Architecture Viewpoint for Modeling Business Collaboration Concerns using Workflow Patterns

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Abstract: Businesses today rarely operate in isolation but must collaborate with others in a coordinated fashion. To address collaboration concerns, business analysts need to design business processes. Business process designs have a direct impact on the required software systems and the corresponding architectural design. Conversely, the architectural design imposes constraints on the business process designs. Unfortunately, business processes and software architectures are often designed separately leading to a misalignment between the two. To bridge this gap we propose the architecture collaboration viewpoint to be used by teams of business analysts and software architects when addressing business collaboration concerns. The collaboration viewpoint uses elements from business process and architecture viewpoints to provide new modeling artifacts for alignment. The design artefacts are mapping tables and workflow pattern diagrams that are used to identify misalignments and redesign the business processes. The viewpoint facilitates the communication between business analysts and architects. We illustrate the collaboration viewpoint for a food supply chain transparency system from a real industrial case study.

1 INTRODUCTION

Businesses today rarely operate in isolation but must collaborate with others in a coordinated fashion. To address collaboration concerns business analysts design business process models (BPMs) that integrate business activities across the collaborating organizations. BPMs have to be supported by underlying software systems, and therefore, they will have a direct impact on the required software systems and the corresponding architectural design. Conversely, the architectural design imposes constraints on BPMs, and as a consequence, an inherent, mutual dependency exists between these two sets of designs.

Business collaboration involves BPMs that span multiple organizations – which we hereafter refer to as *collaboration business processes*. When realizing collaboration business processes multiple software systems need to be taken into account. As a result, the mutual alignment of BPMs and architectural designs becomes very cumbersome. We define the difficulties associated in aligning the two designs as *business collaboration concerns*.

The current practice addresses business process concerns and architectural concerns separately, and sequentially – first the BPMs are designed, then the software architecture is designed using the BPM models as inputs. This approach is to an extent feasible if applied within the context of an individual organization. However, when dealing with multiple software systems the approach is not feasible due to the mutual dependency between business process models and the software architecture.

To address the problem we studied the existing modelling approaches. At present, two distinct sets of viewpoints are used to address business collaboration concerns. Various architecture viewpoints are used for modelling the structure of software systems and are hereafter referred to as *structural viewpoints*. Business process concepts and notations are used for modelling business processes and are hereafter referred to as *the business process viewpoint*. The structural viewpoints do not directly address business process concerns. Likewise, the business process viewpoint does not consider architectural concerns. As a consequence, a business-IT alignment problem arises. The alignment problem has been discussed in the context of individual organizations (Avison et al. 2004; Hong-Mei 2008; Bartens et al. 2014; Aversano et al. 2016) but not in the context of business collaborations.

In this paper we introduce the *collaboration viewpoint* for addressing business collaboration concerns and an iterative design approach for

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applying it. In the collaboration viewpoint we use architectural and business process viewpoints to provide new kinds of models with the corresponding method for applying them. We introduce mapping tables and workflow pattern diagrams as a means of identifying misalignment and redesigning the BPMs. The collaboration viewpoint is meant as means of enabling teamwork between software architects and business process analysts. The teamwork ensures that the business process and architecture views are well-aligned and feasible. We illustrate the viewpoint in real industrial case study for which a safety and quality transparency system for food supply chains is designed.

The remainder of this paper is organized as follows. Section 2 provides background information. Section 3 presents the case study used to demonstrate the collaboration viewpoint. Section 4 presents the collaboration viewpoint and a method for applying it. In section 5 the viewpoint is applied to the case study. In section 6 the related work is presented and in section 7 concluding remarks are made.

2 BACKGROUND

In this section we first discuss the background on software architecture, BPM, and workflow patterns.

2.1 Software Architecture

Software architecture defines the gross-level structure of a software system (ISO/IEC/IEEE 2011). Architecture modeling is important to enhance the understanding of the software system, support the communication among stakeholders, and guide the development process (Tekinerdogan 2014). A common practice to modeling architecture is using different architectural views that address the concerns of a specific group of stakeholders. Architectural views document the architectural design decisions from a specific viewpoint. That means, the designs documented in an architectural view follow the conventions, including models and notations, defined in the corresponding architectural viewpoint. From a given architectural viewpoint one or more architectural views can be designed (Clements et al. 2010; ISO/IEC/IEEE 2011).

In the literature, a number of viewpoints have been identified (Kruchten 1995; Hofmeister et al. 2000; Kruchten 2004; Lattanze 2008; Clements et al. 2010). The Views and Beyond (V&B) approach identifies three major viewpoints: *module*, *component-and-connector (C&C)*, and *allocation*. Module views deal with concerns related to implementation, such as, decomposition and generalization. The C&C and allocation viewpoints are structural viewpoints since they largely refer to the structure of the software system. The C&C views deal with the interaction structure, such as, data flow and message routing. The allocation viewpoint describes how software elements are allocated to the environment of the software system, such as, hardware or development team (Clements et al. 2010).

Recognizing that new viewpoints may be needed to address new kinds of concerns, the ISO/IEC 42010 standard for documenting software architecture (ISO/IEC/IEEE 2011) provides an extensible metamodel for defining new viewpoints.

