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Groupware Architecture for R&D Managers

Kathryn Cormican* and David O'Sullivan

*Corresponding Author

DERi, Department of Industrial Engineering, National University of Ireland, Galway, Ireland

Tel: + 353 91 512292

Fax: + 353 91 562894

email: Kathryn.Cormican@nuigalway.ie

Abstract:

The business environment is changing at an accelerated pace. Contemporary business systems are becoming more knowledge intensive. This is particularly evident in areas such as product innovation where knowledge centric activities are becoming the primary source of sustainable competitive advantage. Consequently, progressive organisations are collaborating with others in order to develop the linkages they require to access and leverage new knowledge and skills for successful product innovation. In this paper the authors surveyed senior R&D managers from Irish organisations in an attempt to ascertain what the key implications of this new knowledge focused networked environment are for their organisations. The findings revealed that effective communication, collaboration and co-ordination structures are imperative for success. A groupware architecture was then developed to support the co-ordination of members in a networked R&D environment. Critical elements of the

architecture were identified and codified into a web enabled prototype. This was implemented in a number of industrial sites to help validate the architecture in terms of its functionality and effectiveness. Findings from this investigation are presented.

Key Words: Groupware Architecture, Product Portfolio Management, Innovation Management, Case Study Analysis

Kathryn Cormican (Ph.D) is a lecturer in the Department of Industrial Engineering at the National University of Ireland, Galway. Her research interests lies in the areas of product innovation management and enterprise integration. Kathryn manages a number of European Union and industry funded research projects in this area. Prior to joining NUI Galway, Kathryn worked as a Management Consultant where she facilitated organisations with product and process improvement initiatives as well as strategic and operational change. She continues to work with many leading organisations helping them to design, develop and deploy new processes and systems.

David O'Sullivan (Ph.D) is research director at the National University of Ireland, Galway and author of over fifty publications including 'Manufacturing Systems ReDesign' (Prentice Hall), Reengineering the Enterprise (Chapman and Hall), and Handbook of IS Management (Auerbach). David leads a number of research projects in the area of innovation management and has also worked on various innovation management issues with leading companies including Nortel Networks, Thermo King, IBM, Hewlett-Packard, Fujisawa and Boston Scientific.

1. Changing Business Environment

Modern enterprises are experiencing a rapid shift from an economy based on manufacturing and commodities to one that places the greatest value on information, services, support and distribution [1, 2, 3]. Much work now consists of converting information to knowledge, using skills, competencies and expertise [4, 5]. Successful companies today are distinguished by their ability to innovate [6]. To do this, they must consistently generate and capture new knowledge and information, disseminate it to the relevant points of action and embody it into their systems, processes and products. Innovation is generally a result of combination, the uniting of disparate entities. According to Miles et al [7] the ability to innovate comes from collaboration both inside and outside the organisation. Collaborating with others increases both access to information and the potential for action. It can also help reduce the cost of development and decrease risk of failure. Collaboration operates through group processes such as communication, co-operation and project co-ordination [8, 9]. These processes do not work independently of one another but are usually intermingled and determined by each other.

With this in mind we are experiencing a radical shift in the way organisations are designed, structured and organised. Visionary firms are transforming their industries via new business designs, new inter-enterprise processes and integrated operations. The business design of the future increasingly uses project focused networks and re-configurable virtual teams to fulfil customer needs, wants and expectations [1, 10]. Competition is no longer between companies but between networks. Networks incorporate a confederation of specialists and they are often used to maximise competencies by pooling resources and exploiting expertise in areas such as product

innovation. They enable organisations to focus resources on its core skills and competencies where they add value while acquiring other components or capabilities that they lack from the marketplace [11].

The rapid emergence of the networked economy has made organisations consider the implications of this new economy for themselves, their industries and their market places. In this view the following research questions were examined in order to increase our understanding of the collaborative process.

- What are the key implications of this new knowledge focused networked environment for R&D managers?
- How can R&D managers support collaboration among distributed teams, working at different sites, different times or in different organisations?
- How can project managers maximise knowledge generation and transfer for product innovation in a networked environment?
- What support structures are needed to manage project portfolios within and between project teams?
- What are the critical elements needed in order to develop a common, standardised way of managing projects in a virtual environment?

The authors surveyed senior R&D managers in Irish organisations in an attempt to ascertain what the key implications of this new knowledge focused networked environment are for their organisations. From these findings, a goal centred groupware architecture was developed to help manage project portfolios across a distributed enterprise. The architecture is supported by a web enabled prototype.

The solution finds potential application in organisations that engage in project-based R&D management. The approach has been prototyped and validated in a number of test sites and these are presented as a series of case studies in the paper.

