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Development of digital products and services: Proposal of a framework to analyze versioning actions

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ABSTRACT

Recent expansion in availability of data and of technological resources, as well as the ease of generating, reproducing and adapting digital products and services (DPS), has greatly expanded our ability to quickly generate a wide range of digital offerings. This increased capacity and complexity in turn demands greater operational and managerial effectiveness of organizations regarding the management of DPS versions and of versioning practices. Although versioning has been the subject of study in many disciplines, there is yet little theory development that explicitly seeks to understand the impact and dynamics of versioning actions. Using grounded theory as a research method, we develop a broad framework for conceptualizing versioning actions with the aim of obtaining better understanding of different versioning strategies and of the impact of versioning actions on DPS quality, taken from the interference analysis of the dimensions of information quality related to the DPS. Our framework encompasses actions directed to the three principal components of the DPS architecture, namely the content, technological and process platform, as well as their subcomponents. The framework aims to help researchers and managers reflect on and select the most effective versioning actions, thus reducing the incidence of unexpected events arising from interdependence among the dimensions of information quality that may otherwise be missed during the planning and definition of the versioning actions.

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1. Introduction

The expansion of the use of information and communications technology resources across different locations, objects, and persons (pervasive computing) is a central feature of the new and still developing information society (Castells, 1996; Gorey & Dobat, 1996). These developments have allowed the collection and storage of data in an unprecedented scale – the so-called big data phenomenon – which constitutes an excellent environment for the development of new digital products and services (DPS) (Goes, 2014; Jagadish et al., 2014). The ease and low cost of reproducing and adapting digital artifacts, compared to the physical products of the industrial era, creates a more dynamic business environment in terms of the creation, correction and improvement of DPS (Shapiro & Varian, 1998). In the words of Woodard, Ramasubbu, Tschang, and Sambamurthy (2013, p.537) "relentless innovation and competitive pressures dictate that firms continually adapt these [digital] artifacts to changing market and technological conditions". These results in a higher frequency of events associated with the life cycle of DPS. More improvement events and the accumulation of new DPS versions to be registered requires greater operational and managerial effectiveness on the part of organizations that undertake versioning practices. In this study, versioning is defined as a set of actions that modify the DPS, including actions directed to its content (improvement, reduction, correction, and/or degradation) and/or to its technological platform (content representation/structure) and/or its process platform (DPS storage, recovery, processing, and presentation).

According to Smith (2010), versioning should be an integral part of academic programs and professional training. However, it is seldom addressed, even in software engineering training programs.

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Regarding scientific research, the subject is the object of studies in different areas, such as business administration (Bhargava & Choudhary, 2008; Gershoff, Kivetz, & Keinan, 2012), engineering (Andrikopoulos, Benbernou, & Papazoglou, 2012; Rezgui, Brown, Cooper, Brandon, & Betts, 1998), computing (Maliappis & Sideridis, 2004; Xue, Orgun, & Zhang, 2008), information science (Tennis, 2006), and geoinformatics (Bakalov, Hoel, Heng, Menon, & Tsotras, 2011). Despite the diversity of areas with interest in the subject, there is yet little theory development that explicitly seeks to understand the impact and dynamics of versioning actions. Equally diversified are the organizational units and professional subdisciplines that practice versioning in companies, with a more intensive and visible use by marketing, operations, and research and development professionals. Regarding the studies on the versioning subject, the bibliographic review described in the second section identifies studies from different areas according to the analysis of the publishing sources. These sources show versioning taxonomies that are piecemeal and ad hoc. The diversity and specificity of the literature on versioning hinder its understanding and use by professionals who need to manage the entire DPS life cycle. According to Van Aken and Romme (2009), fragmentation and specificity impede the application of scientific knowledge by the practitioner. For example, a holistic perception of versioning actions is required from the manager responsible for the DPS, whose actions are comprehensive, covering the conception, definition of sales strategy, operation and evolution of the DPS and who dialogs with professionals from different areas, such as R&D, marketing, and operations.

Although experts in DPS content development, technological platforms for DPS operationalization, and DPS sales and marketing within organizations are different people working in different areas, their actions are interdependent regarding interference with DPS quality. As a result, actions on the different components and subcomponents related to the content or technological platform, for both processing and representation of DPS, must be planned, executed, controlled and adjusted as a whole by the DPS manager. For example, consider the case of a marketing and development professional who must upgrade the DPS content, for which it is necessary to improve the quality of the images in the content, as in a digital book. To achieve this quality, the individuals responsible for the representational technological platform of the DPS may change the images' content structures from the bitmap (BMP) format to the Tagged Image File Format (TIFF). The increase in the size of the image files in the TIFF format creates difficulties for the technological platform of the DPS process because of the longer time needed to transmit and display the contents to the user, which results is perceived as low DPS availability by the user. In other words, there is a gain in the preciseness dimension but a loss in the DPS availability dimension.

The jobs of DPS managers involve activities of conception, definition of sales strategy, and the development, operation and evolution of the DPS, which require cooperation with professionals from different areas, such as R&D, IT, marketing and operations. It is important for DPS managers to have a holistic perception of the diversity of the versioning actions that occur in organizations in order to manage properly the quality levels of their DPS. Considering the fragmentation and specificity of the literature on versioning described in the next section, one can see that the extant literature does not currently provide such a holistic view of the versioning actions from an organizational perspective, as required by the DPS manager. This study addresses this difference between the current (fragmented literature on versioning actions) and the desired (holistic view) situations, defined by Simon (1996) as a "problem space". To explore this gap, we undertook a field study that attempted to more fully understand and describe versioning actions and their interdependencies within the organizational context. For this purpose, information was gathered regarding versioning actions in five DPS-oriented organizations, which are described in Appendix A. Relevant incidents (text units) were identified in the field data and were coded and classified to obtain meanings and to identify patterns according to the fundamentals of the grounded theory research strategy (Langley, 1999).

To achieve the objective of the study, the following specific goals were defined:

- Identify and analyze the DPS versioning actions performed by the different areas of the organizations, aiming to extract codes that allow for understanding and defining of the dynamics of those actions;
- Identify and analyze the variety and essence of the DPS components and subcomponents that can be changed to create a new DPS version; and
- Discuss the complexity of the versioning actions by describing the effects of the interdependencies of the components and explaining said interdependencies based on the systemic effects among the dimensions of information quality related to the DPS.

2. Theoretical review and conceptualization

To discuss the results of the field survey and to propose and present the new knowledge obtained, it is necessary to conceptualize the components and subcomponents that comprise the DPS, and this subject is the first addressed in this section. Next, a bibliographic review on versioning is presented, evidencing the fragmentation and specificity of the subject, as indicated in the description of the "current situation" used to define the "problem space". The third subsection addresses the conceptualization of the dimensions of information quality used to analyze the versioning actions found in the field survey and described in the "Analysis and Discussion of Results" section. Finally, the term "digital product and service" (DPS) is defined.

An understanding of the concepts of the dimensions of information quality and of the DPS components and subcomponents is necessary for the results of this study to be implemented and to help facilitate managerial decisions regarding versioning actions. This mastery is explained by the analysis of the parts that constitute the main results of this study, called "Framework of versioning actions for DPS". The framework covers the diversity of versioning actions in DPS components and subcomponents, and it identifies such actions as possible causes of changes in DPS quality. The effects of these actions are identified from the analysis of the effects of interference on a set of dimensions of the information quality of the DPS.

2.1. Components of DPS architecture

According to Meyer and Zack (1996), one of the central components of the informational product architecture is the repository, which is divided into content and structure. Similarly, we adopt the term DPS repository, which we too divide into content and structure, which are exemplified and defined as follows. Considering a book as an example of a digital product, the information contained in it represents the content; taking the software available on the Internet as a digital service, the ordered set of arithmetic and logic instructions that constitute the algorithm of the computer program represents its content. According to Meyer and Zack (1996), the content may be placed in different logical or physical structures, for example, codified in letters format on a

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paper medium, carved in graph format on a stone medium, or registered in text format on a digital medium in a PDF standard file. Thus, the structure is characterized by the medium and format in which the content is stored, with these aspects constituting what is referred to in this study as the DPS technological platform. The features of the content and structure of the DPS repository have a direct impact on DPS provision and use/consumption because they directly affect the DPS storage, recovery, processing, and presentation.

