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Context-aware goal-oriented business process modeling

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Context-Aware Goal-Oriented Business Process Modeling

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Abstract

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Informed decision making and flexibility have grown to be important standard requirements in the field of business process modeling and design due to the emergence of intrinsically complex variables within the business environment. Traditionally, researches on business process modeling and informed decision making have focused on the configurability of business process models. Our review of literature made us realize that researchers in this field have considerably neglected the main drivers of flexibility and decision-making which have an extensive impact on business process flow. Such drivers form, in our opinion, cross cutting concerns that need to be extracted from within the context of the business process. Context can include, but is not limited to, work force availability, work force experience, system failures, weather conditions, environmental hazards, and financial constraints. In this research we present a new general purpose methodology for aspectized modeling of the context of business processes within the different business domains and also for modeling business processes as goal-oriented finite state machines. Being dependent on context-awareness and goal-orientation, our method deduces recommendations for improving the business process flow. We envisioned how context may be conceptualized, how contextual elements may be distributed across business operational levels according to the goals of the business process, and how business process flow recommendations based on the aspectized contextual facts may materialize. We managed to make our vision concrete by implementing all this into a prototypical framework that made the methodology both usable and testable. We tested our framework within the Airlines and Telecom business domains. The experimental results showed significant improvement in the financial costs and execution time. The results proved the importance of integrating context-awareness, context-modeling and goal-orientation in the field of business process modeling as well as configuration and decision making. By adopting context-awareness based on modern technology we believe that this research is a contribution in the field of intelligent business environments and that it opens the door for more challenging extensions on more complex goal-oriented business processes.

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Chapter 1: Introduction

Business process modeling has been an important area of research for a number of years due to the need for simulating and automating business processes in the software industry. The flexibility of business processes has been a strong motivation for many researches as it offers a means to make business process models both configurable and adaptive. Flexibility is defined as the capability to change without loss of identity [53]. The need for business process flexibility stems from the variance in the context of application of the same business process. The context of a process is basically defined as the surrounding conditions of a business process that cause alteration in its behavior [55]. These surrounding conditions or "context" in our view is a collection of cross cutting concerns which affect the decisions that should be taken and hence directly affect the business process flow and may enforce certain key decisions or customizations on the business model. The changes that are made throughout the process lifecycle can be wider than just changes in the process flow. Changes can be classified according to the handling procedures which are divided into substitution, adaptation and evolution of business processes/sub processes [32][21][31]. Adopting context-awareness and advanced context-modeling; representing context in terms of aspects as well a goal driven modeling of business processes are therefore critical for process change strategies. Despite, the growing importance of the business process context and the advantages of its aspectization, it has not yet drawn researchers' attention. Most researches involving context-awareness focused on pervasive systems and mobile computing. So far neither the aspectization of business process nor contextual business items in general have been considered. In this research we focus on modeling business process context (as aspects) within the business processes and on modeling the goals of business processes. Our research aim is to enrich the field of business process modeling by taking advantage of context-modeling, aspectization and goal-orientation for more effective decision-making within the business processes.

In the rest of this introductory chapter we first brief the reader about the different research domains that our research overlaps with which are business process modeling, context-awareness and aspect oriented development. We then briefly explain our research idea and the motivation behind it to give the reader a basic understanding of what we are aiming at.

1.1. Related Research Disciplines

1.1.1. Business Process Modeling

Business process modeling has lately become an active area of research. The definition of business process varied between two main definitions the first is that a business process is a collection of activities that takes one or more kinds of inputs and creates an output that is of value to the customer [20] and the other definition is a chain of activities whose final aim is the production of a specific output for a particular customer or market [8] . Since the emergence of the business process definition, the idea of business process modeling emerged and many techniques emerged to model business processes [31].

Business process modeling is defined as the activity of representing processes of an enterprise, so that the current process may be analyzed and improved in the future [9]. It addresses the process aspects as business architecture, thus leading to an all-encompassing enterprise architecture. Business process modeling is integral to business process management and re-engineering of a business process could achieve higher business efficiency [9].

Many languages and notations emerged in the last few years. One of these languages is business process modeling notation (BPMN) which is a graphical representation for specifying business processes in a workflow [38]. The aim behind BPMN was to provide a notation that is readily understandable. BPMN is also supported with an internal model that enables the generation of executable code called BPEL (which bridges the gap between BP design and implementation). BPMN defines a business process diagram (BPD), which is based on a flowcharting technique , a business process model, is a network of graphical objects, which are activities (i.e., work tasks) and the flow controls that define their order of performance. BPMN is usually used in representing collaborative (public) business to business processes and internal (private) business processes [37].

Another language for business process modeling which supports configurability of business processes is Event Driven Process Chains (EPC). EPC is a BPM technique used for analyzing processes for the purpose of Enterprise Resource Planning (ERP) implementation. EPCs are directed graphs, which visualize the control flow and consist of events, functions and connectors [13].

The most famous language for business process modeling is the Unified Modeling Language (UML). UML is used to specify, visualize, modify, construct and document the artifacts of an Object Oriented software intensive system under development. UML supports different kinds of diagrams that can represent various aspects of a business

process representation. It supports using structure diagrams (class, component, and deployment diagrams), behavior diagrams (Activity, state machine and use case diagrams), and interaction diagrams (Sequence, Timing and Communication diagrams) [13].

In our solution methodology we used the concept of UML state machines. The business process is represented as a sequence of states and the flow from one state to another depends on transitional conditions between states. The transitional condition depends on the output of the state and the contextual surroundings affecting the current step. Each step is tightly bound to goals to make our solution goal-oriented and according to the goals of the step we identify which contextual surroundings needs to be considered within this step's transitional condition.

1.1.2. Context-awareness

Context is simply defined as implicit situational information[3]. The concept of context consideration stems from the ancient idea of processing language or understanding what a certain human being is saying within its context. The idea of the need to use context for a better design of applications and the context-awareness term were coined by Schilit and Theimer [59] as approaches for incorporating contextual factors into various systems, such as in the area of Mobile applications. Schilit and Theimer[59] considered context as location, identities of nearby people and objects and changes happening to those objects. They typically focus on users and their interaction with the systems [10] [59].

There are other definitions of context which perceive the context as elements of the user environment which a computer can detect or have knowledge of [14]. Hull et al [22] perceive the context to be the aspects of a current situation. The definitions of context are numerous, however within our research we consider the context as all the surroundings of a business process from direct resources required to execute it, to company strategy in which it runs to industry and country regulations affecting it and we represent context in terms of aspects.

Context-awareness exists in many other disciplines other than business process modeling and has received much attention in these areas e.g. Web-based systems [33][19][12], Mobile applications [39] and conceptual modeling[2] [55]. They typically focus on users and their interaction with the systems [10] [59]. Existing frameworks (such as the ECOIN framework [16]) attempt to represent context as properties that can be interpretation-based either on the inbuilt framework structures or based on a generic ontology that has no structure prior to design time. Almost all

context-aware frameworks currently available in the market and even developed for research purpose were coined within the field of pervasive systems and its applications (e.g. smart hospitals and smart homes). The main problem with most of these context-aware frameworks is that they are focused on pervasive systems and mobile entities, that they lack customization for context of business processes and that they are not open source so their usage or extension should be under the supervision of their developers.

1.1.3. Aspect Orientation

Aspect oriented software development (AOSD) is a relatively new emerging technology and methodology [5] [65]. The general purpose of AOSD is the modularization and separation of crosscutting concerns in software. AOSD allows multiple concerns to be expressed separately and automatically unified into working systems. The focus of Aspect-Oriented Software Development (AOSD) is in the investigation and implementation of new structures for software modularity that provide support for explicit abstractions to modularize concerns. Aspect-Oriented Programming approaches provide explicit abstractions for the modular implementation of concerns in design, code, documentation, or other artifacts developed during the software life-cycle. These modularized concerns are called aspects, and aspect-oriented approaches provide methods to compose them. Various approaches provide different flexibility with respect to composition of aspects. Away from the field of computer science and programming aspects could be thought as a mindset or a methodology for thinking of different variables in terms of cross cutting concerns that affect different processes in life. For example, within the business processes domain you can think of quality as an aspect of business processes because quality assurance is a cross cutting concern that affects all the business processes of an organization. Another example, in a software program you can think of security as an aspect of the program as it is a cross cutting concern that affects all the functionalities and classes within the program. Despite the intuitiveness of representing business process surroundings (context) in terms of cross cutting concerns (aspects), research in AOSD focused mainly on concerns related to logging, tracing, debugging, security and program verification [18][40][41] and little research was done on aspectization of scenario based requirements modeling[67]. Other crucial areas of research like business process modeling and context-awareness which incorporate cross cutting concerns have yet to be discovered and this is one important contribution of our research work.

