Continuous product innovation

A comparison of key elements across different contingency sets

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This paper discusses results from an international study of continuous improvement in product innovation. The empirical research is based upon a theoretical model of continuous product innovation (CPI) that identifies contingencies, behaviours, levers and performances relevant to improving product innovation processes. As successful knowledge management is widely recognised as a key capability for firms to successfully develop CPI, companies have been classified according to identified contingencies and the impact of these contingencies on key knowledge management criteria. Comparative analysis of the identified groups of companies has demonstrated important differences between the learning behaviours found present in the two groups thus identified, and in the levers used to develop and support these behaviours. The selection of performance measures by the two groups has highlighted further significant differences in the way the two groups understand and measure their CPI processes. Finally, the paper includes a discussion of appropriate mechanisms for firms with similar contingency sets to improve their approaches to organisational learning and product innovation.

Product innovation; Knowledge management; Contingency planning; Performance measurement.

Introduction

For over 20 years successful product innovation has been considered a key requirement for business success. Under the joint pressures of an increasingly demanding and global market, and the accelerating pace of technological change, both management researchers and practitioners have recognised that companies need to compete on both quality and speed in product development. One of the main consequences of this focus was the emergence of product innovation models almost totally focused on the management of the new product development (NPD) process. Integration among different phases of an NPD project and autonomy of the project team were considered synonymous with best practice product innovation. Concurrent engineering was thought to represent a long-lasting paradigm for product innovation management.

In the early 1990s, a new stream of studies emerged which enlarged the perspective. These studies demonstrated how focusing on single projects is not enough to sustain competition. Success is also dependent on exploiting synergy among projects, for example by fostering commonality and reuse of design solutions over time (Wheelwright and Clark, 1992; Meyer and Utterback, 1993). In this perspective attention progressively shifts from single projects to a project family (Meyer and Utterback, 1993; Sanderson and Uzumeri, 1995) and to the process of learning and knowledge transfer and consolidation (Imai *et al.*, 1988; Lynn *et al.*, 1999; Bartezzaghi *et al.*, 1997a). Many of these studies, however, consider product innovation as occurring only within the boundaries of the product development process. Downstream phases in the product life cycle were still important for innovation but only as long as they represented valuable sources of information or constraints that should be anticipated and considered during development (Clark and Fujimoto, 1991). Recent evidence suggests that other phases in the product life cycle may actually represent additional opportunities for direct contribution in product innovation. This is a direct consequence of increasing pressure for more rapid product development and decreased time-to-market. Several companies, especially in rapidly shifting environments, purposely release to market products that are not fully optimised, followed by a rapid almost continuous stream of enhanced releases (i.e. software industry).

The boundaries of product innovation are therefore changing dramatically. Customer- and supplier-sourced information and opportunities coming in from the field phases are not only stored for informing next-generation product development projects, but can also provide valuable opportunities for product innovation within a product life cycle. These two dimensions are combined in the model of continuous product innovation (CPI) proposed by Bartezzaghi *et al.* (1997b). CPI embraces not only NPD (concept, product and process design and product launch), but also the subsequent phases in a product life cycle (improvements in manufacturing, customisation in sales and installation and enhancements and upgrading during product use). CPI also moves the traditional perspective from a single product to a product family, and thus includes all the interactions between the different products in the family. Hence, innovation may concern a product that is in its development phase, a product that has already been released to market, or a transfer of solutions between products. All of these interactions constitute a very strong potential for learning and innovation that can be exploited only through active design and implementation of mechanisms to enable the required transfer and consolidation of knowledge. Successful knowledge transfer and consolidation can be fostered by particular enablers whose effectiveness strongly depends on the actors involved and their influence on the process, and on the typology of knowledge that is managed.

Drawing on the literature in the broad areas of product innovation, knowledge management and continuous improvement (CI), a model has been developed to describe the CPI process in terms of a set of interrelated variables. This work has been done as part of the joint Euro-Australian CIMA project (continuous improvement of global innovation management). The variables identified within the CPI model include: organisational (or learning) behaviours (which, through a process of "building-in" over time become organisational capabilities); levers, which are specific actions, tools or techniques available to management in developing and consolidating relevant behaviours; performances, which are specific measures relating to the outputs of the product innovation process as well as the improvements in the process over time; and contingencies, which are factors external to the product innovation process but which may have significant impact on the process. This model represents a combination of the CI Maturity model (developed by Bessant *et al.*, 1994) and the intra- and inter-project learning model proposed by Bartezzaghi *et al.* (1997a). The model was refined through a series of intensive case study analyses of companies from three European nations and Australia, leading to the final form as shown in Figure 1. Thus refined, the model was applied to an extensive data collection exercise in 70 firms from Australia, Sweden, Ireland, Italy, The Netherlands, and the UK, using the methodology briefly outlined in the following section.

