Digital Information Asset Evaluation: A Case Study in Manufacturing

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Acknowledgments

We thank Poliform SPA for the availability to host Marco Castelli's thesis internship that provided the basis for the case study presented in this article. In particular, Marco Castelli expresses gratitude to Ing. Andrea Colombo for the support and precious comments during the internship and the data collection.

Abstract

The article discusses a model for information value assessment based on the concepts of information capacity, information utility, and information management costs. Notwithstanding that both state-of-the-art researchers and practitioners consider information as a fundamental asset, there is actually no consensus on what are the determinants of information value, particularly with regard to the increasing number of data available through digitalized processes and services. The model is applied to a case study comparing two information management projects for the improvement of core business processes of a global manufacturing company based in Italy.

Keywords: Information Management; Information Capacity; Information Utility; Information Value; Information Quality; Digital Information Asset.

Introduction

The current competitive, political, and social scenarios point out the relevance of information for policy making, businesses, and everyday interactions at both the global and the local level (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013a; Kallinikos, 2006; The Economist, 2010). Nevertheless, scholars in the field of information systems (IS) have mainly focused their attention on IS business value in terms of return on investments in information technology (IT) (Dedrick, Gurbaxani, & Kraemer, 2003; Glazer, 1993a; Kohli & Grover, 2008; Melville, Kraemer, & Gurbaxani, 2004a) rather than considering information on its own as an economic asset for an organization (Boisot, 1998; Moody & Walsh, 1999).

Taking these issues into account, in this article we discuss the application of a model for the evaluation of the information asset of an organization and its impact on projects or initiatives aiming to a better use and exploitation of this asset for the improvement of business processes. The model has been early proposed and discussed by Viscusi & Batini (2014). The main hypothesis underlying the model is that information value has to be interpreted in terms of determinants such as *information capacity*, *information utility*, and the *costs* related to the design and maintenance of technologies adopted in information management initiatives. Since these projects often require the integration of different internal and external sources for the extraction of useful knowledge, the model supports the estimation of the value of the adoption of technologies, such as data integration technologies, barcode, and Radio Frequency Identification (RFID). To test the model, the paper discusses a case study where it has been used to

This is the accepted version of Batini C., Castelli m:, Viscusi G., Cappiello C., Francalanci C., "Digital Information Asset Evaluation: A Case Study in Manufacturing", Data Base (2018), 49:3, 19-33.
The final publication is available at: http://dx.doi.org/10.1145%2F3242734.3242737

compare two information management projects for the improvement of core business processes of Poliform SpA, a global manufacturing company based in Italy.

The article is structured as follows. First, we provide a discussion of the main literature background and the motivations for the proposed model, subsequently considered. Then, we detail the case study and apply the model. A discussion of the results with current contributions and limitations follows and, finally, a brief summary of the main issues of the current research and an outlook on future work concludes the paper.

Background and Motivations

Notwithstanding the inclusion of creating information value and an information mindset in the IS business value agenda (Kohli & Grover, 2008) and its strategic relevance in a digitalized society and business (Yoo, 2013; Yoo, Henfridsson, & Lyytinen, 2010), the assessment of the value of information as an asset on its own has received little attention in both research and practice. As pointed out in Moody & Walsh (1999), “while hardware and (rarely) software assets are capitalised, the valuation of information has been largely ignored, even though this is a much more valuable asset from a business viewpoint” (p. 2).

Furthermore, the academic interest in information value has evolved in terms of focus for different disciplines. Due to the radical change at the societal and enterprise levels, related to the diffusion of the Internet and the (debated) commoditization of information and communication technologies (Carr, 2003; Stewart et al., 2003), we consider in our analysis mainly the last twenty years as period of interest (see Table 1 for a selection of the main concepts and approaches).

Early studies in information value have been carried out in the area of information economics. Economists have investigated information value mainly from a mathematical perspective by focusing in particular on classical problems of asymmetric information and game theory (for example, see Gilboa and Lehrer (1991), who investigate the close relationship between information functions and cooperative game theory (with the states of the world in the role of players)).

The growing relevance and adoption of enterprise systems and the consequent role of the IT in business shifted the attention towards the value of information associated with companies’ value chains. In the information systems area, in particular, Glazer (1993b) considers the information value associated to a given transaction as the sum of (1) *profits* that result from *increased revenues* and *reduced costs* from *future transactions*; and (2) *profits* from the *sale of the information* itself.

Besides these issues, the adoption of information and communication technologies and in particular of enterprise systems (Markus, Tanis, & van Fenema, 2000) has led scholars in information systems and knowledge management fields to investigate frameworks for the management of information at the organizational level (Moody & Walsh, 1999; Simpson & Prusak, 1995; Skyrme, 1994).

Table 1. Concepts and Main Findings in Information Value Studies (A Selection)

Citations	Area	Technology	Concepts	Findings
Ahituv (1980)	Information Systems	Decision Support Systems	Information Value	The paper provides a first set of characteristics of information value: *timeliness*, *contents*, *format*, and *cost*. Furthermore, the paper investigates the identification of specific variables, their measurement and tradeoffs, and how to formulate a joint value function.
Ahituv (1989)	Information Systems	Decision Support Systems, Accounting Information Systems	Information value	The paper provides a classification of approaches to information evaluation, with regard to (1) *normative value*, (2) *realistic value*, and (3) *perceived value*.
Gilboa & Lehrer (1991)	Economy	Not considered	Information value	The close relationship between information functions and cooperative game theory (with the states of the world playing the role of players).
Glazer (1993)	Information systems	Not considered	Information value Information value chain	The value of information associated with a given transaction is the sum of (1) *profits* that result from *increased revenues* and *reduced costs* from *future transactions*, and (2) *profits* from the *sale of the information* itself.