2.2 BPM

A business process describes how the activities for achieving a particular business outcome are interrelated and how they are executed (Davenport and Short 1998). The process modelling approach has historically gained the attention of businesses when it was effectively used to address inefficiencies in functional organizations (Dumas et al. 2013). At its core, a BPM identifies the events of the business process and the series of activities that are triggered by them (Dumas et al. 2013). In practice, business processes are modeled by business analysts using visual modelling methods. The most prominent business processes modeling language is BPMN (Business Process Model and Notation) (OMG 2011). BPMs address business requirements, and as such, are inputs for the software architects as requirements that should to be addressed in the architectural design (The Open Group 2013).

2.3 Workflow Patterns

Workflow patterns are recurring problem-solution pairs that have been frequently used in business process modeling (Russell et al. 2006). In fact, BPMs can be viewed as being composed of workflow patterns. Since workflow patterns represent well-known problem-solution pairs, it is easier to describe, discuss and redesign a BPM by manipulating its constituent workflow patterns.

In the past, more than a hundred workflow patterns have been identified, categorized and cataloged (van der Aalst and ter Hofstede 2011). The most prominent categories are *control-flow*, *data-flow* and *resource-flow* workflow patterns (Van der Aalst et al. 2003). Control-flow patterns model the execution ordering of activities and are the basis for the patterns in the other categories. The data-flow patterns model how data flows along the flow of control. The resource-flow patterns model how work is assigned to resources (*e.g.* devices, people) following the flow of control. Appendix A provides the summary of workflow pattern categories and the workflow patterns in each category.

3 ILLUSTRATIVE CASE AND PROBLEM STATEMENT

In this section we use a case study from the FIspace business collaboration research project (Verdouw et al. 2014) to illustrate collaboration concerns and describe the problem statement.

3.1 Case: Transparency in Food Supply Chains

A food supply chain network is a collaboration linkage of a series of food operators that transform agricultural input products into finished food products. The food operators involved include farmers, a series of food processors and distributors, and retailers. In addition, mandated by food regulations, various third-parties are involved to guarantee the safety and quality of food. In Europe, for instance, recurring food scandals and crises have led to regulations that mandate centralized animal registry systems (EC 2000; EC 2004; EC 2015) and procedures for tracking and tracing of food products (EC 2002; EC 2007; EC 2011). Guaranteeing the safety and quality of food requires, among other things, the smooth flow of transparency data. Transparency in food supply chains refers to the ability to track and trace input, intermediate and finished food products along the supply chain. A conceptual model of a food supply chain network is depicted in Figure 1.

Transparency in food supply chains is a business collaboration concern that involves multiple food operators. Transparency involves two basic business processes: *data capture* and *data query*. These business processes are implemented within the individual food operators (*internal transparency*) as well as across the supply chain (*external transparency*). A software system that realizes internal transparency is referred to as *Internal Transparency System (ITS)*; the integration of internal transparency systems that realizes external transparency is referred to as *External Transparency System (ETS)*. Recently, the GS1 system architecture is increasingly being adopted (GS1 2015) in realizing both internal and external transparency systems. The

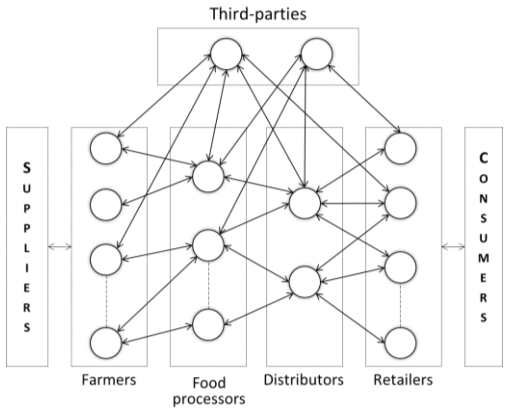


Figure 1: A conceptual model of food supply chain networks. (Circles represent the collaborating organizations; arrowed lines represent the flow of information through the network.).

EPCIS (Electronic Product Code Information System) specification (EPCglobal 2014), which is part of the GS1 System Architecture, provides generic data models and interface definitions for both data capture and data query business processes.

We elaborate business collaboration concerns using the data query BPM depicted in Figure 2. The BPM complies with the EPCIS specification, and is considered the preferred scenario. However, many food operators cannot support it. In the following, we first describe the BPM and then state the collaboration concern related to the model. The data query BPM is initiated when an end-user takes a food product—which can be input, semi-finished or end product—at a food operator and requests transparency data from the food operator's ITS. For the sake of simplicity we assume that each individual food product item has a unique ID and the ID is obtained by scanning the barcode of the product item. The end-user obtains transparency data using a barcode scanner or a smartphone application (*End-User App*). Upon scanning a barcode, the end-user app makes a query request and displays the transparency data returned. When the end-user scans a product item, the app requests transparency data from the food operator (indicated as *focal*). The ITS of the food operator determines where the product data reside. If the data reside locally it fetches the data from its own database; otherwise, it looks up the service address of the food operator (indicated as *partner*) that has the required data at a third-party discovery service. It then makes a query request to the partner food operator ITS, upon which the partner ITS returns the data it has about the item. Since the product may have passed through many food operators—and since transparency data about the ingredients are also part of the transparency data of a product item—this process is repeated until no more transparency data is desired or no more transparency data can be obtained. The focal and partner food operators are identical but drawn in two separate lanes to be able to show the interactions among the food operators clearly. Note, the focal food operator lane represents the one food operator that received the request from the end-user; the partner food operator lane represents all other food operators involved. After all data is gathered, the focal food operator sends the aggregated data to the app, which displays the data to the user.

