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ESSENTIAL CHARACTERISTICS OF AN ERP SYSTEM : CONCEPTUALIZATION AND OPERATIONALIZATION[1]

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Abstract: *The interest of firms in ERP systems has been echoed in both the scientific and professional literature. It is worth noting however that while this literature has become increasingly abundant, there does not yet exist an operational definition of the ERP concept that is, if not unanimously, at least widely accepted. This constitutes a handicap for both the research and practice communities. The present study outlines what could be considered as an ERP by first determining the essentially required characteristics of such a system: integration, flexibility and transversality. Indicators are then provided in order to operationalise these three characteristics. The study concludes by proposing a research framework on the impact of an ERP's key characteristics upon the performance of the system in a given organisational setting.*

Keywords: *ERP, enterprise systems, integration, flexibility, process orientation, transversality, information system.*

1. INTRODUCTION

Since their appearance on the packaged software market in the 1990s, ERP (*Enterprise Resources Planning*) systems have grown rapidly, be it in terms of their relative importance in the market [1; 37; 43] or in terms of their adoption by large firms [26] and even by small and medium-sized enterprises [19; 23; 45]. Both the professional and academic literature has shown a great interest in ERP, based on the high hopes placed in these systems, but also on the serious difficulties encountered by firms that have adopted these. Numerous cases of ERP project failure have been documented, including cases leading to the bankruptcy of the adopting organisations [27; 39].

Whatever the organisational impacts of ERP as seen in the literature, one fundamental question remains however: What can be qualified as an enterprise system (ES)? This can seem surprising given the abundant literature on ERP (see [18]'s annotated bibliography for an illustration of this abundance). This question appears nonetheless founded as an analysis of this literature shows that there lacks a widely-accepted operational definition of what is considered to be an ES. Klaus, Rosemann and Gable [28], following a three-level analysis, that is (i) an historical analysis, (ii) a meta-analysis of the representative IS literature on the

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subject, and (iii) a survey of academic experts, conclude on the existence of wide-ranging perspectives on the ERP phenomenon, and above all on the absence of a commonly accepted definition. It is however essential that there be a consensus in the research community on the definition of the research object, or at least on a set of common indicators. Three reasons for seeking this consensus are given [28]: it facilitates communication among researchers, and between researchers and practitioners, it allows for the development of teaching material on ERP and related concepts in university curricula and in professional training, and it facilitates communication between ERP system vendors, consultants, and their clients.

The present paper aims to contribute to the discussion on the meaning of ERP systems. In order to do this, the next section of the paper focuses on the terminological ambiguity surrounding the term ERP itself. In another section are then examined the characteristics generally attributed to ES in the literature, and a regrouping of these is proposed, in order to refine their analysis. This leads to the identification of three characteristics judged to be indispensable if a system is to be qualified as an ERP system, namely integration, flexibility, and transversality. Indications for the operationalisation of these characteristics are then proposed. Finally, the paper concludes on limitations and research orientations.

2. ERP: A TERMININOLOGICAL AMBIGUITY

In the research literature on the ERP phenomenon, even the term « ERP » itself is not unanimously accepted. However, there is a largely-established consensus [20; 28; 44] on first considering MRP (*Material Requirements Planning*), and then MRP II (*Manufacturing Resources Planning*) systems as the precursors of ERP. Hence, the « ERP » appellation directly follows « MRP II », with the word « enterprise » replacing « manufacturing » to signify that the system extends to the whole of the organisation.

Some object to the ERP label, judging it to be doubly restrictive in that it descends from MRP II and alludes only to planning. Alternative appellations have thus been proposed, including EWS (*Enterprise Wide Systems*), or simply ES (*Enterprise Systems*) [14; 32] to highlight the coverage and integration of all organisational functions, or yet again ERM (*Enterprise Resources Management*) [34, p. 25] to highlight the support for all of the firm's management activities and not only planning.