2. New Way of Working

Product innovation requires distinctive and specialised knowledge, skills and competencies. Consequently, the R&D process is characterised by intricate interdependencies among many specialisms and functions [12]. R&D managers must establish and integrate a number of skills and competencies to develop value added products and services. This often necessitates collaborating with participants from other organisations. Therefore, work must be organised in such a way that enables organisations to create and synthesise information across organisational boundaries and geographies.

In recent years many authors have identified the emergence of innovative organisational forms that enable inter-organisational collaboration. A number of terms have been used to describe these new organisational structures including, “networked organisation” [13, 14] and “virtual organisation” [15, 16, 17]. Network organisations can be defined as alliances of independent operating units bound together by common interests, shared visions and market mechanisms. According to Miles and Snow [13 and 14] they are integrating entities that rely on other companies to perform basic support functions on a contractual and relationship basis. They are co-ordinated horizontally and are designed to be flexible and adaptable to rapidly changing environments.

Snow et al [18] have developed a typology classifying three network types. These are (a) internal, (b) stable and (c) dynamic.

- **Internal networks** are loose associations of assets and business units contained within a single company that subject themselves to market forces.
- **Stable networks** consist of firms engaged in long-term relationships with external suppliers who bring expertise into the parent company.
- **Dynamic networks** are more temporary alliances of firms with key skills usually organised around a lead or brokering firm.

Similarly many authors refer to virtual organisations. Some researchers define the virtual organisation in terms of a structure. For example, Byrne [19] states that a virtual organisation is a temporary network of independent companies that come together quickly to exploit fast-changing opportunities. Others characterise it in terms of a management strategy in order to describe its behaviour. Venkatraman and Henderson [16] define, what they call 'virtual organising', as 'a strategic approach'. This approach is focused on creating, nurturing and deploying intellectual and knowledge assets while sourcing physical assets in a complex network of relationships.

In such organisations, value-generating activities are distributed among different countries and actors. They require a structure that is complex, but at the same time flexible, in terms of constructing internal links (i.e. between functional activities) and external links (i.e. with suppliers and customers). Individual organisations are often required to extend their resources, their control structures and their information systems in order to collaborate with complementary organisations. A comparative

analysis between the traditional way or working and this new paradigm is represented in Table 1.

Insert Table 1

These new forms of organisation have certain characteristics in common. Most notably, (a) they are organised to optimise core competencies (b) they have flatter structures and (c) they promote interaction among organisational units and people.

Comment [KC1]: Volberda, H.W. Beyond or behind the M-form: The structures of European business. In D. O'Neal and H. Thomas, (Eds.) Strategy, Structure and Style. Chichester UK: Wiley

Virtual teams are used to co-ordinate complex business tasks across networked and virtual organisations. According to Townsend et al [20] *"Virtual teams are composed of co-workers geographically and organisationally linked through telecommunications and information technologies attempting to achieve an organisational task"*. However, virtual teams are beset with a range of challenges inherent to their dispersed and often impersonal nature. Kayworth and Leidner, [9] found that virtual teams face challenges in four areas namely; (a) communication, (b) culture, (c) technology and (d) project management. Moving to the new workforce paradigm demands support structures to enable these areas. Managers must therefore invest in the conditions essential to effective collaboration and develop tools to support group processes.

Groupware can support collaborative workgroups that cross functional and geographical boundaries by providing an interface to a shared environment. Many authors describe groupware in terms of technology. For example, Khoshafian and Buckiewicz [21] note that groupware refers to any computing technology that enhances collaborative work over digital media. Others regard groupware in more

philosophical terms. For example, Watson et al [22] note that the purpose of groupware is to support two or more people performing a goal-directed activity. Yen et al [23] found that groupware can significantly influence the way people are able to process, manage, and manipulate a wide range of knowledge and information. Groupware features can enable efficient and accurate sharing of ideas, streamline processes, and permit parallel task execution. This increases the overall level of knowledge and expertise of the team members.

3. Research Approach

The transition to the networked economy poses a significant challenge to researchers and theorists. According to Swamidas [24] meeting such challenges requires moving beyond the deductive, quantitative tools that dominate engineering and management research to incorporate alternate means geared toward induction and description. Gill and Johnson [25] believe that traditional research methods have failed to capture and clarify the substance and totality of organisational life. According to Easterby Smith et al [26] reality is socially constructed rather than objectively constructed. Human action arises from the sense that people make of different situations and contexts rather than as a direct response from external stimuli. McCutcheon and Meredith [27] note that case studies provide an excellent means to help fill these theoretical needs. Qualitative case analysis helps researchers to understand and explain why people have different experiences. According to this view the overriding goal of the research is to provide a contextually bound picture and to illuminate how the organisation has constructed itself. Furthermore, such research methodologies are lauded to be particularly useful in studying the product innovation process [28].

