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ORIGINAL ARTICLE

Incorporating technology in service-oriented i* business models: a case study

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Abstract In recent years, considerable attention has been paid to enterprise information systems. This interest is motivated by the need for achieving better integration of new technologies (hardware and software) with the business processes of an organization. Business processes have become more and more dependent on technologies because technology has a direct impact on business processes, changing the way they are performed and thus also affecting the way analysts design the software system. However, at the present time, there are still some gaps between the definition of business processes and the technologies used in the organization. In practice, organizations have carried out their business processes using different technologies; however, it is sometimes not possible to determine how technologies are useful in achieving current business goals. This is because business models do

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not explicitly consider the technologies in the organizational requirements. The goal of this paper is to present a systematic process for integrating business processes and technologies at the conceptual level. To validate our approach, we present a case study that describes the processes of the inventory management department of a public research center.

Keywords i* · Service oriented i* · Technology modeling · Business services · Business processes

1 Introduction

Since an important aspect in the design of efficient business processes is the use of technology, it is essential to show the infrastructure, exchange, and persistence of information among business actors. Thus, technology that is adapted to the organizational context could improve the performance of business processes. In this work, we refer to the definition of technology as stated by Bouwman et al. (2005) who defines it as: a tool to organize things in a different manner, coordinate processes, and perform tasks more easily. Even though technology is sometimes seen as a physical device (mobile, computer, modem, etc.), we consider it to be system that provides mechanisms for transmitting, processing, and storing information within an organizational context in order to facilitate, automatize, and speed up the work of the organizational actors.

At the present time, there are proposals for the conceptual modeling of business processes that allow the representation of the organizational requirements of enterprise information systems at the design level (Bresciani et al. 2004; Castro et al. 2002; Martinez 2008). However, there are still some gaps between the business processes and the technologies that are used in organizations. In practice, organizations have carried out their business processes using different technologies, but sometimes the technologies do not contribute to satisfying the business goals.

In most cases, the processes are modeled at the conceptual level without considering that there may be technologies that could help to improve the performance of business processes. Several experts consider that embedding technology in the organization can modify the workflow of business processes, and thus the manner in which analysts should design the software system (Bandara et al. 2007; Morales et al. 2011). This research work proposes an approach that provides technology representation at the conceptual modeling level. We consider that if the technology is incorporated at the conceptual modeling level, analysts could determine the most appropriate technological alternative for implementing their business processes and be relatively certain that the selected technologies are the ones that best satisfy the business goals.

The research work in this paper has been done within the i* framework in order to incorporate technologies at the conceptual modeling level. The evaluation of the methodological approach proposed in this paper has been made using the Inventory Management Project. This is a real project of the Inventory Management Department at the National Center for Research and Technological Development (CENIDET).

The paper is structured as follows: Sect. 2 describes the methodological background of our proposal. Section 3 presents the related works. Section 4 presents our approach for incorporating technology in Service-Oriented i* Business Models. Section 5 presents a real case study of an organization in order to evaluate the proposed approach. Section 6 discusses the research results with regard to their theoretical contribution. Finally, Sect. 7 provides the conclusions and an outlook for future work.

2 Background

We propose using the i* framework to incorporate technologies at the conceptual modeling level. Currently, i* is one of the most well-founded organizational modeling techniques (Yu et al. 2011). Its main feature is its expressibility for representing intentional social relations among stakeholders.

i* mainly focuses on: (a) the representation of social and intentional relationships mainly of the network of actors of an enterprise, and (b) the representation of the internal behaviors required to satisfy actor dependencies. Nowadays, there are many research projects that use i* in different application domains in early requirements engineering business process design and system requirements (Cares and Franch 2011; Lopez et al. 2015; Monsalve et al. 2013; Najera et al. 2013). In addition, our proposal uses a modular approach for describing technology entities in i* modules (Franch 2010) in terms of quality attributes offered by technology and conditions of the operational environment required by technology functioning. In this section, we present a brief description of the relevant concepts of our approach (i* framework and service-oriented i*) as the modeling techniques used to model business behavior. In order to selected the most appropriate framework to represent technology at business level, we compared several modeling approaches: Business Modeling Method (BMM) (Montilva and Barrios 2004), Tropos (Castro et al. 2002), UML extension (Eriksson and Penker 1998), and Knowledge Acquisition in autOmated Specification (KAOS) (Dardenne et al. 1993).

The main goal of this comparison is to analyze the views used for modeling an organization. Table 1 shows the comparison among the i* framework and the other approaches analyzed in our research work. Due to space limitations, we only include the comparative table of the approaches analyzed. A complete analysis of these approaches can be found in Santillan (2013).

2.1 The i* framework

The i* framework (Yu 1996) views organizational models as being networks of social actors that have freedom of action and that depend on each other to achieve their objectives and goals, carry out tasks, and obtain needed resources. The i* framework is made up of two models that complement each other: the strategic dependency model for describing the network of inter-dependencies among actors and the strategic rationale model for describing and supporting the reasoning that each actor goes through concerning its dependencies on other actors.

Table 1 Comparing the i* framework with others approaches

Approach	BMM	Tropos	UML extension	KAOS	i*
Input of the approach	Business system documentation	Business system documentation	The objects within the business (people, material, information, and products) that are used or produced in the business	Business knowledge	Business documentation
Role in the development process	It uses business concepts to obtain comprehensive knowledge of a business system before initiating the requirements engineering processes	It adopts the concepts offered by i* for modeling early requirements. Tropos also provides the concepts for architectural and detailed design	It uses business concepts for identifying processes, goals, resources and rules of a business system	It reuses domain knowledge and the application of machine learning technology	It uses a set of modelling concepts for modelling processes, and for analyzing and redesigning them
Methodological approach	It is focused on planning the process of modeling EIS application domains	It is focused on modeling early and late requirements	It is focused on creation of a set of extensions based on the existing UML modeling elements for modeling the processes, resources, rules and goals of a business system	It is focused on requirements acquisition	It is focused on the modelling analysis and design of complex organizational processes
Method to define requirements model	It provides three complementary models for analysing	It provides four phases for generating and implementation	It provides four views for describing a complete business model	It provides three complementary components for acquisition process	It provides two models for representing the networks of intentional dependencies among actors are provided
Output of the approach	Business model	Agent architecture	Architecture of software system	Requirements models	Business model
Main features	It identifies the set of business concepts that must be represented during the process of modeling	It founds on intentional and social concepts, and inspired by early requirements analysis	It provides a set of extensions to add stereotypes or properties suitable to its line of business	It provides high-level abstraction directed by goals	Its expressibility for representing intentional social relations among stakeholders
Orientation	Business system orientation	Goal-oriented	Business-oriented	Goal-oriented	Goal-oriented

The strategic dependency model (SD) involves actors who have strategic dependencies with each other. A dependency describes an agreement (called dependum) between two actors: the depender and the dependee. Dependencies are classified as depender, dependum, and dependee. The type of the dependency describes the nature of the agreement: goal, task, resource, and softgoal dependencies.

The strategic rationale model (SR) is a graph that provides a representational structure for expressing the rationales behind dependencies. The key idea of this model is the representation of the actor behaviors that are needed to satisfy each actor dependency. The strategic rationale model is a graph with four types of nodes (goal, task, resource, and softgoal) and three types of internal links to the i* actor (means end links, task decomposition links, and contribution links). For more information about the i* framework, see Yu et al. (2011).