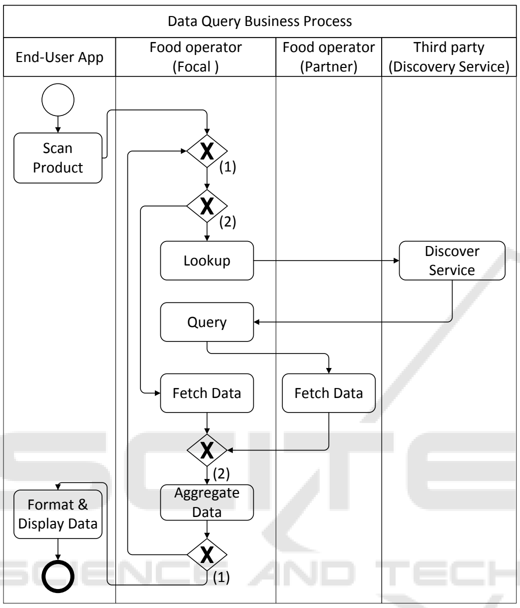


Figure 2: A BPM showing how transparency data is queried across a food supply chain.

The BPM shown in Figure 2 has to be implemented by all the four types of food operators shown in Figure 1. The end-user app should also be provided by the food operators. However, in practice, many of the food operators do not support most of the activities the BPM and cannot provide end-user apps.

3.2 Problem Statement

In the previous sub-section we have described food supply chains and illustrated an inherent business collaboration concern they face regarding transparency. In the case study we identified a number of problems in aligning the BPMs representing the preferred scenario and the software systems that realistically can be realized by the collaborating partners. Specifically, we can define the following problems:

- *Difficulty in Realizing Collaboration Business Processes*

The elements of BPMs have to be supported by businesses depending on their roles. That is, process elements, such as, events, tasks and gateways have to be realized by architectural elements, such as, modules, components and nodes of the software systems that are distributed across many businesses. It turns out that the mapping of BPMs to the diverse software systems is not straightforward. For example, the BPM shown in Figure 2 spans many food operators, many of which are, in practice, not capable of fulfilling all the steps. Particularly, many of the small food operators (mainly farmers) cannot afford to deploy the required software systems.

- *Lack of a Common Model for Supporting the Interaction Between Business Analyst and Architects*

Faced with the problem stated above business analysts and software architects from the various businesses come together to address the problem. However, the two stakeholder types use two separate sets of models hampering the communication between them. Business analysts use BPMs to define business processes. On the other hand, software architects use architecture viewpoints that mainly address concerns related to the structure of the software system. For the given case study, it was required early on to know which activities can be fulfilled by which food operators. Neither the business process models nor the software architecture views provide this information. A common model that depicts the business collaboration concerns (a model that maps elements of BPMs to elements of architectural design) would help to support the communication and the design rationale.

- *Early Validation of the Business Process-Architecture Alignment is Difficult*

Too often BPMs are validated after the software system is realized creating major risks. For example the BPM of Figure 2 has an impact on the software components that need to be deployed at each food operator node. Given only this BPM and the corresponding architectural designs, it is not easy to validate that the two are aligned and feasible.

In light of the above obstacles we formulated the following general research question: *How can we support software architects and business analysts to design BPMs and the corresponding software architecture as a team and minimize the mismatch between the two designs?*

4 COLLABORATION VIEWPOINT

Adapting the template for documenting architecture viewpoints proposed in the ISO/IEC standard mentioned before we propose a collaboration viewpoint shown in Table 1. We describe the viewpoint in detail in the following sub sections.

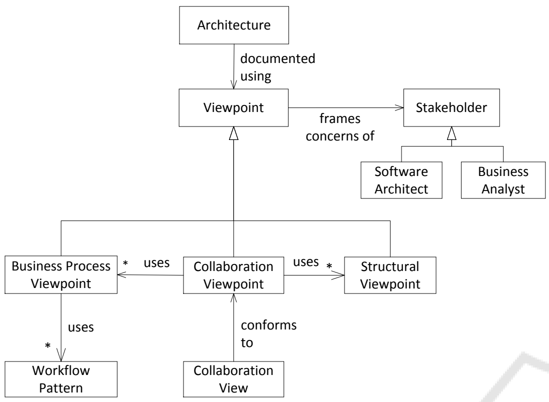


Figure 3: A metamodel for the collaboration view.

4.1 Metamodel

In Figure 3 we present a metamodel that describes the concepts used in the collaboration viewpoint of Table 1. The key stakeholders are identified as *software architects* and *business analysts*. *Collaboration viewpoint* is defined as a subtype of *viewpoint*. Collaboration concerns are addressed in *collaboration views* that conform to the collaboration viewpoint.

4.2 Notations

The collaboration viewpoint uses elements from business process and structural viewpoints. The elements from the two viewpoints are described in the following two sub sections; the models of the viewpoint are described in the subsequent sub sections.

