STUDIA OECONOMICA POSNANIENSIA 2017, vol. 5, no. 12

DOI: 10.18559/SOEP.2017.12.8

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THE MODELLING OF DATA DEPENDENCIES FOR EXECUTABLE BUSINESS PROCESSES

Abstract: The correctness, effectiveness, and efficiency of the business processes supported by information systems are becoming vital to organizations. Poor data quality may be the cause of losses related to organizational processes. There are numerous methods to assess and improve the quality of data within information systems. However, these methods often do not address the original source of these problems.

This article presents a conceptual solution for dealing with the data quality issue within information systems. It focuses on an analysis of business processes being a source of requirements for information systems design and development. This analysis benefits information quality requirements, in order to improve data quality within systems emerging from these requirements.

Keywords: data/information quality, business process design, information system design, IS/IT alignment, data quality dimensions.

JEL Classification: D83; L15; M15.

MODELOWANIE ZALEŻNOŚCI MIĘDZY DANYMI W WYKONYWALNYCH PROCESACH BIZNESOWYCH

Streszczenie: Poprawność, skuteczność i efektywność procesów biznesowych wspomaganych przez systemy informatyczne stają się istotne dla organizacji. Słaba jakość przetwarzanych danych może prowadzić do dużych strat.

W artykule przedstawiono koncepcję rozwiązania dla poprawy jakości danych w procesach biznesowych, koncentrującej się na źródle tych problemów. Dotyczy ona analizy procesów biznesowych w celu określenia wymagań dotyczących projektowania i rozwoju systemów informatycznych wspomagających wspomniane procesy. W szczególności punktem zainteresowania jest analiza relacji między danymi występującymi w procesach oraz opracowanie reguł umożliwiających automatyczną walidację modeli procesów z perspektywy przepływu danych.

Słowa kluczowe: dane/informacje, jakość, modelowanie procesów biznesowych, projektowanie systemów informatycznych, wymiary jakości systemu IT.

1. Introduction

1.1. Research motivation

Nowadays, to survive in a highly competitive and uncertain environment, organizations face numerous challenges in efficiently and effectively executing their data rich business processes, and therefore require strong Information Systems (IS) – business alignment [Ullah and Lai 2011; Mondragón et al. 2013]. To sustain themselves in the market, these organizations need to find ways to better manage and adapt their business processes in response to changes, trends and developments in the business environment [Stalk, Evans and Shulman 1992; Daoudi and Nurcan 2007; Sun and Zhao 2013]. According to Gartner Group [2013], companies must adjust these business processes inter alia to reduce costs, conserve cash and out-innovate their competitors. In order to meet customer demands, organizations have to design their business processes in an appropriate way. In particular, four essential process competencies have been discussed in operations management: process cost, process flow time, process flexibility, and process quality. Process quality refers to the ability of a process to produce and deliver quality products [Heravizadeh, Mendling and Rosemann 2009].

Business processes produce and use big amounts of data and are based on so called information flows [English 2001]. According to Aalst [2005, p. 198], "many business processes leave their 'footprints' in transactional information systems". Here, a process refers to a sequence of activities which are performed in coordination in an organizational and technical environment [Weske 2012]. These activities jointly realize a business goal, reflected by data items in process representation [Soffer and Wand 2007]. Such processes, in practice, can suffer

from quality issues such as a poor level of data quality along their activities or in communication between processes.

The correctness, effectiveness, and efficiency of business processes supported by information systems are becoming vital to organizations [Aalst 2008]. There is an evident need to incorporate data quality considerations into the whole data cycle, encompassing managerial/governance as well as technical aspects [Blake and Mangiameli 2011; Sadiq 2013]. While the need for the alignment of business processes and their support systems has been emphasized and discussed, there is still a great need for systematic approaches and tools regarding data quality [Madnick et al. 2009; Mondragón et al. 2013; Zhu et al. 2014].