2.2 The service-oriented i* framework

The service-oriented i* framework is the result of revisiting and extending the semantics of the i* modeling concepts. According to Estrada (2008), Estrada et al. (2010, 2013), the key idea of the service-oriented approach is to use business services as building blocks that encapsulate internal and social behaviours. Therefore, in those works, complementary models were defined to make it possible to refine the abstract concept of services in low-level descriptions for implementing services.

In this framework, the modeling process starts by considering the enterprise as a service provider and by eliciting the services that the enterprise offers to end customers. The next step consists of determining the way in which the business services satisfy the goals of the enterprise. Once the services have been elicited, each service in the set of business processes required to perform it must be refined.

This framework also proposes the mechanisms for decomposition, refinement, and modularity specifically for business services. The proposed architecture distinguishes three abstractions levels (services, processes, and protocols) and describes a methodological approach to align the business models that are produced at these abstraction levels. For more information about the service-oriented i* framework, see Estrada et al. (2010, 2013).

3 Related works

Despite the fact that information technology experts agree on the idea that business process and information technology design are key elements in the software development phases, there are still gaps in modeling the business processes and the technology together (Bandara et al. 2007). We argue that the study of business processes must not be an isolated task and should always be related to information technology. Therefore, we point out the related works that include technology in their modeling without taking into account the abstraction levels in which they were defined.

The Zachman framework (Zachman 1999) has long pointed out the need to include technology in enterprise modeling, though few modeling techniques have addressed this need specifically. Our proposal shares features with the Zachman framework, but it differs from the Zachman framework because it proposes higher-level models to support the final goal of any software system (i.e., to meet its requirements).

The GERAM framework (Lillehagen and Krogstie 2008) is intended to facilitate the unification of methods from several disciplines that are used in the organizational processes. These include industrial engineering, management science, control engineering, communication and information technology. This framework allows these methods to be combined as opposed to a segregated application.

The TOGAF framework (Group 2011) is an open group standard. The technology domain in this framework is addressed by the use of a technological architecture. This architecture has the business architectures, the data architectures, the application architecture, and the technological architecture. It proposes its own architecture models to represent the technology domain.

The ISO 19440 standard (ISO 19440:2007) defines the generic concepts that are required to enable the creation of enterprise models for industrial businesses. It also provides support for the use of frameworks by industrial enterprises. This standard defines the characteristics of the core constructs that are necessary for computer-supported modeling of enterprises conforming to ISO 19439. However, the ISO 19440 standard does not specify how the constructs for model-based operations need to be implemented. Moreover, the specification does not include the control language that is needed to specify and execute activity behaviour, mainly internal activity.

The ArchiMate framework (Jonkers et al. 2004; Lankhorst et al. 2009), an open group standard, is an open and independent modeling language for enterprise architecture that is supported by different tool vendors and consulting firms. The treatment given to the technologies in this framework is addressed in the technology layer, which offers the infrastructure services (e.g., processing, storage, and communication services) that are needed to run applications, which are performed by computer and communication hardware and system software.

In contrast to the approaches mentioned above, our approach is based on a framework that defines the constructs for modeling an organization at different abstraction levels, including the definition of business behaviour. This framework has been extended to incorporate technology components at the conceptual modeling level, and also to explicitly represent how the technology contributes to achieving the goals of the business. Due to space limitations, we only include a brief explanation of the related works. A complete analysis of the related works can be found in Santillan (2013), where a comparison of research publications that analyze technology at different levels is presented.

4 Incorporating technology in service-oriented i* business models

In this section, we detail the service-oriented approach that was used as the basis of our research work, which enables the analyst to incorporate business processes and technology at the conceptual level. The service-oriented approach allows us to directly link the business services and enterprise goals in order to demonstrate how the services allow business objectives to be satisfied. The concept of service encapsulates a set of business processes that permit the service execution. Finally, each business process is broken down into a set of business functions. The concept of technology module can be used at different abstraction levels to enable the analyst to manage the scalability and the complexity of the models.

Therefore, our approach allows the business to be represented at a high level of abstraction and also allows the business activities to be represented in a very detailed way. This way, instead of having to deal with each function defined in the business model, an abstract representation of services can be used to create relationships with technology modules. This approach is carried out in three phases: (1) the business modeling phase, (2) the technology modeling phase, and (3) the technology incorporation phase.

Figure 1 shows the phases and subphases of our proposal. Note that, even though the technology has been considered in several research works (ISO 19440:2007; Group 2011; Jonkers et al. 2004; Lankhorst et al. 2009), there are no approaches that consider the technology at the same abstraction level where the business models are defined. Most of the current approaches only consider the representation of technology at the architectural level, which is a low abstraction level. In our approach, the technology is represented as modules that can be explicitly incorporated in a business model.

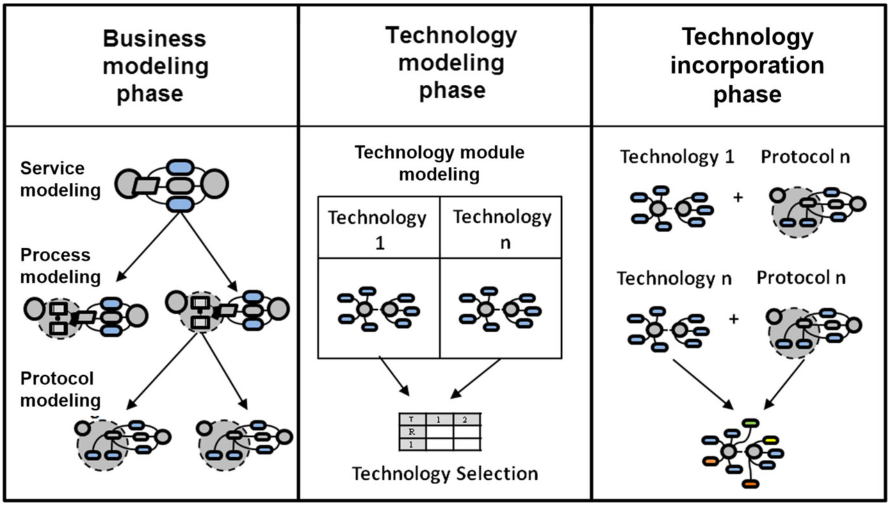

Fig. 1 Overview of our approach for incorporating technology to business models

Thus, our approach enables analysts to represent the positive or negative effects of each evaluated technology on business processes. In fact, these proposed phases could be considered similar to other approaches since they were derived from phases of software engineering techniques. Each phase of our approach is presented below in detail.

4.1 The business modeling phase

This phase represents the organization through three models: (1) the service model, (2) the process model, and (3) the protocol model. The input of this phase is the information about the organization (e.g., organizational manuals, interviews, procedure manuals, experts, etc).

The *service model* represents an abstract view of the services offered by the organization to potential customers. In this model, the business services are associated with the enterprise goals and softgoals. Therefore, it is possible to show how the services are used to satisfy the enterprise goals and also to represent how a business service provides a solution to fulfill the goals of the service customers (Estrada 2008).

