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Towards a Model for Determining the Scope of ICT Integration in the Enterprise: the Case of Enterprise Resource Planning (ERP) Systems

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Abstract: The question of integration of information systems (IS) into the planning and execution of operational activities has been the focus for researchers from different constituencies. Organisational theorists recognise the need for integrating mechanisms for co-ordinating the actions of sub-units within an organisation. Centralisation has been seen as a defensive reaction by organisations when placed under increasing external control , and also as a way to improve the efficiency of information processing, at least for routine tasks. In the meantime, researchers have been sceptical about the ability for structured information systems to deal with the complexity of the information flows within the organisation. Frameworks have also been identifying characteristics of the tasks themselves that have a bearing on the amount of information processing required. The real world is complex and moving, thus managers require flexibility in their interpretation of the mixed signals arising from this complexity. However, managers are working in environments where highly integrated information systems blur the distinction between what is real and what is virtual. There is a need for an integration approach allowing organisations to question which areas of activity are worth integrating, and conversely which areas are better left under local control. Where integrated, managers require processes for the maintenance of data integrity (people, tools, procedures). Based on field work involving two multi-national manufacturing companies, this paper proposes a framework for ERP integration, which describes the evolution of functionality gaps as an ongoing and inevitable process that requires management.

Keywords: ERP, enterprise, integration, framework, complexity

1. Introduction

In examining the extent to which information systems (IS) can be integrated into the planning and execution of an organisation's activities, the researcher may draw from rich seams of research from different constituencies. The question of how best to control and co-ordinate the organisation to meet the needs of its customers, while optimising the use of available resources, has tantalised organisational theorists from the earliest days of industrial and economic growth. Key to the concept of control is information, such that goals may be communicated downwards and performance may be measured and communicated upwards. It has been acknowledged by the earliest students of administrative systems that the major cost of implementing control systems of any sort is the investment in human resources to design and maintain the system. Today, advances in data capture, communication and dissemination technologies have allowed designers to integrate the bureaucratic overhead of administration of task monitoring into the activities themselves. However, this very synergy between task and control can have negative side effects in terms of flexibility that are undermining the gains in efficiency. Indeed, the ubiquity of technology in all areas of the enterprise has displaced the question of efficiency towards the administrative aspect of the task and away from the task itself. In this section the two strands of research (organisational and informational) are drawn together to tease out the dimensions of a framework that might permit researchers to situate the adoption of integrated control systems within the broader context of the organisation and its aims.

1.1 Integration is a design attribute for organisational rationality

To Mintzberg (1989), organisation means collective action in the pursuit of a common mission. Organisation theory is the body of research that addresses itself to the problem of how to organise (Pugh 1997). How organisations should be controlled, by whom, and to what ends, are *the* fundamental issues for the private sector (Mintzberg 1989). An organisation is *instrumentally* rational if the job gets done, *economically* rational if it gets done at the least cost (Thompson 1967). Thompson (1967) uses the analogy of the ad-hoc organisation of the community in the face of a natural disaster to emphasise that instrumental rationality can be achieved in the face of necessity, but that economic rationality requires more co-ordination and advance knowledge of what resources are required and when. Interestingly, research into how managers actually work suggests a constant mode of crisis

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management (Mintzberg 1989), denoting the inability to work to a co-ordinated plan because of the contingencies of the moment. It would appear that despite best efforts to control and co-ordinate, managers have to deal with many sorts of unplanned events thrown at them in quick succession and requiring immediate attention.

Organisational attributes are choices about the optimal design of the organisation in view of its aims. Some structural variables considered in organisational theory are specialisation (functional and role), standardisation, formalisation, and centralisation (Inkson et al. 1968). An increasingly important organisational attribute is the incorporation of information systems into ways of working such that task execution and visibility of that performance are instantaneous. The challenge of studying such organisational attributes is that there are underlying interdependencies between these attributes and contextual factors which are difficult to conceptualise. Formalisation of procedures is a step towards standardisation, which itself is a step towards centralisation. Furthermore, business context, culture and managerial capability are additional "softer" attributes of the organisation which will confound generalisations based on any one set of structural variables. In his work on organisational configurations, Henry Mintzberg (1989) suggests that it is the *combination* of basic attributes of an organisation that define its culture, rather than a focus on any one single attribute.