1.2. Research Problem and Motivation

With the growing number of variables and concerns involved in the decision-making process of any sizable business, designing and adapting business processes is becoming a very complicated task. Within the business domain, concerns surrounding the environment where the processes are being executed give indications that are essential for a business process-related decision. For example if a certain airline company knows that there is a high probability of weather problems on a specific day, this would normally affect the business processes of take-off and landing and if there is a problem in check-in counters, this would very likely change the behavior of the check-in process. If the context of a business process is aspectized and modeled efficiently, this will provide a stronger cause-effect relationship between the demands for process flexibility and their impact on processes and vice versa[55]. Hence, the business processes would be able to automatically change their behavior as if the decision makers were present to analyze the situation and give an immediate solution. For more complex problems where human intervention is a must, knowing the aspects that are affected would help decision-makers better analyze the situation and take important decisions which would save time, effort and money. Representing context variables as aspects is an important addition to the world of business process modeling and context-awareness for the following reasons:

1) Modularization of contextual elements/items allows for reuse of the same context elements in different kinds of business process and in different business domains.
2) The dynamic nature offered by the open Aspects concept of the adaptation model. This allows the weaving of events and advices/actions to take place at run time which is most appropriate for the dynamic environments in which most business processes run.
3) The concept of aspects/cross cutting concerns is more appealing to business people and business process experts than the idea of a process, in business process management, away from the world of computing and software. Business decision-makers always consider aspects before making a decision but the term and idea of context is more distant from the business world.

Today many business process modeling and management frameworks/tools exist, but they do not adequately support the context-based definition and configuration of business process variants. As a result, the process of adaptation of business processes in such tools is time consuming and error prone [21]. In the current business process modeling tools, the process models are disconnected from the relevant context in which they are valid and there is often no traceability to the situation in which the process should take place [55].

As a result, the decisions related to changes in the flow of a business process are taken manually and usually at a late stage after identifying a major contextual variance in the environment of the business process. This could lead to faulty decision-making due to contextual ignorance or right decision-making at a late stage, and in both cases, the outcome is degraded efficiency in the business process management and consequently unnecessary financial costs which could be avoided. In this research work, we propose a new methodology that enables business process experts to model context-aware, aspectized and configurable goal-driven business processes which change their flow and decision according to contextual information obtained from the ambient surrounding of the business process environment. Our solution approach is to extend an existing context-awareness framework by adding Aspects for business contextual elements apriori then use the aspectual facts modeled as decision making criteria for business process modelers to add contextual intelligence to the modelers. The main drivers of our research idea in addition to business process flexibility for large scale business decision making is pioneering in the field of using context-awareness in the field of intelligent business process configuration based on a tight goals connection. Moreover, we try to provide a generalized solution approach that is extensible and generic enough to fit a variety of business domains.

1.3. Thesis Statement

Our objective from this research work is introducing a solution methodology for customizable context-aware, goal-oriented business process models. Our work extends on the existing framework built to detect context-awareness for mobile computing and represents the following contextual aspects:

a. Non human resource utilization

b. Human resource utilization

c. Human resource experience level

d. Organizational strategies (The strategies of the organization in which the business process is running (e.g. whether the strategy is cost cutting or quality focused)

e. The risk factors associated with a process

f. Industry regulations and practices affecting a process

g. Timing/Season of process execution

We translate the above aspects into appropriate configuration decisions related to the business process which would have to be affected by these contextual aspects. The relationship between a business process and context is based on common goals that the context might affect leading to a totally goal-oriented model of context and business processes. This goal-orientation helps us to assess the effectiveness of the solution methodology. We developed a prototypical implementation of the framework as a proof of concept for the validity of our new solution methodology.

1.4. Highlights of our Solution Approach

In this research work we developed a solution methodology based on sensation and identification of the different types of business contextual elements. The solution models the contextual elements related to different business domains by building a library of aspects for each business domain inside one of the existing context-awareness frameworks namely the Java Context-awareness Framework (JCAF). The output of the extended Context-awareness framework is a set of apsectized contextual elements related to business processes for a specific industry. The aspectized contextual facts are utilized as triggers to configure the affected business processes. The business processes are modeled as goal driven finite state machines that take goals and context into consideration to decide on the next best state (business process step to move to). This leads to intelligent decision-making based on appropriate modeling of context of the business processes and their goals which are dynamically updated by business process experts to match with the dynamic nature of business environments [30]. Our methodology of aspectized context-awareness for business processes is explained in details in the solution methodology chapter.

The rest of the thesis is organized as follows: chapter 2 discusses the research background, chapter 3 describes the solution methodology and the specifications for the proof of concept framework, chapter 4 illustrates our experimental results and their analysis, chapter 5 concludes the thesis by highlighting the research contributions and pointing out some future work.

Chapter 2: Research background

Our research contribution is mainly directed to two major research domains, namely: Aspect oriented software development (AOSD) and context-awareness. We integrate with another area of research which is business process modeling and configuration by introducing aspectized context-awareness. We are not the first to discuss the idea of context within business process modeling as it has been discussed before as a high level concept by Rosemann et al. in 2008[55] but we do introduce the idea of conceptualizing business process context in terms of aspects and we define a detailed framework that extends on existing frameworks of both context-awareness and business process modeling to realize the new approach of aspectized context-aware business processes. In this chapter we summarize the theories, approaches, tools and concepts which served as the basis for our work

2.1. Aspect Orientation

Aspect oriented software development (AOSD) is a relatively new emerging technology and methodology [5] [65]. The general purpose of AOSD is the modularization of crosscutting concerns. However, earlier researches in AOSD have focused mainly on concerns related to logging, tracing, debugging, security and program verification [2][56][59] and little research was done on aspectization of scenario based requirements modeling[67]. Other crucial areas of research like business process modeling and context-awareness which incorporate cross cutting concerns have yet to be discovered.

2.1.1. Aspectization Techniques

There are various techniques for aspectization and several tools emerged in the last decade to support AOSD. AspectJ is an aspect oriented extension to Java. It extends the Java language to enable it to support two categories of cross cutting implementations [20]:

1) *Dynamic cross cutting concerns* which define additional implementation to run at certain well- defined points (join points) during the execution of a program.
2) *Static cross cutting concerns* which define new operations on existing types.

AspectJ enables modularization through aspects. The composition between a base and an aspect is defined in terms of base related join points. Cross cutting behavior can be weaved before, after or around join points. The idea of the

order around the aspect is resolved in two ways implicitly (before, after or around) or explicitly (Domain clause) [5] [65].

HyperJ is a tool that supports advanced, multi- dimensional separation and integration of concerns in standard Java™ software [26] [5]. This facilitates adaptation, composition, integration and modularized of Java software components [65]. The cross cutting concerns are represented as a hyper-slice which is a set of modules where all the code is dedicated for a given concern. Hyper-J allows the definition of various composition rules.

2.1.2. Open Aspects

Open Aspects is a new approach for mitigating unplanned changes in systems based on aspect-oriented composition at run time [23]. Open aspects support the so called adaptation models system change events being observed and the corresponding corrective actions to be taken. The main motivation behind open aspects is the flexibility to change, at runtime, the aspect composition according to the base system and the set of aspects that it is applied to. There is a clear separation of base, aspect and adaptation models. In open aspects the weaver derives a model of the running base system needed for making the aspect model effective (both marked with a 'start' tag). While doing so, the weaver examines an adaptation model (also marked with a 'start' tag) detailing all involved system change events to be observed and all corrective actions to be taken in correspondence to the system elements involved.

Open AspectS which is an extension to AspectS, was formulated to examine the open aspects concept. Initially AspectS provided developers with a framework to construct the proper runtime structure of aspect instances. Once instantiated, an aspect instance refers to its associated advice objects which maintain all information about *what* additional code (Computation, an instance of Block Context) has to be performed, *where* (Point cut, an instance of Block Context, to compute all shadow join-points to instrument) and *when* (described through Advice Qualifier attributes). Open AspectS was implemented by Hirschfeld et. al. [23] as a prototype of Open Aspects and it is considered an extension to AspectS. They mainly added an active point cut (Active Point Cut) system element associated with each advice. An active point cut object records the set of join-point descriptors that were associated with that aspect when the installed aspect gets woven into the system. Hence, the set of join-point shadows are obtained by executing the point cut expression (point-cut) associated with the respective advice.

2.1.3. Aspect Oriented Modeling Based on Behavior Context

Shuoping et. Al. [68] introduced a new approach for Aspect Oriented Development which they named Aspect-Oriented Modeling based on Behavior Context (AOMBC) Aspect-Oriented Software Development (AOSD). The main idea behind AOMBC is enabling the software engineer to model the system actions symmetrically. To collaborate with other behavior nodes, behavior context is used to describe their relationships. With the behavior context, the equitable behavior nodes are asymmetrically wrapped with core behavior or crosscutting-behavior and they get weaved together [68]. Thus, AOMBC helps the software engineers build more effective and reusable models[68].

2.1.4. Aspects as Libraries

Another interesting approach that Microsoft has adopted in dealing with cross cutting concerns is the idea of having libraries for the most common cross cutting concerns. Microsoft has identified authentication, authorization, caching, communication, configuration management, exception management, logging and instrumentation, state management, and validation as the most common cross cutting concerns that software developers face [56]. Hence, Microsoft built its Enterprise library which is a collection of reusable software components (application blocks) designed to assist software developers with common enterprise development cross-cutting concerns (such as logging, validation, data access, exception handling, and many others). Application blocks are a type of guidance; provided as source code, test cases, and documentation that can be used "as is," extended, or modified by developers to use on complex, enterprise-level line-of-business development projects [59]. The enterprise library is built for .net applications and uses Inversion of Control and Dependency Injection. We found the idea of building and maintaining an aspects library quite inspiring and adopted it within our proposed solution.