The *process model* represents the functional abstractions of the business process for a specific service. Therefore, each business service is refined into more specific processes. The process dependencies are used to represent the processes that make up each business service.

The *protocol model* describes the execution of the business process in terms of strategic relations (Yu 1996). The strategic dependency model is dedicated to describing the configuration of the dependency relationships among the actors involved in a process model. The protocol model has been extended with i* softgoals that represent non-functional requirements. These are referred to as "quality attributes" of the organization (Morales et al. 2011). These could be performance, user-friendliness, and coherence as well as concerns related to productivity, time, cost, and personal satisfaction. We consider that a quality attribute could be mapped to a specific quality attribute that is offered by a specific technology. This attribute could contribute to the requirements of a business process in a positive or negative way.

The output of the business modeling phase are three models that represent all the organization (service, process, and protocol) and allows us to know to different abstraction levels for the business behaviors.

4.2 The technology modeling phase

Technology modeling to represent the technology involved in business processes is one of the main contributions of our work. This gives an opportunity to assess how a specific technology improves a process and what its advantages and disadvantages are. The input of this phase is the information about technologies and protocol models that represent the detailed description for implementing a specific business service.

The objective of technology modeling is to have a technology representation that can be explicitly incorporated in business process models at the same abstraction level. We take advantage of the concept of module to represent the technology. The representation of technologies includes information about functionalities, specific requirements, quality features, etc. In the technology modeling phase two complementary subphases are carried out (modeling the tecnology and selecting the technology).

4.2.1 Modeling the technology

In this subphase, the goal is to define two models: a strategic dependence model and the model for technology module. The strategic dependence model (protocol model) is represented using i* concepts.

The model for technology module contains information about the general features of a specific technology. This model consist of components, functionality, quality attributes, resources, and dependence relations (Fig. 5).

- Components are represented as i* actor primitives, which represent the technology elements that make up a software system for a specific technology.
- Functionality is represented as i* goal primitives, which represent the first feature that a certain technology provides.
- Quality attributes are represented as i* softgoal primitives, which represent the features of a functionality of the technology expressed in terms of non-functional requirements.
- Resources are represented as i* resources, which represent physical elements that offer or need the technology.
- Dependency relations are described in order to know the dependence among components and other primitives. For example, a dependency in a component is to identify a feature that the technology offers to the business process. Therefore, we define this dependency as a requirement that must be fulfilled in order for the specific technology to operate correctly.

4.2.2 Selecting the technology

In this subphase, the goal is to select the most appropriate technology. This is done through contribution analysis between technology features and business processes. The contribution analysis is made between the features of a specific technology module and the requirements of a protocol model. Every feature of the technology module can contribute positively or negatively to achieve the requirements that are defined in the protocol model. Our approach includes four types of information that should be included for technology to be included in business process models: differentiation features, compositional features, variability features, and integration features.

- *Differentiation features* The representation of a specific technology allows the functionality of the technology and its quality attributes to be analyzed and can serve to assess the usefulness of the technology in the organizational context.
- *Compositional features* The representation of a specific technology allows the components of the technology to be identified.
- *Variability features* The representation of a specific technology enables us to deal with the different features of a technology.
- *Integration features* The representation of a specific technology enables us to be aware of requirements in order to incorporate it into a specific business process.

The output of the technology modeling phase are two models that represent the features of technology components, (e.g., functionality, resources used or generated, goals, and quality attributes) and allows us to differentiate several related technologies.

4.3 The technology incorporation phase

In this phase, the technology incorporated into a business process can be understood as a conceptual process. To do this, that conceptual process must match the features of the technology with the business requirements. The inputs of this phase are the technology models (which represent the characteristics of the technology components) and the protocol model (which represents the description for implementing a business service). The model for incorporating the technology is carried out in the following steps:

1. The identification of correspondences between the technology module and the protocol model. In this step, the functionality that the technology module provides must be identified. This functionality can be viewed as goals in the technology module.
2. The identification of correspondences between the dependencies of the technology module and the business process. In this step, a table that shows the correspondences between the features of the technology module and the elements of the protocol models must be created. The objective of this table is to know how the technology is involved in the business processes.
3. The inclusion of functionality of the module as a new technology alternative to meet goals, perform tasks, or provide resources in the protocol model. In this step, the functionality of the technology module must be added to the protocol model.
4. The creation of new dependencies between the protocol model and the technology module based on the correspondences. In this step, new dependencies between the protocol model and the technology module model must be created. The objective of this step is to add the features of the technology model to the protocol model based on the table of correspondences.
5. The forwarding of the dependencies of the protocol model to the technology module. In this step, the dependencies of original actors need to redirected to the technology module according to the table correspondence.

6. The creation of additional dependencies between the protocol module and the features of the technology module. In this step, the dependencies between the protocol and the features of the technology module must be reviewed to ensure that the specific technology achieves the goals of the business processes. For example, the features defined as output in the technology module must produce dependencies because the features indicate the necessary conditions for the proper functioning of the technology. The features defined as input do not always produce new dependencies because they do not always fit the business process. The objective of this step is to adapt the technology to ensure proper operation.

The output of the technology incorporation phase is a model that incorporates modules that represent the technological components that are inserted into a business model. Our model also represents the dependencies that the organizational environment will have with the artifacts of the new technology.

5 Case study

The validation of our approach was carried out in a real case study. This paper presents an inventory case study which describes the processes of the Inventory Management Department at the National Center for Research and Technological Development (CENIDET). The Barcode and RFID and technologies were evaluated using our approach in order to select the most appropriate technological alternative to automate the inventory processes.

5.1 Case study description

The management of the material resources at CENIDET is carried out by two departments: the Planning Department and the Inventory Management Department. The Inventory Management Department is responsible for planning, coordinating, and evaluating the activities that are related to the management of inventory and the supply of general services and maintenance to CENIDET according to the standards and guidelines established by the Secretary of Public Education (SEP) in Mexico.

The information shown in our inventory case study was obtained through the review of procedure manuals and interviews with the directors and personnel involved in the business processes of the Inventory Management Department. This department is composed of three offices: the purchasing office, the warehouse and inventory office, and the general services office. Due to space limitations, we only describe the process of the warehouse and inventory office, which is responsible for monitoring and recording the inputs and outputs of inventory from stock as well as periodic inventory.

5.2 The business modeling phase

In this phase, we describe the business processes of the Warehouse and Inventory Office using the following abstraction levels: service modeling, process modeling, and protocol modeling.

5.2.1 The service model

In the service modeling activity, we identified the services offered by the Warehouse and Inventory Office (Inventory of goods and consumables; Purchase of goods and consumables; Storage of goods and consumables; Assignment and cancellation of goods and consumables). These services were identified from the procedure manuals (National Center for Research and Technological Development 2009; General Direction for Materials Resources 2007) and through interviews with the stakeholders of the Warehouse and Inventory Office (directors, employees, and the final users of inventory).

Figure 2 shows the services and the dependencies that we found for the Warehouse and Inventory Office. We have assigned the letter S and the numbers 1–5 to describe the services offered. We have assigned the letter D and the numbers 1–14 to describe the dependencies of the services offered. For example, the service "Taking of inventory" is designated (S1); the dependency "Inventory taken" is designated (D1).