1.2. Problem description

Recent studies [Nasir and Sahibuddin 2011; Ibrahim et al. 2013; Nwakanma et al. 2013; Rajkumar and Alagarsamy 2013; Chandrasekaran, Gudlavalleti and Kaniyar 2014; Standish Group 2014] show that many information systems' projects have "challenged" or "failed", in the combination of budget and/or schedule overruns and/or for not meeting users' requirements. In addition, according to the KPMG Survey (2008), on average about 70% of all IS/IT related projects fail to meet their objectives. Even when these projects are completed, many are no more than a mere shadow of their original specification requirements [Standish Group 2014].

A substantial part of system development failures can be attributed to problems that arise during system analysis. Hence, understanding and improving system analysis and design are central to the research mission of the Information Systems (IS) discipline [Iivari, Parsons and Wand 2006]. Other empirical studies [Kappelman, McKeeman and Zhang 2009; Moody 2005; Nasir and Sahibuddin 2011; Nwakanma et al. 2013; The Standish Group 2014] show that more than half of the errors which occur during system development are a result of inaccurate or incomplete requirements. In addition, unclear or poor requirements and errors in specifications are critical factors and the most common cause of failure in system development projects [Kaur and Sengupta 2011; Rajkumar and Alagarsamy 2013].

Data is a critical asset for every organization (Govil and Govil 2008; Redman 2004] and it is important for decision making. The quality of the data affects the quality of decisions [Frank 2008; Xingsen et al. 2009; Ofner, Otto and Österle 2012; Cappiello et al. 2013]. Data quality (DQ) is a term which describes the quality of the content of information systems and the degree to

which a set of characteristics of data fulfils the requirements and is viewed as "fitness for use" by information consumers [Wand and Wang 1996; Wang and Strong 1996; Strong, Lee and Wang 1997; Wang 1998; Caro et al. 2012; Zhu et al. 2014; Laranjeiro, Soydemir and Bernardino 2015]. Wang and Strong [1996] defined the set of dimensions of data quality from the consumer's point of view by means of a systematic multistage survey study. Prior to this research, data quality had been characterized by attributes identified via intuition, and selected unsystematically by individual researchers [Zhu et al. 2014].

As data quality is crucial to organizational success [Madnick et al. 2009; Otto 2011; Glowalla and Sunyaev 2013], many enterprises today are in the process of establishing Corporate Data Quality Management (CDQM) to meet their strategic business requirements [Falge, Otto and Österle 2013]. Data quality directly affects the effectiveness and efficiency of business processes and plays a major role in customer and user satisfaction [English 2001]. Moreover, data quality improvement often requires changes in processes and organizational behaviours [Zhu et al. 2014]. Problems with the quality of the data can have catastrophic consequences [Ofner, Otto and Österle 2012; Woodall, Borek and Parlikad 2013].

Poor data quality is a primary reason for 40% of all business initiatives failing to achieve their targeted benefits [Gartner Group 2011]. In fact, many research reports show that huge amounts of resource and money are spent in organizations due to poor data quality or to improve the quality of the data [Glowalla and Sunyaev 2013; Laranjeiro, Soydemir and Bernardino 2015]. Furthermore, as more business processes become automated, data quality becomes the rate limiting factor for overall process quality.

Generally, the idea of integrating data quality issues into business process models as such is not new. Different approaches and measures have been developed over the years to contend with information quality assessment needs, but the notion of information quality within process modelling and design methods has received relatively little attention [Blake and Mangiameli 2011; Ofner, Otto and Österle 2012]. This research concentrates on the linkage between two topics–information quality and business process modelling, since there is still a great need for methods and models for dealing with quality of information flows in business processes [Mondragón et al. 2013; Zhu et al. 2014]. The focus is on the importance of information quality dimensions for the successful execution of business processes. Furthermore, the research aims to investigate and analyse the business process design and validation using information quality requirements, by developing a conceptual model and tool for business process analysts, designers and practitioners. The tool enters data quality requirements

into business processes design to check and validate a business process, in order to achieve the defined process goals (and the desired level of quality).

