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# Towards the Measurement of Process Integration

**Benoit A. Aubert, Betty Vandenbosch and Muriel Mignerat**

**Abstract**

We offer a formal definition of business process integration. The views of integration in various fields are reviewed and integrated to isolate the four fundamental properties of information that define it: accessibility, transparency, granularity and timeliness. An illustration of a process in the aerospace industry is used to apply the four properties.

**Résumé**

Ce document présente une définition formelle de l'intégration des processus d'affaires. Les différentes perspectives de l'intégration dans diverses disciplines sont examinées et intégrées afin d'en extraire les quatre propriétés fondamentales de l'intégration: l'accessibilité, la transparence, la granularité et le caractère temporel. Une illustration à l'aide d'un processus de l'industrie aerospatiale est utilisée pour appliquer ces propriétés à un cas concret.

**Mots clés**

A1 0107 Conceptual Study

A1 0401 Measures

DA 1001 Organizational Value Chain



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## Introduction

Process integration has been discussed and advocated at length and in great detail by practitioners. In fact, the justification for many ERP implementations has been the integration of business processes and efficiency gains in most business process reengineering efforts have been expected from integration. When asked what integration really means, top-level executives reply with wide-ranging views: *... significant automation ... access to files on computers and automation of supply functions… elimination of paperwork ... integration is inter-enterprise process reengineering* (Low, 2002). Interestingly, these expressions do not relate to a clear concept nor do they provide a formal definition. They are oriented more toward examples and the means to achieve integration.

The research community has also considered process integration in some detail. They describe it using expressions such as tight coordination among activities, standardization and tight coupling, operating as a whole, etc. (Barki and Pinsonneault, 2002; Markus, 2000). Nevertheless, we lack an operational definition or measure. Therefore, while one may be able to discern that a process is integrated, it is not easy to assess the extent to which that is the case, and whether the cost of increasing process integration would be justified for the organization.

We begin by offering a formal definition of process integration. Then we describe its theoretical rationale and provide a qualitative example of how it might be employed. We conclude with a research program designed to explore the empirical value of the definition.

## A Definition of Process Integration

A process is *"a lateral or horizontal organizational form, that encapsulates the interdependence of tasks, roles, people, departments and functions required to provide a customer with a product or service"* (Earl 1994, 13). It consists of flows and activities. An activity *"takes an input, adds value to it and provides output to an internal or external customer"* (Harrington, 1991, 6). Flows consist of goods (materials, components, forms) and data about the goods. Hence, any definition of process integration must incorporate the flow of both data and goods.

It is important to note that integration is concerned with the process itself, not with its output. A process could be perfectly integrated and very efficient but producing an output that is perfectly useless. Similarly, it is conceivable that a process with very little integration could result in a product with very high quality. Process integration is also different from vertical or horizontal integration as defined in Economics (Williamson, 1985). Economics looks at the allocation of the residual rights of decision. When assessing process integration, processes can be crossing various organizational boundaries. A measure of process integration should be usable whether a process is carried out within the organization boundaries or across multiple organizations.

We propose that the level of process integration is the sum of efforts expended by the receiving activities of a process to achieve access, transparency, timeliness, and granularity of goods and data, relative to the total value added by the process.



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$$PI = (VA - \sum_{j=1}^{n} C(a_j) + C(tr_j) + C(ti_j) + C(g_j)) / VA \quad (1)$$

where: VA: Value added by the process, $tr_j$: Transparency for activity $j$,
C($x_j$): Cost of providing property $x$ for activity $j$, $ti_j$: Timeliness for activity $j$,
$a_j$ : Accessibility for activity $j$, $g_j$: Granularity for activity $j$.

Hence, the lower the cost of achieving access, transparency, granularity and timeliness of goods and data relative to the value added by the process, the higher the level of process integration. In other words, the fewer steps, handoffs and physical distance in a process, the greater its integration.

