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A Computer-Aided Process For Assessing The Ability Of Shipyards To Use Technological Innovation

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ABSTRACT

This paper details a prototype personal computer based organizational evaluation system that allows a shipyard to evaluate its potential for technological innovation against a composite innovative organization. The system was developed by a combination of meta-analysis of available literature, interviews, and survey of shipbuilding industry personnel. The system is designed for self use by organizational members, and produces output that serves as basis for dialogue about changes necessary to increase the innovative capacity of a shipbuilding organization. Development and use of the system is explained, and examples of output from 2 field tests is presented. Further system development plans are examined.

Keywords: Technology, Organizational Development, Evaluation, Computer

INTRODUCTION

Organizations generally exploit the advantages of new technologies by adapting those technologies to fit their current organizational structure and strategies. This process in most organizations occurs as short periods of intensive, turbulent change, followed by longer periods of relative calm as the benefits from the change are absorbed by the organization [1]. This is a normal occurrence during the period of technological discontinuity that occurs as a process or market shifts to a newer technology. The United States shipbuilding industry, faced with the loss of the United States Navy as its prime customer, appears to have little experience with those areas of technology transfer that are necessary to maintain competitiveness in a multiple customer environment [2,3].

The research reported in this paper had two purposes. The first purpose was to determine the general ability of shipbuilding firms to use technological innovation to enhance their ability to compete in the emerging global, multiple customer environment. The second purpose was to report on a software-based system that helps increase that ability to compete by measuring the ability to innovate within an

organization and suggests ways to improve it.

LITERATURE REVIEW

An assessment on what works and what does not work with regard to innovation in the shipbuilding industry was accomplished by conducting a literature review, interviews in shipyards with personnel responsible for technological innovation, and a random industry survey. Previous research in technology transfer within the shipbuilding industry supports the idea that, in general, the process of technology transfer is poorly implemented in many shipbuilding companies [2,4]. Many shipbuilding industry leaders point out that technology transfer is often identified as a highly desirable objective, but it is most difficult to obtain and the technology transfer process generally does not work as well as most participants desire [2].

Shipbuilding firms, like many organizations, are in the midst of a paradigm shift from relatively stable markets, based on the application of electromechanical tools to a customer-responsive world of continual innovation based on "technoservices" that require organizations to use technology in rapidly changing ways to satisfy multiple customers [5,6]. Organizations that are successful under this new

paradigm have many characteristics of what are known as learning organizations, i.e., organizations that have mechanisms in place to continually question and change the accepted practices of the organization, whether it be technology or management method [7,10].

One of the primary components of a learning organization is the mechanism it uses to learn from the experiences of other organizations or the results of its own actions. These mechanisms were examined as potential tools to enable shipbuilding firms to more easily assimilate what has worked in other organizations. However, the transfer of these successful mechanisms is often complicated when the root technology has a military use. Often, the technology transfer process is much more complex in the case of the so-called "dual-use" technologies, where a judgment about the threat a technology may pose to national security must be incorporated into the technology transfer decision process. Since the prevailing view is that it is better to err on the side of caution, often such dual-use technologies, while having appealing commercial applications, are restricted from utilization by bureaucratic methods that assume "it is better to be safe than sorry" [8]. This problem clearly is a deterrent to shipbuilders whose primary experience and expertise is in military systems and who wish to shift that expertise to commercial ships.

The existing literature clearly indicates the importance of shipyard executives in the process of using innovation as a competitive advantage factor. It is probably best expressed in the seminal paper in the *Journal of Ship Production* by James Rogness (1992) in which he concludes:

"The problem is that, despite all that has been considered and tried, results have been disappointing, at best. No shipyard has been able to break out of the pack and lead the way to international competitive stature. What more is needed? What more can be tried? The answer to these questions is not comforting. No procedure, tool, or program, in and of itself, is capable of boosting U.S. shipbuilding productivity into international competitive stature. Very little improvement is possible until shipyard executives finally realize that the most powerful productivity constraints in U.S. shipbuilding exist in the form of destructive organizational policies which only they can change."