While these objections are founded, the ERP appellation remains widely used in both the research and professional literature, seemingly for reasons of convenience and antecedence. Being gradually accustomed to its use, people do not seem to be bothered by the weak correspondence between the appellation and its content. One must also note that since it was first coined in 1992 [28], the term ERP has preceded the alternative terms that appeared a few years later. In the rest of this paper, the term in-use will be employed, namely "ERP", whatever its imperfections, with the aim of better defining the content of this term.

3. CHARACTERISTICS GENERALLY ATTRIBUTED TO ERP SYSTEMS

If one refers to various authors [10; 14; 38], an ERP system can be defined as an adaptable and evolutive commercial package that supports, in real time and in an integrated manner, the management of most if not all of a firm's business processes. One can attempt to better define it by looking at its characteristics. In this regard, an attentive observer of both the research and professional literature will denote quite a number of attributes deemed to be possessed by ERP systems.

3.1. IDENTIFICATION OF ERP CHARACTERISTICS

Characteristics generally attributed to ERP systems in the literature are presented in Table 1. In doing so, an attempt has been made to include all characteristics, notwithstanding the different terminologies used by different authors in describing them.

Table 1 : Recapitulation of the main characteristics of ERP systems

Characteristics	Explanatory elements	Authors
Integration	Interconnections between functions and hierarchical levels Interaction between the various processes	[3; 4; 10; 16; 29; 31; 38]
Completeness (generic function)	Wide range of functions Applicable to various types of firms Connectivity with the outside	[10; 16; 29; 38; 44]
Homogenisation	Unique data referential Uniformity of human-machine interfaces Unicity of the system's administration	[10; 16; 29; 38]
Real-time	Real-time update and consultation	[16; 34]
Adaptability (flexibility)	Capability to follow rule and organisation changes (made possible by parametering)	[29; 38; 44]
Openness (evolutionary)	Modularity Portability	[29; 38; 44]
Transversality (process-oriented view)	System designed in regard to the business processes necessary to achieve objectives Focus on value rather than authority flows	[8; 13; 28]
Best practices	System imbeds best practices in the field	[40; 44]
Simulation	Business processes can be simulated	[38; 44]

3.2. REGROUPING ERP CHARACTERISTICS

For a better understanding, ERP characteristics have been regrouped under three dimensions in regards to their nature, namely technical, organisational and informational, as presented in Figure 1. The technical dimension regroups characteristics that refer to the capabilities or facilities for applications development offered by ERP systems in comparison to traditional systems. This includes two basic characteristics: flexibility (adaptability) and openness (evolutionary).

The organisational dimension refers to the system's deployment in the firm. These are the characteristics that best reflect the impact of an ERP system on the organisation, on its structure as well as its practices. This includes integration, completeness (generic function), homogenisation, transversality (process-oriented view) and best practices. The informational dimension regroups characteristics that relate to the quality and usefulness of the information provided by the system, namely real-time (update and consultation) and simulation (of actual business processes).

This regrouping justifies the assertion that ERP systems can be qualified as organisational systems rather than as technical or information systems [8]. Also, existing ERP systems are built upon diverse hardware and software platforms, such as Windows or UNIX. This is an argument for characterising an ERP system more by its functionalities than by its design or technical exigencies [28].

4. ESSENTIAL CHARACTERISTICS OF AN ERP SYSTEM

If one carefully considers the characteristics enumerated above, a number of questions arise. First, are these characteristics truly universal? In other words, do they all apply to all

ERP systems? Second, are all of these characteristics equal, or are some characteristics more essential than others in defining ERP systems? And what would be the indispensable or minimal characteristics required for a system to be qualified as an ERP system? The following discussion attempts to answer these questions.

