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Software Innovativeness - Knowledge Acquisition, External Linkages and Firm Developmental Processes

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- Knowledge Acquisition, External Linkages and Firm Developmental Processes[1]

Abstract: This report covers an empirical research project focused on studying the knowledge acquisition, external linkages and developmental processes in software firms. A large database was been created through 133 interviews that were carried out in cooperation with managers in software firms in 19 countries that were contacted by students taking master's level courses in Sweden. The main 94 interviews followed a structured protocol that contained tables that required Likert scale ratings for a number of actors/sources and measures of innovativeness and various firm developmental outcomes including knowledge accumulation. The protocol was directed at providing answers for various aspects of the general research question: What is the relationship of the level of innovativeness of the products created to the types of development processes employed, external knowledge sources, and the developmental effects flowing from s/w projects?

In the overall product creation process customers were found to be the most important external linkage for the low and medium innovativeness categories. In the high category customers shared the first level of importance with both affiliates and other research institutes. The second and third levels of importance were shared by groups of actor/source that varied with the innovativeness level. When the data were examined according to phases in the creation process the importance of various external linkages that were used fell into several levels depending on the product innovativeness

Most of the business development effects investigated for of the projects were found to be greater for the high innovativeness category than for the low category. This included the knowledge accumulation in the creation processes. Large-sized firms did not show an advantage over smaller ones when it came to producing high innovativeness products nor did the larger firms consistently use more complex software creation processes than did the smaller firms.

Key words: Computer software firms; innovativeness; external knowledge acquisition; product development processes; firm developmental effects; software industry; software projects.

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1. Introduction

The 'new economy' is frequently the subject of commentary in the business news. Many articles connect the information technology, IT, revolution with this new economy. At the heart of IT is the software that works in tandem with the operational hardware. The software products that have been created during the last few decades are seen as new tools that embody significant new knowledge (Baetjer, 1998: 11). These tools, in turn, are thought to increase productivity in many sectors of the industrial economies (Baily and Lawrence, 2001 and Lucas, Henry C., Jr., 1999).

Software (s/w) tools are of course progressing in complexity which means that the innovative challenges continue to increase. As the various national economies develop, increases in productivity will likely require more innovative activity on the part of s/w development teams. An example is a highly innovative software product that was created by Business Solution Builders (BSB) of Belgium to maintain real time information on share holdings within industrial or financial groups. The product version studied for this paper, BSB-portfolio solution, maintains information on participation, trading, and long term placement for first and second tier subsidiaries. The permutations and combinations of information are of course very complex within such holdings. Objectives such as management of the holdings, transparency that is needed for financial reporting requirements, and productivity were provided for. The last objective as to productivity permitted, in a typical situation, 4 to 5 persons for the former paper-based systems to be reduced to only one for the operation of this new product.

Another aspect is that such successful software products often lead to a line of increasingly sophisticated programs that provide even greater productivity. The subsequent versions of the BSB- portfolio solution product provide a whole-in-one solution for institutional asset management, especially focused on the complex accounting, fiscal and reporting side of companies. The latest version automatically generates the entire set of end-period asset related account documents and dramatically reduces the lead-time for global processed accounting data availability from days to minutes or hours. The later versions are IAS ready (International Accounting Standards) and GIPS compliant (Global Investment Performance Standards) and interact with another product, the BSB-TMS (Trading Management Suite) package, for online portfolio management using any web browser. As a result of this line of software creation the BSB-portfolio solution product is the leader on its primary market (major financial institutions in Belgium and Luxembourg) and is also now being sold in both France and Spain. The company that started with 3 employees six years ago was at 80 when the interview on the first highly innovative version was conducted and has now grown to 150. This type of rapid growth based on innovative software creativity also has important economic implications for our industrial societies even apart from the customer companies that are being advantaged by the products created.

Proceeding from these points, it seems that closer examination of the innovative aspects of product development processes used by s/w firms would permit a deeper understanding of this crucial part of the new economy. Such an examination would necessarily involve investigating the learning that occurs in such development processes through the acquisition of knowledge from external sources.

Innovativeness in s/w development is of interest to those managing and/or conducting the projects as well to those studying product development processes. This characteristic of innovativeness has been used as the central organizing principle for this report.

1.1 Problem Formulation

Product development processes are integrally related to both the knowledge acquisition processes that are used in conjunction with external sources and to the firm or business developmental effects that flow from this activity. It was deemed necessary to formulate the problem addressed in view of these relationships. A discrete focus on the knowledge acquisition processes and developmental effects flowing from innovative efforts then facilitates specific treatment of the linkages to external actors both in terms of development process phases and of the effects upon these same linkages.

Most all s/w development projects begin with some loosely described needs of a specific client organization or, in some cases, the needs of a market segment in which the team has some special knowledge and experience. Sometimes the client organization is another part of the team’s own firm. The initial information about the needs could come via the client directly or through an affiliate company, market consultant, university or research institute, etc. Once the project gets underway then suppliers, hardware manufacturers, competitors, various public authorities such as patent offices, and mediating parts frequently come into the developmental process.

It is of interest to describe how these various external sources of knowledge are linked to the development process and what are the effects on the firm’s linkages to these same sources.

The use made of these sources and the effects flowing from both the development processes themselves and the associated knowledge acquisition processes are likely to be different depending on the degrees of product innovativeness that are associated within the processes. One study of highly innovative tangible products has pointed out that new products and processes can even create a discontinuity within the focal industry such that not all existing firms can offer their own version of the newly created product. Such a critical change in product features or manufacturing process then establishes a major developmental shift within the industry. The inability to follow the market demands for the new type of product or process can cause firms to exit the industry. This effect has been illustrated by reference to the minicomputer market in 1965 when Digital Equipment Corp. introduced the first integrated circuit minicomputer that resulted in only three of the firms that existed prior to the introduction surviving into a field of six competing firms (Tushman and Anderson, 1986: Table 3). This type of phenomenon makes the study of different levels of innovativeness of keen interest in dynamic industries.

Other less dramatic effects of innovativeness such as ROI, the percentage of successful products, and various market performance measures have also been studied with respect to tangible product innovativeness levels (Kleinschmidt and Cooper, 1991).

However; a question can be raised as to whether such effects found in tangible product studies also apply to software products. The former tangible product studies may be inadequate to provide the needed understanding for various types of effects flowing from software product development processes. Therefore, it was deemed of interest to describe connections between various levels of innovativeness and effects that flow from various product development projects. Higher levels of product newness could result in differences in effects compared to lower levels of product newness. Differences in innovativeness might also influence the usage of various external knowledge actors or sources.

Product innovativeness has thus been used as the central organizing factor for formulating the general research problem. The context of the general problem needs to be characterized before proceeding.

A first characteristic of the primary s/w product development processes relates to the types of processes used. A development process may be simply a series of linear steps that are followed or it may be more complex with various internal cycles for successive phases of interconnected steps. It is, therefore, of interest to know how the choice of development processes is related to different levels of innovativeness. Another important characteristic is the extent to which outside persons and/or organizations are linked into the different process steps and cycles of a given development project.

The pattern of effects flowing from the chosen development process and knowledge sources used is yet another characteristic of the general problem context. The general problem here is defined in question form as:

> What is the relationship of the level of innovativeness of the products created to the types of development processes employed, external knowledge sources, and the developmental effects flowing form s/w projects?

This problem formulation led to the following research questions:

1. What types of s/w development processes are used by project teams for different levels of innovativeness?

2. What linkages to outside knowledge sources/actors are used in different development phases for different levels of innovativeness?

3. What is the relationship of different levels of innovativeness to the effects flowing from product development processes?

The research project reported here was initiated to provide initial answers to these questions.

Limitations

The main body of the study was conducted by conducting 94 interviews in firms using a structured interview protocol. The characteristics examined were taken from the literature and are not regarded as exhaustive. Other characteristics could also be of importance. The firms constitute a convenience sample that was determined by the willingness of at least one product development manager to permit an interview. The manager chose the specific s/w project to insure that some level of innovativeness was present. These choices suggest bias in willingness to provide data and likely permitted only data collection on projects regarded as having some reasonable degree of success.

The characteristics could thus be regarded as those associated with reasonably successful projects. Thus there is no treatment of factors that might have resulted in unsuccessful outcomes or failed projects.

Disposition

Section 2 deals with the research design and methodology. The theoretical background used to describe the product development process characteristics is given in section 3. The descriptive results are set forth in section 4 and analyses of the external linkage patterns are given in section 5. Conclusions follow in section 6.

2. Research Design and Methodology

A research design was set up to provide initial information regarding the above general problem and the three research questions. It was believed necessary to investigate the various types of product development processes, the pattern of linkages to various actors and different levels of product innovativeness with respect to how these might produce different product developmental effects within each interviewed s/w firm. The following categories of effects flowing from the investigated processes were examined: (a) strengthening of linkages with a wide range of actors; (b) various project success measures such as the firm's reputation and profitability; and (c) internal knowledge acquisition from outside sources and by internal study and potential for use of this knowledge in subsequent development projects.

A protocol covering these topics was prepared in several stages. This involved various types of questions that were tested in 35 early interviews with software firm managers and then in 4 of those firms in greater detail before being finalized for use with the main 94 interviews so that a total of 133 interviews were conducted in 115 groups of companies for this study. The final protocol preparation stage was to reduce the number of questions so that interview times of one and one-half hour to two hours could be foreseen.

The main questions in the protocol were directed to a single s/w project that the interviewed manager chose subject only to the criterion that the product created should include some aspects that were new to the company at the time the product was created. The software did not have to be totally new to the company. The unit of analysis was thus the project rather than the firm.

Students taking a business development strategies master's level course were given the protocol for study in connection with the course literature. Each student group was then required to locate a s/w firm with which to carry out an interview with at least one software firm project manager using the protocol questions in order to better understand the theories and observations reported in the literature. The interviews were to be recorded and transcripts produced. In some instances recorded interviews were not possible, but protocol answers were collected from each participating s/w firm. The responses obtained were monitored as received and additional questions were raised with the interviewees by telephone and email to insure correctness and completeness of the responses when necessary. Since many of the students were on exchange programs the responding s/w firms are widely dispersed within Europe and abroad. The interviewed companies are listed by country in Appendix A.

This research design was adopted, in part, as a way of surveying a substantial number of s/w firms within the available time frame. Most of the interviews were carried out within four periods of several months each over the course of two years during 1999 to 2001. It is believed that the quality of the information obtained in this series of interviews is much higher than would have been possible if data had been collected through a postal survey. In each case an identified interviewee focused for a reasonable time period on the questions raised.

The collected data from the protocols and transcripts was then entered into a Minitab for Windows program to create a case data table for statistical analysis. The presentation and commentary of basic descriptive statistics comes first in each of the sections. This is followed by reporting and commentary on the basis of the analyses that were routinely carried out to test for statistical significance.

The sizes and types of firms interviewed varied widely as did the type of products that had been created. Seven types of firms were derived from our initial analyses. The sample contained examples of six of these distinct types of projects: 1. developed for a single client with no follow-on projects, 2. the same as 1. but with follow-on projects, 3. developed initially for a single client where the firm then discovered a mass market for which customized versions were offered or made, 4. a mass marketed product was discovered based on a program developed for a single client and customized versions were made, 5. a mass marketed product was discovered by the firm itself and customized versions were made for different users, and 6. the same as (5) but in which customized versions were not made. The seventh type that was expected, but for which no example was found in the sample was for a mass marketed product that was discovered based on a program developed for a single client but for which customized versions were not made.

Products of different levels of innovativeness were created in each of these categories and hence these could be examined as a uniform group from the perspective of newness. Therefore, no sub-samples have been broken out along the above product types according to innovativeness levels.

3. Theoretical Framework

The questions structured in the interview protocol were developed from a study of the literature and can be diagrammed as shown in Figure 1. This framework section is organized according to these topics.

The two processes shown in the box are regarded as integral in that the successive steps within these two processes are intertwined and occur simultaneously. As the product is being developed the needed knowledge is also being accumulated. Contacts are made with outside actors/sources through a knowledge acquisition sub-process and various knowledge, s/w components, and other inputs are taken in from these sources to help solve the problems that are encountered (Sheremata, 2002). The combination of these two processes in the creative processes box then produces a wide range of effects. The flow of effects range from physical measures of the product and its performance to opinions concerning the impact of the product on the firm and within the industry.

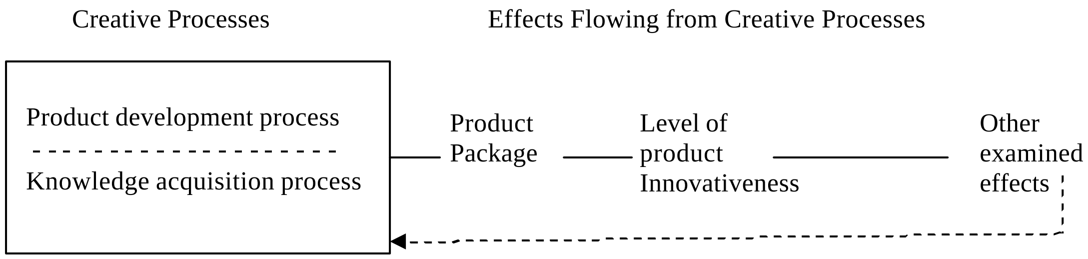

Figure 1. Descriptive Framework

A listing of various categories or types of these effects are useful to explain more fully the present study, but these are not regarded as exhaustive of all effects that could be considered:

1. Product *per se* - new features, performance parameters (size, operational speed, and absence of faults) compared to existing products, comparative price level, type of newness (new platform or specific new parts or modules),

2. Use of product by existing customers and other parties - increases in productivity, new combination utilities that now became possible,

3. Use of product by new customers and other parties - new market segments, increases in productivity, new combination utilities that became possible,

4. Structure of the firm – product enabled improvements to other products, extensions of other product lines, creation of new business unit(s),

5. Opinions concerning extent of newness of product - from those within the firm, from other market actors, from those in broader industry, from those in relevant engineering and scientific fields, from legal experts as to extent of patentability, and from organizations that award recognition prizes for outstanding new products,

6. Changes in knowledge of those involved as a result of product creation and on-going use of product - knowledge enhancement of project team, marketing personnel, management, gained by customers and other users, and gained by other actors within the development process,

7. Changes in relationships to external actors who have been involved in the product creation processes – strengthening of the linkages to those actors, formation of partnership and affiliate relationships that began with a given project,

8. Changes in various classes of knowledge – general-purpose knowledge that can be used for a wide range of s/w projects, context-specific knowledge that can be used for other related products, market knowledge, administrative knowledge, project generated knowledge that is transferable to subsequent products, proprietary knowledge that the firm can use in other later products, and

9. Results judgments – delivery of product on time, within budget, on-going profitability of product if repeated sales are involved, changes in reputation of the firm, opinions concerning overall project success.

Some of these effects have been used in past studies to determine product innovativeness while others have been used to assess outcomes of product development processes. One recent study has organized the factors that have been used in prior research to determine product innovativeness in an interesting and useful typology (Garcia and Calantone, 2002). In general, factors or effects that have been used to determine innovativeness are those categorized under points 1, 4, 5, and 6 above. Those under point 5 are of particular importance in the cases of high innovativeness products largely because the occurrences of such products set off waves of awareness of new possibilities within the competing firms and within industries, in general.

Other listed effects can be used for assessing different aspects of the product creation processes such as changes within the linkages to external actors, profitability, and overall success measures. This is the main objective of the present study – to describe the relationships of the two processes shown within the creative processes box to the other effects that have not been used to determine product innovativeness.

The basis for some of the effect types listed above may be also of interest. With regard to effect 6, personnel knowledge enhancement was taken as a measure of the general learning that occurred during a given project. 'Organizational learning' as a term goes back at least to Cyert and March (1963: 114-125). A few years later Thompson stated that organizations have to be interdependent with other firms and individuals in the environment (1967: 51-82). This was of course a characteristic of business networks. The internal and external sharing of knowledge that occurs in a given project then enhances the personnel knowledge base that is established for future projects. This has been regarded as a positive effect flowing from a given project. Some companies already have internal programs in-place for enabling their personnel to maximize the intake of knowledge in assigned areas so personnel knowledge clearly a firm resource (den Hertog and van Sluijs, 1995: 193+).

For effect 7, strengthening of linkages facilitates more efficient cooperation and hence will aid knowledge acquisition in the future. It has been observed that multilearning extends beyond the company itself to suppliers and vendors. The inter-working sets up a mutual "dependence between suppliers and manufacturers [that] turns upon close cooperation and communication. Contact is frequent, sharing of personnel is common, and information flow is dense…" (Dussauge, *et al*, 1992: 194). It was also pointed out that long-term linkages permit the innovating firms to leverage their technological assets.

With regard to effect type 9, we have used the single word 'reputation' rather than the term 'corporate image' that has the same meaning. Many innovative firms have come to understand that the successful development of new products enhances corporate image or reputation among its stakeholders (Thomas, 1993: 9). The business press of course helps this by publishing reports about performance-related topics that affect stakeholder perceptions. The innovative companies also direct their own marketing programs in ways to build brand name equity for the proposition that they are a leading innovator (Ibid., p. 11). Building corporate image is a multi-year strategic objective that affects "how the company and its products are perceived by its customers" (Twiss, 1974: 122).

Effect type 9 also has a relationship to the well-know effect type 1 since it has been reported that product newness/superiority is the leading factor related to new product success according to discriminant analysis and that this factor was found in 82% of successful new products (Cooper, 1979: 75). Then another study concluded with three rules for developing successful new products. One of these was to "be there first with a new idea" (Davidson, 1976: 120). So being first into the market with a superior product is clearly a way to enhance reputation or corporate image among the company's stakeholders.

Returning to Figure 1, it is customary to first focus on the product package that contains a set of features that hopefully will provide the customer(s) with advantages over those available from currently used products. The package may also contain other elements such as follow-on servicing and technical help over the product's useful life. For customized software this servicing is usually an important element of the product package. For mass-produced software consumer informative packaging is also needed. The success of delivering the advantages to the customer(s) can be objectively measured by the product performance parameters in some cases.

A product that is characterized by a set of features that confer advantages through increased performance also can be judged to have a particular level of innovativeness. As pointed out above this level is determined by examining some sub-set of effects that are associated with the product within the creating firm, market and industry. More will be said about this in the innovativeness section 3.3, below.

Other effects will of course be examined by the firm to assess various aspects of business development for the firm. Feedback to the original two creation processes can be used to assess the efficiency and utility of these processes. The project team or higher management may decide on the basis of the effects produced to institute the use of different, possibly more complex, development processes for subsequent projects. Management and project teams may decide to focus more sharply on linkages to external actors during subsequent projects. Also linkages to different actors/sources may be changed for subsequent projects.

In this Figure 1 framework, the product innovativeness is seen as a connecting variable in that some estimate of its level begins to form at an early point in the project planning cycle. This can be thought of as occurring within the processes box, but of course the final assessment of innovativeness can only be made after the product has been used in the field. so that the associated effects can be assessed. This framework has been used in the organization of the following sections by first explaining the reasoning behind the various inquiries and then presenting hypotheses to provide focus.

3.1 Types of s/w product development processes

The start point for discussions about this subject was the hacker approach that was used in the beginning of the s/w development era and is still used for some low complexity products. This term is applied in situations where a programmer sets out on a development sequence in his or her own way. This can lead to stringing together 'spaghetti code' that is very difficult to understand later, even by its creator. This approach has also more formally been called the 'code-and-fix' model described by Boehm (1988: 61-62). Inattention to the development process can lead to 'thrashing' that can reduce productive work of the project team and even result in early project failure (McConnell, 1998: 101).

One of the earliest s/w development models was the well-known waterfall model. This model prescribes a series of linear steps starting with system feasibility, moving through software planning and requirements, product design, coding, integration, and implementation which involves system testing. Once the product specifications are set or frozen the process is carried out in a sequential series of steps subject only to feedback to the next previous step so it is regarded as too rigid for all but the simplest products. This is because the fixed requirements specifications "tended to produce point solutions optimized around the original problem statement" (Boehm, 1996: 74). The waterfall model is close to the linear stage-gate development process that has been described by Cooper (1990) for a wide range of tangible product development processes. These first three process types do not normally involve the construction of serial prototypes.