This assessment, as well as much of the other literature, tends to confirm the assumption that change management skills are a necessary factor in improving

the ability of shipyards to use technological innovation to become more competitive in a global economy. Thus, the research reported in this paper approaches technology transfer as a change management problem, rather than a purely technical problem.

INDUSTRY SURVEY

While the literature provided an initial set of hypotheses about the technological innovation process in shipbuilding firms, confirmation for these hypotheses was based on information obtained from shipbuilding personnel, naval architects and marine engineers. A series of interviews with various shipyards, both large and small, and consultants to the shipyards, were conducted along with attendance at shipbuilding conferences and seminars. In addition, a major effort was initiated to survey as many U.S. shipyards as possible.

The list of potential respondents was developed by random selection from a list of all shipbuilding firms obtained from the *Society of Naval Architects and Marine Engineers* (1995). From this list, companies were selected that had identifiable personnel, such as chief engineers, technology managers, and so forth, to whom the survey could be directed. From this refined list, a random sample of 150 firms was developed. A snowball technique was then used to provide the actual sample for the study [9]. This technique was used in an attempt to overcome one of the historic problems in survey research in shipbuilding firms, that of poor response. Most researchers who study the shipbuilding industry report very poor response rates, usually about 5-6%. Obviously, this is a threat to generalizability of results.

The snowball technique used in this study consisted of identifying a primary respondent by name at each of 150 shipbuilding firms from a randomly selected list as described above. If a primary respondent name could not be determined for the firm, the firm name was discarded and a new firm randomly selected to replace the discarded firm. Each primary respondent was mailed four questionnaires along with detailed instructions to pass the other three questionnaires to other people engaged in the technology transfer process within the shipbuilding firm. Thus, a total of 600 questionnaires were mailed to 150 randomly selected firms. A second mailing of the questionnaire to non-respondents was made in two months. An invisible coding scheme was used on the questionnaires to provide a method to determine which firms needed follow-up for the second mailing. Otherwise, the replies were kept strictly anonymous, in

an attempt to increase response rate. This procedure yielded 102 usable responses, as determined by completeness of response and self-reported involvement in the technology transfer process.

The questionnaire was developed from past research in innovation and technology transfer, after initial interviews with technology transfer personnel at multiple shipbuilding firms [7,10,11,12,13,14]. This step was necessary to adapt standard questions to the unique culture of shipbuilding. The questionnaire consisted of 21 multi-item area questions and 7 open-response questions designed to determine individual perceptions about the technology transfer process within the respondent's shipbuilding firm. Specific question areas were: (1) the structure and industry sector of the firm; (2) level of success; (3) reward systems used; (4) influences on the technology transfer and innovation process; (5) the role in the innovation process played by the respondent, and (6) several open-ended questions designed to let the respondent describe successful and unsuccessful attempts at innovation within their firm. In addition, there were several other areas important to innovation/technology transfer interaction that were measured by single questions with multiple responses or ranking criteria. A complete version of the questionnaire is available from the authors.

SURVEY RESULTS

Some selected survey results are indicated below:

- 72% of respondents think they are performing better than their competition.
- Most respondents fail more than they succeed at bringing new innovations into their company.
- Only 2% of responding companies have specific reward systems that implicitly reward technological innovation.
- The most important considerations when adopting a new technology are:
 - Customer requirements,
 - The CEO wants the technology, and
 - Others in the industry are using.
- The primary decision criteria used to decide which innovations to use are:
 - Faith innovation will work, and
 - It is a primary customer decision feature.
- Very few firms actually used objective criteria for decision-making about technology, but many have a system that is used to justify decisions once they are made.

- Reasons for technological failure (in rank order)
 - Lack of management commitment
 - No cross-organization input
 - No market reason for innovation
 - Too expensive to be competitive
 - Software unfriendly
 - Ad hoc procedures
 - Culture that rewards heroics
 - Not a core market for company.