To the best of our knowledge, these two issues have not yet been discussed sufficiently, and there is a lack of systematic approaches, models and tools with regards to data quality.

1.3. Methodology

The paper describes the initial research results achieved by the authors. It is based on comprehensive state-of-the-art of papers and projects that deal with the concept. In the first step, the authors identified the recent research papers on business process modelling and software engineering that deal with the issue of quality (including data quality). To this end, the digital libraries of ACM, IEEE and SpringerLink were searched. The irrelevant papers have been sorted out in a multistage procedure. The results of the database search were assessed regarding their potential relevance by means of search expression. We analysed only publications from the last ten years, as older ones were considered out-dated.

Then, we applied modelling to summarize the related research findings and develop a conceptual model that will be utilized in our own research. The created model was to depict what are the relations of data entities with elements of a business process. These relations will be the basis for automatic development of rules for checking quality of the business process model w.r.t. data. The model was initially tested in a Case Study to prove that the relations catalogue is complete. This is an introduction into research on checking the quality of numerous instances of the described process.

The structure of this paper is as follows: section 2 includes an overview of related work and literature review. Section 3 presents the proposed solution. Section 4 addresses the case study and research challenges. The final section presents the conclusions and summary.

2. Related work

In the past two decades many researchers have addressed the problem of data quality from different perspectives. Xu et al. [2002] developed a framework for identifying data quality issues in implementing ERP systems. Other researchers [e.g. Fisher and Kingma 2001; Fisher, Chengular-Smith and Ballou 2003; Jung 2004; Slone 2006] investigated the impact of data quality on the performance of organizational units (including individuals), evaluated the

costs and benefits of data quality initiatives, and assessed the impact of data quality on operations and decision making.

DeLone and McLean [1992, 2003] presented models for evaluating the success of the implementation of information systems, where information quality is one of the central dimensions. They reviewed the existing definitions of IS success and their corresponding measures, and classified them into six major categories.

Other researchers [Wang 1998; Kahn, Strong and Wang 2002; Pierce 2004] claim that an analogy exists between quality issues in product or service manufacturing and in information manufacturing. They suggest assessing the information quality from the product or service quality perspectives, using methods and techniques like total data quality management (TDQM) based on the total quality management (TQM) approach. These perspectives are limited, since they do not focus on process requirements and the design stage, and none of them links to defined soft goals for implementation and their achievement by the process.

A type of this analogy, however in a different form, is suggested by Wand and Wang [1996] in terms of process design. They argue that similarly to the way the quality of a product depends on the process by which the product is designed and produced, the quality of data depends on the design and production processes involved in generating the data. They also emphasize that to design for better quality, it is necessary to first understand what quality means and how it is measured. Sun et al. [2006], and later Sun and Zhao [2013] in their continued study, emphasized the importance of a data-flow perspective in workflow analysis. They argue that given a correct process sequence, errors can still occur during workflow execution due to incorrect data-flow specifications, and no formal methodologies are available for systematically discovering data-flow errors in a workflow model. They presented a data-flow perspective for detecting data-flow anomalies based on concepts of data dependencies in processes.

Another approach to cope with this issue is to improve, redevelop, and revise the data quality perspective of the business processes affected, since the major business processes are supported, controlled and/or monitored by information systems as mentioned above. For example, Lee et al. [2004] investigated data quality improvement initiatives at a large manufacturing firm, which iteratively adapted technical data integrity rules in response to changing business processes and requirements. Cao and Zhu [2013] investigated inevitable data quality problems resulting from the tight coupling effects and the complexity of Enterprise Resource Planning (ERP) systems in their case study in China. The findings show that organizations that have successfully implemented ERP can still experience certain data quality problems, and the efficient operation of ERP systems largely depends on data quality. They

identified major data quality problems in data production, storage and maintenance, and utilization processes. The researchers also analysed the causes of these data quality problems by linking them to certain characteristics of ERP systems within an organizational context.