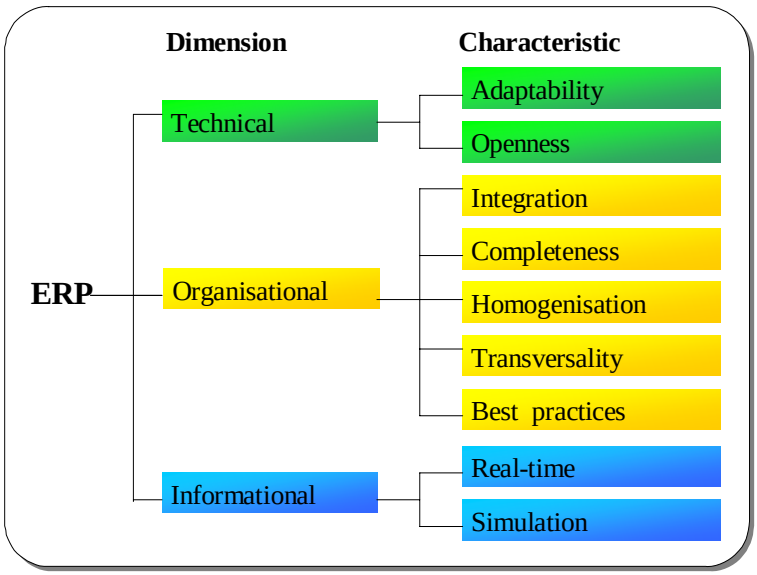


Figure 1: ERP characteristics regrouped under three dimensions

4.1. DISCUSSION OF ERP SYSTEM CHARACTERISTICS

In analysing the characteristics attributed to ERP systems in the literature, one attempts to identify those that are most significant and common to all. A characteristic can then be kept or discarded on the basis of its discriminating power in regard to other characteristics. Redundant attributes can thus be eliminated. The discussion of the characteristics is in the order pictured in Figure 1.

A flexible organisation is one that can use its existing resources and competencies to quickly respond to changing conditions in its environment without significant decreases in performance [15]. The flexibility of the IT infrastructure is a characteristic deemed to be determinant if these technologies are to be at the source of a sustained competitive advantage for the firm [17]. This explains the importance accorded to this issue by IT managers [11]. Flexibility is even more important in the case of ERP systems, given the size of the investment they require and the breadth of their organisational coverage. If an ERP system was not adaptable, it would limit the organisation's development potential in a changing environment.

Also, given that the ERP system integrates various functions of the organisation (production, finance, HRM, etc.), there seems to be both an opposing and a complementary relationship between flexibility and another characteristic, namely integration. On one hand, the more an organisation is integrated, the harder it is to "disconnect" itself [30]. Indeed, it has been found that the more firms adopt integrated technologies, the less flexible they are [9]. On the other hand, integrated processes allow for greater sharing of new information, thus insuring quicker response to changes in the environment and increasing the organisation's flexibility. Hence, even if flexibility appears to contradict integration, the

former criterion completes and relativises the latter, as integration obtained at the expense of flexibility would be problematical.

Openness is a characteristic that appears to be redundant in regard to flexibility. The modularity and portability (openess) that allow an ERP system to evolve with the organisation can be considered as factors of flexibility. In fact, anterior studies [11] include modularity in their definition of flexibility.

Integration is without a doubt the most important ERP characteristic, as all authors concur on this [3; 14; 29; 38]. It distinguishes ERP systems from traditional IS whose « informational fragmentation » has been criticized [12] in that it reflects a vision of the organisation as a set of islands or functional silos that cannot coummunicate with each other, or that communicate little or with great difficulty.

Completeness (the generic functionality) is a characteristic that, pushed to the extreme, becomes unrealistic. A generic system that would work for all types of firms and industries is in fact very difficult if not impossible to design. Forest [20] shows for example that depending upon the nature of their physical flows, manufacturing firms will have IS needs, and ERP needs in particular, that are specific to them. One could in fact develop a typology of ERP systems by taking into account the specificities of the adopting organisations and industries. Whereas Parr and Shanks [35] show that by choosing a specific type of implementation, given their initial motivation for adopting an ERP system, organisations wind up with systems that are not comparable. For their part, Klaus *et al.* [28] note that in its strictly generic form, the ERP system needs to be configured before being used. By adding or eliminating certain elements, the configuration thus creates distinct product types and makes it very difficult to have a standard or common description.