The provision of digital services, the availability of digital products, and their use and consumption occur in the context denominated as DPS process platform or DPS refinery by Meyer and Zack (1996). The DPS process platform involves the activities of content acquisition, content analysis and refining, content storage and recovery, and content distribution and presentation. There are many technological options for storage, from storage of records in files to relational tables in database management systems. In terms of processing technological variations, one can imagine a system conceived for distributed processing or for parallel processing. There are also many presentation options, from interfaces conceived from technologies that are proprietary and specific to a particular supplier, such as the CICS environment from IBM, to open standards such as HTML for Internet or graphic interfaces for mobile devices such as those available for the Macintosh IOS. As will be observed over the course of this paper, the diversity of DPS versions is derived from actions that combine changes in DPS content, technological and process platforms.

Following the definitions used by Meyer and Zack (1996) for the architecture of information products, we will use the term "architecture of DPS" to designate the set composed of: content, technological, and process platforms of DPS. These are the components of the architecture of DPS that can be altered by versioning actions, both for the development of new DPS and for correcting and perfecting those already existing.

2.2. Multiple perceptions of versioning

Versioning is the object of study of researchers from different scientific areas. These include information science, engineering, administration, communication, and computing. Similar to what takes place in the sciences, versioning actions occur in different areas of organizations that practice versioning of DPS and are conducted by different professionals. Marketing, operations, and research and development are among the organizational areas or administrative fields of study with wide interest and direct involvement with managing versions of DPS. Next, the main academic discussions and corporate actions performed in these three areas directly involved with versioning are summarized.

The study by Shapiro and Varian (1998) is of relevance in the marketing area. Their work addresses versioning as an important element in the positioning and pricing strategies of digital products and services. Shapiro and Varian (1998) and Linde (2009) present versioning typologies described in Fig. 1 and address features of digital products and services that, when modified, permit the generation of different versions of the DPS with different perceptions of value for the customer. Unlike a physical product, the most typical and economically feasible action for a DPS is the initial development of the most complete version. Then, some features of this DPS are removed to create new versions (Shapiro & Varian, 1998). The versioning definitions for marketing researchers and practitioners emphasize this reduction: the "versioning literature […] argues that a lower quality version can easily be created by turning off a few features from the original product" (Dey, Lahiri, & Guoying, 2014, p. 591). Regarding the most appropriate moment for the company to remove features from the DPS and generate a new version, Bhargava and Choudhary (2008, p. 1032) conclude that "versioning is profitable when the optimal market share of a lower-quality version when offered alone exceeds the optimal market share of the high-quality version offered alone". Marketing researchers and practitioners praise versioning actions because of their capability to increase the well-being of both the consumer, who gains access to DPS that he/she did not have before, and the company, which increases the longevity and the number of consumers of its products and services (Gershoff et al., 2012).

Shapiro and Varian (1998)	Linde (2009)
1. Convenience	1. Up-to-dateness
2. Comprehensiveness	2. Availability of the information
3. Manipulation	3. Scope of work
4. Community	4. Perception-friendliness
5. Annoyance	5. Processing speed
6. Speed	
7. Data processing	
8. User interface	
9. Image resolution	
10. Support	

Fig. 1. Versioning typologies for DPS found in the literature.

There is a wide discussion among software engineering researchers and practitioners regarding versioning from the standpoint of DPS operations. There are several challenges, and different methods have been proposed for the effective management of versions of codes of programs under development. The pragmatic definition by Smith (2010, p. 51) defines versioning as "a method of maintaining separate versions of files, rather than simply overwriting the old ones". The academic discussion involves frameworks, models, techniques, and methods to manage versions of software under development. Versioning involves "identification, control, recording and tracking of the evolution of software products, objects, structures and their interrelationships […] from the software development point of view" (Maliappis & Sideridis, 2004, p. 150). Current software development practices integrate objects that are available in libraries of reusable objects that interact with other objects, composing and interacting with different information systems. This information system architecture transforms the actions of modifying the codes of these reusable objects into something more critical and meticulous, given the higher impact potential of such objects due to their wide use in different information systems. Maliappis and Sideridis (2004) identify as important components of information systems the evolutionary follow-up of the lines of source code (change tracking) not only of the programs but also of the other entities that constitute the information system, such as: a) database management, in terms of evolutions of database schema and contents of the database; and b) ontology management, providing an overview of causes and consequences of the changes in the ontology. It is also worth noting the versioning studies in software engineering towards collaborative work among development teams of a software factory distributed in different locations in different time zones working with the same objects. These environments experience the challenge of daily changes in the versions of objects built collaboratively among the teams (Seshasai & Gupta, 2009; Xue et al., 2008).

Versioning has implications in the operations area of both products and services, whether they are characterized by physical or virtual activities or by some combination of the two. Versioning is present at several points of product operations, of which we will describe two: a) in the historic recording of possible movement sequences of pieces of equipment for installing and assembling parts of a product, registered in the repository of the Computer

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Aided Manufacturing (CAM) application; and b) in the configuration of equipment that receives operation parameters from the content of the design of the product to be manufactured, which are defined and stored in a digital repository derived from the Product Data Management (PDM) or Computer Aided Design (CAD) applications (Wang et al., 2014). In the case of services, the workflow and business process management system (BPMS) software processes instructions and performs controls based on business process model configurations are stored in its repositories (Bae, Cho, & Bae, 2007). These experiences in the operations area are characterized by operation models stored in repositories of different applications (CAM, PDM, CAD, BPMS) that evolve in time, thus resulting in the challenge of managing different versions of documents.

In the area of R&D, the set of contents that have their evolution recorded and followed up by versions is quite large. Examples include datasets used in simulations, configurations of parameters used in software to simulate dataset processing, and the evolution of texts used collaboratively among researchers to analyze, discuss, and present research results. The value added by versioning practices in R&D is significant in terms of speed and the quality of the results. According to Beaman et al. (2012, p. 6) "versioning of datasets greatly [simplifies] tasks necessary to repeat experiments, re-use data and provide easier accessibility". The wide introduction of information and communications technologies in society has helped generate the phenomenon known as information explosion (Ma, Wang, Lai, & Zheng, 2010). For researchers, this has brought a major challenge in handling "big data", highlighting the need for resources for the preservation, analysis, and publication of data within the concept of the "big data life cycle" (Arend et al., 2014). Yilmaz (2012) highlights the importance of versioning in modeling and simulation tools, to address problems of lack of proper documentation, as well as the validation and distribution of models.

2.3. Dimensions for the analysis of information quality

There is no consensus in the literature regarding the amount, scope, and forms of grouping to describe and present the dimensions of information quality. Eppler (2006) identified 70 dimensions of information quality largely used in the literature. Variations occur depending on the taxonomy adopted from the many options available in the literature on the subject. For example, Huang, Lee, and Wang (1999) describe 15 dimensions classified into four categories: intrinsic dimensions, accessibility dimensions, contextual dimensions, and representational dimensions. To analyze the versioning actions found in the field survey, we will use thirteen of the dimensions of information quality, defined as follows:

- The accuracy dimension is the "degree of conformity of a measure to a standard or a true value. Level of precision or detail" (Eppler, 2006, p. 364);
- The authenticity of the information involves the analysis of the number of interlocutors, translators, editors, transcribers and other intermediaries who have worked with the information since its origin at the primary source (Yadav, 2010);
- The availability dimension "is the aspect of quality that measures whether a Web service [a type of DPS] is available or ready for immediate use. Availability is measured using the probability that the service is available" (Nath & Singh, 2010, p. 48);
- The comprehensiveness dimension of a certain piece of information "is considered appropriate when the readers perceive that the content is correct and sufficient for their needs, which means that there is not so much content that it is difficult to locate the desired information but also that the information is not reduced and incomplete" (De Sordi, Meireles, & Azevedo, 2014, p. 664);
- The concurrency of distributed information is discussed in terms of numbers of physical, digital and mental locations (English, 1999);
- The confidentiality dimension "is the assurance that information is not disclosed to unauthorized persons, processes, or devices" (Schou & Trimmer, 2004, p. VI);
- The convenience dimension refers to the amount of work that the information consumer must perform to be able to use the DPS (Forslund, 2007);
- The identifiability, also called traceability or documentation by some authors, is associated with the level of existence and quality of the metadata (size, generation date, author, title, keywords) and meta-information (summary) that describe the information (Eppler, 2006; Loshin, 2011);
- The integrity, also called freedom from error by some authors, is the extent to which the information is correct according to the last generation or update, in other words, whether the information is not corrupted or adulterated (Kahn, Strong, & Wang, 2002);
- The preciseness of the information is the level of detail of the information; for example, for a picture it could be the number of dots per inch (pixels), while for a number, it could be the number of significant digits (Königer & Reithmayer, 1998);
- The reliability, also called reputation or believability by some authors, is analyzed according to the level of credibility of the information source (Kahn et al., 2002; Wang & Strong, 1996);
- The timeliness dimension refers to the moment of information generation or update, which is expected to be adequate for the occasion and the user's expectation (Lee, Strong, Kahn, & Wang, 2002; Loshin, 2011);
- The uniqueness, also called equivalence of similar information, involves the analysis of the existence of available similar contents (English, 1999; Hawkins, 1999).

2.4. Digital product and service (DPS)

The results of this study apply to both static and the dynamic content. Static content is related to the digital product, while dynamic content is related to the digital service. The content is a product that is ready and stored, and it requires the actions of the DPS process platform for the access, transmission and display of the content to the end user. A service requires more from the processing platform because it is not sufficient to access the content, and the content must be generated or updated from other sources; in other words, it requires more access and more processing. Despite the difference in the demand for resources, both the digital product and the digital service have three DPS architecture components: content, technological and process platform. The user's perception is analyzed using the same criteria, that is, using the same dimensions to analyze the information quality. Obviously, the perceptions of results attributed to the dimensions related to the digital product and the digital service vary because of the different technical requirements. It is expected that the content of the digital service is better perceived by the end user regarding the timeliness dimension, whereas the digital product must have a better perception regarding the availability dimension (less processing and less diversity of platforms involved).

Considering that a digital product and a digital service have the same architecture components and that they can be analyzed using the same set of dimensions for analyzing information quality, for the central elements of the framework proposed and described in

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this study, a single denomination was chosen: DPS. A more comprehensive and detailed denomination is more appropriate for the variety of informational entities whose versioning actions can be analyzed by the framework.

3. Research method

The theoretical contribution of this research is characterized by the framework for the analysis of versioning actions, based on the data that emerged from a field study conducted with five companies. Epistemologically, this theoretical contribution was inferred by induction from the field data, as postulated by grounded theory research: "the theory's variables or constructs must emerge from, or be "grounded" in, the data rather than be taken entirely from a previously published theory and imposed on the current set of data" (Lee and Hubona, 2009, p. 246). To satisfy the principle of emergence as required by the grounded theory research, which declares that "the grounded theory must fit the data under study, and it must meaningfully explain the behavior under study" (Glaser & Strauss, 1967, p. 3), this research used the techniques of content analysis and discussion sessions, according to the procedures described below.

Although there are several theories that address DPS versioning actions, the bibliographic review showed that the discussion has been rather specific and sectoral. There has been a lack of literature that discusses or at least systemically indicates the diversity of organizational actions, of different professionals and of different areas that are capable of influencing DPS quality. Considering the breadth and diversity of the constructs and their ramifications, this study sought to collect information from different actors in the content and intellectual property field. To compare and discuss the multifaceted and fragmented literature on versioning according to the practices in organizations, the researchers conducted discussion sessions on versioning practices in five Brazilian organizations that perform DPS development and management: two software houses, two publishers of university books, and one engineering, research, and development company with a strong tradition in software development. For companies to be eligible for inclusion in the study, they needed to perform DPS development and evolution, in addition to being accessible; i.e., the authors needed to have a previous contact that would allow access to important personnel. We gained access to these organizations as a result of previous research engagements with two of the software houses, as authors of books and content for the two publishers, and as consultants for the engineering company.

The data-gathering sessions at each of the five organizations lasted approximately 120 min and involved experienced professionals from the organization with at least five years in DPS development and evolution in the company. In the case of the publishers, experienced editors who work in the publishing of books with more than five editions participated in the study. In the case of the software houses and the engineering, research, and development company, the participants were product (software) managers who have worked on the development of the same products (software) for more than five years. The sessions for discussing versioning practices were held in the offices of each organization between May and November 2014.

The researchers initiated the discussion sessions on versioning practices with a brief explanation of variations in versioning practices in editing and software organizations. They highlighted examples in the literature, including the versioning typologies by Shapiro and Varian (1998) and Linde (2009). After the different types of versioning were introduced, the representatives of the organization were stimulated to talk about the following: a) the company's attitudes towards and definitions of the practice of versioning, providing examples of the actions taken in the company; b) the perceived concerns and risks of these versioning actions, both technically (DPS quality) and commercially (DPS sales); and c) details of the company's versioning actions, indicating who does it, when it is done, how it is done, and why it is done. After the initial presentation, the researchers interacted with the interviewees as little as possible, only inquiring when a piece of information given by the professionals was not well understood. All the discussions of the professionals of the five organizations were recorded, with their consent, to analyze them later through the application of content analysis techniques (Miles & Huberman, 1994).

The identification of codes and themes from the initial analysis of the dataset collected in the field, according to the content analysis technique (Miles & Huberman, 1994), was performed by a team of researchers. The codes and themes, initially identified and defined by the team of researchers for content analysis, were applied later by the same researchers to perform the individual tasks of text reading and analysis. The results of these analyses were then consolidated among the researchers, and the divergent points were identified and discussed by the team of researchers. Multiple analysts were used in this study, a method also called researcher triangulation (Patton, 1987, apud Yin, 2001, p. 121). The disagreements that appeared upon the semantic interpretation of the text excerpts regarding the versioning actions were settled by listening to the speech recordings and, if necessary, by sending an e-mail to the interviewee asking for further details.

4. Analysis and discussion of the results

The first phase of content analysis as proposed by Miles and Huberman (1994, p. 92), called "Summarizing and packaging the data", considers the conversion of the interviews into texts and the definition of categories of codes for analysis. The recordings of the five sessions were listened to and transcribed using text-editing software. The first code of analysis defined was the versioning action, the central object of the discussion sessions in the companies. Thus, the texts were read to identify the text excerpts associated with the versioning activities described by the interviewees. This task resulted in the identification of 18 excerpts, which are all recorded in the second column of Table 1. The second phase of content analysis according to Miles and Huberman (1994), denominated "Repackaging and aggregating the data", is comprised of the identification of the themes and the relationships among them. For this, several analyses of the 18 excerpts associated with the versioning actions declared by the companies were performed. It was observed that some of these actions were directly associated with the DPS content change, others with the change of the DPS content structure, and the rest with the DPS process platform; in other words, they involved one or more of the components of the DPS architecture. The classification of the 18 excerpts of versioning actions according to those three components of DPS architecture was performed and is recorded in the third column of Table 1, which is divided into three parts: a) content, b) technological, and c) platform.

In order to identify themes and relations associated with versioning actions per Miles and Huberman's "Repackaging and aggregating the data" phase, we separately analyzed excerpts of our data which described versioning actions for each of the three components of DPS architecture. The largest group concerns the content component, summing 13 of the 18 excerpts identified (see the first 13 rows of Table 1). Of these 13 excerpts associated

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Table 1
Analysis and classification of DPS versioning actions practiced by the five companies of the study sample.

