of levels. It could be applied to management for strategic and troubleshooting functions or designers who are involved in day-to-day distributed communication. Part C provides a grounding in the fundamentals of distributed work, with the *Workspace* and FMEA providing a summary of practice and problems. The need exists to improve both distributed design and distributed communication, which may involve building on levels of social competence.

### **Commitment to process phases**

The cost and value of distributed support should be considered, resulting in a decision regarding the level of implementation. For projects where only low levels of informal distribution are evident full implementation of the D4D framework would be unnecessary. However, a general infrastructure should still be in place, including management

understanding of distributed design theory and the capability to prescribe appropriate action. Culture should also be considered. Implementation of any new process or tool encounters some degree of difficulty. This may be especially relevant here where distribution is often not regarded as a primary issue in an industrial setting. Process phase 0 would therefore become more important in increasing a general awareness of the field. Incentives may be provided while distributed champions (advocated in DDSpace) may help implementation. Specific phases of the D4D framework may also be used in isolation. Figure 2 below summarises individual features. A summary of application issues, detailed in the first example, is also included, showing the *who* and *duration* of each process phase. Although the core phases last a maximum of 4 weeks these need not be completed in a strictly serial nature. The exact time required will vary depending on size of project and organisation but at least 2-3 weeks is recommended to improve distributed work.



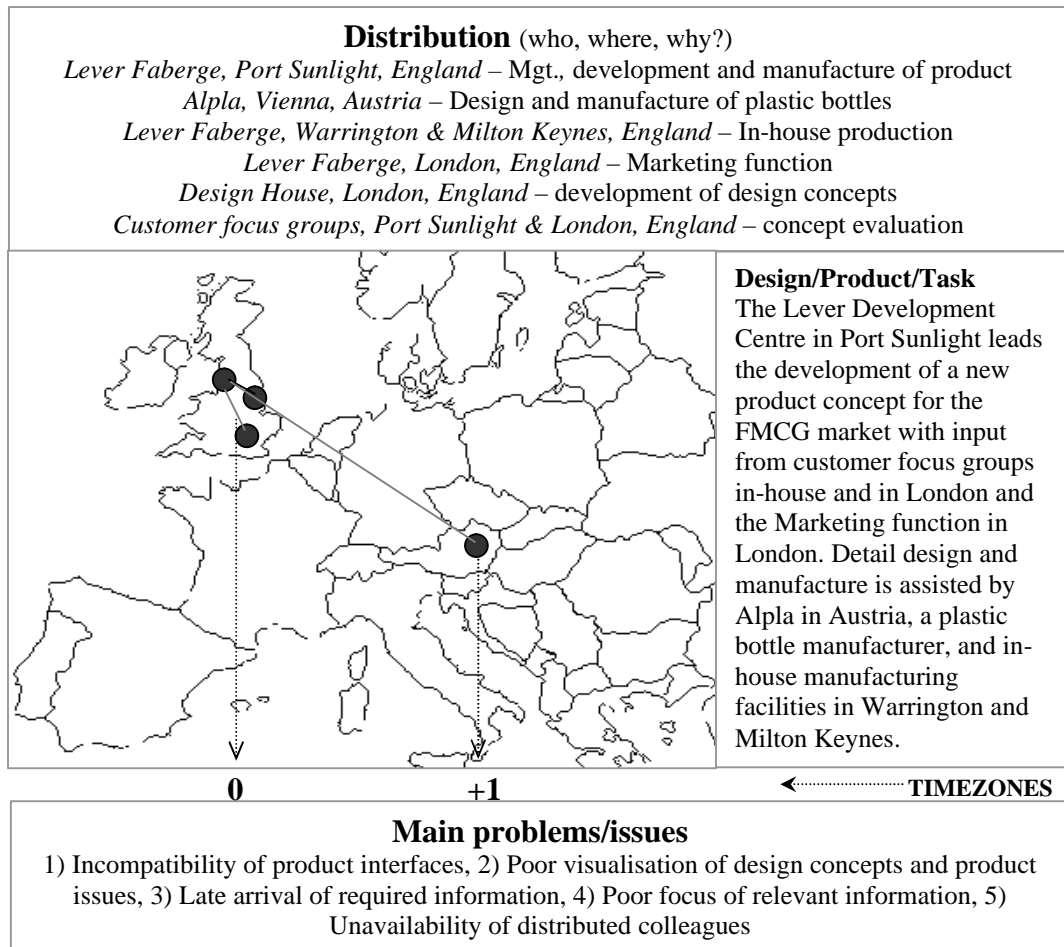
**Figure 2 Implementation and use of process phases**

## Worked Examples

To fully detail the D4D framework and evaluate its use, it is applied to the representative cases. A summary of the project scenario in each case is first presented after which the main steps of the D4D framework are detailed. Each example is a mixture of what happened (problems and constraints, reactive measures) and the newer course of action generated by the framework (matrix strategy, proactive measures).

## Lever Case

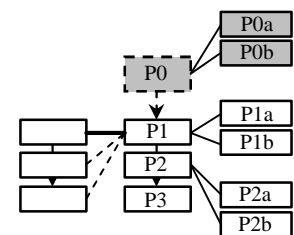
The Lever sample case scenario is now addressed using the D4D framework. The scenario is first summarised in Figure 3 below.



**Figure 3 Case Two Scenario Summary**

### P0 Build Distributed Infrastructure

The initial infrastructure build should take at least 2-3 weeks and be conducted by senior management to produce organisational recommended actions. Periodic checks should then take place on a continual basis to ensure basic needs of distribution are being met. On a training level 1 week courses should be given to all project staff involved in distributed work. This ensures that the people infrastructure is sound and builds upon adequate process measures.



***P0a Distributed Training:*** First step involves becoming familiar with the distinguishing features of the organisation in the context of distribution. The *Workspace* and FMEA is used to build an understanding of the main elements of distributed practice and common distributed failures. Other thesis content, such as the cases, may also prove useful.

Defining organisational characteristics should be put in context using the *Workspace*. Important aspects of the people, product, process and tools elements include:

- **Environment** – including collaborators and technology as well as the physical, cognitive and virtual dimensions of space;
- **Knowledge and Information** – an appreciation of information needs at different stages of the design process and procedures for location and re-use;
- **Management and Teams** – including scale, interaction, identity, structure and trust;
- **Culture** – including geography, company, discipline and technology.

Training material should be packaged on a general level with appropriate elements highlighted in each organisation. Such contextualisation is aided by the following step.

### *P0b Model current process*

#### *Lever Characteristics*

The defining characteristics of the Lever environment related to distribution are:

- **Original design activity** – there is a continual need for innovation and difficulty in communicating early phase design intent and creative thought across distance. Adaptive/variant design activity exists in the form of value improvement projects, scaling jobs and satisfying local market needs, although technological and organisational support for design re-use is non-existent.
- **Large variety of collaborators** – across discipline and organisation, including marketing, manufacturing and customers. Relationships and levels of trust vary and consistency leads to success. Design activity is sometimes marginalized through other functions, usually marketing, while the case site acts as a consultancy centre for other sites with little or no design expertise;
- **Need for physical representation** – leading to difficulties regarding distributed visualisation. Rapid prototyping used at all stages of the design process and designers are conditioned in using physical models to develop ideas, while high levels of print media are used in the collocated space. Even though products are significantly less complex than in ABB VG problems still exist at product interfaces.