One of the essential dichotomies in the planning and management of routine activities is the trade-off between control and flexibility. With Enterprise Resource Planning (ERP) systems, the interdependence between control and other structuring attributes (such as formalisation, centralisation, specialisation) is configured in the software. As researchers had forewarned, the complexity of the control system made it necessary to invest in specialised skills to design and maintain the system (Child 1973). Without the ability to conceptualise integration as an organisational attribute among others, organisations risk becoming slaves to their self-imposed technostructure.

1.2 The use of information technologies for control

Since the earliest days of the application of information technologies to automate manual tasks, the question of integration has intrigued practitioners and academics alike. The potential for the technology to make information flow was understood, but its use in planning and monitoring of performance entailed a trust in the parameters and algorithms in the machine that had hitherto not existed. As far back as 1958, Leavitt & Whisler suggested that "information technologies" would undermine the decision making role of the middle manager, consigning them instead to jobs that were highly structured. The authors argued that the spread of information technology would be rapid because it would make centralisation much easier, making top executives less dependent on subordinates. In addition, the faster processing of information would shorten the feedback loop that tests the accuracy of original observations and decisions.

There is a relationship between the need to process information and uncertainty deriving from the external business environment. Organisations require "integrating mechanisms" (Galbraith in Pennings, 1983) for co-ordinating the actions of sub-units towards a common objective. Centralisation and standardisation have been seen as a defensive reaction by organisations when placed under increasing external control (Mintzberg 1989), and also as a way to improve the efficiency of information processing, at least for routine tasks (Galbraith 1974). An information system by definition supports the centralisation of control (Markus & Robey 1988). Under conditions of uncertainty, there is a tendency to increase the amount of information sought (Thompson 1967). Earl & Hopwood (in Lucas et al. 1980) refer to the tendency in the MIS area to perceive uncertainty as "threatening rather than inevitable", and, rather than exploiting information for its "educative" (Gorry 1971) potential, information systems professionals tend to design models that mask reality with "assumed certainties".

In parallel to the evolution of the capacity of systems to handle information at speed and in large volumes, the "determinist" consequences of information systems for centralisation has been the subject of much debate (Orlikowski in Knights, D. and Willmott, H. 1988). ERP systems simultaneously centralise ownership of information resources and democratise access to that information, mixing therefore, to an unprecedented extent, centralising and decentralising effects. On the one hand they promote local, cross-functional cooperation and control, breeding skills that are eminently transferable across sub-units. On the other, a best practice model of transaction processing imposes a common standard across the organisation. As Davenport (1998) notes, the real challenges hinges on where to draw the boundary between centralization of control and autonomy of decision making.

Researching the organisational impact of information systems is challenging because the interaction of people with technology in the execution of business processes is so intertwined that it becomes difficult to differentiate organisational from technical factors (Markus et al. 2000). Researchers must differentiate between the symptoms and the cure. Inefficiency and frustration may be the result of poor process design, or incomplete implementation, or a combination of both factors. When the template falls short of actual physical procedures, data quality will inevitably be impacted. Researchers have noted that although ERP systems may be introduced, physical procedures are not always changed, such that a mismatch develops between virtual processes and physical processes (Staehr, Shanks and Seddon in Adam and Sammon, 2004; Lee and Lee 2000).

The literature that provides the theoretical framework for this study of integration unites the themes of organisations and control mechanisms. Organisations require co-ordination mechanisms to transform strategy into operational targets. ERP systems are considered to be an advanced form of control mechanism. Managers are the enactors of this co-ordination, and their decisions are informed by data concerning both performance targets and actual consumption of resources. ERP systems superimpose new patterns on this co-ordination, with an, as yet, poorly researched impact on the quality of decision making.