Company name and excerpt Identifier (*company acronym + number*)	Text excerpt regarding the versioning Action	Component of the DPS architecture involved in the versioning Action						
		(**A**) **Content plataform**					(**B**)	(**C**)
		Event		Intent		Taxonomy Categories	Technological plataform	Process plataform
		Inclusion	Exclusion	Favorable/ Advance	Unfavorable/ Simplification			
Totvs ***Tot-1***	Until recently, we released versions of our products every 18 months, now the new functionalities are introduced to the market through new releases every two months.	X		X		Improvement		
Simworx ***Sim-2***	Some software products have undergone continuous improvements for more than ten years, with code inclusions and modifications according to the evolution of the numeric method used in engineering simulations. The company evolves and saves snapshots of software versions delivered to the customer in SVN versions manager. Some systems have more than ten years of versions saved and described in the SVN.	X		X				
Dextra ***Dex-3***	[…] for applying an Agile methodology, we use what we call split to incorporate improvements requested by the customers or corrections, timely maintenance, to quickly put the modified code into production (lean start-up) and for it to be validated in practice by the customer, in other words, to avoid insisting in the wrong path for a long time and to take the right path as soon as possible.	X		X				
Saraiva ***Sar-4***	The new edition is the most traditional form of content expansion. The evolution of a work in terms of a new version occurs not only through the incorporation of new contents developed by the author but also through the incorporation of supplementary material available on the book's website, in the section of support to the reader/teacher, which may contain support texts, exercises books, software, and other supplementary materials.	X		X				
Atlas ***Atl-5***	The evolution of commercially successful books occurs through new versions that incorporate new contents into the book.	X		X				
Totvs ***Tot***-6	Software errors are eliminated by urgent corrections performed unitarily through updates. Ordinary and less urgent corrections are performed periodically, are accumulated, and are implemented in the software product through bimonthly releases.		X		X	Correction		
Dextra ***Dex-7***	Splits [already described in Dex-3] are used for both software improvement and corrections. [] The refactoring action involves code cleaning to improve the understanding of the developers. During development, the professional may identify and assign a Technical Debt that will be solved in the future by him/her, when he/she has time, or by another developer. The person identifies the class of debt that may be small, medium, or large. Cleaning or refactoring occurs both for classes and for services/methods of the objects stored in the repository.		X		X			
Saraiva ***Sar-8***	Normally, the corrections occur at each reprinting of the books.		X		X			
Atlas ***Atl-9***	Corrections are performed at every new edition [reprinting] of the book.		X		X			
Totvs ***Tot-10***	Each product has three versions. The difference between the simplest version, Series 1, and the full version, known as Series T, is in the code reduction. Series 1 targets the market of small companies.		X	X		Reduction		
Saraiva ***Sar-11***	In the concept of University Notebooks, the higher education institution defines the chapters of a book to be supplied, and the book is condensed according to the students' demand, defined by professors and course coordinators.		X	X				
Atlas ***Atl-12***	We have customer institutions that select chapters of the book to be supplied as handouts.		X	X				
Saraiva ***Sar-13***	The compact version involves content simplification in terms of adequacy to the style of the original writing of the book. In other words, the type of writing is changed to meet the specific context of the target audience. This occurs especially when adapting texts used by readers from undergraduate courses (four years) to those of	X			X	Degradation		

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Table 1 (*continued*)

Company name and excerpt Identifier (*company acronym + number*)	Text excerpt regarding the versioning Action	Component of the DPS architecture involved in the versioning Action						
		(**A**) **Content plataform**					(**B**)	(**C**)
		Event		Intent		Taxonomy Categories	Technological plataform	Process plataform
		Inclusion	Exclusion	Favorable/ Advance	Unfavorable/ Simplification			
	technical courses (two years) with a reduced hourly load. […] Books with color figures in the original edition may be printed in black and white.							
Totvs ***Tot-14***	The intermediate version, Series 3, has the same set of software as the full version, Series T, with the difference being the access permission levels that are more limited in terms of available functions.							X
Dextra ***Dex-15***	One of our customers provides information services from the São Paulo stock exchange (BOVESPA), and for this, he has software to follow-up and analyze stocks. Recently, he asked for a variation that consisted in the introduction of a time reducer for data update in the screen of the application used by his customers. This involved a technical degradation that will allow our customer to offer a differentiated product at a more accessible price; however, with longer times between updates of the traded stocks data, in 15-min intervals, while the original service provides updates almost in real time.							X
Simworx ***Sim-16***	To improve the performance of the numeric simulation application in terms of processing time, we adopted the parallel processing computational model. For this, it was necessary to modify the architecture of the application's computer program.							X
Saraiva ***Sar-17***	Some books were reissued in the ePub format instead of PDF, which allows greater text handling flexibility to the reader.						X	
Atlas ***Atl-18***	PDF does not allow search functionalities, so we converted some books to the ePub format. The URL links were broken in this process and stopped working.						X	

with the content components, 9 are associated with the two versioning actions found across all five organizations: the inclusion of new content (texts or lines of program code) with the objective of evolving the DPS; excerpts about the exclusion of content with the objective of eliminating defects in the DPS. Among the other four excerpts relevant to actions about the component content, we also noted the occurrence of other possible combinations: the inclusion of features unfavorable to the DPS and the exclusion of features favorable to the DPS. We thus defined two interrelated themes as content analysis categories to be applied to the excerpts related to versioning action related to the content component:

a) Event theme, which can be of two types, a.1) the inclusion of content, or a.2) exclusion of content. We noted that even when the interviewee mentions alteration of content, the objective is alteration to exclude something negative from the DPS or to include something positive. The event theme is associated with an effective change in the content of the DPS;
b) Intent theme, which may be of two types, b.1) favorable to the content of the DPS, that is to say, acting directly on the essence of the content as a whole to develop or evolve, or b.2) unfavorable to the content of the DPS because it represents a simplification of available content, normally undertaken for commercial or marketing purposes. It may seem counterintuitive to deliberately degrade content, however, this may permit the firm for example, to implement a "less for less" market strategy (Mayfield, Mayfield, & Genestre, 2001; Tucker, 2001).

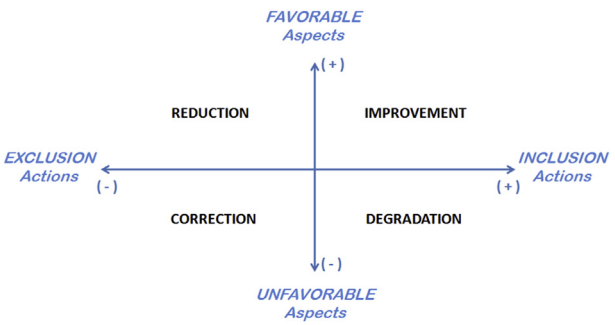

Fig. 2. Typologies of DPS content-based versioning actions.

4.1. Typologies of content-based versioning actions

The combination of the event and intent themes, both of which consisted of two types (inclusion and exclusion, and favorable and unfavorable, respectively), resulted in a taxonomy of four categories to describe DPS content-based versioning actions. Fig. 2 illustrates the four proposed taxonomy categories, denominated as reduction, improvement, correction, and degradation. The following paragraphs define the four categories and show examples of the versioning practices reported by the five companies in the sample.

The improvement category covers the inclusion of favorable content, that is, content that allows the evolution of the DPS. In the

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case of the software segment, the most typical example is the inclusion of new lines of code that provide new functions to the DPS. In Table 1, the text excerpts associated with the indicators Sim-2, Tot-1, and Dex-3 are examples of this versioning action towards DPS improvement in the software format. The versioning action of content improvement most used in the publishing area is the release of a new edition of a book, for example, with the incorporation of new contents developed by the author. Another example is the coloring of figures originally in black and white, which improves the detail of the content of the figures, making them more accurate and informative. In Table 1, the excerpts associated with the indicators Sar-4 and Atl-5 indicate versioning actions towards the improvement of the DPS in the book format. The versioning action characterized as improvement has a direct reflection on one of the dimensions of information quality, the comprehensiveness dimension, increasing it.

