Actors and Factors in IS Process Innovation Decisions

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Abstract: Information system process innovation (ISPI) describes new ways of developing, implementing, and maintaining information systems. This paper investigates ISPI decisions in three organisations over four development generations. The analysis reveals dependencies between the actors and factors in the decision processes; it shows how the actors employ different combinations of factors, and how the factors influence the actors' decision making. Self-Organizing Map clustering demonstrates that in the three organisations, the combinations of ISPI and actors vary over time, and these variations may be partly explained by power dependency between the organisations. The dependencies identified here are novel. The actors and factors found in past research are validated, and the dependencies between the actors and factors enhance confidence in the validity of the concepts and dependencies, as well as in expanding and emerging theory.

1 INTRODUCTION

Information System Process Innovation (ISPI) is a *new way of developing, implementing, and maintaining information systems in an organisational context* (Swanson, 1994). In the context of IS Development (ISD), a specific ISPI is chosen for a specific development project. This decision implies that there is an intention to use the innovation and that the use is recorded. Thus, information system innovation decisions (Rogers, 1995) and research on the decision processes (Turk et al., 2005; Howlett, 2007) contribute to the understanding of how organisations make decisions about process innovations. The need for a deeper understanding of ISPI decision making, its actors, factors and their dependencies, is not, however, widely recognised in the literature. Rather, the literature has focused on decision making in general, including how resources or role networks are mobilised and brought to bear on particular developments (Davis, 2006), or the role position has a leadership status in decision making (Kadushin, 1968). Past studies emphasise several factors that actors use in decision making, such as political tactics, rules and regulations concerning power, personal or internal control, and personal goals (Mintzberg, 2009), or the importance of professional knowledge (termed '*expert power*') held by those in power (Howlett, 2007). Past studies also view decisions as outcomes of negotiations generated by a single actor and a single factor at different organisational levels where the actors are dependent upon one another (Fomin and Lyytinen, 2000), even though decision making tends to be a social activity generated by the interaction of multiple factors. Thus, such decisions resemble the outputs of large organisational decisions as products of combinations of factors linking different planes of reality, known as organisational learning (Fomin and Lyytinen, 2000). Decision making is claimed to be a rational choice with resource constraints and known parameters (Howlett, 2007). (Safir et al., 1993) argue that decision making is both a bounded rational and political process, and decision makers resolve conflicts by selecting the '*best*' alternative. (Xue et al., 2008) state that in decision processes, the actors share governance in organisations by collective decision making, and an IT department can influence the decisions of other units through its IT functional power. The prime focus of previous studies is on a single time period, and in a small

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number of organisations, involving a limited number of actors. Further, the impact of decision making at different organisational levels has been largely ignored. Most studies consider a single decision maker and ignore the dependencies between the actors (Fomin and Lyytinen, 2000). They also lack insight into the '*real*' actors making decisions in information system development and into the '*real*' factors affecting decision making in ISD. Finally, no studies explore the dependencies between actors and factors of ISPI decision making in ISD projects.

Given the richness of past research, but acknowledging its shortcomings, this paper investigates the actors and factors affecting ISPI decision making. The study seeks answers to two questions: 1) What actors and factors affect decision making over ISPIs?; and 2) How do the actors depend on each other and the factors and vice versa? The study analyses 208 separate ISPIs decisions comprising 263 ISPI decision events, and uncovers 9 actors and 13 factors affecting ISPI decision making. We found that there is an important dependency between the actors in decision making at firm, department, IS project and individual designer levels. Actors belonging to the same category are similar, and IS project groups make decisions based on different factors than those at the firm and department level. Firms, business units, and boards of directors in the business units make decisions in a similar way, whereas IS project groups and IS working groups make decisions based on different factors than those of IS steering groups supervising IS projects. Further, department level and individual level decision making is based on different factors, even if the same individuals belong to the same department. In the decision events, groups in departments behave differently than in individual decision making. The paper is structured as follows. Section two describes the research method. Section three justifies the main concepts, and data collection. Section four introduces the results of analyses employing data mining methods. Finally, section five discusses the contribution, implications, limitations, and future research directions and draws conclusions about the results.