2.1.5. Aspect Oriented Paradigm and Business Process Modeling

Although the aspect-oriented (AO) paradigm's initial goal was to help in programming modularity and reusability yet in 2010 Machado et al [44], researched the concept of the application of Aspect oriented concept to the design of business processes to improve their usability and understandability of process models. The research introduced the idea of cross cutting composition to have the common concerns of a business process (such as quality check procedures) modularized into an aspect that could be used by all business processes. The research claimed that the application of AO concepts to the design of BPs is important in the consideration of usability and understandability

[44]. However, the research focused on the business process usability and reusability in terms of aspects but there were no researches or even indications in the future works for using aspects to model the context of a business process [44].In 2011 Machado et al [44] discussed variability in business process and proposed an approach to manage such a variability. The management of variability is based on a compositional and parametric approach with Aspect-Orientation [66]. It leverages and extends an existing tool to address variability in a specific domain yet it was not validated nor was its effectiveness evaluated . Again here the focus is to model common components as aspects and identify variability at the different aspect joint points and start working on the flow yet the idea of representing context of a business process in terms of aspects was neither mentioned nor proposed in the future work of this research.

2.2. Context-awareness: State of the Art

J. Coutaz et al. [7] define context as "not simply the state of a predefined environment with a fixed set of interaction resources. It is part of a process of interacting with an ever changing environment composed of reconfigurable, migratory, distributed, and multi scale resources." In this section we define the context-awareness disciplines, techniques and latest researches.

2.2.1. Disciplines of Context-awareness

Context-awareness exists in many disciplines other than business process modeling and has received better research focus in these areas e.g. Web systems [33][19][12], Mobile applications research [42] and conceptual modeling [2] [56], indoor presence, smart household and energy saving [66][62], healthcare and patient monitoring[4] , knowledge management[50][25] as well as requirements engineering[12]. In the IS discipline, the term 'context-aware' was coined by Schilit and Theimer [59] as approaches to incorporating contextual factors into information systems, such as in the area of Mobile applications. They typically focus on the users and their interaction with the systems [10], [59].Context in this area of research is often reduced to the notion of locality (e.g. what is the closest restaurant? How can I disable incoming phone calls if I am in a meeting room?), and user characteristics (e.g. what type of food does the user of the mobile application like?). Existing frameworks such as the ECOIN framework [16] attempt to represent context as properties that can be interpretation-based either on the inbuilt framework structures or based on very generic ontologies that have no structure prior to design time.

2.2.2. Context-awareness Frameworks

Almost all context-aware frameworks currently available in the market and even developed for research purpose were coined within the field of pervasive systems and its applications (e.g. smart hospitals and smart homes). According to Matthias Baldauf in his survey of context-aware systems [43] context can be sensed in many different ways like applying sensors, network information, device status and browsing user profiles or some other repositories of data. Most of these types of context sensation means have been put into consideration in most of the context-aware frameworks developed for pervasive systems.

The following are the different architectures for context-aware frameworks [43]:

A. **Direct Sensor Access:** This architecture is based on sensors that are built-in within the framework and information is extracted through direct interaction with the sensors. This is not suitable for distributed systems as they do not have capabilities for managing simultaneous sensor accesses.

B. **Middleware Infrastructure:** This architecture is based on encapsulation of low-level sensing details in the middleware, and is more extensible than the direct sensor access

C. **Context Server:** This architecture allows a number of clients to access remote data sources. It is the distributed version of the middleware approach. The entire sensor gathering data is within the context server and clients start requesting data from the context sensors. The overhead is the communication protocol, network performance and quality of service parameters

D. **Blackboard model:** This architecture is based on the blackboard idea and SOA, all sensors post their information on blackboard and entities interested in some information on the blackboard register their interest in this information so that whenever these information is updated, the interested parties are notified (event based notification model). The main overhead of this architecture is the necessity of having a centralized server to host the blackboard.

The table in figure 1 summarizes the existing frameworks that were examined by Baldauf in his survey and the main features and characteristics of their architecture.

Architecture	Sensing	Context Model	Context Processing	Resource Discovery	Historical Context Data	Security	Privacy
CASS	Centralised Middleware	Sensor nodes	Relational data model	Interference engine and knowledge base	n.a.	Available	n.a.
CoBra	Agent based	Context Acquisition Model	Ontologies (OWL)	Inference engine and knowledge base	n.a.	Available	Rei Policy language
Context Management Framework	Blackboard based	Resource servers	Ontologies (RDF)	Context recognition service	Resource servers + subscription mechanism	n.a.	n.a.
Context Toolkit	Widget based	Context widgets	Attribute-value tuples	Context interpretation and aggregation	Discoverer component	Available	Context ownership
CORTEX	Sentient object model	Context component framework	Relational data model	Service discovery framework	Resource management component framework	Available	n.a.
Gaia	MVC (extended)	Context providers	4-arg predicates (DAML + OIL)	Context-service module (first-order logic)	Discovery service	Available	Supported (e.g. secure tracking)
Hydrogen	Three layered architecture	Adapters for various context types	Object oriented	Interpretation and aggregation of raw data only	n.a.	n.a.	n.a.
SOCAM	Distributed with centralized system	Context providers	Ontologies (OWL)	Context reasoning engine	Service locating service	Available	n.a.

Figure 1: Context-aware Frameworks Comparison (Adapted from Baldauf , 2007 [43])

Another set of context-awareness tools was introduced by Zhao et al in 2012 [57] whose main purpose is to cater for the increasing number of devices that are invisibly embedded into our surrounding environment as well as the proliferation of wireless communication and sensing technologies which are the basis for visions like in ambient-intelligence, ubiquitous and pervasive computing [57]. This research builds on the pervasive Computing in Embedded Systems (PECES) project which developed the technological basis to enable the global cooperation of

embedded devices residing in different smart spaces in a context-dependent, secure and trustworthy manner [57]. It focuses on providing tools for application developers to build and test context-aware applications based on context ontology that is related mainly to pervasive and mobile computing and not directed to the field of business process modeling by any means.

The main problem with the above context-aware frameworks is that they are focused on pervasive systems and mobile entities, that they lack customization for context of business processes and that they are not open source so their usage or extension must be under the supervision of the entities developing them. The problem of closed source doesn't exist for the JCAF which stands for Java Context-awareness Framework. The JCAF as described by Jakob Bardram in his paper about design implementation and evaluation of the JCAF [28] is an open source tool that is based on the Java programming language and utilizes the concept of java interfaces for context-awareness within pervasive systems for which it was developed. The background for JCAF was a research into a context-awareness infrastructure in hospitals [28].The JCAF is built on the following main pillars [28];

1) Context Service: A service receives, manages, stores, and distributes context information for entities.
2) Entities: An entity models something that you want to manage context information for(e.g. A Person, A Patient)
3) Context Item: Something that an entity uses (e.g. PC), the relationship between the entity and the context item is important (e.g. A person **uses** a PC)
4) Context Clients
    - Context Monitors: Context clients that specialize in sensing, resolving, and submitting context information
    - Context Actuators: Context clients which are specialized in using context information
5) Context Events: A context service allows special context clients (entity listeners) to register interest in events in specific entities and to receive a notification of the occurrence of such an event.

The main useful thing related to JCAF is its being open source and the idea of context services which can convert the context information that is sensed to XML format. This would make it possible, with the addition of some classes, to extract the sensed XML into some repository that can be accessed within the

new framework. We will further introduce the JCAF and explain it in details in the methodology section of this document. Figure 2 represents the JCAF infrastructure.

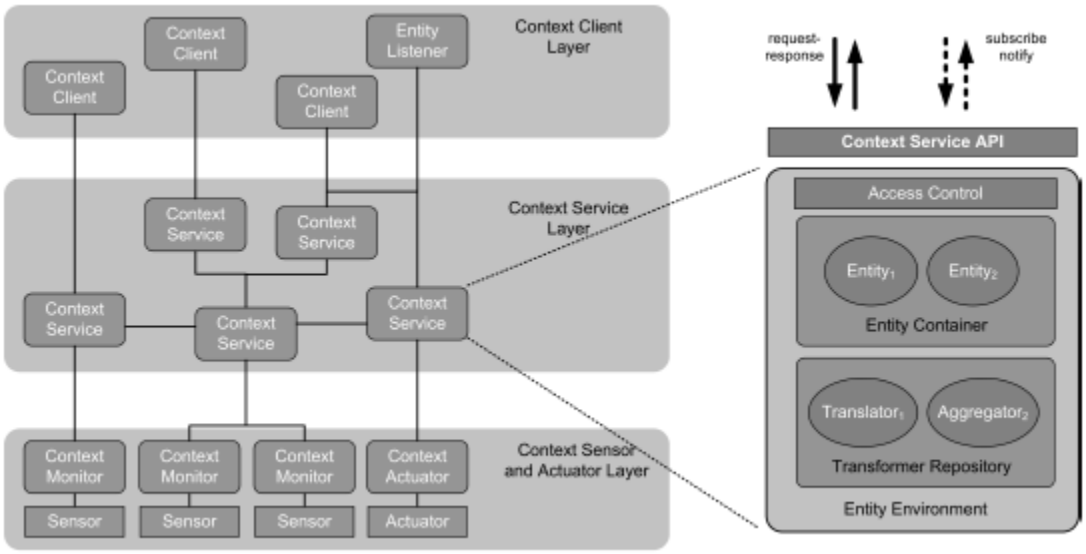

Figure 2: JCAF Runtime Infrastructure (Adapted from Jakob E. Bardram , 2005 ([28]))

2.2.3. Context Description & Structure

Context structuring and linking to real causes is a prerequisite to context conceptualization within the business process modeling discipline. This is why a significant part of the research background section of this thesis is dedicated to context structuring.