Soffer [2010] explores the inaccuracies of data in situations where the information system does not truly reflect the state of a domain where a process takes place. The mentioned research discusses the potential consequences of data inaccuracy. The work also provides the foundation to support the design of robust processes that avoid problems related to data inaccuracy.

Glowalla and Sunyaev [2013] examined the application of process-driven data quality management (PDDQM) techniques (such as Workflow and DFD) based on a review of the literature. They provided two options to integrate data quality into existing process models: within-model integration and across-model integration. Within-model integration allows enhancing existing process models with data quality information by integrating data quality checks. Across-model integration provides a new process model with an information product-centric perspective, linking it to existing models. Furthermore, the researchers also examined the impact of the integration approach on the models' complexity and patterns for complexity reduction [Glowalla and Sunyaev 2013].

A lot of research efforts have been devoted to the design of process models and the development of process-based information systems to support their execution. These all depend on the quality of the representation of data/information in the information system [Soffer 2010]. The alignment between business needs and IS/IT capabilities is therefore still a prominent area of concern. Moreover, efforts have been made in defining methods and techniques for evaluating and measuring information quality. These efforts focus on measuring the properties of information, but little attention and few studies have addressed the notion of information quality in the context of business process design and validation outcomes [Ofner, Otto and Österle 2012]. Moreover, such information quality methods or frameworks should derive from and rely on fundamental principles.

The existing literature regarding business processes design and validation lacks methods and models for dealing with quality of information flows in business processes. Existing design methods in business process management remain manual and require a lot of effort, and therefore result in the inefficiency of design tasks and potential errors in workflow models [Sun and Zhao 2013]. The focus of research attention [e.g. Sadiq et al. 2004; Sun et al. 2006; Trcka, Aalst and Sidorova 2009] on combining data flow with activity flow, i.e. data-aware process design, has been undertaken to some extent to avoid design time errors [Soffer 2010; Cappiello et al. 2013]. This issue is crucial when it comes to

numerous instances of business processes models, which bring us to the world of Big data analysis and the additional challenges emerging from this fact.

This research is concerned with the process design and validation activities to reflect the requirements from information systems as represented in the real-world. Therefore, a framework is required to describe the design and validation activities in terms of information quality within organizational processes, and to overcome the main shortcomings.

3. Solution proposal

3.1. Process representation–background

Process representation is said to be a representation of a process or real-world system behaviour, if observation at a given time enables to infer the state of the real-world system (at the same or at a different time). Changes happening in the real-world should be reflected in data values appearing in information systems. Hence, we can operate over the real-world and change its state based on its reflection. Business process models can be used to make the process explicit as-is. However, a gap is created between the requirements engineering process to-be and the as-is process. To overcome this gap and to acquire an optimal fit between the designed process and its planned outputs, and finally to achieve a soundness of the processes used for the engineering of future information systems, there is a great need for a structured process to lead and direct the practitioners.

Business process design is based on a set of requirements which are collected and analysed by professional process analysts. Processes in practice can suffer from quality aspects such as poor design or poor level of data quality within their activities or in communication between different processes. Consequently, a process can fail and achieve undesired and poor results as outcomes. Furthermore, designing a process without taking quality considerations into account is probably going to fail as discussed above. The poor outcomes are a result of a low level of strictness in DQ dimensions, since there are dependencies over data values in a process. Moreover, the data flow in processes and along their activities is the basis for the representation of data requirements in IS stage. Hence, if we want to ensure that IS works properly and thus presents desired data values in high quality, we have to check the values of these data items before recording them to IS to ensure DQ and the presentation of desired values.

Basically, an information system, as a means for real-world representation, can suffer from quality aspects such as a poor level of representation, i.e. inconformity between the real-world system behaviour and its representation as a process or in an information system.

3.2. The conceptual model

Based on the literature review discussed in the previous section, we identified the artefacts of the process modelling as e.g. process and activity. Then, we built a conceptual model of the process to summarize the terms, constructs, and their relationships by using the UML class diagram (Figure 1). The developed model will be further applied for the identification of relations of different data constructs within the process. This is to enable the development of rules for automatic validation of the business process against the data flow quality requirements. A description of the model can be seen below.