2 RESEARCH METHOD

This study takes a qualitative historical, descriptive, and longitudinal multi-case (Xue et al., 2008; Menard, 2002) perspective over a 43-year time period in which ISPI decision making is studied in three firms. From these firms, the cases have been selected so that they either predict similar outcomes (i.e. literal replication) or produce contrasting results but for predictable reasons (i.e. theoretical replication) (Yin, 1994). Theory triangulation is applied by interpreting a single data set from multiple perspectives, and methodological triangulation is sought by using multiple methods to understand the research problem (Denzin, 1978). The concepts and their dependencies are validated with the grounded theory approach (Eisenhardt, 1989; Glaser, 1992). The emergent theory, the various concepts, and their dependencies, offer new theoretical constructs for understanding the ISPI decision phenomenon from different perspectives. During the research, theoretical background knowledge (Glaser, 1992) was gained, which increases the credibility of the study. The data collection involved three Finnish firms that were part of the same '*parent*' company. Firm A is a big paper-producer, whereas B specialises in designing, implementing and maintaining information systems. Firm C evolved from B in 1995, and until the end of 1997, C formed a division within B. Since their founding, 1984 for B and 1995 for C, B and C have co-operated closely with A. The ISPI definition formed the basis for the interviews and data collection in the study. To address the research questions, 27 tape-recorded semi-structured interviews were conducted, investigating experiences of ISPI decision making in IS projects. The interviewees included project managers, IS department managers, systems analysts, vice-presidents, and programmers, who had been involved in multiple ISPI processes and decisions during their working careers that extended over 10 to 30 years in the case firms. Archival data encompassing the period 1960-1997 was studied, and it represented a secondary source of data. Published news about changes in the firms' environments and documentation of developed systems, system development handbooks, minutes of meetings etc. were gathered. Triangulation involved checking different data sources simultaneously to improve the reliability and validity of the data.

3 OPERATIONALIZATION

Based on Swanson's (1994) terminology, ISPIs cover both technological (Type Ia) and administrative innovations (Type Ib). Management innovations (M) include project management guidelines or organisational arrangements (Swanson, 1994). Description innovations (D) include the use of standardised modelling techniques. Tool innovations (TO) include capital-intensive software assets. Core technologies (T) consist of improvements in technical platforms that are critical to delivering IS products.

One recurring aspect of ISPI concerns how the technologies, skills and routines used in delivering information systems change in a set of organisational sites (Friedman and Cornford, 1989) - called a locale. ISPI decisions influence the specific scope of technologies, skills and routines that need to change as a result of the decision. A locale is an empirical environment, an organisational unit, where the specific actors learn to understand and make decisions about ISPIs. A locale consists of information system development (ISD) and ISPI decisions. In this study the locale was affected by the IS department outsourcing of firm A in 1984.

Based on an extensive empirical analysis of the historical evolution of IS development, (Friedman and Cornford, 1989) point out that the four types of ISPI innovations are often '*horizontally*' closely related, and they can thus be classified into a set of evolutionary generations. The first generation (from the late 1940s until the mid-1960s) was largely hampered by '*hardware constraints'*, i.e., hardware costs and limitations in capacity and reliability (lack of T innovations). The second generation (mid-1960s until early 1980s), in turn, was characterised by '*software constraints'*, i.e., poor productivity of systems developers and difficulties in delivering reliable systems on time and within budget (lack of D, M, and TO innovations). The third generation (early 1980s to the start of the 1990s), was driven by the challenge to overcome '*user relationship constraints'*, that is, system quality problems arising from inadequate perception of user demand and resulting inadequate service (lack of M, D, and TO innovations). Finally, the fourth generation (from the beginning of the 1990s) is affected by '*organisational constraints'* (lack of M, and D innovations). In this case, constraints arise from complex interactions between computing systems and specific organisational agents, including customers and clients, suppliers, competitors, co-operators, representatives and public bodies (Friedman and Cornford, 1989).