Overall, the results of the survey confirmed that management was indeed extremely important in the technology adaptation process in the shipbuilding industry. This clearly echoed the conclusions of Rogness mentioned previously. In addition, the tone of the replies indicated an industry in denial. With the United States shipbuilding industry constructing less than 1% of the global newbuilding market, arguably the 72% who perceive that they are doing better than the competition are [2,15]:

- Either in denial of international competition, or
- Do not understand that the U.S. shipbuilding industry is moving from a single customer (the United States Navy) to multiple customers, mostly in the commercial sector.

This type of attitude is not uncommon among personnel in industries which have been relatively stable for many years and which are beginning to undergo dramatic changes. The steel industry, airlines, banking, and the telephone industry are past examples of industries where this behavior has been observed [16,17,18]. The problem is, that when in this situation, many companies still refer to their historical successes and fail to realize that those methods and procedures are no longer applicable.

DETERMINATION OF SYSTEM

The objective of this project was to produce a system which enhances the capability of shipbuilders to utilize new technologies to increase their competitiveness in a global market. The system was to be usable by *all* shipbuilders, which greatly complicated the development process. However, the funding organization specified that the objectives of the project were to "increase the international competitive ability of United States based shipyards." Thus, the system had to be responsive to the individual company situation across a wide variety of organizations. Given this constraint, the type of system and method used to reach the objective was changed from that initially visualized as a result of the literature review, the industry survey, and

interviews. In essence, it became apparent that the system was expected to be more useful if it enhanced the shipbuilder's ability to *recognize the need for change* rather than provide prescriptive directions on how to change. A "self-help" model which could assist shipbuilders in doing a better self-assessment of their innovative potential and capabilities would be much more useful than an expert system model which assisted shipbuilders in evaluating the probability of success of potential innovations.

The outcome of this phase of the research process was to develop a technology transfer model which could be used to benchmark each shipbuilding company against a composite innovative company. As in most good bench-marking efforts, the composite innovative company is not necessarily based on the most innovative shipbuilding companies, but rather those companies which are world class in the function being benchmarked [19]. The results of this approach gives two important parameters for self-assessment. The first is alignment (both internal and with the composite company) which can be critical information with the emerging emphasis on teams and effectiveness.

The second parameter is the relative position of the shipbuilding company with the composite company, which gives information on areas that may need improving. Perhaps the most significant feature of the system is the self-help feature. The major benefit of the system is the dialogue framework that it develops. Through the use a facilitator, questions such as "Why do we score so low in the management section?" or "Why do we have so little agreement (alignment) on technology issues?" are explored by those who are responsible for technological innovation in the company. Thus, by increasing communication and group effectiveness, the system increases the capacity for innovation within a company [7,12,14]. The system develops no prescriptive answers, but rather becomes a means of stimulating serious questions about individuals and company policies in a non-threatening environment. Use of the model should be most effective when used by upper management teams, but it is designed to be used at any level and should prove to be particularly useful in reviewing alignment of various internal groups and teams.

In this dynamic world in which the shipbuilding industry has found itself, some positive changes have already been noted since the survey was completed in January of 1996. In particular, there has been increased interest in changing the business management model for many shipyards. This is

especially true with regard to teams and concurrent engineering. This change may be driven, in part, by the United States Navy, because of its teaming requirements in the bid process for major new projects, i.e., the LPD-17 project.

In addition, topics such as incentive pay for innovation and productivity, process improvement and change management are becoming more common in articles in shipbuilding industry journals and in the National Shipbuilding Research Program. Despite these positive changes, which were generally not reflected in the responses, it is still believed that a self-help innovation system which develops internal dialogue is the most overall useful tool to increase technological innovation, within the immediate future, in shipbuilding companies.

DEVELOPMENT OF THE MODEL

The system is based on a meta-analysis of existing literature on technology transfer and innovation as well as the results of the shipbuilding industry survey and interviews with participants in the innovation process. The model is shown in Figure 1.