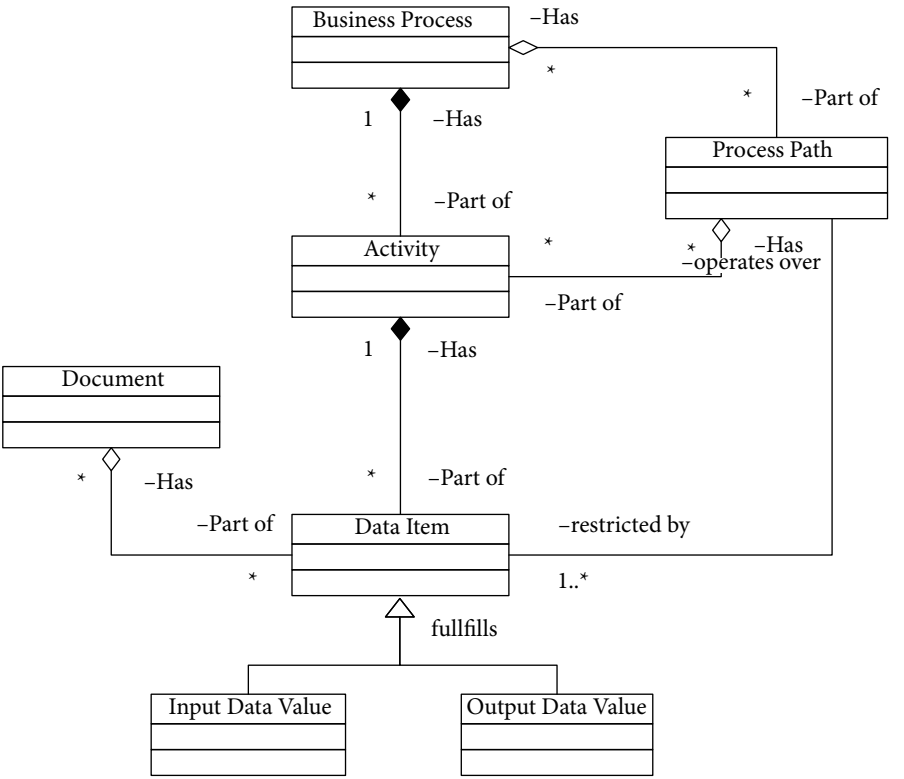

Figure 1. The conceptual model

A business process refers to a set of activities. The process specifies which steps are required and in what order they should be executed. It is also known as: routing definition, procedure and workflow script [Aalst 2004], e.g. purchase order, tax declarations and insurance claims processes. In general, the business process includes cases (also named process instance or job), which are handled and need to be processed by following the process definition, e.g. a customer order, a job application, an insurance claim, a building permit, etc. Each case has a unique identity.

The activity (also named step, task, process element, or work-item) is a logical unit of work, e.g. typing a letter, stamping a document, and checking personal data [Aalst 2004]. Basically, an activity contains (processes) one or more data items. A data item is a data element or a character in a document that consists of values, which are represented as fields in a database. Data value is raw data in a data item, i.e. a collection of characters, and can be given any text, numeric, date or Boolean value, etc. Any data value can be an input for an activity or an output of an activity. Document is the name for a collection of data items (e.g. forms, applications, certificates, enquiry). It is similar to the data entity–it is an object of data in a business process which is stored in a database that can have relationships with other entities.

A process path is one possible trajectory or route within a business process that includes a sequence of activities in an order from the initial activity to the final activity that have dependencies between them. In fact, a trajectory in a business process describes the sequence of data items by the dependence on data values.