The inclusion of value added by the process enables one to compare the degree of integration of simple and complex processes. The cost of providing accessibility, transparency, granularity and timeliness of the goods and data needed to build a table is much less than that needed to build a car. However, a table is much less valuable than a car, so it is conceivable that the degree of process integration might be the same. When comparing two tables that are built using the identical process but of materials of different value, the value added by the process will be identical, so the degree of process integration will be the same. Two processes that add the same amount of value may have very different levels of integration depending on data flows. Exactly the same value is added when you go to a teller as when you go to an ATM machine, but the latter is a much more integrated process, in addition to being more secure and less error-prone. Two different companies can build exactly the same sub-assembly for a car, with very different levels of process integration.

Our definition does not presume that integration is a consequence of a customer driven or pull system such as Kanban rather than a resource driven or push system such as Fordism. In other words, the integration of a system in which the capacity of each process defines how many units are produced is measured in the same way as a system in which units are produced only if the next activity needs them. In both instances, the measure of process integration is the cost of acquiring the goods and data needed to conduct the next activity.

## Theoretical Support

In order to develop our measure, we first reviewed the concept of integration in various fields. Information Technology and Logistics, because they frequently view their environments as a series of processes, provided several insights. Elements in other fields were also gathered.

**Integration in IT.** Many researchers interested in information technology have investigated business process integration. Early studies stemmed from the work on business process reengineering. Language used to describe and/or define integration includes: single point of data capture, treating geographically dispersed resources as though they were centralized, linking parallel activities, synchronizing production and control activities (Hammer, 1990). More recent work done in this line of research considers Enterprise Resource Planning (ERP) technology and



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discusses transparency of information and processes (Champy, 2002), synchronization, coordination, and coupling (Barki and Pinsonneault, 2002; Markus, 2000). An integrated process has also been described as an efficient process, containing only the required activities (Christiaanse and Venkatraman, 2002; Hammer, 2001).

A more technology-oriented lens has also been adopted to study integration. For instance integration was studied at the database level in IT. Goodhue, Wybo, and Kirsch (1992) defined data integration ad the "*use of common field definitions and codes across different parts of the organization*". EDI was presented as an early enabler of integration. For example, Truman (2000) measured the extent to which manual procedures were replaced by automated ones for merging data from the EDI system with the company system. Enterprise Application Architecture (EAI) also considers the the problem of integration. EAI looks at common understanding of information between systems and coordination of these systems (often in different organizations) to ensure seamless execution of the activities. This enables an integrated value chain in the organizations and across them (Hasselbring, 2000; Opie, 2002).

In recent years, integration of processes between organizations, rather than inside a single organization, has renewed interest in the concept of process integration. Electronic commerce, especially with its business-to-business orientation, studied facets of integration. Dan *et al.* (2001) studied integration through "*middleware*" enabling the exchange of information between entities in a clear and instantaneous manner. Along with the use of rules to route information, this enabled separate organizations to work as a single virtual organization. Integration is also perceived to be "dynamic coordination" which could be enhanced by workflow technology in an E-business context (Meng *et al.*, 2002). In a multi agent context, system integration is decomposed into three levels: information, process, and integration of sub-systems (Sikora and Shaw, 1998). The first one addresses the integration of databases and systems. The second is defined as coordination between stages and activities, and the third is a higher-level concept, creating larger, coordinated networks (Sikora and Shaw, 1998).

**Integration in Logistics.** In logistics, the notion of process is widely used. Some authors in this field also use the analogous terms supply and value chain. Chandra and Kumar (2001) believe that integration is achieved through synchronization of activities in the value chain. Harrington (1991) defines process efficiency as the extent to which resources are minimized and waste is eliminated.

Sabbath (1995) describes an integrated process as "linked organizationally and co-ordinated with information flows". This is compatible with Narasimhan and Wook (2001) who emphasize linkages within the organization and with clients and suppliers, enhancing coordination. Close coordination and central programming was the core of the discussion by Gustin, Daugherty, and Stank (1995) who insisted on the seamless character of the integrated processes.

Armistead and Mapes (1993) tried to measure integration through five reflective items: Shared ownership of the master production schedule; Level of adherence to manufacturing plan;, Job titles spanning traditional functions; Integration of information systems; Visibility and spread of transmission of information. No reliability evaluation was offered. The three items related to information accessibility are compatible with Mollenkopf, Gibson, and Ozanne's (2000)



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definition. They offered two components: dissemination of information and coordination of activities. The other items (job titles and adherence) would be consequences of integration.