2. The research objective

The objective of this research is to propose a framework which would allow the question of integration to be modelled alongside other related organisational attributes. It was anticipated that some of these attributes, identified already in the literature, such as centralisation, standardisation and specialisation, will figure in the framework. Equally, it was anticipated that other attributes will emerge from the empirical work, which is based around the implementation of ERP in two multinational manufacturing organisations.

The research objective was operationalised into three separate research questions which together yield a picture of the scope of integration in the organisation, and a suggestion for the interdependence between integration and other organisational attributes. Research Question 1 was concerned with discovering the key organisational attributes relating to the implementation of ERP. Research Question 2 was concerned with developing a causality map between these attributes. Research Question 3 drew on the output from Question 1 and 2 to suggest a conceptual framework for the consideration of integration as a set of interdependent organisational attributes. It is envisaged that this framework could be used by managers to evaluate the potential impact of integration on the organisation, as well as a providing a diagnostic tool for the isolation of dysfunctional behaviour and its potential causes.

2.1 Profile of the case studies

In this research, two case studies of successful multinational companies (KPC and SIT) are used to explore the impact of integration on the organisation. Both cases studied are multi-national manufacturing organisations with mature ERP implementations. Table 2 compares the profiles of the two cases studied.

Table 1**: Comparison of case study profiles**

	Firm A	**Firm B**
Industry	Pharmaceutical	Data management
Turnover 05 ($bn)	38.72	9.66
Employees	100,000	26,500
WW operations	119	52
Manufacturing sites	80	3
Head Office	London, UK	Boston, USA
ERP System	SAP R/3	Oracle 11.03
Architecture	Single instance	Single instance
Server location	Pennsylvania, USA	Boston, USA
Go-live	Phased 2004	Big-bang 2001

The Key Pharma Company, KPC (real name withheld to allow more detailed reporting), is a leading manufacturer of pharmaceutical products, with a highly successful product portfolio in consumer healthcare, prescriptions drugs and vaccines. With annual sales of nearly €30 billion, and a R&D budget of €5 billion, KPC is in a dominant position in its marketplace. The manufacturing organisation involves more than 20 autonomous plants worldwide. Managing the supply chain to efficiently satisfy demand is extremely complex. With over 30,000 Stock Keeping Units (SKU's) or lines of product, any one of the 600 sources of demand could be ordering 300-600 SKU's each. The case study focuses on the KPC plant in Cork, Ireland, a bulk site which is part of the global Manufacturing and Supply organisation. KPC Cork ships 4,000 batches of goods per year and local managers are proud of their "customer service" record for deliveries, in the context of the complex and sometimes unpredictable scenario described above. KPC Cork was part of the roll-out programme for a new ERP system (based on SAP version 4.0), which involved all the sites in the Manufacturing and Supply organisation. The ERP project had the overall goal of implementing FDA compliant business processes throughout KPC, using the best practice templates that had been designed by KPC around SAP standard functionality. The scope of the ERP project at KPC Cork was the integration of processes in all the main business areas (Production, Finance, Sales, Quality), excluding process control at the manufacturing execution level.

The second case is SIT, a market leader in data management solutions, which sees itself as specialising in helping customers to derive more value from their corporate data. The company is following an aggressive growth path, with 17% growth in consolidated revenue in 2005, which was the year in which the case study was carried out. Revenues have since then continued their upward growth trend, topping $11.2 billion in 2006. SIT Ltd employs over 26,500 people in 52 operations worldwide. Manufacturing is concentrated in three sites, one of which is Cork, Ireland. SIT has evolved into a "solutions" company, delivering not just hardware, but also information "lifecycle" tools and consulting services. A key complexity of such full service offerings is the management of the information flows related to executing a single customer order, which increasingly is constituted of hardware, software and services. Many of these revenue lines are executed by multiple locations, over different time horizons, yet the customer will require a single sales order, single invoice and single goods shipment. SIT implemented a single instance global ERP system in 2001. This big bang implementation addressed user requirements for transaction processing in all back office activities relating to sales order processing, manufacturing, materials planning, distribution and finance. The Oracle based system supports 4,500 users in 52 countries worldwide, 3 of which involve manufacturing operations.