#### *Lever Problems/failures*

The FMEA is used to highlight potential distributed problems and possible solutions. A main problem regards *poor quality of distributed work/ insufficient understanding* due to distributed sites with little or no design experience. The FMEA details the following:

**Potential effects of failure** – Poor quality of work, project delay, breakdown in relationships and communication. SEVERITY = 8;

**Potential causes/mechanisms of failure** – Unrealistic expectations of work, insufficient training and support, low awareness of experience. OCCURRENCE = 8;

**Current process controls** – None. DETECTION = 3;

**Recommended actions** – Competence checks, training, understanding checklists.

Other typical problems in the Lever environment such as those regarding poor representation should be examined in the FMEA and used to increase an awareness of distributed challenges in the Lever team. The FMEA increases understanding of the root cause of problems, often the most important information.

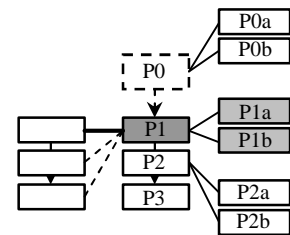
#### *Lever Recommended actions*

The examination of distributed characteristics and challenges should result in the identification of organisational support to enable the distributed infrastructure. The following actions may further support distributed work in the Lever environment:

- A greater investment in technological support which enables the sharing and storing of design work to facilitate communication and re-use;
- A higher level of design influence in projects with a reduction in the controlling role that the marketing function plays in distributed work;
- A clear, consistent design process which is visible to all designers and includes support for distribution;
- Individual designers should form networks with other separated designers in the same situation, thereby building a culture of *assistance*. There should be some level of overlap and distribution in each part of the development to cater for learning and to combat designer isolation at each of the satellite design offices.

## P1 Define Project Context

A small team of project managers should complete the matrix method, using an understanding of organisational constraints. This can be completed on a collocated individual basis initially with sharing of results then required for consensus between distributed parties. A brainstorming session should initiate the exercise with completion in no more than 1 week. Representatives of each distributed party should then meet for 1 day to finalise the scenario, after which the results should be made available to all project staff. This should happen at least 2 weeks before the start of the project to allow the opportunity for feedback. Past scenarios and results could be used in the training courses of P0.



The *Matrix* is used to detail the constrained and chosen conditions for the sample scenario, assisting management in strategic decisions and designers in project familiarisation. The constraints are first detailed in table 1 below. As detailed in chapter 6, conditions have varying levels of difficulty, resulting in an overall level of difficulty for the project.

### P1a Detail Project Constraints

The Lever constraints are detailed in Table 1 below.

**Table 1 Matrix constrained conditions (Lever)**

Characteristics	Constrained conditions	Comments
Number of partners/size of team	More than 2	Maximum size of team around 12 plus several customer focus groups each containing several people
Language	Different	Austrian and English plus marketing and manufacturing terminology
Competence/quality of distributed work	MEDIUM	When collaborators are each operating outwith their own discipline knowledge of design is not comprehensive
Number of interfaces (distributed team complexity)	MEDIUM	
Location/scale of distribution (top end)	Different country	Different time-zone but few problems relating to time
Organisation	External	Collaboration across all 3 conditions and most problems associated with internal different department (Marketing)

Level of collaboration (intensity)	HIGH	Large collaborative design and influence. Constrained as designers can't do all aspects of project themselves
Design activity	Mostly original	Innovation need for market success
Discipline	Different	
Type of collaboration	Mixed	Mostly creative at front end of design process and mostly technical towards end
Distribution of components	Sub-system	Distributed on an idea/perspective level as well as the physical product (design v marketing v manufacturing)
Number of interfaces (product complexity)	SMALL	
Technical complexity	LOW	Still some level of technical considerations, especially at end of process and regarding manufacture
Creative load	HIGH	Highest point at beginning of project

High difficulty constraints include *high creative load*, *different disciplines*, and *medium competence level*. Intensity of collaboration also needs to be high in order to maximise the communication of original design ideas and merge all necessary viewpoints. However, the non-complex nature of the product, *low number of interfaces* and *consistent collaborator environment* ensure that the distributed scenario does not prove over difficult.

### **P1b Define free conditions**

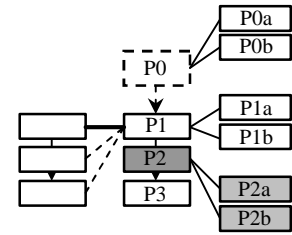
In light of the distributed difficulty open conditions should facilitate satisfactory distributed performance, without adding to the distributed 'load'. Two chosen conditions shown below in Table 2 are different from the sample case scenario as it happened and would have a significant effect on the success of distributed work. These include marketing, design and manufacturing teams *around the same size* and the design function having an *equal influence* with marketing in the distributed project. In the actual case, most of the design decisions have been made before the design function becomes involved. Marketing contacts are often inconsistent and friction often occurs as marketers do not possess enough design knowledge.

**Table 2 Matrix free conditions (Lever)**

<b>Characteristics</b>	<b>Chosen conditions</b>	<b>Comments</b>
Environment (collaborators)	Consistent	Marketing contacts often inconsistent in general Lever environment
Time/ mode of communication	Mixed	Distributed communication usually predominantly asynchronous. More synchronous communication advocated here to help with visualisation issues
Comparative scale/size of collaborating team	Around same size	Where possible a consistent marketing pool with higher levels of design experience and understanding
Lifetime of collaboration	Permanent	
Role of team	Equal influence	Each group (marketing, design, manufacturing) with project lead at different stages of the design process. Final decisions made jointly by senior most marketing and design personnel
Environment (tools)	Low-cost/ Sophisticated	Day to day low cost satisfactory with option of more advanced communication and visualisation tools advised

## P2 DDSpace

The DDSpace should be defined in a maximum 2 weeks and is divided into 3 sections. Firstly, project managers and senior personnel at each location should allocate resources. This is followed by interaction design with a focused collocated meeting between distributed parties (again at managerial level) producing the interaction map and related documents. Finally, relevant awareness elements should be brainstormed by the complete team, if small enough, or representatives at every level, if too large. Enough time should have elapsed between the first two stages and the third to allow all team members to reference public DDSpace documents for comment.



DDSpace is used to increase awareness of the main contents of distribution and distributed work interactions within the project context. It is divided into people and product.

### P2a People Space

People space focuses on the distributed team and defines roles, responsibilities, relationships and interactions. Relevant conditions from the *Matrix* should be considered and detailed. The aim is to foster sufficient team identity and trust through achieving a shared understanding and agreeing on common objectives. Ideally, all members of the people space (or at least representatives of the major functions) should be involved in a collocated meeting to initiate DDSpace activities. The key requirement of people space in the Lever environment is the ability to transfer knowledge, facilitate the flow of ideas and facilitate a learning infrastructure where less experienced designers can develop their understanding and competence. The following conditions from the Matrix indicate a medium level of distributed difficulty:

- Number of partners/size of team – *More than 2*;
- Language – *Different*;
- Competence/quality of work – *Medium*;
- Environment (collaborators) – *Consistent*;
- Number of interfaces (distributed team complexity) – *Medium*.