Regarding approaches for structuring and describing context, it was found that in the area of context modeling a substantial amount of research has already been conducted, for example in the form of context ontology [6]. For instance, the Context Ontology Language [60] is designed to accommodate selected aspects of context such as temperature, scales, the relative strengths of aspects and further metadata. It is designed to relate measurements back to the semantics expressed in a system. In terms of limitations for the process flexibility discussion, however, it lacks linkages to causes, both in terms of guiding goals and environmental stimuli.

Rosemann [55] identifies an interesting onion model for structuring context elements related to a business process. Rosemann widens the scope of context elements consideration to include environmental context related to the economy or the general environment where the business process operates as well as immediate context elements which directly affect the flow of a business process. The Rosemann onion model will be the basis of the context model structure that we adopted in this thesis and hence it will be discussed in details.

Rosemann [55] divides the context into four disjoint categories as indicated in the model shown in figure 3

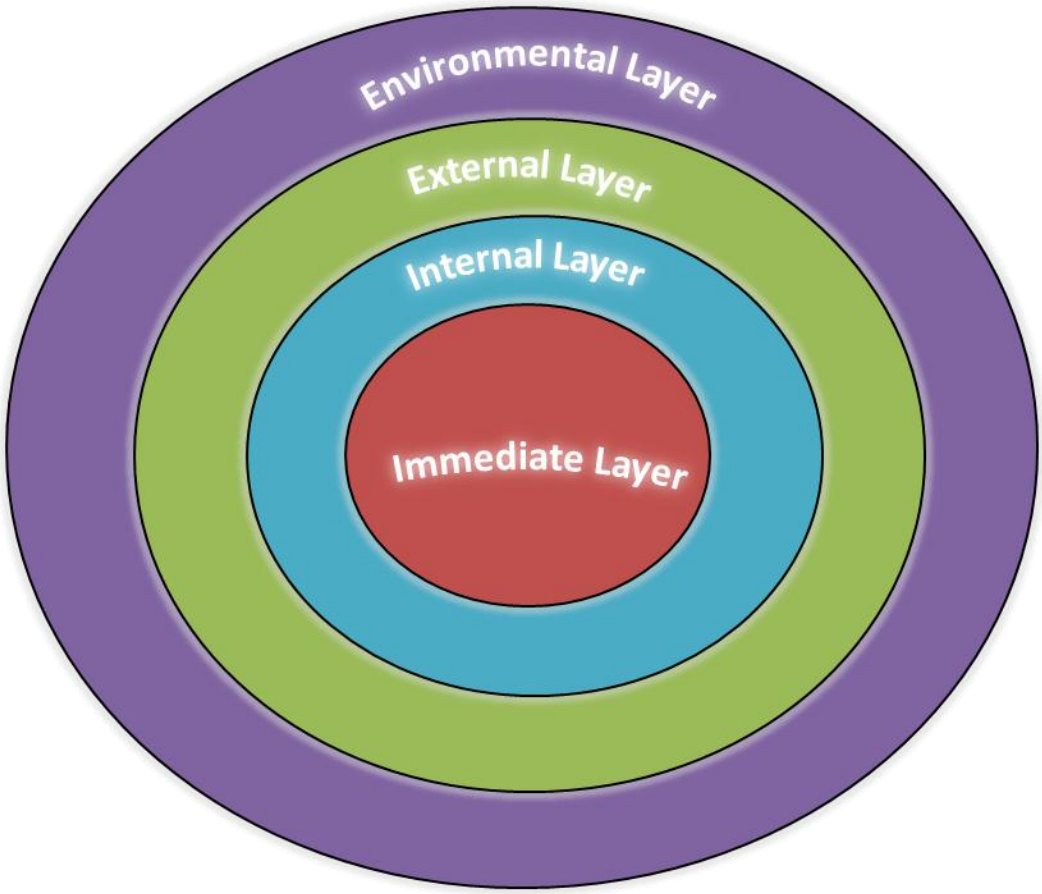

Figure 3:Onion Model for identifying BP Context (Adapted from Rosemann et al., 2008 [55])

As the Meta model shows, Rosemann [55] proposes a taxonomy that divides the different facets of context into four concentric layers of an onion model:

The Immediate Layer:

The immediate context of a business process includes those elements that go beyond the constructs that constitute the pure control flow, and covers those elements that directly facilitate the execution of a process. Due to this central role, elements there tend to be already well-considered in existing business process modeling techniques such as EPC, BPMN, etc. The elements of an immediate context are typically essential to the understanding and execution

of a business process (e.g. what data do I require? Which organizational resource is in charge of the next activity? What application supports this process step?).

The Internal Layer:

The immediate system (viz. the process) is embedded in the wider system of an organization. Various elements of an organization have indirect influence on a business process and we call this second layer, the internal context. The internal system of an organization incorporates elements such as resources, norms and values, concerns and interests, strategy, structure and culture. These categories cover, for example, the corporate strategy (enterprise plan) and related process objectives. A change from a quality-focused strategy to a cost-cutting strategy, for instance, will have an impact on a broad range of business processes (e.g., elimination of quality control activities and scaling down of special resources) [55]. As can be seen, the internal context captures all elements that are part of the organizational system in which a process is embedded. Consequently, typical further examples for internal context variables are the main internal stakeholders in an organization and their risk perceptions, communication and logistical infrastructures (e.g. regional distribution of factories) as well as financial and other resources (legal experts, R&D) [55]. For collaborative business processes that span multiple organizations the internal context would be the sum of the involved organizations.

The External Layer:

The external context compromises the elements that are outside the organization control but reside within the business network where the organization operates. These might not affect the minute steps of a business process but will definitely have an impact on the overall design of the business process. The elements of an external context include the following:

1. Elements related to suppliers, competitors, investors and customers. External context variables can be further identified from frameworks such as the Five Forces model [49]
2. Factors related to a specific industry (e.g. overall demand for the services of an industry, technological innovations) and regulations such as industry-specific practices (e.g. supply chain management practices)

In general, external context elements need to be considered to achieve conformance objectives in addition, or substitution, to performance objectives [48].

The Environmental Layer:

This is the outermost layer and it captures the overall environment as a system with comprehensive boundaries. These elements includes items like environmental variables /factors such as weather (e.g. increasing call volume during storm season), time (e.g. different business operating models on Sundays or before Christmas) and workforce related factors (e.g. overall shortage or strike)

The four layers described above are intersecting and may affect one another leading to direct impact on the business process. Rosemann [55] identifies examples such as:

1. An element on the same or more inward context layer can *mediate* the impact of a context element. Mediation is about one context element leading to an alleviated effect of another context element
2. An element on the same or more inward context layer can *moderate* the impact of a context element. Moderation is about one context element controlling the effect of another context element (i.e. makes it more or less significant)
3. An element on the same or more inward context layer can *mitigate* the impact of a context element. Mitigating is about one context element reducing the significance/impact of another context element

A similar onion model has been used earlier by Alexander et al [1] in the process modeling area to identify, and display, the relationships between different types of stakeholder roles relevant to the business process fit.

2.2.4. Different Context Modeling Techniques

Rolland et al [56] for instance, suggest a context-oriented procedure based on objectives to identify requirements chunks in goal-based modeling. The basic idea for determining goals and relevant context in a model is centered on the notion of a requirement chunk, which is a pair < Goal, Scenario > and denotes a potential way of achieving a goal in a given scenario (i.e. one instantiation of the process).

Yu et al [69] use the i* framework to capture rationales behind processes relating to goals, tasks, resources and actors. Their framework allows for the explicit articulation of the interdependencies between a process and (some parts) of its environments, mainly the stakeholders and related environmental resources.

Rosemann et al [55] define a goal-oriented process modeling approach to be able to identify relevant contextual elements (figure 4). The granularity and scope of a business process model is closely linked to the goals of the depicted process. By examining why a process exists and what the objectives and goals of the process are, the

context factors that pose relevance to the process can be predetermined and modeled at a formal level over and above the typical description levels of organization, data, resource and IT [28] [57].