Studying ISPI requires the identification of those who *actually* make choices concerning changes in development practices. The decision authority of an ISPI refers to a collective or individual decision where a group of actors, or a single actor, has direct or indirect influence on the decision. The decision actors were hare determined inductively from the data and classified according to three decision authority levels: centralised (CEN), distributed (DIS), and situational (SIT) (Table1, available by separate request).

3.1 Data Collection and Categorisation

The data was gathered for the period 1954-1997 and arranged in a manuscript, which included descriptions of all ISPI events, ISPI decision actors, and the factors affecting decision making, technological platforms, organisational structures, and changes in business organisations. These events were arranged in chronological order and written into a base-line manuscript that identified all ISPI events in the firms. As the analysis contained several important omissions, more data was gathered and a second version of the manuscript written. This manuscript was divided into two parts: the first part covered the years 1954-1990 (in firms A and B) and the second part included the years of 1984-1997 (in firms B and C). The new manuscript was again amended for errors and omissions. Using this base-line data set, all recognised ISPI events were arranged into a chronological table - one row for each ISPI event. Each row included a description of the firm, the ISPI, the year the event decision was made, and the actor(s) involved. Each ISPI event was then categorised into four time generations (time generation 1 had no data, and it was omitted from the analysis), three firms, and four ISPI categories. Finally, the ISPI events were categorised into three decision authority levels. The main concepts in the data are as follows: four ISPI categories (M, T, TO, and D); three locales (ComA, ComB, and ComC); three time generations (Gen2, Gen3, and Gen4); and three decision authority levels (CEN, DIS, and SIT). The decision authority levels were further classified into nine sublevels (CEN1, CEN2, CEN3; DIS1, DIS2; SIT1, SIT2, SIT3, SIT4) to clarify the different actor types, such as firm level (CEN1), business level (CEN2), and board of directors (CEN3). The final data for analysis contained 208 separate ISPIs decided in decision events, as some ISPIs were decided upon in the organisations several times, and some ISPIs were decided upon in more than one locale. When several types of ISPIs were observed to be part of the same decision event, these were split into separate ISPI decision events.

4 ANALYSIS

4.1 Dependencies Between ISPI Categories, Locales, Time Generations, and Actors

To discover data characteristics, such as regularities and dependencies, and to get ideas/hypotheses for further analysis, the data was first visualised by a Self-Organizing Map (SOM) (Kohonen, 1989) clustering method. Historical studies in information systems research have characteristics that support the use of SOM, which has been applied successfully in many exploratory data analysis tasks. The gathered data has typically rather high dimensionality, i.e. each sample consists of several independent variables, such as factors, and the data itself in a table form does not easily show its actual contents and is only partly understandable. In addition, when the SOM results are consistent with the further analysis results, additional confirmation for the findings is achieved. SOM is a clustering and visualisation method that projects original data onto a lower dimensional map space so that the topological dependencies between the data points are preserved. This means that data points that are close to each other in the dataset tend to be represented by units close to each other on the map space - which is typically a one- or two-dimensional discrete lattice of units (clusters) determined by codebook vectors. SOM-based exploratory data analysis involves typically training a 2D SOM, and after training, the resulting mapping is visualised and analysed. If there are clear similarities and regularities or variable dependencies within the data, these can be observed by the pronounced clusters on the resulting map.

To carry out this type of exploratory analysis, a typical visualisation step is *component plane plotting* (Kohonen, 1989), where the components of codebook vectors are drawn in the shape of a map lattice. A 2D SOM of 10x10 units (codebooks) was trained with the collected data consisting of 208 data points of 19 variables: Gen2, Gen3, Gen4; M, T, TO, D; Com(A), Com(B), Com(C), CEN1, CEN2, CEN3; DIS1, DIS2; SIT1; SIT2; SIT3, and SIT4.

Figure 1 presents the resulting SOM component planes (the colouring of the component planes and the corresponding colour bars show the values of the variables in the different units (clusters).