4.2.1 BPMN

We adopt the BPMN modelling method to represent BPMs (OMG 2011). BPMN is widely used among business analysts and is also easily understandable for software architects. BPMN models are used in three ways. First, we consider the BPMs as models of collaboration business processes. Second, we use elements of the BPMN models in mapping tables (see section 4.2.3). Third, we use fragments of BPMs in workflow pattern diagrams (see section 4.2.4).

4.2.2 Architectural Design

We consider the models of *C&C* and *allocations* views particularly relevant for the collaboration view. These structural views are generally not fully intelligible to business analysts. We, therefore, consider only the elements of the models of these structural views as modelling elements in the mapping table. The architectural elements we consider most relevant are *components* and *nodes*.

4.2.3 Mapping Tables

The mappings of business process and architectural elements are made using two tables shown in Table 1:b. The first table captures how business process elements are allocated across the collaborating partners; the second table captures how architectural elements are allocated across the collaborating partners. The tables are used for both redesign and validation purposes.

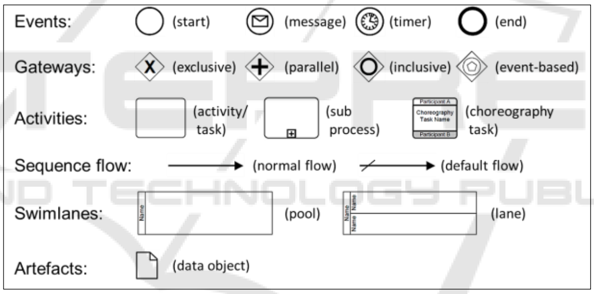
4.2.4 Workflow Design Diagram

Workflow patterns are represented using a *workflow pattern diagrams*. In a workflow pattern diagram the BPMN elements that belong to distinct workflow the patterns are delineated using dashed-line blocks. To delineate the BPMN elements the BPM diagram will mostly require simplification. The creation and application of workflow pattern diagram is demonstrated in section 5.

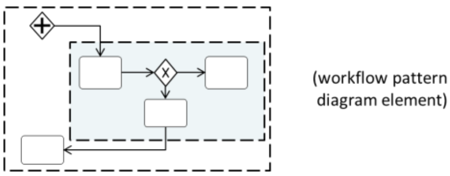
4.3 Method for Applying the Viewpoint

Figure 4 shows the method for applying the collaboration viewpoint. The method is started by business analysts; they design the initial BPMs in step 1. In step 2 they identify the relevant workflow patterns and draw workflow pattern diagrams for each BPMs. The two steps are displayed sequentially but, in reality, they are intertwined. Next, in step 3, an iterative process of capturing the software architecture, assessing alignment and redesigning of both BPMs and architecture starts. This step is done by software architects. In step 4 the business analysts and the software architects work as a team to allocate elements of the BPM and architectural designs to collaborating partners using mapping tables. They use the workflow pattern diagrams to facilitate the allocation. In this step they identify misalignments and determine if redesign is required. The next step, step 5, depends on whether or not redesign is required. If redesign is required the next step is to redesign the BPMs and workflow pattern diagrams. At this stage the mapping tables are used again to reallocate elements to collaboration partners. We consider the redesign of BPMs and workflow pattern diagrams as the responsibility of the entire team though the main responsivity rests on the business analysts. After the redesign of BPMs and workflow pattern diagrams the software architects redesign the software architecture (step 3). If redesign is not needed the BPMs, the workflow pattern diagrams and the mapping tables are documented in collaboration views following the documentation outline proposed in the next sub section.

Table 1: Collaboration viewpoint documentation guide.

<table>
<tr><td>Viewpoint Element</td><td>Description</td></tr>
<tr><td>Name</td><td>Collaboration Viewpoint</td></tr>
<tr><td>Stakeholders</td><td>Business Analysts
Software Architects</td></tr>
<tr><td>Elements</td><td>Elements from OMG's BPMN 2.0 specification
Elements from structural viewpoints (mainly Allocation and C&C viewpoints)
Workflow patterns</td></tr>
<tr><td>Relations</td><td>Maps to – defines the allocation of elements of BPMN models to collaborating partners
Maps to – defines the allocation of element of structure views to collaborating partners
Maps to – defines the allocation of elements of BPMN models to workflow patterns</td></tr>
<tr><td>Properties of Elements</td><td>Properties as defined in the structural viewpoints, BPMN specification, workflow patterns</td></tr>
<tr><td>Properties of Relations</td><td>Properties as defined in the structural viewpoints, BPMN specification, workflow patterns</td></tr>
<tr><td>Constraints</td><td>Constraints as defined in structural viewpoints, BPMN specification, workflow patterns
Each BPMN element should be mapped to a collaboration partner and a workflow pattern</td></tr>
<tr><td>Notation</td><td>a) BPMN element notations*:


b) Mapping Tables:
<table>
<tr><td>Collaborating partners / BPMN Elements</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Events</td><td colspan="4"></td></tr>
<tr><td>…</td><td></td><td></td><td>…</td><td></td></tr>
<tr><td>Activities</td><td colspan="4"></td></tr>
<tr><td>…</td><td></td><td></td><td>…</td><td></td></tr>
<tr><td>Gateways</td><td colspan="4"></td></tr>
<tr><td>…</td><td></td><td></td><td>…</td><td></td></tr>
</table>
<table>
<tr><td>Collaborating partners / Structure Elements</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Components</td><td colspan="4"></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nodes</td><td colspan="4"></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
<tr><td>…</td><td></td><td></td><td></td><td></td></tr>
</table>

c) Workflow Pattern Diagram (dashed-line blocks represent a workflow pattern):

</td></tr>
<tr><td>Relation to other views/viewpoints</td><td>BPMN 2.0 specification, workflow patterns catalogue, allocation and C&C viewpoints.</td></tr>
<tr><td>Examples</td><td>See section V</td></tr>
</table>

* The list only widely used BPMN elements; for a complete list of BPMN elements refer to the OMG BPMN 2.0 specification (OMG 2011).