### *Resource allocation*

The first step involves identifying all major tasks and assigning team members with responsibility. Each member should be aware of their colleagues' backgrounds and who is responsible for what, with particular emphasis on more experienced members of the team and organisation where advice may be sought. Team profile and work allocation documentation and an expertise directory should be distributed to each member of the team. *Guru's* may be assigned to act as expertise hubs, although care has to be taken not to overwork certain team members.

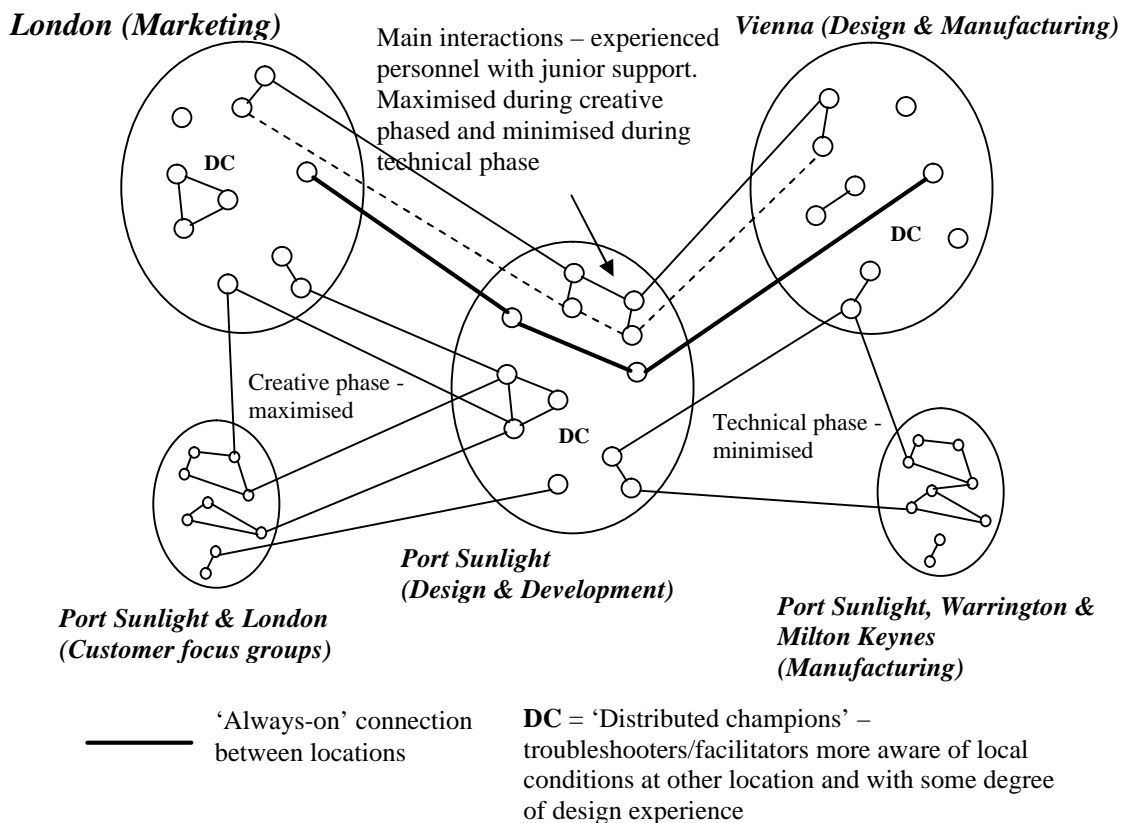
### *Interaction design*

Main interactions are identified based on the need for facilitating the flow of ideas and transfer of knowledge. Necessary technical collaboration should also be considered. Interaction design will change depending on the stage of the design process while the design function should act as a conduit for all distributed activity. The following features are modelled in Figure 5 below.

- Design and development function as the hub of distributed activity with marketing as an input and manufacturing as the output;
- Distributed interaction is maximised at the beginning of the design process, allowing for a certain degree of informal interaction, to facilitate the flow of ideas and generation of innovative solutions during the creative phase;
- Distributed interaction is minimised and formalised towards the end of the design process when the creative phase is superseded by the technical phase.

The following measures are the same as those employed in the first example:

- Distributed relationships should involve only experienced personnel with inexperienced back-up to facilitate learning and account for unavailability;
- At each location there should be a small group of ‘distributed champions’, more aware of the local conditions at the other location and who tackle communication difficulties between locations. Champions in marketing and manufacturing functions should have a higher than average level of design experience/understanding;
- There should be an ‘always-on’ connection between the groups (for a small number of identified personnel) so that contact can be made at any time;



**Figure 5 Interaction map (Lever)**

**P2b Product Space**

An integrated view of people and product may be achieved by mapping the organisational/team structure to the functional structure, thereby providing a transparent view of team responsibility and interaction.

Product structure should be considered in people space interaction. The Matrix conditions show a relatively small level of distributed difficulty:

- Distribution of components – *Sub-system*;
- Number of interfaces (product complexity) – *Small*;
- Technical complexity – *Low*;
- Creative load – *High*.

Finally, DDSpace should include team examination of relevant awareness elements. Awareness needs may be identified through project context or collaborators profiles. A collocated brainstorming session should work through elements related to people and product, creating and answering constituent questions. The answers to these questions, addressed on either a team or individual level, should help increase understanding of key elements, leading to improved distributed work. The output should then be made publicly available. Team examination of relevant awareness elements should take account of the low complexity of product, the relatively complex amount of interactions, particularly during the creative, early phases and the medium amount of team interfaces. This leads to the identification of the following awareness elements as being particularly useful for DDSpace:

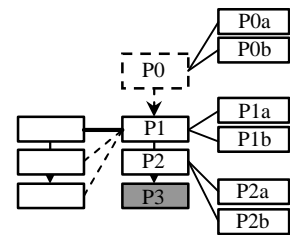
- *Communication, Cultural, Knowledge, Product.*

Relevant product questions based on the core framework may include:

- *Who* else is working on the development and visualisation of the product?
- *What* are the results of my changes?
- *Where* do I best view the embodiment of the design?
- *Why* have certain features been added?

### P3 DDJourney

By this stage, an understanding of distribution and its fit within the project in question should be well advanced. The DDJourney should be generated in a maximum 1 week by project managers and senior personnel, before being made available to all project staff for feedback. A collocated meeting of distributed representatives should form the core of the exercise. A task force should be set up with representatives of each location to monitor the journey through the project and provide reactive support.