Continued

Table 2 *Continued*. Concepts and Main Findings in Information Value Studies (A Selection)

Citations	Area	Technology	Concepts	Findings
Skyrme (1994)	Information systems	Not considered	Information value and quality	The paper defines ten aspects, adding value to generic information: *timeliness*, *accessibility*, *usability*, *utility*, *quality*, *customization*, *medium*, *repackaging*, *flexibility*, *reusability*.
Simpson & Prusak (1995)	Knowledge management	Not considered	Information value Value added information	The paper discusses five universal elements of value in information: *truth*, *guidance*, *scarcity*, *accessibility*, and *weight*. These elements are context dependent.
Boisot (1995, 1998)	Economy, Knowledge management	Not considered	Information value	Information goods are indeterminate with respect to value. As a paradox, producing useful structured information reduces its value because it enhances *diffusibility*.
Moody et al. (1999)	Information systems	Not considered	Information value	The paper discusses seven laws of information: 1) information is infinitely *sharable*; 2) the value of information increases with *use*; 3) information is *perishable*; 4) the value of information increases with *accuracy*; 5) the value of information increases when combined with other information (*integration*); 6) more information is not necessarily better information (*pertinence*); 7) information is *not depletable*.
Melville et al. (2004)	Information systems	Interorganiza-tional Information Systems (IOS), Enterprise systems	IT business value	IT business value extent and dimensions are dependent upon internal and external factors: *complementary organizational resources* of the firm, *partners*, *competitive and macro environment*.
Sajko et al. (2006)	Knowledge management	Not considered	Information assessment Information value	The process of assessment should consider the *value for a business*, *costs* to produce, buy, reconstruct, change or compensate for information, *time*, and the importance (*intensity*) of each dimensions of information value.
da Cruz & dos Santos (2016)	Information Science	Not considered	Information value	The process evaluation includes seven steps supporting researchers dealing with the *search* and *use* of scientific information.
Raban & Mazor (2013)	Information science	Information shop	Information value	The value of information is not known before consumption. The *perceived value* of information changes during the actual usage of information with a consequent role of *post-consumption experience* on information value.
Bauer, Korunovska, & Spiekermann (2012)	Information Systems	Social Network (Facebook)	Personal Information Valuation	Depth of *usage* and *patterns behaviors* may have an impact on the user *willingness to pay* (mixed results from this exploratory study).
Spiekermann & Korunovska (2017)	Information Systems	Social Network (Facebook)	Personal Data Valuation	The valuation of personal data includes (1) short-term (*market awareness* and *data use control*) and (2) long-term (*engagement*, *psychological ownership*, *market morality*, and *technical market design*) value drivers.

Here it is worth noting a first association of information value to *information quality* dimensions, such as accuracy, accessibility, completeness, currency, reliability, timeliness, and usability. Indeed, information is increasingly being recognized as a key economic resource and the basis for achieving competitive advantage (Moody & Walsh, 1999). However, the information value decreases if information contains errors, inconsistencies, or out-of-date values. Therefore, high information quality levels can be considered an initial guarantee for the potential usefulness of the information objects. Data and information quality literature provides a thorough classification of quality dimensions. Analyzing the most relevant contributions, it is possible to define a common basic set of quality dimensions including *accuracy*, *completeness*, *currency*, and *consistency* (Batini & Scannapieco, 2016; Lee, Pipino, Funk, & Wang, 2009):

- *Accuracy* is defined as the closeness between a value *v* and a value *v′*, considered as the correct representation of the real-life phenomenon that *v* aims to represent. For example, "Jon" is an inaccurate representation of the name "John."
- *Completeness* is the extent to which data are of sufficient breadth, depth, and scope for the task at hand. A null value in a database is an example of incomplete data.
- *Currency* concerns how promptly data are updated. A change of address of a business that is updated after one month in a business registry is an example of out-of-date data.
- *Consistency* is the absence of any violation of business rules in a database. In the relational model of data, any violation of referential integrity is an example of inconsistency.

The correlation between the information value and accuracy has been analyzed by Moody and Walsh (1999): the higher the accuracy of information, the higher its usefulness and value. Low accuracy levels can be very costly since they can cause both operational errors and incorrect decision-making. Moody and Walsh (1999) also point out that information value also depends on the age of the information. Information is often very dynamic and its validity decreases over time. With the advent of the web, new quality dimensions have been investigated for characterizing the quality of an information source, e.g., *believability* considers whether a certain source provides data that can be regarded as true, real, and credible, and *reputation* or *trustworthiness* considers how trustable is the information source. Furthermore, the growing of the investments in information technology (IT) poses the question of the IT business value, mainly in the information systems field. In an accurate survey, Melville et al. (2004b) have shown how IT business value degree and dimensions are dependent upon internal and external factors (complementary organizational resources of the firm, partners, and competitive and macro environment). This perspective on IT business value is particularly relevant for the studies that consider the overall information life cycle management as a key source of information value; among them, the ones that are focused on risk analysis dimensions are worth mentioning (e.g., see Tallon et al., 2007).