**Other Elements**. Marketing has provided links with logistics by insisting on the alignment of supply capabilities with customer requirements. This requires integration, defined as the existence of interfaces between the two functions' respective processes to ensure adequate exchange of information (Morash and Clinton, 1998).

On a very different note, the human system is often though of as an integrated system which "*interprets sensory input and makes decisions about what should be done at each moment"* (Marieb, 2001, p. 1189). An integrated system is constantly and instantaneously readjusting itself. Research trying to reproduce the human body views the challenge of integration as one of taking numerous components (and interactions) into account simultaneously (Cheng *et al.*, 2001)

Table 1 summarizes the properties of integration:

| **Properties of Integration** | **Author(s)** |
|---|---|
| Common understanding of data (models and structure) | Goodhue *et al.* (1992), Hasselbring (2000) |
| Coordination | Gustin *et al.*, (1995), Meng *et al.*, (2002) Mollenkopf *et al.*, (2003), Morash and Clinton (1998), Sabbath (1995) |
| Data integration (with interconnectedness/access) | Armistead and Mapes (1993) Chiang, Lim, and Storey (1991), Hasselbring (2000), Mollenkopf *et al.*, (2003), Opie (2002) |
| Efficiency | Christiaanse and Venkatraman,(2002), Zairi and Sinclair (1995) |
| Instantaneity | Dan *et al.*, (2001), Marieb (2001) |
| Interdependence | Cheng *et al.* (2001), Venkatraman (1994) |
| Joint and interfaced activities | Morash and Clinton (1998), Vargas, Cardenas, and Matarranz (2002) |
| Maximizing linkages | Adam and McCormack (2001), Narasimhan and Wook (2001), Sabbath (1995) |
| Open sharing of data | Hammer (2001) |
| Organized group of activities without extraneous irrelevant activities | Hammer (2001) |
| Single capture of information | Hammer (1990), Truman (2000) |
| Standardization | Bhatt (2000) |
| Synchronization | Chandra and Kumar (2001) Hahn *et al.* (2000) |
| Technical interconnectivity | Venkatraman (1994) |
| Tight coordination among discrete units | Markus (2000) |
| Transparency | Champy (2002) |
| Treatment of dispersed resources as if they were centralized | Hammer (1990) |

**Table 1 – Properties of Integration**



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A brief examination of the properties listed in Table 1 reveals that they are not at the same level of abstraction. Some are characteristics of the information within the process, some are properties of the activities, some may be seen as consequences of information properties, and others pertain to the sequence of the activities. However, commonalities exist[1].

Many elements address the notion of *transparency*, the ability to understand what is being passed on. Transparency can be achieved through translation among several "languages" (a more flexible approach) or through standardization, establishing one common language (a more totalitarian approach). Some take transparency to the extreme, by insisting on standardization, while others encourage transparency through the structure of the data models. Transparency enables common understanding of models and structure. It also enables (along with access) data integration and open sharing.

*Accessibility* is also a recurring element. Terms used include "technical" interconnectivity, linkages and interconnectedness. All refer to the ability to access data from each required point within the process. Accessibility has many consequences. It enables information sharing, treatment of resources as if they were centralized, and the single capture of data. When coupled with timeliness, it permits synchronization of interdependent activities.

*Timeliness* also emerges as an underlying property. To enable coordination and synchronization, information has to be up to date. Combined with access discussed earlier, it permits all activities to be executed at the appropriate time. There is no delay in treatment (instantaneity).

The last element is more specific to data integration as described by Goodhue *et al.* (1992). It is the *granularity* of the information. All information exchanged in the process has to be provided at the right level of detail. Appropriate granularity enables the elimination of extraneous activities that would be required to decompose or summarize the information.

An underlying preoccupation is the efficiency of the process. By reducing delays, translations, waiting times, and redundant activities, processes are made more efficient. This leads us to the idea of minimizing the cost of achieving the four properties as described in equation (1).