#### *Proactive*

The switching framework details basic design and/or collaborative actions for the distributed team, at different stages of collaboration and in response to different situations or problems. Specifically switching behaviour should take account of the main stages discussed above – the creative stage where interaction is maximised and the technical stage where interaction is minimised. Further switching behaviours include:

- Ongoing *distributed* collaboration with *collocated* meetings every 1/2 weeks at beginning of process rising to 3/4 weeks later in the process. These should take place between the ‘distributed champions’ and other relevant personnel at that time while extra collocated sessions may be added depending on progress;
- *Creative* collaboration at the beginning of the design process which focuses on *concepts, creating* and the *global* view of the product from *local* perspectives (namely design, marketing and manufacturing);

- This maximised early phase session above should be a *tightly-coupled* activity with high levels of *co-operative* and *synchronous* collaboration. The switch between *creating* and *evaluating* should take place around once a week to measure progress and plan future actions;
- *Technical* collaboration towards the end of the design process should focus on *details* and the *global* view of the design, merging all three main perspectives;
- Collaboration should become more *loosely-coupled* and *individual* with *information exchange* and *asynchronous* work comprising day to day behaviour. *Collaborative design* activity and *synchronous, tightly-coupled* work should take place on a weekly basis and when required during important interface integration periods. *Evaluating* should also take place during these sessions.

Specific awareness elements further detail the distributed process:

- *Knowledge awareness* should be augmented at the beginning of the project to increase awareness of the available knowledge base;
- *Cultural awareness* at the beginning increases the common understanding between distributed groups and especially the customer base;
- *Communication awareness* during the initial phase as interactions are complex;
- *Product awareness* during the initial stages where the design takes shape and visualisation can be a problem;
- *Goal and Interface awareness* when changing from creative to technical phases of the process to ensure progress and minimise reconstitution problems.

Within a live project the above journey should be further detailed with dates. It should be generated and used in a similar fashion to a Gantt chart, acting as the main supporting tool for distributed design process management.

### *Reactive*

In reactive mode DDJourney addresses problems. The FMEA and awareness and switching method is used. The Lever sample case scenario contained 5 distinct problems, namely:

1. Incompatibility of product interfaces;
2. Poor visualisation of design concepts and product issues;
3. Late arrival of required information;
4. Poor focus of relevant information;
5. Unavailability of distributed colleagues.

Problems 3, 4 and 5 may be addressed through the actions prescribed in DDSpace where a greater awareness of people and product as well as a transparent interaction design may aid in information transfer and availability. The root cause of problem 1 can be attributed partly to having only one week of detail design in the original project [section 5.5.1, p.79]. By involving the design function to a greater extent as stipulated in the *Matrix* and interaction design, such problems may be discovered earlier in the process. Problem 5 is included in the FMEA as *Unavailability of colleague*. Recommended actions include increasing awareness of colleagues work processes, team needs and finding alternative means of fulfilling needs. Overall, the identification of such problems should result in a higher frequency of *collocated* or *synchronous* and *tightly-coupled* collaboration while *interface* and *product* awareness may address problems relating to product and *communication* and *knowledge* the people.

Each encountered problem, counteractive measure and resultant effect on problem should be recorded in an experience database for future use. Future problems may therefore have

several counteractive options generated automatically, together with notes on previous success and application.

## Summary of Value

### Success criteria

The D4D framework has now been partly evaluated through its application to the sample cases from chapter 5. The first means of evaluation is the extent to which the framework meets certain criteria believed to be required for success.

- **Transferability and tailorability** – The framework was used in two very different scenarios with appropriate support developed for each. Further evaluation is required to test the extent to which the framework can be used. However, the *Matrix* and awareness and switching method would seem to cater for a large range of scenarios.
- **General and specific level support** – This is met through proactive and reactive support respectively. The proactive domain is satisfactory with detailed prescriptions generated through DDSpace and DDJourney. Such actions should dramatically increase levels of team awareness for distributed phenomena and possible support. Reactive support is weaker although further testing in the field is required. It may prove difficult to address distributed problems when they occur. However, value does exist in being able to define and understand problems, putting in place counteractive measures for later stages in the process.
- **Fit onto existing processes** – The framework is flexible enough to fit within existing company prescriptions, ‘bolting-on’ to a stage in the core design process as shown in figure 1. Certainly, of the dozen or so companies investigated throughout the research period, fit would not have presented a problem. Indeed, some of the D4D actions may already exist in some form within an organisation. The framework packages and highlights the most important factors for distribution.
- **Transparency** – This was catered for in many features of the D4D framework. At all times the framework aims to clearly show the needs and actions of designers and their distributed colleagues. Examples include resource allocation documents, interaction design maps and switching ‘journeys’. Each of these should be shared within the distributed team as public artefacts.

### Problem application

Appropriate support can therefore be generated. Full validation regards *effectiveness* and the resultant performance of distributed teams. Implementation in live projects is therefore required and constitutes further work. However, effectiveness may be estimated in the extent to which distributed problems are addressed by the framework. In each case 3 main types of problems existed:

- **Incompatibility of sub-systems** – including problems at product interfaces. This was arguably the main problem in each case. Although primarily a design issue it is made substantially worse by distribution. It can be addressed by more effective distributed teamwork. Specifically, an integrated view of people and product space should provide extra support where required. Product and interface awareness should address problems together with highly formal switches.
- **Conflict with distributed team** – including problems regarding language and unavailability. The D4D framework should enable the sharing of experiences and backgrounds which may help in future collaboration. Production of public artefacts and the interaction design map clearly show responsibility at each process stage.

- **Information related problems** – including sourcing and timeliness. Information flow and knowledge transfer is at the core of the D4D framework with interactions and team awareness aimed at ensuring an efficient knowledge transfer infrastructure.

Additionally, one of the primary inputs to the design of the D4D framework was the FMEA. If this process has been completed with any measure of success, most distributed problems should at least be addressed in prescriptive support. On a specific level table 3 below maps the anecdotal problems presented in chapter 7 [p.122] to the deliverables of the D4D framework. Problem codes are shown and detailed in appendix D.

**Table 3 Specific level evaluation**

Case	Anecdotal problem	Appropriate support
ABB Vetco Gray	<b>ID8:</b> Poor distribution of information/data	Resource allocation documentation. Interaction map. Always on connection. Learning loops with back-up.
	<b>ST13:</b> Difficulty in visualization/transfer of meaning	Distributed infrastructure and new organisational support. Mostly technology issue although relevant awareness questions may focus context (esp. cultural and product).
	<b>PT18:</b> Duplication of effort	Experience database. Relevant awareness questions (esp. knowledge). Overall process support leads to higher levels of efficient distributed work.
	<b>PE29:</b> Quality of distributed work/lack of competence/experience at distributed location	Learning loops. Distributed training. Expertise directory. Relevant knowledge awareness questions.
	<b>CU41:</b> Different terminology/nomenclature	Expertise directory. Distributed Champions. Temporary placements. Relevant awareness questions (esp. cultural and knowledge).
	<b>SY42:</b> Lack of consistent systems, resources at different locations	Matrix of Characteristics. Distributed infrastructure.

In conclusion, the D4D framework, at this stage of development and evaluation, represents a viable means of supporting distributed design practice. The key aspect of prescriptive support is its *formality* – a framework has been created specifically for distributed work which aims to increase the awareness and visibility of distributed issues and necessary design actions. In summary, there are three main benefits for an organisation using the D4D framework and supporting methods:

- Increased awareness and understanding of distributed practice, highlighting appropriate elements which affect or are effected by distribution;
- Heightened appreciation of distributed failures and counteractive measures;
- Understanding of appropriate distributed behaviour and a method whereby formal communication processes may be generated, addressing a significant need for satisfactory distributed work.