Our previous work (Chapman *et al.*, 1999) on the outcomes of this contingency analysis reported the development of two key attributes of knowledge management related to product innovation from a wide range of previous literature on this topic. The two attributes developed were:

1. (1) the sourcing and acquisition of knowledge; and
2. (2) the transfer and consolidation of knowledge.

This earlier paper also discussed the impact of the identified contingencies in the CPI model on these two key attributes of knowledge management.

Research methodology

The development of the CPI Model drove the preparation of a detailed company questionnaire to investigate these elements of product innovation. A sophisticated computer based tool was developed and tested during the case study research period, then administered to 70 companies using either a facilitated workshop delivery mechanism, or a well-supported remote delivery approach. Companies were given detailed feedback reports that identified strengths and possible weaknesses in their CPI processes and compared their responses with the remainder of the database.

This paper will focus on a comparison of the key elements of the CPI model between groups of companies as identified by the knowledge management/contingency (KM/C) analysis discussed in our earlier paper. Application of the KM/C analysis to all companies is shown in Figure 2. This Figure also shows the two major groups of companies (Group A and Group B) used for the comparisons in this paper.

The scales on the axes in Figure 2 represent the sum of the Likert responses for each company across the relevant contingencies included in the criteria for each axis. Details of the contingency classification scheme are contained in our earlier paper (Chapman *et al.*, 1999). Those companies included in Group A have adopted a locally based approach to knowledge management, whilst those in Group B exhibit a global approach.

Locally based approach (Group A)

This group commonly contains small companies operating in domestic markets with highly customised and low complexity products, with only domestic NPD and operations activities. Generally these companies have low "technical" intensity and few inter-firm relationships. They typically operate in an environment of low knowledge accessibility and low labour churn. Such firms thrive in national cultures characterised by low uncertainty avoidance, but high collectivism (see Hofstede (1980) for an explanation of these terms).

Global system approach (Group B)

This group commonly contains large companies operating in global markets with standardised and high-complexity products. Global NPD and operations activities are also common. Generally these companies have a high "technical" intensity and many inter-firm relationships. They operate in an environment characterised by high knowledge accessibility and relatively high rates of labour churn. They are common in national cultures demonstrating high uncertainty avoidance, but low collectivism (Hofstede, 1980).

It should be noted that our initial KM/C analysis postulated company types for the two remaining quadrants of Figure 2 as well; however, currently the numbers of companies falling into these sectors are too low for statistical comparison.

We will now compare how the two groups of companies, identified in Figure 2 and described above, compare in terms of the levers used, behaviours exhibited, and performance measures used to evaluate innovation outcomes.

Analysis of behaviours

The behaviours that were identified in the literature as being relevant to knowledge management were:

- Individuals and groups use the organisation's strategic goals and objectives to focus and prioritise their improvement and learning activities.
- Individuals and groups use innovation processes as opportunities to develop knowledge.
- Individuals use part of available time/resources to experiment with new solutions.
- Individuals integrate knowledge among all the different phases of product innovation.
- Individuals transfer knowledge among different product innovation cycles.
- Individuals abstract knowledge from experience and generalise it for application on new processes.
- Individuals make knowledge available to others by presenting it in reports, databases, product and process standards, etc.
- People try to assimilate and use knowledge from external sources.

Each of these behaviours was examined across two dimensions, frequency and diffusion (expressed as how often and how widespread, respectively, the behaviours were observed in the organisation's innovation processes). Respondents were asked to assess these two dimensions on a five-point scale.

For frequency the categories were:

1. (1) the behaviour was never shown;
2. (2) the behaviour was only rarely shown;
3. (3) the behaviour was shown rather frequently;
4. (4) the behaviour was very frequently shown;
5. (5) the behaviour was always shown as a part of day by day work.

For diffusion the categories were:

1. (1) the behaviour was not seen anywhere within the innovation process;
2. (2) the behaviour was confined to one part of the innovation process;
3. (3) the behaviour was confined to some parts of the innovation process;
4. (4) the behaviour was diffused in most of the innovation process;
5. (5) the behaviour was spread throughout the innovation process.