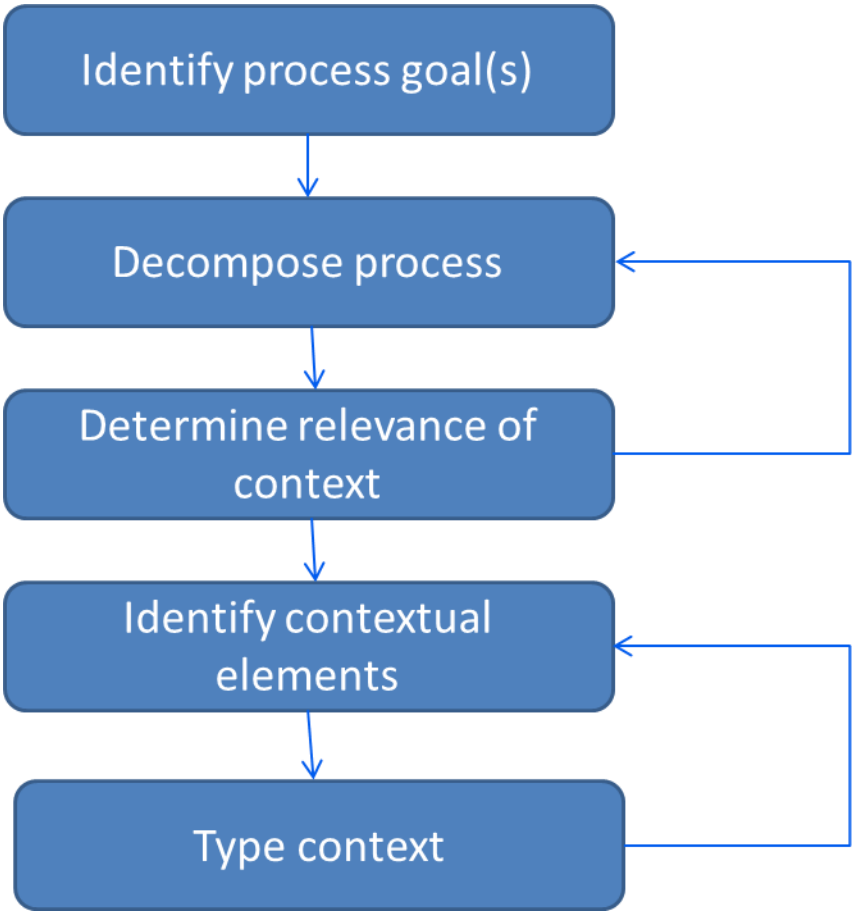

Figure 4:Procedure for context identification (Adapted from Rosemann et al., 2008 [55])

Selmin Nurcan et al [47] introduced a context model for BPM (CM4BPM) and a role-based business process model (RBPM), and presented an approach allowing enacting processes with respect to the context. Nurcan presents an approach for business process (BP) modeling which supports the explicit definition of the context related knowledge in order to make instance adaptations "context-aware". The approach consists of using contextual knowledge in order to enhance the adequacy and the coherence of the assignments during the enactment of the business processes, for instance, actor-to-role or process-to role assignments. In order to efficiently use the contextual information in business process enactment rules, the context related knowledge (CRK) should be formally defined (figure 5).

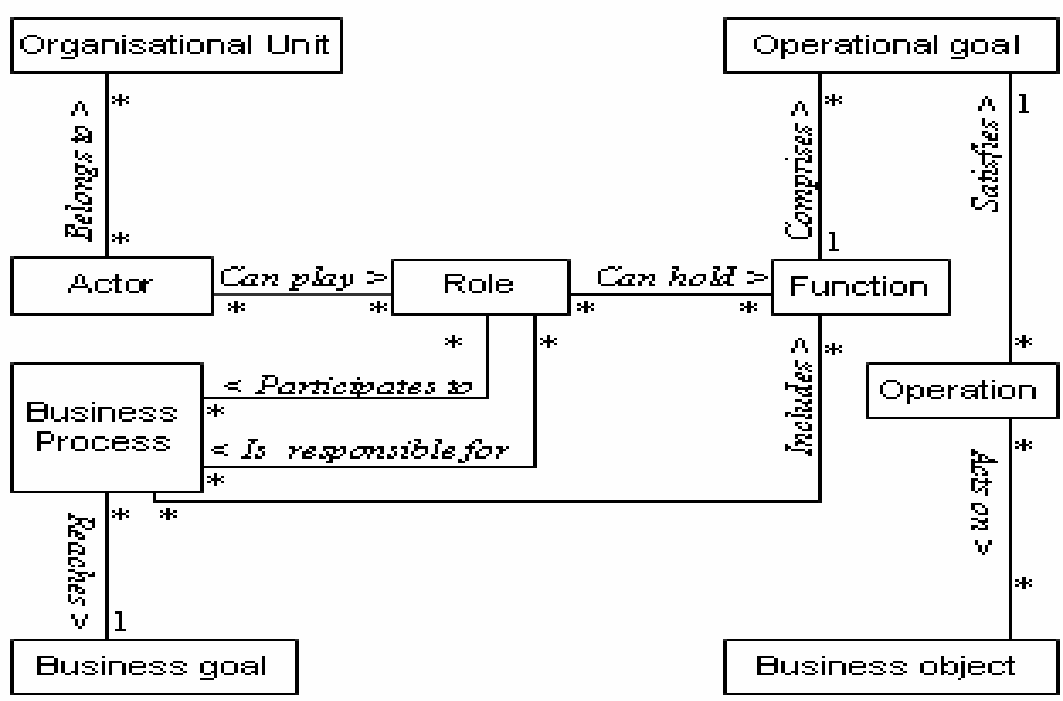

Figure 5: The Meta model for RBPM (Adapted from Nurcan et al., 2009 [47])

Ioan Salomie,[27] uses a context model based on representing actors, resources and policies from the real world and uses BDI (Believes Desires Intentions) agents for context management and processing. The basic context model is defined as a triple C = <R, A, P> where: R is a set of context resources; A is a set of actors which interact with context resources; and P is a set of real context related policies. The context model is mapped onto different real contexts by populating the sets with real context specific elements. The mapping result is a specific context model CS = <RS, AS, PS >. The relationships between the context model's elements are represented by using is-a type relations in a general purpose context ontology core.

Castelli et al [70] proposed the four « W » model. Their research starts from the consideration that any elementary data atom or any higher-level piece of contextual knowledge, in the end, represents a "fact" which has occurred. Hence, the model accounts for those facts and any data/knowledge atom can be represented as 4 fields' tuple (Who, What, Where, and When) : "someone or something (Who) does/did some activity (What) in a certain place (Where) at a specific time (When)" [70].

The four-field tuple structure was designed to deal with information coming from various data sources.

. Users and services, from everywhere, can retrieve knowledge atoms via a simple API[70]. The W4 Model was an interesting idea at the time it emerged,. Huifang et al [24] worked on depicting the context information of the mobile workers' shipment business process. The research summarized the context ingredients of the mobile workers' business process and analyzed the relationships between them [24]. The context model introduced in the research is a post context model that illustrates the context of a business process after it has been run for the purpose of process redesign and reallocation of resources and not in real time to alter the behavior of the business process. The context model in this research focuses on resources contained within a business process and the status of the business process regardless of whether it is running or not running.

2.2.5. Context Modeling Using UML

In this section we describe the context modeling experience in UML. We will go into details of the model to show how already existing UML diagrams and class diagrams can visually model the context of a business process.

Christof et al [61] described Context Modeling Profile (CMP), a lightweight UML extension, as a visual language for context models in mobile distributed systems. The resulting models visualize Meta information of the context, i.e. source and validity of context information, and reflect privacy restrictions. The profile provides several well-formedness rules for context models. A case study of meeting room context is used to illustrate the approach as shown in figure 7.

As depicted in the above figure context can be modeled using a UML class diagram. It is also possible to denote the characteristics of context, e. g. the access rights, in the context model by using comments. Derivation rules can be specified by adding constraints to model elements and derived context items can be notated in the UML way with a preceding ”/”, like the derived activity of a person in the meeting system[61].

Sheng et al [51] define syntax for Context UML, including a Meta model and a notation (figure 8). The Meta model defines abstract syntax of the language, while the notation defines the concrete format used to represent the language (also called concrete syntax). Sheng introduces the abstract syntax of Context UML proving that UML presents a rich modeling language for context modeling and this idea supports the choice of UML for context modeling in our research work.

2.3. Business Process Configuration Models

This section describes early and recent studies on different models that cater for business process configuration. Various organizations, even within the same industry, have various ways and rules that affect the way they perform their different business processes since flexibility of business process is an inevitable goal for every organization. The concept of business process flexibility, variability and configuration of business process especially within specific organization has been discussed extensively in the literature.

One way of handling business process flexibility is utilizing the Software Product Lines (SPL) perspective. Schnieders et al [64] described extensions for business process modeling languages allowing the construction of process families. However, they did not consider appropriate modeling of business process context [63].

Montero et al [45] discussed another SPL conceptual methodology that used feature models and business process models to cater for business process flexibilities; they produced a process that generates business process instances using the SPL perspective [63].

La Rose et al [36] introduced a configurable model for modeling business process that is based on a questionnaire approach to cater for business process model configuration. In their research, the answers for the questionnaires provide the method to select the best configuration of a business process.