The research design employed in this study is that of a multiple site case study using numerous sources of information. Case studies can be used to accomplish various aims; to provide description, test theory or generate theory [29]. The nature of this study is exploratory; it attempts to generate theory in addition to building on existing theory. It focuses on the new organisational structures in a highly creative and competitive environment. The case study method allows an investigation to retain the holistic and meaningful characteristics in real life events such as organisational and managerial processes. According to Eisenhardt [29] theory building researchers typically combine multiple data collection methods such as observation, field work, interviews and surveys. Over twenty interviews were conducted by the authors across eight organisations whose principal activity is product design and development. The goal of these interviews was to;

- understand the product innovation process in specific industrial contexts,
- identify actors and players in the process
- identify critical success factors in terms of best practice, methods and enabling technologies for R&D managers
- discuss how companies must improve in order to maintain long term competitive advantage in the new networked environment.

The sample chosen for this analysis was selective, based on Irish organisations with a reputation for being innovative. The industrial sectors of the organisations were healthcare, computing, pharmaceuticals, telecommunications and electronics. The size of the organisations varied from 150 to 1,500 people. All eight organisations

surveyed were multinational organisations, with only one of these having their world headquarters in Ireland. Table 2 provides a profile of these companies.

Insert Table 2

Initially, the interviews were exploratory in nature. Open-ended questions were used without imposing any rigid agenda. This allowed the respondents to tell their own story in their own way. Care was taken in the course of the interviews to restrict actual questioning unless it proved necessary to prompt the speaker or clarify a point, but an attempt was made not to lead the interviewee. Afterwards, semi-structured interviews were conducted to ensure all aspects of the research was covered. Here, key questions were posed giving some room for explanation and elaboration. The data was analysed within and across the participating organisations or cases. This helped to develop initial theoretical frameworks and to compare these premises to the literature and cases. Comparing and contrasting theoretical frameworks across case settings refines conceptual definitions and strengthens internal validity, enhancing testability of resulting theory [30].

4. Implications for R&D Managers

Here we report on the findings of our study. More specifically, we identify and explore key criteria that R&D managers should consider when managing a portfolio of product innovation projects in a networked environment. They are grouped into five categories and explained in more detail below.

4.1 Project Goal Alignment

Product innovation team members incorporate experts from a wide variety of functions and disciplines. Therefore, it is a major challenge to keep everyone focused in the same strategic direction. This can be particularly difficult when team members are distributed across geographical borders. Therefore, in a project focused environment it is imperative that an infrastructure is provided that drives the organisation's strategies and their associated performance measures down the organisation to the operational level. This implies that all product innovation strategies should be linked to performance measures such as cycle time, cost, quality and these measures should be deployed into all projects. Therefore, the groupware architecture must align strategies and goals with projects and initiatives to ensure both deployment and traceability.

4.2 Customer Centric Product Innovation

The product innovation process must be customer driven in order to sustain competitive advantage in international markets [31, 32]. A clear understanding of user needs is critical to product innovation and all operations must be driven by these needs. External knowledge and information such as market dynamics, new technological advances as well as customer and supplier requirements are key imperatives in the connected economy [31, 33]. The product development team must seek to continuously establish the voice of the customer and translate that value into the product concept. The groupware architecture must enable the systematic identification of current and emerging customer requirements and expectations and help to translate them into concrete product specifications.

4.3 Effective Use of Information and Knowledge

The product innovation process involves synthesising and reusing existing knowledge and information [34]. However, in a project focused team based structure, skills and knowledge developed during the collaboration process can be lost after the team is broken up and redistributed among other teams or groups working on newer development projects. Furthermore, many organisations face difficulties in transferring knowledge and information from one organisational unit to another. In order to avoid repeating mistakes and reinventing solutions it is important that communication channels are open and effective. All team members must be seamlessly connected with each other, with their functional specialisms and with other product innovation teams. Therefore, the architecture must adopt a knowledge management approach to help add or create value by leveraging know how, experience and judgement resident within as well as outside the organisation.

4.4 Informed Decision making

R&D managers must be able to access and leverage knowledge and information to the point of decision. This supports the findings of other researchers (see [35, 36]). It is accepted that getting the right information to the right people, at the right time, in the right format improves decision making, stimulates innovation and helps sustain competitive advantage. Therefore, product innovation team members must be equipped with all the necessary information in order to perform tasks and make informed decisions. Furthermore, it is essential that this information is reliable, accurate, complete and up to date. From this analysis, it is evident that the groupware architecture must identify and integrate the key players in the product innovation process. It must also incorporate a mechanism to capture minimum critical

information from all members in the product innovation group (including customers and suppliers) and leverage that information to the point of decision.