Table 2 summarizes the projection of the components identified in the literature review into the four properties associated with integration.

[1]Authors' names for each property are omitted in the discussion to simplify the text. Please refer to Table 1.



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| Properties of Integration | Projection into the Four Fundamental Properties |
|---|---|
| Common understanding of data (models and structure) | Transparency |
| Coordination | All activities are performed on time and information for these is accessible in a timely manner (timeliness) |
| Data integration (interconnectedness) | Combination of accessibility and transparency |
| Efficiency | All four properties required to be achieved at the lowest possible cost would ensure an integrated process, thus maximizing efficiency |
| Instantaneity | Timeliness |
| Interdependence | Any action during an activity that requires another action will generate a trigger (timeliness) with the appropriate information (accessibility) |
| Joint and interfaced activities | Accessibility |
| Maximizing linkages | Accessibility |
| Open Sharing of data | Accessibility and transparency |
| Organized Group of Activities without extraneous irrelevant activities | Granularity |
| Single capture of information | Accessibility |
| Standardization | This is an extreme case of transparency |
| Synchronization | Timeliness |
| Technical interconnectivity | Accessibility |
| Tight coordination among discrete units | Accessibility and Timeliness |
| Treatment of dispersed resources as if they were centralized | Accessibility |

**Table 2 - Projection**

## Integration and Information Quality

In a study of 22 business processes that included those that generated products for external customers, those that generated products for internal customers and those that improved other processes, Kock, McQueen and Corner (1997) found that approximately 90 percent of the exchanges were of data. It is difficult to conceive of any process with distinct tasks and activities that doesn't require data to move it forward. In fact, most of the literature on business process improvement focuses almost exclusively on the role of information and information systems (Broadbent and Weill, 1999; Bhatt 2000b). To ensure that our properties comprise all the necessary attributes of information as well as of processes, we reviewed the research on information quality. The standard definition of product quality, *fitness for use* (Juran 1989), is appropriate in this context. In other words, *information is of acceptable quality if it is fit for use for its intended purpose* (Strong, 1997). In our application, if it helps to integrate the process, it is fit for use for its intended purpose.



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Information systems researchers have a long history of assessing information quality and have developed many measures and conceptual schemes to describe it. In one of the earliest studies, Zmud (1978) derived several dimensions of information quality. He found that high quality information was relevant, accurate, factual, complete, reliable, timely, orderly, precise, readable and reasonable. Because he was working with paper reports, accessibility was not part of his scheme. O'Reilly (1982) operationalized Zmud's definition and found that accuracy, specificity, relevance, reliability and timeliness were indicative of information quality as well as accessibility.

Subsequently, researchers have used many additional words to describe the dimensions of information quality. We find that, for the most part, these dimensions are not mutually exclusive. For example, DeLone and McLean (1992) added understandability, and clarity. While these words do indeed have different meanings from those Zmud used, we find it hard to imagine that someone evaluating a system would think that it was understandable but not readable or clear but not orderly. In developing the dimensions of information that result in process integration, it is critical to ensure their orthogonality. They must be mutually exclusive and collectively exhaustive.

**Accessibility.** Accessibility has long been identified as a dimension of information integration and from time to time, it is also included as a dimension of quality. Culnan (1984) defined accessibility as having three dimensions: reliability, convenience and ease of use. The user of the information has to be sure that the access method to use the information is dependable and that the information is available when it is supposed to be available. In addition, the access method must be convenient in comparison to access methods for other data, and finally, the data must be easy to manipulate (Strong, Lee and Wang, 1997).

**Transparency.** Transparency refers to the ease with which information that is passed from one task in a process to another can be understood. Goodhue (1995, p. 1841) provides a clear distinction between information that is transparent and that which is not:

> *Meaning: On the reports or systems I deal with, the exact meaning of data elements is either obvious or easy to find out.*
>
> *Confusion: There are so many different systems or files, each with slightly different data, that it is hard to understand which one to use in a given situation—the data is stored in so many forms, it is hard to know how to use it effectively.*

Lee, Strong, Kahn, and Wang's (2002) use of the terms understandability, consistency and completeness all refer to our notion of transparency. Of course, the extreme of transparency is standardization. For example, UPC codes are perfectly transparent. Everyone who uses them knows what they mean and how to interpret them.