The evolutionary process is a model in which prototype products are produced in several stages for trials in the intended use environment (Boehm, 1988: 63). The first version may even be a 'throw-away' prototype just to try to understand the user requirements and to refine a product definition. Modifications and additions are then made to bring the product closer to the expected needs. Another close model is the incremental-iterative or iterative model in which several modules are developed in parallel to produce a series of prototypes that are sequentially integrated according to a common plan with defined objectives and within a given architecture framework (Cusumano and Selby, 1997: 54-55). A criticism is that the architecture may be fixed too early. An advantage is that the product is not completely designed in advance and thus the specifications evolve during the process which is an advantage for more complex products.

The synch-and-stabilize model was a further development of the basic waterfall model and was reported by Cusumano and Selby (1997) to be used by Microsoft. It is said to involve 'daily builds', i.e. the building of frequent prototype modules for compatibility testing. The concurrent model also involves sequential system integration as well as staged prototype releases (Aoyama, 1993).

The spiral process is more complex in that several cycles are setup for moving through a first phase of determined objectives, alternatives and constraints, a second phase for evaluating alternatives and resolving risks, a third phase for developing and verifying the product in several cycles, and a fourth planning phase in which the work in the next cycle of the process is setup according to Boehm (1988: 64+). This model was further elaborated as the win-win spiral model to assure that the diverse demands of a wide range of the involved stakeholders are taken into account in the earliest stages of each development cycle (Boehm, 1996). Sequential prototype versions are produced in both of these spiral models.

The Rational Unified Model is a web-enabled proprietary software engineering process that provides guidance for project teams through the complete development process. It contains software tools that permit the using teams to make further gains. It provides for module integration and prototyping according to the Rational Unified website (1999).

Thus all of these s/w processes developed subsequent to the waterfall model provide for the production of sequential prototypes during the course of product development. Virtual products have many possibilities for built-in errors (bugs) and this seems to lead to the use of prototyping practices. Thus at this stage in the s/w revolution it seems logical that most products will be created using a process that will produce a series of prototypes along the way. However; there is some evidence that using development processes that produce prototypes may not be so very wide spread. Dutta et al (1998: 82) reported that

> "Prototyping methods for ensuring software requirements were used by 58% of the reporting organizations…"

in their study of Benchmarking European Software management Practices. This seems to have been an increase from the 40% figure found in a 1994 study. Another point is that the waterfall model can be used repeatedly for creating a first, second, etc. product versions and the team will still say this model was being used.

Considering this line of references it seemed logical that few projects would be carried out using solely a hacker approach or the waterfall model. This led to a first hypothesis:

H1. Significant percentages of software project teams do not actually use the hacker approach or the waterfall model for product development.

Another aspect of the development process is the vision that set it in motion. Microsoft begins a given process by creating a vision statement in which the goals for the product are defined and in which the user activities that need to be supported by the product are ordered (Cusumano and Selby, 1997: 56). Stolterman (1992: 7-8) discusses the vision conceived by the system designer at the outset of a project and reported that sometimes this vision sometimes comes too early and results in misdirection of the project. This is an interesting aspect of development processes – how can the original vision for a product be described? Unfortunately, it has not been possible to answer this question within the frame of this empirical study.

During the study we discussed whether larger companies were using more complex software process types. It is also of interest to determine whether there is a relationship between the number of company employees and the process type used. It could well be that larger software companies have had more time to experiment with processes of greater complexity as in the case of Microsoft. This together with the expectation that most companies are likely to be using processes that produce prototype products led to the following hypothesis:

H2. Large- sized companies, measured as number of employees, use more complex process types in a given project.

This objective then necessitated the collection of data on company sizes associated with each project.

3.2 Knowledge acquisition process

An important feature of product development processes is the manner in which these are conducted with respect to external linked knowledge sources. There are many properties of such linkages including the direct task-related activities that both sides of a given linkage carry out such as the two-way transmission of knowledge, commitment of resources, joint task completion, and of course socialization between participants. Of these, knowledge transmission is of great importance for innovative projects because the overriding need is to learn what new set of product features will work for a given set of needs and how these features can be efficiently created. The acquisition of knowledge involves learning about the new relationships and properties that give definition to the new product.

The absence of sufficient knowledge linkages can restrain innovation within firms. For example, small and medium-sized enterprises (SMEs) can be especially disadvantaged in establishing an appropriate network of contacts with external sources of scientific and technological expertise and advice according to Rothwell and Dodgson (1991: 125). Empirical studies have shown that innovative SMEs enjoy a high level of linkages with external agencies compared to less innovative ones. In two separate studies of 100 innovative SMEs in the UK and 80 high-technology firms in Italy it was found that most of the firms studied had a significant link in at least one of the following areas: contracted-out R&D, joint R&D ventures, marketing relationships, links with educational establishments, other public sector bodies and research associations." (Rothwell and Dodgson, 1991: 128). The employment of qualified scientists and engineers is also an important determinant of the firm's ability to acquire and use know-how from external sources (p. 131) since this is necessary to establish absorptive capacity for external knowledge.

Another study of twelve leading technology-based SMEs in Britain, Denmark, Holland, and Ireland showed that all enterprises enjoyed a variety of often very strong external technical links with universities, research institutes and with other industrial companies, usually suppliers and customers. These enterprises were also increasingly developing corporate strategies for handling technology, just as sophisticated as those in large enterprises. Most of the enterprises initially gained technological expertise on the basis of externally acquired know-how. Among the most important continuing sources of external technical information was feedback from users and suppliers (Dodgson and Rothwell, 1989).

Hauschildt in dealing with 'the acquisition, processing and transfer of knowledge of a new quality' produced a classification model of the numerous informational relationships involved in innovations. According to this model, the innovative system, i.e., the enterprise in that study, was at the center of numerous informational relations such as markets, scientific systems, public authorities, and mediating parties. In that model each of the above-mentioned groups is either a sender or a recipient within the network and any one of the parties may initiate this informational relation. The innovation processes cover all stages from the discovery and development of a new product or technique up to its diffusion into the economy and are considered to be information processes, that is processes in which knowledge is acquired, processed, and transferred (Hauschildt, 1992: 105-106).

Another study examined the determinants and performance impacts of external technology acquisition and concluded with the suggestion "…that firm performance is negatively impacted by…" such acquisition" (Jones, et al, 2000: 277).

From these studies and initial pilot interviewing the belief was formed that linkages to various external knowledge sources would likely be of importance in software development processes. In order to investigate the involvement of various knowledge sources/actors during the s/w projects studied a table containing actors in row positions was set up. Types of actors investigated by both Hauschildt (1992) and Tidd and Trewhella (1997: 362-367) were included. Four phases of a development process were used as column headings in an effort to simplify the idea plus five stages given by Cooper (1990) for the stage-gate system. The result was the following Table 1 and responses as to the importance of the listed sources/actors in each of the four phases of idea, go decision, development, and commercialization were taken from the interviewees on five point Likert scales. Data on the types and lengths of the relationship were also gathered as shown.

There is general stress in the literature on s/w development regarding the importance of the customer during the creating process. Hauschildt (1992: 107), for example refers to the work of Gemünden from 1980 who found that the creator-customer interaction was important for both low and high aspiration level innovations. In the case of projects undertaken in response to a specific customer request it is of course the specific customer that is involved from the beginning. In the case of projects undertaken by a s/w firm to create a product for a particular market need it may be a lead user customer that is involved in early concept testing and in later beta testing.

Table 1. Product Development Process Phases and External Sources

Phases/Sources	*Idea phase*	*Decision phase*	*Develop-ment phase*	*Commer cialization phase*		*Type of relation-ship**	*Length of relation-ship (yrs)***
Markets:							
Customers							
Suppliers							
Hardware manufact:s							
Competitors							
Affiliated companies							
Other sources							
Scientific system:							
Universities							
Other research inst:s							
Other sources							
Public authorities:							
Patent offices							
As financial promoters							
Other sources							
Mediating party:							
Market consultants							
Technical consultants							
Business incubator							
Press							
Fairs/conferences							
Other parties							

Notes: * Relationships can be divided into: a - acquisition of companies; b – other looser forms of cooperation; c- acquisition of proprietary rights; d – recruitment of other employees; e – cooperation with customer; f – joint-ventures; g – licensing; h - recruitment of key managers; i - use of consultants and other temporary employees; j - others? Named:________________

Note: ** Total length of the company-to-company relationship with the particular actor including the project period.

In many cases, the customer has a perception of the problem they want the software to solve for them, but they cannot translate this into precise requirements. For example , the customer may not have thought out how the new software will interface with its existing systems. The developer then has only informal, very imprecise and fuzzy requirements to start with. These will given more structure and definition during the development process and of course have to be changed as more is learned about the requirements and what is technically possible and economically feasible.

The software development process must therefore be not only open-ended, but also transparent. Feedback from the customers becomes important not only in the idea phase but also in the design and development and the commercialization phases so as to align the end product to customer needs and wants as these are made explicit. The software development process, therefore, must be transparent and designed to allow visibility of what is being developed and allow communication between customer and developer, so that the developer continuously can receive feedback from the customers. In this way a software development project has more in common with an R&D-project, than it does with a typical tangible product development project.

It is normally expected that specific projects will have fewer linkages than does the company as a whole. However; this expectation depends on the relative size of the project to the company. In a small company of say 30 employees or less a large project could use nearly all of the existing linkages and generate some new ones as well. We have noticed that at the project level studied here some linkage patterns are as dense as those typically found at the company level for tangible products. This seems to be related to the all importance in s/w projects to know who can help solve problems once these are identified. Those persons who can contribute to the needed solutions are often known personally to members of the project team, but not to other company employees.

So while the software creation processes does involve close interactions with the customer(s) or user(s) it also involves a large number of other actors as indicated by Table 1 and some of these other actors could be of greater importance in the overall process. This led to the following hypothesis as a way to examine this aspect.

H3. The customer is the most important actor/source for the overall product creation process independently of the level of innovativeness.

The importance of any of the actors/sources could of course vary across the project phases. It would appear that customers, for example, would be of great importance to the decision, development, and commercialization phases, but is the importance nearly equal across these phases or does it vary considerably? The suppliers might be more important in the development phase than in the idea phase as another example. The development phase is where the main design and programming work is performed and where modifications are made to better fit the users' needs as these are sequentially discovered. It is of interest to find out who the most important actors are in this phase. Examination of the importance ratings across the various phases of the creation process, therefore, was seen as being of interest. To pursue this aspect another related hypothesis was set up.

H4. The importance of the customer in each of the four process phases is larger than the importance of all other sources/actors independent of the innovativeness level.

In this process competitors would likely be scanned in the beginning of a project to see what features might be considered for similar purposes and then at intervals through the remaining phases to make sure that the firm was not going to be bringing a second best product in to the market. This suggested the next hypothesis.

H5. The importance of competitors is relatively constant across the four process phases independent of innovativeness level.

There was insufficient guidance from the literature to form hypotheses regarding the other sources/actors.

3.3 Determination of innovativene ss

An initial issue was how should innovativeness in s/w products be determined. This raised the issue of what effects flowing from the interaction of the product with various parts of the firm and with the industry should be recognized for making this determination. Software innovativeness can be related to several aspects of the product such as its features and performance parameters, the impression of its newness on various market actors, the amount of marketing and technical knowledge that was generated during its creation, the novelty of its architectural structure, and the presence and content of its various modules. Some of these aspects have been used by a number of researchers to construct dichotomous, triadic, tetra or more categorization schemes (Garcia and Calantone, 2002: 117). Note; however, that 'architectural structure' used above does not refer to the forging of new market linkages with new technology through the creation of new industries or to the reformation of existing ones in the sense used by Abernathy and Clark (1985). This term is used herein to distinguish between software that is based on a new platform and one that is directed to a change within one or more modules of an existing architectural relationship.

A difficulty with nearly all of these categorization approaches is that terms such as radical, breakthrough, revolutionary, new-to-the-world, significant technical change, moderate, new generation, incremental, evolutionary, routine, etc. were fixed to the categories. This was for the purpose of providing a series of easy-to-understand labels. These different approaches can be, therefore, applied with conflicting results to various innovations (Garcia and Calantone, 2002: 122-123).

Various classifications have been used in the literature to evaluate levels of innovativeness. An early approach was a map created by Booz, Allen and Hamilton with dimensions of 'newness to the market' and 'newness to the company' along the two axes. Six categories were discerned varying from New-to-the-World to Cost Reduction projects. Kleinschmidt and Cooper (1991: 243) followed this approach in developing a triad innovativeness categorization in which physical products were classified as being:

- Highly innovative when new-to-the-world and ones that were innovatively new to the company's product lines.

- Moderately innovative when consisting of new-to-the firm lines, but ones where the products were not new to the market; and new items in the firm's existing product lines.

- Low innovativeness comprising all others such as modifications to existing products; redesigned products to achieve cost reductions; and repositionings.

The performance results of the physical product development processes studied were then shown to vary according to these three different levels of innovativeness. The results showed a U-shaped curve when moving from low through moderate to highly innovative products

(Kleinschmidt and Cooper, 1991: Figure 2, p. 245). This type of variation was found for ROI and the percentage of successful products in each of the three innovativeness categories as well as for various market performance measures. A possible reason for the variation found was advanced. This was that highly innovative products were not as risky as conventionally assumed. Such new products had features that permitted higher performance and once customers began to buy-in to these advantages profitability could be very good.

Most firms are very familiar with the low innovativeness products because these are close to the current product line variations. This means that cost saving measures can easily be taken to increase profitability. The moderate innovativeness products fall between these favorable conditions and so require special considerations and care. Some of this has to be learned anew because of lack of familiarity. The moderately innovative products showed lower results possibly due to these reasons. The reasoning for the variations found seems conceptually to apply to s/w products as well as to the tangible products of this earlier report.

In another study published two years later it was stated that the last product type included in the moderately innovative category had quite different success/failure results from the first included innovative products categorized as establishing new lines (Cooper and Kleinschmidt, 1993: 100-101). The last type, new items in existing product lines were much more successful (83%) than were the first type, 47%. While success/failure is quite a different measure than product and market performance measures, this finding suggests that if the 'new item in an existing product line' had been reassigned to the low innovativeness category the resulting U-shaped relationship might have been even more pronounced. This also tends to cast doubt on the practice of placing products into categories based on the relationship to new or existing product lines for innovativeness purposes.

Another theoretical treatment of pioneering vs. incremental product innovation defined the first category as "technological breakthroughs" and the second type as "product line extensions or modifications of existing products" (Abdul Ali, 1994: 48). This is a simpler approach; however it has the weakness of neglecting products that are substantially new, but are not 'breakthroughs'.

Yet another two-category approach of discontinuous vs. incremental innovations was used by de Brentani (2001: 171) in a study of new business services. As pointed out in that study there are two dimensions used to describe innovativeness: "…newness to the developing firm, to the outside world or to both of these." (see p. 170). Furthermore recent studies have focused on newness of the technology more broadly than just to the developing firm. Thus both technological and market perspectives have been taken into view. Also the factor of product superiority/quality that is based on competitive advantage conferred by virtue of its features and uniqueness has been used by Cooper (1992: 117) as have unique benefits to the customers by Veryzer (1998). Both of these relate to the inflection mid-portion of the relevant technological S-curve where the product performance is rising steeply (Jones et al, 2000: 260).

The above mentioned literature study and innovativeness typology by Garcia and Calantone (2002) sets forth a large number of other categorization approaches that will not be separately taken up.

A principal task in the present study was to decide how to define different innovativeness categories. Should the Booz, Allen and Hamilton and Kleinschmidt and Cooper approaches or a simpler two category approach such as Abdul Ali's and de Brentani be used. For a s/w development manager to determine whether a given product was new-to-the-world was seen as very difficult due to the fragmented nature of the industry. Very similar products may have been created, but not widely used and since the industry is global a valid response would depend on a comprehensive knowledge of several possible market segments that could be geographical dispersed. The same problem was foreseen with respect to new-to-the-market. Should the local, countrywide, EU-wide, or global market be taken in to focus?. Could the managers identify a recent product as one that was a 'technological breakthrough'? This series of doubts lead to another approach described below in sub-section 4.1, below, in which three innovativeness categories were set up in a manner similar to Kleinschmidt and Cooper (1991).

However; there is an important difference in this study. It was not deemed important to give labels to the various categories. Such labels would only lead to confusion both for the interviewees and for the readers. What we set out to do was to study the relationships of the other effects flowing from the creative processes illustrated in Figure 1 to the processes within the creative processes box. What was needed for this purpose was a continuum of innovativeness levels across the projects. Whether one was labeled 'radical' and another 'routine' was not of interest during the interviews. This then led to another approach wherein certain measures of selected effects associated with the products were used to construct an index so that a single measure of innovativeness could be produced for each product. This approach will be more fully described in subsection 4.1 below.

3.4 Firm business developmental effects flowing from s/w projects

Product development projects have a number of results other than the main one of creating a successful product within time and budget constraints. These results are seen as effects that have a range of impacts on the firm for future development projects and for longer term market success. It was believed to be of interest to investigate such effects as an extension of the success measure termed "impact on the company" that is a result of "the product's sales and profits" that was referred to by Cooper (1994: 62).

It can be said that the developmental effects focussed on here have the potential of aiding the firm to complete future projects by strengthening linkages to external actors, adding to retained knowledge, and/or increasing the firm's overall competitive position. In general, these are the 'other effects' that are mainly categorized in points 2, 3, and 7-9 of the effects list given in explanation of Figure 1 in the beginning of section 3. Such effects can range from the more traditional market performance measures used by Kleinschmidt and Cooper (1991: 245) to internal learning that is taken in from various projects. This point is supported by Hamel (1991) in his study of different learning patterns within joint ventures.

One issue that arises from the Kleinschmidt and Cooper report on performance measures varying with innovativeness is the concavity of the U-shape curves mentioned above. The average performance values for the low and high innovativeness products can be compared with the moderate category for the same measures by taking the percentages by which the moderate values are shown to be below those averages. For the ROI measure shown in Fig. 2 of the Kleinschmidt and Cooper report this percentage is 69%, a fairly deep concavity. The overall market performance success measure in Fig. 4 of that same report calculates to an 18% concavity. The range of these concavity percentages is from 13.1% to 69% in this earlier report and these measures will be referred to later on when testing the next hypothesis which is:

H6. Effects flowing from the development processes show a U-shaped variation when moving from low through moderate to highly innovative products.

A special category of effects flowing from s/w development projects is that the linkages to a number of sources/actors as shown in Table 1 are frequently changed due to the contacting and inter-working that occurs during the project. Strengthening of these linkages will likely help the firm carry out other projects in the future. This implies that some of the means used in the development processes should also be seen as having an effect property that is altered by the activity within the process. This then was another reason for the feedback arrow in Figure 1 above.

Another type of effect flowing from a given development project is that various types of knowledge are gained within the firm as a result of carrying out the associated tasks. Some of this knowledge comes through linkages to external sources/actors as above-mentioned and some is acquired through the team's internal learning. Torrisi (1998, 131) states that "As innovative activities require a wide range of know-how and capabilities, [software] firms cannot rely only on their internal competencies, but have to establish linkages with external sources of knowledge and expertise." This leads to an interesting distinction between general-purpose and context-specific knowledge that provide firms with different capacities (see, Ch.6, 140-144). General purpose skills are defined as those which "provide firms with absorptive capacity and ability to re-use local knowledge for different purposes, that is the ability to abstract knowledge from a specific context in order to allocate this knowledge to different uses." Context-specific skills are distinguished by providing " firms with the capacity to solve problems by way of trial-and-error, know-how, and experience."

General-purpose skills provide the firms with the ability to evaluate and absorb external knowledge. This, in turn, may favor the establishment of linkages to external sources of innovation, particularly to universities, research institutes, and consultants. Torrisi makes the point that skills in mathematics and computer science are good proxies of this type of capabilities in the s/w industry (see, p.142).

This distinction suggested that measuring both general-purpose and context-specific knowledge at the beginning and at the end of a given s/w project would be of interest to determine the change in capacities that is an effect of the specific s/w development process. To these were added knowledge on the market side and on the administrative side in an effort to measure more knowledge changes associated with a given project. Before and after measures on these four types of knowledge were taken and used to determine the knowledge accumulation that occurred in these four categories over the course of a given project.

Several other measures of knowledge accumulation were also taken and these will be explained further in the Effects sub-section 4.4 below. These considerations lead to the following conservative hypothesis based, in part, on a slightly modified schema taken from Torrisi:

H7. The knowledge accumulation in higher innovativeness products is equivalent to that in the medium and low innovativeness categories of products.