4.5 Project Portfolio Management

Successful product innovation depends on exploiting synergy among projects, such as reusing existing designs, market knowledge and customer requirements [37]. In this view, attention moves from single isolated projects to the project family, or project portfolio. Portfolio management recognises that organisations' efforts to innovate will include the development of both radically new, core products as well as small scale, product enhancements. Managers must maximise the value of the portfolio and seek the right balance of projects. They must also ensure that the projects and the spending breakdown mirror the business's strategy. In this view, the groupware architecture must focus on the portfolio when planning and executing product innovation projects. Furthermore, the portfolio must be balanced in terms of optimal investment mix between risk versus return, maintenance versus growth, and short term versus long term projects.

The implications of the above criteria suggest that R&D managers need to interact with a broad range of information and capabilities in the course of managing a portfolio of product innovation projects. Furthermore, it is increasingly clear that they should seek to optimise communication, co-ordination. In particular, project co-ordination across functional areas and with geographically dispersed sites must be enhanced.

5. Groupware Architecture

An organisation has a commonly held body of ideas, values and beliefs, which constitute what they call an organisational architecture, framework, or model [38]. Architectures are used by organisations to explain to themselves and to others how a system, process or organisation functions. They drive the organisation's requirements, structures and processes and therefore the behaviour of its members [7]. Shepherd and Ahmed [32] claim that they are a mechanism to achieve better co-operation, co-ordination and communication amongst those involved in product innovation projects.

A groupware architecture has been developed to support collaborative workgroups by providing R&D managers with a framework for understanding and improving the product innovation management process. It incorporates a process that encourages a systematic approach to distributed product innovation management. It is designed to help managers to make decisions about potential changes to be made in terms of systems, processes and people, in order to improve performance and innovation. It also provides R&D managers with an appreciation of the factors involved in added value, and can help determine strategies for improvement. The groupware architecture incorporates best practice techniques and takes the requirements identified into consideration. In other words, it aims to; (a) encourage project goal alignment, (b) improve customer focus, (c) promote the effective use of information and knowledge, (d) enhance decision making capability, and finally, (e) support portfolio management.

The architecture enables a dynamic framework for stimulating and capturing abstract ideas and translating them into concrete functional specifications and ultimately successful projects. It also considers both proactive and reactive problem resolution. The goal is to help generate, collate and integrate disparate pieces of information (i.e. complaints, requirements, ideas and problems) and translate them into successful projects. The architecture incorporates a stage gate facility. A stage gate is an operational roadmap for driving product innovation projects from idea to implementation [39]. It separates this process into a series of activities (stages) and decision points (gates). Each stage contains a set of defined concurrent activities, incorporating industry best practices. Gates are the check points where senior managers decide whether to continue funding a project, terminate, delay or refine the project. This allows innovations to be synthesised, filtered and prioritised taking into consideration the organisation's goals, requirements and constraints. This architecture is illustrated in figure 1. It adopts a systems approach to the product innovation process and it identifies four major flows namely; controls, mechanisms, inputs and outputs.

Insert figure 1

5.1 Controls

Controls help to guide or constrain an activity. They identify limitations, or restrictions to the product innovation management process. Elements such as requirements (i.e. customer requirements, conformance requirements, corporate requirements, employee requirements etc.) strategic thrusts (i.e. leadership, policy, resources, processes etc.) and measures of performance (i.e. time, cost, quality, environment

etc.) constrain the process. Controls ensure that whatever is done in terms of product development strategically aligns with the company's long term strategy. For example, requirements identify the pressures exerted by various stakeholders in the organisation that must be complied with. These requirements influence the strategies and supporting measures pursued to achieve the organisation's vision. By deploying these requirements, strategies and measures into the innovative efforts of the organisation, a portfolio of actions better aligned to achieve the organisational goals is achieved.

5.2 Mechanisms

Mechanisms help to identify who or what is performing the activity. They can also constrain the product innovation management process. They relate to how the organisation is organised in terms of individuals and teams. Teams represent the resource constraints of the organisation. Clearly, the more people available to work on projects the weaker this constraint. Employee performance reviews are another dimension to this constraint. More specifically, employees that are linked to goals through their performance appraisal system are motivated to engage in projects and this element of the development process must also be incorporated to increase the flow of innovations.