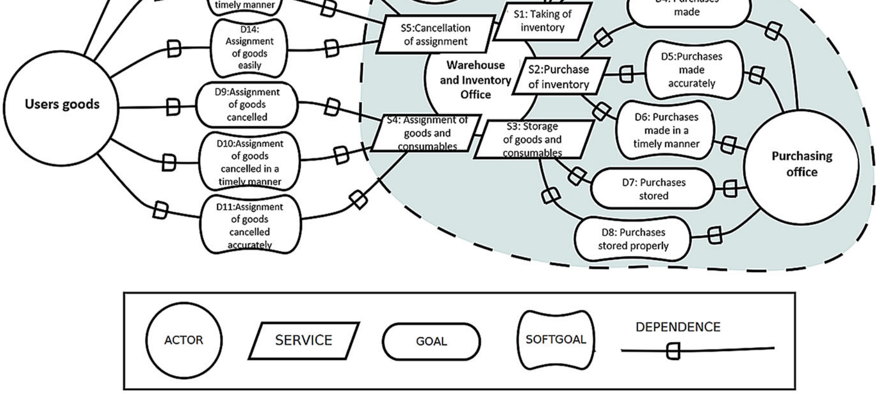

Fig. 2 The service model for the inventory case study

5.2.2 *The process model*

In the process modeling activity, we selected the service "Taking of inventory" due to the high dependency of this process on the current technology for inventories. When the user delegates the service goal to the service provider, the service provider is responsible for making the service goal operable by dividing it into subgoals that can be achieved by the execution of specific business processes.

Figure 3 shows the processes that we found for the "Taking inventory service". We have assigned the letter P and the numbers 1 and 2 to described the processes offered. We have assigned the letter G and the numbers 1 and 2 to describe the goals and subgoals of the processes offered. For example, the process "Collect inventory information" is designated (P1); the goal "Inventory taken" is designated (G1).

5.2.3 *The protocol model*

In the protocol modeling activity, we identified the business process in terms of strategic relationships. Figure 4 shows the tasks delegated by the Warehouse and Inventory Office to the Inventory committee. With the aim of unifying the letters in the following models, the letters will be used depending on the type of model. In this case, we have assigned the letter R and the numbers 1–25 to describe all the elements in this model. The letter R is used since the model is a Rational model.

For example, the goal "The warehouse spaces managed" is designated (R1), while "Inventory taken" is designated (R2).

5.3 The technology modeling phase

In this phase, we defined models for representing the Barcode and RFID technologies that were implemented in our inventory case study. A contribution analysis was also made to select the most appropriate technology alternative for implementation. The technology modules defined in the Barcode and RFID models include the differentiation, composition, variability, and integration features that were explained in Sect. 4.2. In this section, two complementary subphases were carried out: modeling the technology and selecting the technology.

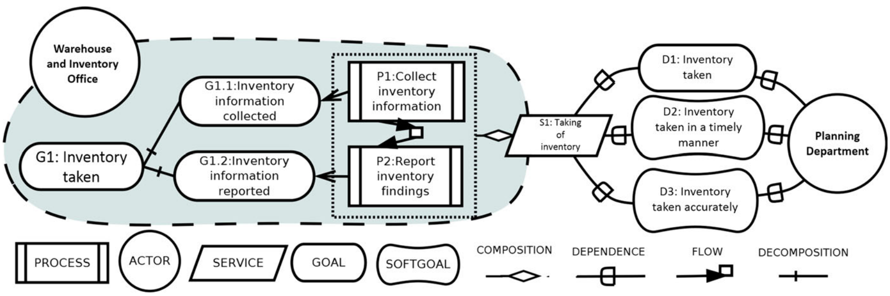

Fig. 3 The process model for "Taking inventory service" of the inventory case study

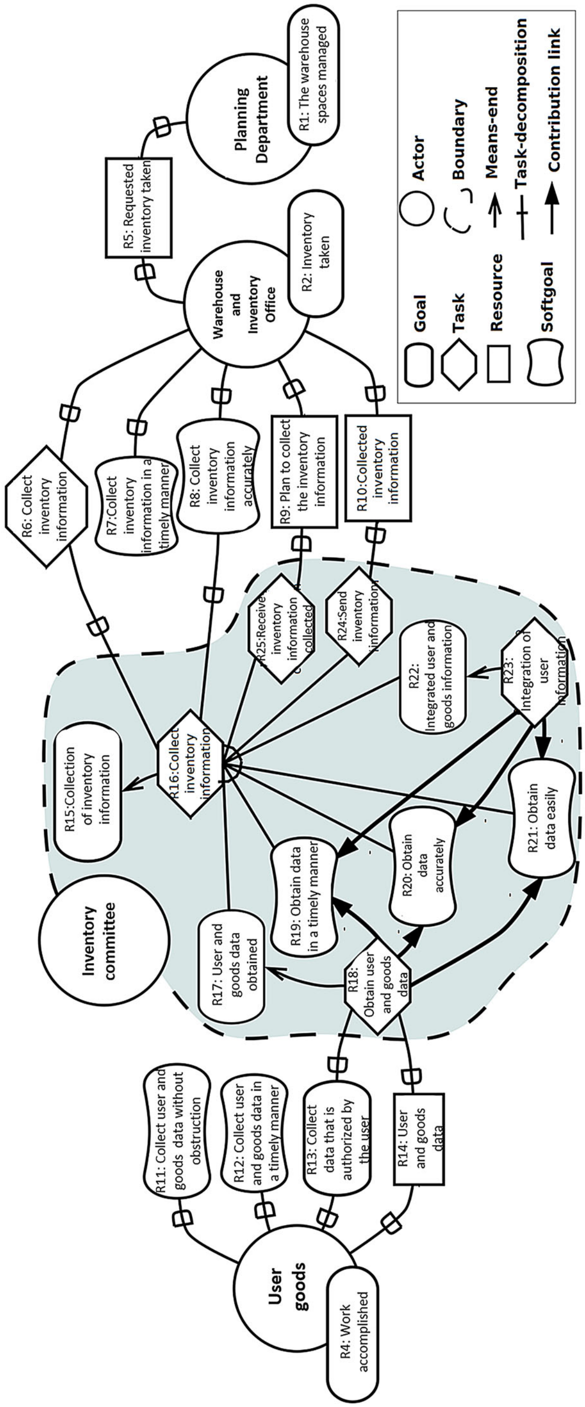

Fig. 4 The protocol model for "Collect inventory information" for the inventory case study

5.3.1 Modeling the Barcode and RFID technologies for the inventory case study

In this subphase, we take advantage of the concept of module to represent a specific technology. The Barcode and RFID models are presented below.

The Barcode technology: It is a widely used technology that uses light for automatic identification and data collection. A Barcode System consists of three components: a label, a reader, and a printer. The label has parallel lines of different thickness that store information. It is attached to the physical objects that are identified. The reader is used to collect the data that is stored in the label. The printer is a computer peripheral for printing barcode labels or tags. A Barcode System can be classified based on the bar code reader type used to collect the information of the object (the laser reader and the wand reader). The wand reader requires direct contact with the barcode label. The reader and the label must be properly aligned and there should be no obstruction between them.