Figure 3 and Figure 4 compare the behaviours of Group A companies and Group B companies, first on the basis of the frequency with which behaviours occur, and then, the diffusion with which they occur. For each group, the percentage of respondents who reported low frequency or diffusion (category one or two on the five-point scale), were subtracted from those who reported high frequency or diffusion (category four or five on the five-point scale). Were the companies to report an equal number of lows and highs, the behaviour would plot at zero on the relevant figure.

Figure 3 tells us that all behaviours occur more frequently in the companies whose contingencies place them in the global systems category (Group B). Those adopting a local approach exhibit behaviours less frequently across the board, with negative ratings for behaviours 1, 3, and 8. The lowest rated behaviour for both groups was behaviour 3 (individuals use part of available time/resources to experiment new solutions.) Clearly, when it comes to product innovation, organisations do not specifically set aside time for experimentation. For both groups, there is a high level of awareness of the knowledge-generating capability of the innovation process (behaviour 2). Further, both groups see the need for innovation to be a company-wide activity (behaviour 4).

In Figure 4 we compare the diffusion of behaviours between the two groups. Again the Group B companies report significantly higher levels of behaviour diffusion. Behaviour 3 is again relatively weak in terms of diffusion, and behaviours 2 and 4 are again strong. Behaviour 7, which refers to the embedding of knowledge within vehicles (reports, databases, product and process standards, etc.), rates very highly in both groups, which indicates that knowledge capture is quite strong. If behaviour 5 is any indication, however, this knowledge is accessed and transferred to other innovation projects less extensively. It appears that, in terms of knowledge acquisition, organisations tend to be internally focused (behaviour 8), with both global and local company groups reporting low values for the number of staff accessing external sources of knowledge. Weakness in this area could lead to lags in implementing changes to product innovation processes, or bringing new products into production.

Levers

Levers are mechanisms that managers use when managing the product innovation process, even though they may not be consciously aimed at improvement and stimulating learning.

Lever categories and examples of specific levers

1. (1) Product family strategies: 1.1 product family plans; 1.2 carry over policies; 1.3 standardisation policies.
2. (2) Innovation process definition: 2.1 stage-gate processes; 2.2 company innovation procedures.
3. (3) Organisational integration mechanisms: 3.1 teamwork; 3.2 organisation structure; 3.3 committees.
4. (4) Human resource management policies: 4.1 personnel rotation; 4.2 departmental assessment and staff development plans; 4.3 remuneration and reward systems; 4.4 empowerment programs.
5. (5) Project planning and control: 5.1 project termination reports; 5.2 design reviews.
6. (6) Performance measurement: 6.1 comparison of measurements against previous results or with other subsidiaries or leading organisations.
7. (7) Design tools and methods: 7.1 standardised design methodologies and procedures; 7.2 libraries of standard design solutions; 7.3 integration procedures (e.g. QFD, design for manufacturability).
8. (8) Computer-based technologies: 8.1 IT systems; 8.2 computer aided technologies (e.g. CAD, CAM, CAE); 8.3 prototyping technologies.

Two issues are of interest here: first, the difference in the use of levers between the two groups; and second, the extent to which the use of levers acts as a predictor of behaviour within each group. The first issue is addressed in Figure 5.

For organisations in Group A, project planning and control is the most common lever used in managing product development activities. Group B companies report a high usage of organisational integration mechanisms to influence behaviours. The wider geographic spread of Group B companies apparently places greater emphasis on the need for such activities to better manage their innovation processes. Group A companies, being somewhat more self-contained, can focus on the project more than the process. In terms of continuous improvement, the emphasis should be on the process. Of particular interest is Lever 1, the product family strategies, where Group A organisations report a higher usage than Group B. Group A companies generally have a narrower product range and tend to focus on product, rather than process improvement.

Given that the CIMA model proposes the use of levers to influence behaviours, and thus improve product innovation performance, we would expect to see some correlation between the use of levers on behaviours, and the prevalence, in terms of frequency and diffusion, with which those behaviours are observed. Figure 6 shows the relative usage of all levers on each behaviour for the two groups. This Figure does not show the extent to which individual levers are used to impact behaviours. This is the subject of ongoing research to identify the more effective levers for specific behaviours, given the contingency group into which an organisation might fall.

Figure 6 gives a strong indication that levers do influence behaviours. For Group B, the weakest behaviours in terms of both frequency and diffusion were Behaviours 3 and 5, and as can be seen from Figure 6, the average percentage of usage across all levers was lowest for

Behaviour 3, and third lowest for Behaviour 5. For Group A companies, the case is less strong, but still evident. The weakest behaviours for this group were Behaviours 3, 8, and 1. Levers were least used on Behaviour 8, third lowest on Behaviour 3, but somewhat surprisingly, most used on Behaviour 1. We suspect that many companies in this group have a break in the loop. They see levers such as integration mechanisms, human resource management policies, performance measurement, and computer-based technologies feeding into their strategic planning process, but they do not see strategic plans as having a major impact on improvement and learning activities.