5.3 Inputs

Ideas and problems are the primary input to the product innovation process [40]. Innovations that map well with the controls and mechanisms of the organisation flow more easily into the system to become projects. Organisations can regulate the number of innovations by tightening the controls and increasing or reducing the

resources. Poor goal definition or customer requirement definition results in the development process to become cluttered. Poor resource (i.e. teams, equipment and budgets) availability reduces the amount of new ideas that can be managed. The principal concept is that many new ideas and problems are encouraged through the system and the constraints regulate which innovations are allowed to become goal centered projects. If innovations are initially matched with goals then their likelihood of proceeding through the funnel increase.

5.4 Outputs

Outputs deal with performance measurement and evaluation. It helps to ascertain whether the product development actions implemented led to the results envisioned. Outputs enable the status of the organisation's strategies, measures and deliverables to be viewed. Each of these modules contain a special results section that allows those team members who are responsible for the success of these goals to monitor and update the status of each activity. Critical knowledge can be captured about the results of the organisation's activities such as; percentage complete and project status. An exception report allows the R&D manager to concentrate their efforts on activities that are performing poorly. The exception report highlights all categories (i.e. requirements, measures and projects etc.) that are performing poorly. This enables the product manager to focus exclusively on those activities that are not reaching the required standard.

6. The Prototype

In order to validate the groupware architecture, critical elements or modules were identified and codified into a form based prototype. The web enabled prototype

allows minimum critical information relating to elements of the architecture to be captured and represented in structured forms. It also provides an instrument to enable the effective identification, communication and measurement of performance parameters and provides a common language and methodology for engineers and managers. The modules in the prototype are classified according to the architecture and include: Constraints (Customers, Goals); Inputs (Ideas and Problems, Projects); Mechanisms (Teams); and finally Outputs (Results) (see table 3). These modules are explained in more detail below.

Insert table 3

6.1 Customers

The customer's module deals with customer relationship management. This element acts as a constraint to the product innovation process. It uses structured forms to help capture the voice of the customer so product developers can deploy these requirements into their product designs for effective solutions. Customer information can be generated from existing information such as warranty claims and order requirements. Additional information can be generated by encouraging and capturing complaints and also by soliciting requirements through Delphi forecasting and Kano analysis techniques. Delphi forecasting is a structured process for collecting and distilling knowledge from a group of experts while Kano analysis is a tool used to prioritise customer requirements. The Customers module promotes customer focus by providing a link to all relevant players in the supply network.

6.2 Goals

The Goals module deals with the strategic planning stage of the product innovation process. This is where the direction for product innovation endeavours is identified and publicised so that all projects can be aligned with the strategic direction of the network. This module enables the identification, definition and communication of the requirements of key stakeholders (e.g. customers, corporate etc.). It also enables the measures of performance the organisation wants to achieve in terms of product innovation management and the strategies adopted to achieve these measures. Statements can also be defined (e.g. mission statement, vision statement). The prototype uses forms to capture critical information with respect to each module. By doing this, information and knowledge is made accessible to all team members involved in the product innovation process through simple web browsers.

6.3 Ideas and Problems

Ideas and problems are the seeds of innovation activities and are inputs into the product innovation process [40]. Problems can be identified proactively (e.g. failure mode and effect analysis) or reactively (e.g. warranty analysis). Ideas can be generated through focus groups, benchmarking, competitive analysis etc. These modules help to structure formal ideation and problem solving definition for the user. Again forms help to capture critical information (see figure 2). The user is encouraged to deploy goals into the idea or problem so that their impact can be evaluated. Ideas and indeed problems can also be ranked according to their priority. This feature empowers everybody to participate in idea generation and facilitates the cross fertilisation of ideas. Minimum critical information such as title (i.e. name of the idea), stimuli (i.e. what prompted the creation of the idea) and creator (i.e. the person

who developed the idea) are captured on a form. The form also allows ideas to be mapped on to the organisation's goals so they can be ranked according to their practicality and effectiveness.

Insert figure 2

6.4 Projects

Innovative actions are implemented through projects. Projects can be defined as actions that require significant resources in order to be implemented. Management must decide how appropriate potential projects are relative to the organisations current goals. As projects are developed, they are refined, merged or split, based on the constraining forces such as the goals of the organisation, or the teams available to implement the project. The eventual projects that are implemented by the organisation should better contribute to the achievement of the goals than would occur from an ad hoc process. The projects module permits the entire team to share project information effectively. It also enables project managers to structure workflow and schedules, and to respond promptly and effectively to unplanned changes. It provides easy access to schedules, resource allocation information and activity status information for all projects in the portfolio. This facility also provides the integration that enables managers throughout the firm to see how schedules and events impact the projects underway. Managers can be aware of disrupted schedules and take steps to manage their individual projects effectively in response.