In the inventory case study (Fig. 5), the model for the Barcode system dependencies was composed of the following tecnology components: a barcode reader, barcode labels, and a barcode printer. The main function of the Barcode System for our inventory case study was "Object data collected". The softgoal dependencies identified were quality attributes of the function described (e.g., "Object data collected accurately, in a timely manner, and easily").

The resource dependencies were considered to be resources that the technology offers, (e.g., "Object data and Barcode label"). The quality attributes that the Barcode System requires for correct operation were: "Label kept legible, line of reading without obstruction, and Barcode label aligned adequately". The only resource that the Barcode System requires to be able to read the label of the object

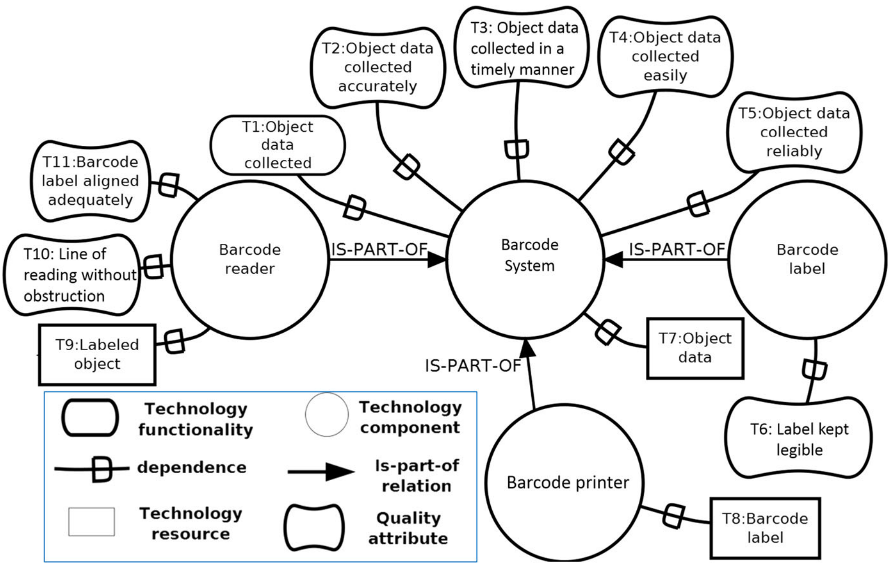

Fig. 5 The model for the Barcode System dependencies

was “Labeled object”. The model for the Barcode System required adding new modules with new dependencies and new components. The variability was defined based on the type of reader (the laser reader or wand reader) (Fig. 6).

The Radio Frequency IDentification (RFID) technology: It is a technology that is used to automate wireless identification and data capture using radio frequency. A basic RFID System consists of two components: a tag and a reader. A tag is an incorporated antenna and a microchip that is placed on the physical object to be identified. The reader is used to capture the data stored in the tag. There are two general categories of RFID tags: active tags, which have their own source of power; and passive tags, which do not have their own source of power.

In the inventory case study (Fig. 7), the model for the RFID system dependency was composed of the following technology components: a RFID Reader and RFID Tags. The main function of the RFID System for our inventory case study was “Physical object identified”. The softgoal dependencies identified were quality attributes of the function described (e.g., “Physical object identified without obstruction, accurately, and in a timely manner”).

The resource dependencies were considered to be resources that the technology offers, such as “Physical object information”. The technology module specifies certain conditions that must be met for the proper functioning of the RFID