Table 1 shows that economy and knowledge-oriented perspectives usually pay little attention to the type of technology mediating the information provision and its use/consumption, whereas in management of information systems approaches, information value can be hardly disentangled from the technological and organizational resources and environment (as we have seen above discussing the impact of enterprise systems on the study of information value). The challenge of providing support to the evaluation of available information has been investigated in the area of information science by Cruz et al. (2016) who propose a seven-step model supporting researchers dealing with the search and use of scientific information. Considering information valuation in digital marketplaces, Raban and Mazor (2013) investigate by means of an experiment the pre- and post-purchase perceived value of information, thus questioning the user's willingness to purchase information as well as the subjective and experience values associated with information. Furthermore, the user side of information value, especially for what concerns the willingness to pay, has received special attention with regard to social networks as shown, for example, by the exploratory study carried out by Bauer et al. (2012) on Facebook users and the contribution by Spiekermann and Korunovska (2017) who identify in their value theory 1) short-term (market awareness and data use control) and 2) long-term (engagement, psychological ownership, market morality, and technical market design) value drivers for personal data valuation. As a consequence of the above discussion, a unified interpretative framework for information value has to consider a set of characteristics which can provide dimensions suitable to evaluate information facets at a different level of abstraction.

Taking the above issues into account, we now consider one of the earlier comprehensive surveys on assessing information value carried out by Ahituv (1989), outlining that "the value of information cannot be separated from the value of an information system for exploiting the information" (p. 315), thus "the quantity of information is not likely to serve as an argument in the information value function" (p. 318), which is "a multiple attribute function. Its arguments are characteristics of an information system; its results (i.e. dependent variables) relate to benefits" (p. 318). It is worth noting that Ahituv (1989) provides a classification of the available approaches to information evaluation, which we consider as a starting point for current research on information value and our interpretive framework.

Table 3. Information Value: Approaches and Organizational Level of Application, Elaboration from Ahituv (1989)

Approach	Type of evaluation	Organizational level
Normative value	Analysis, modelling (ex-ante)	Operations
Realistic value	Real-life cases, experiments (ex-post)	Operations Control, Management Control
Perceived value	Subjective (ex-ante)	Management Control, Strategic planning

As shown in Table 2 the approaches can refer to 1) *normative value* when they are based on ex-ante analyses of the context and theoretical assumptions on the decision maker behavior; or else to 2) *realistic value* when they are concerned with ex-post measurements of outcomes in both real-life cases and experiments; or finally to 3) *perceived value* when they provide a subjective evaluation based on the perception of the users or of the decision makers.

Also, Table 2 provides for each approach the organizational level of potential application. Besides the three approaches, Ahituv (1980) provides a first set of characteristics of information value: *timeliness* (dimensions: *currency, response time,* and *frequency*), *contents* (dimensions: *accuracy, relevance, level of aggregation*, and *exhaustiveness*), *format* (dimensions: *media, color, structure, presentation*, etc.), and *cost*.

As said, a further characterization of information value has been provided by Moody and Walsh (1999), through the identification of seven laws (see Table 3), governing its behavior. Table 3 shows these laws and, for each of them, a tentative correspondence with information value characteristics identified by Ahituv (1980) as well as a set of information value determinants identified in the literature review discussed early in this Section (see also Table 1).

The determinants in Table 3 are *information diffusion* (Boisot, MacMillan, & Han, 2007), seen as the degree of population that can be reached or actually shares information for a given format, *information quality* that concerns content accuracy, relevance, and *timeliness* (Batini & Scannapieco, 2006), *information structure* as the information *format* (structured, semi structured, and unstructured) as well as the degree of integration of the current information asset (Batini, Cappiello, Francalanci, Maurino, & Viscusi, 2011), that is, the information content. Furthermore, Viscusi and Batini (2014) attempt to make explicit the relation between information value and the determinants in Table 2, introducing *information capacity* as a determinant of *utility*. Yet, as for a definition of information capacity in this article we adopt the one proposed by Viscusi and Batini (2014), which state that information capacity refers to "the current stock of understandings informed by a given installed base", representing "the potential of a digital information asset that can be defined and evaluated independently from the usage." Thus, *information capacity*, on the one hand, includes the *utility* attributes, identified by Ahituv (1980, p.64) for the case of a reporting system; on the other hand, information capacity includes them in a wider classification suitable to cover other systems. Among the laws shown in Table 3, it is worth noting that Law 6 is expressed in Moody and Walsh (1999) by a curve made of a growing part, where more information leads to more value, and a decreasing part, where more information leads to decreasing value and information overload. Finally, in line with Ahituv (1980), we argue that a joint utility function for information value includes information capacity attributes and *costs* (see Figure 1). On the basis of these premises, in the next Section we are going to discuss first the model used in the case study, subsequently presented in this article.

Table 4. Information Value Laws, Characteristics, and Determinants

Information Value Laws (L)	Characteristics	Determinants
L1. Information is (infinitely) sharable	Format	Information diffusion
L2. The value of information increases with use	Contents	Information quality
L3. Information is perishable	Timeliness	Information quality
L4. The value of information increases with accuracy	Contents	Information quality
L5. The value of information increases when combined with other information	Format	Information structure (integration)
L6. More is not necessarily better	Cost	Information utility
L7. Information is not depletable	Timeliness	Information quality

