Requirements Engineering for e-Business Advantage

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Abstract

As a means of contributing to the achievement of business advantage for companies engaging in e-business, we propose a requirements engineering approach that incorporates a business strategy dimension. We employ both goal modeling and Jackson's Problem Frames approach to achieve this. Jackson's context diagrams, used to represent the business model context, are integrated with goal-models to describe the complete business strategy. We leverage the paradigm of projection in both approaches while maintaining traceability to high-level business objectives as a means of simultaneously decomposing both the optative and indicative parts of the requirements problem, from an abstract business level to concrete system requirements. We integrate use of role activity diagrams to describe business processes in detail where needed. The feasibility of our approach is shown by a case study.

1 Introduction

Much evidence indicates that companies are able to gain business advantage over their direct competitors via strategies that leverage IT [1-8]; however, this advantage is only made sustainable through managerial skills in understanding how to use IT as part of a greater strategy for competitive advantage, rather than by superior IT infrastructure or competency of IT staff alone [9, 10]. Organizations thus face many challenges in order to achieve sustainable business advantage over their competitors: they must not only devise effective business strategies, but it is critical that they ensure their IT systems are in harmony with and provide support for their business strategy [11].

An e-business system enables marketing, buying, selling, delivering, servicing, and paying for products, services, and information, primarily across nonproprietary networks, in order to link an enterprise with other *participants* (i.e., current and target customers, agents, suppliers, and business partners) [12]. One of the challenges of enabling business advantage in an organization's e-business initiative is ensuring that the e-business system in fact addresses the real-world problems the business intends to solve. This means understanding the activities and *business processes* through which the organization intends to generate value; i.e., its business strategy [11]. Business strategy is thus within the bounds of the problem domain of e-business systems.

We do not propose that requirements engineers should create an organization's business strategy for competitive advantage. However, requirements engineers can contribute to an organization's business advantage by ensuring that requirements of e-business systems align with, support, and enable its business strategy. To achieve this, requirements engineers must at least understand the business strategy, and have a means of representing strategic context within the requirements engineering framework. Unfortunately, few requirements engineering approaches adequately incorporate the representation of business strategy, or sufficient means for describing business processes that support the strategy.

We thus propose a requirements engineering approach for e-business systems that incorporates business strategy and business process dimensions as a means of contributing to a company's achievement of business advantage. Our approach integrates Jackson's *problem diagrams* [13] with goal modeling. We employ Jackson's *context diagrams* to describe business problem context, and goal-modeling to capture all optative properties of the system, including business goals, strategic objectives, activities and any other business or systems requirements. We leverage the paradigm of projection in both approaches as a means of simultaneously decomposing both the optative and indicative parts of the requirements problem down to the *machine*. We use role activity diagrams to model business processes where needed.

The rest of this paper is organized as follows: section 2 presents the background to our work; section 3 describes our approach and shows how a Problem Frames approach, goal modeling, and business process modeling (BPM) are integrated; section 4 presents a proof-of-concept case study from the literature describing Seven-Eleven Japan; section 5 offers some conclusions.

2 Background

In this section, we discuss previous research and the requirements engineering techniques we use in our approach. Section 2.1 reviews requirements engineering research that addresses e-business issues. Section 2.2 discusses problem frames, their background and their potential to describe and decompose complex problem contexts. Section 2.3 discusses uses of goal modeling to refine business goals and strategy to system requirements. Section 2.4 reviews business process modeling in requirements engineering.

2.1. Requirements Engineering for e-Business

Most requirements engineering research addressing e-business does so indirectly in the context of requirements for Web-based systems or Web applications development [14-17]. Web-based systems research however focuses on architectural, usability, and other design-oriented concerns rather than business aspects. Also, by virtue of being "Web-based," this research effectively excludes issues of e-business systems that do not use the Internet for connectivity or Web browsers for user interfaces. Other research addresses issues of *value analysis* of e-commerce applications development, but neglects *requirements analysis* [18, 19]. A different view is taken in [20], where a requirements-driven systems engineering approach that considers organizational aspects in an industrial e-business project is presented; however, the focus consists primarily of dependencies between organizational actors and goals rather than business strategy and processes.