Also included within the evaluated developmental effects are those that have the potential to increase the firm's overall competitive position: such as enhancing its reputation so as to be seen favorably by future customers and of course making a profit. There seemed to be a basis in the literature for structuring a hypothesis for such developmental effects.

Thus, a broad hypothesis for effects, in general, was also evolved under the same conservative assumption that the level of innovativeness will have no influence on developmental effects.

H8. There are no more extensive internal company developmental effects for products with high innovativeness than for those of lower innovativeness.

3.5 Influence of firm size

Another aspect of this study was to look into the variation of innovativeness as a function of size of the company that created the software product. Abdul Ali (1994: 50) gave proposition P1 as follows after reviewing prior studies that offered evidence both ways as to a positive relationship between firm size and inventive effort:

> "P1. Introduction of pioneering products is more likely to increase with firm size."

However, one must consider that these earlier studies were based on tangible products created using physical scientific principles and engineering rather than virtual ones and that the s/w industry is in a stage of rapid change and is highly fragmented with low barriers to entry. This seems to mean that the risks of developing software are sufficiently low so that innovative projects can be undertaken by a large number of rather small-sized firms.

Another proposition set up by Abdul Ali is based on market structure considerations in order to predict the occurrence of pioneering versus incremental product innovations. The use of such a proposition depends upon having detailed information about the structure of the market that gave rise to the new product. The s/w market is so highly fragmented into numerous market segments that this approach was not seen as being of use for the present study. However, Abdul Ali's proposition P7. is still of interest for the same reason:

> "P7. In an industry where technology is changing very rapidly, different firms participating in that industry will more likely develop a stream of pioneering products than would a single firm creating a persistent monopoly." (Abdul Ali, 1994: 55)

So it seems possible that innovative new products could be created in a very wide range of firms. Also it has been concluded that firm size "does not show any significant effect on the propensity to search for external sources of technological change" (Torrisi, 1998: 140). A somewhat contrary conclusion was made by Cassiman and Veuglers (1998: 2) "that small firms are more likely to restrict their innovation strategy to an exclusive make or buy strategy, while large firms are more likely to combine both internal and external knowledge acquisition in their innovation strategy".

Another interesting study in this regard is one carried out on the radicalness of tangible product innovations in the food, paper, chemical, rubber, machinery and electrical equipment industries as a function of firm size (Ettlie and Rubenstein, 1987). The conclusion was that no discernable relationship between radicalness and firm size existed up to about 1,000 employees. At firm sizes between 1,000 to 11,000 employees there was a significant, direct relationship, but beyond that larger firm sizes inhibited the introduction of radically new products

Another point is that the complexity of s/w is rapidly increasing and this could discourage smaller firms from engaging in the creation of increasingly complicated products. Any treatment of issues related to firm size depends on what is meant by small or large firms. In the Ettlie and Rubenstein 1987 study based on tangible products about 27% of the firms were above 11,000 firm size whereas in the sample used in the present study only 17% were in this category. Firm sizes of 350 or less were about 48% in that earlier study versus 65% for the current study so the s/w firms in our sample are of course of smaller size. Firm sizes of less than 500 are considered to be small for various U.S. reporting and government fee purposes, but this figure has been based mainly on the earlier set of tangible product manufacturing companies. It seems that a much lower division point is called for when examining s/w firm sizes. Another break point in firm size is at a much lower number of 80 employees and the current sample contained 55% at and below this number. This low level encompasses firms that are run primarily by the start-up entrepreneurial team and also those that have brought in some business and financial managers. For analysis purposes we will take this size as the crude division between small and large companies.

After considering the above point it seemed that a more conservative approach to structuring another hypothesis was called for in this situation:

H9. S/w innovativeness is positively associated with larger-sized firms.

If a significant proportion of smaller sized firms are actually engaged in pressing forward with innovative products then this hypothesis will likely be rejected.

4. Descriptive Results

4.1 Partition of data according to innovativeness

Based on reported studies including those mentioned in sub-section 3.3, Determination of Innovativeness, and taking into account the likely low reliability of responses as to whether a given s/w product was 'new –to-the –world' or new-to-the- market' a slightly different method was used in this study. It was believed of importance to incorporate in the innovativeness dimension the several aspects mentioned in sub-section 3.3 in order to give a more comprehensive measure. These were: judgments as to the product's newness from the perspective of various market actors, its features and/or performance characteristics, its architectural structure, and the presence and content of its modules. The alternative would be to use only one or two of these aspects to represent an innovativeness dimension that would be less comprehensive.

One better approach seemed to be the collection of data on these various aspects and to then construct an index so that a comprehensive overview measure of innovativeness would be produced for each product. The aspect of features and performance relate to the technological S-curve by providing input as to how large an increase in product performance was obtained by the product created in a given project. This aspect can, perhaps, best be summarized by the concept of uniqueness of product benefits. The characteristic of architectural structure was handled by asking the interviewees whether the focal product was considered to have created a new platform. This question and others concerning the included modules were used to frame the scope of the innovativeness in terms of whether the product was considered to be a new product platform (implying that new architectural relationships were used) or to only contain new modules for an existing product that had already a defined architecture.

In order to capture these different aspects interview questions were constructed so as to permit an innovativeness index to be set up for each product. First, respondents were requested to respond on five-point Likert scales to provide indicators of the following four dimensions:

1. Newness to the company (1.1 to the project team, and 1.2 to company management).

2. Newness to the market (2.1 to the customers, and 2.2 to the competitors).

3. Uniqueness of product benefits (3.1 feature set difference over close prior developed product, and 3.2 product performance compared to closest available competitive product in the relevant market segment).

4. Scope of innovativeness (4.1 new product platform, or 4.2 new modules for an existing product).

An innovativeness index was then formulated using the scale of 1= minor differences to 5=major differences for the interviewee responses regarding each indicator. To do this a first set of mean values was determined for the first three dimensions and for the 4.1 and 4.2 indicators taken separately. The reason for this procedure was that it was necessary to evaluate the newness responses for the fourth dimension separately since many responses used the 4.1 and 4.2 indicators in an alternative manner. This permitted two other modified mean value sets to be determined: one for the mean values without the 4.1 values and another for the mean values without the 4.2 values. As the last step the mean of the above-mentioned first set of values and each of the two modified mean value sets was determined and used as an innovativeness (INN) index for the projects. This procedure of calculating multiple sets of mean values assured that the 4.1 and 4.2 indicators had the same weighting in the final index values and that the total value for dimension 4 did not exceed the average of these two measures. Calculated in this manner the projects ranged from a low index value of 1.000 to a high of 5.000.

Perhaps it should be mentioned here that dimension 1.2, newness to company management, was later found to be the most important factor included in the innovativeness index for explaining the number and importance of external linkages according to regression equations that are reported in a companion study (Segelod and Jordan 2002). This could be of interest to some readers since 'newness to the firm' is one of the measures used in former studies, but this apparently has not been divided into the management and project team sub-measures according to our reading of a recent literature analysis article (Garcia and Calantone, 2002). That former measure was, however, broken down into the two sub-measures of 'market know-how and 'technology know-how' according to this article (see p. 124) which might provide close to the same sub-measures as those we used.

The case data table was then divided into three sub-samples of data: those with low, medium and high, innovativeness levels. Determining the indice values at which to separate these three categories required careful consideration. The literature contains many opinions about categorization of innovativeness as mentioned in section 3.3 above. One of the latest studies is a literature review that concluded that "in a random sample, radical innovations are rare and should [be] not account for more that 20% of the sample," and that "likewise, incremental innovations should account for no less that 20% of the sample." (Garcia and Calantone, 2002: 120). These conclusions were based in part on the use of 30% for highly innovative, 47% for moderately innovative, and 23% for low innovativeness products in the earlier Kleinschmidt and Cooper study (1991). This means that the 1991 study was later judged to have included somewhat too many products in the first category.

This and other associated literature provided some limits to keep in mind but could not be relied upon in the present study. Rather than divide the sample numerically into sub-samples the cases were examined for likely break points by reviewing the data regarding innovativeness. This was approached in the following manner.

Work with an innovativeness index began before all of the interviews had been completed. The data from the first 82% of the cases was checked against reported statements as to the extent of innovativeness. In each case the general statements seemed consistent with the innovativeness measures obtained. Next several different ways to construct an index based on the above four dimensions were investigated. Differences in category classification were found for 22 of these cases depending on the formulation of the index. The data was re-examined again for consistency and this lead to use of the above described index formulation.

The later examination of the innovativeness measures in the full 94 cases showed two possible breakpoints for the low to medium categories between 3.1 to 3.3 and for the medium to high between 4.0 to 4.3. The cases were first divided along the limits of low = or < 3.1, medium between 3.1 to < 4.1 and high = or > than 4.1. Then a second division using the limits of low = or < 3.3, medium > 3.3 to < 4.10, and high = or > 4.10 was taken. The two cases that changed from low to medium were reviewed with the result that these were determined to be better categorized in the medium range so the higher limit of 3.3 was used for the low to medium limit.

As to the medium-high limit there were 18 values in the 4.00 to 4.3 interval all of which were regarded after review as showing medium innovativeness. In each of these cases there was at least one evaluation parameter that raised doubt as to its inclusion into the high category. For this reason the second breakpoint of 4.3 was used for medium to high division. On this basis twenty-six (26) cases were assigned to the low innovativeness category, forty-five (45) to medium innovativeness and twenty-three (23) to high innovativeness. Summary results are given in Table 2 below.

The purpose of constructing the index was to provide a tool for analyzing the developmental effect variables across a range of innovativeness. In the pursuit of this purpose the exact formulation of the index is considered to be of lesser importance.

Table 2. Summary of Project Innovativeness Indices

Innovativeness Level	*INN indices selection ranges*	*Range of INN indices*	*Number of Projects*	*Percentage*
Low	= or < 3.30	1.0000 to 3.2500	26	27.7 %
Medium	>3.30 to < 4.30	3.3056 to 4.2778	45	47.9
High	= or > 4.30	4.3000 to 5.0000	23	24.5

A comparison of the percentages in this study with earlier divisions may be of interest:

	<u>Low</u>	<u>Medium</u>	<u>High</u>
Kleinschmidt and Cooper (1991)	23%	47%	30%
Garcia and Calantone (2002)	>20	balance	<20
Present study	27.7	47.9	24.5

The sub-sample sizes established for this study are close to the above two comparisons and as such show general conformity to the literature. Of perhaps greater interest is to look into examples of these three sub-sample categories that were broken out herein.

Examples of these three innovativeness categories may be of interest here:

Low level – Abobase System is located in Tallinn Estonia and is associated with Oracle and Hewlett-Packard. The focal product, RL-2002.2 was a customized program created for the Statistical Office of Estonia (SOE) that was designed for processing population census data. It converts handwritten data from paper to digital format, searches for logic errors and corrects them, creates databases and delivers reports in the form demanded by the user. The development process was carried out by a team of 7 (that changed in composition so that a total of 15 persons were involved) requiring 65 man-months. Customers were rated as the most important external actor with suppliers, and hardware manufacturers (due to licensing) being of lower importance depending on the particular phase. Competitors were only of low importance in the first two phases and affiliates were not rated as being of importance in the process. The program was given mainly low to medium newness ratings for both the company and the competitor (dimensions 1 and 2). Only the customer had the highest newness rating. Dimension 3 ratings for feature differences and performance gain were in the same low to medium range. For dimension 4 the program was given the lowest rating with only an Oracle storage module mentioned as being new. The innovativeness index was determined to be 2.528, a relatively low measure.

Medium level - Ivy Learning Software is an U.K. company that creates educational software for subject matter such as DOS to Windows, multimedia to internet materials. Topic areas cover people and communication skills, health and safety, finance for non-financial people, operations management, strategy and planning, and languages, etc. The focal project was to create a program for delivering existing computer based learning courses via the internet so that customers can access the programs on intranets and directly from the internet. The development process was carried out by a team of 7 requiring 56 man-months. Competitors were very important information sources in the idea phase, particularly at fairs and conferences, and also in the decision and commercialization phases. Customers were rated as very important in the decision and commercialization phases. Technical consultants were of importance in the development and commercialization phases. Other external actors/sources were regarded as not important. The program was given medium newness ratings for both the project team and company management (dimensions 1), but newness for the customers and competitors (dimension 2 for the market) were rated as very high. Dimension 3 ratings for feature differences and product performance gain were low to medium. For dimension 4 the program was given the highest rating as a new platform, but only medium as to newness of included modules. The innovativeness index was calculated to be 3.650, a medium level measure.

High level – X-Hive is a software company located in Rotterdam, The Netherlands that has created a native XML database program. This X-Hive/DB product "enables developers of XML applications to store, search, and retrieve XML documents in a fast and scalable manner" (X-Hive website, 2002). The product permits the location and retrieval of the smallest element within large quantities of data and provides a foundation for mission critical applications and large volume XML data environments. Storage and retrieval was made more robust than in the traditional XML, which permitted storing data as only tabular or text files. The development process was carried out by a team of 20 requiring 150 man-months and entailed close inter-working relationships with a lead customer and several cooperation partners. These relationships were seen as large success factors when viewed in retrospect. The program was given the highest newness ratings for both the company and the market (dimensions 1 and 2). Dimension 3 ratings were given as slightly lower. For dimension 4 the program was rated as a totally new platform that contained a totally new native XML storage module. Thus the innovativeness index was calculated to be 4.722, a relatively high measure.

4.2 Product development processes used

The second analysis phase was to determine summary statistics for the types of processes commented on above in section 3.1 that were used for the projects. These various types of processes were taken from the literature as an initial basis for studying basic software development processes. The interview protocol provided for responses as to usage of these basic process types and for ‘other models’. The first objective was to obtain information as to the usage of the earlier hacker approach, and of the stage-gate and waterfall models and to determine the extent of usage for the prototyping models. We were interested to learn about the usage of these various software process models with respect to: a. size of company, b. team size, c. project size and d. level of innovativeness. Do the small companies tend to use the simplest process models and the largest companies tend to use the more complex ones?

Our objectives in this regard were not as comprehensive as for earlier studies directed primarily toward the investigation of software process usage or of systems development methodologies usage (Fitzgerald, 1998) and therefore the findings in this section 4.2 are not considered to be directly comparable to such studies. We did not attempt to investigate the usage of “formalised systems development methodologies” that are comprehensively reported by Fitzgerald (1998: 321).

The number of firms using the various models/approaches together the averages for the usage of each process type are given in columns A. and B. of Table 3. Firm size was investigated by collecting data on: 1. the number of total firm employees, and 2. the number of employees in the country in which the project was carried out as shown in columns C., D. and E. Team size was evaluated according to the number of members who worked on the project (column F.) and then the ratio of this number divided by the number of employees in the country in which the project was carried out (column H.). Project size was evaluated in terms of man-months expended (column G.) and then by two ratios of the project size divided by the number of total firm employees (column J) and of the project size divided by the number of employees in the country in which the project was carried out (column K.). The last column, L., is for the mean and range of innovativeness index values for each process type. As shown, columns C. and D. - L. give the averages for the process types listed as 1 to 10 in the left-hand column.

The process types used were identified for all 94 projects. The responses for the hacker approach (1) seemed to indicate that no recognizable process methodology had been used. In some cases the type of process used was not clearly identifiable by the respondent among the alternatives presented in the protocol. However; the procedure of using a step-wise process such as the stage-gate or the more usual waterfall method was familiar to most respondents once an explanation was given. In other cases proprietary or customized models had been used and information regarding these was gathered.

Initially it was assumed that only one type of process would be used in any given project; however, the data showed several interesting points in this regard. The first is that there were 36 projects out of the sample of 94 that used a mix of the processes (type 9) for a presence of 38.3 %. Thus the use of a mixture of models was unexpectedly found to have the highest frequency of use. The second point was that 10.6% used proprietary and customized models that contain steps and procedural sequences also found in other models. So the use of mixed models can be said to be about 50% in this sample. The reason may be that systems designers and program managers prefer to draw in different aspects of the various processes at various stages of the work depending on their judgment as to utility for specific purposes. The judgment to know when to draw on different process types is of course refined by experience and is part of the reason for the critical importance of system designers and program managers. This also gives support to the view that software programming is a creative endeavor that has characteristics close to artistry (Stolterman, 1992).

A second interesting finding was that the waterfall model (2) was used exclusively for 15 of the projects or 16.0 % for the second highest frequency. Proprietary and customized models (10) were in third place at 10.6% and then the Rational Unified Process at 8.5%.

Table 3. Types of Development Processes Used

Process type	*A. Number of firms*	*B. Usage, within 94 cases, %*	*C. Average number of total firm employees §*	*D. Range of total firm employees §§*	*E. Ave. employees in county of project*	*F. Ave. Team Size*	*G. Ave. Project Size, man-months*	*H. Ave. of team size/ employees in county of project*	*J. Ave. Project size/total firm employees*	*K. Ave. Project size/ employees in country*	*L. INN Index values Average Range*
1.Hacker approach	4	4.3	3.5	1 to 6	2.75	4.0	97.75	2.420	34.96	37.20	3.53 3.00-4.18
2. Waterfall	15	16.0	218[1]	24 to 88,500	106.86[7]	9.7	146.60	0.209[12]	1.99[14]	2.18[19]	3.28 1.81-4.72
3. Incremental	7	7.4	30	5 to 55	27.00	3.3	67.80[10]	0.234	3.74[15]	4.42[20]	3.58 1.97-4.27
4. Evolutionary	7	7.4	248[2]	8 to 17,067	85.57	8.6	39.86 [11]	0.310	2.02	2.30	3.50 1.81-5.00
5. Spiral	2	2.1	1,025	50 to 2,000	505.00	20.0	732.00	1.010	14.40	72.01	2.56 1.00-4.12
6. Sync-and-stabilize (Microsoft type)	2	2.1	386	9 to 763	386.00	5.0	64.00	0.336	6.72	6.72	3.81 3.48-4.14
7. Rational Unified Process	8	8.5	34[3]	10 to 11,058	31.14[8]	15.3	343.25	0.396[13]	9.39[16]	11.32[21]	4.17 3.65-5.00
8. Stage-gate	3	3.2	400[4]	130 to 11,500	3,450.00	12.3	460.00	0.007	0.41	0.156	3.49 2.77-4.40
9. Mixed models	36	38.3	6,131.6[5]	3 to 200,000	5127.90	15.1	260.65	0.438	3.62[17]	3.316[22]	3.94 2.28-5.00
10. Proprietary & Customized models	10	10.6	1,397[6]	10 to 316,303	476.50[9]	30.3	361.26	0.167	0.36[18]	0.585[23]	3.38 2.44-4.83

§ Averages were computed after dropping out the few cases that had values more than one order of magnitude smaller or larger than the closest remaining cases in order to give a more accurate assessment of the average firm size using the particular process type as noted below. In addition a few case of special consideration values were dropped as being too much larger than the remaining ones also as noted.

§§ The full ranges of total company employee totals are given.

Notes:

1. Computed without two cases with employee sizes of 19,200 and 88,500.
2. Computed without one employee size of 17,067.
3. Computed without one employee size of 10,000.
4. Computed without one employee size of 11,500.
5. Computed without eight cases of employee sizes of 90,000 to 200,000 as a special consideration. The average across all projects was 30,368 employees.
6. Computed without two cases with employee sizes of 100,000 and 316,303.
7. Computed without one in-country employee size of 50,000.

8. Computed without one in-country employee size of 5,000
9. Computed without one in-country employee size of 40,000.
10. Computed without one project size of 2 man-months.
11. Computed without one project size of 1,500 man-months.
12. Computed without one value of 0.0002.
13. Computed without one value of 0.01.
14. Computed without two values of 0.001.
15. Computed without one value of 0.04.
16. Computed without two values of 0.257 and 0.041.
17. Computed without inclusion of the same values as dropped from column C for this model plus one value of 48.
18. Computed without one value of 24.
19. Computed without one value of 0.002.
20. Computed without one value of 0.04.
21. Computed without two values of 0.257 and 0.09.
22. Computed without inclusion of one value of 48.
23. Computed without inclusion of one value of 24.

The lowest usages were found for the hacker approach (1), spiral (5), sync-and-stabilize (6), and stage-gate that were 4.3 % or lower. Other analyses of Table 3 are organized in the following sub-sections.