Homogenisation refers to the existence of a unique data referential, the uniformity of human-machine interfaces, and to the unicity of the application system's administration [38]. Among these elements, the first one is deemed by Lequeux [29] to be indispensable in qualifying a solution as an ERP system, in addition to integration and adaptablity. One must note however that homogenisation is subordinate to integration. Hasselbring [25] indicates that reducing the heterogeneity of IS is one dimension on which to intervene in order to achieve integration. The same can be said of a unique data referential or data base that supports the integration of information flows within the firm, in conjunction with a workflow management system [7].

Transversality refers to the process-oriented view of an ERP system [13]. Its importance comes from the fact that ERP systems are composed of functional modules, and are generally implemented module by module, that is, in a vertical manner. If care is not taken, this could threaten the horizontal design of the organisation, as it is this design that allows one to remove non value-adding activities from business [6]. Beretta [7] adds that without a process-oriented view, advantages in terms of integration would not be obtained from an ERP. A number of failures of ERP projects are in fact due to a lack of transversality in the installed system; for instance, « balkanisation » appears when each organisational entity uses the installed ERP software to consolidate its power base by accentuating its differences [8]. A process-oriented view would put the functional specificities more into the background while promoting informational integration and communication between units. This view would also render more apparent the need for and scope of process reengineering.

Imbedding best practices would not be considered as an essential characteristic of ERP systems. The reason is that this notion is based on adopting generic processes that, despite being exemplary, offer few possibilities of gaining a competitive advantage [14]. Certain authors go further by questioning the universal applicability of so-called « best practices »

[41]. Harrington [24] even qualifies as fallacious the idea that there exist business practices applicable to all organizations. Also, best practices within countries, industries, or specific firms may diverge from the practices imbedded within an ERP system.

The capacity for real-time operation and simulation in an ERP system are consequences of its successful integration. It is this integration that allows the same information to be communicated in real time to all parts of the organisation, and allows simulating the effect of an input on all activities of the organisation. Markus [30] notes for instance that non-integration limits the capacity of a firm, or of a group of cooperating firms, to take important decisions, even when the necessary data reside somewhere in a system.

4.2. OPERATIONALISATION OF ERP CHARACTERISTICS

The preceding discussion leads us to limit essential characteristics to three: integration, flexibility, and transversality. One could say that these are the minimal requirements for a system to be qualified as an ERP or enterprise system. This being said, one can note that from an operational perspective, the major difficulty resides less in the number of characteristics retained than in their qualification.

4.2.1. Operationalisation of integration

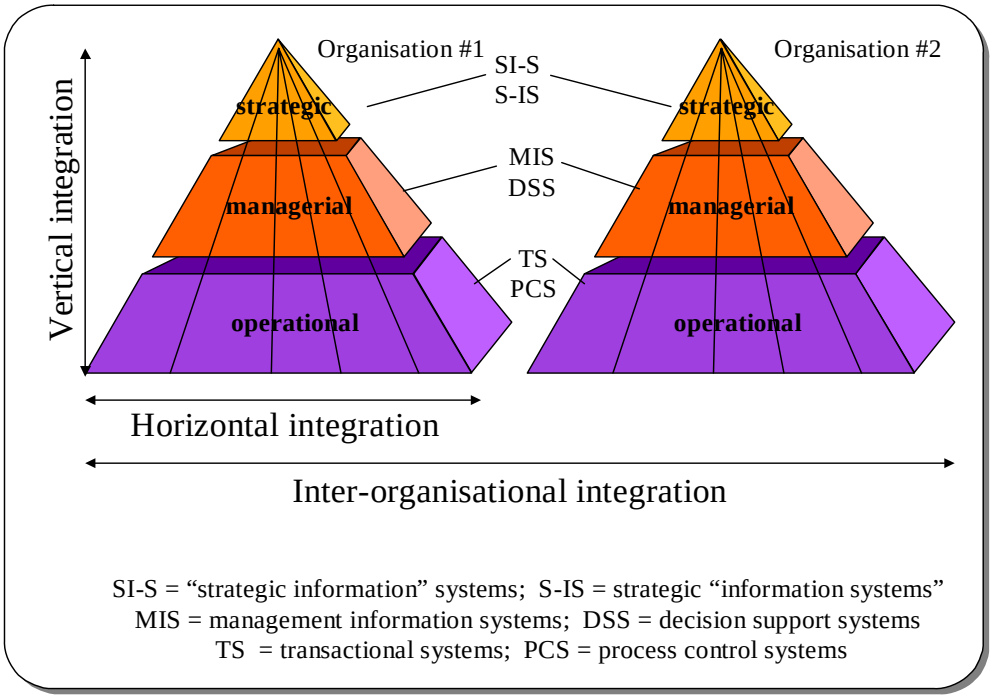
The concept of integration is not exclusive to the IS domain. As underlined by Barki and Pinsonneault [3; 4], this concept occupies a central place in many fields of research other than IS such as management, strategy, and operations management. In the IS field, integration is defined from three perspectives [3] : one is technical, referring to the interconnectivity of IT and a shared conceptual schema for data bases ; a second perspective is inter-organisational, referring to IT-based links between business processes of two or more independent organisations; a third perspective envisages integration in the form of co-ordination and co-operation within project teams and between these teams and other entities in the organisation.