Hallerbach et al [21] presented a context-based approach for configuring and managing process variants The research allows for configuration of process variants through applying a context dependent set of well-defined change operations to a base process.- The context in this research is confined to only two context variables: the implementation cost and quality of the process. Their research introduced the approach and stressed that there is a need for integration of context-awareness to manage business process variance but does not discuss how this need can be achieved.

Rosemann et al [35] introduced the concept of having context-aware taxanomies and through mining algorithm and extraction of certain knowledge from those taxanomies the business process could be configured. However, the research did not detail how the configuration is done as it was merely an expression of a new idea.

De La Vara et al. [37] describe an approach to include contextualization within business process models . Their research incorporates the concepts of context as facts and statements to represent contextual information [63]. The

research describes a process to introduce contextualization into business process models through context analysis. The context analysis allows the derivation of the conceptual model that can be monitored at run-time [37]. The approach consists of four stages: modeling of initial business process, analysis of business process context, analysis of context variants and modeling of contextualized business process [37]. First, an initial version of the business process that needs to express its context is modeled. Next, the rest of stages have to be carried out while relevant context variations (changes) are found and they are not represented in the business process model. Relevant context variations influence the business process and imply that business process execution has to change.

If a context variation is found, then the business process context is analyzed to find the context properties that allow process participants to know if a context variant holds. A context analysis model is created, and the context variants of the business process are then analyzed. Finally, a contextualized business process model is created on the basis of the final context variants and their effect on the business process [37].

Business process context is analyzed in the second stage of the approach. This stage aims to understand context, to reason about it and to discover the context properties that influence a business process. In this research the context is specified as a formula of word predicates. Word predicates can be facts (they can be verified by a process participant) or statements (they cannot be) [37]. The research does not show any empirical evidence of the effectiveness of such a way in business process configuration but puts forward a theory that needs to be verified.

Santos el at [63] introduced the idea of building a new model for business process configuration based on nonfunctional requirements of a business process associated with context. The research uses a methodology similar to Vara et al's [37] methodology in representing context and configuring the business process yet adds the factor of representing non-functional requirements as one of the pillars that determine the business process path. The research introduces the concept and the process outline with no details about the related steps and the formal definition of context and non-functional requirements. In addition, it does not provide any actual experimental work or results to prove it.

2.4. Previous Case Studies

This section describes earlier case studies conducted in the field of context modeling for business processes that are based on Rosemann's onion model. Karsten et al [34] conducted a case study about claim processing business processes in an Australian insurance company in the financial services sector. The study identified relevant context elements and placed them in a matrix then classified conceptual categories according to their impact on the business process. The last step was using internal feedback structures to take feedback from certain context elements that, according to the process perspective, affect the enhanced process [34]. The case study asserts that context and context change requires different response strategies in process design. They suggest that certain context elements can be mapped to a rule-based system to govern the variability in claims processing. This is not only applicable to the case study but to any framework or research that involves extending context-awareness for business processes [34].

Rosemann et al [32] examined the Australian airlines check-in processes using the onion model discussed earlier. Rosemann concludes his case study by emphasizing that through appropriate context modeling that takes into consideration the different context layers, wise configuration decisions can be taken as described above. In addition, process flexibility and process contextualization is still in the explorative stages and extensive studies must be done to enhance the context model proposed and prove its effectiveness [32].

Chapter 3: Solution Methodology and Framework Specifications

3.1. The Solution Methodology

In this research work we introduce a solution methodology based on sensation and identification of the different types of business contextual elements. The solution models the contextual elements related to different business domains by building a library of aspects that could be tailored and used for various business domains within an existing context-awareness framework. The framework we selected is the Java Context-awareness Framework (JCAF). The output of the extended Context-awareness framework is a set of apsectized contextual elements related to business processes for a specific industry. The aspectized contextual facts are represented as triggers to configure the affected business processes. The business processes are modeled as goal driven finite state machines that take goals and context into consideration when deciding on the next best state (business process step to move to). This leads to an intelligent decision-making process which is sensitive to the context of the business processes and their goals. The later become dynamically updatable by business process experts to incorporate the constant changes in business environments. Our methodology of aspectizing context-awareness for business processes is summarized in the following steps and sub steps (which will be explained later in full details throughout the rest of this chapter):

3.1.1. Context Sensation, Identification and Modeling

Since our solution and methodology are focused on context-aware business processes then the first two basic questions that come to mind; 1) How do we get to sense and identify the context of business processes? 2) What are the contextual aspects that should be taken into consideration?

Based on our literature search and business experience our main focus will be on the following contextual aspects; Non human resource utilization, Human resource utilization, Human resource experience level, Organizational strategies (The strategies of the organization on which the business process is running (e.g. whether the strategy is cost cutting or quality focused), The risk factors associated with a process, Industry regulations and practices affecting a process, Timing, Season, and Location

However, the methodology explained is extensible to cater for any other contextual aspects and so is the design of the prototypical framework which is developed to prove the solution methodology proposed in this research.

The above contextual aspects are different. Some of them are physical, others are virtual and logical. Hence, the context sensed by our context-aware framework is divided into the following three major types:

- Physical Context: which is sensed through physical sensors (e.g. location, light, sound, movement, touch, temperature and air pressure) [43].
- Virtual Context: This is information that is not related to any physical sensation. It could be retrieved from databases or induced from non-physical resources (e.g. the user interaction with a system, the tasks pending on someone, the employee experience) [43].
- Logical context: which is the information deduced from the combination of physical and virtual contextual facts. For example, a logical contextual piece of information could be an employee's current position which is deduced by analyzing logins at desktop PCs and a database mapping of devices to location information [43].

The framework takes in low level contextual data from physical and virtual sensors and converts them to high level contextual variables using the Logical sensors. Hence, the logical sensors are the ones feeding the contextual variable information to the framework.

In our solution methodology we focus on contextual aspects that are not predictable i.e. that need to be continuously sensed and accordingly instant changes in the flow of business processes need to take place. Predictable contextual aspects (e.g. the increase in the number of Airlines passengers on a specific holiday season) are already identified in advance and their handling process is well-defined.

From our review of literature and research on context-aware systems which were mostly developed for the sake of pervasive systems and ubiquitous computing, we discovered several existing frameworks that deal with the types of context and sensors described earlier. We found the most convenient one of them to be the JCAF for the following reasons;

- JCAF is an extensible Open Source tool

- It supports the extraction of context information from the different types of context sensors (physical, virtual and logical context sensors)
- It allows the addition of new libraries of aspects which makes it possible to model contextual concerns as aspects/cross cutting concerns related to the business process entity
- It provides easy ways to add classes representing different types of entities
- It provides easy ways to add new packages
- It takes the quality of context (QoC) aspect into consideration. It has a get_Accuracy and Secure methods within the JCAF Context Item class and these methods can be overridden to specify the combination of quality guarantees for the context items [28]

The exact steps for extending the JCAF framework to support the representation of context of a business process in terms of aspects are described later in this chapter.

Context variables are represented as aspects and we perceive this as an important addition to the world of business process modeling and context-awareness for the following reasons:

- Modularization of contextual elements/items to allow for reuse of the same context elements in different kinds of business processes and in different business domains.
- The dynamic nature offered by the aspects concept and their adaptation model. This allows the weaving of events and advices/actions to happen at run time which is most appropriate for the dynamic environments in which most business processes run.
- The concept of aspects/cross cutting concerns is more appealing to business people and business process experts than the idea of a process, in business process management, away from the world of computing and software. Business decision-makers always consider aspects before making a decision but the term and idea of context is more distant from the business world.

3.1.2. Context Classification

After appropriately extracting and sensing contextual information in terms of aspects, the contextual data is classified into the four contextual layers defined by Rosemann [55]: Immediate, Internal, External and

Environmental layers.