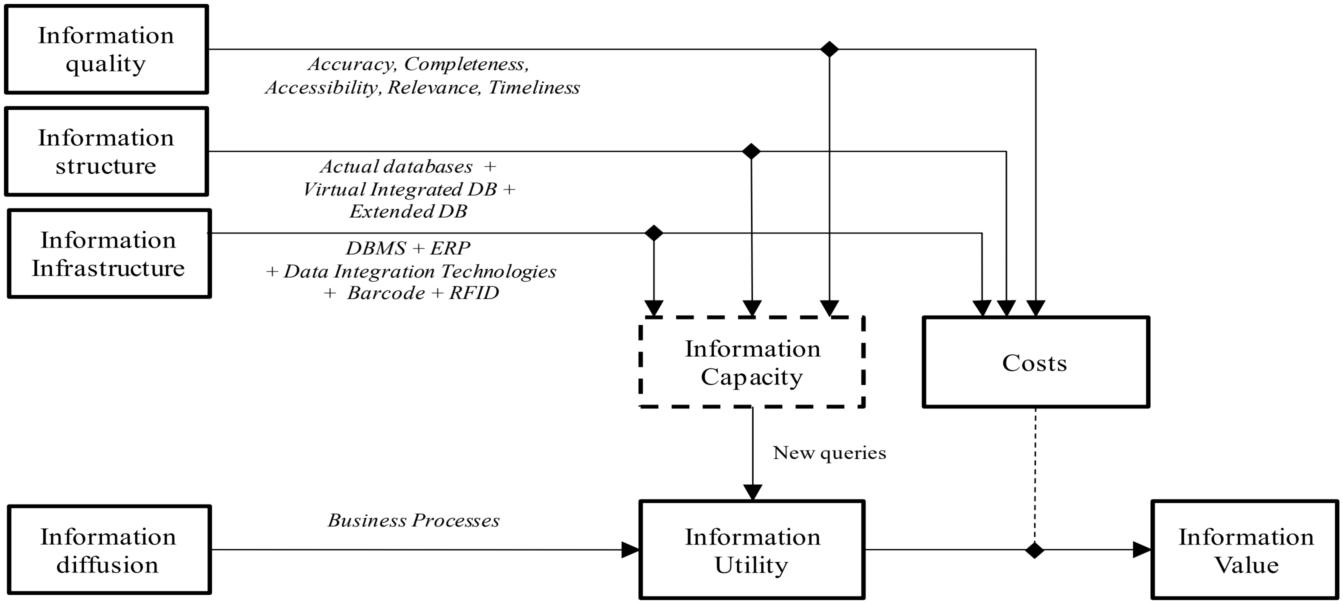

Figure 1. A Unified Model of Information Capacity and Value, Extending Viscusi and Batini (2014)

Information Capacity, Utility, and Value: A Unified Model

In this section we discuss a model for the assessment of information capacity and value in the context of information management projects, usually characterized by the need to integrate and transform raw data into a consistent and coherent set of information valuable for the organization.

The model is based on the one discussed by Viscusi and Batini (2014), although representing an alternative instantiation of it due to the different perspective adopted with regard to information utility as well as the role and impact of the costs. Figure 1 shows the proposed unified model where information value is related to the multiple factors considered in Table 2, namely:

1. *Information quality*, defined as the ability to measure the suitability of data along the processes in which they are involved;
2. *Information structure*, defined as the degree of integration of the data structure considered, in terms of the set of the database schemas considered and the current application load;
3. *Information infrastructure*, defined in terms of the data integration technologies adopted;
4. *Information diffusion*, defined as information flow and exchanges are enabled by the business processes that use the different queries.

The main hypothesis underlying the proposed model is that information value has to be interpreted in terms of *information utility*, which is characterized by the overall *information capacity* of the considered information system.

As for the model instantiation, we assume that an organization *O* is characterized by 1) the *business process structure* that provides details on the information diffusion, 2) a *data architecture* modeling the information structure, and 3) a set of *users* at the different organizational levels. The *business process structure* of the organization *O* is a set of business processes $BP = [bp_1, bp_2, \ldots, bp_m]$. The *data architecture* is the set of databases $DA = [db_1, db_2, \ldots db_n]$ managed in the organization. Let us assume that each database is managed by a distinct organizational unit in *O*. Processes in *BP* make use of a set of queries $Q = [q_{11}, q_{12}, \ldots, q_{1k1}, \ldots, q_{n1} \ldots q_{nkn}]$, where each query is applied to a single database, and the application load associated to each database db_i is made of queries $q_{i1}, q_{i2}, \ldots q_{iki}$. We assume that no middleware is available to query different databases at the same time. This is the typical "silos" structure of databases of an organization *O* made up of several units characterized by high autonomy. Moreover, the set of users *U* that access the system for decision or operational purposes is divided into different categories $U = [u_1, u_2, \ldots, u_p]$ according to their organizational level. Then, we assume that the data architecture (*DA*) of the organization can be enriched and extended through the adoption of two different technologies:

- *A virtual data integration (DI) technology*, which allows the organization to manage the *n* databases as a single virtual database, accessible through a global schema resulting from the integration of local source schemas. The adoption of a DI technology enables the extension of the data architecture to a new one defined as DA_{DI} = [*integrated_db (db*$_1$*, db*$_2$*, … db*$_n$*), db*$_1$*, db*$_2$*, … db*$_n$].

- *Barcode (BC)* or, alternatively, *RFID* technologies able to extend the previous architecture DA_{DI} into a new architecture DA_{DI+BC} or $DA_{DI+RFID}$ = [*extended_integrated_db (db*$_1$*, db*$_2$*, … db*$_n$*), db*$_1$*, db*$_2$*, … db*$_n$] where the extended database is obtained from the integrated database including new data gathered by barcodes and RFID technologies.

The adoption of DI, barcode, and RFID technologies allows users to submit new queries on the data architecture, providing users with new valuable information.

In fact, in a DI architecture, the number of queries related to a source s_i can be extended by considering the schemas that have common nodes with s_i. In particular, we define as *NQ* the set of new queries that can be expressed in the DI architecture and that could not be expressed on local schemas. In Figure 2 three schemas are represented: larger white (empty) nodes correspond to clusters of borderline nodes and examples of new queries are represented with dotted lines. Such new queries result from an extension of the queries that can be defined locally on one source (AL_i – Application Load of the i-th source) and that are represented with a solid line.