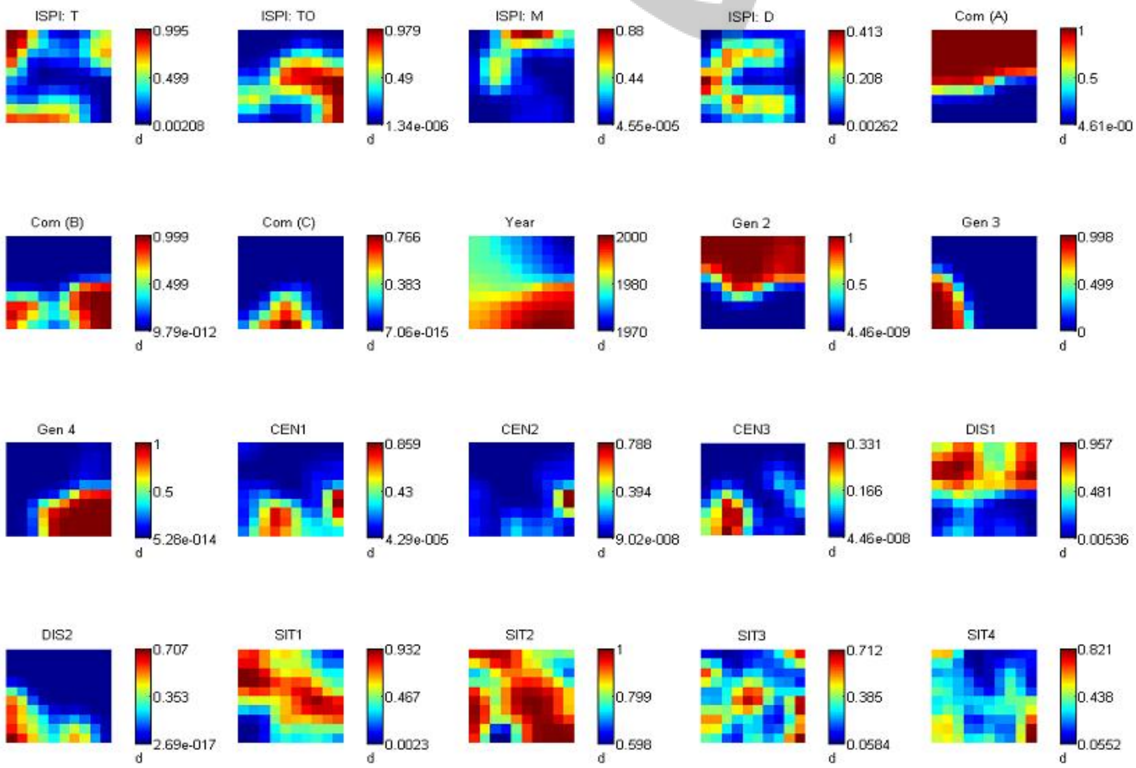

Figure 1: Component plane presentation of the Self-Organizing Map trained by the collected data.

The figure 1 shows that there are visible dependencies between the three locales (A, B, and C) and time generations (2, 3, and 4); A goes almost hand-in-hand with the second time generation (Gen2), whereas B and C consist of third (Gen3) and fourth generations (Gen4). In addition, as firms A, B and C have high values (close to 1) in separate and almost non-overlapping map areas (see component planes Com (A), Com (B) and Com (C)), it can be deduced that the other data variables are able to separate the firms. This means that the firms have used their own combinations of ISPI categories, time generations, and actors. This is interesting, as the three firms are related and their roots are in the internal information IS department of firm A. As to the actors, it is demonstrated that A is not involved with the centralised actors (CEN1, CEN2, or CEN3) or distributed actor 2 (DIS2) as much as B and C. A utilizes distributed actor 1 (DIS1) more than B and C. The situational actors seem to be spread over all the firms. As regards ISPI categories, A seems to differ from B and C by category M; the other categories (T, TO, and D) are represented by all firms. Also, though less obviously, the dependency between A and Gen 2 is the history of A, because it outsourced its IS department to B in 1984. Therefore, the decision power balance was shifted from A's internal IS department to B, and they have now both the IT knowledge and the business knowledge. A power dependency between the actors engenders a political perspective to IS development and ISPI decisions.