Process usage according to firm size - As raised by hypothesis H2 it was also of interest to determine whether there is a relationship between the company size and the process type used. To pursue this relationship the results shown in columns C. - E. were calculated. Based on column D, it can be said that all the processes except for the hacker approach and incremental type were used across a range of small to large company sizes. The use of these two types extended from the single one-man company in the sample up to 55 employees. A mid-size range extended on up to some 17,000 employees used the evolutionary, spiral, sync-and-stabilize, Rational Unified, and stage-gate processes. The size ranges of firms for the spiral, sync-and-stabilize, and stage-gate processes can not be relied upon due to the small sample sizes; however. The three processes that were used by the widest range of firm sizes were the waterfall and the last two, mixed models and proprietary & customized models.

There were 11 companies with total employee sizes in the range of 88,500 to 200,000 and 8 of these used the mixed models type for the project studied. Two of these large companies used the proprietary & mixed models and one used the waterfall.

The data for number of employees in the country of the project (Column E.) did not change these general findings. It should, however, be pointed out that the high average in-country employee figure for stage-gate is unreliably based on only three cases, one of which had 11,500 employees. Also the evolutionary process shows a much lower in-country employee average than for the total employees in the firm. This means that this process tended to be favored for use by small national units of larger multinationals.

Process usage according to team size – Column F data shows three levels of usage by team size. Small teams (1 to 7 members) were found for the hacker, incremental and, surprisingly, for the sync-and-stabilize, but the first and last of these were unreliable due to the small number of cases. The mid-size teams (8 to 15) can then be distinguished from the large team sizes (20 and 30 members) for the spiral and proprietary & customized models, that were rather expected results.

Column H gives the averages of team size divided by the number of employees in the country in which the project was carried out and is a measure of how large the team is with respect to the in-country size of the firm. An average above 1.00 indicates that the companies using a given process tended to draw-in outside resource persons for work on the project. The average of 2.420 for the hacker process type was caused by one of the firms that used 3 outside persons to supplement the small company size of 4 persons for doing the project. A more typical average value is that shown by the waterfall model (2) wherein the figure of 0.209 showed that on average about one-fifth of the in- country staff worked on the project. The mixed models (9) showed that nearly one-half of the in-country employees were engaged in the projects, on average. This seemed to mean that the projects in which this model was used were of large size. And this was indeed found as commented below.

Process usage according to project size – Focussing on those process types with 7 or more observations the following is seen in column G. A lower project average size range of some 40 to 147 man-months is shown for the waterfall, incremental, and evolutionary models. Then a higher range of 261 to 732 is shown for the Rational Unified, mixed, and proprietary & customized models. These last three models seemed to be preferred for the larger sized projects.

Columns J. and K. show the project sizes divided first by the total firm number of employees and then by the number of employees in the project country, respectively. Projects that are large compared to the number of available internal employees have high values as shown for the hacker and spiral processes, however, these as well as the models 6, and 8 have unreliably few observations.

The differences between the columns J and K values for the last two process types were also of interest. The project sizes for the mixed models compared to the two measures of firm size tended to be an order of magnitude higher than for the proprietary & customized models. These higher values for the mixed models reflect primarily the usage of these models by smaller sized firms for carrying out large projects. The most extreme case was a 144 man-month project completed by a three person firm size for a 48 value in both column K and J. This one was removed before computing the average shown due to its distortion effect. The next largest was a 400 man-month project carried out by a 22 person firm for an 18.18 value. For comparison the highest retained values among the last process type were around 2. These computed values can not be seen by an examination of the averages given in Table 3.

Process usage according to innovativeness level - As shown in column L, process types 7 and 9 had high average innovativeness indices. This means that the usage of the Rational Unified Process and of mixed models tend to be associated with higher innovativeness products and hence can be recommended for projects that are foreseen as more innovatively challenging. The Rational Unified Process average of 4.17 put its usage in the high-medium innovativeness category while the mixed models average of 3.94 puts this one more in the medium innovativeness range.

The wide index ranges show that all process types except the hacker approach and sync-and-stabilize model have been used across a broad spectrum of innovative projects with the exception that the Rational Unified Process shows usage in a higher innovativeness range of products. The responses for use of the stage-gate model have been interpreted in the generic sense that the process used was mainly linear and subject to checks at gate points or milestones. The hacker approach (1), spiral (5), sync-and-stabilize (6), and stage-gate (8) process types all show extremely limited usage in this sample so no general conclusions can be drawn. However; as shown by Table 4, below, these are used as part of mixed process types in those 36 cases.

The proprietary and custom models (10) found were: Merise, Pace, MS Team, MS Development Life Cycle, Oracle case method, PROP (by Ericsson), Interactive Consulting, Engagement, two instances of internally customized models, and one of 'prototyping' that appears to be similar to items 3-6 in Table 3.

Perhaps it should be mentioned that the low average innovativeness index value for the spiral model (5) was surprising, but could be largely due to one of the two projects that had an index value of 1.00, hence this average is considered to be unreliable.

Summary of process models usage - It appears from the Table 3 data that the last two process types are used by the largest companies and for larger sizes of projects. Companies with total employee sizes of 90,000 to 200,000 used mixed models or proprietary & mixed models types. As to project size, the averages of the ratios of the project size to either of the two measures of firm size (columns J and K) is higher for the use of mixed models. So even small sized firms undertake large projects using such mixed models. The largest sized teams tend to prefer use of the proprietary & customized models. The highest innovativeness products tended to result from use of the Rational Unified Process and mixed models.

4.3 Analysis of mixed model category

Since the mixed models category was so large a closer look was taken to determine more about its characteristics. Table 4 gives the number of uses found for each process type within these mixes. There were 28 projects that mixed two models, 6 that mixed three models, and one project each that mixed four or five process types.

The most popular component type for the mixed type category is the waterfall process. This may occur because it can be used for the development of smaller parts (modules) of a complex product once the specifications have been set. Another usage of the waterfall model found is that it can be employed sequentially to produce prototypes of the software product *in seriatim* or as one interviewee put it:

> "We used a waterfall model, but corrected in an evolutionary way."

Process types 2, 3, and 4 were frequently involved in mixed models, in pairs, with 7 instances of waterfall mixed only with evolutionary and 5 instances of waterfall mixed only with incremental. There were only two instances of evolutionary mixed only with incremental.

Table 4. Mixed Process Model Usage of Basic Types

Process type	*Number of usages among 36 mixed models*	*Usage, %*
1.Hacker approach	8	9.3
2. Waterfall	19	22.0
3. Incremental	14	16.2
4. Evolutionary	13	15.1
5. Spiral	11	12.8
6. Sync-and-stabilize (Microsoft type)	4	4.7
7. Rational Unified Process	6	7.0
8. Stage-gate	6	7.0
Other mixed models	5*	5.8

Note: * One instance of V-cycle, two of Projacs (an evolutionary plus incremental process type similar to MS Project), one of Oracle case method, and one of prototyping. For one case a mixed customized RUP and Tollgate (Ericsson) was classified under the RUP (7) category.

When the number of mixed usages of the hacker approach are added to those of the exclusive uses in Table 3 the percentage of usage amounts to 13.6 % and for the waterfall the total usage percentage is 36 % when the mixed use cases are each counted as a single instance.

This data then supports the rejection of hypothesis H1 as to nonuse of the waterfall process, notwithstanding that some responses could have been for sequential usage in the same project so that prototype products were produced. This H1 hypothesis was:

H1. Significant percentages of software project teams do not actually use the hacker approach or the waterfall model for product development.

The hacker percentage total use of 13.6 % comes almost entirely from the mixed category (4.3 % using only hacker) so affirmation of the H1 hypothesis as to that hacker approach is supported.

It is of interest to reflect on the presence of prototyping in the use of the various process types. The hacker approach, the waterfall, and stage-gate do not usually have the production of sequential prototypes as an objective. So exclusive usage of those types would logically be more applicable to lower innovativeness products in which the operating parameters could be fixed at the start of a project with greater certainty. The mean of the average INN Indices for those three types is 3.43 whereas the mean of the averages for the remaining types that all encompass prototyping (except for the low spiral value that is regarded as unreliable) is 3.73. This difference of 0.30 does not support a conclusion, but may show a tendency to favor a process type that includes prototyping when higher innovativeness products are to be produced.

In order to check further on such a tendency these mixed process types were checked to find the number that used only a mix of the three above process types that do not involve the use of prototyping. There was one project that used only the hacker and waterfall processes. There were no instances of the other two possible pairs and none of the three used together.

The Table 3 data also permits hypothesis H2 to be rejected as formulated. This was:

H2. Large sized companies, measured as number of employees, use more complex process types in a given project.

A wide range of company sizes (24 to 88,500 employees) reported the use of the waterfall model that is considered to be a simple model. Also the incremental, evolutionary, and sync-and-stabilize models are used by even smaller sized companies. So it is possible to conclude that not all large companies use the more complex processes in their projects. Only in the case of the hacker approach was one of the process types in Table 3 found to be restricted to use by very small sized companies. This means that some of the more complex development process types are used across a wide range of company sizes that include small-sized ones.

Another point of interest in this data is that the percentage usage for prototyping processes is 75.5% which was determined by subtracting the non-prototyping process usage figures from the remaining ones in Table 3 less the one mixed case mentioned above that used two of the non-prototyping processes together. This then was just over the range of 57% to 75% given by Fitzgerald (1998: 324) for not using formalised methodologies and for using such methodologies, respectively. This indicates that a strong majority of software processes are carried out with prototyping methods.

4.4 Results from external linkages during s/w processes

As stated above in sub-section 3.2 an interesting set of characteristics of product development processes comes from the linkages between the project teams and external sources/actors. For this reason the means of the importance totals obtained for the three categories of low, medium, and high innovativeness are given in Table 5 for the development process as a whole. The theoretical maximum value for each cell is 20 since each of the four phases could be given a rating of 5. For the purpose of interpretation, ratings of 8.5 and above are considered to be of greater importance and have been shown in bold type.

The first objective here is to describe the general patterns found for the various actors/sources with respect to the three innovativeness categories. The patterns were regarded as being of interest in themselves and have been taken up first before reporting on the statistical significance of the compared mean values

Table 5. Means of the Importance Totals for Linkage Sources §

Sources used in development process	*Mean of mean importance values in the development process*			
	Low Innov.	*Medium Innov.*	*High Innov.*	*Difference between High and Low mean values*
Markets:				
Customers	**13.360**	**13.895**	**14.500**	1.140
Suppliers	8.063	7.759	7.467	- 0.596
Hardware manufacturers	6.917	7.174	7.529	0.612
Competitors	6.950	7.472	7.563	0.613
Affiliated companies	**9.385**	**9.083**	**11.875**	2.490
Markets mean	**8.935**	**9.077**	**9.787**	0.852
Scientific system:				
Universities	5.714	5.500	**9.364**	3.650
Other research institutes	6.667	6.429	**10.500**	3.833
Scient. Sys. Mean	6.191	5.965	**9.932**	3.741
Public authorities:				
Patent offices	5.800	6.471	**9.571**	3.771
As financial promoters	5.857	7.167	**8.800**	2.943
Public Auth. Mean	5.829	6.819	**9.186**	3.357
Mediating party:				
Market consultants	7.546	**8.556**	**9.000**	1.454
Technical consultants	7.333	7.982	**9.167**	1.834
Press	7.267	7.071	8.462	1.195
Fairs/conferences	7.714	8.480	**9.667**	1.953
Mediating Party mean	7.465	8.022	**9.074**	1.609

Note: § This table shows the means of the importance totals for each linkage source across the entire development process separated by low, medium and high Innovation projects.

The most important external actor in the overall s/w development process appeared to be the customer since mean importance values above 13 were found in each of the three innovativeness categories. Affiliate companies were also of high importance across the three innovativeness categories due to the high mean values found, and particularly for the high innovativeness category. This brought into focus, for the high innovativeness column, the universities, other research institutes, patent office, government financial promoters, marketing and technical consultants, and fairs/conferences all of which had means of importance totals above 8.5. These linkages were of greater importance to the high innovativeness category than for the two lower innovativeness categories. Dealing with greater technical complexity tended to emphasize these actor types, except perhaps for the fairs/conferences, but then once a high innovativeness product has been released it would often be in the firm's interest to show it widely in public meetings.

The column on the right-hand side of Table 5 shows the differences between the high and low innovativeness mean importance totals. These differences are all positive and range from 0.612 to 3.833, except for the negative value for suppliers. In general, this shows a pattern of the external actors being of greater importance for the high innovativeness category. Cooperating with external actors when creating high innovativeness products seems to mean that greater importance has been given to external linkages due to the greater technical and marketing challenges. The Scientific systems and Public Authorities actor types were also of particularly large importance for the high innovativeness category as shown by the differences of greater than 2.9 in this right-hand column.

Suppliers were the class of external actors that provide hardware, standardized business software, and office necessities to these firms. They could also supply standardized modules such as thesaurus programs for spell checking, but they do not usually provide solutions to the problems that confront the project teams. This means that their contributions are not seen as helping to overcome the more complex problems. Rather it is the customers and, particularly, the affiliate firms that provide inputs as the complexity of solutions and, hence, innovativeness increases. This is reflected in the successively lower importance values for suppliers when moving across the columns in Table 5.

The general pattern of increasing importance is not uniformly stepped when moving from low to high innovativeness. Those actors/sources that show lower than expected importance values in the medium innovativeness category are affiliate companies, universities, other research institutes, and press. None of the actors/sources show higher than expected medium category values. Also none of the medium values are greater than for the corresponding high innovativeness values except for the above commented suppliers. This means that the general pattern is somewhat more varied than what can be predicted simply from the low and high categories.

The pattern of the external actors being of greater importance for the high innovativeness category can also be clearly seen in the mean values given in the last row in each of the four sections of Table 5. In each section the high innovativeness column shows the highest mean value. Compared to the low innovativeness mean values those of the high category are 0.852 (markets mean) to 3.741 (scientific system) higher. While stepped increases in the mean values across the three innovativeness categories were found in all but the above five line items, the comparison between in the high and low categories tends to support the view that cooperation arrangements are associated with firms that innovate significantly more. This view has been earlier advanced by Sandven:

> "[o]ne of the most robust results from recent European surveys on innovation is that firms which are involved in formal cooperation arrangements tend to innovate significantly more: they have much higher shares of new products in their sales profiles than firms which do not undertake collaborative R&D or technology development." (Sandven, 1996: 3, referring to European Commission, Green Paper on Innovation, Bulletin of the European Union Supplement 5/95, Table 22, p. 92)

Technical linkages have been shown to be highest in emerging and dynamic industries, and Hagedoorn (1993) points out the computer software industry as the best example of an industry to which firms external knowledge acquisition is especially important.

These comments as to the general pattern seen in Table 5 require some modification when the statistically significance of the differences in the means are taken into consideration. The data treatment was to first determine whether the data was normally distributed. For this purpose Anderson-Darling statistics were run on all of the distributions of the means. A majority of the underlying distributions for Table 5 were found to be normal so that t-Tests could be used for comparison of the means. For comparisons wherein one or both of the distributions were found to be non-normal Mann-Whitney nonparametric statistics were run to determine significance.

For the comparisons made vertically within each column between the customers and each other actor/source significant differences were found at several levels, but not for each of the actors/sources, while for the comparisons across the innovativeness categories significant differences were, in general, not found.

The statistical testing carried out in conjunction with Tables 5 permits Hypothesis 3 to be answered. It was:

H3. The customer is the most important actor/source for the overall product creation process independently of the level of innovativeness.

In the low and medium innovativeness categories the largest sum of the importance ratings was found to be for the customer and this sum was significantly different from each of the other actors/sources at $p < 0.05$. For the high category there was a first level of importance occupied by the customers, affiliates, and other research institutes. The t-statistics were all above the test limits for particular degrees of freedom in the case of the normally distributed data and the Mann-Whitney significance levels were at $p < 0.01$. This shows that the customer were the most important of the actors/sources investigated only for the first two innovativeness categories. As a consequence of this result H3 can be rejected because in the high category the customer is at the same level of importance as two of the other actors/sources.

This result is considered to raise a caution with respect to software creation processes for the finding of Gemünden that was referred to by Hauschildt (1992, 107) to the effect that the creator-customer interaction was important for both low and high levels of aspiration toward innovations. The differences between the high and low innovativeness categories shown in the right-hand column are not statistically significant except for the patent offices under Public Authorities. The distributions of the high and low categories importance ratings overlap too closely for the other actors/sources when compared to the customers. For such overlapping distributions much larger sample sizes would be needed to show statistical significance, but the general pattern of all positive differences between the high and low innovativeness categories is still believed to constitute an interesting indication.

Perhaps it should be re-iterated that Table 5 is based on the mean values of the sums of the ratings obtained during the interviews across the four phases of the total development process. Also the 'other sources and parties' and 'business incubator' row entries shown in Table1 have been dropped out due to the small number of data points.

The data shown was further analyzed to find the pattern of usage of the actors/sources as determined by the significant differences in the means within each of the innovativeness categories. The pattern of usage varies across the three innovativeness categories as shown in Table 6. Each pattern starts with a first level initiated by the all-important customer linkage, but quickly varies.

First, the layout of Table 6 needs to be explained. The actors/sources are shown in descending order of the means given in Table 5. Each distribution of the means was compared for statistical significance against the next lowest distribution with either t-tests or Mann-Whitney depending upon the normality of the distributions. The levels (1,2,3) were set up according to the statistical significance of the differences in the means in Table 5. When a significant difference between two compared means was found the actor/source having the lower mean was used to start the next grouping class. The mean of that actor/source was then used as the higher mean value in the comparisons made until the next significant difference appeared at which point the next level was set up. Thus by checking the statistical

Table 6. Usage Patterns for Actors/Sources in Table 5

Level	Initiating Actor	Connected Actor	Statistical Significance
Low Category Innovativeness			
1	Customer	- Affiliate	s
2	Affiliate	- supplier - fairs/conferences - market consultants - tech. consultant - press - competitors - hardware manufacturers - other research instit.	ns
		- govt. finances	s
3	Gov't finances	- Patent office - universities	ns
Medium Category			
1	Customer	- affiliate	s
2	Affiliate	- market consultant - fairs/conferences - tech. Consultant	ns
		- suppliers	s
3	Suppliers	- competitors - hardware manufacturers - Gov. finances - press - patent offices - other research instit.	ns
		- universities	s
High Category			
1	Customer	- Affiliate - other research instit.	ns
		- fairs/conferences	s
2	Fairs/conferences	- Patent office - universities - tech. consultant - market consultants - govt. finances - press - competitors - hardware manufacturers - supplier	ns

significance in descending order the breakpoints for starting each new level was determined. This procedure permitted the actor/source levels to be seen as sets that have similar importance to the project teams during the s/w creation processes.

Within each level in Table 6 the differences between the means are shown as the higher mean minus the lower mean, for example, in the lower category level 1 that reads customer (mean) – affiliate (mean) and was found to have a statistically significant difference at $p < 0.05$. Statistical significance is denoted 's' and non-significance by 'ns'.

This type of presentation then means that the customer is alone in level 1 for the low and medium categories, and shares this first grouping class with affiliates and other research institutes only in the high innovativeness category.

In the low and medium categories the affiliates start level 2 of the linkages. Within this second level the differences in the means are not significantly different; therefore these can be seen as a closely related set of linkages during the product development process.

However; in the high category affiliates and other research institutes are also in this first level together with customers indicating the importance of these actors/sources when the innovativeness stakes are larger. This finding has also to be understood from the standpoint of frequency of usage of the linkages to affiliates and other research institutes. The first of these were used in about one-third of the high category cases and the latter were used in about one-fourth of the high category cases. This means that when these two actors/sources were involved in a high innovativeness product creation process they had average importance values that were as significant as were the customers. However; there were many other high innovativeness products that were created without involvement of these two actors/sources.

In this high innovativeness category, level 2 starts with fairs/conferences and contains all of the other actors/sources. This means that the interviewees from the teams have viewed all of the remaining linkages, *in toto*, as having statistically insignificant differences in importance.

It is of interest to observe that the importance position of the suppliers goes down from third to sixth to 13th as the innovativeness increases across the three categories. This effect was seen horizontally across Table 5 from the stepped decreases in importance, but this has been confirmed by the vertical comparisons within each of the three innovativeness categories. In the low category the supplier is in level 2 together with eight other actors, but in the medium category these actors moved into level 3 together with six other actors/sources. In the high category the suppliers are also in level 2, but in the last position.