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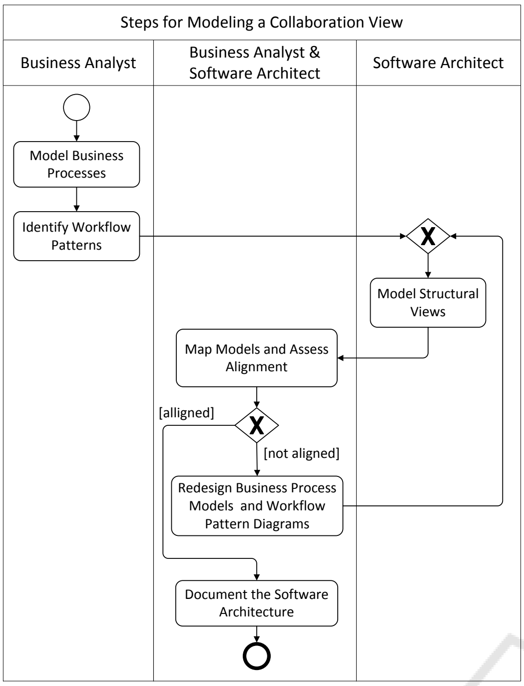

Figure 4: A process diagram representing the process of modeling a collaboration view.

4.4 Documenting the Architecture

When documenting the software architecture the collaboration views are described in detail after the BPMs and the software architecture views are presented. We propose the outline shown in Table 2 for documenting the software architecture.

Table 2: Overview of the software architecture document including collaboration views.

1.	Introduction
2.	Documentation Roadmap
3.	Business Process Models
4.	Software Architecture Module Views
5.	Software Architecture C&C Views
6.	Software Architecture Allocation Views
7.	*Collaboration Views*
	7.1 Introduction
	7.2 Workflow Patterns of BPMs
	7.3 BPM-Organization Mappings
	7.4 Architecture-Organization Mappings
	7.5 Summary
8.	Summary
9.	Directory-Index, Glossary, Acronym List

5 APPLYING THE COLLABORATION VIEWPOINT

In this section we illustrate how the approach shown in Figure 4 is applied in the real industrial case mentioned in section 3. The first step of designing the BPMs is already demonstrated in the BPM shown in Figure 2. The second step is identifying the workflow patterns. Figure 5 shows the workflow

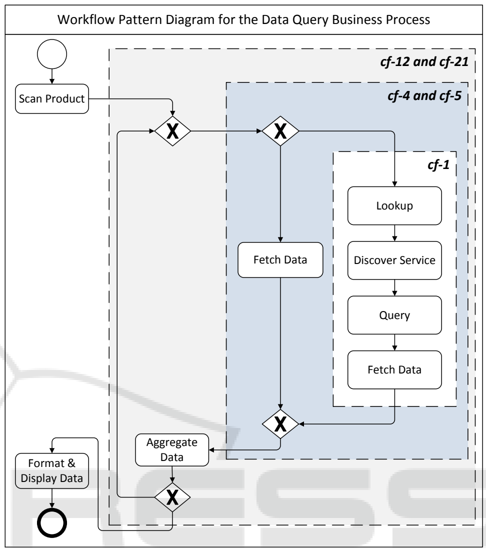

Figure 5: A workflow pattern diagram for the query business process model.

patterns of the BPM we identified. The workflow patterns are: *sequence* (*cf-1*), *exclusive choice* (*cf-4*), *simple merge* (*cf-5*), *multiple instances without synchronization* (*cf-12*) and s*tructured loop* (*cf-21*). A further analysis shows that the workflow patterns *cf-4 and cf-5* belong together. Similarly, the workflow patterns *cf-21 and cf-12* belong together. Therefore, we identify three workflow patterns, two of which are composite patterns.

The third step of the approach is to capture the existing software architecture that is already in place. For the sake of simplicity we distinguish between two major groups of food operators in terms of their existing software systems, *i.e.* their ITSs: *small food operator* and *large food operator*. Similarly, we identify three components of an ITS: a *data query component*, a *data aggregator component* and a *product data retrieval service*. In relation to the business process shown in Figure 2 the data query component implements the *lookup* and *query* tasks and the 2nd XOR decision; the data aggregator component implements the aggregate data task and the 1st XOR decision; the data retrieval service implements the *fetch data* task.