Basically, we distinguish between two main types of dependencies: mandatory dependency and a conditional dependency. Mandatory dependency concerns the situation where the data value of data item B is affected by the data value of data item A, and the value of data item A needs to be known. If the data value of data item A in the representation is unknown, then the process will not be properly executed. For example, if we want to calculate the insurance premium (data item B) for shipping cargo in export service we need the cargo volume value (data item A) in representation as a mandatory value. Without this value (i.e. cargo volume) the process is expected to be in a deadlock situation. In other words, there is at least one transformation in a process' laws that cannot execute properly, if A is unknown.

Conditional dependency is a dependency in which the value of data item B is affected by the value of data item A, but uses it under some conditions, i.e. "conditionally depends on". The process may be executed without using this value; hence, data item A in a representation can be unknown. For example, approving a customer order (data item B) conditionally depends on receiving

a down payment from a customer (data item A), conditioned by the customer's risk level. If the customer's risk level (another data item) is low and there is no down payment received, i.e. the down payment value (data item A) in the representation is unknown yet or null, the process is still in progress since the customer risk level is low.

The identification of these dependencies is especially important while the development of rules which enable the automatic validation of a business process based on its model. The case study will further elaborate on the issue.

4. The case study

The case study which validated the model is based on the process of international forwarding and moving industry. The global freight forwarding and moving industry is vast, both in terms of the market size and the large number of people employed in it. It is also considered as one of the most important industries today and the most influential on logistics supply chain management [Manners-Bell 2014]. According to the European Freight Forwarders Association (EFFA), the term "freight forwarding industry" refers to a set of global logistics services for the exporter and importer in moving cargo to an overseas destination, which include services of any kind relating to the carriage, storage, handling, packing etc., using modern information and communication technology. Basically, the management and operation of the process is done by an international freight forwarder [Manners-Bell 2014].

An international freight forwarder is an agent for the exporter and importer in moving cargo to an overseas destination. These agents are familiar with the export and import rules and regulations of foreign countries, the methods of shipping, and the documents related to foreign trade. The global service includes sub services such as carriage and inland moving, storage, warehousing, freight consolidation, cargo insurance and more. Once the order is ready for shipment, freight forwarders should review all documents to ensure that everything is in order. This is of particular importance with letter of credit payment terms. They may also prepare the bill of lading and any special required documentation. After shipment, freight forwarders can route the documents to the seller, the buyer, or to a paying bank. They can also make arrangements with customs brokers overseas to ensure that the goods comply with customs export documentation regulations. A customs broker is an individual or a company that is licensed to transact customs business on the behalf of others.

Our case study focuses on the sales process of import services at Ocean Group Ltd. – an international forwarding company with more than 70 years

of experience in the forwarding of cargo to all corners of the world. Figure 2 presents the process as the UML Activity diagram. It should be noted that the process has numerous instances and even simplified, has many different data items associated.