**Timeliness.** Timeliness refers to the currency of the information passed from one task to another.

**Granularity.** As described above, granularity refers to level of detail. Information passed from one task in a process to another must balance conciseness and completeness. In a completely



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integrated process there is enough information for the people to perform each activity without overloading them with excessive detail.

To test whether these four attributes are both complete and parsimonious for the information aspect of processes, we compared them to the fifteen dimensions of information quality developed by Lee *et al.* (2002). Their list is the amalgamation of academic and practitioner views of information quality. Table 3 provides our categorization.

| Information Quality Dimension | Process Integration Attribute |
|---|---|
| Accessibility | Accessibility |
| Appropriate amount | Granularity |
| Believability | n/a |
| Completeness | Granularity |
| Concise representation | Granularity |
| Consistent representation | Transparency |
| Ease of operation | Accessibility |
| Free-of-error | n/a |
| Interpretability | Transparency |
| Objectivity | n/a |
| Relevancy | Granularity |
| Reputation | n/a |
| Security | n/a |
| Timeliness | Timeliness |
| Understandability | Transparency |

**Table 3 – Comparison of Information Quality Dimensions and Process Integration Attributes**

The five dimensions that our properties do not cover refer to the correctness of the data and to its security. It seems to us that correctness is such a basic attribute of information that it need not form part of a measure of integration. Security concerns may hamper the integration of a process, but are not a measure of its integration. For example, if privacy concerns preclude the transfer of data from one task to another, the receiving task may find that the information it is provided is not sufficiently granular. This supports the complete and parsimonious character of the four attributes of information.

## Process Integration: An Example

To test the practicality of the process integration attributes, we applied them to a process involving the exchange of control documents between manufacturers and their numerous sub-



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contractors in the aeronautical industry. This process was selected from a public source for its short description and illustrative power. It was not documented for this research.

*For every shipment, the supplier must complete a mandatory inspection that consists in choosing randomly an item in the shipment and inspect it. This leads to the writing of a certificate of conformity, also called a certificate of compliance. A copy of this certificate is kept in the supplier's documentary vault while another copy is joined to the shipment. If the item is found to be non-compliant with the manufacturer's requirements, a supplier report of non-conformity (RNC) is sent to the manufacturer describing the defect and asking for a study of the non-conformity. If the manufacturer accepts the non-conformity, he sends back the RNC mentioning that the article is accepted "as is". Otherwise, the RNC is sent back mentioning that the article is rejected. Sometimes, a certificate of acceptance or a certificate of rejection can replace the RNC. Once again, a copy of both of these documents is kept in the vaults of both the supplier and the manufacturer.*

*When the shipment arrives at the manufacturer, quality control documents are inspected. If the supplier has a sufficiently good rating for the manufacturer, inspection at reception can be skipped. Otherwise, another inspection is made and, if it is successful, the received items are placed in the inventory. If the inspection finds a defect, all the received part are immediately placed in quarantine and the non-conformity is studied. A RNC is filled and if the item can be accepted "as is", it is placed in the inventory. The refusal of the item is not included in the boundaries of this process because it involves another complex process of repairing; reworking or modifying the item.*[1]

To see if the fundamental properties are applicable, a brief evaluation of each is performed. The value of integration is not computed since there is no indication of the value added during the process. However, this information should be available to the process owner.

**Accessibility**: In this process, accessibility is partially lacking. For example, when the manufacturer asks for a study of the non-conformity, it lacks access to the details enabling the automation of the decision. Since the documents are on paper and are delivered along with the parts, no treatment of information can take place before the parts arrive. A way of making the information accessible (and thereby increasing integration) would be to ask the client to do the inspection at the supplier's site. In this way, the information about non-conformity and the information about the acceptance (or rejection) would be made immediately available. It is important to note that it might not be cost effective to achieve this higher level of integration.