3. The research methodology

The premise of this study is that data and process integration are inherent parts of an ERP package. Organisations make considerable assumptions about the level of integration between functions, plants, and headquarters when implementing an ERP system. Although differences exist between the different ERP systems, and these differences will have an impact on the fit with individual business process requirements, it is assumed, as with Gattiker & Goodhue (2005), that the differences are less important than the similarities. The similarities are that all ERP systems are highly integrated at a data level, and all ERP systems use workflow logic to automate the flows of information through the different stages of its transaction process. It is via this data and process integration that different functions can access and transact information relating to the use of common enterprise resources.

Following the Barua et al. (1995) recommendations for evaluating IT investments, Gattiker & Goodhue (2005) selected a fine grained unit of analysis (the plant) and within that the functions examined are close to the operating core of the business (manufacturing planning and control, as well as execution processes). The logic here is that longer lasting transformative benefits on the organisation are more likely to be derived from core value-adding activities of the company, rather than from administrative functions Barua et al. (1995). This research study includes both core operational and support functions, as ERP is inherently an administrative (support function) tool, yet its impact is most felt at the transactional level (operations). The data from interviews regarding ERP impact was classified with respect to organisational parameters, and these parameters had been identified as seed categories from the literature, but other themes also emerged from the analysis of managerial perceptions. The seed categories included themes such as centralisation of responsibility, standardisation of processes and gaps between template process and reality. The emergent attributes include granularity of information, process flexibility and manual manipulation of data.

Business processes were used to analyse findings as an embedded unit of analysis, in order to better identify areas of the organisation where the integration impact was most strongly felt. ERP systems superimpose a process based view of business activity, with integration at data and workflow level. In many cases, these new processes cross traditional functional boundaries, thus it was considered important to be able to view the impact equally from the process level. The definition of processes is closely allied the physical management of resources in the organisation, such as inventory, customer orders, cash, labour or plant capacity. Information flows in a logical and chronological order between different stages of the process as the physical resources are transferred, consumed and transformed through different stages of the supply and demand cycles.

Interviews with managers from both cases were carried out in the period from April 2005 to August 2005 and involved meetings with 76 managers from different functions affected by the implementation of the ERP system. SIT had gone live on their ERP system in October 2001, so these interviews reflect the views of managers using a relatively mature system. Table 1 shows a summary of the numbers of managers interviewed, broken down by case and by function.

Table 2**: Breakdown of interviews by case and by functional area**

	SIT			KPC		
Function	Cork	US	Total	Cork	UK	Total
Finance	5	9	14	1	1	2
Manufacturing / Distribution	13	6	19	9	7	16
Sales	4	3	7	1		1
IS	4	2	6	3	3	6
Engineering	2		2	1		1
HR	2		2			
Total	30	20	50	15	11	26

Interviews were carried out using a semi-structured format, and each interview lasted one hour. The interviews were recorded and transcribed, yielding over 400,000 words of raw research material. A robust coding methodology was applied to reduce the data and avoid paralysis by data analysis (Yin 2003). Observations from the transcripts were extracted to a matrix structured by research question, yielding a total of 3,202 observations. Cell entries were either abridged versions of the original quote, summarised to capture the issue raised. Using hyperlink functionality between Microsoft Excel and Word, each extracted observation was linked back to the original transcript, thereby retaining richness and avoiding “too thin cell entries” (Miles & Huberman 1994). The observations were coded at three levels, identifying the interviewee, the business process commented, and the theme (organisational attribute). The business process was recorded independently of the functional affiliation of the interviewee. For example, observations regarding shipment decisions were classified as pertaining to the “Deliver” process, and were commented upon by managers from Finance, Materials, Manufacturing, Distribution, and Sales. The themes began as a set of 13 seed categories, developed from the literature review, and complemented by themes which emerged from the data.