The correction category involves the exclusion of unfavorable aspects in terms of DPS content. That is, it allows eliminating DPS defects. In the case of the software segment, a very well-known corrective versioning action is the launching of new releases that correct errors detected in previous releases, as shown in the text excerpts associated with the indicators Tot-6 and Dex-7. In the publishing segment, identified content errors are corrected by the release of a new book edition or through reprinting in the case of printed books. The field survey detected correction actions in the publishing segment, as observed in the text excerpts associated with the indicators Sar-8 and Atl-9. Thus, the versioning action categorized as correction has a direct reflection on one of the dimensions of information quality, the accuracy dimension, increasing it.

The reduction category implies content reduction, that is, from the perspective of the DPS manager something favorable to the product is being excluded, which results in a reduction of value in terms of DPS content. Regarding the software segment, Totvs, a software house, generates simplified versions of its products at lower prices targeting small companies, as shown in the text extract associated with the indicator Tot-10. In the case of the publishing segment, an example is the reduction of a book by the partial sale of some chapters at the request of a university that acquires a significant quantity of books. This phenomenon is illustrated in the text excerpts associated with the indicators Sar-11 and Atl-12. Thus, the versioning action categorized as reduction has a direct reflection on one of the dimensions of information quality, the comprehensiveness dimension, reducing it.

The degradation category implies the inclusion of unfavorable features to the content. From the perspective of the DPS manager it is a step backwards in terms of the already existing content. In the field survey, the Saraiva publisher indicated the change of wording of undergraduate books (4-year courses) to a simpler and more understandable language for students enrolled in technical courses (2-year courses), as seen in the text excerpt associated with the indicator Sar-13. No DPS degradation action was identified among the software companies in the sample. An example of a deliberate degradation in the software segment is the case of the Global Positioning System (GPS) service, made available by the US Department of Defense (DoD). From 1970 to 2000, the GPS service available for civilian users was degraded for security reasons: “the accuracy and precision of GPS-derived locations were degraded by a process known as selective availability (SA); after May 2000, SA was disabled” (Hulbert & French, 2001, p. 869). The SA adds intentional, time varying errors of up to 100 m to the publicly available navigation signals. A more recent and common example of software degradation is the introduction of annoyances in the form of on-line ads to website users, which can only be turned off by subscribers. Another example of on-line ads occurs with the trial versions of web applications, that is, those not yet acquired by the users (Shapiro & Varian, 1998).

There are many options for DPS degradation in terms of the involved DPS entity because they may occur through actions on any of the three components of the DPS architecture: content, technological, or platform. The dimensions of information quality that may be negatively impacted are equally diverse. The two examples shown above are associated with the content component of the DPS. In the case of the GPS, the software functions are directly modified, that is, it has direct implications on the accuracy dimension of information quality of the DPS, reducing it. By contrast, the inclusion of on-line ads weakens the DPS in terms of the comprehensiveness dimension of information quality, increasing it although this is a negative content growth, considering that the ads are irrelevant to the DPS users. These contents only pollute the environment and hinder the DPS operation by imposing additional work on the user, including closing pop-ups or searching for relevant information in the midst of all the advertisements.

The versioning typologies found in the bibliographic review and described in Fig. 1, the typology by Shapiro and Varian (1998, p. 110), denominated “versions of versioning”, and the typology by Linde (2009, p. 382), denominated “types of versioning”, address an issue that in this study we call dimensions of information quality. The two typologies focus on the sale of a finished and static product, denominated information product, as observed in the titles of the articles: “Versioning: The smart way to sell information” (Shapiro & Varian, 1998) and “Pricing information goods” (Linde, 2009). This study seeks to work with both static and dynamic information; therefore, it uses the denomination of digital product and service instead of only product.

4.2. Framework of versioning actions for DPS

In terms of DPS platform, the growing availability and diversity of information and communication technologies (ICT) resources give DPS managers a high degree of flexibility to compose different versions of their DPS. This becomes evident when we consider the different technological components involved in tasks associated with the DPS process platform: content acquisition, content analysis and refining, content storage and recovery, and content distribution and presentation (Meyer & Zack, 1996). Some of the versioning actions reported by the companies are directly associated with a change in the DPS process platform, such as the actions described in the text excerpts associated with indicators Dex-15, Tot-14, and Sim-16. In the case of Dex-15, the DPS variation was a result of an increase in the data acquisition time for later storage and presentation. This is a differentiated service option for the end user: data updated over longer intervals of time at lower prices. The versioning action described by Tot-14 involves the creation of different access profiles according to the level of service required by the client company, enabling access to differentiated sets of programs. Hence, different business functions are activated according to the level of service agreed on with the software house Totvs. In the case of Sim-16, the versioning actions modified the architecture of the simulation application programs in terms of executable codes to allow the parallel processing of the simulation calculations, the central object of the application.

The three versioning actions associated with the process platform analyzed in this study (Tot-14, Dex-15, and Sim-16) affected different dimensions of information quality and resulted in different perceptions of the DPS quality. In the case of Tot-14, the

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perception of the comprehensiveness dimension of the content was modified, making the product less comprehensive in terms of the business functions available in the contracted information system. The timeliness dimension of the content was modified in Dex-15, making the information service less agile and dynamic. Despite the differentiated perception of the DPS by the customers, these actions did not require modifications of the DPS content, only changes in the technological resources involved in the service processing, i.e., in the DPS process platform. In the case of Sim-16, the parallel processing of the executable codes of the programs that constitute the simulation application resulted in a faster calculation execution and faster delivery of results; that is, the timeliness dimension of the content was modified, making the information service more agile, dynamic, and attractive to its users.

In addition to the modifications of the DPS content and process platform, another component of DPS architecture that can be developed through versioning actions is the content structure, i.e., the medium and the format of the content. Some of the versioning actions reported by the companies are directly associated with the content structure, such as the actions described in the text excerpts associated with the indicators Sar-17 and Atl-18. These two excerpts present versioning actions of publishers associated with the change of the file format of the digital book, which migrated from the PDF to the ePub format. The objective of these actions was to enable word search capability throughout the digital text, a feature demanded by readers. These versioning actions modify the perception of the convenience dimension, making the DPS closer to the use context of the end customers, in this case, readers of digital books. The replacement of a content structure is used by the DPS manager as a means to propose both the DPS upgrade and downgrade.

The analysis of the versioning actions practiced by the five surveyed companies demonstrates that versioning may occur from actions performed on any of the three components of the DPS architecture: content, technological, or process platform. Ultimately, these actions directly influence the dimensions of information quality, the DPS dimensions in this case, which influence customers' perceptions of the value of the referred DPS. Fig. 3 shows this scenario of versioning actions, representing a framework that considers the three components of the DPS architecture, the unfolding of these components into subcomponents for a better understanding of the possibilities of the versioning actions, and their relationships with the dimensions of information quality and the perception of value of the DPS. There is a high degree of interdependence among the components included in Fig. 3, stressing that the most comprehensive versioning actions may influence more than one of the DPS architecture components. An example of a comprehensive versioning action is the migration from an information system to a distributed computing model. This demands changes not only in the application's processors, i.e., the content's process platform, but also in the languages and other tools used to develop an adequate programs' architecture, i.e., changes associated with the content's structure.

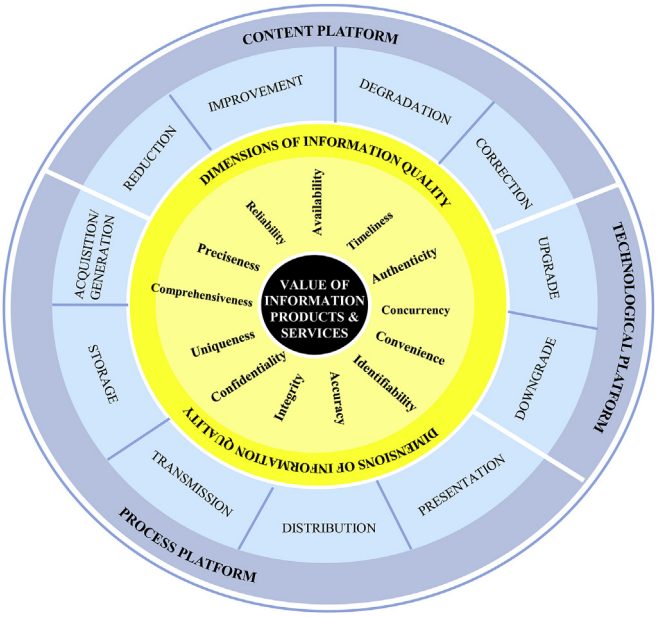

Fig. 3. Framework of versioning actions for DPS.