4.2 Factors Affecting Decisions Over ISPIs

On the basis of the literature and the interviews and archival material, 13 different factors affect ISPI decisions (Table 3, available by separate request). The factors were identified by comparing the literature and the empirical data. For each actor, the data set was converted manually into a binary matrix based on the factors affecting its decision making. The presence of a factor was denoted by 1 and its absence by 0 (c.f. Ein-Dor and Segev 1993), and for a single actor the minimum and maximum number of factors were 1 and 13. The factors were as follows. (1) Decision authority and position, (2) Political tactics, (3) Expert power, (4) Power, (5) Personal control, (6) Internal control, (7) Rationality, (8) Governance, (9) Dependencies between decision makers, (10) Resource constraints, (11) Organisational learning, (12) Organisational setting and centralisation, and (13) IT function power. The actors of centralised decision making and the factors (F1 to F13) affecting decision making in locales A, B, and C are shown in Table 4 (available by separate request). The table highlights that the factors affecting decision making are the same in A, B and C. This is novel and can be explained by the fact that the decision makers in A became the decision makers of B and C after the outsourcing. Table 5 shows that the most important factors affecting decisions at the distributed level are F4 (power), F5 (personal control), F6 (internal control), F8 (governance), and F13 (IT function power) when counting the factor occurrences (Table 5, available by separate request). Table 6 shows that the most important factors affecting decisions at the situational level are personal control (F5), organisational learning (F11), expert power (F3), governance (F8), and internal control (F6). (Table 6, available by separate request).

4.3 Dependencies Between Actors and Factors

In ISPI decision making it is necessary to validate the dependencies between the actors and factors. This is clearly a so called unsupervised learning problem, where the goal is to find an unknown hidden structure in unlabelled data. For this, two different data mining methods were used: Sammon mapping (Sammon, 1969) for data projection and UPGMA (Unweighted Pair Group Method with Arithmetic mean) (Fitch and Margoliash, 1967), also known as the average linkage method, for generating a hierarchical binary cluster tree from the data. The results of the methods are finally validated by reflecting on them with the understanding of the organisations and the related literature. A natural choice for the analysis is to project the actors and the factors represented by binary vectors to a lower-dimensional 2D space in a manner that preserves the topological dependency between the actors as well as possible. Topology preservation means that those actors that are close to each other by the given factors can be observed as neighbours in the 2D projection. Sammon mapping (Sammon, 1969) belongs to a class of multi-dimensional scaling (MDS) methods and has been used for this task previously. Sammon mapping calculates the distances of the original actors and tries to produce a 2D plot on the 2D plane of the actors in such a manner that the corresponding distances between the projected actors are as similar as possible with respect to their original distances. When the data is binary (factors exist (1) or not (0)) it is natural to use city block distances in measuring similarities. City block distances give the number of different 1s and 0s between two actors. Figure 2 shows the result of the Sammon mapping method.

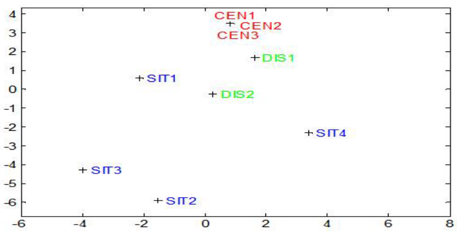

Figure 2: Sammon mapping of the 9 actors based on their corresponding factors affecting the decisions. The closer the actors, the more common are their decision factors.

In the figure, the names of the actors are coloured according to their predefined categories. The red-green-blue colouring schema reveals that the *within-group* variation of the actors is lower than the *between-group* variation. The centralised decision actors are closer to the distributed ones than to the situational ones. Moreover, the distributed decision actors are in the '*middle*' of the other two actor groups. The city block distances of the actors defined by their factors can also be measured on the basis of figure 2. The UPGMA method (Fitch and Margoliash, 1967) is a popular and widely used method for linkage analysis. The method uses a pair-wise distance matrix of actors as the input and produces a hierarchical cluster tree showing the distance dependency of the actors. The tree consists of a root, branches, nodes, and leaves. In the dendrogram plot of the tree, both the grouping of the actors according to the labelled leaves (similar actors are near each other) and the distances between the actor groups can be observed. As in Sammon mapping, city block distances are used between the actors. Figure 3 provides a dendrogram plot of the hierarchical UPGMA cluster tree for the actors.