4. Findings of the case study

The empirical data was analysed to answer the three research questions mentioned in the research objective section of this paper. These questions form a vehicle to investigate the effect of ERP driven integration in today’s multinational company.

Research question 1: Key organisational attributes

Research question 1 identifies the organisational attributes associated with ERP driven integration. These observations were coded based on whether the impact of the attribute was perceived to be related to organisational, decisional or integration themes, and categorised by process area. The field data is aggregated across both cases (n=2,818), and plotted according to three dimensions. Figure 1 summarises the results of this analysis of organisational attributes. Organisational themes (y-axis values) included Centralisation, Goals, Compliance and Skills. The 695 observations classified under the organisational themes related to the positive aspects of centralisation, goal clarity, compliance and the development of new skills. Integration themes (x-axis) included Correlation, Granularity,

Accuracy / Consistency, Automation and Aggregation. Again, the 883 observations in this category emphasised the positive aspects of integration, particularly the analytical potential. The Decisional themes (denoted by size of bubble) were Manual, Flexibility, Gap Virtual vs. Physical, Uncertainty and Latency. The 1,060 observations under the decisional theme were largely negative feedback regarding the difficulties of exploiting ERP data.

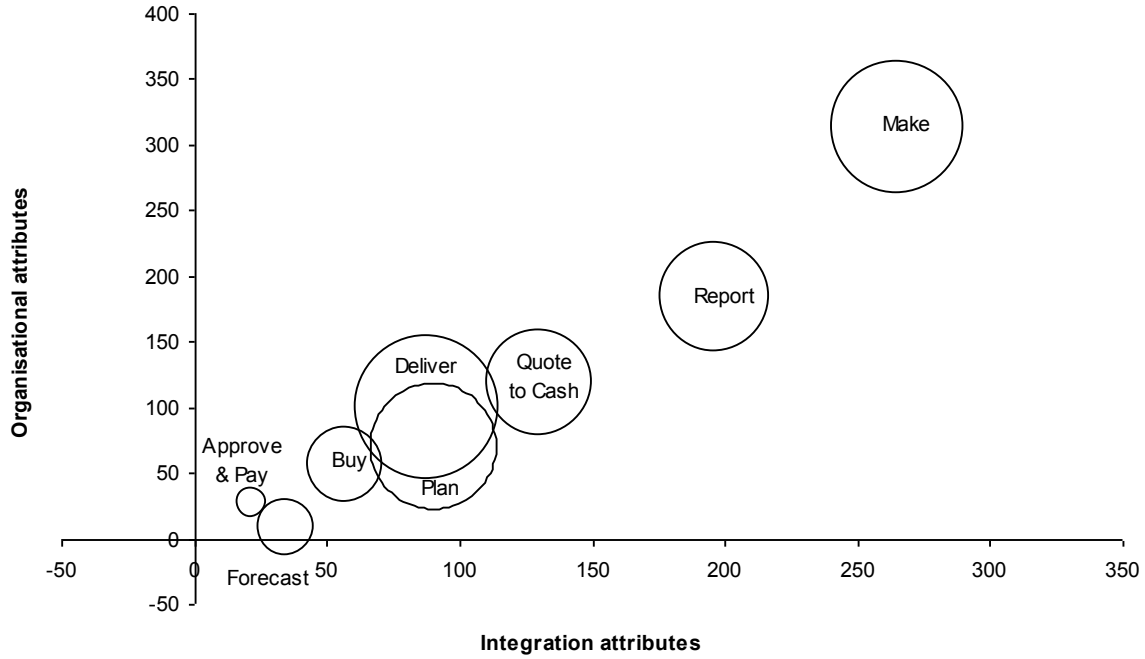


Figure 1**: The organisational impact of ERP integration by business process area**