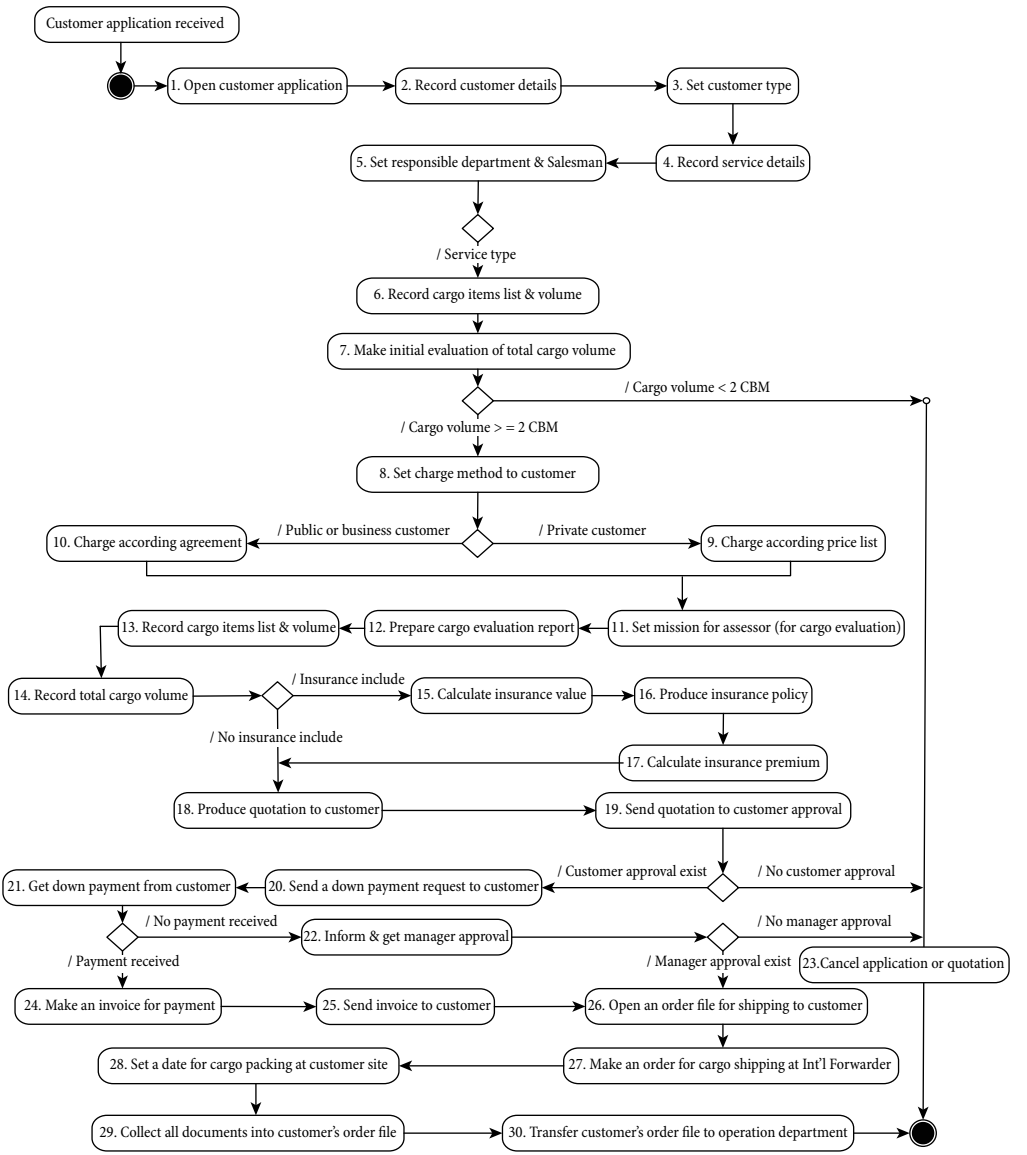

Figure 2. The case study UML Activity diagram–Sales process of Sea Export service

Table 1 presents the list and details of all data items in our case study.

Table 1. Case study data items

Data item	Description	Examples of data values
D1	Customer application status	Received/Closed/Cancelled
D2	Customer application no.	String
D3	Application date/time	System Date/Time
D4	Customer name	String
D5	Customer address	String
D6	Customer type	Private or Business
D7	Degree of risk	Low/High
D8	Service type	Export/Import/Storage
D9	Shipping destination (name of state)	Countries list
D10	Port at destination	Ports list
D11	Shipping requested date	Date
D12	Insurance include	Yes/No
D13	Responsible department & salesman	Export/Import/Storage
D14	Cargo items list of customer	Items list
D15	Initial evaluation of cargo volume	Amount value
D16	Mission for assessor	Opened/Closed/Cancelled
D17	Assessor cargo evaluation report	Items list report
D18	Total cargo volume	Amount value in CBM (Cubic Meter)
D19	Charge method per CBM (Cubic Meter)	Charge according agreement or price list
D20	Total charge value	Amount value in US$
D21	Insurance policy no.	String
D22	Total insurance value	Amount value in US$
D23	Insurance premium value	Amount value in US$
D24	Quotation to customer	Opened/Approved/Cancelled (Form)
D25	Customer approval	Yes/No
D26	Down payment request	Yes/No
D27	Down payment received	Yes/No
D28	Customer invoice	Form
D29	Manager approval	Yes/No
D30	Customer order file	Opened/Closed/Cancelled
D31	Shipping order at Int'l Forwarder	Date
D32	Packing date at customer	Date