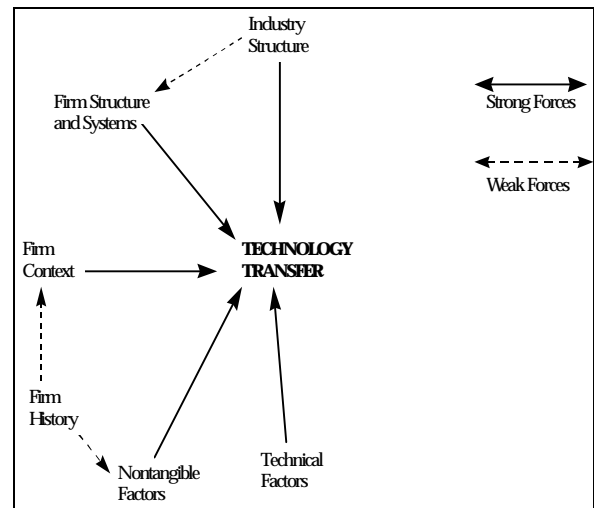


Figure 1, Influences on technology transfer process in shipbuilding companies.

Table 1 shows the elements of each of the primary influences in figure 1. The model elements in table 1 were used to develop question areas that measure the degree of innovation capacity inherent in an individual shipbuilding company or subgroup. These elements in most studies were found to be responsible for significant portions of the explainable variation in innovative capacity between different companies or groups [7,8,10,12,14,20,21].

INDUSTRY STRUCTURE Strategic Group Competitive Analysis Market	FIRM CONTEXT Performance Perceptions Decision Domain Target Sponsors Agent Size
FIRM STRUCTURE Reward Systems Top Management Culture Organizational Structure Accounting Systems	FIRM HISTORY Traditional Markets Traditional Skills Perceived Strengths
TECHNICAL FACTORS Type of technology Relatedness Congruence	NONTANGIBLE FACTORS Non-Quantifiable Factors Underestimating Cost Underestimating Benefit Risk

Table 1, Elements of Technology Innovation Influence Model

INNOVATION QUOTIENT

The model of influences was used as a framework to develop a question-based software system designed to be used by individuals within a shipbuilding company. The individual answers users provide are then aggregated in a post-processing module that allows graphic comparisons of various areas that show the overall innovation potential of the group or individual being evaluated. The aggregate answers can also be used to suggest areas for improvement that will increase the technological innovative capability of the company. The measure of potential for innovation has been termed the "Innovation Quotient", or **IQ**, in an effort to give the system a short, easily recognizable name.

While the soundness of the system is based on the current information available on innovative companies, the usefulness of the model is also directly affected by the format of the software used in the self-evaluation portion of the system. The software will continue to be improved as more user-friendly input software and more beta-test user response is gathered. A short description of the existing software will be given here

After working with C++ as a language for the initial proof of concept software, it was decided that it would be more effective to use a commercially available software authoring package. Since many of the procedures needed in the system have aspects similar to data bases, we decided to use *Microsoft FoxPro version 3.0* as a development system. This

product provides both software development and the ability through the licensing agreement provided with the *FoxPro* authoring package to distribute the finished product to interested parties in the shipbuilding industry without having to pay additional royalties for use. An important part of this project is to distribute the end product to as wide an audience in the shipbuilding industry as is possible. The software developed with the *FoxPro* system runs on any Windows® or Windows 95® equipped personal computer. During the test period the software was also successfully run on a Macintosh computer.

SYSTEM TESTING

In actual use, the software portion of the system is used by the various stakeholders in the shipyard innovation process. The software captures the perceptions of the stakeholders through recording in a database file the answers the participants in the process give to the questions asked in the software. The answers the participants in the process give are used for two purposes. First, the answers of the respondents are compared to a set of answers that would be the norm for an innovative company. This is done through a Likert form additive scale that allows an overall measure of innovative capacity and also allows evaluation of innovative capacity in relation to a composite of innovative companies in several sub-areas that are components of the model.