These results reveal a strong linear relationship between centralisation and integration. That is, the stronger the consensus around the need for a centralising force in the organisation, the stronger the perceived need (among managers) for integration. This relationship holds across the different process areas. It could be deduced from this data that organisational goals are well understood and assimilated in the different functions, and that centralisation of the organisation is wholly accepted. There is a good understanding among managers of the impact of centralisation for data integrity, and a good understanding of the potential to use the associated wealth of highly granular information for different decision scenarios. This linear relationship would seem to suggest a broad acceptance among managers that centralisation is necessary from the point of view of goal focus, and that the more centralised the organisation, the more integration is required and accepted. The corollary of this finding, not tested in this sample, would be that more decentralised organisations would have difficulty accepting integration. On the other hand, what is equally striking from these results is the level of unanimity in the frustration felt throughout the business in exploiting corporate information for decision support. Because of performance and security issues with the technology, and its' fit with actual business activities, managers are obliged to resort to much manual manipulation of the information derived from the ERP system in order to get to the meaning they require.

It was of interest to note that the acceptance of centralisation varied between the two cases observed, with SIT showing more consensus on centralisation for Buying and Shipping, than KPC who were more forceful in their support for centralisation for Planning and Making. It is thought that the regulatory environment explains the KPC willingness to accept compliant manufacturing processes, whereas SIT had moved Purchasing to a global process, and were debating how to change the Deliver process from a site specific activity to a global basis. These nuances demonstrate that the acceptance of integration should be considered from a site and functional level.

Research question 2: Causality map between attributes

The analysis of Research question 1 served to establish the existence of a strong relationship between the centralisation attributes and the integration attributes. Integration is accepted by managers as it is understood that it is a pre-requisite for better control and visibility of organisational activity. The granularity of information available possibly encourages requirements for managers to correlate data in ways that were not envisaged by the integrated applications used, and with information from other sources. The increased accuracy of information benefits Manufacturing and Finance particularly. The downside of this integration is that ERP systems are inflexible and unforthcoming with meaningful information. Organisations seek to exercise control and reduce uncertainty by multiplying the number of data points, but the implementation of tools and procedures to collect the data in a changing reality becomes a cause of bureaucratic inflexibility. This inflexibility is a cause for users to resort to workarounds, which engender gaps between the physical reality and the virtual picture used to monitor its progress. These gaps or virtual blind-spots mean managers return to manual methods in manipulating information for decision making purposes. This additional manipulation introduces latency in reporting, which is compounded by response time issues deriving from the technical architecture. The net result is a requirement for skilled resources in the manipulation of corporate data to derive meaning. Thus, as integration increases with centralisation, there is a corresponding increase in the necessity for skills to manipulate and digest the ensuing glut of data. Finally, and perhaps most worryingly, users in the most sensitive execution areas (Manufacturing and Deliver processes) are handicapped by inflexibility in the transaction processing system, whereas their focus should be on material availability and customer satisfaction respectively.

These elements are depicted graphically in Figure 2.