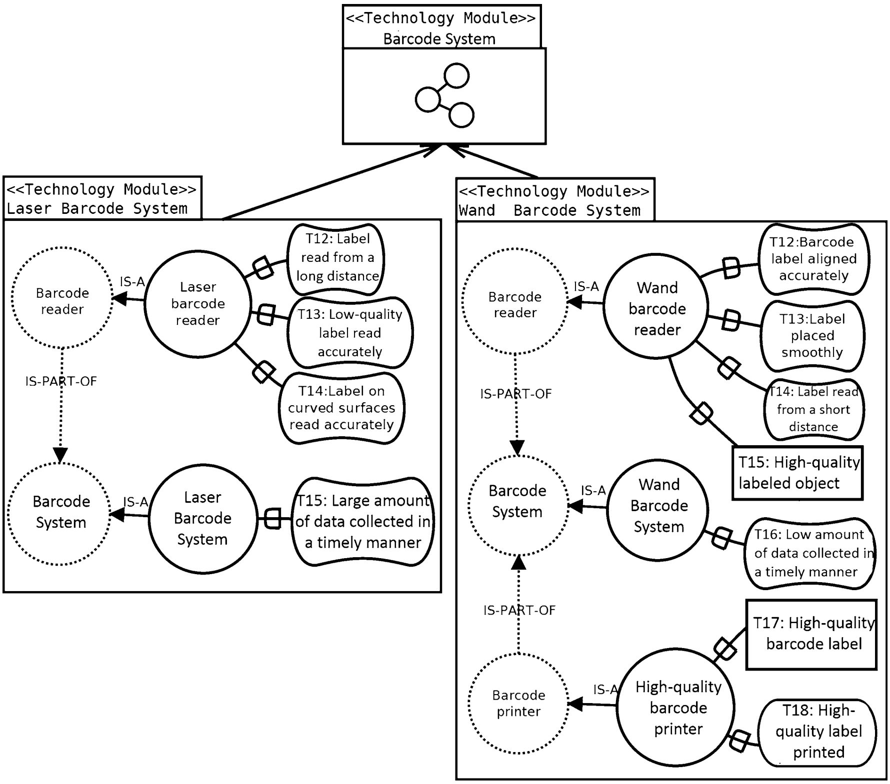

Fig. 6 The model for the Barcode technology module

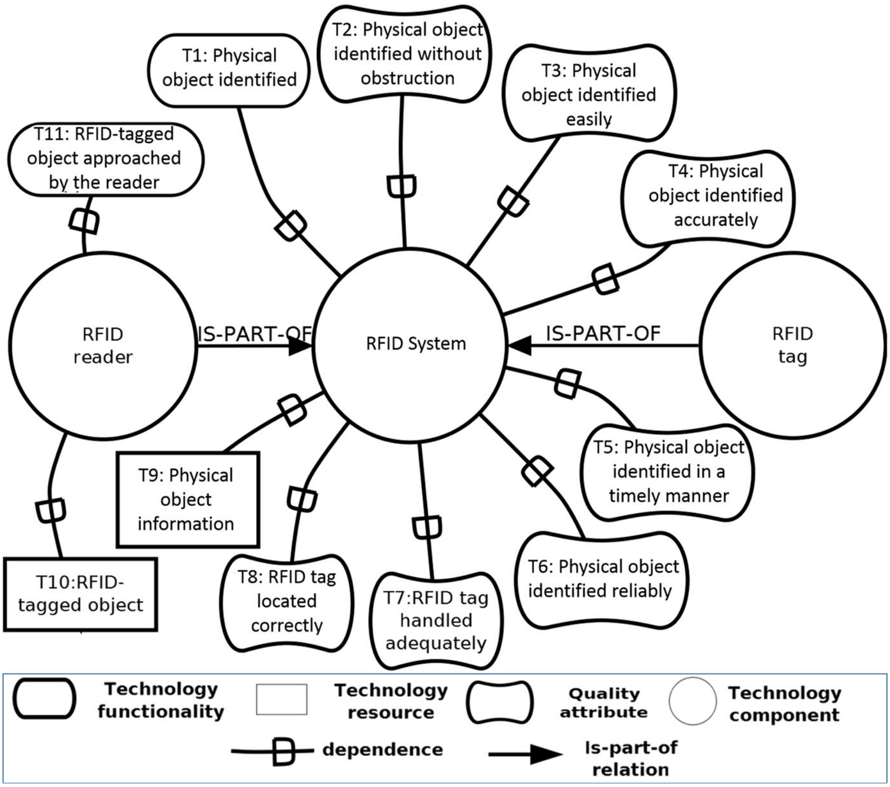

Fig. 7 The model for the RFID System dependencies

technology (e.g., quality attributes, resources, and functions). The quality attributes that the RFID System requires for correct operation were: "RFID tag handled correctly, and RFID tag located correctly". The only resource that RFID System requires to be able to read the label of the object was "RFID-tagged object". The functionality required was "RFID-tagged object approached by the reader". The model for the RFID System required adding new modules with new dependencies and new components. The variability was defined based on the type of tags used (active or passive) (Fig. 8).

5.3.2 Selecting the technology for the inventory case study

In this subphase, the technology selection has been carried out by contribution analysis between the features of a specific technology module and the requirements of a business process (the protocol model for the inventory case study). Every feature of the technology module can contribute positively or negatively to the achievement of the requirements defined in the protocol model. The main objective of the contribution analysis is the selection of the most appropriate technological alternative to improve a specific business process.

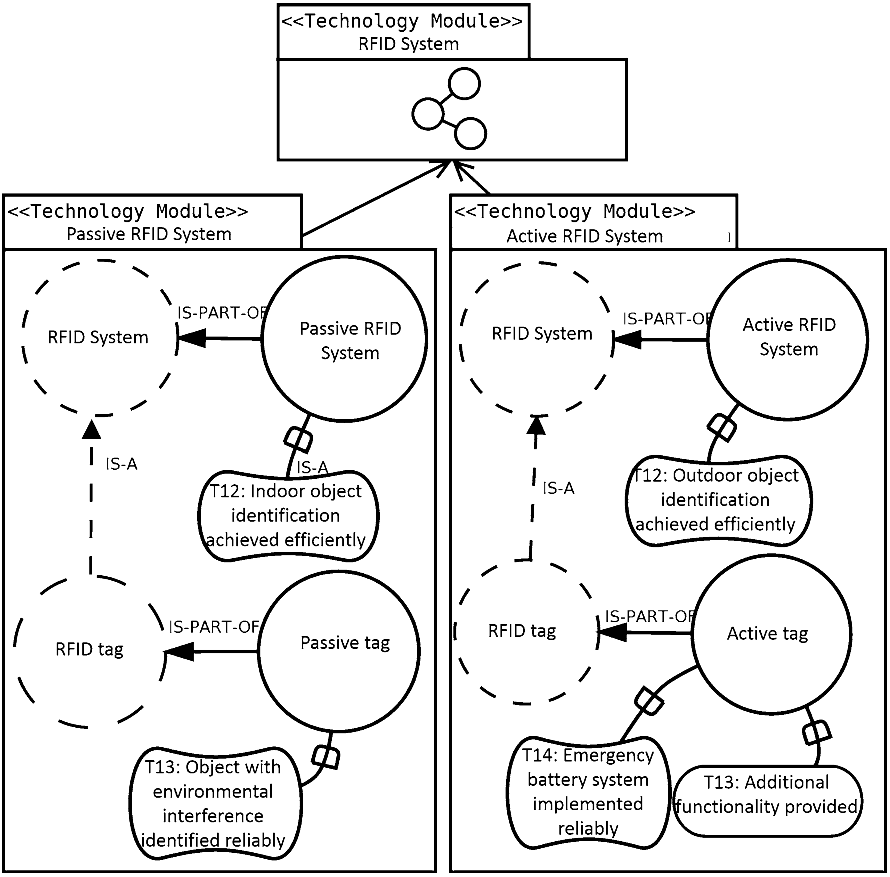

Fig. 8 The model for the RFID technology module

Tables 2 and 3 present an example of the contribution analysis for the Barcode and RFID technologies . With these tables, the analysts can determine if the features of a technology affect the requirements of the inventory system positively or negatively. The columns of the Tables 2 and 3 correspond to the features of the technology module that can contribute to the requirements of the business process. The rows correspond to the requirements of the protocol model that can be contributed by the features of the technology. The following symbols are used to indicate positive and negative contributions: the symbol (+) and (−) indicate positive contributions and negative contributions, respectively. The "TPos" and "TNeg" columns show the total of positive contributions and negative contributions, respectively. If the quality attribute does not affect the technology, there is no symbol in the table.

In Table 2, for example, for the Wand Barcode technology, the feature "Object data collected in a timely manner" contributes positively to the requirement "Collect inventory information in a timely manner". In contrast, the feature "Low

Table 2 The contribution results of wand and laser barcode technology for the inventory information protocol

Barcode technology														
	T1	T2	T3	T4	T5	T6	T10	T11	T12	T13	T14	T16	TPos	TNeg
Wand														
R7			+									−	1	1
R8		+											1	0
R11								−			−		0	2
R12			+						−		−	−	1	3
R19			+					−	−		−	−	1	4
R20													0	0
R21				+			−	−	−		−		1	4
Positive contributions for Wand														5
Negative contributions for Wand														14
	T1	T2	T3	T4	T5	T6	T10	T11	T12	T13	T14	T15	TPos	TNeg
Laser														
R7			+									+	2	0
R8		+								+	+		3	0
R11								−					0	1
R12			+									+	2	0
R19			+					−				+	2	1
R20		+								+	+		3	0
R21				+			−	−					1	2
Positive contributions for Laser														13
Negative contributions for Laser														4

amount of data collected in a timely manner" contributes negatively to the same requirement. In Table 3, for example, for the Active RFID technology, the features "Physical object identified without obstruction" and "Physical object identified easily" contribute positively to the requirement "Obtain data easily". For the Passive RFID technology, the features "Physical object identified in a timely manner" and "Indoor object identification achieved efficiently" contribute positively to the requirement "Collect inventory information in a timely manner".

The determination of the technological variant to be integrated in the business model can be accomplished in two ways: by calculating the total number of positive contributions or by prioritizing requirements. In this case study, the selection was made directly by calculating the total number of positive contributions. The contribution analysis made by the barcode technology allowed the analyst to determined that the Laser barcode technology offered 13 contributions, while the wand barcode technology only offered 5 contributions. Similarly, the same analysis for the RFID technology allowed the analyst to determined that the Laser RFID technology offered 15 contributions, while the active RFID technology only offered

Table 3 The contribution results of active and passive RFID technology for the inventory information protocol

RFID technology														
	T1	T2	T3	T4	T5	T6	T9	T10	T11	T12	T13	T14	TPos	TNeg
Active														
R7					+					−			1	1
R8				+		+						+	3	0
R11		+											1	1
R12					+					−			1	1
R19					+					−			1	1
R20				+		+						+	3	0
R21		+	+										2	0
Positive contributions for Active														12
Negative contributions for Active														4
Passive														
R7					+					+			2	0
R8				+		+					+		3	0
R11		+											1	0
R12					+					+			2	0
R19					+					+			2	0
R20				+		+					+		3	0
R21		+	+										2	0
Positive contributions for Passive														15
Negative contributions for Passive														0

12 contributions. Therefore, we selected the Laser Barcode technology and the passive RFID system for integration into the protocol to collect inventory information.