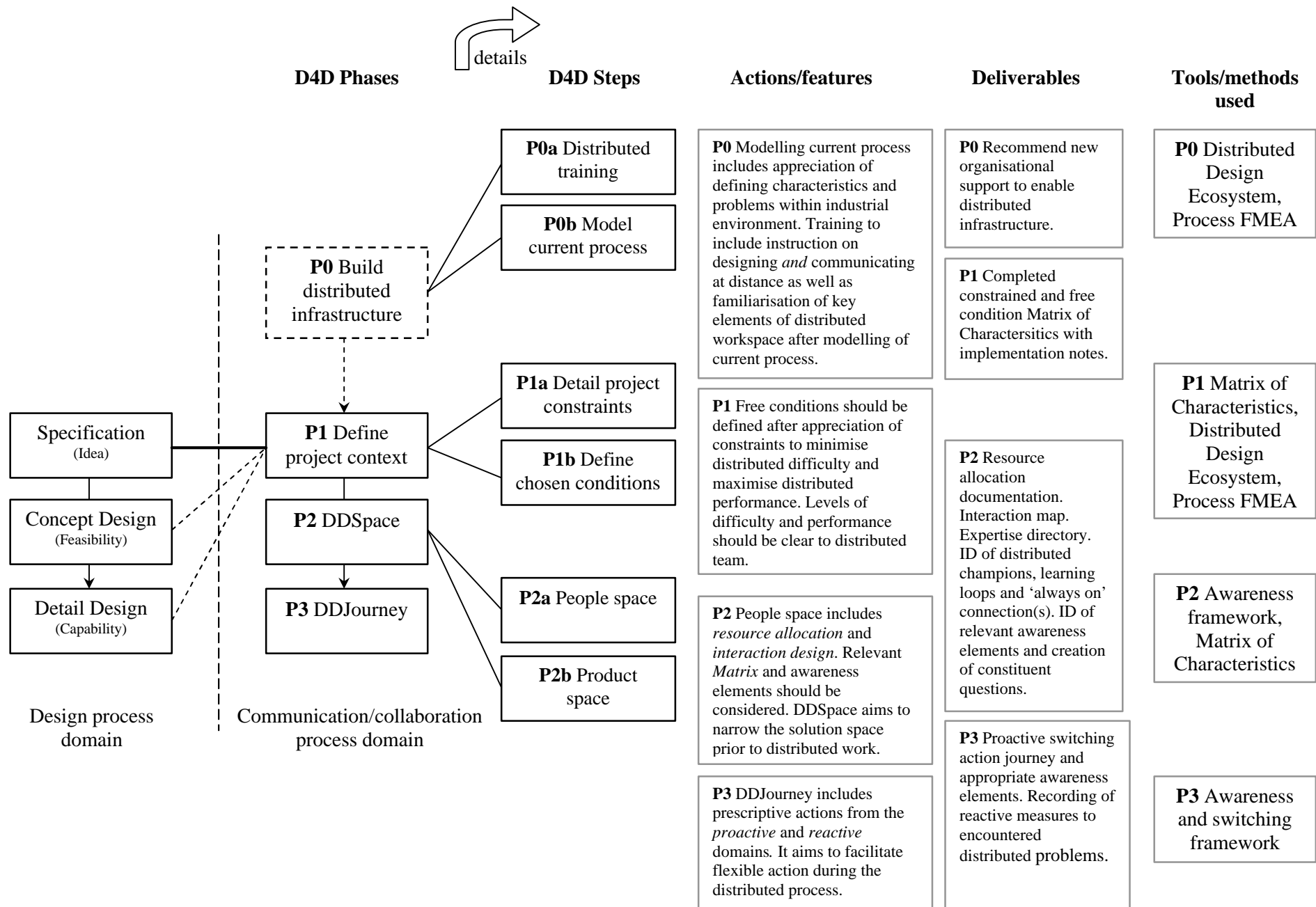
The framework caters for high levels of context in design and distribution, highlights the core issues and provides the right support at the right time in the process. It is flexible, appropriate and timely.

Future work includes further detailing of the framework and implementation within an industrial environment. For example, relevant awareness questions and more detail in the switching maps is required. However, this is only possible given more detail from the sample

organisation or distributed project. The D4D framework has been presented at a level which shows operation and effectiveness, yet retains sufficient generality to detail the means of transferability within various contexts.