Performance measures

Performance measurement of the innovation process has long been in the "too-hard" basket (Brown and Svenson, 1988; Roussel *et al.*, 1991; Brown and Gobeli, 1992). To suggest a set of performance measures that would be relevant to all firms, or even a group of firms, would be presumptuous. As Werner and Souder (1997) state: "R&D effectiveness measurement methods are so individually varied and uniquely designed for particular situations that they almost defy systematic classification". On the assumption that what gets measured gets managed – and improved – we asked the respondents to nominate which performance indicators they used to measure the performance of the product innovation process. The types of performance measures used reflect largely on the rationale for measurement. von Bonsdorff and Andersin (1995) suggest several functions of measurement, but in terms of the innovation process Kerssens-van Drongelen (1999, p. 49) suggests that the primary functions of measurement are "supporting diagnosis by managers and fuelling learning". This latter function is the central theme in the categorisation of firms according to the two attributes: the sourcing and acquisition of knowledge, and the transfer and consolidation of knowledge.

The kinds of measures employed in responding firms are shown in the list following Figure 7, with the questionnaire results shown in Figure 7.

Key to performance measures

1. (1) Time to market measures: 1.1 concept to launch time; 1.2 time for concept phase; 1.3 time for design phase; 1.4 time for initial production phase; 1.5 time for launch phase; 1.6 overrun.
2. (2) Product performance: 2.1 unit cost; 2.2 production cost; 2.3 development cost; 2.4 technical performance; 2.5 quality.
3. (3) Design performance: 3.1 manufacturing cost 3.2 manufacturability; 3.3 testability; 3.4 number of product redesigns.
4. (4) Impact on firm's competitiveness: 4.1 sales in domestic market; 4.2 sales in regional market; 4.3 sales in global market; 4.4 domestic market share; 4.5 regional market share; 4.6 global market share.
5. (5) Impact on firm's product portfolio: 5.1 profits; 5.2 sales of portfolio; 5.3 profits of portfolio.
6. (6) Other metrics: 6.1 total R&D expenditure; 6.2 planned vs. actual project spending; 6.3 return on investment (ROI); 6.4 number of patents and licenses generated; 6.5 score on customer satisfaction audit.

The measures of impact on the firm's competitiveness (category 4) clearly reflect the grouping of the companies, according to their contingencies, into either local (Group A) or global (Group B). The importance of domestic and regional sales performance is substantial for Group A companies, whilst Group B companies focus on global markets. In all other areas, Group B companies report a greater use of performance measures. This is to be expected for organisations that operate globally, and where performance measures are required for reporting and control purposes.

Flamholtz (1996) categorised performance measurement systems functions on the basis of output measures and process measures. The range of performance measures reported by firms are very much output measures, which have limited value in terms of process improvement. Further they rely heavily on production performance measures (Category 2) and project performance measures (Category 6 – other). This is hardly surprising, given that the firms surveyed are all manufacturing companies. Perhaps the best measures for evaluating performance of the product innovation process are 6.2 planned vs actual project spending, and 6.5 score on customer satisfaction audit. These measure how well the process was executed, and how well the new product met the customer's expectations.

The measures, however, are poor performers in so far as they cannot be used to evaluate improvement in the product innovation process. This is where the CIMA methodology for assessing continuous improvement in product innovation is of value. The learning and improvement aspects can be evaluated by assessing whether or not those behaviours that encourage learning and continuous improvement in the product innovation process spread throughout the organisation. This spread is measured by observing the frequency and diffusion of the behaviours identified in the model. As these behaviours become more widespread and frequent, they become embedded as capabilities that enhance learning and continuous improvement in the product innovation process. Further research is currently being carried out to identify specific levers, for encouraging appropriate improvement behaviours in different groups of organisations, depending on their contingencies.

Discussion and conclusion

Our research indicates that all the relevant variables; behaviours, levers and performance measures are influenced by contingencies. This contingency approach is based on the premise that there can be no single best way to manage and improve organisational performance (Emmanuel *et al.*, 1990, p. 57). This is especially so for the product innovation process. By categorising organisations according to their knowledge management capabilities, we have attempted to provide guidelines for firms as to how they might improve their innovation processes.

For organisations that adopt a "locally based" approach to knowledge management we suggest they place more emphasis on levers that rely less on high technology and inter-firm connections. The preferred levers for organisations in the "locally based" category are product family strategies and project planning and control activities.