The person responsible for DPS development must fully understand and manage the versioning actions on the three components of the DPS architecture to achieve and maintain ideal conditions for the different dimensions of information quality associated with the DPS. Some dimensions of information quality tend to be more sensitive to actions on a specific component of the DPS architecture, such as the DPS availability and confidentiality dimensions related to actions on the process platform component and the comprehensiveness dimension related to actions on the content component. However, overall, all the dimensions of information quality are associated with versioning actions (content, technological and process platform) to a greater or lesser extent. The analysis of the versioning action on a DPS component must be comprehensive, considering not only the first impact on the most perceivable dimension of information quality but also the systemic effects of the interdependence among them. Understanding of the interdependencies among the dimensions of information quality is a critical aspect for the efficiency of versioning actions, given that an action impacting one dimension may have effects on other dimensions. For example, let us consider the intention of a DPS manager to improve the content by upgrading the quality of the images (increase of the accuracy dimension). To achieve this, the people responsible for the DPS change the content structure of the images from the bitmap (BMP) format to the Tagged Image File Format (TIFF). The increase to the size of the image files, now in the TIFF format, creates a difficulty in the process platform as a result of the longer time needed to transmit and show the content to the user, which might be perceived as low DPS availability by the end user (reduction of the availability dimension).

In addition to a good command of the typology of content-based versioning actions and the framework of versioning actions for DPS, the person responsible for the DPS must have a good understanding of the dimensions of information quality and the dynamics of the interdependence among them. When considering a versioning action on any of the three components of DPS architecture, the manager must be aware of the dimension of information quality directly associated with the action and must know the other dimensions strongly associated with it. This will give the manager greater competence to execute the process of analysis and selection among the possible versioning actions, thus preventing actions with unexpected consequences for the DPS. The application of the framework to support the decision-making process regarding DPS versioning actions is exemplified and described in the subsequent section. The descriptions of the performed activities will allow for a better understanding of the associations between the dimensions of information quality and the components of the DPS architecture. In addition, the practical and applied aspects of the logical abstractions generated in this study will be shown.

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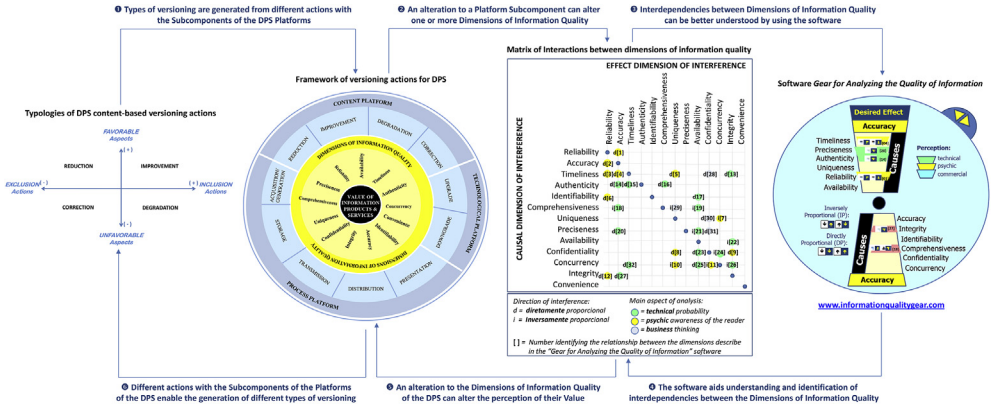

Fig. 4. Systemic view of the abstractions developed in this article in support of managerial decisions about versioning for DPS.

5. Applying the framework to managerial decisions about versioning

The application of the first logical abstraction derived from this research, called "Typologies of DPS content-based versioning actions" (Fig. 2), goes beyond the capacity to diffuse information and collaborate with the development of an organizational culture suited to the management and development of DPS. Our typology can also contribute insights to the discussion of platforms, product and service families, and other related matters. Despite the possible applications of this typology, this section addresses only the second logical abstraction, called "Framework of versioning actions for DPS" (Fig. 3). This is because the framework is specifically related to the analysis of versioning actions, which is the central theme of this research. In this research, we understand the typology as an intermediate product, which is important for the process of development and comprehension of the proposed framework.

Below, we describe the way we use our framework in organizations as an instrument to support the DPS manager in conducting sessions of analysis and selection of versioning actions for DPS. For an analysis session it is important that the manager responsible for DPS as well as personnel responsible for the three components of DPS architecture – process platform specialists, technological platform specialists, and content platform specialists be involved. The manager responsible for DPS should chair the session.

At the beginning of the session the DPS manager should ask each specialist to describe each of the subcomponents related to his respective component of the DPS architecture, beginning with the most peripheral part of the framework (see Fig. 3), which should be visible to all. Next, the manager should explain the information quality dimensions present in the central part of the framework, describing how each of these may be influenced by the components and consequently altering the user perceptions of DPS quality, and finally, the perceived value of the DPS, which is the central element in the framework. In order to explain the dimensions of information quality, we recommend that the manager provide a brief description of each dimension to be considered in the session. An example of a descriptive table of the dimensions of information quality is provided in Figure B.1 of Appendix B, which describes examples of complementary instruments for the application of the framework. By the end of the first activity, all participants should have an understanding of the components and their subcomponents and of the dimensions of information quality.

Before beginning the analysis of each possible versioning action, it is important for the DPS manager to describe the desired state for each of the information quality dimensions, emphasizing those which are most critical to the perception of value of DPS customers. Once this is done, versioning actions may be presented for the group to analyze. For each action the group should identify which components and subcomponents will be directly or indirectly affected. There should be a discussion and analysis of the consequences of each action for each subcomponent. The impact on each subcomponent should be described in writing and its understanding confirmed by all present. The next step is to identify information quality dimensions influenced by the proposed actions. To accomplish this, we recommend that the DPS manager present an example of an association matrix containing the dimensions of information quality, indicating possible interactions between the dimensions. It should be stressed that this is only an illustrative example, the purpose of which is to demonstrate the importance of thinking systematically about interactions between the dimensions of information quality, seeking to identify deviation amplifying and deviation limiting loops.

An example of a table describing interactions among information quality dimensions is found in Figure B.2 of appendix B. The DPS manager should comment on the relations between dimensions. For this, we suggest the delivery and reading of something similar to what is found in Figure B.3 of appendix B, which describes the 32 relations presented in Figure B.2. A way found by the authors to facilitate the exposure and consolidation of the content of Figures B.2 and B3 is their concatenation in a software. The "Gear for Analyzing Information Quality" software was developed (available for download at www.informationqualitygear.com), which enables the DPS manager to conduct a more interactive and dynamic discussion with the members of the team responsible for the life cycle of the DPS.

The fact that the "Gear for Analyzing Information Quality" indicates interrelations between information quality dimensions from the perception of both technical and commercial viewpoints, with strong interdependence between them, aids the understanding of the teams that manage the life cycle of the DPS, especially the actions involved in versioning, as being interdisciplinary, made up of professionals from different areas of the organization.

A consideration of the set of interactions between the subcomponents of each action, especially the dimensions which are critical to DPS, should facilitate the technical analysis of each versioning action from a qualitative perspective. Aside from matters related to costs, technological restrictions, norms and standards, the framework should help the DPS manager to incorporate another aspect to possible versioning actions: the qualitative analysis of DPS from the perspective of the dimensions of information quality.

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Pratt (2009, p.860) recommends in his editorial that it is better "to construct figures that help you visually represent your findings. I find figures particularly good for depicting processes. Such figures are often used to summarize findings". Following the suggestion of Pratt, we conclude this section by presenting Fig. 4, which describes the systemic view of the four abstractions developed in this article in support of managerial decisions about versioning for DPS.