This seems to mean that for software firms' suppliers are not one of the most important types of linkages. Suppliers in the manufacturing industries on which earlier studies were based have a different range of functionality than do suppliers in the software industry. The means supplied within the manufacturing industries are often more crucial to the solutions to problems encountered in the development teams than are the types of goods provided by suppliers in the software industry. In software the problem solutions are more conceptually based and help is often more likely obtained from affiliates or consultants and in the high innovativeness category from the scientific system and public authorities than when tangible (physical) materials and forms are of greater importance. The 'suppliers' to software creation teams may thus be classified in wholly other ways than through parts, equipment, consumables, etc. Rather, it is the intellectual or conceptual content of those means that is of greater importance in software.

The patterns revealed in Table 6 suggest that actors/sources were aligned by relative usage depending on innovativeness level of the products involved. Overall the results in Table 6 provide support for the findings that the customer provides the most important linkage for the low and medium innovativeness categories. For the high innovativeness category customers are one of the three most important linkages that innovative firms have. The results can also be seen as providing limited support for the findings that the suppliers are also one of the two most important linkages (Håkansson, 1989; 1990; Rothwell and Dodgson, 1991; Woolgar *et al.*, 1998). Suppliers are in the second statistical level for both the low and high categories but only in level 3 for the medium category.

In the next table, Table 7, the means of the importance ratings for each of the three innovativeness categories are given for each of the four process steps together with the mean lengths of the relationships for each actor/source type. This was done to permit a more detailed analysis of the actors/sources involved in the four phases of the s/w development process.

In Table 7 mean importance values for the customer linkages were above 3.00 for all four phases and all three innovativeness categories. No other actor/source has such high values. This finding supports, in a more detailed way, the indication from Table 5 that customers constitute an important external linkage for the s/w products studied. The highest mean values shown in the idea phase for customers are for the low and medium innovativeness categories that have values of over 4. This may be due to a tendency for firms that create highly innovative products for defined market segments to consider themselves to be the best generators of novel ideas rather than external sources including customers.

Other importance mean values that were considered high within the each of the four phases for specific actors/sources are shown in bold. These were the most important linkages within each of the four process phases.

In the affiliate companies row the mean values for the high innovativeness category in the last two phases were from 0.375 to 1.083 greater than for the medium innovativeness category. This appears to mean that for high innovativeness products the affiliate companies linkage was of more importance to the creating firm than for lower innovativeness products. Undertaking higher innovativeness seems to mean that external support was of greater importance. This also confirmed the large importance values of the affiliates in the high innovativeness category as shown in Table 5.

The scientific systems section of Table 7 showed a similar effect in the case of the high innovativeness category in that the average importance values were always higher than for the two lower innovativeness categories. Both university and research institutes were of greater importance in the high innovativeness category. A similar effect was also seen in the reliance on public authorities in the next section of Table 7 for the first three process phases. The results in the mediating parties section were more mixed, but did seem to show increased importance for the use of most of these actors/sources in the high innovativeness category compared to the other two categories, except in the development phase wherein the highest values were often found in the medium category.

Table 7. Mean Importance Values in the Development Phases §

Phases/Sources	*Idea phase*			*Decision phase*			*Development phase*			*Commercialization phase*				*Mean Length of relation-ship (yrs)*		
	Low	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*		*Low*	*Medium*	*High*
Markets:																
Customers	**4.040**	**4.047**	3.833	3.440	3.628	3.727	2.560	3.023	3.023	3.320	**4.091**	**3.903**		5.94	4.25	4.01
Suppliers	1.875	1.828	1.400	1.625	1.786	1.667	2.625	2.724	2.533	1.938	1.536	1.867		**6.32**	**4.66**	3.75
Hardware manufacturers	1.417	1.727	1.471	1.583	1.591	1.647	1.833	2.435	2.118	2.083	1.714	2.437		**6.58**	**6.57**	4.16
Competitors	2.812	2.900	2.846	2.250	2.414	2.643	1.882	1.741	1.571	1.625	2.321	2.083		5.80	4.72	3.37
Affiliated companies	2.538	1.958	2.429	2.462	1.958	**3.125**	1.769	2.542	**3.625**	2.615	2.625	**3.000**		4.79	3.50	4.50
Markets Means	2.536	2.492	2.396	2.272	2.275	2.500	2.134	2.493	2.574	2.316	2.457	2.767		5.89	4.74	3.96
Scientific system:																
Universities	1.444	1.385	**2.500**	1.333	1.235	**2.636**	2.286	1.722	2.700	1.400	1.312	**2.200**		5.25	4.50	4.44
Other research institutes	2.333	1.250	**3.000**	1.333	2.000	**3.333**	1.833	2.333	**3.200**	1.400	1.583	**2.400**		10.50	5.00	6.00
Scient. Sys. Means	1.917	1.318	2.750	1.333	1.618	2.985	2.060	2.028	**2.950**	1.400	1.452	2.300		7.88	4.75	5.22
Public authorities:																
Patent offices	1.100	1.765	**2.429**	1.400	1.813	**2.286**	1.000	1.412	1.857	2.556	1.800	**3.000**		3.80	3.31	5.24
As financial promoters	1.143	1.429	**2.500**	1.429	1.286	**2.800**	1.571	1.714	**3.000**	2.000	1.429	2.000		3.50	5.00	3.73
Public Auth. Means	1.122	1.597	2.650	1.415	1.550	2.543	1.286	1.563	2.429	2.278	1.615	2.500		3.65	4.16	4.49
Mediating party:																
Market consultants	2.182	1.944	**2.769**	2.273	2.278	2.000	1.273	2.167	1.462	1.818	2.294	**3.214**		4.17	2.75	3.32
Technical consultants	1.833	1.885	2.364	2.167	1.769	2.250	2.250	**3.125**	**3.636**	1.083	1.708	1.545		2.21	2.09	2.08
Press	1.400	1.550	1.769	1.200	1.300	1.385	1.467	1.632	1.538	3.200	3.025	**3.769**		3.80	5.05	3.22
Fairs/conferences	2.143	2.333	2.400	1.429	1.500	**2.067**	1.500	2.000	1.733	2.643	3.083	**3.467**		5.50	4.71	4.25
Mediating Party Means	1.890	1.928	2.326	1.767	1.712	1.926	1.623	2.231	2.093	2.186	2.528	2.999		3.92	3.65	3.22
Averages of section means	1.866	1.834	2.531	1.697	1.789	2.489	1.776	2.079	2.512	2.045	2.013	2.642		5.34	4.33	4.22
Differences between Innovation levels		-0.032	0.697		0.092	0.700		0.303	0.433		-0.032	0.629			-1.01	-0.11

Note: § This table shows the mean importance values in each development phase separated by low, medium and high innovation categories for the 94 cases. The Likert scale used was: 5 = very important; 4 = important; 3 = of medium importance; 2 = of low importance; 1 = a linkage exists with the actor but was of no importance for the particular cell in the table.

The relationship length columns on the right-hand side of Table 7 show higher average mean values in the markets and mediating parties sections for the low innovativeness category with respect to the high innovation category. An explanation may be that the lower innovativeness products tend to relate to the upgrading of existing products for which long-time external linkages are already in place among these actors/sources. So the firms tend to continue the use of those previous cooperating outside actors. In the case of high innovative products new linkages have to be set up in order to solve various technical and market issues so the relationship lengths tend to be lower.

Next, the Table 7 data are described from the perspective of the three innovativeness categories within each of the four process phases. In the idea phase there is no clear pattern of greater importance for any of the actors, except for the scientific systems and public authorities that seem more important for the high innovativeness category. The same pattern was found for the decision phase, except for the affiliates and fairs/conferences. For these actors/sources greater importance values for the high innovativeness category were found. These are the figures that are shown in bold in Table 7 in the decision phase columns. A few of the actors/sources in the development phase show means for other actors that are larger than for the customers in the same innovativeness columns, but these were not significant differences.

The averages of the mean section values at the bottom of the table columns was of interest in that the values for the high innovativeness category were above those for the two lower innovativeness categories with respect to all but two phases/sources. This implies from an overall perspective that the high innovativeness projects have the most important linkages to external actors. This is likely due to the greater level of knowledge that is taken in from them during the development process steps. The two exceptions to this generality from the mean section values were the idea phase for markets mean and the development phase for the mediating parties mean.

The data underlying Table 7 was subjected to several statistical procedures. Table 8 gives the significance conclusions for the data according to the low, medium and high innovativeness categories with respect to each of the four process phases. This was done as an alternative to presenting a table of the statistics.

First, the distributions of the means were checked for normality using Anderson-Darling statistics. This first step was very quick since to compare central tendency values between two distributions with normal curve tests both distributions must be of normal character. The customer distributions were all non-normal so that it was possible to go directly to statistical testing using nonparametric tests. The statistical significance of the differences in means was then determined by Mann-Whitney nonparametric tests at $p < 0.05$. The objective was to determine whether the differences between the means for the customer and each other actor in each vertical column were statistically significant.

Assessment of the importance of customers across the four phases of the s/w creation process is difficult from the data in Tables 8 due to the mixture of significance and no significant differences for the various measures. However; different sets of linkages of similar statistically significant importance have been found for the three innovativeness categories when examining the four process phases.

Low innovativeness - In this first category, the customers are clearly the most important external actor in the idea and decision phases, but this changes in a rather marked manner for the development phase and even for the commercialization phase. In the third, development, phase seven of the external actors have the same statistically significant importance central tendency measures as do the customers, namely: the four other actors in the markets section of Table 7, universities, other research institutes, and technical consultants. Thus it is possible

Table 8. Significance Conclusions for Mean Importance Values Across the s/w Processes

Idea Phase	*Significant difference in means of customer to other actor/sources found for:*	*Significant differences of customer to other actors/sources NOT found for:*
Low	All other actors	No entries
Medium	All other actors	No entries
High	All others except for……….……..>>	Other research institutes, and government financing
Decision Phase		
Low	All other actors	No entries
Medium	All other actors	No entries
High	All others except for….……... > >	Affiliates, other research instit., patent offices, and government financing
Development Phase		
Low	Patent office*, government financing, market consultants, press, and fairs/conferences	All others
Medium	All others except for……………..>>	Supplier, hardware manufr, affiliates, government financing, and technical consultants
High	Hardware manufr, competitors, mark-et consultants, press, and fairs/confer.	All others
Commercialization		
Low	All others except for…………..…..>>	Affiliates, patent offices, government financing, press, and fairs/conferences
Medium	All others except for…………..…..>>	Press, and fairs/conferences
High	All others except for…………..…..>>	Press

Note: * Based on One-Way Analysis of Variance F-test.

to say that in development phase these seven actors are used together with customers as the most important to that particular phase. This was an expected result because the main program construction occurs in this phase and the customers do not perform that function, but universities, other research institutes and technical consultants often are involved in such work. The other actors in the market section of Table 7 also are called on as needed.

In the commercialization phase for the low innovativeness category the actors that were given importance ratings that have central tendency values similar to the customer were: the affiliates, patent offices, government financing, press, and fairs/conferences. According to Table 7 the mean for customer importance is 3.320 while the range of the other close means are from 2.000 to 3.200. Those actors/sources that have significantly different central tendency values are, with one light exception, much lower than this range.

This Table 8 analysis shows that the relative importance of the customer in the low innovativeness category decreases when compared to some of the other actors/sources in the last two process phases.

Medium innovativeness - In this category the customers are clearly the most important external actor in the idea and decision phases, but this also changes in a noticeable fashion for the development phase and even for the commercialization phase. In the third, development, phase only five external actors have the same statistically significant importance central tendency measures as do the customers, namely: the suppliers, hardware manufacturers, affiliates, government financing, and technical consultants. The first three and last of these are the same as for the low category. Thus it is possible to say that in development phase these five actors are used together with customers as the most important to that particular phase.

This was an expected result in the medium category for several reasons: 1. the main program construction occurs in this phase and the customers do not perform that function but technical consultants of course do this type of work, 2. the products here were closer to the boundaries of the prior programs and to modules that are associated with the product being created and this meant that cooperation with suppliers, hardware manufacturers, affiliates was of greater importance.

In the commercialization phase for the medium innovativeness category the actors that were given importance ratings that have central tendency values similar to the customer were only the press and fairs/conferences. This seems to mean the accessing the public forums to advertise the new product is of statistically equal importance to involvement with the customer in this final phase.

High innovativeness - The customers were not found to be the single most important external actors in any of the four process phases. In the idea phase other research institutes and government financing shared the highest importance rankings with the customers. In the decision phase affiliates and patent offices also came into this short list. Government financing was at this same first importance level in these first two phases since the idea of a high innovativeness product is of course discussed with public funding authorities in detail at the start of the project when such support is used.

Then in the development phase the list goes up to include seven of the actors/sources: suppliers, affiliates, universities, other research institutes, patent offices, government financing, and technical consultants. The connection of most of these to the development phase is explained above.

In the commercialization phase for the high innovativeness category only the press is given importance ratings that have a central tendency value similar to that given to the customer. Innovating firms want public recognition within their market segment for their clever new product.

Overall the customer is of statistically greater relative importance compared to the other actors/sources in the first two stages of the development processes in the low and medium categories of innovativeness. In the high category there are a few actors/sources that were found to be statistically as important as the customer in these first two phases. In the third, development, phase of the projects there are many actors/sources that are statistically as important as the customer independently of the innovativeness category. This means that the relative importance of the customer decreases during this third phase. In the commercialization phase the press is as important as is the customer in each innovativeness category. This goes for fairs/conferences also for the two lower categories. A few more actors of importance similar to the customer emerged for the low category commercialization in this last phase. Also, it appeared that other research institutes and universities were much more important to the high innovativeness category than to the two lower categories when these linkages were used for a given project.

In Table 6 it was shown that for the overall process of creating high innovativeness products the customers, other research institutes, and affiliates were statistically at the same importance level. This overall finding has now to be modified when one is looking at the difference project phases.

Hypothesis 4 can be taken up at this point. It was:

H4. The importance of the customer in each of the four process phases is larger than the importance of all other sources/actors independent of the innovativeness level.

An examination of Tables 7 and 8 led to the conclusion that this hypothesis can not be accepted based on statistically significant differences.

In connection with Table 7 it was necessary to check the few values for other sources/actors in the development phase that were actually higher than for the customer. In each comparison where a larger mean value was found for an actor/source other than the customer the difference was not found to be statistically significant. This meant that no other source/actor was statistically more important than the customer.

The second stage shown by Table 8 was to check the statistical significance of the comparisons of the calculated mean values in which the customers did have the higher mean values. The customers were statistically more important than any other actor/source for all innovativeness categories in the idea phase and for the low and medium categories within the decision phase. Thus the importance of the customers in the idea phases is statistically larger than the importance of all other sources/actors independent of innovativeness level. If this same statement could be made for the other three phases then hypothesis 4 could be affirmed, but such a conclusion can not be reached.

Continuing with the analysis, the high innovativeness category within the decision phase showed only four instances of non-significant comparisons in the means, but for those four actors/sources it can not be concluded that the customers have a statistically higher importance. The last two phases do not permit support for stating that the customers have higher mean values since the differences were found not to be significant. One exception to this conclusion is that the high innovativeness category in the commercialization phase does show a statistically significant larger customer mean importance value for all except the press source.

The conclusion here must be that Hypothesis 4 can not be accepted based on statistically significant differences in the mean importance values and hence must be rejected.

Hypothesis 5 can be taken up also. It was:

H5. The importance of competitors will be relatively constant across the four process phases independent of innovativeness level.

The rationale for this proposition was that competitors likely would be scanned in the beginning of a project to see what existing features might be considered usable and then monitored throughout the later phases. Table 7 shows that the mean values for the competitors in the idea phase is above those same values for the second, third and fourth phases for the same innovativeness categories. The question then became whether these differences were significant. For this purpose the normality of the distributions was check with Anderson-Darling statistics. None of the plots were normal although several were close. In view of this finding Mann-Whitney non-parametric statistics were taken on the idea phase competitor values against the other three phases. None of the differences between the idea and the decision phase were significant; however, all differences for idea vs. the development phase were significant. Both the low and medium innovativeness categories showed significant differences between the idea and the commercialization, but the high innovativeness category did not.

These findings cause Hypothesis 5 to be rejected since the idea phase means are significantly greater than the development phase in each of the three innovativeness categories. The competitor mean values have different patterns for the idea to the decision and commercialization phases comparisons.

The average values for competitor importance across the three innovativeness categories for each of the four phases are 2.85, 2.42, 1.75 and 2.06, respectively. This tends to support the hypothesis that competitors are monitored most closely in the idea phase, then somewhat less in the decision phase and that competitors are of lowest importance in the development phase rather than being monitored in a relatively constant manner during the s/w process. It was in the development phase where the programming was carried out that monitoring of the competitors was at the lowest point.

4.5 Effects associated with the projects

A number of effects flowing from each project was evaluated on a 1 to 5 point Likert scale as summarized in Section 3.4. These were:

a. the potential for transfer of knowledge from this project to other subsequent internal projects,
b. the strengthened business linkages between the firm and a range of knowledge sources/actors,
c. enhancement of firm personnel knowledge during a given project,
d. retention of proprietary knowledge so that the creation of later products can be enhanced,
e. enhancement of the firm's reputation, and
f. the project was seen as profitable for the company.

An overall rating of success was also taken on this same Likert scale as were four different types of gains in knowledge due to completion of each project. The effects measured for the three innovativeness categories were then compared by computing the mean values for each of the effects as set forth in Table 9.

Table 9 shows in the right-hand column that high innovativeness products were associated with increased mean evaluations for all 12 of the measured effects when compared to the low innovativeness category. Differences in the means of greater than 0.80 have been shown in bold. On a five-point scale this magnitude of difference is equivalent to a 20% increase. Factors 2-4, related to the extent of personnel knowledge enhancement that occurred during the project, were of particular importance since each difference was over 0.9. The knowledge enhancement for management shows the greatest difference of all of the factors at 1.223. An explanation is that more innovative products rapidly increase both technical and marketing knowledge within the firm and provide new pathways for firm development. These findings support the view that higher innovativeness products provide increased knowledge enhancement for the firm and are, at the same time, more profitable.

Since factors 2-4 show that the extent of personnel knowledge enhancement is larger for the higher innovativeness products encouraging more innovative products that have new features and give greater performance is a wise business development strategy. This will also lead to increases in firm retained knowledge and some of this new knowledge will likely aid the creation of later products. This suggests that the assessment or results for a given project should take knowledge enhancement into account as well as profitability that was also found to be greater for the more innovative products.

Table 9. Mean Effect Evaluations for High, Medium and Low Innovativeness s/w Projects

Evaluated Effects	*Low Innovative-ness*	*Medium Innovative-ness*	*High Innovative-ness*	*Difference between High and Low*
Mean of innovation indices	2.586	3.802	4.667	2.081
1. Potential for transfer of knowledge from this project to other subsequent internal projects	3.462	4.364	4.190	0.728
Extent of personnel knowledge enhancement that occurred during this project for:				
2. Project team members	3.423	4.250	4.364	**0.941**
3. Marketing personnel	2.522	3.317	3.500	**0.978**
4. Management personnel	2.833	3.159	4.056	**1.223**
Average for personnel knowledge enhancement	2.926	3. 575	3.973	**1.047**
5. Extent to which the firm will likely be able to retain the knowledge gained as proprietary so that the creation of later products will be enhanced	3.731	4.159	4.364	0.633
6. Extent to which firm reputation has likely been enhanced by this project	3.615	4.089	4.435	**0.820**
7. Extent to which this project is seen as profitable for the company in comparison to other projects of similar complexity	3.120	3.727	4.263	**1.143**
8. Overall project success	3.750	4.274	4.500	0.750
Gain in knowledge as result of creating the product				
9. general-purpose	0.962	1.073	1.457	0.495
10. context -specific	1.904	1.933	2.022	0.118
11. Market-side	1.568	1.352	1.957	0.389
12. Administrative-side	0.978	0.900	1.065	0.087

The profitability measure, effect 7, is the second largest difference between the high and low innovativeness categories at 1.143 that constitutes 29% of the available scale value. Overall project success, factor 8, while showing a difference of 0.750 did not register so large of a scale range difference (19%).

The general-purpose gain in knowledge, effect 9, is also greater for the higher innovativeness products than both of the lower two categories and this may indicate that more generalized knowledge acquisition is associated with higher innovativeness products. The context-specific knowledge gain, factor 10, also shows the same general pattern so this effect appears to apply to the context-specific type of knowledge also. Factors 11 and 12 will be handled below.