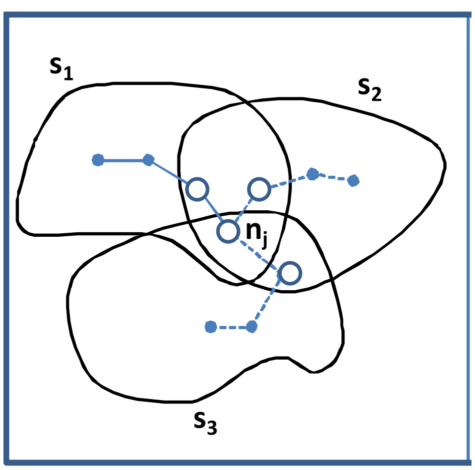

Figure 2. Example for the Definition of the Set of New Queries NQ

Considering such a scenario, the *information capacity* of a data architecture DA_{DI} ($IC(DA_{DI})$ in the following) is expressed by the formula:

$$IC(DA_{DI}) = \frac{|NQ| + \sum_i |AL_i|}{\sum_i |AL_i|}$$

Note that the information capacity can be affected by data quality issues. In fact, the number of retrieved instances might be decreased by errors and missing data able to hamper a join operation. However, considering the new queries that are enabled by the integration technology, we can move to the concept of information utility. Let us assume that each triple [u_i, bp_j, q_{lk}] related to a user u_i of a process bp_j performing a query q_{lk} on a database db_l, is characterized by a *query_to_process utility(*u_i*, bp*$_j$*, q*$_{lk}$*)*, corresponding to the value that the query q_{lk} result conveys to the process bp_j performed by the user u_i. As an example, consider the scenario in which a retail firm can integrate its own data with territorial marketing information provided online; the utility of the data, and in particular the utility of the new queries enabled by the integration, can be measured as the potential revenues for a company resulting from the selection of the optimal location to start its own business. It is worth noting that the *query_to_process utility* may be evaluated according to the three information value approaches shown in Table 2. The aggregation of the utility for all the new queries generated by the evolution of the information infrastructure provides the overall information utility:

$$Utility(DA_{ICTTechnologies})$$

Yet, in order to move from utility to information value, we have to evaluate the costs of technologies (see Figure 1) that we model as a) the costs related to the design of the technological solution, and b) the run time costs of query execution, evaluated for a three-year period. The *information value* gathered by an organization *O* adopting a generic set of information and communication technologies (ICTs) to extend its information infrastructure is finally quantified by considering the following formula:

$$Value(DA_{ICT\ Technologies}) = \frac{Utility(DA_{ICT\ Technologies}) - Ctot_{ICT\ Technologies}}{Ctot_{ICT\ Technologies}}$$

In order to verify the applicability and effectiveness of the information value model described, in the following sections we report a case study carried out at Poliform SpA, an Italian manufacturing company.

Case Study

Poliform is a leading player in the international furniture market. The company has always based its strategy on the continuous improvement of product quality by aligning its products and production chains with solutions that are considered outstanding in contemporary lifestyle trends. Poliform was established in 1970, as an evolution of a small artisan's shop dating back to 1942. The Poliform brand is today synonymous with luxury, life style, and excellence in quality. Poliform's numerous lines include systems and furnishings for the whole house: bookcases, complements, wardrobes, and beds. Poliform has been heavily involved in the realization of the London's West End Quay, the AOL Time Warner Center in New York, the Presidential Chambers of the Clinton Library in Little Rock, and the Palmolive Building in Chicago. Over the years, Poliform has developed an information system automating most of its business processes. The information system considered in this article (with fieldwork carried out by the one of the authors in 2011) was implemented in the second half of the 1990s and constantly updated to allow continuous improvement of business processes' efficiency. The design and evolution of the information system paid great attention to the support processes of the supply chain. Poliform has based its supply chain on a *pull-based* model. In this model, also known as *build-to-order*, customer orders trigger the events in the supply chain. The supply chain involves a network of organizations and business processes designed to supply raw materials and their transformation into semi-finished and finished products, which are then distributed to customers.

The main actor in the supply chain is the manufacturer of the product, which is connected to direct suppliers, stores, and customers. Production planning, done on a weekly basis, is automatically triggered by the shipping plan, developed from the office in charge of shipping. Employees in charge of production management eventually modify the production plan on the basis of the availability of raw materials, as in the case of delays in deliveries, after coordination with the logistics. Load planning is defined taking into account shipments from marketing, operations, procurement, and sales. A coordination between the shipping department, the production manager, and the purchasing department is needed to check that production proceeds on time and the management of maintenance or replacement of machinery, which could actually slow down production is often required.

Poliform's software has achieved over the years a high integration of the main operational processes, using the *Baan Enterprise Resource Planner (ERP)* software and related database to manage and schedule the whole production chain, from design and production to sales and distribution. Besides the Baan database, two other databases are involved in the process, *K-Files* and *Dynamics AX*, both strongly connected with Baan. K-Files maintains an electronic copy of all documents associated with the sale. We do not consider further the K-Files database in the following. Dynamics AX is used for the management and control in real time of all activities of Poliform stores.