The next step, step 4, is mapping the allocation of BPMs and architectural design elements to the collaborating partners. Table 3 shows how currently the BPM elements are supposed to be allocated across the two types of food operators; Table 4 does the same but for architectural elements instead of the elements of the BPM. The tables are interpreted as follows. A '+' sign in a cell implies that the business process or the architectural element is allocated to the corresponding collaboration partners and the collaboration partner indeed supports the element. For instance, the *scan product* task should be supported in *large food operator* nodes and it is indeed supported. A '–' sign implies that the business process or the architectural element is allocated to the collaboration partner but the collaboration partner fails to support the element. Using the above example, the *scan product* task should have been supported by *small food operator* nodes but it is not. An empty cell implies that the element is not relevant for the specific collaboration partner. Typically, these tables require knowledge of the state of affairs in all collaboration partners, which could be many, and it may require more than the simple +, – and *empty* entries. As shown in the table, it turns out that small food operators implement none of the required architectural elements adequately and large food operators provide only part, in this case only the *product data retrieval service* structural element.

Table 3: Mapping of business process elements to the corresponding collaborating partners.

BPMN Elements \ **Collaboration partners**	Small Food Operator	Large Food Operator	Third party
Events			
Start	-	+	
End	-	+	
Gateways			
XOR {1}	-	-	
XOR {2}	-	-	
Tasks			
Scan Product	-	+	
Lookup	-	-	
Discover Service	-	-	+
Query	-	-	
Fetch Data	-	+	
Aggregate Data	-	-	
Format and Display Data	-	+	

Table 4: Mapping architectural elements to the corresponding collaborating partners.

Structure Elements \ **Collaboration partners**	Small Food Operator	Large Food Operator	Third party
End-User App	-	+	
Query Component	-	-	
Data Aggregator Component	-	-	
Product Data Retrieval Service	-	+	
Discovery Service			+

From the above tables it is clear that the desired business processes are not aligned with the existing architecture. The next step, step 5, is redesigning the BPMs and workflow pattern diagrams; obviously a new allocation is necessary for cases depicted in Table 3 and Table 4. For instance, though small food operators do not fulfill the allocated tasks, it turned out that they are, however, willing to (and usually do) delegate the tasks to third parties and pass the required transparency data to them. Moreover, in the food sector third-party transparency data repositories are mandated by law as described in section 3.1. In Table 5 we show the new allocation of architectural elements to new collaborating partners, improving the misalignment shown in Table 4. (Similarly, a new allocation table for Table 3 can be produced but is not included for brevity.) The new allocation allows all food operators (small and large) to comply with the EPCIS specification; but now a new misalignment arises because the third party has yet to support the newly allocated elements. It also raises an issue related to data capture. Because small food operators have to pass transparency data to a third-party, the data capture (which so far was local and trivial) is now a collaboration concern.

Table 5: New allocation of architectural elements to collaborating partners.

Structure Elements \ **Collaboration partners**	Small Food Operator	Large Food Operator	Third party
End-User App			-
Query Component			-
Data Aggregator Component			-
Product Data Retrieval Service		+	-
Discovery Service			+

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As part of step 5 workflow pattern diagram are used to redesign the BPMs (which is the opposite of what is done in step 2). Unlike in step 2 we (re)design the workflow pattern diagrams first and then we apply them to (re)designing the BPMs.

We start the redesign process with the workflow pattern diagram because the workflow patterns identified earlier seem to capture the fundamental essence of the query BPM and may not need modifications. The BPM, on the other hand, may change substantially. In Figure 6 we provide the improved workflow pattern diagram that contains the same three workflow patterns but in a different configuration. The change in the configuration of the workflow patterns is a direct consequence of the new allocation. The details of the consequences of the new allocation are shown in the new BPM provided in Figure 7. As in the previous business process the new business process is triggered by the end-user app but all query requests are always sent to the third party. Instead of all food operators, the new model involves only large food operators in the query business process. Small food operators no longer need to maintain their own transparency data and to support the *fetch data* task, because the third-party supports this task on their behalf. When these and other redesign issues are resolved the software architects (re)design the software architecture by going back to step 4.

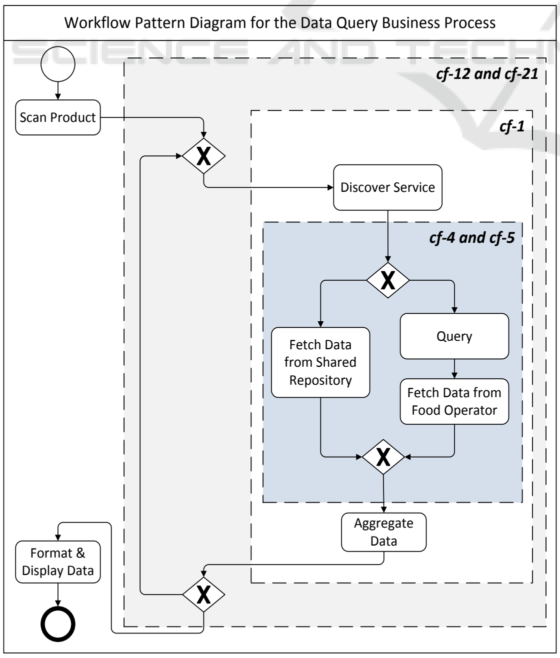

Figure 6: Improved workflow pattern diagram for guiding the design of an improved query BPM.