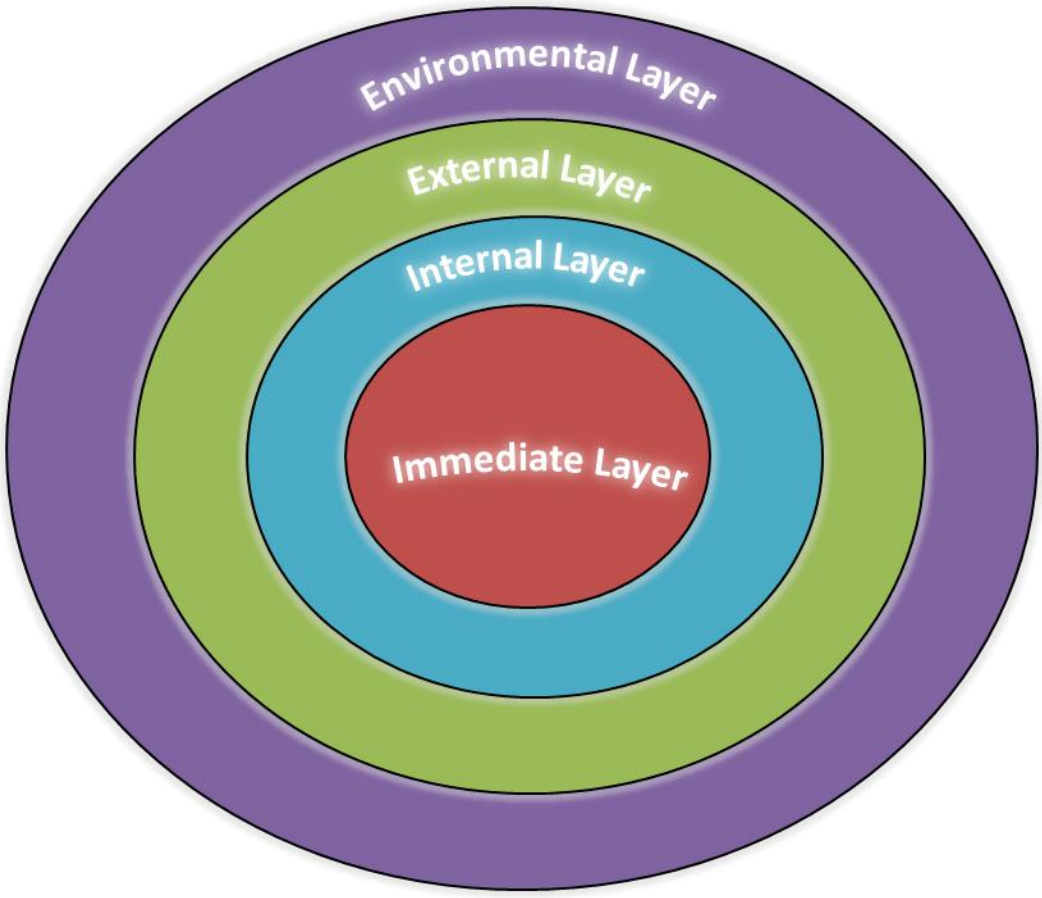

Figure 6:Onion Model for identifying BP Context (Adapted from Rosemann et al., 2008 [55])

- *Immediate Context:* includes those elements that go beyond the constructs that constitute the pure control flow, and covers those elements that directly facilitate the execution of a process. Due to this central role, elements tend to be well-grounded in existing business process modeling techniques such as Enterprise Process Chains (EPC), Business Process Modeling Notation (BPMN), etc. The elements of an immediate context are typically essential to the understanding and execution of a business process (e.g. what data do I require? Which organizational resource is in charge for the next activity? What application supports this process step?).
- *Internal Context:* The immediate system (viz. the process) which is embedded in the wider system of an organization. Various elements of an organization have indirect influence on a business process. The internal system of an organization incorporates elements such as resources, norms and values, concerns and interests,

strategy, structure and culture. These categories cover, for example, the corporate strategy (enterprise plan) and related process objectives. A change from a quality-focused strategy to a cost-cutting strategy, for instance, will have an impact on a broad range of business processes (e.g., elimination of quality control activities and scaling down of special resources) [55]. The internal context captures all elements that are part of the organizational system in which a process is embedded. Consequently, typical examples of internal context variables are the main internal stakeholders in an organization, their risk perceptions, communication and logistical infrastructures (e.g. regional distribution of factories), financial and other resources (legal experts, R&D) [55]. For collaborative business processes that span multiple organizations the internal context would be the sum of the involved organizations.

- *External Context:* Compromises the elements that are outside the organization control but reside within the business network where the organization operates. These might not affect the minute steps of a business process but will definitely have an impact on the overall design of the business process. External contextual elements need to be considered to achieve conformance objectives in addition, or substitution to, performance objectives [48].
- Environmental Context: This is the outermost layer and it captures the overall environment as a system with comprehensive boundaries. These elements include facts like environmental variables/factors such as weather (e.g. increased call volume during storm season), time (e.g. different business operating models on Sundays or before Christmas) and workforce related factors (e.g. overall shortage or strike)

The importance of context classification lies in the fact that the layer to which a contextual variable, or its constituent elements belong to, defines the level of impact of this contextual variable or element on the business. In more specific terms each contextual layer would have a specific set of goals (whether high level business goals or operational goals) that it impacts (i.e. the contextual variables or elements that belong to this contextual layer and would impact the high level goals and operational goals that this contextual layer impacts). The goals that are impacted by each of the four contextual layers defined by Rosemann [55] would differ for each industry considered within the scope of the framework.

With these important links of contextual variables and constituent elements to goals we are able to identify which contextual variables affect which business process. As we link the goals of the business process with the goals of the contextual variables and detect the common goals, we would identify which contextual variables and elements affect

which business processes and which business process steps to take. The business processes would have to register their interest in receiving updates about the contextual variables which affect them. This part will be explained in details in the step about business process configuration.

The contextual variables/elements classification cannot be automatically deduced by any automatic classification technique. It is the general impression whenever classification is mentioned that there will be a rigid set of classification rules and hence each contextual variable will be evaluated according to these rules and then the classification result is out. However, this cannot be the case for context within the field of business process modeling. Although the definition of each contextual layer is specifically defined by Rosemann, it would still differ from industry to industry and various industry experts may have their differing views about them (e.g. weather could be an immediate context item in one industry while in another industry it could be an environmental context item). As a result, the most appropriate approach for classification is to allow the industry/business process experts to define their own classification in an easily updatable way.

One of the most convenient and easily understandable methods of classification is to define for each industry (and process within the industry) a repository as depicted in figure 7 and 8 below.

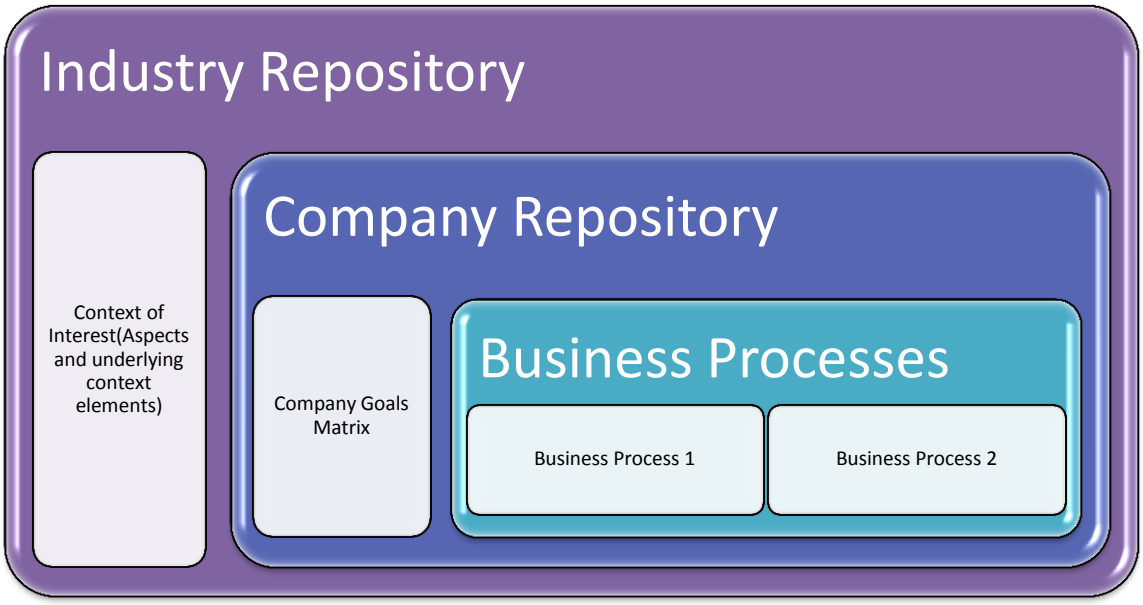

Figure 7: Industry Repository

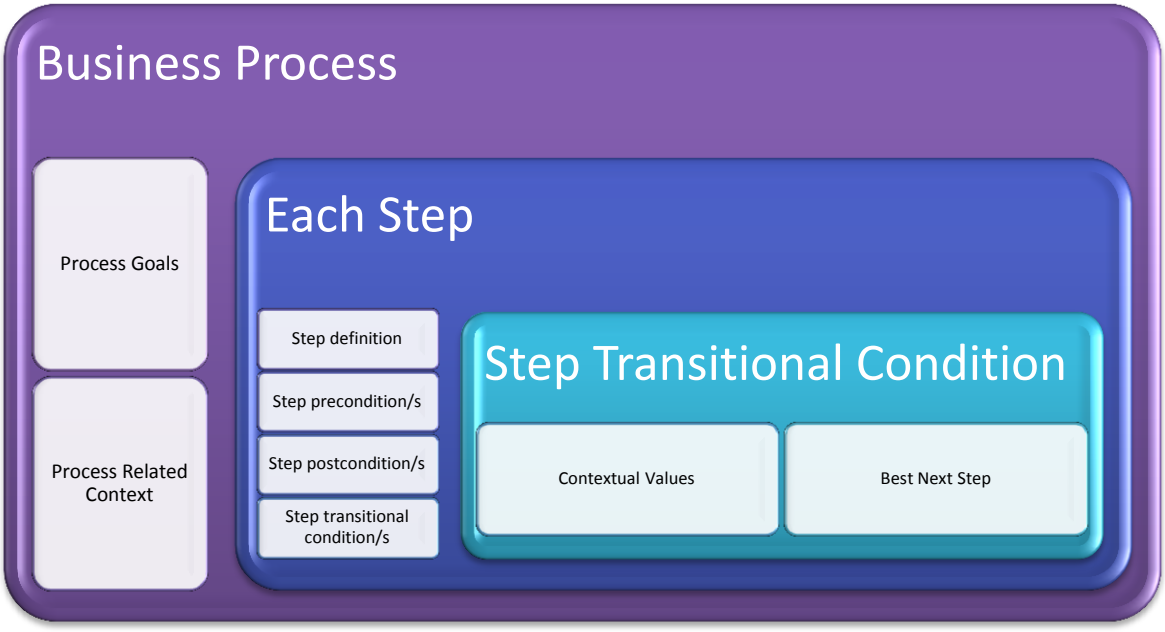

Figure 8: Business Process Repository

The industry repository should include the following:

- *Contextual Repository.* This is an XML file containing the four contextual layers defined by Rosemann and the link of each contextual layer to contextual aspects that are of interest to this industry. This XML file is read and converted to aspectized contextual layer objects within our framework. Of course, this file is defined for the first time through a simple graphical user interface that is easily understandable to business domains experts.