Overall, with the exception of [20], what little e-businesses systems requirements engineering research there is, fails to propose concrete requirements engineering approaches. The methods and techniques proposed tend to focus on producing end-products of architectural and usability design or value analysis rather than system requirements. None of the research addresses issues of business strategy and business process directly, upon which business advantage is based.

2.2. Problem Frames

Problem Frames, as a requirements engineering approach [13], with its strong emphasis on describing and decomposing problem contexts as they exist in the real world, is potentially a powerful tool for requirements analysis of e-business systems. Research on Problem Frames has focused on what one does when one has got the frame and wants to engineer from there [21-23] or on proposing variations of frames [24] or new frames [25, 26]; only Cox and Phalp attempt to derive appropriate problem frames from business process models for an e-business system [27].

While problem diagrams serve as powerful means of linking requirements to problem context, they are weaker at relating requirements to each other when projecting from problem context towards the *machine*. This is important in problem decomposition of complex systems, where complex problems are projected into increasingly detailed sub-problem diagrams. The detailed description of explicit linkages (traceability) between requirements in problems and those in the projections of their sub-problems in a *progression of problems* (see [13] pp. 103-4) is missing. We thus propose the addition of goal modeling as an effective means of describing that requirements projection.

2.3. Goal Modeling, Business Objectives, and Strategy

Goal-oriented modeling techniques in requirements engineering provide a mechanism for requirements projection in goal refinement. As such, goal modeling serves as a means of linking high-level strategic goals to low-level systems requirements [28]. In fact, a number of goal-oriented techniques have been proposed for modeling business goals and objectives in requirements engineering [29-33]. While this research tends to treat business goals as discrete, independent entities, other approaches assemble business goals and their sub goals into structures representing complete business strategies, and then anchor requirements to the strategy model [34, 35].

However, despite their application to modeling business goals and strategy, goal-oriented modeling techniques have a number of shortcomings. First, they tend to be deficient in describing problem context [34]. Second, goal models tend to bloat quickly, threatening manageability [36]. This is potentially a show-stopping problem in development of large e-business systems, which can be very complex. Third, as goals are inherently hierarchical, it can be difficult to discern where a business goal is situated in the hierarchy and how it relates to the business problem context. Moreover, for every business goal, there is always a discoverable super goal, and thus goal-modeling requires upper bounding of the problem domain [13, 37].

2.4 Business Process Modeling (BPM) in Requirements Engineering

A business process is a "set of partially ordered activities intended to reach a goal" [38]. Requirements engineering techniques have been used to address issues of business process; however, most of these techniques are inadequate when applied to e-business systems.

Structured Analysis (SA) has been used to model processes in examining context [39, 40]; however, SA only considers data flows between external entities and the system in context diagrams, and thus effectively ignores processes and interactions between external entities [13, 41]. In e-business systems the *participants* are the external entities. Describing their direct relationships and interactions is fundamental to understanding the e-business problem [12].

Use cases are sometimes employed to describe business processes [42], but they have been viewed in the requirements engineering community as inadequate for describing complex business requirements [23, 43], including processes. In contrast with standard use cases, Buhr's *use case maps* provide an expressive notation to represent complex architectural behavior processes [44, 45]. They treat processes primarily as machine activities, typically ignoring the human and organizational aspects of business processes, which are critical to describing e-business systems.

Eriksson *et al.* propose modeling business processes with UML activity diagrams [46]; however, activity diagrams were originally designed to describe how activities affect the state of software-focused objects, not business processes. Eriksson *et al.* do not justify why UML activity diagrams are better suited to describing business processes than recognized BPM notations.

To overcome the inadequacies of requirements engineering approaches to BPM, we employ role activity diagrams [47], a well-recognized BPM notation, in our approach.