6.5 Teams

The teams module represents the human resources that are available to the product innovation process. It acts as a constraint on the process since the availability and quality of people limits the amount and type of innovative actions that can be undertaken by the organisation. The level of constraints imposed by this module can be reduced through training and education. By providing more employees with the necessary skills, they can engage in the process and allow more actions to flow though the process. This module facilitates the effective co-ordination of team activities by organising and prioritising tasks, activities and deadlines. It can use an organisation's existing e-mail system to disseminate new or updated information and regular status reports between team members so everyone has access to complete, accurate and timely information. A performance review tool can also be included in this module, which incorporates skills, competencies and progress. It enables reward and appraisal systems to be linked to participation levels that can increase motivation towards change.

6.6 Results

This module deals with performance measurement and evaluation. It helps to ascertain whether the product development actions implemented led to the results envisioned. The results module enables the status of the organisation's strategies, measures and deliverables to be viewed. Each of these modules contain a special results section that allows those team members who are responsible for the success of these goals to monitor and update the status of each activity. Critical knowledge is captured about the results of the organisation's activities such as; percentage complete, status (green meaning good, red meaning poor and amber meaning fair

and finally, a check mark meaning complete). An exception report allows the product manager to focus exclusively on those activities that are performing poorly.

7. Case study

The validation of frameworks and methodologies is a complex and difficult operation. Such research deliverables are not possible to validate through controlled experiments. Therefore, other approaches have to be used. In an attempt to validate the architecture, the prototype was populated with company specific data in each test site. This helped us to compare each organisation's current situation with best practice. In this way problems and weaknesses were identified and prioritised and strategies for improvement were subsequently defined and ranked. This also allowed us to determine whether the architecture could support real life situations. Finally, this process enabled us to ascertain whether the architecture fulfilled the design goals identified from the outset. For the purposes of illustration we explore problems from three cases in more detail and report on findings from this investigation.

Company A is a design and manufacturing facility. The organisation focuses on designing and developing next generation products and the level of innovation employed in these product designs is moderate. Company A has an abundance of information regarding its product innovation projects. However, this information is often difficult to locate as it is often distributed across different document archives. The organisation also has many new product ideas in its development pipeline. However, there are not enough resources in terms of people, time, budgets and equipment available to develop them. Therefore, it seems that the organisation requires, (a) a central system that captures minimum critical information, (b) a

systematic portfolio planning process to facilitate effective selection and prioritisation of projects and (c) an effective resource allocation mechanism to assign people, equipment, tools and machines to projects.

Company B designs, manufactures, and markets a broad line of high-performance linear, mixed-signal and digital integrated circuits. The organisation's strategic focus lies in research and development and product innovation. Company B also suffers from poor project management and poor resource management. These activities are managed in an ad hoc manner as opposed to a planned way. Effective contingency planning is also deficient. In sum, there is too much crisis management. It seems that the organisation needs to follow a structured process to enable effective portfolio management of projects in order to keep track of schedules and resources.

Company C is a mature manufacturing facility located in the west of Ireland. This company produces medical devices, diagnostics and nutritional products. The problems that Company C face in terms of product innovation management are strategic in nature. Company C recognises that it must move away from cost reduction manufacturing activities towards more value adding product design activities in order to rejuvenate its aging product portfolio. It must begin by collaborating with the key players in the medical devices industry namely clinicians and academic institutions in order to develop new product concepts that fit with its manufacturing processes. The organisation must work with these partners to develop specific strategies, measures and requirements that can be deployed into individual projects in their new portfolio. The organisation also needs a structured, formalised system for portfolio planning and management.

7.1 Project Goal Alignment

All cases agreed that their organisations required a more systematic approach to R&D management. Some have invested large sums of money on improvement activities but many feel that goals are not effectively deployed at operations level. For example in one case site (Company B) Hoshin plans were developed at corporate level to identify and prioritise the organisation's strategy. Hoshin Planning, otherwise known as "*management by policy*" is a simple and effective technique for business planning. It is used to deploy the vital few goals or policies throughout the organisation [41]. However, while these plans were comprehensive, there was evidence to suggest that there was a large gap between strategy development and project implementation. In other words, product strategies were not directly deployed into individual projects. The architecture helped to identify an infrastructure that drives the organisation's strategies and their associated performance measures down the organisation to the operational level. This helped to ensure that organisations' goals were deployed into each action and deliverable. It also helped to focus and integrate team effort and permit delegation.