For organisations that adopt a "global system" approach to knowledge management we recommend more emphasis be placed on integrative and communicative levers such as organisational integrative mechanisms and computer based technologies.

One area where greater emphasis and ongoing research is evident is that of performance measurement systems for the product innovation process. The measures used by organisations are largely output measures, which indicate the success or otherwise of each product innovation, but do little to improve the innovation process. The CIMA model addresses a key concept for improvement of the product innovation process by identifying and measuring important learning behaviours in the area of knowledge management.

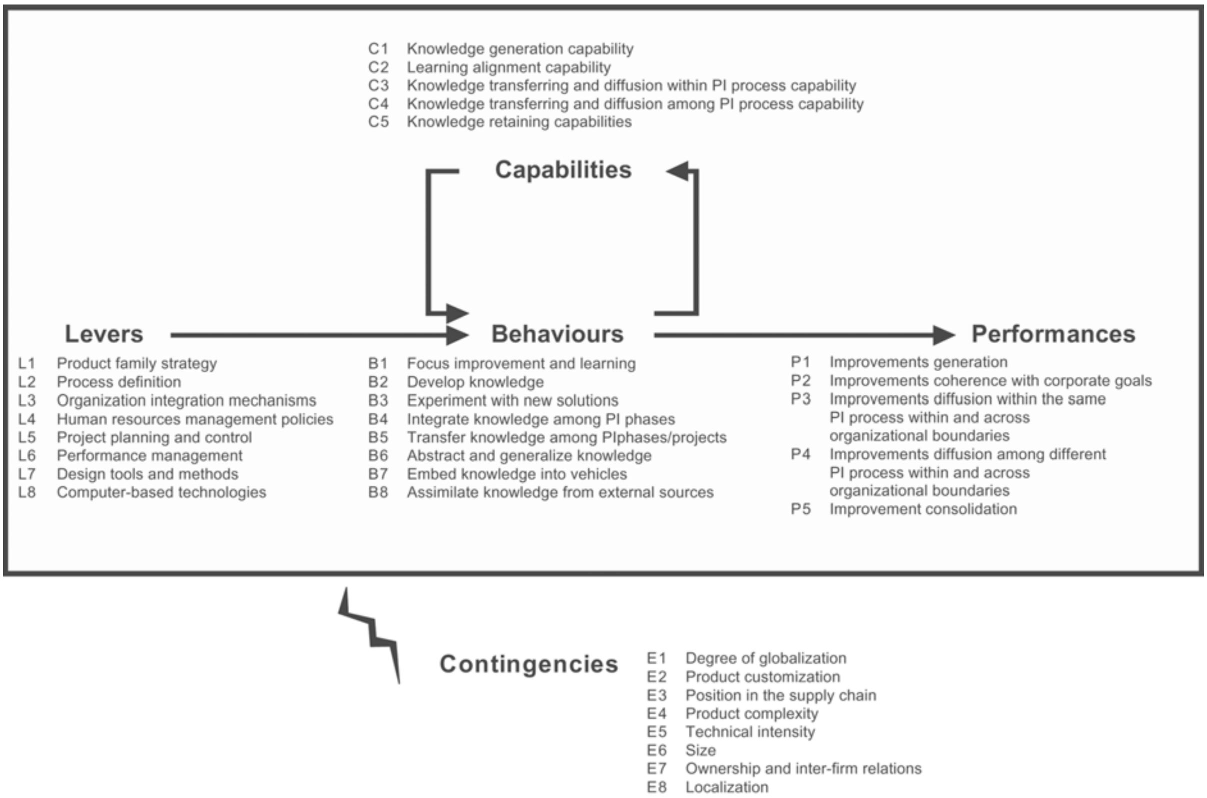

Figure 1 ***–-*** *Elements in the CIMA model for learning in product innovation processes*