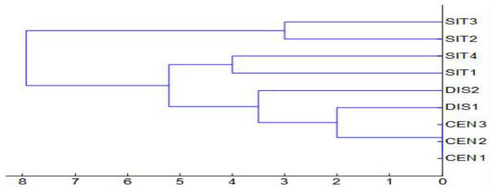

Figure 3: Hierarchical cluster tree produced by an UPGMA linkage algorithm and city block pairwise distances between the actors. The horizontal axis shows the calculated mean city block distances of the grouped actors.

The length of each branch represents the mean distance between the two connected (grouped) actors, and the distances are computed according to their factors. The calculated mean distances between the actors and group of actors are given in the horizontal axis. For instance, the mean distance of actor DIS1 to actor group CEN1, CEN2 and CEN3 is 2 in the city-block distance measure. The names of the actors are coloured according to their categories. Similar observations as for the Sammon mapping results are apparent: the *within-group* variation of the actors is lower than the *between-group* variation, meaning that the actors belonging to the same category are most similar to each other. The situational decision making actors 2 (SIT2) and 3 (SIT3) are furthest away from the other actors. SIT2 refers to the IS project group, and SIT3 refers to the IS work group or development group in a chosen project area. The firm, the business units, and the board of directors in the business units make decisions in a similar way. Firm A and firms B and C, on the other hand, are not too far from each other. The IS project steering group is closer to the distributed decision makers - that is the departments inside A, B and C. The IS project steering group is, however, far away from the IS project group and the IS work group or development group in a chosen IS project area. This means that the IS project group and the other smaller groups working with it make decisions based on different factors than the IS steering group. An individual designer sits between the IS steering group and project group when making decisions based on some factors.

The same type of analysis was conducted for the 13 factors, i.e., by Sammon mapping and a hierarchical cluster tree by the UPGMA linkage algorithm based on the distances between the factors defined by their corresponding actors (see Figures 4 and 5). This way each factor is a vector where each vector item (total of 9 items) is either 0 or 1 according to the actors where the factor exists. So, for instance, factor F1 is given by a vector (1,1,1,1,1,1,0,0,1). City block pairwise distances were utilised.

The figures 4 and 5 show that the factors form two separate groups where the actors are closer to each other: in the first groups there are factors F1, F2, F4, F5, F8, F9, and F13, and the other group consists of the rest of the factors, i.e. F3, F6, F7, F10, F11, and F12. The majority of the left hand side factors are related to ISD projects resources, tools, knowledge, and project control, and the majority of the right hand factors are related to department and organisational issues, such as the department's power and decisions over single individuals (Figure 4). This means that the ISD projects and departments and individuals clearly make decisions based on different factors, even if the individuals belong to the same departments. In the decision event the project groups in the organisations behave differently to individual decision making.

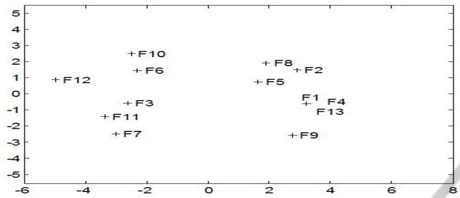

Figure 4: Sammon mapping of the 13 factors based on their corresponding actors. The closer the factors, the more common are their actors.

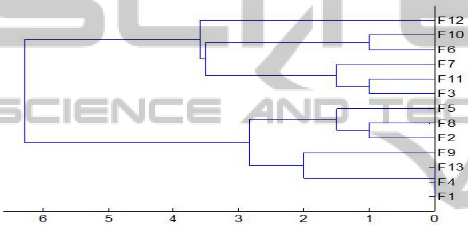

Figure 5: A hierarchical cluster tree produced by UPGMA linkage algorithm and city block pairwise distances between the factors. The horizontal axis shows the calculated mean city block distances of the grouped factors.