## **APPENDIX**

## **Complete D4D Framework**



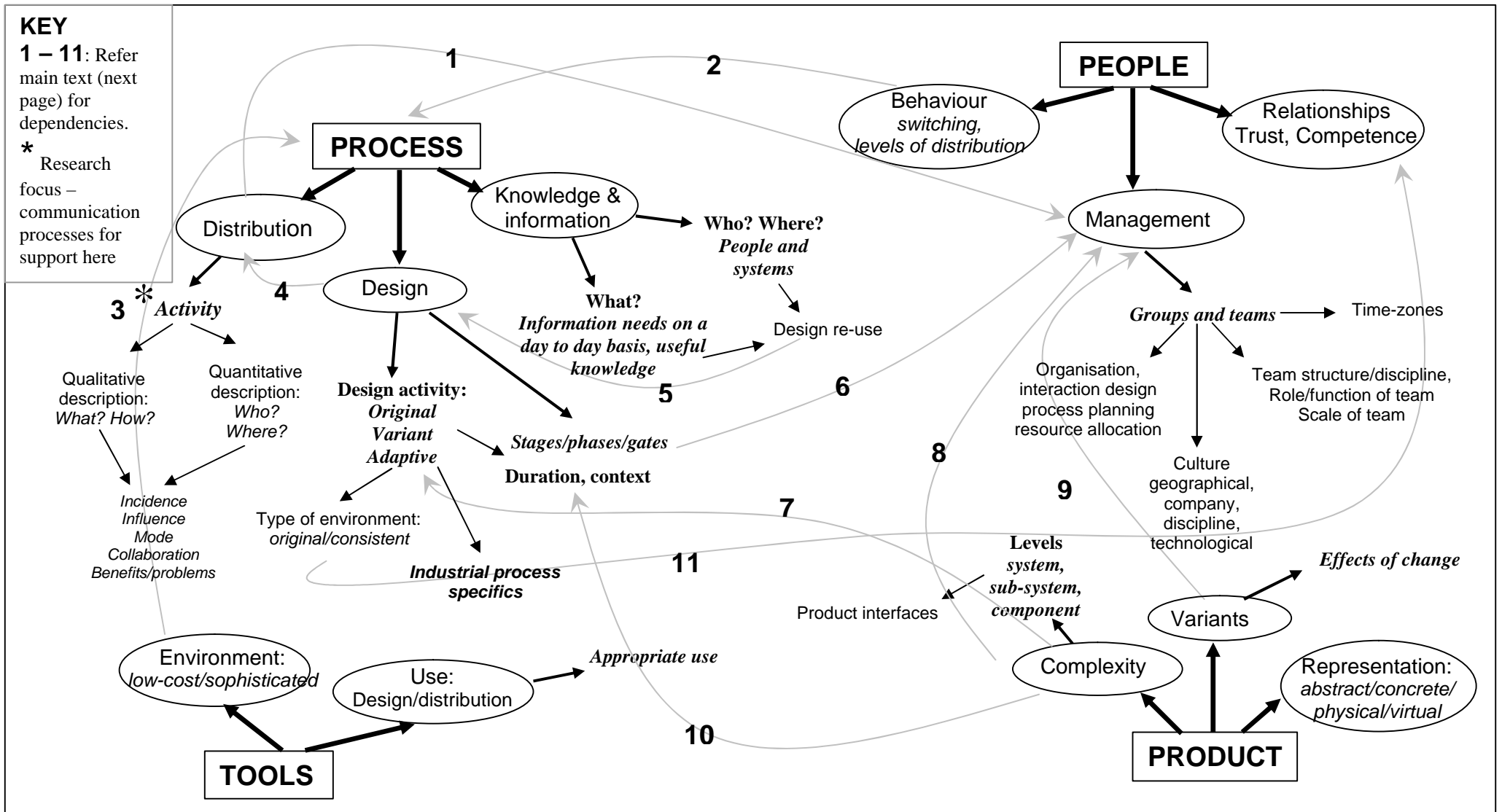
## **Distributed Design Workspace**

The *Workspace* serves as a template for different distributed environments, enabling appropriate elements to be identified and placed in context. It should be used at the beginning of a specific distributed project or even as part of general organisational development for distributed work. Each element of people, process, product and tools should be discussed in light of the organisational context. The detailing of these elements would then highlight areas of the organisation to be considered for distributed work and identify required extra support for distributed work. For example, examining the product domain for ABB VG would highlight the importance of product complexity and structure and may necessitate the implementation of support, possibly through altering the design of teams.

**KEY**

**1 – 11:** Refer main text (next page) for dependencies.

**\*** Research focus – communication processes for support here



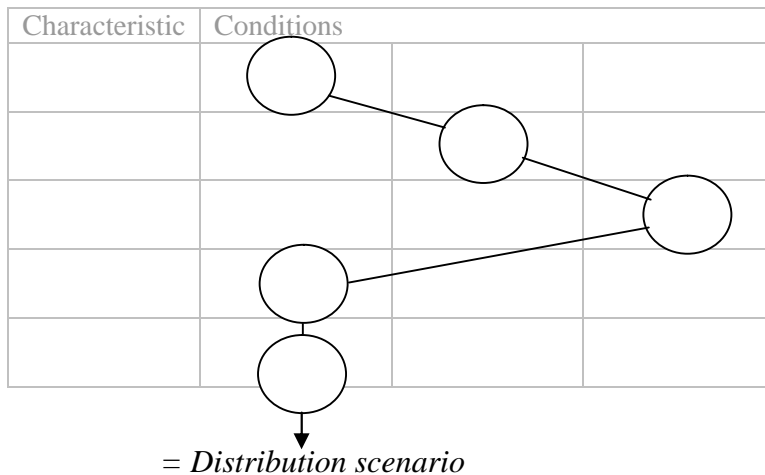
## Matrix of Characteristics

The complete matrix is shown below. In total, 20 characteristics comprise the matrix. Possible conditions have varying degrees of difficulty in a distributed context. In most cases, difficulty potentially increases as shown from left to right.

**Matrix of distribution characteristics**

Category	Characteristics	Possible conditions		
		Increasing rate of potential distributed difficulty —————→		
People	<i>Number of partners/size of team</i>	2	More than 2	Very large
	<i>Language</i>	Same	Different	
	<i>Competence/quality of distributed work</i>	HIGH	MEDIUM	LOW
	Environment (collaborators)	Mostly consistent	Mixed	Mostly original
	Number of interfaces (distributed team complexity)	LOW	MEDIUM	HIGH
Process	<i>Location/scale of distribution (top end)</i>	Different room	Different region/country (same time-zone)	Different country (different time-zone)
	<i>Time/ mode of communication</i>	Mostly/all synchronous	Mixed	Mostly/all asynchronous
	<i>Organisation</i>	Internal same department	Internal different department	External
	Comparative scale/size of collaborating team	Around same size	Significantly smaller/larger (> 3:1)	
	Level of collaboration (intensity)	LOW Information exchange only	MEDIUM	HIGH Large collaborative design and influence
	Lifetime of collaboration	Permanent	Temporary	
	Role of team	Lead design/management	Equal influence	Extra labour
	Design activity	Mostly variant/adaptive	Mostly original	
	Discipline	Same	Different	
	Type of collaboration	Mostly technical	Mostly creative	Mixed
Product	<i>Distribution of components</i>	Complete product/system	Sub-system	Component
	<i>Number of interfaces (product complexity)</i>	SMALL	MEDIUM	LARGE
	Technical complexity	LOW	MEDIUM	HIGH
	Creative load	LOW	MEDIUM	HIGH
Tools	Environment (tools)	Sophisticated	Low-cost	

Different distributed scenarios can be generated by employing a morphological matrix method, as shown below. This shows the immense range of different scenarios that can exist within distribution – over 306 million exist within the matrix ( $3^{14} \times 2^6$ ).



*Different conditions are chosen for each distributed characteristic depending on the context, to result in a range of unique scenarios.*

### Morphological selection

#### Evaluating different scenarios

The *Matrix* facilitates a formal specification of the distributed environment where distributed conditions for specific characteristics may either be described or prescribed, depending on constraints and strategy respectively. Constrained conditions for each distributed characteristic should be completed first in a project. For example, the Lever sample case may involve constraints on creative load (high). Free conditions should then be chosen to give the project the best chance of success. For example, only collaborators with a high level of competence and experience may be chosen.

- **Free conditions:** Primary strategic decisions may revolve around the environment, whether to install specialised tools or make do with a *low-cost* environment, as found in the cases. In certain contexts low cost environments may suffice for successful distributed work, while in others specialised tools may be required. At the time of writing, Lever were aiming to implement more advanced tools for distributed work while ABB VG were content with their information systems infrastructure.
- **Constrained conditions:** Constraints may include level and location of distribution. For example, if no collocated expertise is available interaction may only take place, say, in an asynchronous fashion with colleagues who speak a different language.

Where possible, strategy should maximise the advantages of distributed work and minimise shortcomings of the situation. Certain conditions are not compatible and too many difficult conditions could result in project failure. The addition of difficulty weightings for each condition could result in an overall scenario rating which would advise, say, the management team on the suitability of different scenarios. High difficulty conditions include *distribution of components across locations, high technical complexity and high number of interfaces*.

## **FMEA**

The FMEA can be used to increase an awareness of typical distributed failures and the means by which they may be addressed. As detailed in 7.3.3 the value of the FMEA method is not in producing RPN numbers but in the process of completion, specifically the detailing and contextualisation of the communication failures. An understanding of the cause and effect of problems will improve distributed communication through increasing team awareness of how failures can occur and what to do to minimise them. A partially completed matrix should be consulted by the management or distributed project team. Potential failure modes and cause and effect details should be examined, with a decision made on which ones are relevant within the given context. The team should then complete the sections on *current process controls* and *recommended actions*. The RPN numbers may also be completed to increase the level of context. New organisational support in the form of these actions is the other main output of the FMEA together with an increase in team awareness of the distributed communication process.