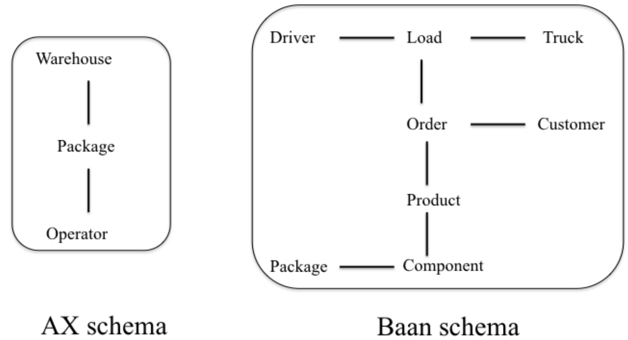

Figure 3. The AX and Baan Source Schema

Further, Dynamics AX performs inventory management, quality assurance, and shipment management. Barcodes used for the identification of handwork are detected with mobile terminals connected through radio frequency and laser scanner. The joint usage of the Baan ERP database and the warehouse Dynamics AX database makes possible the management of order entry, invoicing, and tracking of goods in the warehouse. We show in Figure 3 the logical schemas of the two Baan and Dynamics AX databases using a graphical formalism adapted from the Entity Relationship graphical model (Batini, Ceri, & Navathe, 1991); names represent entities, namely classes of things relevant in the database (e.g., order with order number "#2345," user with ID "#TR18"); unlabeled lines represent relationships among entities that correspond to classes of facts relating things (order "#2345" is issued by user "#TR18"). Since the reading of the barcode is used only for the storage of finished products in stock and loading of packages on the trucks, huge inefficiencies have been experienced due to lack of information in the monitoring of order processing; in fact, operations control managers involved in the task communicate by telephone with workers or go to the factory to control that products are completed by the due date.

The relevant people from Poliform involved in the case study were the employee responsible for strategy and governance, a process manager, IT executives, and operations managers. Besides IT executives, involved in *support processes* according to the Porter value chain (Porter, 1985), the other participants are involved in *primary processes* with different roles and approaches to information value, according to the classification provided in Table 3 and as shown in Table 4, where we adapt from Ahituv (1989) the association among organizational roles, type of information systems they are involved in, and types of information value approach most adequate to each case.

Table 5. Poliform Organizational Roles, Types of ISs, and Related Information Value Approaches

Organizational role	Type of Information System	Information value approaches: Existing Information System	Information value approaches: Proposed Information System
Operations	Transaction Processing System	Realistic	Normative
Process manager	Structured Decision System	Realistic/Perceived	Perceived
Responsible for strategy and governance	Decision Support System	Perceived	Perceived

Application of the Model to the Case Study

The above-discussed model has been applied with the active participation of the Poliform managers to evaluate the return on investment coming from the adoption of data integration, barcode, and RFID technologies. The initial data architecture is DA = [AX, BAAN]. We have considered the following two actions related to the adoption of corresponding enabling ICT technologies:

- *Action 1 – improve the utilization of the current digital information asset* (*Moody's Law 5*). This is achieved through the adoption of a virtual data integration (DI) technology for the AX and BAAN databases. The resulting data architecture is DA_{DI} = [*Int(AX, BAAN), AX, BAAN*], where *Int(AX, BAAN)* is the virtual integrated database, which can be used by managers and workers to extract more information from the actual data.
- *Action 2 – extend the digital information asset with new data* (*Moody's Law 6*). This is realized by extending the DA_{DI} architecture with new information on the state of progress of the order along the production process; it is worth reminding that barcodes are currently used in the system only for getting the inbound and outbound time of packages in the production chain. New information can be acquired using barcodes (BC) and RFID, resulting in a new database *Ext[Int(AX, BAAN)]* that extends with new entities and relationship the *Int(AX,BAAN)* database.

Consequently, the new data architecture is:

DA_{DI+BC} or $DA_{DI+RFID}$ = [*Ext[Int(AX,BAAN)],AX,BAAN*]

The four data architectures (DA, DA_{DI}, DA_{DI+BC}, and $DA_{DI+RFID}$) will be now compared using the proposed model of information value, to choose the solution that ensures the best return on investment. To this end, considering the two different actions we detail a method made up of a series of steps, adopting the approach to information value reported in Table 4.

Action 1: Improve the Use of the Current Digital Information Asset

In this action the adoption of the DI technology extends the data architecture DA into the architecture DA_{DI}.

Step 1. Design of the Enriched Conceptual Schema

[*Organizational role*: IT executive; *Information value approach*: none]

The output of Step 1 is made up of the integrated schema Int(AX, BAAN), and the two source schemas AX and BAAN. Notice that some of the attributes of Package appear in AX while others are in BAAN.

Step 2. Selection of Business Processes

[*Organizational roles*: responsible for strategy and governance and process manager; *Information value* approach: perceived value]

In this step, we focus on the main processes that are positively influenced by the availability of the integrated schema. Top managers of Poliform analyzed the Porter's value chain (Porter, 1985) of processes, and decided to focus on the *outbound logistics process*.

Step 3. Query Ranking and Selection

[*Organizational role*: operations; *Information value approach*: perceived value]

Once the relevant processes were selected, the schema output of Step 1 was shown to operations managers. The result was the identification of queries on the integrated schema DA_{DI} not expressible in the previous architecture DA. Also, operations were asked to provide scores on a [0,1] scale on the information value of queries, based on their experience. The identified queries and scores are shown in Table 5. The queries with a score greater or equal to 0.5 (Q1 and Q2) were selected for the subsequent step.

Step 4. Evaluation of Utility

[*Organizational role*: operations; *Information value approaches*: normative and realistic]

At this step three different aspects of the information utility are worth considering: its market value, the monetary and non-monetary benefits, and the usefulness in decision-making (Boisot, 1998; Remenyi, Money, Sherwood-Smith, & Zahir, 2000). Information concerning the management of shipments by Poliform does not have a market value, and it is difficult to estimate its utility in decision making.