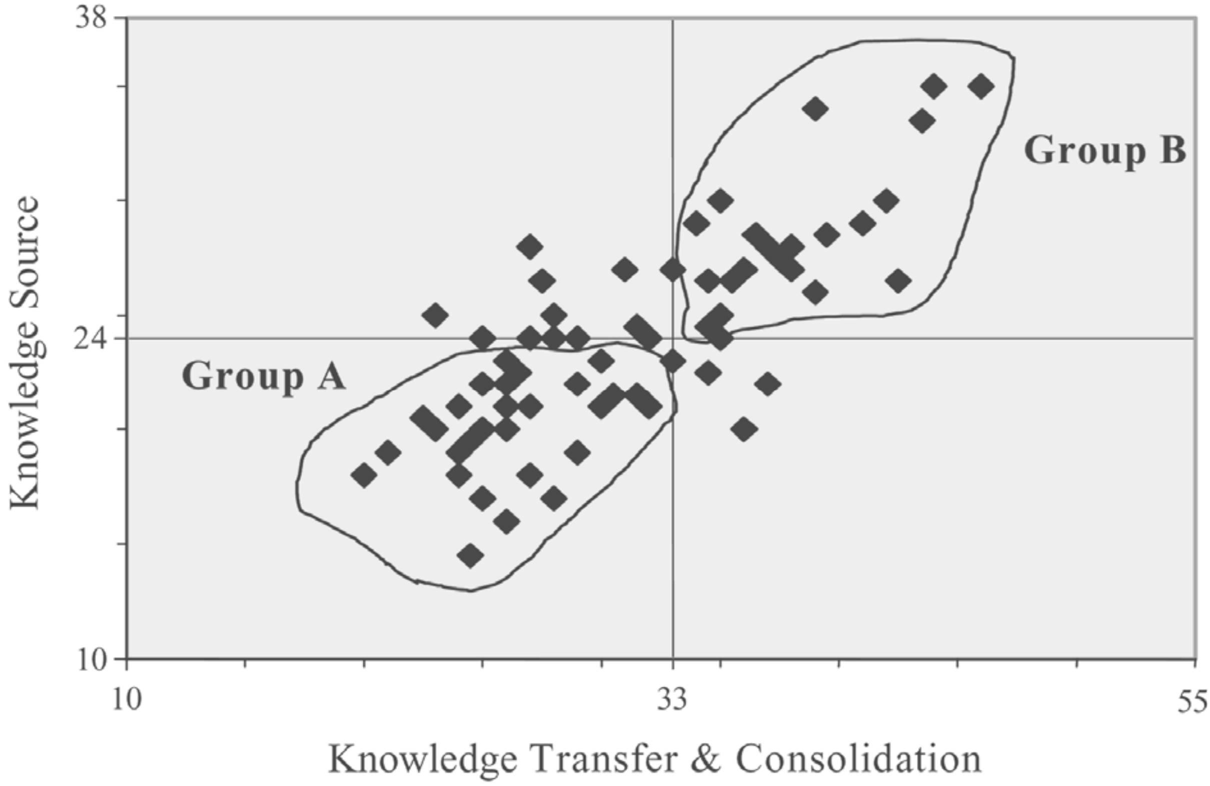

Figure 2 *–- Companies grouped by knowledge management criteria applied to contingencies*