Although the FMEA was completed with respect to the two main case study environments, it is possible to generalise findings to other contexts. This is due to the nature of the method focus: the team communication process. Basic human interaction issues are highlighted in response to the barriers provided by distribution. It is believed that this can be transferred to other contexts

**Process FMEA Matrix**

<b>Process category</b>	<b>Potential Failure Mode</b>	<b>Potential Effects of Failure</b>	<b>S E V</b>	<b>Potential Causes/mechanisms of failure</b>	<b>O C C</b>	<b>Current process controls</b>	<b>D E T</b>	<b>R P N</b>	<b>Recommended actions</b>
<b>Information and Data</b>	Incompatibility of data/information	Unable to re-use data/information	6	Different systems/tools	5	Supplier evaluation and applied IT policy	2	60	Increase awareness of re-use needs and spend more time on improving usability of information at end of project
	Unable to find/source information	Gaps in understanding/available facts leading to possibility of incorrect assumptions	8	Poor storage of information/data. Low process support. Poor integration of resources.	7	None	2	112	Increase awareness of who knows what, relevant information sources and training.
	Insufficient information	Gaps in understanding/available facts leading to possibility of incorrect assumptions	8	Reluctance to share information (lack of trust). Poor distribution of information.	7	Information repositories. Brainstorming meetings	2	112	Incentive schemes to enable sharing. Greater awareness of distributed team and specific needs.
	Too much information	Knowledge 'swamp' – using wrong information or using information the wrong way	4	Poor storage and classification of information/data	4	Information systems controller/IT officer	2	32	Implement consistent approach in storage and classification. Increase awareness in distributed practice.
	Timeliness of information transfer	Gaps in understanding/available facts leading to possibility of incorrect assumptions. Delay in project.	8	Poor relationships. Conflicting priorities. Unrealistic expectations of work.	9	Process phase gates.	3	216	Increase incentive for knowledge sharing. Increase or relate common objectives. Increase awareness of colleague workloads.
<b>Signal Transfer</b>	Misunderstanding/misinterpretation of actions/work	Breakdown in communication/relationship. Delay in project. Error in design work.	7	Low awareness of colleagues background and experience. Poor technological support. Poor communication style.	9	None/Design review	4	252	Increase in tools support. Increase in awareness of distributed colleague. Training.
	Making incorrect assumptions	Error in design work. Delay in project.	6	Incomplete or ambiguous information.	7	None	5	210	Process checks after distributed interaction. Training.
	Ambiguous information	Need for clarification and delay in work. Possibility of making incorrect assumptions.	5	Incomplete information. Lack of competence, poor communication style.	7	None	4	140	Template/checklist for information documentation/sharing. Training.
	Difficulty in visualisation/transfer in meaning	Need for collocated interaction and delay in progress. Misunderstanding, incorrect assumptions.	6	Complexity of task. Lack of competence/experience. Poor communication style.	6	Software visualisation tools.	3	108	Asynchronous interaction for complex work. Training.

### Process FMEA Matrix

<b>Process category</b>	<b>Potential Failure Mode</b>	<b>Potential Effects of Failure</b>	<b>S E V</b>	<b>Potential Causes/mechanisms of failure</b>	<b>O C C</b>	<b>Current process controls</b>	<b>D E T</b>	<b>R P N</b>	<b>Recommended actions</b>
Signal Transfer	Not understanding reasoning behind decisions	Inefficient design re-use. Duplication of error. Lack of understanding.	6	Incomplete documentation. Poor communication style.	8	None.	2	96	Project completion template. Training. Increase awareness of available expertise.
Process/taskwork	Too many members managing process/information	Conflict. Duplication of effort. Design error. Inconsistent information.	7	Poor process control/resource allocation/management.	5	None/Project planning	2	70	Clear management strategy. Transparent team member roles. Communal controlled supported systems.
	Unaware of previous work/other sites	Duplication of effort. Unrealistic expectations of work. Sub-optimal design work.	7	Poor integration of resources and storage of information.	8	Collocated meetings. Intranet.	6	336	Distributed site contacts. Creation of transparent people network.
	Duplication of effort	Wasted resources. Low morale. Project delay.	7	Unaware of previous work. Unclear role allocation.	6	None	5	210	Identification of common goal and similar job function teams followed by increase in knowledge transfer.
	Lack of ownership/autonomy	Low motivation. Project delay. Poor quality.	7	Poor management strategy. Inability to identify as part of a team.	6	None	3	126	Checks for distributed competence. Incentive schemes.
	Insufficient resources	Low motivation. Project delay. Poor quality.	8	Poor understanding of needs. Lack of investment.	5	None	2	80	Initiate improvement/needs meeting within communities of practice.
	Conflict in design work	Breakdown in relationships. Project delay. Poor quality.	5	Low awareness of colleagues work and circumstances.	8	Design review/ collocated meetings	2	80	Increase awareness of distributed teams needs and problems. Collocated meetings at strategic points.
	Incompatibility of sub-systems/interfaces (especially product level)	Project delay, poor quality. Design 'turbulence' and strain on relationships.	8	Organisation of distributed sub-groups.	9	Detail design, Design review/ collocated meetings	2	144	Increase awareness of distributed teams needs and problems.
	Insufficient representation	Poor visualisation. Poor understanding of consequence of actions.	6	Poor tool support. Geographic separation.	8	None	2	96	Strategic collocated meetings.