7.2 Customer Centric Product Innovation

The architecture was designed to promote customer centric design. The voice of the customer can be established by analysing complaints, warranty and customer satisfaction rates. This value can then be deployed into the product concept. By understanding key requirements in advance and prioritising these developments, effort is focused and costly rework is reduced [33, 39]. This in turn can lead to lower costs of production as well as shorter lead times to market. Company A and B

employ customer focused cross-functional team-based structures for product innovation initiatives. However, we found that requirements engineering was virtually non-existent in Company C. This organisation tried to compete using an inwardly focused strategy. Today, in the networked economy the organisation realises that there is a need for a stronger link to customers. They understand that they must be more customer focused. In other words, they must begin to develop relationships with their customers that promotes mutually beneficial long-term commitment. The architecture provided them with the infrastructure to begin this transition to a more customer focused organisation.

7.3 Effective Use of Information and Knowledge

The development process involves synthesising and reusing existing information and knowledge. The architecture was found to support the knowledge process by helping to; develop knowledge (i.e. identify, generate and acquire information and knowledge), combine knowledge (i.e. find synergies, reuse existing knowledge), consolidate knowledge (i.e. prevent it from disappearing) and distribute knowledge (transfer it to the appropriate points of action). This was achieved by developing structured forms to help capture critical information and data. By doing this, information is made accessible to all team members involved in the product innovation process through simple web browsers. Companies A and B believed that this facility could help them to manage their knowledge base in a virtual environment. In particular Company A found that information could be centralised and avoid having information distributed across multiple archives.

7.4 Informed Decision Making

By obtaining critical information from all members in the product innovation group (including customers and suppliers) and leveraging that information to the point of decision issues, problems and assumptions can come to the surface where they can be examined, analysed and rectified. Managers can take quick effective action to bring projects back in line if necessary. All cases found that this visibility facilitated the necessary dialogue among project managers. This ensured integrity in reporting and allowed everybody to see how projects are progressing.

7.5 Project Portfolio Management

The architecture provided all R&D managers with a structured approach to manage project portfolios. This helped managers use all available knowledge and information in order to generate, select and prioritise projects that strategically align with their existing portfolio. By doing this R&D managers were equipped with a means of making decisions about changes to be made in terms of systems, processes and people. This in turn helped them to improve performance and innovation. We also found that this facility helped R&D managers to manage by exception. In this instance, managers could focus exclusively on activities that are not reaching the required standard.

The case study has shown how a sample of organisations using a management framework, based on a systematic process, can identify problems and improve performance. The case study analysis also discovered that improvements could be made to the architecture and system. For example, more emphasis could be placed on optimising effective resource management. The case study analysis discovered

that R&D organisations have an abundance of ideas but do not have systematic processes in place to assign people, equipment, tools and machines to projects. Activities should be structured in such a fashion as to give optimum performance. In other words, resources should be effectively used to carry out tasks for the right reasons, at the right time, to meet the right requirements and to give the right results. Also, organisations are investing heavily in customer relationship management (CRM) systems to help manage; (a) sales force automation, (b) marketing automation, (c) business intelligence and, (d) customer service/support automation. Such an application could link up to the Customers module in the prototype in order to integrate this information and add more value to the architecture and system.

8. Conclusion

Increased intra-organisational collaboration, growth in knowledge intensive work and developments in information communication technology have enabled the shift from hierarchical, bureaucratic organisations to decentralised networked organisations where information and decision making move horizontally. This has a major impact on activities such as new product development where organisations are forming networks to pool resources and maximise competencies and capabilities. Furthermore, communication, collaboration and co-ordination are key elements in the foundation of creating a durable competitive advantage in a distributed environment. Costly breakdowns in communication often occur even in the traditional world of co-located groups. However in a distributed team environment where team members are spread across geographical boundaries, it is imperative to make substantial efforts to ensure adequate and effective project co-ordination. Knowledge assets cannot be exploited effectively in distributed product innovation until an architecture

guiding the development and use has been identified. R&D managers need a structured approach with a common language to help manage product innovation projects in a distributed environment. Moreover they require a systematic methodology that (a) aligns projects to goals, (b) improves customer focus, (c) promotes the effective use of information and knowledge, (d) enhances decision making capability, and finally, (e) focuses on portfolio management.

To this end, a goal centred groupware architecture in order to guide operations in a networked environment was developed. This architecture was designed to enable an inclusive and participative approach to product innovation management. Critical elements were codified into a web enabled prototype and implemented in multiple case sites. From this, we learned that the architecture can act as a blueprint for organisations to manage product innovation efforts in a distributed environment. Future work will focus on developing new applications of this tool for specific environments such as information technology development and process improvement initiatives. An adaptation of this architecture is being developed for small owner managed enterprises that comprises minimum critical features and functions. Work is also being conducted to extend the architecture's features. For example, a facility to optimise customer relationship management and a tool to enable effective resource management is under development. Finally, the possibility of incorporating new technologies in the prototype such as intelligent agents using the semantic web is being explored.