Table 6. Queries Ranked According to the Perception of Information Utility by Operations

Data Integration Architecture		
#	*Query*	*Query to process utility*
Q1	*Which is the progress of a package whose order is scheduled for a given load?*	*0.9*
Q2	*How much is the total volume of already completed orders that are part of a load?*	*0.8*
Q3	*Which are the packages managed by a given operator?*	*0.3*
Q4	*Which driver will manage the delivery of a given load?*	*0.3*
Q5	*Which vehicle will deliver a given load?*	*0.3*

Concerning the monetary benefits, we have adopted an estimation based on the labor-time savings from the use of more valuable information. If we assume that query Q1 is performed 60 times a day and query Q2 is performed 30 times a day, we can estimate one minute saved for sparing the manual computation of the query answer. Assuming 312 labor days in a year, the total yearly savings (S) correspond to 468 hours; assuming wages equal to 20 € for an hour, projected to three years, leads to a final savings of

$$Stot_{DI} = 28{,}080€$$

Step 5. Evaluation of Costs

[*Organizational role*: IT executives; *Information value approaches*: normative and realistic]

The IT cost evaluation considers both design time and run time costs (Batini et al., 2011). The total amount of design costs plus a three-year estimation of run time costs corresponds to

$$C_{totDI} = 9{,}420€$$

Step 6. Value of Action

[*Organizational role*: process managers; *Information value approach*: normative and realistic]

At this step it is possible to calculate the value of the action for a three-year period with the following formula:

$$Value(DA_{DI}) = \frac{Stot_{DI} - Ctot_{DI}}{Ctot_{DI}} = 1.98$$

where a positive value indicates that the initial investment will be completely absorbed and will lead to savings for the organization over the years.

Action 2: Extend the Digital Information Asset with New Data

The Poliform's assessment showed that a major issue for people who organize Poliform's shipments is to know whether the product will be ready for shipment before the agreed date or if they must postpone or cancel an order. The lack of updated information on the progress of the production of an item forces planners to contact the managers of the factory to know the stage of processing reached by the different parts of a product and if the product will be completed by the scheduled date of shipment. Due to the high number of daily orders processed, it was not possible to monitor the production of each component of the order. Consequently, the lack of some products was often discovered only during the truck-loading phase.

To this end, Poliform used a barcode system for the control of the packages, but at the time considered in this article the first check was performed only at the end of the production process because the label with the barcode was applied to the box only when the components of the furniture were packed; thus, the barcode identified the whole box and not the individual components it contained. To overcome this limitation, we proposed to acquire information on the main processing steps of each component.

Table 7. Comparison of Barcode and RFID Technologies

Characteristic	Barcode	RFID
Data capacity	< 20 characters	100 - 1000 characters
Read/write	Read only	Both
Level of automation	Data collection needs operator	Data collection unattended
Precision of reading	Errors due to manual readings	High
Cost	Negligible	5 cents a tag

The detection of the production process could be automated through barcodes or RFID. In Table 6 we shortly compare the two technologies. Yet, in what follows we consider the two technologies equivalent in gathering new information, while we differentiate the analysis when considering costs.

Step 1. Design of the Enriched Conceptual Schema

[*Organizational role*: operations; *Information value approach*: none]

The implementation of this action enables the realization of the architectures DA_{DI+BC} and $DA_{DI+RFID}$, whose schemas can be obtained by adding to the integrated schema of the DA_{DI} architecture new information on production, conveyed by BC or RFID.

Step 2. Selection of Business Processes

[*Organizational roles*: responsible for strategy and governance and process manager; *Information value* approach: perceived]

The employee responsible for strategy and governance and process managers identified *operations* and *outbound logistics* as the value chain processes more positively influenced by the new technologies.

Step 3. Query Ranking and Selection

[*Organizational role*: operations; *Information value approach*: perceived]

As for the DI architecture, the operations were asked to express and rank queries useful for operations and outbound logistics according to the value perceived. The identified queries' utility is reported in Table 7. Also in this case we selected queries whose *query_to_process utility* is greater than or equal to 0.5.

Table 8. Queries' Information Utility as Perceived by the Operations at Poliform

Barcode or RFID		
#	*Query*	*Query_to_process _utility*
Q6	*At what stage of processing are the parts of a product of the orders scheduled for a given load?*	*0.9*
Q7	*At what stage of processing are the parts of a product of the orders scheduled for a given customer?*	*0.4*

Step 4. Evaluation of Utility

[*Organizational role*: operations; *Information value approaches*: normative and realistic]

If we assume that queries Q1 and Q2 (see Table 6) are performed respectively 60 times a day and 30 times a day, estimating one minute saved for each manual computation of the query answer, and that the query Q6 is performed 30 times a day estimating five minutes saved for the manual computation, the total time savings in a year corresponds to 1,248 hours, which corresponds to 74,880 € savings in three years (assuming wages equal to 20 € for an hour). A further benefit refers to the reduction of the number of changes in the load plan: this is an activity that currently occurs with high frequency and is caused by not having updated information on the production phase of products to be shipped. The availability of up-to-date information about the production of each component would enable Poliform to plan loads much more effectively and avoid re-scheduling. The total savings in time corresponds to 416 hours, about 24,960 € savings in three years.

Thus, the total three-year savings obtained adopting barcode or RFID is

$$Stot_{DI+BC\ \text{OR}\ DI+RFID} = 99{,}840€$$

Step 5. IT Cost Evaluation

[*Organizational role*: IT executives; *Information value approaches*: normative and realistic]

Here costs differ significantly between barcode and RFID technologies, so we deal with them separately.

- *Case of barcode adoption* - Here, the cost of tags is negligible, while barcode readers cost around 100 € each. An analysis of plants led to the conclusion that at least 60 readers were needed, resulting in a total cost of equipment (including the cost of the data integration solution) of nearly 20,000 € for three years.
- *Case of RFID adoption* - Compared with the barcode solution, we have here a cost of 5 cents per tag, that, assuming average of 200 daily orders with each one consisting of about 20 packages of three items each, leads to a daily cost of 600 € and a yearly cost approximately equal to 190,000 € in addition to the cost of antennas and other software and hardware equipment.