### Process FMEA Matrix

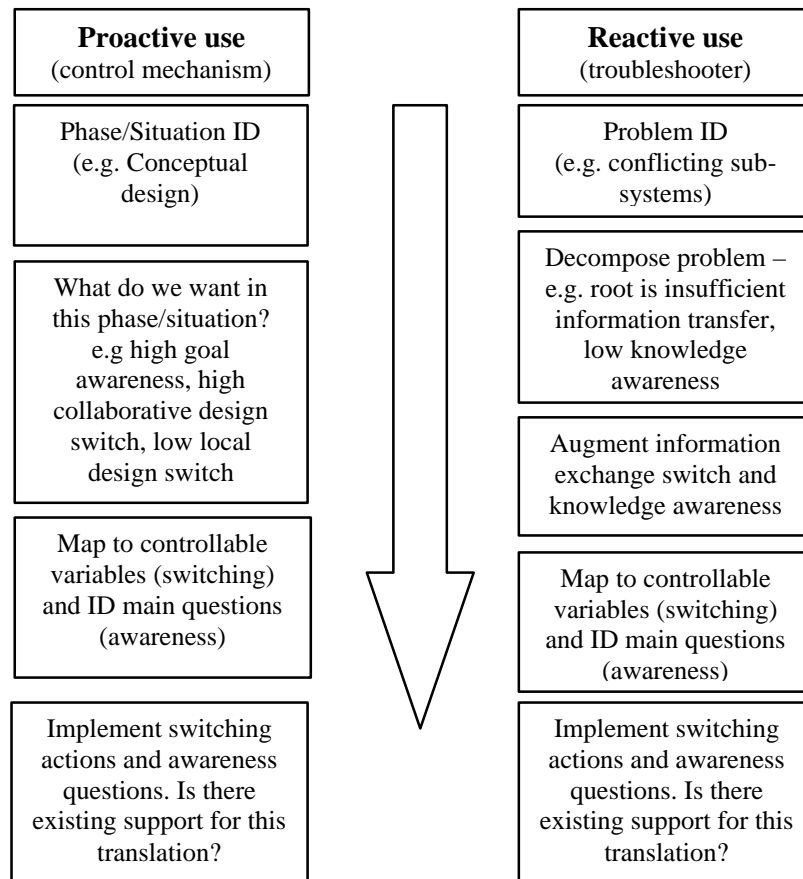
Process category	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes/mechanisms of failure	OC	Current process controls	DET	RPN	Recommended actions
People/teamwork	Unavailability of colleague	Gaps in knowledge/ understanding. Possibility of incorrect assumptions. Project delay.	6	Conflicting objectives/job functions. Different work processes.	9	Activity diaries	2	108	Increase awareness of colleagues work processes team needs and alternative means of fulfilling needs.
	Not being informed of/unexplained design decisions	Reduced understanding. Breakdown in trust. Low motivation.	7	Low levels of trust, perception of competence/unimportance/ Irrelevance.	6	Team meetings	3	126	Awareness of team needs. Use of shared workspace.
	Poor quality of distributed work/ insufficient understanding	Poor quality of work. Project delay. Breakdown in relationships and communication.	8	Unrealistic expectations of work. Insufficient training. Low awareness of experience.	8	None	3	192	Competence checks. Training. Understanding checklist.
	Lack of response/non-communication	Breakdown in relationships. Gaps in knowledge/understanding.	7	Heavy workload. Poor relationship.	6	None	1	42	Provide incentives. Increase awareness of colleagues work. Create information 'gurus'.
	Vague communication of requirements/actions	Misinterpretation. Gaps in knowledge/understanding.	5	Language difficulties. Poor communication style.	6	None	2	60	Training. Template for information exchange.
	Lack of trust/poor relationship with distributed colleague	Poor quality of work or project failure.	9	Social conflict. Conflicting objectives. Low awareness of colleagues background.	5	None/team design	3	135	Collocated meeting at start of project. Consistent point of contact. Agreed agenda and work practices.
	Inconsistent point of contact at distributed location	Lack of trust/poor relationship with distributed colleague.	8	Different scales of collaborating parties. Unavailability of colleague. Low perception of worth.	7	None	2	112	Consistent point of contact supported by technology systems.
	Inability to identify as part of a team??	Low motivation. Low amount of knowledge transfer/information sharing	7	Lack of common goal. Low awareness of other team members.	6	Collocated meetings	4	168	Incentives. Collocated meetings. Increase awareness of other members activities and share experiences.
	Unrealistic expectations of work	Conflict. Poor project estimation and delay.	6	Differing scales of collaborator. Low awareness of experience.	7	None	3	126	Increase awareness of experience, competence and workload/objectives.

**Process FMEA Matrix**

<b>Process category</b>	<b>Potential Failure Mode</b>	<b>Potential Effects of Failure</b>	<b>S E V</b>	<b>Potential Causes/mechanisms of failure</b>	<b>O C C</b>	<b>Current process controls</b>	<b>D E T</b>	<b>R P N</b>	<b>Recommended actions</b>
<b>Culture</b>	Different work processes/techniques	Project conflict. Unavailability. Misunderstanding.	<b>7</b>	Different cultures/backgrounds/job functions.	<b>9</b>	Intranet	<b>2</b>	<b>126</b>	Increase general awareness of collaborators practice. Swap team members between locations.
	Different perceptions of criteria/phenomena	Different evaluation of work. Conflicting decisions.	<b>6</b>	Different cultures/backgrounds/job functions.	<b>7</b>	None	<b>4</b>	<b>168</b>	Create location profiles. Swap team members between locations.
	Different working languages/terminology	Misunderstanding. Need for confirmation. Project delay.	<b>6</b>	Different cultures/backgrounds/job functions.	<b>8</b>	Glossary of terms	<b>3</b>	<b>144</b>	Swap team members between locations.

## Awareness and Switching theory/method

Put simply the awareness and switching framework can be used to prescribe different areas of focus in various projects and at different stages of the process. It could be used in industry as a type of project management tool, similar to a Gantt chart, where the behaviour of designers for distribution is mapped out. For example, in ABB Vetco Gray the *global switch* should represent a focus when attempting to integrate various sub-systems of a drilling site. In Lever, *knowledge awareness* should be highlighted at the start of Value Improvement Projects. The framework can therefore be used to satisfy appropriate and timely needs, or at least put in place a plan for their management. The core stages are shown below.



### Awareness and switching utilisation

#### New Awareness Elements

New awareness element	Definition	Case example
Knowledge	Awareness of where to find relevant information and knowledge as well as knowing whether it exists	Being unaware of past projects resulted in duplication of effort [s.7.3.1.1, p.121] while progress slowed when not knowing who to contact for information (ABB VG) [s.5.4.1, p.66]
Goal	Awareness of how the collaborative task is proceeding and the status of the main objective. Related to workspace awareness although 'workspaces of the mind' is a	Engineers measured their most recent design against the overall design need in the diaries (ABB VG) [Fig. 7-3, s.6.3.1, p.91]

	more applicable term.	
Product	Awareness of the realisation/embodiment of ideas on a product level. Essentially understanding the representation.	Designers were often unaware of the full range of effects that their design changes had on the realisation of the product unless presented with a physical model. The lack of sufficient product awareness also prevents adding value to the design (Lever) [s.5.5.3.1, p.82]
Communication	Awareness of the level of understanding in distributed collaborator. Related to signal transfer and is the result of reduced informal awareness.	Realising that factory representative didn't understand potential trial problems pre-empted a visit to explain in person (Lever) [s.5.5.1, p.77]
Interface	Awareness of the impact of own work/needs on the rest of the distributed team	Marketing department would often pursue a product concept without checking the design feasibility (Lever) [s.5.5.3.1]
Cultural	Awareness of the habits, practices and overall profile of distributed collaborators	Knowing that collaborators in Norway were rarely at desk during afternoon pre-empted use of e-mail over telephone at certain parts of the day (ABB VG) [s.5.4.1, p.67]

### New Switching Elements

Switch	Details
Local/Global	Design work on different product levels, including component, sub-system and overall system identifies the local/global design switch. Designers continually swap perspectives between the local view of design, a component or sub-system and the global view – the overall product or system. A local view example in the ABB VG case is a valve compared to the global view that is the overall drilling tree.
Concepts/Details	Switching between work on concepts and details and creating and evaluating design work represent relatively standard activities of designers. This behaviour is usually contingent on the stage of the design process.
Creating/Evaluating	
Information Exchange/Collaborative Design	The switches between information exchange (IE) and collaborative design (CD) are modelled in chapter 7. These show ongoing information exchange punctuated by periods of collaborative design once a critical mass of information is received or a deadline imminent.
Creative/Technical.	Switching between creative and technical work was a common occurrence in the Lever case and less frequent with ABB VG engineers who tended to focus on technical work most of the time. Again, this switch may be dependent on the stage of the design process.