**Transparency**: This process is highly standardized. All the information to be collected and saved is regulated because strict norms are imposed on aerospace companies for security reasons.

[1] Illustration of the process taken from: Dussart, A., Aubert, B. A. and Patry, M., An Evaluation of Inter-Organizational Workflow Modelling Formalisms, Cahier du GReSI , 02-06, HEC Montreal, , 2002, 38 p.



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Clients and suppliers are ISO certified. This high level of standardization ensures transparency. No translation nor transformation of the information is required in this case.

**Timeliness:** Timeliness is not perfect. For the activity "deciding if parts go into the inventory", having the updated information before the parts actually arrive would enable advanced treatment. This would enable the client to direct the parts directly to the appropriate place (the inspection zone or the inventory) depending on the manufacturer rating.

**Granularity**: The information appears to be at the level of the item description, which would suggest that the level of granularity is appropriate. Adjustments between two different levels of granularity may be required when the item is rejected since the information required for repairing or reworking the item is more detailed than the simple description of the non conformity problem. However, it is outside the process considered.

For each property, it would be possible to evaluate the cost of increasing the level of the property. This would increase the level of integration. As mentioned along the discussion on accessibility, the managers would have to evaluate if this increased efficiency, acquired through higher integration, would be profitable. The breakdown of integration into these four fundamental properties enable very focus analysis of the process and specific changes can be suggested to improve it.

## Discussion

Our definition of integration encompasses the four fundamental properties of integration discussed (often indirectly) in the literature. Because it incorporates cost, our definition provides a balanced way for organizations to assess the potential of technology to integrate processes. We do not propose that total or perfect integration is the ideal. Total integration precludes distinctiveness and creativity. Perfection along one of the attributes is also less than ideal. If you conceive of a system in which a single entity is all knowing and undertakes all the tasks in a process, timeliness would be compromised. If you conceive of a massively parallel process taking the least amount of time possible, accessibility would be extremely costly.

Another key consequence is flexibility. It is not clear if very strong integration can be achieved without compromising flexibility. For example, in an inter-organization process, would complete transparency or perfect/constant access impede a change of suppliers? Integrating processes across organizations is a difficult task. Doing so with an infinite number of suppliers is probably utopia.

An additional issue is the boundary of a given process. When measuring the level of integration of a process, one has to define its limits. However, many processes are linked because the information is exchanged in more than one direction. or the process is a sub-processes of a larger process. Activities within a process may be producing information used by another process in the organization. By integrating one process, and minimizing its cost, the organization may be hampering optimization efforts in another process. It is essential to look at interfaces between processes. This means that integration can be assessed for a given process, or measured for a higher level supra-process.



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While conceptually it is relatively easy to imagine "dissolving frontiers" between organizations, integrating processes across organizations will continue to provide challenges. Processes involving suppliers, clients, and sub-contractors will be inherently more complex. Integrating them will imply assessing the four properties in different organizations. For example, transparency will mean high levels of inter-organizational communication. Meanings will have to be shared. Current initiatives described by Hammer (2001) in the health and insurance industries for agreeing on common vocabulary and document definitions may be a first step toward such transparency.

Finally, the measure of process integration will have to be flexible enough to assess processes inside one organization as well as processes crossing organizational boundaries. By formally measuring the four properties across organizations, participants in a joint process will be able to target their efforts toward integration much more precisely.

## Future Directions

This paper has provided a conceptual frame for studying process integration. Now it is necessary to test the four attributes in a variety of settings in both manufacturing and service industries and for both core processes and support processes. By comparing the detailed evaluations of the four properties with managers' perceived level of integration, we will be able to assess the face validity of the measure. Case studies will also help test the extent to which these four properties really encompass the integration concept.

In addition to qualitative assessment of the attributes, it is important to develop a tool that measures the attributes and calculates the cost of providing them. Such a measure will have to be generic enough to cover different types of processes, and numerous forms of activities within one process. It must cumulate the series of marginal costs for each property in the process. Such a tool would enable organizations to compare different technological and process strategies with formal and reliable data.

Clearly, work on process integration is just beginning.



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