For her part, Markus [30] distinguishes organisational integration (both internal and external) from systems integration. The first is viewed as a tight co-ordination of the various activities undertaken by different individuals, work groups or organisations such that a unified business process is formed. Systems integration is viewed as creating strong links between different IS and data bases. Hence, organisational integration as defined by Markus [30] regroups Barki and Pinsonneault's [4] second and third perspectives, whereas systems integration corresponds to their first perspective, namely the technical one. Systems integration is often necessary to achieve organisational integration but it is not always sufficient [30]. When one then speaks of an ERP system, the underlying type of integration is basically systems integration, but its evaluation cannot ignore the organisational integration that it induces, and that it is deemed to support.

The integration of an ERP system can be envisaged from two angles, considering the integration perimeter (organisational coverage) and the intensity of integration (depth of integration). In the first view, integration can be vertical, horizontal, or inter-organisational [36] (see figure 2). Vertical integration refers to the degree of interconnection (connectivity, compatibility) between hierarchical levels in the organisation. Horizontal integration is ascertained by the interconnection between various organisational functions or departments, whereas inter-organisational integration refers to the firm’s interconnection with its business partners.

In the second view, one distinguishes the extent to which integration is achieved, be it vertical, horizontal, or inter-organisational. In this regard, Toussaint *et al.* [42] mention the

quality of integration, this being ascertained through the co-ordination of behaviours (presentation, execution, and data access) and of communication (tracking of messages



Source : adapted from [36].

between sender and receiver, structure of the information exchanged, way in which information is exchanged and processed).

Figure 2: Integration perimeter

4.2.2. Operationalisation of flexibility

The concept of flexibility has been widely studied in the filed of operations and production management [5; 15]. It has also been approached from within the IS domain [11; 17; 22]. Whereas operations management studies obviously focus on the flexibility of the productive apparatus (manufacturing flexibility), and IS studies are preoccupied with the flexibility of the IT infrastructure, both fields show similarities in their definition of the concept, and in the difficulties confronted in order to operationalise and measure it. The operational definitions and measures of the two obviously differ however, given that they apply to two different systems. One can also note that IS flexibility may have an effect on manufacturing flexibility.

In the short term, flexibility means the capacity to adapt to changing conditions by fully using all existing resources, and in the long term, it indicates the capacity to introduce new products, new production resources and methods, and to integrate these within the existing production system. For D'Souza and Williams [15], the flexibility of the production system or manufacturing flexibility is a multidimensional construct that represents the ability of the manufacturing function to make the necessary changes in reaction to changes in the firm's environment, and to do so without significant negative effects on the firm's performance.