Second, the answers are compared to each other so that the degree of correlation between each of the participants can be determined. By forcing each of the participants in the innovation process to specify their perceptions about important elements of the process or technical area being considered, potential problem areas can be identified and dealt with in a more efficient and effective manner, leading to an improved technology transfer process. The software displays the information both as text and in graphical format, thus facilitating comparison between and among stakeholders in the innovation process.

The first group to utilize the beta version of the software was selected from a major shipbuilder, whose expertise is mainly in building combatant vessels. A subgroup of that shipyard was a team whose responsibilities include evaluating new innovations for possible implementation.

After some introductory remarks on the purpose of the model, six members of the group utilized the software. The recorded answers were analyzed and in a follow-up session the results were

discussed with the group. Examples of two graphic outputs for this group are presented in appendix 1. Topics that were explored with the group as a result of the graphic results were:

- What was the source of the relatively low scores in the firm structure construct?
- Why were there large variations in scores in the technical construct?
- Was the difference in the profile shapes significant in regard to decisions made about technologies?

In addition, many other areas were explored that discussion of the results facilitated. The end result was that the participant agreed that there were some firm-level structural problems that upper management needed to remedy and there was also a need for increased communication in certain areas within the R&D organization. The comments of the participants was generally favorable, with most criticism directed at improvements that needed to be made in the software user interface.

Figure 5 illustrates the results obtained from the upper management group of a marine telecommunications company. While this is a different industry from what the system was originally designed, we wanted to test the system with a successful organization that we knew was in a dynamic competitive industry. As you can see, the results are different in 2 ways. The first difference is the degree of convergence shown in the group innovation profile. Even though there were 11 participants with varying job titles, the degree of convergence is higher than the shipbuilding company sample. This profile is what we expected of a successful company in a competitive industry. While it is possible to debate whether groupthink could possibly lead to the same profile, our initial analysis supports the view that there was increased ability to deal with technological innovation in this company.

The overall innovation quotient (IQ) for the telecommunications group, shown in Figure 4, is also different from the IQ for the R&D group, shown in figure 3. The overall IQ score is indicative of the comparison with a composite innovative company. Thus, factors in the industry structure variable, as in the telecommunications industry, could mean that a company could have a lower innovation score because of variables such as size and number of competitors. While most of the factor scores are somewhat higher for the telecommunication group, the industry structure factor is a lower score. This is consistent with what would be expected, given the difference in size and competitive market for the two companies.

The face validity of the system and user comments have been very positive to date. Further testing, reliability analysis, and question improvement are expected to be accomplished in the follow on project.

FUTURE POTENTIAL

The results of the shipbuilding test group have been encouraging. The **Innovation Quotient** software clearly was successful in creating meaningful dialogue and suggestions for ways in which the innovation process could be improved in the test group.

In December, 1996, the system and test results were presented to a larger group of shipbuilding industry representatives. The presentation included a demonstration, question and answer session, and feedback from the participants on the anticipated usefulness of the system.

Based on our test results and the additional industry feedback received from the December 1996 presentation, we propose the following as the direction for future work on the IQ system. We should first improve the self-help characteristic of the software. This will be an important step because the increasingly competitive environment of the shipbuilding industry. It is believed that the software can be developed to the point in which companies could self-administer and self-analyze the results without sharing them with outside facilitators. The ability to use outside facilitators will be retained, and the system user will have the option to make the results/review proprietary. This improvement of the self-help feature will require that the questions in the authoring section be updated as innovative practices in companies change. These continual improvements will not only involve the update of the questions, as required, but also the upgrades in software to make it more user friendly. We should then add options to the graphic output section of the post-processing module to allow more combinations and types of outputs to suit individual needs so that self-analysis is easier to accomplish. These improvements should be done by a central group in the shipbuilding industry, most likely the originators of the software concept.