3 Addressing the e-Business Problem

This section is organized as follows: section 3.1 justifies application of the Problem Frames approach to business strategy. Section 3.2 discusses both the idea of a *progression of problems* and why it is appropriate to the e-business domain as a means of expressing context. Section 3.3 shows how goal modeling can represent the requirement set. Section 3.4 integrates role activity diagrams to describe business processes.

3.1. Business Strategy as Problem Diagrams

Based on a broad survey, Oliver defines business strategy as "the understanding of an industry structure and dynamics, determining the organization's relative position in that industry and taking action either to change the industry's structure or the organization's position to improve organizational results" [48].

This definition of strategy is similar to Jackson's definition of a *problem diagram*. Jackson describes the world in two ways; the way the world is (*indicative* mood, i.e. the problem context) and the way in which we want to change the world (*optative* mood, i.e. the requirements) [13, 41]. Oliver's "understanding of an industry structure and dynamics," and "determining the organization's relative position in that industry" is Jackson's *indicative* mood. "Taking action either to change the industry's structure or the organization's position to improve organizational results," is Jackson's *optative* mood, the way in which the organization desires to change the real world.

We propose that an e-business strategy can be represented as a *problem diagram*, in which the e-business system is represented as the *machine*. We recognize that an e-business system is in fact a collection of many machines working in concert, but at this level of abstraction, we represent the entire system as one *machine*, in accordance with Jackson's rule [13]. The participants in an e-business system represent *domains of interest* [13, 41]. As noted above, the *requirements* are the *optative* part of the strategy; i.e., the objectives, activities, and business processes of the firm through which it attempts to succeed in its business. We consider all optative properties of a system to be requirements, including business goals, objectives, activities, business processes, policies, and any other business or systems requirements.

3.2. A Progression of Problems

E-business problems at the highest level of business strategy are in fact very distant from the *machine*. To refine requirements from high-levels of abstraction down to the *machine*, the paradigm of a *progression of problems* is particularly useful (Fig. 1). The complexity of e-business systems as well as the need to align requirements with the highest levels of business strategy has in fact pushed the requirements problem into what Jackson would describe as "deep in the real world" [13].

The *domain* DA in Fig. 1 represents the *indicative* properties of the e-business problem context at the level of business strategy. *Requirement* RA represents the *optative* properties of strategy. Through analysis of DA and RA, it is possible to find a requirement RB that refers only to DB while satisfying RA [13]. DB represents the projection of DA, but at a lower level of abstraction. Through this process of analysis, problem projection, and refinement, ultimately the requirement refers just to the *machine*.

While the paradigm of a *progression of problems* serves as a powerful framework for decomposing e-business strategy down to *machine* requirements, the Problem Frames approach provides little explicit linkage between requirements at different levels of the progression. In the example above, requirement RB must satisfy requirement RA, and RC must satisfy RB, which satisfies RA, and so on. In order to ensure that system requirements are indeed in harmony with and provide support for business strategy, explicit traceability from lower level requirements to the highest level is necessary; however, while Jackson proposes analysis of DA and RA in order to find RB [13], a framework for doing so is not described. Moreover, the Problem Frames approach provides no direct linkages between RA and RB.

3.3. Integrating Goal Modeling with Progression of Problems

Goal modeling is a useful technique to describe explicit linkages between lower-level requirements and higher-level objectives [28], and therefore using goal-models to represent the requirements part of the problem diagram is a possible means to trace requirements between problem diagrams in progression. Goals represent objectives that the system ought to achieve, and refer to properties that are intended to be ensured [37]. Goals are thus requirements at a higher level of abstraction. Therefore, we treat goals as *optative*, as we would a requirement, equally bounded by the problem domain [13, 41]. Goals may be formulated at different levels of abstraction, from high-level strategic concerns to low-level technical ones [28]. This is a useful tool in describing the requirements part of problem diagrams when developing e-business systems. We therefore propose the integration of goal modeling with problem frames as a means of helping ensure that the requirements are in harmony with and provide support for business strategy.