Synthesizing different points of view in the literature, Golden and Powell [22] propose a quadri-dimensional view of flexibility: a temporal dimension, range, intention, and focus. The first dimension refers to the time it takes the organisation to react to change. The second is ascertained by the variety of responses available to the organisation in order to face both foreseen and unforeseen changes. The third is meant to determine if the organisation is proactive or reactive, offensive or defensive in regard to change. The last dimension refers to the internal or external orientation of the organisation's flexibility.

The last two dimensions (intention and focus), as opposed to the first two (temporal and range), could be considered as qualifiers of flexibility, but not necessarily as definitional elements of this concept. As noted by Golden and Powell [22], intention and focus depend on the context. Whatever the intention or focus, flexibility is not put in question as it is a strategic choice of the organisation. In all circumstances however, a system that reacts less quickly (temporal dimension) or proposes fewer responses to change (variety) will be considered as less flexible. Intention and focus would then constitute secondary dimensions, whereas the other two dimensions would be primary.

To measure flexibility's temporal dimension, Golden and Powell [22] propose efficiency and responsiveness measures, whereas they propose measures of versatility and robustness for the range dimension. Here, efficiency means the ability to maintain the same performance level while changes occur. Responsiveness will be ascertained by the quickness with which the organisation adapts to change. Versatility and robustness both refer to the range of activities that can be accomplished by a system, the first one relating to foreseen changes whereas the second relates to unforeseen changes.

For their part, Byrd and Turner [11] have developed a measure of IT flexibility, taking into account both the technical infrastructure (data, applications, networks) and the human infrastructure (competencies for effective management of IT). The technical infrastructure is measured by four indicators: connectivity, compatibility, functionality of applications, and data transparency. The human infrastructure is ascertained through: technological management, business abilities, management knowledge, and technical knowledge. Note that the first two are redundant with the measure of integration, denoting again the intertwined relationship between these two concepts. Note also that on the criteria of connectivity and compatibility, the measure of flexibility developed by Byrd and Turner [11] is redundant with the integration measure defined in the preceding section of this paper. In fact, these two criteria were attached to integration in the latter's second-order factor analysis.

It does not appear surprising, at least theoretically, that the notion of integration appears in the conceptualization of flexibility, as these two notions are inter-related and inter-dependent: by enabling the links between the various organisational functions and levels, integration allows fore the instantaneous diffusion of information throughout the organisation, which then allows immediate adjustments made necessary by the new information. This theoretical relationship between integration and flexibility is not necessarily confirmed in practice. Beach *et al.* [5] note for example that it is as important as it is difficult to have the connectivity between internal and external systems (intra and inter-organisational integration) come into play in order to improve flexibility.

The flexibility of an ERP system could thus be measured by using a combination of the two preceding approaches, however avoiding a redundancy with the measure of integration. As shown in Figure 3, this characteristic could be operationalised under four dimensions, that is, two dimensions from Golden and Powell [22], namely the temporal dimension (efficiency and responsiveness of the system) and the system's range (versatility and robustness), and two from Byrd and Turner [11], namely part of the technical dimension that is not redundant with integration (functionality of system applications and data

transparency), and the human dimension (managerial and technical knowledge, business and managerial abilities in regard to the ERP system).