5 CONCLUSIONS AND DISCUSSION

The results of the study show that the actors in the three firms used their own combinations of ISPIs over time. Firm (locale) A went almost hand in hand with the second ISPI time generation (from mid-1960s until early 1980s), whereas B and C consisted of third (early 1980s to the beginning of the 1990s) and fourth (from the beginning of the 1990s) ISPI time generations. The dependency between A and time generation two was the history of A, as it outsourced its internal IS department functions to B in 1984. The outsourcing turned the internal IS department into a separate profit centre (independent firm B), which necessitated greater emphasis on A's needs and infrastructure. In 1989 B established a new software house, firm C, to serve the needs of A by concentrating on applying object-oriented technologies in A. In A, B and C, decision making groups were developed during the IS projects in response to time and resource pressures. The empirical findings of the study also validated several factors in past studies and their dependencies. These factors included decision authority (Howlett, 2007; Mintzberg, 2009), political tactics (Mintzberg, 2009), expert power (Howlett, 2007), power (Mintzberg, 2009), personal control (Mintzberg, 2009), internal control (Mintzberg, 2009), rationality (Howlett, 2007), governance (Xue et al., 2008), dependencies between decision makers (Fomin and Lyytinen, 2000), resource constraints (Howlett, 2007), organisational learning (Fomin and Lyytinen, 2000), organisational setting and centralisation (Safir et al., 1993), and IT function power (Xue et al., 2008). The theoretical implications in this study were new concepts and dependencies uncovered in the ISPI decision making. The several managerial and practical implications were as follows. First, the Self-Organizing Map (SOM) clustering method revealed that within the three organizations, the combinations of ISPIs and actors varied over time. The variation could be partly explained by a power dependency between the organisations over time in ISPI decisions. Second, the analysis showed that the factors depended on the actors and vice versa in ISPI decision making. A dependency means that an actor needs another actor's approval, control, or support. The dependencies were also a new discovery not found in previous studies. SOM has been used successfully in explorative data analysis where characteristics such as conditional probabilities between the variables and their properties should be observed where the data is too difficult to comprehend to extract relevant information. The uncovered dependencies between the different factors and actors were novel, and the figures in this study may act as models of ISPI decision making. Third, dependencies between A, B and C, ISPI categories, and ISPI development generations and actors were found. Furthermore, the study showed that the factors influenced the actors' decision making in ISPIs to a specific direction based on the implemented information systems. Fourth, in ISPI decision making, it is necessary to validate the dependencies between the actors and factors also with other analyzing methods. For this, two different data mining methods were used: Sammon mapping (Sammon, 1969) for data projection and UPGMA (Unweighted Pair Group Method with Arithmetic mean) (Fitch and Margoliash, 1967), also known as the average linkage method, for generating a hierarchical binary cluster tree from the data. We showed how UPGMA, Sammon mapping and Self-

Organizing Maps together were suitable for studying our research problems because the identified concepts and dependencies were validated, and the data mining methods validated the dependencies. Finally, methodological triangulation was sought by using multiple qualitative methods in data collection and analysis, such as historical, descriptive, longitudinal multi-case, and grounded theory approaches (Eisenhardt, 1989; Glaser, 1992) to understand the research problems. As knowledge discovery is a research area which focuses on methodologies in order to find out valid, novel, useful and meaningful patterns from large data sets, our research fulfilled its requirements because knowledge discovery uses data mining methods in data analysis, and we used Sammon mapping for a data projection and UPGMA as the data mining methods. Information retrieval, on the other hand, gathers relevant information for example from unstructured and semantically varied data in texts, which is in line with our study, as we gathered a large number of textual interview data and used the Self-Organizing Map in analyzing the data. We claim that it is important for the knowledge discovery and information retrieval community to see how its methods can be applied to information systems science, innovation literature and decision making studies when a great amount of qualitative and longitudinal empirical data is converted to quantitative data. A limited number of case firms affects the generalisability of the findings. The amount of data concerning ISPI decisions and actors and factors could be considered small, which reduced the accuracy of the analysis. In the future it is important to study other organisations in the same manner, and to compare the results as a next step in generalisability. Finally, the longitudinal data was important, as a horizontal survey would not have addressed the research questions as to the dependencies between ISPI actors and factors and vice versa over time, the factors influencing ISPI decisions, and the actors who dominated ISPI decisions during the ISPI development time periods.

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