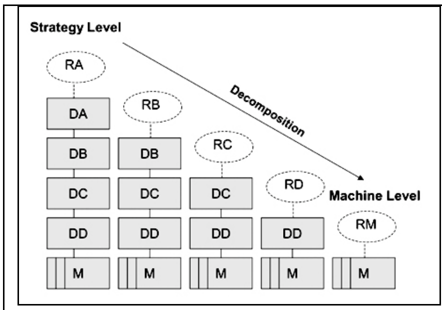

Fig. 1. A Progression of Problems (adapted from [13] p. 103)

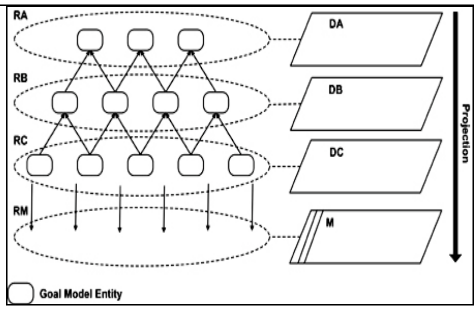

Fig. 2. Goal Model Integrated with Progression of Problems

The integration of a goal model with a progression of problems is illustrated in Fig. 2. The optative requirements at each level are described in terms of a portion of a larger goal model. The goal portions represent requirements at a level of abstraction equivalent to that of the *domain* to which they refer within the progression of problems. Each goal entity refers to specific *domains of interest* within the referred domain. The goal model enables explicit connections to requirements at adjacent levels in terms of super goals and sub goals. The sub goals are in fact projections of their super goals, and satisfaction of the sub goals guarantees satisfaction of the super goals in the same way that satisfaction of RB guarantees satisfaction of RA (Fig. 2). The context diagrams in the progression of problems (DA, DB, DC, …) complement the goal model by providing problem context at various levels of abstraction with explicit linkage to requirements. Moreover, the integration of context diagrams with goal modeling also improves manageability of goal models of complex systems. The sub problems enable a decomposition of the requirements, represented as portions of the goal model, into manageable chunks, while still maintaining explicit linkages. Also, individual business goal entities are situated in the context of the problems at explicit levels of problem abstraction.

3.4. Business Process Model

Jackson's problem diagrams, even when augmented with goal models, are inadequate for describing business processes. While we can represent discrete activities that make up a process as optative properties of a problem, there is no notion of order in problem diagrams or goal modeling to enable description of these activities as a process. In addition, goal models when decomposed down to the level of atomic activities in a process bloat at the bottom-level and become unmanageable. We thus propose integrating business process modeling (BPM) to alleviate the above concerns (Fig. 3).