5.4 Technology incorporation phase

In this phase, the modules corresponding to the selected technologies are explicitly integrated in the business model of the organization. To do this, the features of technology are mapped with the requirements of the business process. Following the case study, we present the incorporation of the technology module for the Laser Barcode and the Passive RFID technologies for the collection of inventory. The models obtained are the basis for making a final decision on the technology solution to be implemented.

5.4.1 Laser Barcode technology integration

The integration of the Laser Barcode Technology takes into account the dependency model (Fig. 5), and the technology module model (Fig. 6). This integration is shown in Fig. 9.

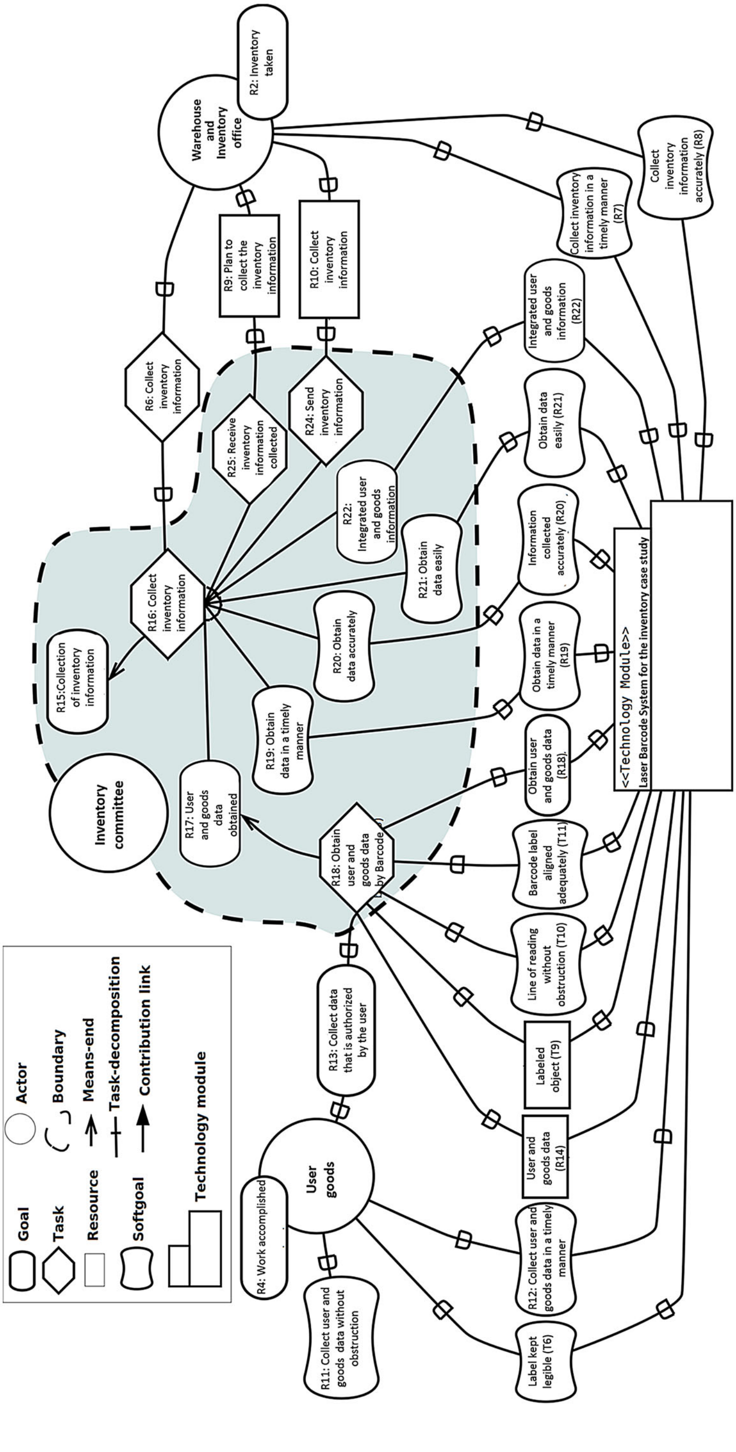

Fig. 9 The protocol model for the process "Collect inventory information" (Barcode technology)

The function offered by the model for the Barcode System is defined by the goal "T1: Object data collected". This function matches the requirement "R17: User and goods data obtained" of the protocol model. The feature "T2: Object data collected accurately", matches the dependency"R7: Collect inventory information in a timely manner". Also, the feature "T2: Object data collected accurately", matches the softgoal"R20: Obtain data accurately".

One of the functions of the technology module is to obtain the goods and user data using Barcode technology as a new artifact to accomplish the task "R17: User and goods data obtained". Moreover, the correspondence between the feature "T3: Object data collected in a timely manner" of the model for the Barcode System and the dependency "R19: Obtain data in a timely manner" of the protocol model has created the new dependency defined with the feature "R19: Obtain data in a timely manner". Also, the correspondence between the feature"T3: Object data collected in a timely manner" of the model for the Barcode System and the quality attribute "R12: Collect user and goods data in a timely manner" of the protocol has led to the forwarding of "R12: Collect user and goods data in a timely manner" to the technology module.

Finally, the features "T10: Line of reading without obstruction" and "T11: Barcode label aligned adequately" have created additional dependencies since they are necessary conditions for the correct operation of the technology.

5.4.2 Passive RFID technology integration

The integration of the passive RFID technology is carried out taking into account the dependency model (Fig. 7), and the technology modules model (Fig. 8). This integration is shown in Fig. 10.

The function offered by the model for the RFID System is defined by the goal "T1: Physical object identified". This function matches the requirement "R17: User and goods data obtained" of the protocol model. The feature "T5: Physical object identified in a timely manner", matches the dependency "R7: Collect inventory information in a timely manner". Also, the feature "T5: Physical object identified in a timely manner", matches the dependency "R19: Obtain data in a timely manner".

One of the functions of the technology module is to obtain the goods and user data using RFID technology as a new artifact to accomplish the task "R17: User and goods data obtained". Moreover, the correspondence between the feature "T4: Physical object identified accurately" of the model for the RFID System and the softgoal "R20: Obtain data accurately" of the protocol model has created the new dependency defined with the feature "R20: Information collected accurately". Also, the correspondence between the feature "T4: Physical object identified accurately" of the model for the RFID System and the dependency "R8: Collect inventory information accurately" of the protocol has led to the forwarding of "R8: Collect inventory information accurately" to the technology module.

Finally, the features "T7: RFID tag handled adequately" and "T8: RFID tag located correctly" have created additional dependencies since they are necessary conditions for the correct operation of the technology.