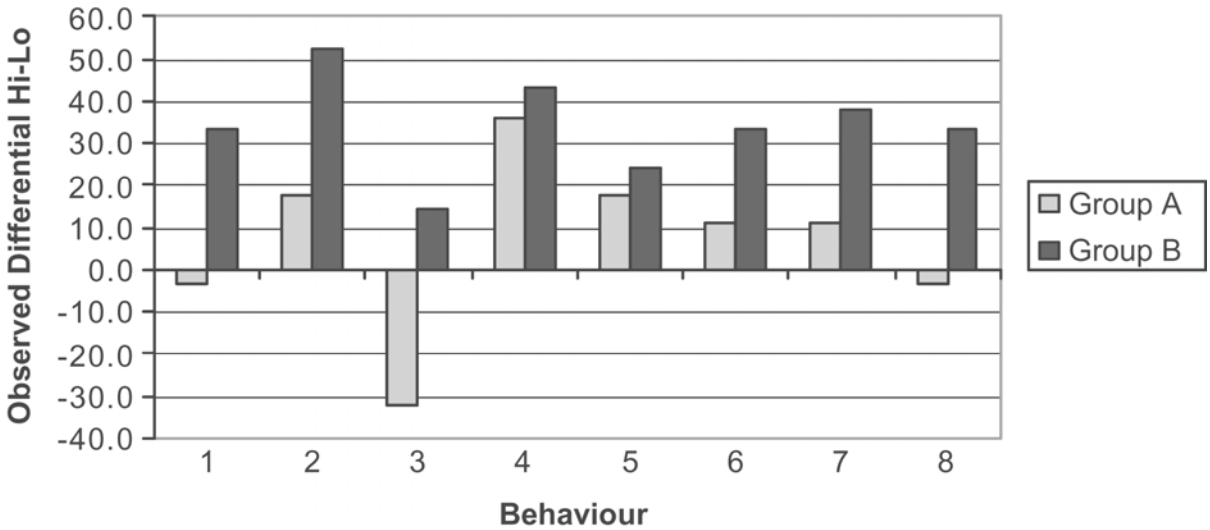

Figure 3 *–- Comparison of behaviour frequency*

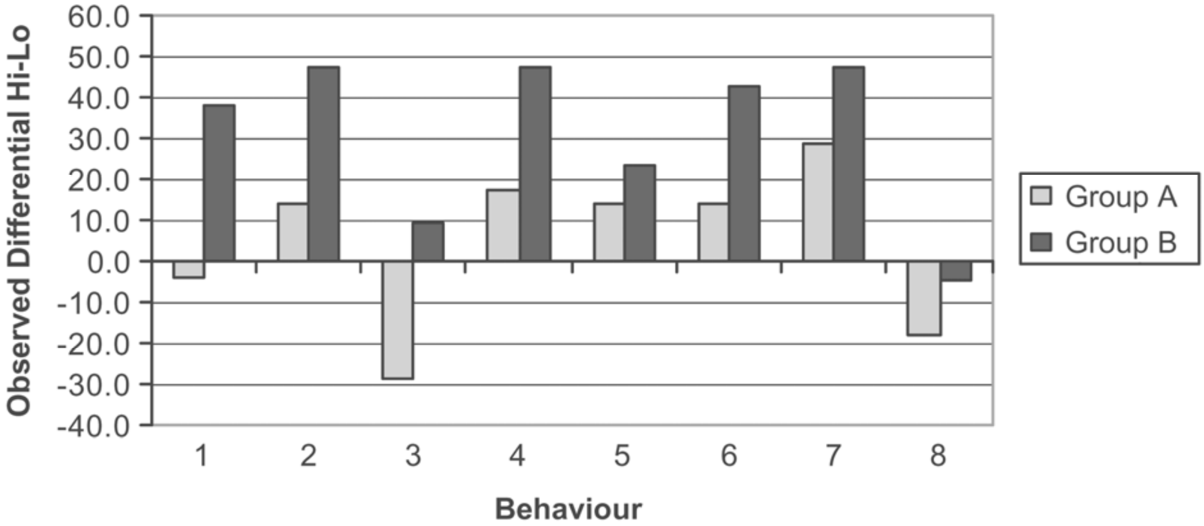

Figure 4 *–- Comparison of behaviour diffusion*

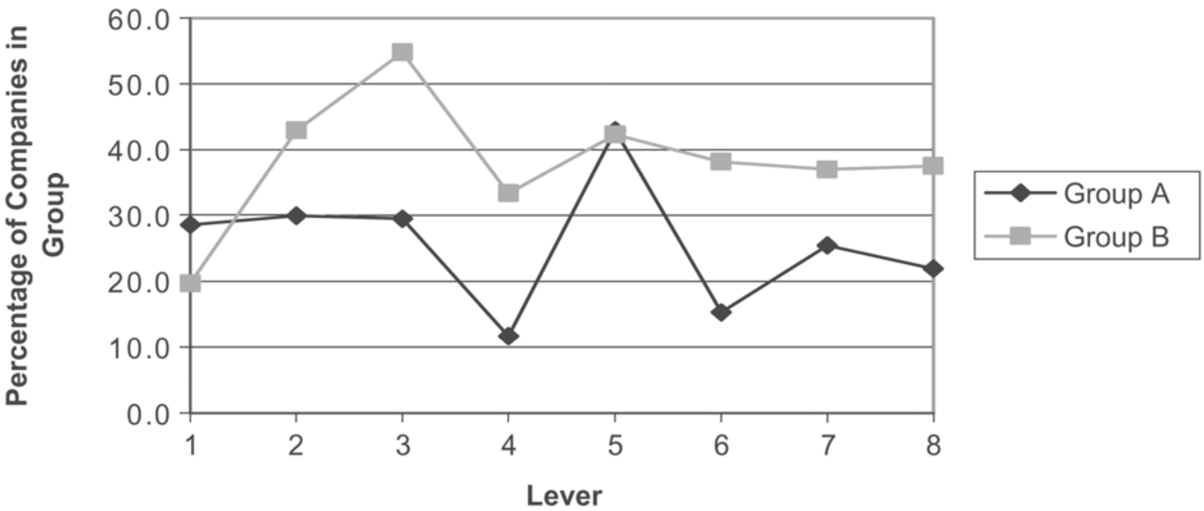

Figure 5 *–- Average use of levers across all behaviours*