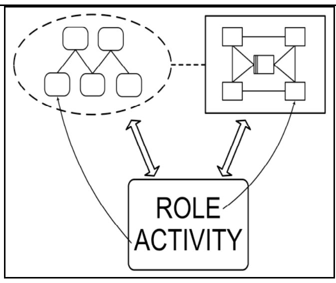

Fig. 3. RAD Providing Business Process Detail to Problem Diagram

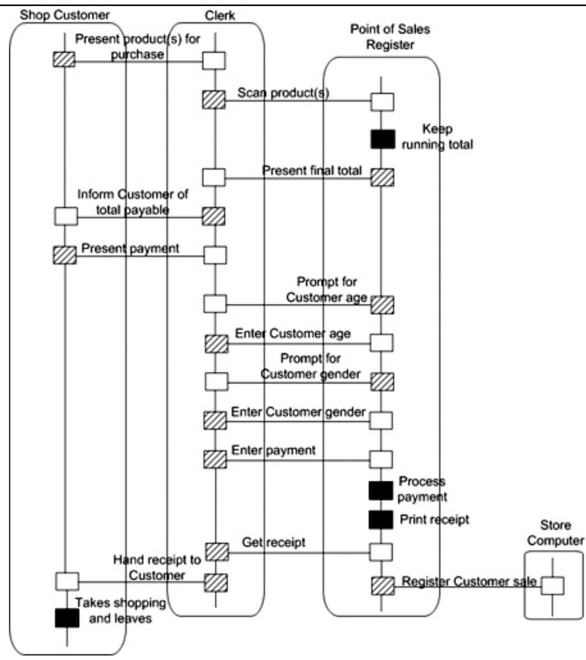

Fig. 4. Business Process RAD Describing RC-DC

A role activity diagram (RAD) describes business processes in great detail, including both indicative and optative properties, in a clear and succinct manner. The roles represent domains of interest, and are indicative properties. The activities, which are actions and interactions between roles, represent optative properties. The goals that business processes achieve are represented in the goal model.

Roles can be viewed as either black box or in more detail as white box, allowing representation of different abstraction levels of a particular problem (contained solely within the role). This gives the engineer the opportunity to understand not only how domains interact but also how they act internally.

It might be argued that if we can show both indicative and optative properties in a business process model, this would then be sufficient on its own in describing an e-business problem; however, business processes only describe discrete goals that the process's activities achieve. Without the wider perspective of the goal model there is no notion of where the process fits in the overall business strategy. Also, while describing business process is important to certain aspects of the e-business problem, not all aspects of the problem involve processes.

4 Proof of Concept Case Study: Seven-Eleven Japan

We use a business case from a number of sources in the literature of Seven-Eleven Japan's e-business system [12, 49-52] to illustrate our approach.

4.1. Overview of SEJ's Business Strategy

Seven-Eleven Japan (SEJ), like its US progenitor, manages a national network of convenience stores. Unlike Seven-Eleven USA, SEJ generates value by leveraging and controlling ownership of information to optimize efficiency across a value chain with an unparalleled manner of sophistication. SEJ positions itself in the center of a value chain that includes suppliers, third-party logistics providers, and franchise shops, all of whom are independently-owned companies, yet all of whose objectives are maximizing throughput of products ultimately sold to franchise shop end-customers.

SEJ bases its strategy for competitive advantage on an extremely high level of competency at anticipating consumer purchases store-by-store, item-by-item, hour-by-hour, and then providing customers with products they want when they want them. SEJ's strategy leverages IT to accomplish its strategic objectives, and gain business advantage over its competitors. Its ownership of information enables sophisticated supply chain management to reduce inventories, lower costs, and increase sales. SEJ moves information between itself and its partner companies via an ISDN network (incidentally, SEJ's e-business strategy is *not* Internet-based, nor are its systems Web-based). To better understand customer demand, SEJ actively gathers and analyses purchasing information in real time, and correlates this with other social and environmental factors, including neighborhood demographics, planned local events like festivals, and the weather. SEJ then uses an acutely tuned just-in-time delivery system to meet that demand, generating remarkable value. It is these activities and their objectives that constitute the optative part of the SEJ e-business problem.

4.2. Progression of Problems of SEJ

Let us examine the progression of problems of SEJ's e-business system from the top, macro-level of business strategy down to the machine devices used in the franchise shops (see Fig. 5 below). Note that for the purposes of describing the approach we are only concerned with a particular sub-problem within Fig. 5 and that Fig. 5 describes only part of the SEJ e-business system problem. The macro-level business strategy is the top-level problem that is deepest into the world. It is here that we bound our problem, because it is here that SEJ bounds their problem.

The progression of problems consists of an indicative part, which we describe as a progression of context diagrams, and an optative part, which we describe as a goal model. We chose to represent the goal model in GRL notation [31, 53] because of its expressiveness in representation of both abstract and non-abstract goals, tasks, and resources, which we felt would be helpful in modeling requirements for SEJ's complex e-business system. Please note that the entities in the goal model are grouped by dashed-line ellipses (RA, RB and RC in Fig. 5). The goal entities within the ellipses represent requirements referring to context diagrams in the progression at equivalent levels of abstraction (DA, DB and DC in Fig. 5). The integration of the goal model and the context diagram at each level in the progression presents a *problem diagram* for that particular level of abstraction.