The final improvement to the system is to develop an additional set of questions so the self-analysis software could be used to evaluate the team-based management potential of a company. This will require additional meta-research in order to develop a composite of key best-in-class team attributes. This teaming software would be used in a similar fashion to

the innovation software except it would be specifically applied to teams and groups in which teamwork is important. It would also be a self-help package which would result in two main outputs as in the IQ system, recommended suggestions and dialogue.

This improvement would provide two self-help packages, one on innovation and one on team based management, which should be very useful to the shipbuilding industry. The software packages would be maintained and updated by an Innovation and Team Management Center established as a subgroup of the Gulf Coast Region Maritime Technology Center in New Orleans.

In summary, the computer-aided process for assessing the ability of shipyards to use technological innovation seems to be a powerful tool for shipbuilders because of its self-analysis concept. It allows companies to take a serious look at their innovative processes, without involving an outside consultant and the corresponding risk of loss of competitive advantage. With the increased importance of integrated teams in shipbuilding, the proposed team management function of this computer-aided process should prove to make the basic IQ system even more useful.

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APPENDIX

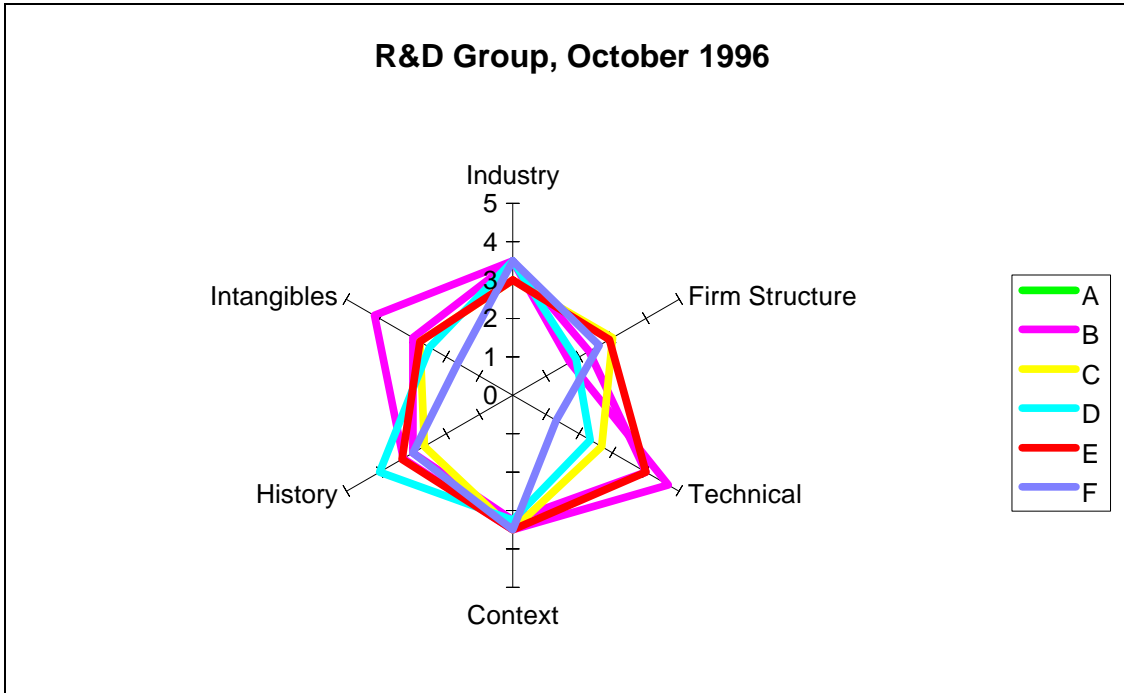


Figure 2, Group Innovation Profile, Research and Development Group

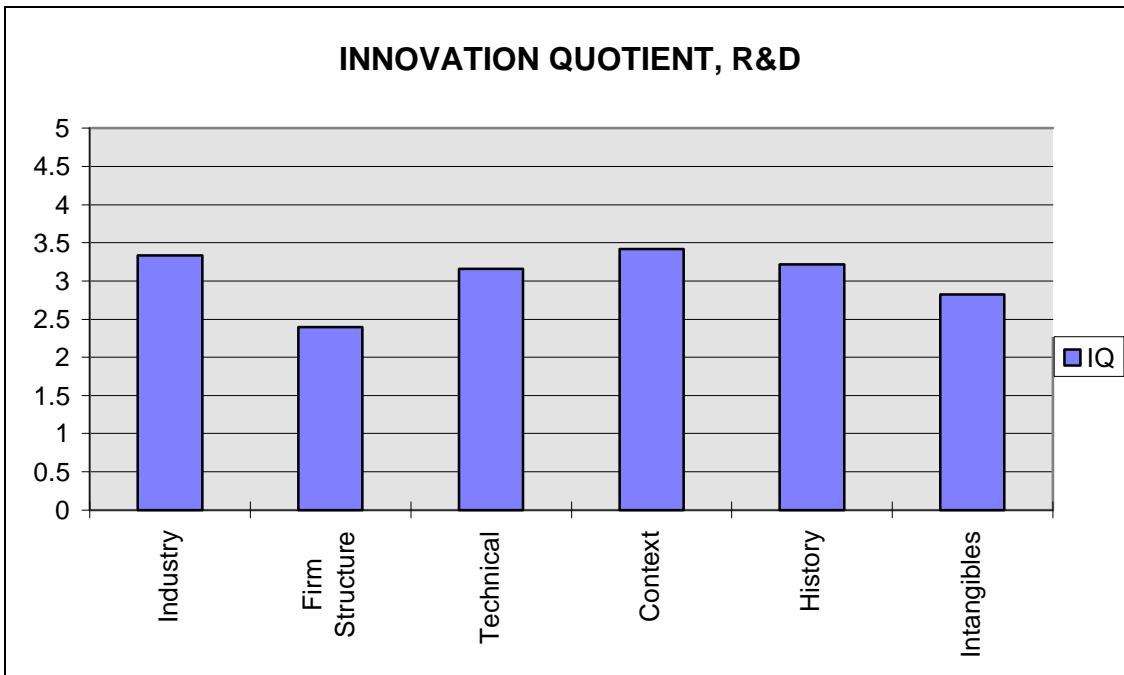


Figure 3, Overall Innovation Quotient, Research & Development Group, October 1996