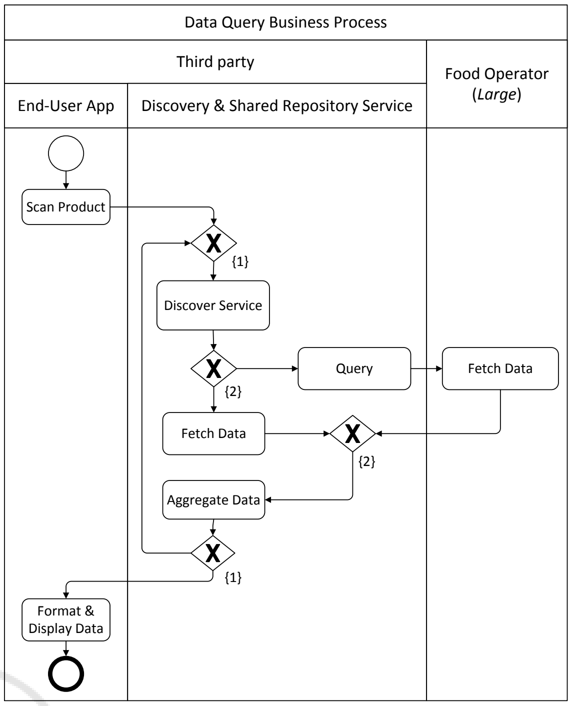

Figure 7: Improved query business process model.

6 RELATED WORK

The prominent way addressing business processes and software architecture concerns along with other concerns, such as general vision for the system, concerns related to technology, *etc.* in a consistent manner is to follow guidance provided by an enterprise architecture framework. The Zachman (Rational Software 2001) and TOGAF/ArchiMate (The Open Group 2013) frameworks are probably the most widely used and include the modeling of business processes and the designing of software architecture as part of the larger enterprise architecture. These framework use largely fixed categories of perspectives and concerns (*e.g.* vision, business concerns, software architecture concerns, *etc.*) Moreover, they follow a hierarchical conceptualization of models in which requirements cascade from vision, to BPMs, to software architecture and finally to technology architecture. A hierarchical approach suggests the use of elaborate methods to get the design at a higher hierarchical level before moving to the next. There are for instance extensive methods for analyzing the *as-is* BPMs and designing elaborate *to-be* BPMs (Sharp and McDermott 2009) before a large scale architectural design process commences. These approaches do not directly address business collaboration concerns that often arise when different organizations are involved.

Business collaboration concerns could probably be addressed generically as cross cutting quality concerns across different viewpoints. In this respect business collaboration concerns could be viewed as concerns that cut across business process and architecture viewpoints. In this regard the concept of architectural perspectives is suggested that include a collection of activities, tactics and guidelines to be used across a number of the architectural views to address quality concerns (Woods and Rozanski 2005). In this context, Rozanski and Wood define several architectural perspectives for selected quality concerns such as security, performance, scalability, availability and evolution. In order to capture the system-wide quality concerns, each relevant perspective is applied to some or all views. In this way, the architectural views provide the description of the architecture, while the architectural perspectives can help to analyze and modify the architecture to ensure that system exhibits the desired quality properties. However, no architectural perspective for addressing business collaboration concerns has been addressed yet. Since business collaboration is not cross cutting concern in many other viewpoints than the ones we considered we have chosen for defining an explicit viewpoint for the business collaboration concern.

Architecture consistency analysis has been mainly investigated in relation to consistency between software code and software architecture. Hereby, architecture consistency implies that the architecture design elements can be mapped to the implementation elements. In case the relationships between the architecture and implementation do not correspond then these are called architectural violations. If the relations that are present in the architecture are also found in the implementation then this is convergent relation. In case the architecture relation is not present in the implementation then this is called an absence relation. A successful design recovery technique that is used for architecture consistency checking is the reflexion modeling approach as proposed by Murphy et al. (Murphy et al. 2001). In this paper we have also focused on consistency of the architecture but now from a business model perspective in which we focused on business collaboration concerns.

Business collaboration concerns are also addressed as business process choreography – as opposed to business process orchestration. In this respect recent research show that it is possible to automate the generation software from business processes choreography models (Autili et al. 2015). Such an approach do not, however, constraints that are imposed on business process choreography models by the software architecture.

7 CONCLUSIONS

Traditionally business analysts and software architects address collaboration concerns separately which often leads to a misalignment between the business process and architecture. This problem is to an extent manageable in the context of an individual organization though a careful design of the business processes before proceeding with the design of the software architecture. This approach is however not feasible when considering collaboration concerns that involve multiple organizations. In this context, we have identified three key collaboration concerns: ensuring that the BPMs are indeed supported by software components, ensuring that business analyst can communicate effectively with software architects in search of better design solutions, and validating the architecture with respect to the BPMs.

To cope with these problems we have proposed the architecture collaboration viewpoint that supports the communication between the business analysts and architects, and that helps to align the business process models and the software architecture of the collaboration system. The viewpoint has been applied for a real industrial case study on food supply chains. The business collaboration concerns that are discussed in this paper and experienced within case study were addressed using the collaboration viewpoint.