Overall Table 9 shows that all of the measured effects associated with new software projects increased when comparing high to low innovativeness products. Thus it appears that substantial gains in company personnel knowledge and in profitability compared to other projects of similar complexity can be achieved in software creation projects where decisions to raise the innovativeness level can be made while satisfying a particular client or the needs of a given market segment.

The statistical testing showed that the differences found for factors 1-8 in the right-hand column are each significant according to Mann-Whitney statistics at $p < 0.05$. This test was used because the data was non-normal. The differences shown for factors 9-12 were shown to be non-significant using Mann-Whitney tests for all but factor 10 for which both distributions were normal. For that one factor a T-test was used. Due to this finding of nonsignificant differences no further reliance will be taken on the four factors at the bottom of Table 9. It should be noted; however, that the right-hand column differences are, nevertheless, all positive which indicates a tendency for more knowledge gains for the high innovativeness category over the low one.

Most of the evaluated factors in Table 9 show stepped increases across the three innovativeness categories. The exceptions to this finding are in factors 1 and 11-12. The potential for transfer of knowledge from the focal project to subsequent internal projects, factor 1, shows a slightly higher value for the medium category than for the high category, but this is not a statistically significant difference. Notwithstanding the statistical result, a possible explanation could be that the projects classified in the medium category created general utility knowledge that can be perhaps more readily transferred to other later projects than do the high innovativeness products. This greater importance for the medium category is not seen in factor 5 when proprietary knowledge is in focus or in factor 9, gain in general-purpose knowledge. When the knowledge is proprietary to the firm then the high category gives the greatest effect gain.

At this point an answer for hypothesis H7 can be advanced here. This hypothesis was:

> H7. The knowledge accumulation in higher innovativeness products will be equivalent to that in the medium and low innovativeness categories of products.

Items 2-5 each depend on knowledge accumulation and will be used mainly to treat this hypothesis. Each of these effects shows that the high innovativeness products were found to provide statistically significant more knowledge than the low innovativeness category rather than equivalent knowledge accumulation. Thus this hypothesis can be rejected as to the low category.

For the medium category, however, the differences between the mean values for the high to medium categories are not significant for effects 2, 3 and 5. This means that the central tendency values of the ratings for these three effects are statistically equivalent for these two categories. Only for factor 4 was a significant difference found. This means that the knowledge enhancement of management personnel shows significant differences between each of the three innovativeness categories. This single factor is not; however, sufficient to change the overall conclusion here, which is that this hypothesis has to be affirmed as to the medium category of innovativeness. Three of the four factors evaluated for this purpose direct this conclusion.

Factors 6 and 7 also show significant differences between the high and medium categories so that there were some additional effect gains on a statistically significant basis between these two higher innovativeness categories.

The effects of strengthening linkages to various actors/sources were also evaluated across the three categories of innovativeness as shown in Table 10. Some linkages were more strongly affected by higher innovativeness than others. Nine (9) out of the 10 linkages were shown in the right-hand column to be strengthened more by projects in which high innovativeness products were created when compared to the low innovativeness category. The linkages to the customers were uniformly the most strengthened of all the evaluated linkages since the values were 4 or above on a 1 to 5 scale. Due to this high linkage strengthening effect the mean values of the differences between the categories is of less interest for the customers.

Table 10. Strengthening of Linkages to Other Parties §

Evaluated linkage and other effects	*Low Innovative-ness*	*Medium Innovative-ness*	*High Innovative-ness*	*Difference between High & Low*
Extent to which this project strengthened business linkages between the company and the following: 1. To the customer(s)	4.000	4.333	4.391	0.391
2. To external technical consultant(s)	2.273	2.341	2.526	0.253
3. To external marketing consultant(s)	1.778	1.846	2.500	0.722
4. To suppliers	2.333	2.233	3.000	0.667
5. To hardware manufacturer(s)	1.882	1.975	3.263	**1.381**
6. To competitors	1.737	2.238	2.737	1.000
7. To cooperation partners	2.632	3.293	4.100	**1.265**
8. To affiliated companies	2.562	2.583	2.545	-0.017
9. To universities or research institutes	2.000	1.833	2.929	0.929
10. To others	1.750	1.900	2.500	0.750
11. Average strengthening for all 10 linkages	2.295	2.458	3.049	0.754
12. Extent to which firm reputation has likely been enhanced by this project	3.615	4.089	4.435	**0.820**
13. Extent to which this project is seen as profitable for the company in comparison to other projects of similar complexity	3.120	3.727	4.263	**1.143**
14. Overall success of project	3.750	4.274	4.500	0.750

Note: § Some other effects are also repeated from Table 9 as items 12-14.

Excluding the linkage to customers for this reason, the range of high to low positive effect differences is from 0.253 for external technical consultants to 1.381 for hardware manufacturers. Of particular note are the linkages to hardware manufacturers, 5, and to cooperation partners, 7, which are strengthened substantially more (above 30% of scale range) by processes in which the high innovativeness products were created.

The hardware difference in the right-hand column is partial caused by the lower than average (1.882 to 2.295) value of the strengthening for the low category column that implies less importance for such actors in the low innovativeness products. On the other hand, the large difference shown for the cooperating partners is due partially to the larger than average (4.100 to 3.049) value for the high innovativeness category. This implies that linkages to the cooperating partners during the creation of high innovativeness products were strengthened to about the same level as were the customer linkages. Such linkages will likely come into use in subsequent projects.

Overall the high innovativeness products are associated with gains in linkage strength compared to low innovativeness products. This conclusion is based on significance tests for the differences in the means shown in the right-hand column. There are of course many characteristics to take into account when judging the strengthening of the linkages noted as factors 1-10 in Table 10 such as extent of cooperation achieved, knowledge transmitted, problems solved, etc. Quick responses to questions as to strengthening of such linkages, at best, would be only approximations of the effects flowing from the focal project work since not all of these various characteristics would likely have been summarized in the responses. For this reason $p < 0.15$ was used to assess statistical significance.

The distributions of the low category means in Table 10 were non-normal according to Anderson-Darling statistics, except in the cases of the cooperating partners (7) and the 'other' line item (effect 10). Only for factor 10 was there a normal distribution for the high category means value to use for comparison. This necessitated the use of a non-parametric significance test (Mann-Whitney) on the differences in the means for linkages 1-9 shown in the right-hand column. Of these linkages 1, 3, 5, 6, 7, and 9 were found to be significant. In addition, linkage 4 was very close to the test value of $p < 0.15$ at $p = 0.1569$. The statistically significant strengthening of the six linkages has been interpreted as a positive business developmental effect for s/w companies.

The increased strengthening of the linkages occurs in a stepped pattern across the three innovativeness categories except for the actor types: suppliers, affiliate companies, and universities or research institutes. For suppliers (effect 4) the medium category value is slightly lower (0.1) than is the low category, but this difference is not significant. Only for the high to medium categories was the difference significant.

The affiliate companies (effect 8) are unusual in this series of linkages because the strengthening effect is nearly equivalent across the three innovativeness categories. It is not particularly high at an effect value of some 2.5 compared to the customer effect values of 4 and over. This could mean that for the sampled projects the affiliate company linkages were more of a 'business-as-usual' type rather than being one of the key relationships for solving the problems that were encountered in the project work. In some projects it could be expected that the affiliate company linkage would be of extreme importance and thus should be greatly strengthened as a result of the project. Notwithstanding these low strengthening values it should be recalled from Table 5 that affiliates were very important linkages from an overall perspective. actor type. Companie s within the same business group usually already have strong linkages and high frequency contacts are in place so that higher values for strengthening could be expected even for the low innovativeness category.

Affiliate companies seem to have a special status in software projects. Results have been unexpected for this actor type. Companies within the same business group usually already have strong linkages and high frequency contacts are in place so that higher values for strengthening could be expected even for the low innovativeness category.

It was expected that stepped increases would be seen in the next to last linkage type (9), universities or research institutes, but this did not occur with stepped increases. What can be said is that the strengthening of the linkages is considerably greater for the high innovativeness category than for the lower two categories.

Thus Table 10 shows that for six of the linkages there is a significant strengthening of business linkages that is greater for the high innovativeness category than for the low category. Strengthening of business linkages to competitors (effect 6) requires some explanation. In most of the cases in this study activities of the closest competitors were monitored by project team personnel or involved marketing persons. In some cases the competitors were engaged rather directly usually at trade shows, but this does not mean that such linkages have much content except for direct product functional comparisons. The high to low difference of 1.000 (25% of the value range) does show; however, that such monitoring activities are of greater importance in the case of the higher innovativeness products.

Another hypothesis can now be taken up. Hypothesis 6 was:

H6. Effects flowing from the development processes will show a U-shaped variation when moving from low through moderate to highly innovative products.

Analysis of Table 9 data leads to rejection of H6. Table 9 shows stepped increases for effect 7, profitability in comparison to similar complexity projects whereas Kleinschmidt and Cooper (1991: Fig. 2) reported a U-shaped curve centered on the moderate category of ROI, a similar measure that calculated to a 69% concavity, i.e. a step-down. The stepped increases found for this effect 7 are significant at $p < 0.05$. Table 9 also shows stepped increases in effects across the innovativeness levels for effect 8, overall project success whereas Kleinschmidt and Cooper (1991: Fig. 4) reported a U-shaped curve centered on the moderate (or medium) category [this calculates to an 18% concavity]. For effect 8 two of the three comparisons of the means are also significant which also substantiates the same rejection for H6.

The general conclusion from Table 9 is that a U-shaped curve was not found. The high to low innovativeness category differences shown in the right-hand column for effects 1-8 were all statistically significant. At least one of the other two possible comparisons of the mean values shown was also significant. This means that the comparative mean values of the medium category were significant when compared to either the low or the high category mean values. As mentioned above the stepped statistically significant increases in effect 7 were substantiated for all three comparisons of the means. The same holds for effect 6.

Overall the earlier reported universal U-shaped curve for tangible product performance measures (or effects in the present study) is not supported in software firms so H6 must be rejected on the basis of this limited comparison.

Further analysis of Table 10 shows some ancillary results that tend to support the conclusion for rejection of H6. The average strengthening of the linkages reported in item 11 shows stepped increases rather than a U-shaped curve; however, significance tests for these averages as opposed to the separate effect values were not taken. The effect of the strengthening of linkages could have some importance for the development of future products that can be seen as relating to future market performance. Individual linkages show mixed significance patterns. The same statistical procedures as for Table 9 were carried out with the exception that $p < 0.15$ was used as mentioned above. These showed the significance results given in Table 11 for the differences between the means for the ten linkages as shown in columns B, C, and D.

The significance of these differences between the means were regarded as usable for linkages 1, 3, 5, 6, 7, and 9 due to the pattern of two of the three possible comparisons showing significance below the required p-value. The differences in means between the high and low categories for these linkages in Table 10 were then significant and the differences between these two category means and the medium category were supported by at least one other comparison.

Taking the above into consideration it can be said that there is no evidence in these results to support a U-shaped curve. To show such a curve the significant differences between a lower medium value and high values on both of the other two categories would be needed. There are no such patterns. Linkages 4 and 9 showed lower medium category values than were expected from the assumption that stepped increases would be found. Neither of these linkage medium values was significantly below the compared low category value. None of the differences were significant for linkage 10. Consequently there is no evidence on which any conclusion other than rejection of H6 can be based.

Table 11. Significance of Differences Between Mean Values in Table 10 §

A. Business linkages strengthened between the company and the following that will likely help in the future:	*B. Low to Medium Differences*	*C. Medium to High Differences*	*D. High to Low Differences*
1. To the customer(s)	s	ns	s
2. To external technical consultant(s)	ns	ns	ns
3. To external marketing consultant(s)	ns	s	s
4. To suppliers	ns	s	ns
5. To hardware manufacturer(s)	ns	s	s
6. To competitors	s	ns	s
7. To cooperation partners	s	s	s
8. To affiliated companies	ns	ns	ns
9. To universities or research institutes	ns	s	s
10. To others	ns	ns	ns

Note. § In this table the notations are s = significant and ns = nonsignificant.

This line of reasoning based in principle, on Tables 9 and 10 also leads to rejection of the H8 broad effects hypothesis which was:

H8. There will be no more extensive internal company developmental effects for products with high innovativeness than for those of lower innovativeness.

Contrary to this hypothesis the Tables 10 and 11 data show significant stepped increases in many of the linkage effects. When examining low to high innovativeness categories linkages 1, 3, 5, 6, 7, and 9 all show positive and significant increases. The medium to high categories show the same for effects 3-5, 7 and 9. Overall 11 of the 18 increases between the two sets of category values are significant (61%). Effect 8, affiliate companies, shows only nonsignificant differences. These are regarded as findings that support rejection of H8.

Also significant differences between high category means and at least one of the two lower categories were found for linkages 1, 3, 4, 5-7, and 9 (70% of the effects). These findings taken together with the results shown for effects 12, 13, and 14 that are also statistically significant indicate that H8 must be rejected.. In this regard it should be pointed out that effects 1-8 in Table 9 also show statistically significant increasing company development effects for the high innovativeness category compared to the low category and that, in addition, effects 4, 6 and 7 show the same type of increases for the high to the medium categories.

There are more extensive internal company developmental effects for products with high innovativeness than for those of lower innovativeness. Therefore; H8 was rejected.

4.6 Influence of firm and project size

The results show that size of the firm and of the project do not have strong influences on innovativeness. This implies firstly that, in general, small firms in the study were innovative to roughly the same extent as were the larger firms and that, secondly, a wide range of project sizes is associated with innovative products. One of the findings reported below was that one range of small firm sizes actually had the highest innovativeness.

Notwithstanding these general findings there are some interesting differences that can be seen between the Pearson correlation coefficients for the variation of firm size to the innovativeness indices for the three innovativeness categories. As shown in Table 12 the low innovativeness category showed a low positive correlation coefficient of 0.230 with the number of firm employees in the countries in which the projects were carried out, whereas both the medium and high categories showed negative coefficients of smaller size. Correlation coefficients have been reported rather than R^2 since the query here is for positive and negative tendencies in the data. The differences need to be seen also from a statistical significance viewpoint. The low category coefficient in the first row has a p-value of 0.268. Compared to this the p-values of the medium and high categories were 0.625 and 0.452, respectively.

Table 12. Variation of Firm and Project Size with Innovativeness Categories

Correlation of Innovativeness to	*Innovativeness Categories*			*All projects*
	Low	*Medium*	*High*	
No. firm employees in country of project origin	0.230*	-0.075	-0.165	-0.059
Total global firm employees	0.224	-0.089	-0.228	0.040
Project size, man-months	0.095	0.190	0.210	-0.030
Team size, number of employees	-0.067	0.253	0.247	0.019

Note: * Pearson product moment correlation coefficients

A possible tendency can be derived from these findings. This seems to indicate that there is a slight tendency within the low innovativeness category for larger firm sizes to have higher product innovativeness, whereas within the other two higher categories a weak trend can be made out for larger firm size being a slightly increasing disadvantage with respect to higher innovativeness levels.

Another way to state this is that the smaller-sized firms could be said to have a slightly greater association with higher innovativeness projects than did the larger-sized firms. This tendency is also supported by the second row entries for the total global number of firm employees which show a low positive correlation coefficient in the low category indicating that increasing size gives an advantage for creating higher innovativeness products within that low category range. This tendency then reversed for the medium and high categories as shown by the negative correlation coefficients and larger global firm size is then a disadvantage for creating the more innovative products within the higher two innovativeness categories. This tendency is not observable in the correlation coefficients taken across the full range of projects. Rather it only comes to light by an examination of the three categories of innovativeness.

The data in the first two rows of Table 12 has been presented as support for the above tendency and relies mainly on the positive and negative aspects of the correlation coefficients rather than their statistical significance that is low. The p-values for these correlation coefficients have a wide range. The first row coefficients had p-values ranging from 0.268 to 0.625 which permits wide speculation as to the trends or tendencies in the underlying data. In the second row the coefficients for the three innovativeness categories had p-values between 0.272 to 0.559. The relatively low significance levels of the number of employees in the country of project origin (first row) and of total global firm employees (second row) correlated with the innovativeness indices make any definitive conclusion impossible, but a mention of the above tendency seemed worthwhile nevertheless.

In view of this tendency a sensible developmental strategy for smaller firms therefore might be to seek out and plan projects that permit the placement of high values on the measures of innovativeness. This type of strategy should also incorporate the use of practices that capture maximum advantage from the business developmental effects that have been summarized in Tables 9 and 10.

Project size was also investigated because it was thought that larger projects might be the more innovative ones. There is some weak evidence to support this proposition in the medium and high categories since these categories had low positive coefficients. The very low positive coefficient and poor statistical significance precluded any use of the project size correlation for the low category. The number of man-months used for the projects was correlated with the innovation indices across all of the cases with the result of a –0.030 correlation coefficient that had only a 0.780 p-value. So there was no overall relationship found.

When project size was broken out into the three innovativeness categories, the low category coefficient in the project size row was found to be unreliable with a p-value of 0.651. Focus on the medium and high categories was of greater relative interest because the coefficients became increasingly positive and the p-values were better (0.210 and 0.362, respectively). These show a weak tendency for the larger project sizes to have greater innovativeness measures within each of the medium and high categories.

The fourth row, team size, correlated with the innovativeness indices within the medium and high categories showed a similar and slightly stronger supporting pattern. The fourth row p-values are 0.744 for the low, 0.093 for the medium, 0.255 for the high categories so that no reliance can be taken on the low category for such support.

A conclusion from the Table 12 analysis was then that large firm size did not show an advantage over smaller firms when it came to producing high innovativeness products. There was; however, a very slight advantage for larger firms to produce more innovative products, but only in the low innovativeness category. So this may not point to much of an advantage. Larger project sizes in terms of man-months expended in the projects and team size did show a slight advantage for greater innovativeness in the medium and high innovativeness categories.

The correlation coefficients across all projects shown in Table 12 were weakly positive or negative depending on which measure of firm size was used. When all projects were examined in terms of global firm revenues the correlation was 0.090 and the relationships for the three categories were: low category 0.172, medium –0.115, and high –0.164.

This analysis of the correlation coefficients shown in Table 12 led to more detailed analytical work on the overall relationship of firm sizes to the innovativeness indices (INN). The inquiry for this part of the study was to determine how different firm size ranges correlated with these indices and the extent to which the averages for the INN indices within size ranges differed. The data developed is given in Tables 13, 14 and 15, below.

In the first of these three tables, Table 13, the p-values for the 5 levels shown as the set A size ranges were lower on average (0.307 compared to 0.481) than those shown in Table 14 for the 8 levels used for the set B size ranges. These two different size sets were used to better determine how size might affect innovativeness. The set A size levels were then somewhat better from a statistical significance standpoint and were taken up first for analysis. When a low confidence limit of 80% was used the correlation coefficients found for the first three levels from 0 to 11,000 employees could be used to analyze for tendencies. At the first level from 0 to 40 employees the innovativeness of the products increased with greater numbers of employees. This may well show that companies of this size are primarily managed by the founding team and as more internal resources are acquired the willingness to produce increasingly complex products also increases.

Table 13. Number of Firm Employees Correlated with Innovativeness Indices over 5 Size Ranges

Set A Size Ranges (5 levels)	*Correlation Coefficient*	*p-value*	*INN Indices average*	*Number of cases*
0-40	0.251	0.128	3.90	38
41-350	-0.373	0.087	3.59	22
351-11,000	-0.328	0.199	3.29	17
11,001+	0.239	0.355	3.68	17
45,000+	0.101	0.767	3.78	11
0-45,000+				105*

Note: * The total of 105 is due to the double counting in the 45,000+ size range.

At about 40 to 50 employees many new firms take in business managers who begin to emphasize profitability and capacity utilization depending on the main business model used, i.e., packaged s/w or single client solutions in the software industry. This increased financial focus may then result in greater caution against the undertaking of more innovative and hence riskier projects. Turning again to the data shown there were two trends of note. The first was that the innovativeness indices averages were lower for the two levels that encompass employee sizes of 41-11,000 employees than for the other smaller and larger firm size ranges. The second was that within the two size ranges encompassing these employee sizes the innovativeness indices decreased with increasing firm size. This implies that there was a weak tendency for larger employee sizes to be associated with lower innovativeness, but only within those ranges. For firm sizes above 11,000 there were also positive associations with innovativeness which then means that increasing size again became an advantage for more innovative products.