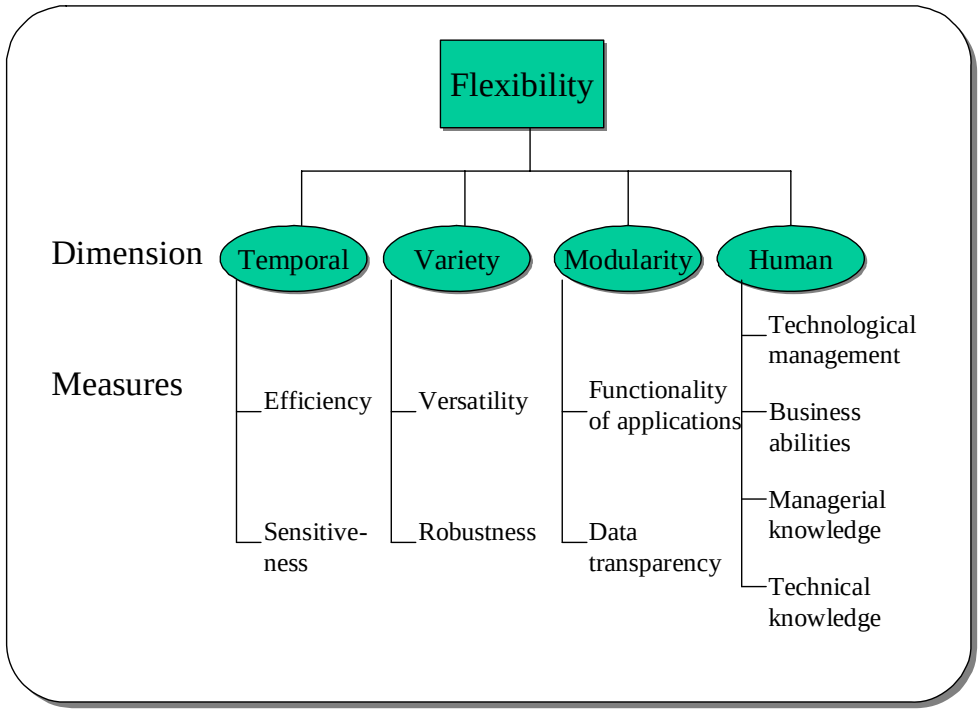


Figure 3: Flexibility dimensions and measures

4.2.3 Operationalisation of transversality

The process notion is central to transversality. This notion is defined as an activity or a set of activities that are linked in an ordered fashion, and that transform inputs into outputs for customers in a repetitive flow [21]. Such a definition emphasises value-adding activities, repetitiveness, and a customer-orientation. The process is thus a conceptual scheme that helps managers to assess the utility or value of each specific activity [7].

Various aspects of a process cannot be apprehended through traditional accounting measures but rather through performance indicators such as production cycle times, delivery delays, output quality, productivity, customer satisfaction, and learning [33]. Understanding their activities from an horizontal rather than vertical perspective would thus allow business firms to get closer to their customers while simultaneously increasing the quality of their organisation and their competitiveness [2; 21]. Operationalising the transversality of an ERP system requires measuring the extent to which it is process-oriented. For Forsberg *et al.* [21], there are various manifestations of an ERP infrastructure's embodying a process-orientation: use of a common language, customer focus, cooperation, holistic or « big picture » view, reduction of costs and delays, increased learning, standardisation and co-ordination. In order to measure the transversality of an ERP system, one could ascertain to what extent it meets these conditions (see Figure 4).