6. Conclusions

The contributions of this study are the result of the presentation and description of three artefacts: Typologies of DPS content-based versioning actions, Fig. 2; Framework of versioning actions for DPS, Fig. 3; and the Gear for Analyzing Information Quality (www.informationqualitygear.com). These artefacts focus on the analyses of possible alterations to the DPS to support communication between the different professionals involved in the planning, selection and execution of versioning actions. Thus, it is hoped that analytic capacity can be improved in addition to the understanding of the different risks and the care that needs to be taken with some possible actions for altering the DPS that are under consideration by the professionals in the team responsible for the new version of the DPS.

The utility of these artefacts can be seen through the difficulties involved in maintaining the alignment of the commercial and technical demands of the DPS with every alteration that is made for technological reasons (technological platform), operational issues (process platform) or even strategic issues (content platform). For better proof and understanding of the strategic dimension within the alteration process associated with the DPS life cycle, Typologies of DPS content-based versioning actions (Fig. 2) have been developed, whose content (types) help to compose and explain one of the three platforms (Content Platform) described in the Framework of versioning actions for DPS (Fig. 3).

The evidence of the risks involved in possible actions in any one of the three DPS platforms can be seen using the same knowledge and artefacts proposed to aid their mitigation. Irrespective of the aspect or which of the three platforms of the Framework of versioning actions for DPS (Fig. 3) is altered, the perception of the end user of the DPS can be understood by analyzing the dimensions of information quality, which have a high level of interdependence and are very sensitive to alterations to any of the three platforms. These interdependencies between the dimensions of information quality were shown in Figure B.2, described in Figure B.3 and represented more dynamically and practically through the Gear for Analyzing Information Quality software.

This study is inductive. From the observations made at the five companies under study, the Typologies of DPS content-based versioning actions were developed, followed by the Framework of versioning actions for DPS and the Gear for Analyzing Information Quality. A limitation of this study is the non-application and verification of these artefacts in the field by teams responsible for managing the DPS life cycle. This aspect is characterized as an opportunity to continue the research.

Appendix A. Organizations that participated in field interviews

Below are described the five organizations that participated in field interviews.

Firm: **Totvs** Industry: Software
URL: http://en.totvs.com/
Description: Founded in 1983, Totvs is the largest software producer in Latin America and the sixth in the world in the development of integrated management software. Over the last decade it has acquired over 50 software developers and currently offers a large portfolio of corporate information systems. Totvs currently employs around 12,000.

Firm: **DEXTRA** Industry: Software
URL: http://www.dextra.com.br/
Description: Founded in 1995, Dextra develops customized software to order for clients in a variety of industries. It employs around 80 specialized personnel.

Firm: **SIMWORX** Industry: R&D
URL: http://www.simworx.com.br/en
Description: Founded in 1997, Simworx develops numeric simulations for the analysis of physical phenomena, especially for oil and gas exploration. It offers its simulations as software packages which fulfill specific functions such as simulators of well productivity, simulators of water injection for fracking, and simulators for diverse drilling operations. Simworkx employs about 20 people.

Firm: **SARAIVA LIVREIROS EDITORES** Industry: Publishing
URL: http://www.editorasaraiva.com.br/
Description: Founded in 1914, Saraiva creates and distributes content for the primary, secondary and college education markets. Its educational solutions incorporate diverse technologies such as adaptive learning and subscription digital libraries as well as content and platforms for distance learning. It owns 115 brick and mortar stores in 17 Brazilian states, making it the largest book and entertainment retailer in Brazil. It markets its own dedicated e-reader, the "Lev". Saraiva employs around 6000.

Firm: **EDITORA ATLAS** Industry: Publishing
URL: http://www.editoraatlas.com.br/
Description: Founded in 1944, Editora Atlas has published over 3000 titles in Accounting, Economics, Management, Law, Social Sciences, Quantitative Methods and Information Sciences. It employs about 200.

Appendix B. Examples of support instruments for application of the framework

In this section, we present three figures which aid DPS managers to apply the "Framework of versioning actions for DPS" to the analysis of possible versioning actions. The first of these, Figure B.1, describes thirteen dimensions of information quality in a less theoretical and more pragmatic way, using questions. This directs the attention of managers and specialists to relevant aspects to be considered. Figure B.2 describes 32 interactions between the 13 dimensions of information quality described in Figure B.1 while these 32 interactions are described in Figure B.3. The last two figures (2 and 3) help to guide those in the session to the importance of considering systemic relations between dimensions in order to avoid partial or simplistic analyses.

Before displaying and describing the matrix of interactions between dimensions of information quality (Figure B.2), the manager should explain that the matrix does not consider all of the possible interrelations between dimensions and that the relations may not be applicable to all organizational and technological contexts. We present some interactions in order to illustrate the systemic effects that exist between dimensions of information quality. Beyond the completeness and accuracy of the interactions between dimensions, the logical abstraction that we propose seeks to sensitize participants to the need to reflect upon the interactions between the dimensions of information quality before deciding on a DPS intervention.

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Dimension of Information Quality	Principal Aspect to be Analyzed
Accuracy	Is the information faithful to the facts that it represents?
Authenticity	Is the information presented in the same way it was originally communicated by the primary source that generated it, or was it subject to additional work such as transcription, translation or editing?
Availability	Is the information easily accessed by those who have a right to it?
Comprehensiveness	Is the information that the target audience requires complete, without additional unnecessary information?
Concurrency	In how many minds, physical or virtual locations is the information available?
Confidentiality	Is the information accessed only by those who have a right to it?
Convenience	Is the information easily processed or manipulated by its target audience?
Identifiability	Is the way that the information is identified representative, relevant and faithful to its content?
Integrity	Is the information integral, whole, or is it corrupted or adulterated?
Preciseness	Is the information sufficiently detailed to be used immediately?
Reliability	Is the source of the information considered credible by the target public?
Timeliness	Is the information constantly generated or updated at intervals considered adequate by the target audience?
Uniqueness	Is similar information easily found or is it difficult to obtain to the point of being seen as scarce or rare?

Fig B.1. Description of the thirteen Dimensions of Information Quality.

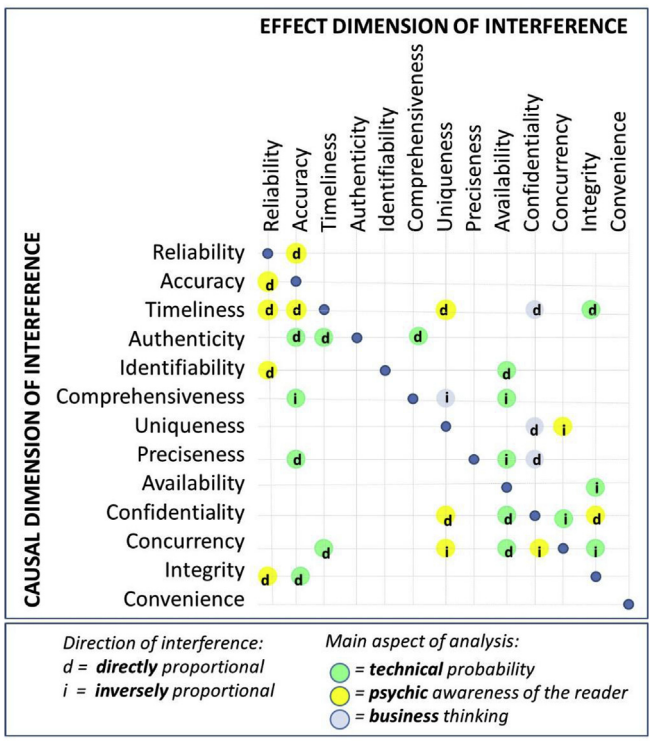

Fig B.2. Matrix of Interactions between dimensions of information quality.