For comparative purposes it is necessary to comment on several of the differences between the current data set and similar data from the mentioned study of radicalness of tangible product innovations carried out by Ettlie and Rubenstein in 1987. The correlation coefficients were generally higher for the s/w firm data presented here than for the earlier study. The relatively large negative coefficients in the 41-11,000 employees size ranges of set A were not found in the earlier tangible product study. In the 50-350 range of that earlier study there was a weak ($r = -0.15$ coefficient at $p= 0.29$) negative relationship. The most directly comparable coefficient in the current study was $r = –0.373$ at $p= 0.087$ which was a much more significant finding.

One possible reason for these differences between tangible and s/w products may come from the heavy attention to manufacturing processing that is needed for the former type of products. The earlier study points out that “many significant new products actually incorporate any number of interrelated technologies and innovative components” and that these frequently require changes in manufacturing processes (Ettlie and Ruberstein, 1987: 91). These different aspects then require specialists in many different disciplines and usually also require internal firm production of at least some of the components. These needs then raise the sizes of firms dealing in tangible products more quickly as sales increase in the early years of the companies.

For s/w products manufacturing processing is not regarded as a problem. If the program operates as intended it can be put onto an appropriate carrier medium. Rather it is much more important to assure that all included modules function as intended within the program as well as in association with other connected parts of the operational system within which the program is used. This then implies that specialists in a wide range of technologies are not needed within the companies and that clever s/w minds are the principal resource for success. It does not take so many clever people to create an unusually innovative s/w product.

The size range B levels in Table 14, below, show that the 21-40 employee range had the highest innovativeness average (4.25) when compared against all other size ranges in the sample. Also the next size range, 41-80 had an innovativeness index average of 3.88, the next highest. Then a comparison of the two largest employee size ranges against the lowest INN average (for the 1,201-11,000 sizes) also showed that these were significantly higher averages. This analysis indicates that firms in the 21-80 size ranges were associated with higher innovativeness products than were the smallest size range of 0-20 or the largest company sizes.

Table 14. Number of Firm Employees Correlated with Innovativeness Indices over 8 Size Ranges

Set B Size Ranges (8 levels)	*Correlation Coefficient*	*p-value*	*INN Indices Average*	*Number of cases*
0-20	0.127	0.553	3.69	24
21-40	-0.381	0.178	4.25	14
41-80	0.615	0.025	3.88	13
81-350	-0.319	0.402	3.18	9
351-1,200	0.236	0.511	3.70	10
1,201-11,000	0.133	0.776	2.71	7
11,001- 45,000	-0.260	0.619	3.48	6
45,001+	0.094	0.783	3.78	11
0-45,001+	0.040	0.702	3.68	94

To further explore the phenomenon of innovativeness versus s/w firm size the averages for the indices gathered for several of the size levels were compared. The INN indices distributions of were all normal according to Anderson-Darling tests so t-tests were used to compare the averages for these. The comparative results are given in Table 15 separately for the two size range sets A and B.

When a low confidence limit of 85% was applied all comparisons were found to be significant. For set A, this implies that companies in the very broad 41 to 11,000 size ranges did have lower innovativeness averages than the companies of 0-40 size and the very largest size of 45,000+. From this finding it did not appear that innovativeness was positively associated with large firm sizes.

Another way to see that innovativeness is not positively associated with larger-sized (over 80 employees) firms is to look into the eight regression plots for the set B size ranges that are shown in the two page Appendix B. By serially comparing these plots that are laid out by increasing size ranges one can see that the lines of regressions for the innovativeness measures were positively sloped for some size ranges and then negative for other ranges in nearly an alternating pattern. Also, note that the magnitudes of the innovativeness measures vary considerably (between the two outer values of 2.71 to 4.25) as size continuously increases. One can see that the two size ranges 21-40 and 41-80 have the two highest innovativeness index averages as above noted.

Table 15. Comparison of Innovativeness Indices Averages by Firm Size Ranges

Set A Size Ranges	*INN indices average*	*Compared to size range*	*That had an INN indices average of*	*p-value for the compared averages*
0-40	3.90	41-350	3.59	0.091
0-40	3.90	351-11,000	3.29	0.019
11,001+	3.68	351-11,000	3.29	0.091
45,000+	3.78	351-11,000	3.29	0.054
Set B Size Ranges 21-40	4.25	0-20	3.69	0.021
21-40	4.25	41-80	3.88	0.120
21-40	4.25	81-350	3.18	0.005
21-40	4.25	351-1,200	3.70	0.074
21-40	4.25	1,201-11,000	2.71	0.001
21-40	4.25	11,001-45,000	3.48	0.016
21-40	4.25	45,001+	3.78	0.107
11,001-45,000	3.48	1,201-11,000	2.71	0.042
45,000+	3.74	1,201-11,000	2.71	0.010

These two results show by the regression plots show that the innovativeness indices are not positively associated with firm size. In this regard it is important to observe that the y-axis numerical ranges shown in the different plots have been shifted automatically by the statistical program. The dotted curves shown are the 95% confidence bands.

It is clear that the firms comprising the 21-40 size range had the highest set of innovativeness measures at an average of 4.25. By comparison the two size ranges of 81-350 and 1,201-11,000 showed 3.18 and 2.71 respectively. Both of these were significant differences at below p = .01. From this it appeared that at least two of the larger size ranges were negatively associated with innovativeness. Additionally it was found that all firm size ranges above 80 had significantly lower innovativeness averages than did the 21-40 range at p-values lower than 0.11.

At this point the last hypothesis can be taken up. It was:

H9. S/w Innovativeness will be positively associated with larger-sized firms.

Taking Tables 12-15 together it appeared that innovativeness cannot be said to be positively associated with larger-sized firms, i.e., firms with 80 or more employees. There were negative associations in both the 81 to 350 and the 1,201 to 11,000 size ranges in the set B data that also had low innovativeness measures. Due to these it cannot be said that such a positive association between firm size and innovativeness exists in the current sample of s/w firms.

In view of the above data and discussion this hypothesis must be rejected on the basis of data shown in these tables.

5. External Joint Usage Patterns During Development Process

It was believed to be of interest to study the patterns of external joint usages among various actors/sources. The patterns were analyzed by determining Pearson product moment correlation coefficients for the sums of the importance ratings across the four phases of the development processes. These sums of the importance ratings across the development processes used for the 94 cases that are given in Table 5 were compared to find those joint usages that correlated within the selection criterion of greater than + or – 0.550 at $p < 0.3$ significance level. An implication of examining this range of correlation coefficients was that the coefficient of determination, R^2, being accepted was a minimum of 0.30.

The purpose of this analysis was to obtain an understanding of how the joint usages of various actors/sources change when moving from the low innovativeness category of products to the high category. Since there are many combinations of external actors/sources that could be of importance during s/w development cycles it was of interest to find those joint usages that are employed differently depending upon the level of innovativeness involved. Finding the patterns where the importance ratings for the various actors/sources show interesting correlation coefficients is one way to describe the joint usage of these external actors/sources within the software creation processes that were investigated. Correlation coefficients have been reported rather than R^2 since it is usage patterns for the external linkages that was investigated. This analysis then extends the differences between the three innovativeness categories beyond those shown by the data given in Table 5 for the separate actors/sources.

Table 16 sets forth Pearson product moment correlation coefficients for the listed actors/sources that were within the specified correlation limits. Within each cell the left-hand, top value was for the low category (in normal type), the middle value for the medium category (in Italics), and the right-hand, bottom value shows the high innovativeness category value (in bold type). Joint usages that are not reflected in this table of course exist for specific s/w projects, but the lower correlation coefficients indicate that such joint usages are less reliable for providing a general view of such projects from the standpoint of different innovativeness levels. The correlation coefficients are significant to $p < 0.10$ unless noted with a superscript as explained below the table and the F statistics for the data without superscript notations ranged from 3.48 to 114.57. In view of the selection criteria of examining correlation coefficients within the + or – 0.550 range it was felt that some leniency as to significance levels could be taken. The over-riding purpose of this analysis was to find patterns of external joint usage rather than to establish the statistical significance of specific relationships.

In this Table 16 the positive correlation coefficients vary from 0.551 to 0.987 while the negative correlations are in a narrower range of from –0.618 to –0.786.

Table 16. External Joint Usage Correlation Coefficients of Importance §

Sources/ sources	*Principal Market sources*					*Scientific System*		*Public Authorities*		*Mediating Parties*			
	Customers	*Suppliers* *Lo Med Hi*	*Hardware Manufact-urers*	*Competi-tors*	*Affiliates*	*Universi-ties*	*Other research Institutes*	*Patent office*	*As Financial Promoters*	*Market Consultants*	*Technical Consultants*	*Press*	*Fairs/conf erences*
Markets Customers					**0.637**								
Hardware Manufacturers		0.614 *0.634* **0.789**			0.604								
Competitors	**0.681**	*0.681*	*0.702*		0.551 **0.555**[2]								
Scientific System Universities	**0.663**			-0.677 **0.947**									
Other research Institutes	**0.785**	0.898 **0.820**	0.716[1] *0.901* **0.870**	**0.986**		*0.801* **0.987**		*0.582*[1]					
Public Authorities Patent office	**0. 624**[1]			**0.816**									
Government Financial Promoters	**0.591**[2]			**0.804**[1]		0.919 **0.930**	**0.987**[1]	0.963 *0.704*					
Mediating Parties Market Consultants			0.663	**0.597**			**0.754**[1]	**0.876**	**0.929**				
Technical Consultants					-0.618[1]		-0.786[2] **0.941**	*0.599* **0.689**[1]	**0.652**[2]	0.696 *0.650* **0.788**			
Press								0.640			0.579[1]		
Fairs/conferences		*0.568*	**0.553**						-0.644[1]		**0.784**	0.558 *0.636* **0.719**	

Note. § The correlation coefficients are calculated as Pearson product moment coefficients and are taken on the importance rating sums for each of the compared actors/sources. The superscript notations are for p-values: 1. 0.1 to 0.2; and 2. 0.2 to 0.3..

The numbers of correlation coefficients above the + or – 0.550 analysis limits varies as shown by Table 17 below. This showed that the low and medium innovativeness categories contained fewer joint usages than did the high category and that only the low category has negative correlations among the actors/sources. These negative correlations seem to show a trade-off strategy of using one or another type of external actor/source rather than both when these were for competing inputs. More will be said about this in connection with Table 19, further below.

Table 17**.** Correlation Pattern Among Actors/Sources Within The Three Innovativeness Categories

Innovativeness Category	*Number of positive correlations*	*Number of negative correlations*	*Total correlations above limits of +/- 0.550*
Low	11	5	16
Medium	11	0	11
High	28	0	28

The high innovativeness products seem to be developed using considerably more joint linkages compared to the other two lower categories. This indicates that the high category products require more outside knowledge to be taken in during the creation processes. Further, these knowledge-providing actors/sources have not been used as trade-off inputs as in the low innovativeness category where the negative correlation coefficients were found.

So what are the joint linkage patterns for these three categories? The patterns are shown in Table 18 below. There are nearly three times as many joint usages for the high category as for the other two categories. The use of the linkages to the all-important customers in association with uses of other actors only appears in the high category. These are not particularly strong correlation coefficients since they range between 0.550 to 0.785; however they did show a tendency that when the customers' importance was greater then it was regarded as important to simultaneously engage these other actor/sources shown in the first part of the right-hand column. The monitoring of competitors also takes on increased importance in connection with the use of other external actors/sources for the high category products.

The joint usages that occur in more than one of the innovativeness categories are shown in bold type. The bold joint usages are then those that seem to be used together in a fashion that is somewhat independently of innovativeness. This independence holds **across all three categories** for the supplier to hardware manufacturers, market consultant to technical consultant, and press to fairs/conferences since joint usage of these pairs was found for all three categories.

In addition, joint usage of linkages was found between pairs across two categories for the following:

Low and Medium categories: Supplier to hardware manufacturer, Research institutes to hardware manufacturers, and Patent office to government financial promotion,

Medium and High categories: University to other research institutes, and Patent office to technical consultants, and

Low and high categories: Competitors to affiliates, and universities to government financial promotion.

The joint linkages that are shown in standard typeface are unique to the particular innovativeness category in which they occur. This means, in the markets section for example, that the joint usages of customers together with competitor monitoring, affiliates, university and research institute linkages, and both the patent office and government financial promotion are more highly correlated for the high innovativeness products than for either low or medium innovativeness projects.

Attention to these different patterns of joint usages that depend upon the innovativeness level could be of advantage to software development teams and management.

It is now possible to construct a picture of the three innovativeness categories of software projects with respect to the actors/sources that provide external cooperation. The low category did not show joint usages between the all-important customers and other actors/sources. The inter-connections among the market actors were for the suppliers to hardware manufacturers and then from the competitors to the affiliates and then from the affiliates to the hardware manufacturers. These four types of actors were used in an inter-related way when conducting low innovative projects.

Table 18. Positive Correlated Joint Usages Among Actors/Sources by Innovativeness Categories

INN Category/actors & sources	*Low category*	*Medium category*	*High category*
Markets			Customer to Competitor Affiliate University Resh Instit Patent off. Finl Prom
	Supplier to Hardw Man	**Supplier to Hardw Man** Competitor Fairs/conf.	**Supplier to Hardw Man** Resh Instit Hardw Man to Resh Inst. Fairs/conf
	Competitor to Affiliates	Competitor to Hardw Man	**Competitors to Affiliates** University Resh Inst. Pat Office Finl Prom Market Consul
	Affiliate to Hardw Man		
Scientific system	**University to Finl Prom**	**University to Resh Instit**	**University to Resh Instit** **Finl prom**
	Research Inst. to Supplier **Hardw.Man**	**Resh Inst to Hardw man**	Resh Instit to Finl Prom Mkt consul Tech consul
Public Authorities	**Patent Off. to Finl Prom**	**Patent Off. to** Resh instit **Finl Prom** **Tech consul**	**Patent off. to** Mkt consl **Tech consul** Fincl Prom to Mkt consul Tech consul
Mediating parties	**Mkt Consul to** **Tech Consul** Tech Consul to Press **Press to** Patent Off. **Fairs/conf**	**Mkt Consul to** **Tech Consul** **Press to** **Fairs/conf**	**Mkt consul to Tech Consul** Fairs/conf to Tech Consul **Press to Fairs/conf.**

In the medium category, suppliers were also used in a somewhat consistent manner together with hardware manufacturers, but then also connected to the usage of inputs from both the competitors and information picked up at fairs/conferences. The importance of inputs from competitors is also correlated with that from the hardware manufacturers in the medium innovativeness category of projects.

In the high innovativeness category projects the teams take on much more joint activity with the external actors/sources. In addition to the customer inputs that were used jointly with those from other actors/sources mentioned above, the monitoring of competitors was correlated with usage of affiliates, universities, other research institutes, activities in the patent office, government financial promotion, and market consultants.

The use of scientific system and public authorities actors/sources in the high innovativeness category showed that the market and technical consultants tended to be closely used together with linkages to other research institutes, activities in the patent office, and to government financial promotion. This pattern does not show in the lower two innovativeness categories. It may be also of interest to point out that the correlations for the joint usages of the scientific system and public authorities are all above 0.930 for this high category. The importance sums for each of these were all above 8.5 (out of a possible 20) according to Table 5 wherein these were analyzed separately. So these are very important usages that are used in a joint fashion when creating high innovativeness software products.

Table 18 can be used as checklist for inter-related contacting of actors/sources depending upon the innovativeness that is judged for a given project. Fewer inter-related working channels can be expected for low and medium innovativeness projects.

Turning now to the six negative correlations shown in Table 16 and mentioned in Table 17 some tendencies for trade-offs in the usage of linkages can be found. These are understood to show alternative process practices since similar types of knowledge and skills reside in several of the actors/sources. Table 19 sets forth these process tendencies. In this connection it should be mentioned that, as shown in Table 16, the last four of these negative relationships have p-values ranging from 0.1 to 0.3 indicating weaker tendencies.

Table 19. Process Tendencies among Linkages Between Actors/Sources showing Negative Correlations §

Correlation coefficient	*Between actors/sources*	*Likely tendency*
-0.663	Hardware manufacturer to market consultants	Greater reliance on hardware manufacturer may reduce the importance of market consultants
-0.677	Competitors to universities	Monitoring of competitors may be put over to the involved university
-0.618	Affiliate to technical consultants	Affiliates importance may be reduced as technical consultant is more relied upon
-0.786	Technical consultants to other research institutes	Use of technical consultants may be traded-off against use of connected research institutes
-0.644	Fairs/conferences to government financial promotion	Greater use of fairs/conferences may decrease reliance upon government financial promotion

Note: § The correlation coefficients shown in this table are all from the low innovativeness category

6. Conclusions

The general problem was divided into the following research questions in section 1:

1. What types of s/w development processes are used by the project teams for different levels of innovativeness?

2. What linkages to outside knowledge sources/actors are used in different development phases for different levels of innovativeness ?

3. What is the relationship of different levels of innovativeness to the effects flowing from product development processes?

   Answers to these hinge on what is meant by ‘innovativeness’. The following measures were used to construct innovativeness indices for all products examined as explained in sub-section 4.1:

   1. Newness to the company

   2. Newness to the market

   3. Uniqueness of product benefits in terms of feature set difference and product performance compared to closest available competitive product, and

   4. Scope of innovativeness meaning the creation of a new product platform rather than upgrading of one or more modules for an existing product.

As to research question 1, it was found that process models wherein prototype generating models such as the incremental and evolutionary were mixed with nonprototype models exemplified by the waterfall model tended to be preferred for the more innovative products (38.3% of the next to highest innovativeness index average). The highest innovativeness index average (4.17 out of 5) showed use of the proprietary Rational Unified Process. The waterfall model was used over a wide range of innovativeness, from 1.81 to 4.72, so its use seemed to be generally applicable to all projects. Only a few uses of the hacker approach and the spiral and sync-and-stabilize models were found.

It was also concluded that large-sized firms do not consistently use more complex s/w creation processes than do smaller firms.

The second above research question was: What linkages to outside knowledge sources/actors are used in different development phases for different levels of innovativeness? This question was approached in two steps. The first was to examine the processes in an overall way for each of the actors/sources without regard to the particular development phase in which they were used. The second step was to breakdown the data for each of these according to the four development phases of idea, decision, product construction, and commercialization. The conclusions were for:

Step 1. Customers were found to be the most important linkage for the low and medium innovativeness categories when the overall product creation process was examined on the basis of statistical significance by summing the importance ratings for each linked actor/source. The customers, affiliates and other research institutes had the same high level of importance in the high category. When those two actors/sources were used in a project they had importance average values that were as significant as the average for the customers. At the second level of importance the importance of the actors/sources also varied with the innovativeness level. For the low category this second level started with the affiliates and contained eight other actors/sources, and for the medium category the second level also started with the affiliates that were together with only three others, but for the high category the second importance started with the fairs/conferences and then contained 9 of the 13 total external linkages. These and other difference shown in Table 6 seem to indicate that the high innovativeness products are handled in a special manner with respect to the usage of external actors/sources.

Step 2. When analyzed within each of the four phases of the s/w creation process the customers were found to be the most important external actors/sources for the low and medium categories within the idea and decision phases of the creation process. With two exceptions customers are also the most important linkage for the high innovativeness category in the idea phase and with 4 exceptions also for the decision phase as well. This pattern changes markedly for the last two phases.

In the development phase about half of the examined linkages to actors/sources other than the customer are just as important statistically as are the customers for each of the three innovativeness categories. The actors/sources; however, are quite different in each of these three categories as shown by Table 8. In the commercialization phase there are 5 excepts to the customer as the most important external actor for the low innovativeness category and for the medium category it is the press and fairs/conferences that are on the same statistical importance level, but for the high category only the press on that same high statistical level with the customer. Thus the customers could not be shown to be the most important linkage when compared to many other the other actors/sources for the high innovativeness category or in the development phase for any of innovativeness categories. Notwithstanding these findings, it has been concluded that none of the other actor/sources could be shown statistically to be more important than the customers.

The third research question was: What is the relationship of different levels of innovativeness to the effects flowing from product development processes? The findings reported herein show larger developmental effects for projects that produced high innovativeness products compared to those of lower innovativeness. The developmental effects examined are those shown in Tables 9 and 10.

Management personnel knowledge enhancement, gain in reputation by the firm, profitability compared to other projects of similar complexity, strengthening of linkages to hardware manufacturers, cooperation partners, universities and other research institutes, and marketing consultants were all found to be have importance evaluations that were greater on a statistically significant basis ($p < 0.05$) for the high innovativeness category than for either the low or medium categories. In additionally to these effects, the potential for transfer of knowledge from the focal project to subsequent projects, knowledge enhancement for project team members and marketing personnel, extent to which the firm will likely be able to retain knowledge that is proprietary for the enhancement of later products, and overall project success are all significantly greater for the high category than for the low category.