We now describe this progression in finer detail. Our aim in the example presented here is to demonstrate traceability and alignment with requirements at higher-levels, deep into the real world. To understand the optative part of the business strategy we explore the goal model at its highest level (RA). SEJ's requirement is to *Stock products that customers want when they want them according to changing needs*. This meets the goals *Reduce lost opportunity/customer* and *Minimize unsold perishables* and is achievable by *Just-in-time delivery*, which in turn supports the goals of *Maximize use of limited floor space, Shorten inventory turns* and *Maintain constant freshness of perishable goods*. These can be met by *Development of effective decision support systems*. The scope of the requirement set can only be understood by an exploration of its context.

The corresponding context diagram (DA) shows the *machine* domain *SEJ Value Net Integrator System*. This retrieves the *Just-in-time* data it needs from the *Franchise Store* domain (interface *a*). To know what to deliver just in time (a goal in RA), the needs of the *Shop Customer* must be understood (interface *b*). The *machine* domain provides the necessary information to the *Supplier* (interface *f*), which in turn uses a *Logistics Partner* to deliver the goods, supporting the goal *Just-in-time delivery*. The shared phenomena *e* represents the delivery schedule, the goods themselves and delivery address. The *Logistics Partner* must also provide its schedule details back to the *SEJ system* (interface *d*) about its delivery (interface *c*). The *Franchise Store* also provides details of the sales of perishable goods, how the store is stocked and how this affects the sale of goods. Inventory and sales information is highly automated; its requirements can only be understood by decomposing the problems.

To meet the goal to *Develop effective decision support systems* (in RA) that helps achieve the requirements of RA, the Requirement Set RB has three goals and a number of supporting tasks. RB focuses on how the *Franchise Store* can work effectively to meet SEJ's requirements. Thus, in order to *develop effective decision support systems* one must *identify sales trends down to an hourly basis*. To meet this requirement one must have *analysis of customer needs in real time*. Allied to *sales trends* is the *constant monitoring of tastes*.