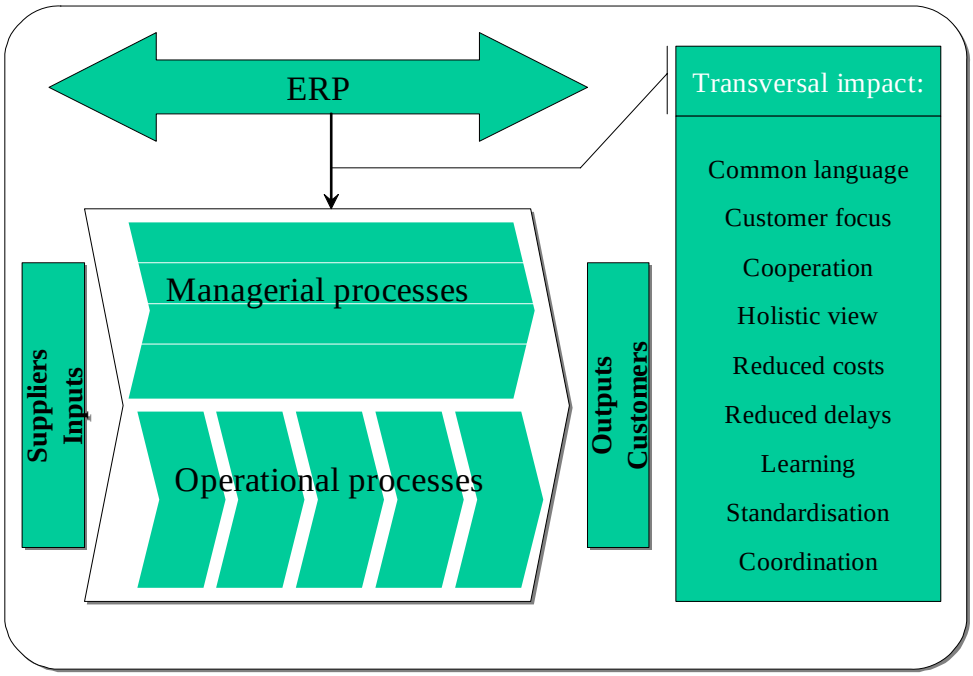


Figure 4: ERP transversality

5. LIMITATIONS AND IMPLICATIONS FOR RESEARCH

IS research can profit from a more precise definition of ERP systems. In this paper, we have attempted to take stock on what is actually meant by the ERP appellation. To do this, we have placed an emphasis on determining the minimal or indispensable characteristics that a system should possess to be qualified as an ERP system. We have then tried to define these characteristics in order to facilitate their operationalisation. This approach is strictly theoretical however, and would require empirical validation based on the characterization of ERP systems actually implemented in organisations. Another research avenue would be to further pursue the operationalisation of ERP integration, flexibility and transversality in order to measure these characteristics across actual ERP systems.

Other research paths are summarised in Figure 5. Given that previous studies have suggested the existence of mutually dependent relationships between ERP chasracteristics, notably between flexibility and integration [9; 30], it would be interesting to pursue such analysis further by examining the nature of the interdependencies between flexibility, integration and transversality, and by assessing the impact of such relationships on the ERP system's performance.

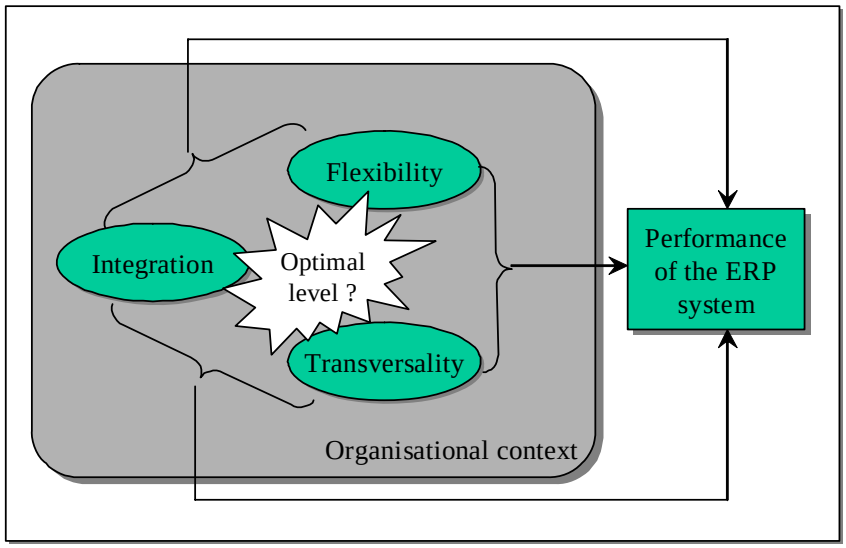


Figure 5: Research avenues on the impact of key characteristics of ERP systems

One could also envisage research that aims to evaluate a system's performance level as determined by its levels of flexibility-integration-transversality. Hitt *et al.* [26] suggest that there is an optimal level of functional integration beyond which diseconomies of scale begin to appear. The problem would then be to determine optimal levels of ERP flexibility, integration and transversality, if they exist, in relation to organisational or industry factors. This paper hoped to contribute to a better understanding not only of what is actually meant by the term "ERP" or "enterprise system", but also to raise applied research issues that are of interest to firms that have implemented or plan to implement ERP systems, and to vendors and consultants that assist in their implementation

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