These different effects found for the high innovativeness category mean that knowledge accumulation was greater in processes in which high innovativeness products were created than in cases where the products were of lower innovativeness.

The results suggest that some additional attention could well be given to maximizing the business development values that are associated with such high innovativeness projects. For personnel knowledge enhancement specific objectives could be set up so that the types of knowledge that could be expected to be generated can be in focus from the project inception. The acquisition of specific types of knowledge could be outlined and made part of the task requirements in a manner that has been suggested by den Hertog and van Sluijs (1995: 193+ and 2000). This means that the use of knowledge management practices should be considered especially for the high innovativeness projects from the outset.

The greater effect on linkages to external actors also suggested that special attention to that part of the s/w creation process would be sensible. Several practices come to mind. Individual members of the project team could be assigned a linkage manager role for one or two external actors in much the same way that advertising agencies use account executives. This would permit a deeper and more consistent focus on knowledge that could be obtained from the separate external actors. Coordination of the linkages across the project could also be of importance since some joint linkages were of greater importance than others as show in Table 18. This might be appropriate for a given project team member. Overall coordination could be a useful practice to maximize the learning potential that seems to exist within high innovativeness projects. This might be a task for the project manager to consider adding to his or her already over-busy assignments list.

Other interesting conclusions are:

A. Large-sized firms did not show an advantage over smaller ones when it came to producing high innovativeness products. The highest innovativeness average values were found for firms in the size range of 21 to 40. From this finding it can be suggested that firms of this size are particularly well situated to grow larger since the higher innovativeness was also found to be positively associated with the advantages flowing from the various business development effects that were measured.

B. The high innovativeness category of products had nearly three times the number of the more highly correlated joint usages of external actors/sources as did either of the lower two categories as shown by Table 17. This seemed to show the greater intake of outside knowledge during the processes in which the high innovativeness products were created. The joint usages of inputs from customers were more highly correlated with inputs from many other actors/sources in this group of products. This supports the above suggestion that some additional resources could usefully be allocated to the management of external linkages during s/w projects.

C. The largest companies (total employee sizes of 90,000 to 200,000) used either the mixed models or proprietary & mixed models process types. These were also used for the larger sizes of projects. Even small sized firms undertook large projects using such mixed models. The largest sized teams tend to prefer use of the proprietary & customized models. The highest innovativeness products tended to result from use of the Rational Unified Process and mixed models.

A summary of the conclusions regarding the hypotheses is given in Table 20. Commentary concerning these conclusions are below and following the table.

As to H1, very low usage was found in this sample of s/w projects for the hacker approach and for the spiral, sync-and-stabilize, and stage-gate models. A mid-range of usage was found for the incremental, evolutionary, Rational Unified, and the proprietary & customized processes between about 7% to 11%. The highest usages were for the waterfall at 16% and mixed models at some 38%. In addition, 22% of the mixed models specified usage of the waterfall process for an overall usage figure of 36%. Addition of the mixed model usage of the incremental, evolutionary and spiral models also substantially increases the overall usage of those models in the sample.

This means that H1 has been affirmed for the hacker approach, but rejected as to the waterfall since it is actually used by a significant percentage of the project teams.

Regarding H2, large companies make substantial use of both simple models such as the waterfall and the much more complex models such as mixed models and proprietary & customized models. The company size range for the waterfall is 24 to 88,500 and for the more complex models 3 to 200,000. So it has been concluded that size of the company is not a determinant of process usage.

Table 20. Summary of Hypotheses Findings

Hypothesis No.	*Hypothesis*	*Result*	*Discussion location*
1	Significant percentages of software project teams do not actually use the hacker approach or the waterfall model for product development.	Affirmed as to hacker Rejected as to waterfall	Sec. 4.2
2	Large sized companies, measured as number of employees, use more complex process types in a given project.	Rejected	Sec. 4.2
3	The customer is the most important actor/source for the overall product creation process independently of the level of innovativeness.	Rejected	Sec. 4.3
4	The importance of the customer in each of the four process phases is larger than the importance of all other sources/actors independent of the innovativeness level.	Rejected	Sec. 4.3
5	The importance of competitors is relatively constant across the four process phases independent of innovativeness level.	Rejected	Sec. 4.3
6	Effects flowing from the development processes show a U-shaped variation when moving from low through moderate to highly innovative products.	Rejected	Sec. 4.4
7	The knowledge accumulation in higher innovativeness products is equivalent to that in the medium and low innovativeness categories of products.	Affirmed as to the medium innovativeness products Rejected as to low innovativeness products	Sec. 4.4
8	There are no more extensive internal company developmental effects for products with high innovativeness than for those of lower innovativeness.	Rejected	Sec. 4.4
9	S/w Innovativeness is positively associated with larger-sized firms.	Rejected	Sec. 4.5

The overall importance of the customer within the s/w creation process varied with the innovativeness of the product produced. Treatment of H3 followed from the finding that the customers were the most important external actor for the low and medium categories, but that they shared this position with both affiliates and other research institutes in the high category as pointed out in Step 1. That is set forth prior to Table 20. This last finding means that H3 must be rejected as constructed. Having reached this conclusion it is necessary to point out that these two actors/sources that were found to have equally significant importance as had the customers in the overall creation process were only used in one-third to one-fourth of the high innovativeness product processes. It could then be said that this is not such a very meaningful rejection of H3.

When the importance of the customer was examined within each of the four phases of the s/w creation process with respect to H4 it was necessary to consider both variations within the innovativeness of the product produced and the particular phase of the process. As detailed in Step 2, above the table, there is considerable variation in importance attached to the linkages with different actors/sources depending on these two factors, particularly, in the development (programming) and commercialization phases.

For H5, the importance of the competitors was found to vary across the four process phases. The importance values for competitors in the idea phase means were significantly greater than in the development phase for each of the three innovativeness categories. The competitor mean values showed different patterns for the idea to the decision and commercialization phases comparisons. This supported the expectation that competitors are monitored most closely in the idea phase.

Regarding H6, there was no evidence found to support a U-shaped variation in effects when moving from low to medium to high innovativeness categories as was earlier reported for tangible new products developments (Kleinschmidt and Cooper, 1991).

The conclusion for H7 as to knowledge accumulation was that the measure of such accumulation was significantly greater in the high innovativeness category than in the low category, but was not statistically greater than in the medium category. Focussing on building knowledge as an internal firm development strategy, therefore, depends on carrying out medium or high innovativeness product developments.

As to H8 the data showed significant stepped increases in many of the linkage effects when moving from low to high innovativeness. It must also be pointed out that the main effects 1-8 in Table 9 showed statistically significant increasing company development effects for the high innovativeness category compared to the low category. The conclusion was that there are more extensive internal company developmental effects for products with high innovativeness than for those of lower innovativeness.

For H9, it was concluded that large firm size did not show an advantage over smaller firms when it came to producing higher innovativeness products. The highest innovativeness average values were actually found for firms in the size range of 21 to 40. Larger project sizes in terms of man-months expended in the projects and in terms of team size did show a slight advantage for greater innovativeness in the medium and high innovativeness categories compared with the low category.

Reflecting further on these conclusions we have looked into the possibility that we have been dealing with a sample that has been biased toward high innovativeness projects. One of the initial criteria for inclusion of a project was that there should exist 'some aspects that were new to the company at the time the product was created, but that the software did not have to be totally new to the company'. However, it did not appear that this criterion was closely followed. There were 26 projects that had innovativeness indices of 3.25 or lower. Further, one-half of those were lower than 2.6 for a total of about 14% of the projects in the sample.

A histogram of the indices taken on a 40 point interval scale shows that the data is skewed toward the high end of the 1 to 5 range. However, this is due mainly to the fact that only two of the projects had index values of 1.00 and then a gap occurred until a value of 1.9. From that point onward the distribution appeared to be of a normal configuration. This seems to mean that nearly all interviews were based on products that had some aspects of newness even if these were not so great when measured by the innovativeness index. This together with the distribution of the low, medium, and high innovativeness categories that reasonably conformed to the percentages set out by Garcia and Calantone (2002) indicates that the sample is not unduly biased toward high innovativeness products.

However; we have to say that we believe the sample was biased toward successful projects. The average of the overall success ratings was 4.16 on a scale of 1 to 5. Only in a few interviews did it appear that the chosen project had disappointing results. We did not intend to treat successful vs. unsuccessful projects of products in this study. Rather we wanted to learn about the software processes and linkages that were used to gain knowledge and create the end results. We thought this could best be done by examining projects that were well remembered by the interviewees. Nearly all of those turned out to be successful ones.

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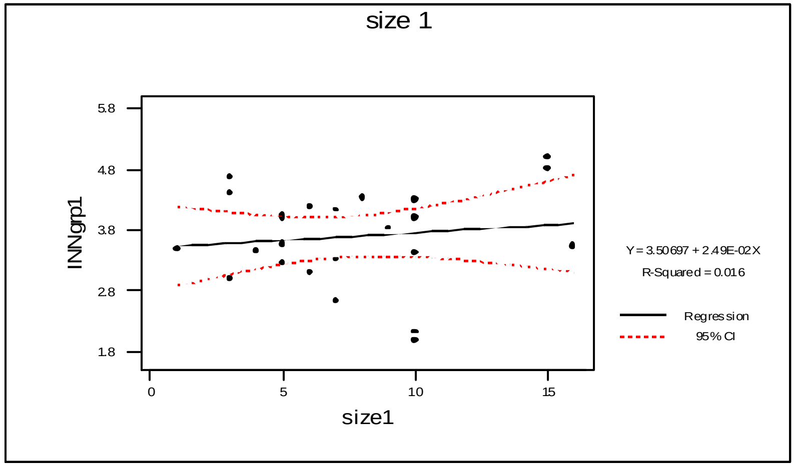
Appendix A. Interviewed companies by countries of origin

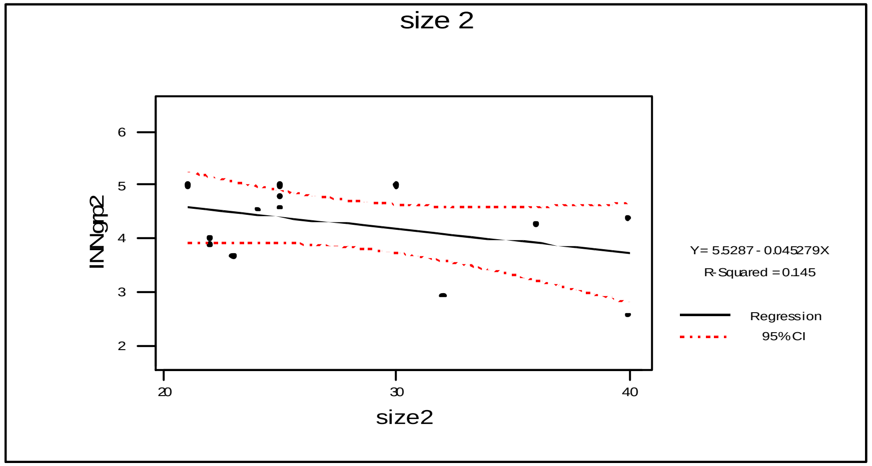
Country	*Number in country*	*Totals for country groups*	*Companies (notations for 'other firm(s)' are for firms that preferred anonymity)*
Spain	8		Reuters Dss, Artecesoft, 6 other firms
Italy	6		AEA, Sinfo Pragma S.p.a., Resiban S.R.I., RiskMap, 2 other firms
France	6	20	Cap Gemini Ernst & Young, Moore-Paragon, Siemens Landis&Staefa, IBM, 2 other firms
Germany	6		Debis, Hewlett-Packard, Medio, 3 other firms
Austria	3	9	Alcatel, Trans-flow, 1 other firm
Belgium	5		Business Solution Builders, Synes, Ubizen, 2 other firms
Holland	4	9	X-Hive Corporation, 3 other firms
U.K.	2	2	Ivy Learning, 1 other firm
Finland	5		Anilinker Oy, Icon Media Labs, Globalics, Mica Solutions, 1 other firm
Norway	2	7	Objectware, Divineo
Russia	2		Speech Technology Center, Star SBP
Lithuania	1		Alna
Slovenia	1		Hermes Softlab
Estonia	2	6	Index Net, AS Abobase System
USA	2		Hewlett-Packard (2 cases)
Canada	4		Altersys, 3 other firms
Australia	3		Ericsson Australia, 2 other firms
Peru	1	10	1 firm
Sub-total		62	
Sweden	31	31	Nexus, Intentia, Altcom, MedVind IT, Citerus, Tofs, EQUA Simulation Technology Group AB (formerly BrisData), TietoEnator, Kost och Näringsdata, BroadVision, Marratech, Bonanza, Upright Engineering, Emerson Energy System, Paradox Entertainment, Envox Group, Front Capital Systems, Medvind IT, Clinitrac, Svenska Market Management Partners, ICL Invia, 10 other firms
Total		94	

Appendix B. Firm Size vs. Innovativeness Indices Regression Plots for Set B Size Ranges

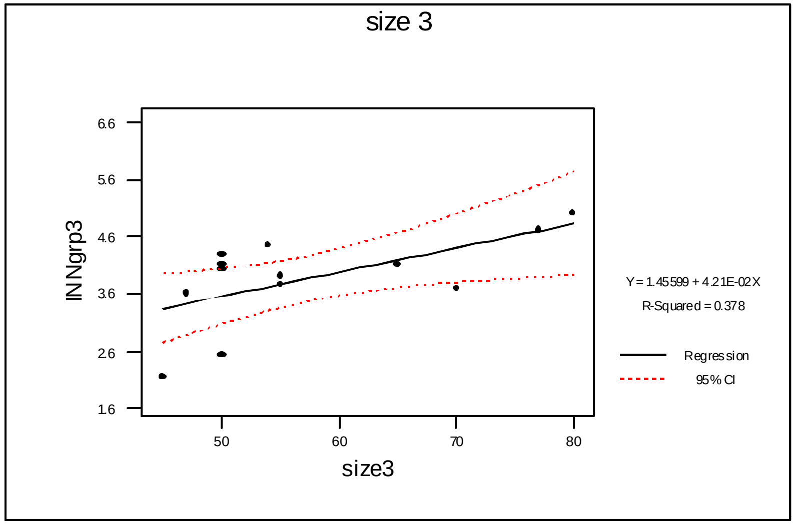
Size 0-20 INN = 3.69



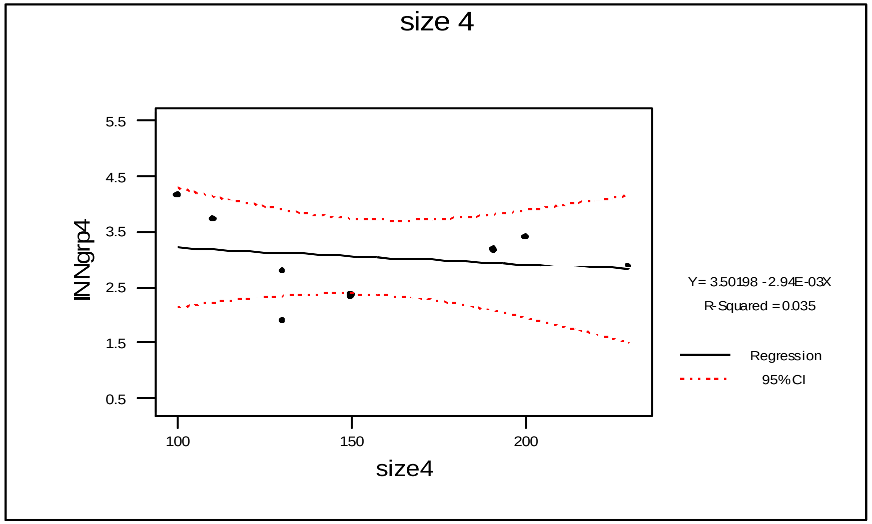
Size 21-40 INN = 4.25



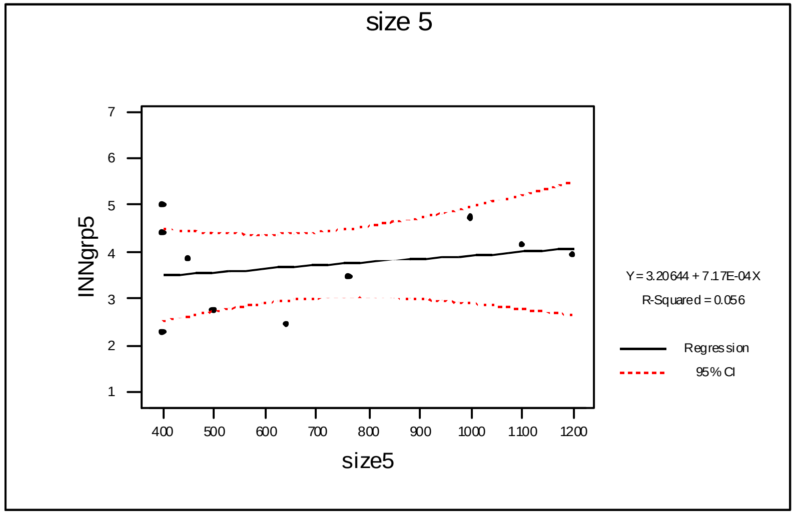
Size 41-80 INN = 3.88



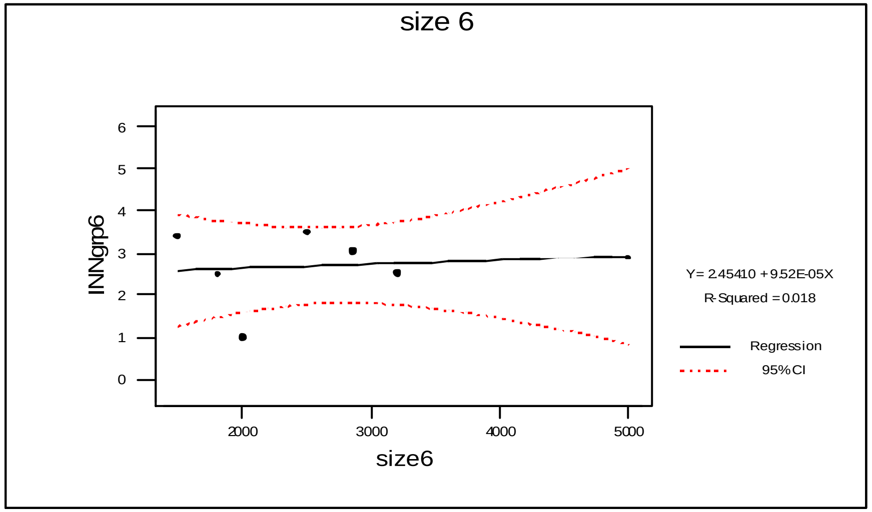
Size 81-350 INN = 3.05



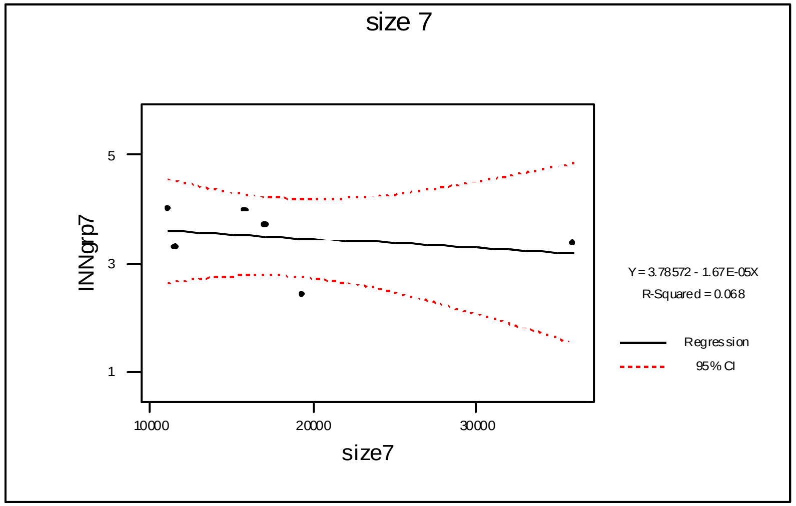
Size 351-1,200 INN = 3.70



Size 1,201-11,000 INN = 2.71



Size 11,001-45,000 INN = 3.48



Size 45,000+ INN = 3.78