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APPENDIX A – WORKFLOW PATTERNS

Pattern Categories	Patterns*
Control-Flow (CF)	
Basic	Sequence (cf-1), Parallel Split (cf-2), Synchronization (cf-3), Exclusive Choice (cf-4), Simple Merge (cf-5)
Advanced Branching and Synchronization	Multi-Choice (cf-6), Structured Synchronizing Merge (cf-7), Multi-Merge (cf-8), Structured Discriminator (cf-9), Blocking Discriminator (cf-28), Cancelling Discriminator (cf-29), Structured Partial Join (cf-30), Blocking Partial Join (cf-31), Cancelling Partial Join (cf-32), Generalized AND-Join (cf-33), Local Synchronizing Merge (cf-37), General Synchronizing Merge (cf-38), Thread Merge (cf-41), Thread Split (cf-42)
Multiple Instance	Multiple Instances without Synchronization (cf-12), Multiple Instances with a Priori Design-Time Knowledge (cf-13), Multiple Instances with a Priori Run-Time Knowledge (cf-14), Multiple Instances without a Priori Run-Time Knowledge (cf-15), Static Partial Join for Multiple Instances (cf-34), Cancelling Partial Join for Multiple Instances (cf-35), Dynamic Partial Join for Multiple Instances (cf-36)
State-based	Deferred Choice (cf-16), Interleaved Parallel Routing (cf-17), Milestone (cf-18), Critical Section (cf-39), Interleaved Routing (cf-40)
Cancellation and Force Completion	Cancel Task (cf-19), Cancel Case (cf-20), Cancel Region (cf-25), Cancel Multiple Instance Activity (cf-26), Complete Multiple Instance Activity (cf-27)
Iteration	Arbitrary Cycles (cf-10), Structured Loop (cf-21), Recursion (cf-22)
Termination	Implicit Termination (cf-11), Explicit Termination (cf-43)
Trigger	Transient Trigger (cf-23), Persistent Trigger (cf-24)
Resource-Flow (RF)	
Creation	Direct Distribution (rf-1), Role-Based Distribution (rf-2), Deferred Distribution (rf-3), Authorization (rf-4), Separation of Duties (rf-5), Case Handling (rf-6), Retain Familiar (rf-7), Capability-Based Distribution (rf-8), History-Based Distribution (rf-9), Organizational Distribution (rf-10), Automatic Execution (rf-11)
Push	Distribution by Offer - Single Resource (rf-12), Distribution by Offer - Multiple Resources (rf-13), Distribution by Allocation - Single Resource (rf-14), Random Allocation (rf-15), Round Robin Allocation (rf-16), Shortest Queue (rf-17), Early Distribution (rf-18), Distribution on Enablement (rf-19), Late Distribution (rf-20)
Pull	Resource-Initiated Allocation (rf-21), Resource-Initiated Execution - Allocated Work Item (rf-22), Resource-Initiated Execution - Offered Work Item (rf-23), System-Determined Work Queue Content (rf-24), Resource-Determined Work Queue Content (rf-25), Selection Autonomy (rf-26)
Detour	Delegation (rf-27), Escalation (rf-28), Deallocation (rf-29), Stateful Reallocation (rf-30), Stateless Reallocation (rf-31), Suspension-Resumption (rf-32), Skip (rf-33), Redo (rf-34), Pre-Do (rf-35)
Auto-start	Commencement on Creation (rf-36), Commencement on Allocation (rf-37), Piled Execution (rf-38), Chained Execution (rf-39)
Visibility	Configurable Unallocated Work Item Visibility (rf-40), Configurable Allocated Work Item Visibility (rf-41)
Multiple Resource	Simultaneous Execution (rf-42), Additional Resources (rf-43)
Data-Flow (DF)	
Data Visibility	Task Data (df-1), Block Data (df-2), Scope Data, Multiple Instance Data (df-4), Case Data (df-5), Folder Data (df-6), Workflow Data (df-7), Environment Data (df-8)
Data Interaction	
Internal Data Interaction	Task to Task (df-9), Block Task to Sub-Workflow Decomposition (df-10), Sub-Workflow Decomposition to Block Task (df-11), To Multiple Instance Task (df-12), From Multiple Instance Task (df-13), Case to Case (df-14)
External Data Interaction	Task to Environment - Push-Oriented (df-15), Environment to Task - Pull-Oriented (df-16), Environment to Task - Push-Oriented (df-17), Task to Environment - Pull-Oriented (df-18), Case to Environment - Push-Oriented (df-19), Environment to Case - Pull-Oriented (df-20), Environment to Case - Push-Oriented (df-21), Case to Environment - Pull-Oriented (df-22), Workflow to Environment - Push-Oriented (df-23), Environment to Workflow - Pull-Oriented (df-24), Environment to Workflow - Push-Oriented (df-25), Workflow to Environment - Pull-Oriented (df-26)
Data Transfer	Data Transfer by Value - Incoming (df-27), Data Transfer by Value - Outgoing (df-28), Data Transfer - Copy In/Copy Out (df-29), Data Transfer by Reference - Unlocked (df-30), Data Transfer by Reference - With Lock (df-31), Data Transformation - Input (df-32), Data Transformation - Output (df-33)
Data-based Routing	Task Precondition - Data Existence (df-34), Task Precondition - Data Value (df-35), Task Postcondition - Data Existence (df-36), Task Postcondition - Data Value (df-37), Event-based Task Trigger (df-38), Data-based Task Trigger (df-39), Data-based Routing (df-40)

* The names of the patterns are shortened; the pattern ID's (numbers between brackets) are original (van der Aalst and ter Hofstede 2011).