Based on the Activity Diagram of our case study described above, we built a matrix summarizing all dependencies that exist between the various data items listed above and their values in the selected process. The matrix includes the

two-category classification of the mandatory and conditional dependencies. If there is a dependency between data items it is identified as 1; if no dependency exists it is marked as 0. To obtain a correct matrix, we identified all possible paths in a process distinguishing between mandatory and conditional dependencies. The size of the matrix depends on the number of data items within the process.

The matrix can help us identify the type of potential failure dependencies among the data items with respect to various data quality dimensions generated by Wang and Strong [1996], e.g. accuracy, completeness, timeliness etc. We name these potential failures as data quality deficiencies. A data quality deficiency is an inconformity between the view of the real-world system that can be inferred from a process representation and the view that can be obtained by directly observing the real-world system. For example, a dependency between data items exists for a shipping destination and port at destination and recording a wrong data value about a requested destination can lead to process deficiencies or failures. The potential results of these deficiencies are: first, the customer cargo will be delivered to the wrong destination, and second, the wrong value about a requested destination can lead to issuing wrong prices to a customer. Another example of a dependency between data items exists in the assessor evaluation report, i.e. cargo items' list report and total cargo volume evaluation. Missing items in a cargo items list can lead to process deficiencies or failures and the potential results of this deficiency can be (1) a wrong value in a total cargo volume evaluation and (2) wrong charge in quotation according the total cargo volume.

Processes in practice can suffer from quality aspects as mentioned above. Such an analysis at the design stage can help business process analysts and practitioners to predict potential failures in the process earlier, to fix these issues and prevent further failures within the information system design process. The identification of data dependencies and the generalization of the types of these dependencies, especially w.r.t. missing data or not reflecting the initial data model defined for the process, may result in development of rules enabling for the automatic checking of the business process model and improving some of the explained problems. This is the focus of the further research of the authors.

5. Conclusions and summary

The literature regarding business processes design and validation lacks methods and models for dealing with the quality of information flows in business

processes. Existing design methods remain manual and result in inefficiency in design tasks and potential errors in workflow models. The focus of research attention has been on the data-aware process design and it has been investigated already to some extent, yet avoided design time errors. Consequently, a process can fail and achieve undesired and poor quality results as outcomes. These outcomes are due to the low level of strictness about DQ dimensions, since there is dependency over data values in process. Furthermore, since our research is concerned with process design and validation activities, a framework is required in order to describe the design and validation activities, in terms of assuring information quality within organizational processes, and in order to overcome the main shortcomings.

The most significant theoretical contribution expected from this research is the creation of a linkage between information quality and business processes modelling combined to generate a framework, method and model for understanding the importance of information quality for the success of business processes; later on it will be a basis for IS requirements definition. As mentioned above, there is a remarkable lack of studies, methods and models in business process modelling and IS domains' literature, especially on theoretical frameworks that might help deal with information flow quality and reflect the requirements for information systems. Consequently, the contribution concerns the creation of a method or model for information quality, in order to analyse and validate processes in an organization.

The practical contribution of this research is providing processes designers, practitioners and IS workers with a usable and friendly framework and method, intended to develop attributes and dimensions for the evaluation and validation of information quality requirements in the IS development process at the analysis and design stages.

The expected outcomes from the application of the model and method (encompassing quality checking rules) based on our case study analysis are: first, the ability to identify potential failures at an earlier stage of the development of the process with respect to the dimensions of data quality. Second, preventing the implications of unidentified potential failures such as receiving the wrong decision(s) in a process and/or a waste of valuable time, unnecessary expense, or unnecessary work.

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