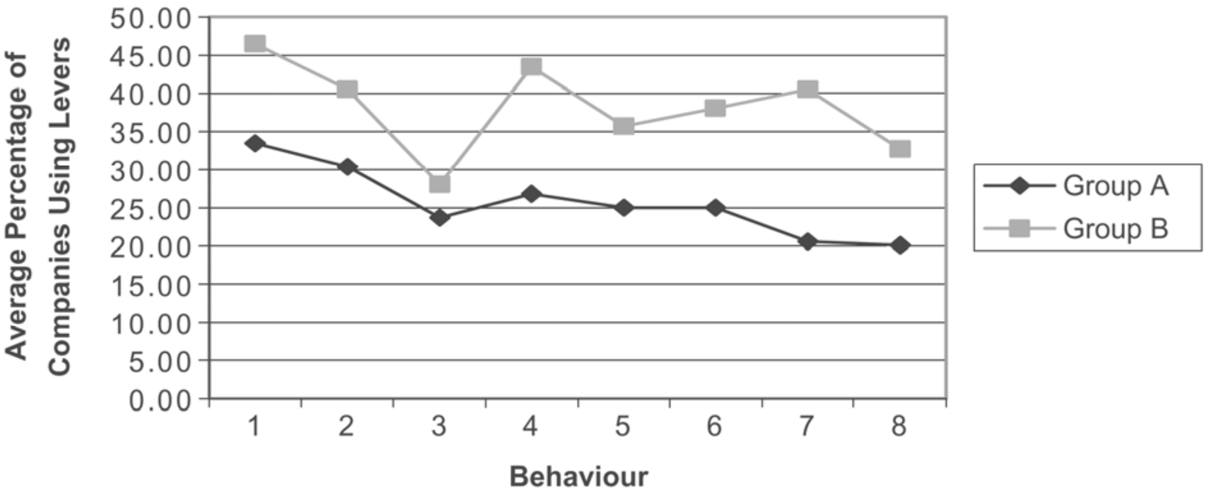

Figure 6 *–- Average use of levers for each behaviour*

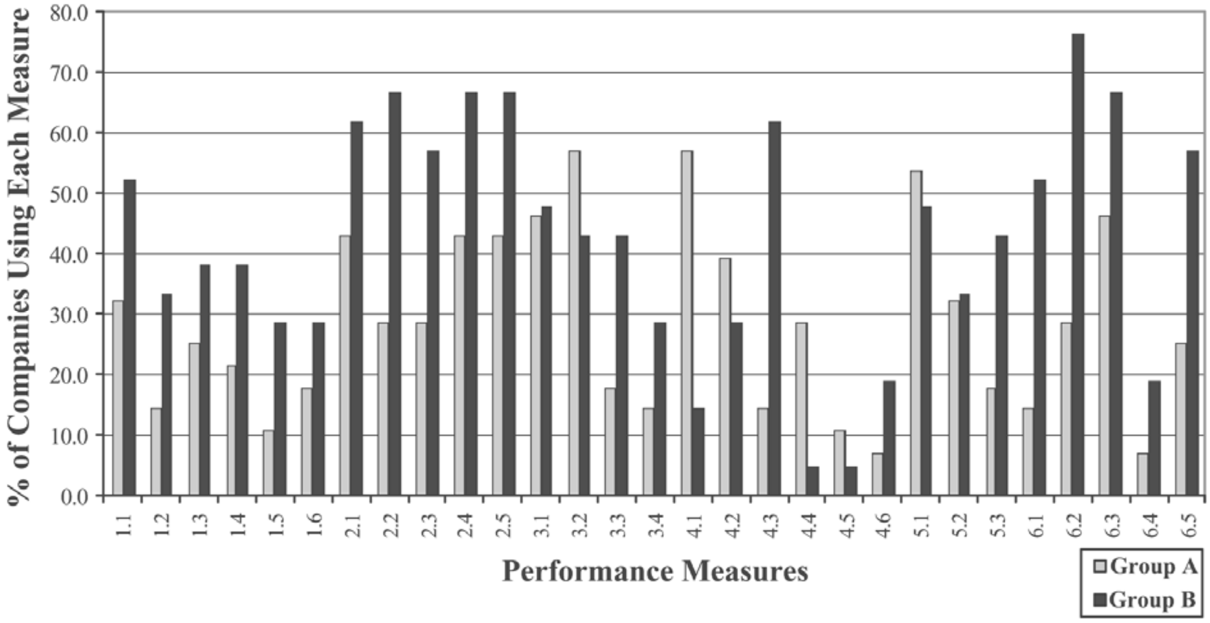

***Figure 7* –-** *Percentage use of performance measures*

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