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[1] Reliability X Accuracy
• The less the reader trust the source and / or the generation method of information (Reliability), less inclined to believe that the information is truthful (Accuracy);
• The more the reader trust the source and / or the generation method of information (Reliability), most tend to believe that the information is truthful (Accuracy).
[2] Accuracy X Reliability
• The higher perception of Accuracy by the reader, higher the Reliability on source of information;
• The lower perception of Accuracy by the reader, lower Reliability on source of information.
[3] Timeliness X Reliability
• The more Timeliness the information, the better, increasing the prestige of the source and making it more Reliability;
• The less Timeliness the information, the worse, undermining the image of its source and making it less Reliability.
[4] Timeliness X Accuracy
• The more information is Timeliness it tends to be Accuracy (updated and hence correct);
• The less Timeliness is the information it tends to be less Accuracy (outdated and therefore wrong).
[5] Timeliness X Uniqueness
• The more information Timeliness, the harder it is to find, i.e., more Uniqueness considering that there are high costs to keep information current (it is most common to find dated information—static reports);
• *Note that the hypothesis on the reverse situation does not exist (less current, less rare), whereas there are various information that remain rare (Uniqueness), although not updated (Timeliness).*
[6] Identifiability X Reliability
• The worse the definition of information or the Identifiability, the lower the Reliability of its source;
• The more well defined the information or the Identifiability, the greater the Reliability of its source.
[7] Uniqueness X Concurrency
• The more Uniqueness of information, the smaller the number of copies (physical or digital), i.e., Concurrency of information;
• The less Uniqueness of information, the greater the number of copies (physical or digital), i.e., Concurrency of information.
[8] Confidentiality X Uniqueness
• The higher Confidentiality, the smaller the number of people accessing and hence the greater is the perception of the information Uniqueness;
• The lower Confidentiality, the greater the number of people accessing and hence the lower the perception of the information Uniqueness.
[9] Confidentiality X Integrity
• The greater Confidentiality, the lower the amount of people accessing and lower the risk of misuse or deliberate change, resulting in greater Integrity of information;
• The lower the Confidentiality, the greater the number of people accessing and increased the risk of misuse or deliberate change, resulting in lower Integrity.
[10] Concurrency X Uniqueness
• The smaller the number of copies (physical or digital) i.e., Concurrency of information, greater the Uniqueness;
• The greater the number of copies (physical or digital) i.e., Concurrency of information, lower the Uniqueness.
[11] Concurrency X Confidentiality
• The lower the number of copies (physical or digital) i.e., Concurrency of information,, the less accessible it is and therefore greater the Confidentiality;
• The greater the number of copies (physical or digital) i.e., Concurrency of information, it becomes more accessible and therefore lower Confidentiality.
[12] Integrity X Reliability
• The less Integrity of the information, the lower the Reliability of its source (which did not know to preserve the information integrity).
• *Note that the opposite hypothesis is not true: integrity is expected; full Integrity of information does not alter the Reliability of the source.*
[13] Timeliness X Integrity
• The more Timeliness the information, the more recently created, the less time to be exposed to risk; consequently, greater the likelihood of information Integrity;
• The less current the information, the less recently created, the greater the time exposed to risk; consequently, less the likelihood of information Integrity.
[14] Authenticity X Accuracy
• The more Authenticity of information (primary source) less involvement of intermediaries (translators, editors who heard etc.), therefore lower probability of distortions and greater probability of Accuracy of the information;
• The less Authenticity of information (secondary or third source) greater the involvement of intermediaries (translators, editors who heard etc.), therefore greater the probability of distortions and lower the probability of Accuracy of the information.
[15] Authenticity X Timeliness
• The more Authenticity of information (primary source) more direct and faster the communication and therefore more Timeliness of the information;
• The less Authenticity of information (secondary or third source) more action and time are necessary and therefore less Timeliness of the information.

Fig B.3. Description of the 32 relations between the dimensions of information quality.

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[16] Authenticity X Comprehensiveness • The more Authenticity is the information (primary source), the greater the likelihood that the information is Comprehensiveness (easier is speaking about various aspects); • The less Authenticity is the information (secondary or third source), the lower the probability that the information would be Comprehensiveness (more difficult is speaking about various aspects).
[17] Identifiability X Availability • The more well defined the information or the Identifiability, the easier it is to be found and greater the Availability; • The worse the definition of information or the Identifiability, the harder it is to be found and lower the Availability.
[18] Comprehensiveness X Accuracy • The greater the Comprehensiveness in extent (wordiness), the easier it will be to generate contradictions and therefore the lower the Accuracy; • The less the Comprehensiveness in extent (cohesion), the more difficult it will be to generate contradictions, therefore, greater the Accuracy.
[19]Comprehensiveness X Availability • The greater the Comprehensiveness of the content, the larger the physical or digital representation of the information (for instance in Mb), more difficult access, and less Availability; • The less the Comprehensiveness of the content, the smaller the physical or digital representation (for instance in Mb) and the easier its access and Availability.
[20] Preciseness X Accuracy • The less Preciseness the information rather far from reality and, therefore, less Accuracy; • *Note that the opposite hypothesis is not true: high precision does not make the information more Accuracy.*
[21] Preciseness X Availability • The more Preciseness of information, higher the physical / digital representation (for example, in Mb), therefore more difficult access and lower Availability; • The less Preciseness of information, lower the physical / digital representation (for example, in Mb), therefore easier access and higher Availability.
[22] Availability X Integrity • The less Availability of the information, less access and lower exposure to risk; consequently, the greater is the Integrity of the information; • The more Availability of information, more access and greater exposure to risk; consequently, the lower is the Integrity of the information.
[23] Confidentiality X Availability • The greater Confidentiality, the lower the amount of people accessing and lower the competition for resources (physical or computer); consequently, the greater the probability of Availability of information; • The lower Confidentiality, the greater the number of people accessing and greater competition for resources (physical or computer); consequently, the lower is the probability of Availability of information.
[24] Confidentiality X Concurrency • The higher Confidentiality, the smaller the number of people accessing and therefore fewer copies Concurrency are needed (low amount of physical or digital copies of information); • The lower confidentiality is, the greater the number of people accessing and hence more copies are required Concurrency (larger amount of physical or digital copies of information).
[25] Concurrency X Availability • The smaller the existence of copies (physical or digital) i.e., Concurrency of information, the greater the competition for the same and, consequently, the less Availability; • The greater the existence of copies (physical or digital) i.e., Concurrency of information, the lower the competition for the same, and hence the greater is its Availability.
[26] Concurrency X Integrity • The greater the existence of copies (physical or digital) i.e., Concurrency of information, the greater the difficulty of updating and increases the risk of tampering, therefore lower Integrity; • The lower the existence of copies (physical or digital) i.e., Concurrency of information, the smaller the difficulty of updating and reducing the risk of tampering, therefore greater Integrity.
[27] Integrity X Accuracy • The smaller the Integrity of information, or the higher adulteration, less Accuracy of the information. • *Note that the opposite hypothesis is not true; greater integrity does not alter the Accuracy of the information.*
[28] Timeliness X Confidentiality • The more Timeliness the information, the more attractive to the market, therefore the more Confidentiality (access controlled and paid for); • The less Timeliness the information, the less attractive to the market, therefore the less Confidentiality (access facilitated).
[29] Comprehensiveness X Uniqueness • The less the Comprehensiveness in extent, the harder it will be to find, and therefore greater the Uniqueness; • The greater the Comprehensiveness in extent (wordiness), the less difficult to be found and, therefore, lesser Uniqueness.
[30] Uniqueness X Confidentiality • The more Uniqueness of information, more attractive it is for the market, so greater the Confidentiality (controlled and paid access); • The less Uniqueness of information, less attractive it is to the market, thus lower Confidentiality (easy access).
[31] Preciseness X Confidentiality • The more Preciseness information, the more attractive to the market, so higher Confidentiality (controlled and paid access);
• The less Preciseness information, the less attractive to the market, so less Confidentiality (easy access).
[32] Concurrency X Timeliness • The greater the existence of copies (physical or digital), i.e., Concurrency of information, the greater the difficulty and the longer the time for updating, thereby decreasing the Timeliness; • The smaller the existence of copies (physical or digital), i.e., Concurrency of information, the lower the the difficulty and time required to update, thereby increasing the Timeliness.

Fig B.3. (*continued*).

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