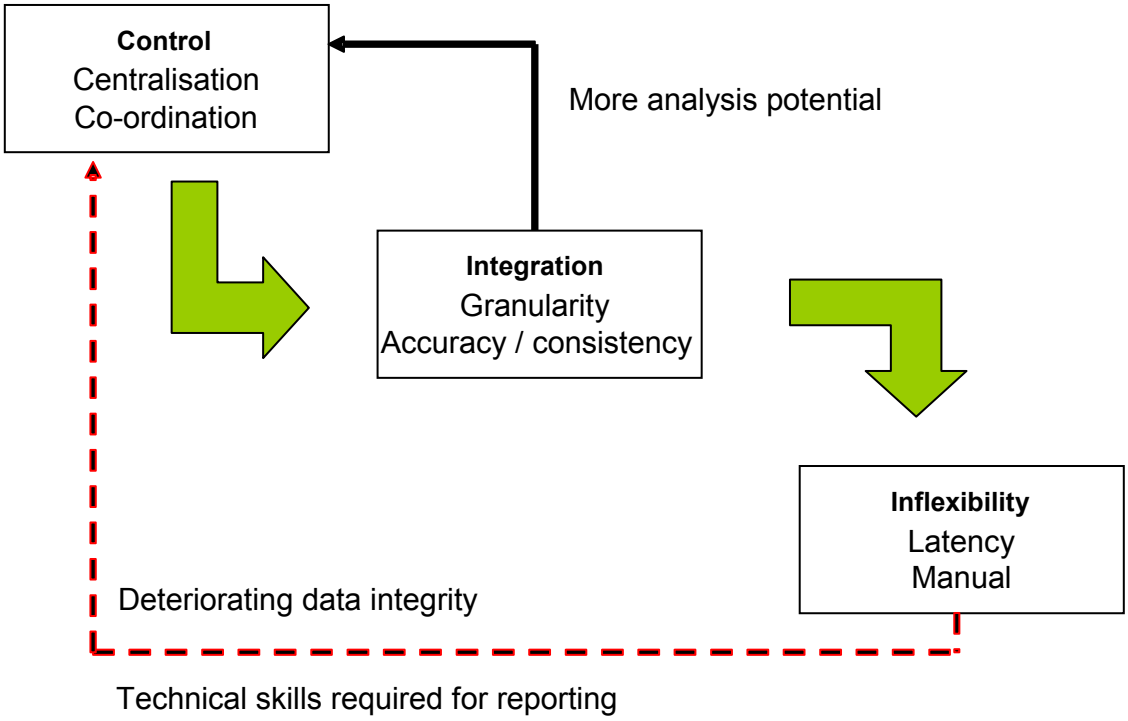


Figure 2**: Understanding the causality between control, integration and its impact**

Research question 3: Conceptual framework for ERP integration and functionality gaps

The first two research questions highlighted the themes related to the impact of ERP driven integration on the organisation, and the causality associated with these themes. The final research question draws on this output to suggest a framework for the conceptualisation of integration in the organisation, named here as "the Zipper effect" and shown in Figure 3. At go-live (t^0), a certain number of gaps will exist between the configured ERP processes and the way the company actually works. These will typically be dealt with by workarounds, but managers do not have visibility of the impact for data integrity of these workarounds, or their cost. The suggestion behind the Zipper effect is that these gaps between the physical and the virtual will inevitably emerge over time, but that acknowledging that they exist is the first step in addressing them. The second step is to establish

processes for monitoring these gaps, analysing and explaining them. Once recognised, the third step for organisations is to have the resources and procedures in place to be able to resolve them.