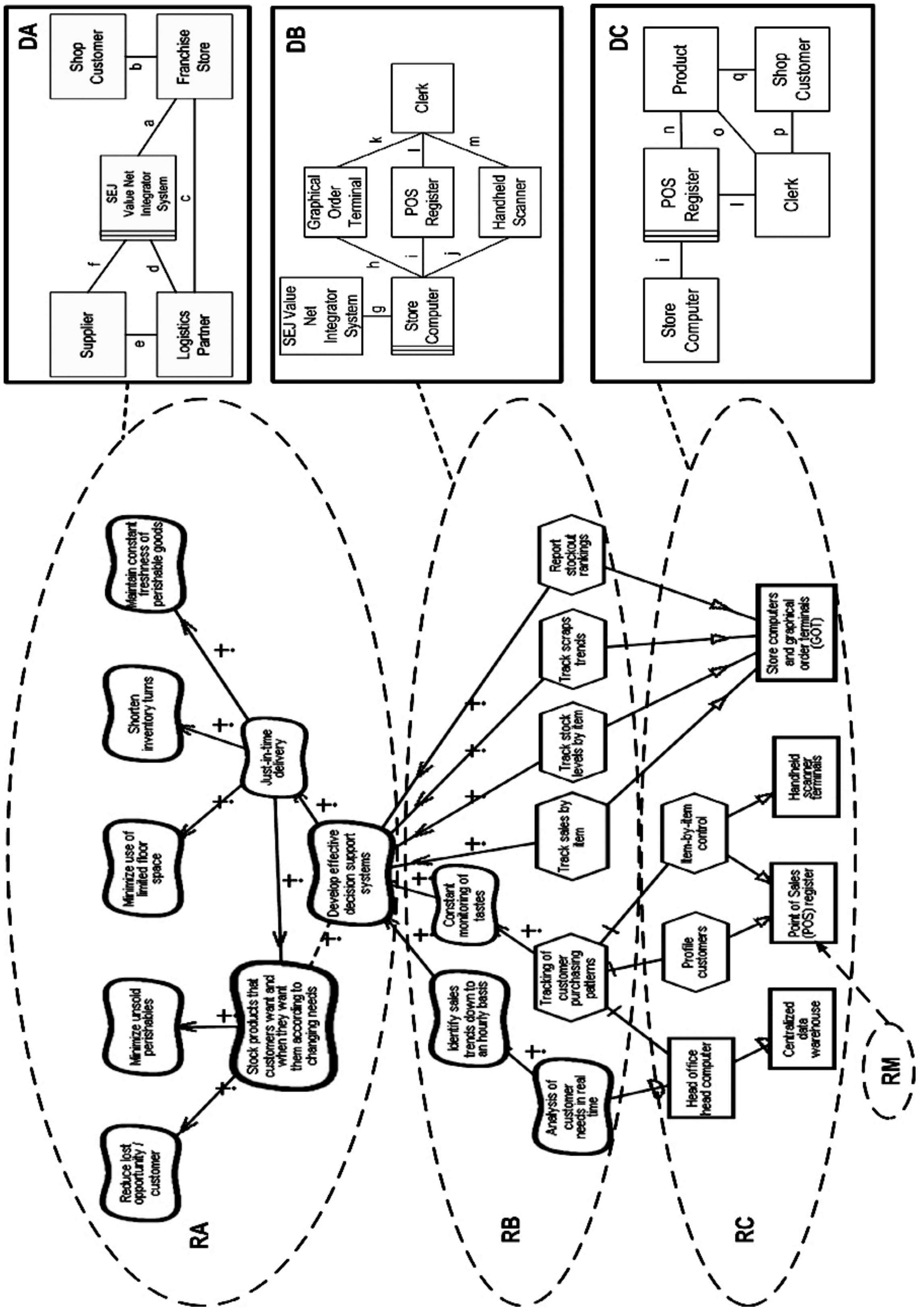

Fig. 5. SEJ Progression of Problems: Integrated Goal Model and Context Diagrams

The context diagram at DB is a progression from that of DA. To meet the Requirement RB, DB's context shows the composition of the *Franchise Store* of DA. The *Graphical Order Terminal (GOT)* is a device that allows the *Clerk* to track and report on sales and stock that is held in the store (interface *k*). The *GOT* accesses the *Store Computer* by interface *h* in order to do this. The *Handheld Scanner* is a device that allows the *Clerk* (interface *m*) to scan product barcodes of items on the shelves and in the shop storeroom for *Item-by-item control* of inventory. The *Handheld Scanner* accesses the *Store Computer* via interface *j* in order to provide regular updates. The *Clerk* also interacts with the *Point of sale register (POS)* to take customer purchases (interface *l*) and the *POS* informs the *Store Computer* (*i*) of these (described in the next paragraphs). The *Store Computer* processes and then relays information to the *SEJ Value Net Integrator*, in real time (interface *g*), thus meeting the goals in RB critical to the success of the strategy captured in RA.

Referring to the goal model, the requirement set RC contains a number of devices. However, our focus in this example is the *POS*, represented as a GRL *resource*. It has two tasks that have to be performed to satisfy *Tracking customer purchase patterns* (in RB). These are, *Profile Customers* and *Item-by-item control*. We thus present the domains of interest in the context of the *POS* in DC.

In DC, the *Shop Customer* takes his *Products* (interface *q*) to the *Clerk* for purchase (interfaces *p* and *o*) and then pays for them (*p*). The *Clerk* scans the *Product* information via the barcode (*n*) into the *POS*. The *Clerk* enters the *Shop Customer* profile and payment details into the *POS* (interface *l*). Finally, the customer profile and product information is sent to the *Store Computer* by the *POS* (interface *i*) for storage, processing, and transmission to SEJ, meeting its goal in RB (*Analysis of customer needs in real time*) and task (*Tracking of customer purchasing patterns*).

While in our model, our requirement RM refers to the *POS* register directly, we recognize that the *POS* is in fact a fairly complex machine. Its problem context would likely be decomposed into a domain DD, and further into recurring problem frames. We do not illustrate this here, because this is not the focus of our paper. Jackson describes numerous examples of this type in his book [13].