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Dimension	Old	New
Environment	Stable, physically collocated functions	Dynamic, competency-based networks
Added Value	Transform materials	Synthesise information
Size	Large	Small
Capability	Supervision	Collaboration, co-ordination
Development	Sequential	Concurrent
Organisation	Functional and centralised	Autonomous multi skilled teams
Management focus	Hierarchy	Relationship management
Communication	Formal information system	Continuous, flexible and multi-directional
Decision making	Vertical	Vertical and lateral
Contact	Face to face	Digital networks

Table 1 Comparative analysis between old and new paradigm

ID	Contact	Product	Strategic Focus	Structure	Typology	Culture
A	R&D Manager	Temperature Control Units	Product and process innovation	Function Oriented	Make to order and engineer to order	Dynamic vibrant assertive
B	R&D Manager	Electronics	R&D and product innovation	Autonomous, cross-functional teams and virtual teams	Engineer to order and make to stock	Innovative Customer focused
C	Product Manager	Medical Devices	From cost based to product innovation	Function Oriented	Made to stock	Static and listless
D	Product Manager	Electronics	Product and process innovation	Team Based	Make to order	Dynamic Customer focused
E	Product Manager	Tele-communications	R&D	Process Oriented	Engineer to order	Dynamic
F	Product Manager	IT Solutions	Product and process innovation	Team Based	Engineer to order and make to order	Innovative participative
G	R&D Manager	Pharmaceuticals	R&D and new process development	Team Based	Make to stock	Regulated controlled
H	Supply Chain Manager	IT Solutions	Next generation product development	Process Oriented	Made to stock	Dynamic

Table 2 Profile of case organisations

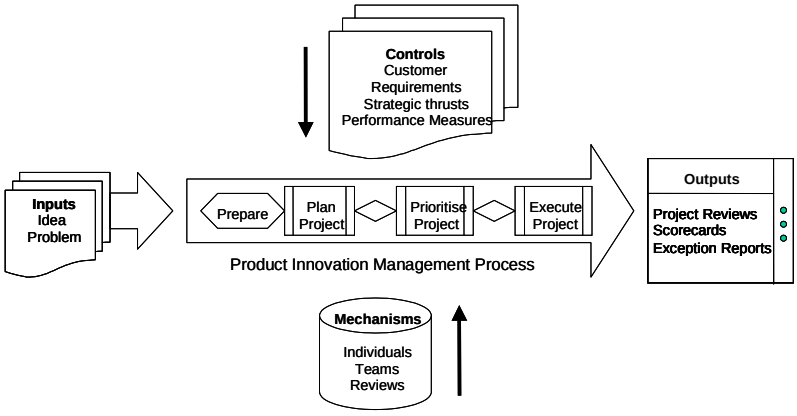

Figure 1 Groupware architecture

Flow	Module	Forms in the prototype
Controls	Customer	Warranty analysis Complaints Feedback survey
	Goals	Statements (mission, vision) Requirements Strategies Measures
Mechanisms	Teams	Individuals Teams Performance reviews
Inputs	Ideas	Mind maps Brainstorming Databases of idea associations
	Problems	Failure mode and effect analysis Engineering change requests
	Projects	Workflow Schedules Activity status
Outputs	Results	Project reviews Scorecards Exception reports

Table 3 Key elements in the prototype

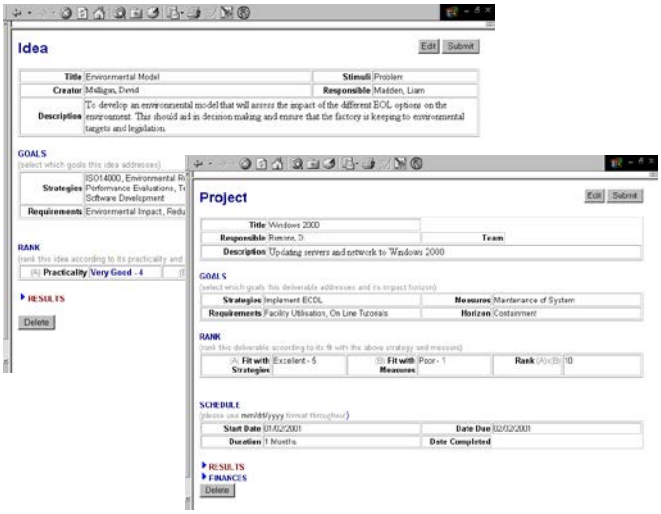

Figure 2 Forms to capture critical project data