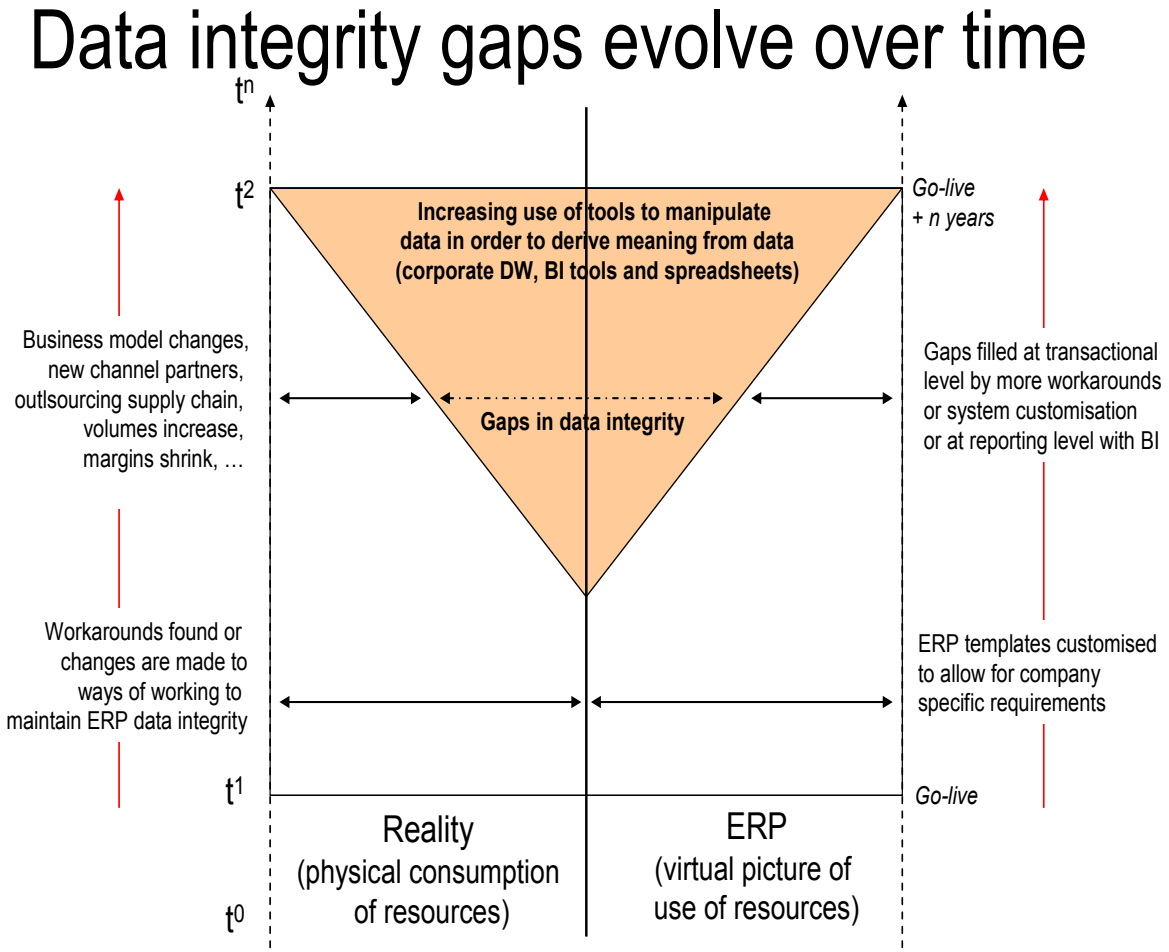


Figure 3**: The Zipper effect: modelling the divergence of ERP from reality**

5. Conclusions

This research highlights a fundamental difficulty for the use of ERP systems in large corporations. Integration involves "virtualising" the communication process through the use of information systems such as ERP. The accuracy of the information is a function of the closeness of the template parameters to the actual way of doing business. The two cases studied demonstrate that the virtualisation of business processes engenders constraints that negate the original purpose of improved control. These constraints arise from either the virtual or the physical context. The combination of a centralised technical architecture and large volumes of highly granular information creates latency issues (virtual context) which impacts at both an execution and a reporting level. The inflexibility of the standardised ways of working to the evolving business imperatives (physical context) obliges managers to resort to manual methods when analysing performance variances, defeating the original aim of an integrated approach to performance control, and incurring an additional cost.

Another key lesson from this study has been that an integrated model of how businesses function is theoretical and ill adapted to the reality of how businesses operate. Managers in both studies confessed to their inability to build conceptual models of the decision processes required in the demand and supply processes of the firm because of their sheer complexity. In such complex scenarios, the imposition of standardised procedures appears to inhibit rather than encourage an understanding of the key variables. Accordingly, the notion of integration should be treated as a normative force in organisational administration, along with other organisational attributes, but not as a once-off solution embodied in the ERP software. Raising the awareness of integration as a

parameter of organisational design should be an objective for researchers and practitioners alike, rather than being left in the hands of vendors of "solutions".

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