4.3 Business Process Representation

The business process is shown as a role activity diagram (RAD) in Fig. 4 (in section 3.4). The *Shop Customer* in the RAD presents his products for purchase to the *Clerk*. The *Clerk* scans the products to record the product details in the *Point of Sales Register* (*POS*), which keeps a running price total. When all products have been scanned, the *POS* presents a final total amount payable. The *Clerk* informs the *Customer* of the amount payable, who then presents payment to the *Clerk*. We do not discuss how payment is made since this is another sub-problem and not part of our example.

In order to achieve the task *Profile customer*, the *POS* prompts the *Clerk* to enter the *Customer's* age, followed by gender, prior to concluding the payment transaction. One of the requirements of the *POS* is that the cash drawer not open and sales cannot complete until the *Clerk* has entered this information. The *Clerk* then enters the payment into the *POS*, which prints a receipt. The *Clerk* hands this to the *Customer* who takes his shopping and leaves.

This process thus meets the objectives *Item-by-item control* and *Profile Customer*. The *POS*, meanwhile, *Registers the Customer sale* with the *Store Computer*. This interaction contains both product information and the profile information of the customer who bought the products. As products are scanned, the *POS* records the bill of sale enabling *Item-by-item control* of inventory as products are sold off the store's shelves. Product data is also associated with the customer profile data, and time and date of purchase, which helps enable *Tracking of customer purchasing patterns* in RB.

The RAD describes the activities in RC involved in achieving the requirements *Profile customers* and *Item-by-item control*. These activities can be traced to higher-level objectives in the goal model. The roles in the RAD are taken from the context diagram DC ensuring that the process model describes both the optative and indicative properties at the equivalent level in the progression of problems.

4.4. Discussion of the Integrated Approach

The indicative problem context diagrams in the progression of problems and the optative goal model mutually complement each other. Goal modeling provides explicit linkage between requirements in problem diagrams at different levels of abstraction as determined by the context diagrams. This integrated approach thus offers a means of helping ensure that requirements are in harmony with and provide support for business strategy. This in turn helps enable business advantage (assuming that the strategy is correct), as requirements are aligned top-down from the highest level of problem context and business strategy.

We also suggest problem context diagrams improve manageability of goal models of complex systems, by breaking down requirements into more manageable goal model portions. Moreover, the context diagrams enable explicitly situating individual business goal entities in the context of the problems they address at equivalent levels of abstraction. Finally, the context diagram at the top-level of the progression of problems bound the goal model as it bounds the problem from SEJ's point of view.

However, this is not enough. The problem diagram provides no means of describing process. The RAD in Fig. 4 describes explicitly how the interactions between the domains in DC achieve requirements in RC in a business process. Understanding this process in detail is fundamental to understanding the nature of the e-business problem.

5 Conclusion

In this paper, we present an integration of recognized requirements engineering approaches to meet the needs of the e-business systems domain. Problem diagrams provide context for the indicative business problem and can be projected down to system requirements. Coupled with this, goal modeling captures the optative requirements that fit the problem context. Each projected sublevel of the goal hierarchy in itself represents the requirements set for the context at that level in the projection. When appropriate, we use business process models to describe the optative and indicative properties of the e-business system.

Jackson describes a requirement as "the effects in the problem domain that your customer wants the machine to guarantee" [13]. Organizations engaging in e-business rely on their systems to enable their strategy and gain business advantage. It is thus at the level of strategy that companies like Seven-Eleven Japan bounds the requirements problem for their e-business systems. While we do not propose that requirements engineers make business strategy, they can contribute to achievement of business advantage by ensuring that IT systems requirements are aligned with, provide support for, and enable business strategy.

While the approach we propose is based on research that is still in its early stages, the integration of the Problem Frames approach, goal-oriented modeling techniques, and business process modeling may offer promise as a requirements engineering tool for e-business systems.

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