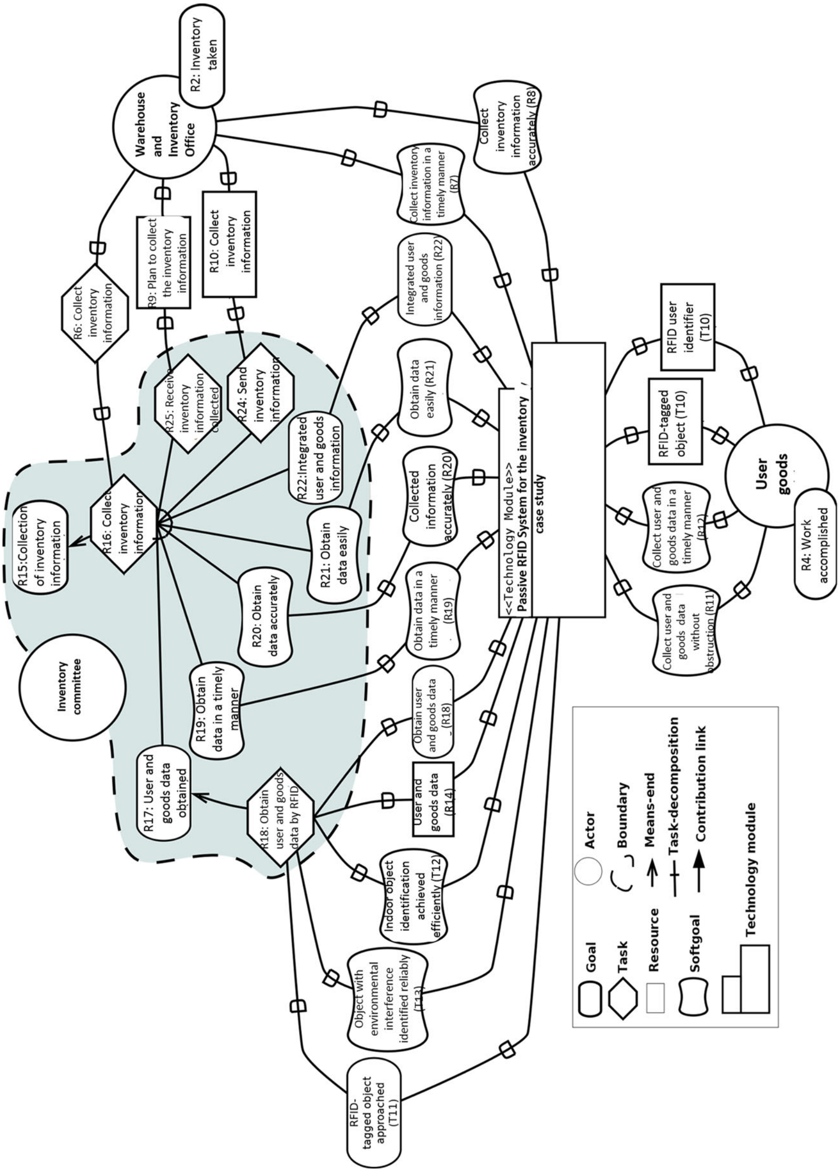

Fig. 10 The protocol model for the process "Collect inventory information" (RFID technology)

5.4.3 Analysis of results for the Barcode and RFID technologies

The features found in the Barcode technology are the following:

- *Differentiation* The Barcode System collects data accurately, easily, and in a timely manner.
- *Composition* The main components of the Barcode System are: the reader, the label, and the barcode printer.
- *Refinement* The specific features of the Barcode System are derived from the features of the reader (wand or laser). The wand reader provides a short-range input, while the laser reader offers a long-range input.
- *Integration* The main features of integrating the Barcode technology for collecting data required by the user to operate the technology are accurately and in a timely manner.

The features found in the RFID technology are the following:

- *Differentiation* The RFID System collects data accurately, easily, and in a timely manner.
- *Composition* The main components of the RFID system are: the reader and the RFID tag.
- *Refinement* The specific features of the RFID system are derived from the features of the tag (active and passive). The passive tag offers objects trust identification in an interference environment, while the active tag offers the capability to implement additional functionality.
- *Integration* The main features of integrating the RFID technology for collecting data to release the workload of the user who operates the technology are accurately, easily, and in a timely manner.

6 Discussion

The first achievement of the case study is the depth of knowledge about the organizational context obtained by the analysts for the Inventory Management Department of CENIDET. Therefore, after applying our approach to the inventory system, we obtained 22 models: 5 services models, 5 process models, and 12 protocol models. The knowledge obtained from these models enabled the analysts to make explicit the relationships between the low-level activities performed by individual actors and the strategic goals of the business. Our approach also showed the dependencies that existed among the actors to fulfill the business goals. This knowledge enabled the analysts to determine if there were activities that could be improved by using technological components.

The second achievement of the case study is the knowledge obtained by the analysts about the specific technologies to be evaluated (the Barcode and RFID technologies). It is important to point out that many times analysts tried to incorporate a technology to the organization, but they did not have complete knowledge about the functionalities and quality attributes of the technology. For example, in the technology incorporation phase of the case study, the analysts analyzed two technology models. Each model had 3 actors, 4 functions, 10 quality attributes, and 1 resource. The analysts were also able to explicitly determine the potential contribution of each technology model to fulfill the goals of the Inventory Management Department of CENIDET. Our approach obtained a numerical factor that determined the positive or negative contribution of the Barcode and RFID technologies. This numerical factor and the features for differentiation, composition, refinement, and integration were the tools used for the selection of the technology to be implemented.

The third achievement of the case study is the knowledge about the inclusion of the Barcode and RFID technologies in the business model. We obtained the integration model for 6 business processes, and we also analyzed the inclusion and the implementation of these technologies. The integration of technologies in the case study was conducted through different technological variations. There are still some aspects of our approach that need to be improved. Specifically, the creation of several models at different abstraction levels can be activities that are time-consuming and require great effort by the analysts. However, the analysts will appreciate the modularity of these modeling layers.

The analysts of CENIDET commented that the models allowed several relevant element to be considered that might have been complicated to consider without a systematic approach. Most of the analysts of CENIDET found the explicit representation of all the features (quality attributes) of the Barcode and RFID technologies to be useful because this representation was very helpful in distinguishing the differences of the two technologies.

7 Conclusions and outlook

This paper presents an approach for incorporating technology in business models, which allows to systematically evaluate the contribution of a specific technology to fulfill business goals. In order to demonstrate the practical usefulness of this approach, a use case has been developed for the process of Inventory Management Department of CENIDET, a public research center in Mexico.

Based on our experience with CENIDET case study, we consider that, when a technology is incorporated in the conceptual model of in organization, analysts will be able to precisely determine the most appropriate technological alternative to improve the performance of the organization. Thus, they will be certain that the selected technology will satisfy the goals of the organization.

One of the advantages of our approach is that both software and hardware are represented in an abstract way. Therefore, new software components or new hardware components can be represented by making their properties explicit as quality attributes. Another advantage is the explicit representation of the relationships between the organizational goals and the low-level activities required to perform the processes.

We also believe that the treatment of technologies as a key modeling aspect in early phases of software development will help to avoid problems in the implementation phases. The case study developed in this research work has provided preliminary evidence of the usefulness of our approach for technology representation at the conceptual modeling level.

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