Step 6. Value of the Action

[*Organizational role*: process managers; *Information value approach*: normative and realistic]

Using barcodes, we can calculate the total value of the solution:

$$Value(DA_{DI+BC}) = \frac{Stot_{DI+BC} - Ctot_{DI+BC}}{Ctot_{DI+BC}} = 3.99$$

while using RFID leads to a value estimated as:

$$Value(DA_{DI+RFID}) = \frac{Stot_{DI+RFID} - Ctot_{DI+RFID}}{Ctot_{DI+RFID}} = -0.82$$

Discussion of the Results

The case study discussed in previous sections aims to provide, on the one hand, a contribution for testing state-of-the-art theories and models, in particular the proposals by Ahituv (1980, 1989) and Moody and Walsh (1999); on the other hand, the case study provides an observational design evaluation of a model built for the assessment of information value. As for testing state-of-the-art theory, the case study has applied all three approaches proposed by Ahituv (1989), effectively using each association with a specific organizational level, as shown in Table 4. Indeed, the case study has confirmed the perceived value approach as suitable for higher strategy decision levels (in our case the employee responsible for strategy and governance) and process control, whereas operations rest on a mixed approach of the normative and realistic value. Considering the figures in Table 8 (where we have approximated cost and savings) for the solutions assessed at Poliform, a first result is related to savings in the adoption of data integration (DI) technologies. This result confirms the Law 5 proposed by Moody and Walsh (1999). Conversely, we notice the comparatively low impact in savings of DI technologies with respect to barcode and RFID technologies for new information acquisition, corresponding to the growing part of Moody's Law 6 (Moody et al., 1999).

Table 9. Costs, Savings, and Value of the Three Solutions

Solution	Costs (3 years)	Savings (3 years)	Value
DI	9,500€	28,000€	1.95
DI + Barcode	20,000€	100,000€	4.00
DI + RFID	570,000€	100,000€	-0.82

This result confirms state-of-the-art perspectives that consider DI advantageous in organization-wide coordination and decision making, when information resources are driven by business strategy and integrated into the product and process dimensions of the enterprise (Francalanci & Morabito, 2008; Kettinger, Grover, Guha, & Segars, 1994). As for their value, adding barcode technologies to DI technologies results in an increase in value (1.95) less significant than the increase in savings. Yet, the valuation does not consider the costs related to low data quality of barcode technologies. Furthermore, the use of RFID technologies resulted in a negative impact on information value (-0.82), thus partially confirming the complexity of factors that may enable their adoption (Quetti, Pigni, & Clerici, 2012). As for contribution to practitioners, the model proposed in this paper and tested in the Poliform case study may contribute to a better evaluation of investments in information asset management, potentially reducing their risk.

As for observational design evaluation, a set of two 40-minute interviews has been carried out with the Poliform employee responsible for strategy and governance and process manager in February 2012. As for the process manager, he recognizes a certain usefulness of the model considering that

> the analysis has clearly shown the causes of low performance of information flows in the logistic process. The use of an architecture for integration may represent an important first step to improve the logistic process, but only through the adoption of systems for production monitoring to efficiently produce and manage plans for shipments.

Furthermore, the process manager points out that the model may elicit a set of non-IT and labour-related benefits from previous IT investments: "reducing the time needed to plan the logistic process can free up resources that can be used to support those involved in the handling of goods in the warehouse and loading them onto trucks." This shows also a potential contribution of the model in providing hints on IT productivity (Brynjolfsson, 1993) through the assessment of information value as a complementary IT resource. Finally, the interview with the employee responsible for strategy and governance provides a provisional positive evaluation of the potential application of the model to further core processes of the company: "the type of solutions proposed to improve the logistics of Poliform may also be applied to other business units of the company, considering they are using the same software, and therefore suffer the same problems."

Conclusion

This article has discussed the application to a case study of a model for information value assessment, an alternative instantiation of the one presented by Viscusi and Batini (2014). The case study has considered two information management initiatives for logistics and operations at Poliform, an Italian manufacturing company. It is worth noting that the case study has been carried out not only for the evaluation of the proposed model, but also to provide an empirical test through a case study to the issues and constructs discussed in two state-of-the-art conceptual contributions (Ahituv, 1989; Moody & Walsh, 1999) that we consider relevant in the study of information value. In particular, the case study has investigated two dimensions (*information structure* and *information diffusion*) of information capacity and utility. The results show that information integration may provide a lower improvement in costs and savings (impact of information structure dimension) compared with the contribution of information acquisition through barcode and RFID technologies (joint impact of information structure and information diffusion dimensions). The unbalanced contribution to value of information integration and new information acquisition may have potential important implications for managers interested in extending their current information asset. Future work will investigate information quality, in its relationship with utility, cost, and value, while also considering intangible aspects of information asset value. The article is not exempt from limitations, especially related to the use of a single case study as an evaluation for the framework as well as considering costs as a main resource of benefits, thus delegating to future work the exploration of other sources of value and competitive advantage, such as differentiation and business model innovation. Finally, a research path we consider suitable for further investigations concerns information value dimensions as factors for digital business strategy (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013b). This research path is open because “information abundance” as a key external digital trend impacts digital business strategy through the performance of digital information assets and resources (Brynjolfsson & McAfee, 2011).

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Appendix

Table A1. Acronyms for the Constructs Used in the Math Expressions

Acronyms	Constructs
AL	Application Load
BC	Barcode
BP / bp	Business Process
Ctot	Total cost
DA	Data architecture
db	Database
DI	Data integration technology
IC	Information capacity
ICT Technologies	Information and communication technologies
Int	Integrated schema
NQ	New query
O	Organization
Q / q	Query
RFID	Radio-frequency identification
Stot	Total savings
U / u	User