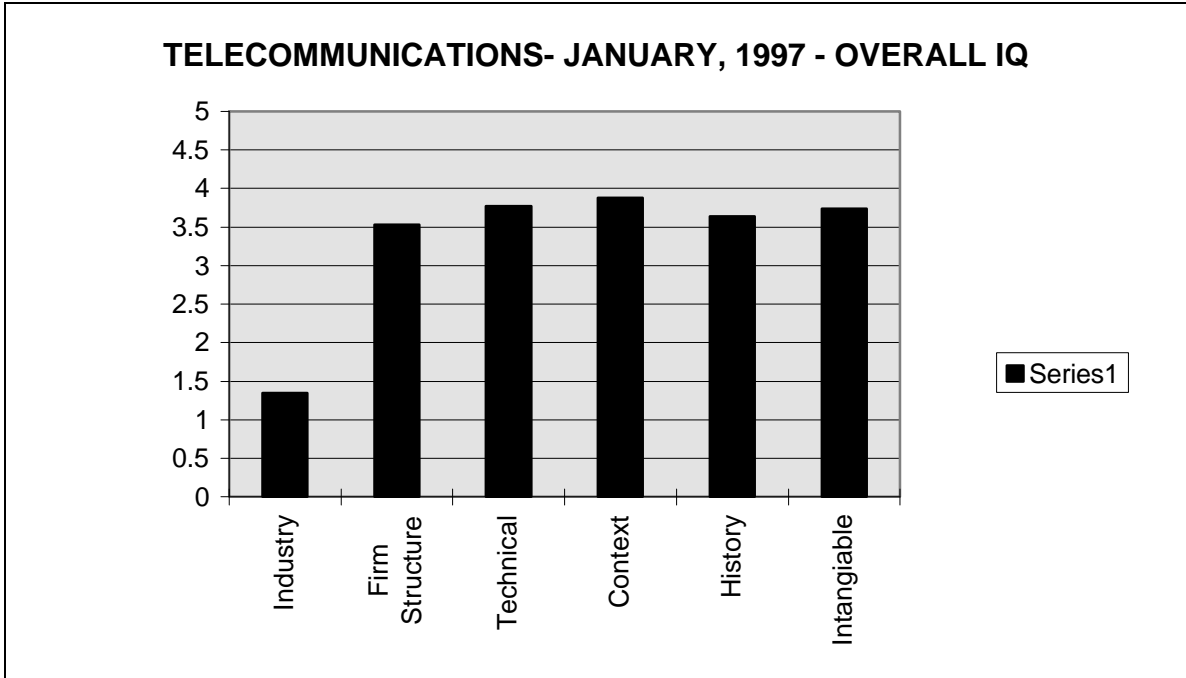


Figure 4, Overall Innovation Quotient, Telecommunications Group, January 1997

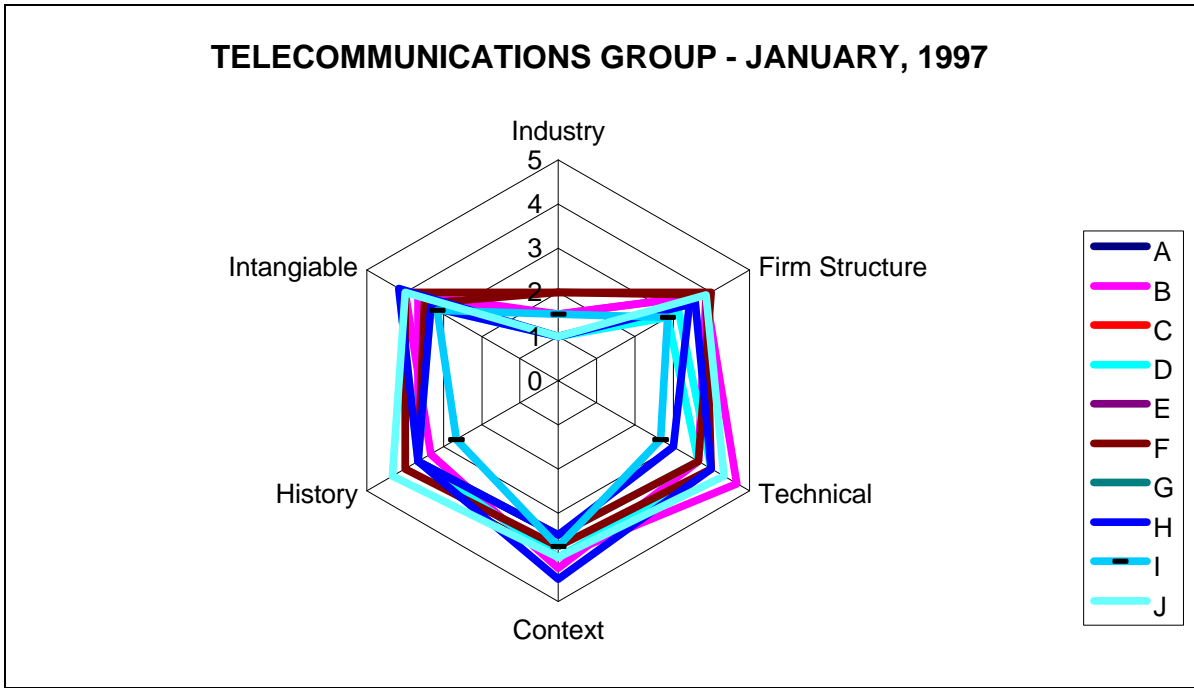


Figure 5, Group Innovation Profile, Telecommunications Group, January 1997

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