- *Contextual Variables Repository.* Within the same XML file mentioned above we define (in our framework and could be any kind of database in any other framework) the different contextual variables that lie under the different contextual aspects related to this specific industry in particular. This file is defined for the first time through a simple graphical user interface that is easily understandable to business domains experts.

The XML file is converted into an aspectized contextual variable object which carries the contextual elements, their contextual aspects and their contextual layer classification inside it. It is to be used within the next step of matching context to goals and eventually to affect the relevant business processes.

By following the above methodology, contextual items of interest to an industry are easily identified and updated by business experts and the classification is easily done as well as the links between the contextual layers and

contextual aspects and the variables which will prove to be extremely important within the next step of business process configuration (step 1.1.4) according to the contextual input.

3.1.3. Business Goals Definition

After appropriately sensing the context by utilizing JCAF and classifying contextual elements, we need to identify the goals related to the company being examined so that we can model and configure the business processes related to this company in a goal-driven context-aware manner which is the main point of our research.

After examining the goals within different business domains we realized that the goals are not unified across an industry. In fact, the goals vary for each company. Hence, the goals definition will need to be done on a company level under the industry and it will be defined by business experts in an easily updatable format. Strategic goals are to be defined first then operational goals under each strategic goal.

The framework has companies' repositories, where each company expert defines the company goals. The company repository consists of the following:

- *Goals Repository;* This is an XML file (in our framework and could be any kind of database in any other framework) containing the list of strategic goals of the company and the sub-goals (operational goals of each strategic goals)
- *Business Process Repository;* these are XML files (in our framework and could be any kind of database in any other framework) each file representing a Business process under this company. The exact method of modeling business processes will be explained within the step 1.1.4.
- *Goals to Contextual Layer Repository;* This is an XML file that defines the relationship between the four contextual layers (Immediate, Internal, External, Environmental) and the goals of the company.

3.1.4. Business Process Modeling and Configuration

In this solution methodology, we found that an appropriate way for modeling the business processes would be in terms of finite state machines as depicted in the following example (figure 9);

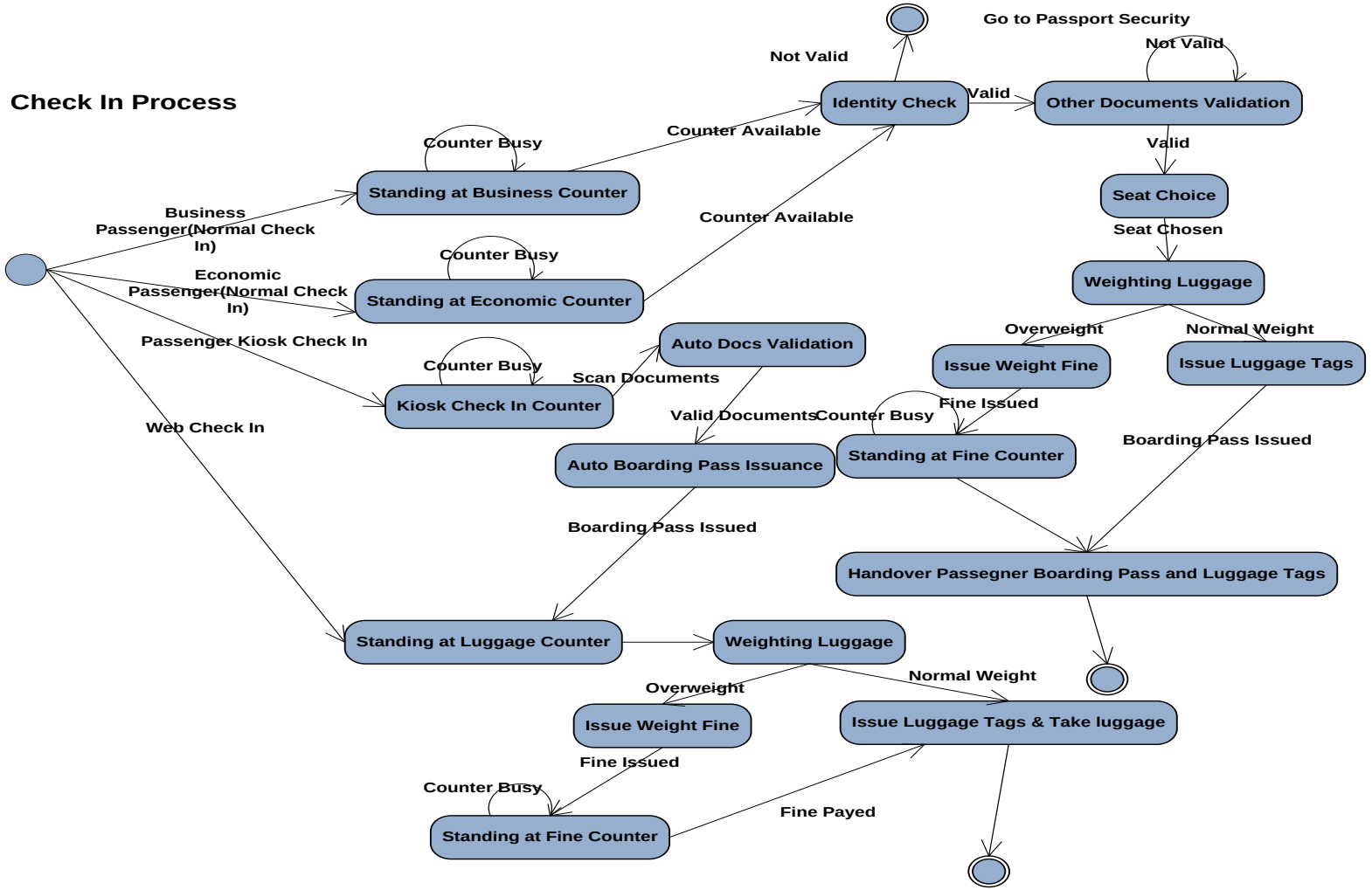

Figure 9: Check-in Business Process Example

The business process is a sequence of states. Moving from one state to another happens through identifying certain conditions and according to these conditions the business process moves to the next best state. For the business process configuration to happen based on the context of the business process and its goals, the following steps take place:

1) Identifying which aspectized contextual variables/ elements affect which business processes and which steps to take within these processes. This is achieved by identifying the goals of the business process under investigation. It comes by studying the business behind the process and the wider picture that the business process fits in, which comes from the understanding of the overall business domain. As mentioned above, the goals of the company will be placed in a goals repository within a certain industry repository. For each company repository that we have business processes defined under, and for which the definition incorporates the goals of the process, the states (business process steps), the goals of each state (business process step), the preconditions of entering this state (business process step) , the post conditions when exiting from this state (business process step) and the conditions to jump from one state to another (these conditions are related to the context of the process and the post conditions of the step) are defined. These definitions are made through a simple graphical interface and are updatable by business experts.

2) Comparing the goals of the business process to the goals of the different aspects of contextual elements that are of interest to the company under which the business process lies and detecting any common goals. If common goals are found then the business process is affected by the context and through common goals we are able to identify which business process steps are affected.

3) For the contextual elements that are affecting a certain business process according to the goals matching, the systems asks the business process expert, while defining the recommendations (transitional conditions) of moving from one state (business process step) to the next best state, to incorporate these contextual elements in the definition of the recommendation based on ranges of values for these contextual elements.

4) The business process registers its interest in contextual aspects of common goals and this happens through existing functionalities in JCAF. The business process runs and is triggered by changes in the contextual aspects it registered in. According to the changes in values of the contextual aspects and the conditions for jumping

from one state/business process step to another (as per the business process definition), the business process decides on the best sequence of steps/states to take given a certain contextual input at a specific instance in time.

It is through the above four main steps that we applied our methodology of modeling context of business processes in terms of aspects and closely coupling them to industry goals. We model business processes as finite state machines. They are goal-driven so that we can achieve flexibility of business process modeling and configuration based on aspectized context-awareness and goal orientation. This combination helps us arrive at flexible, configurable and fully aware business processes, which in turn helps decision makers and business domain experts save tremendous business efforts and costs.

3.1.5. System Architecture

The architecture of the prototypical framework is shown in figure 10.

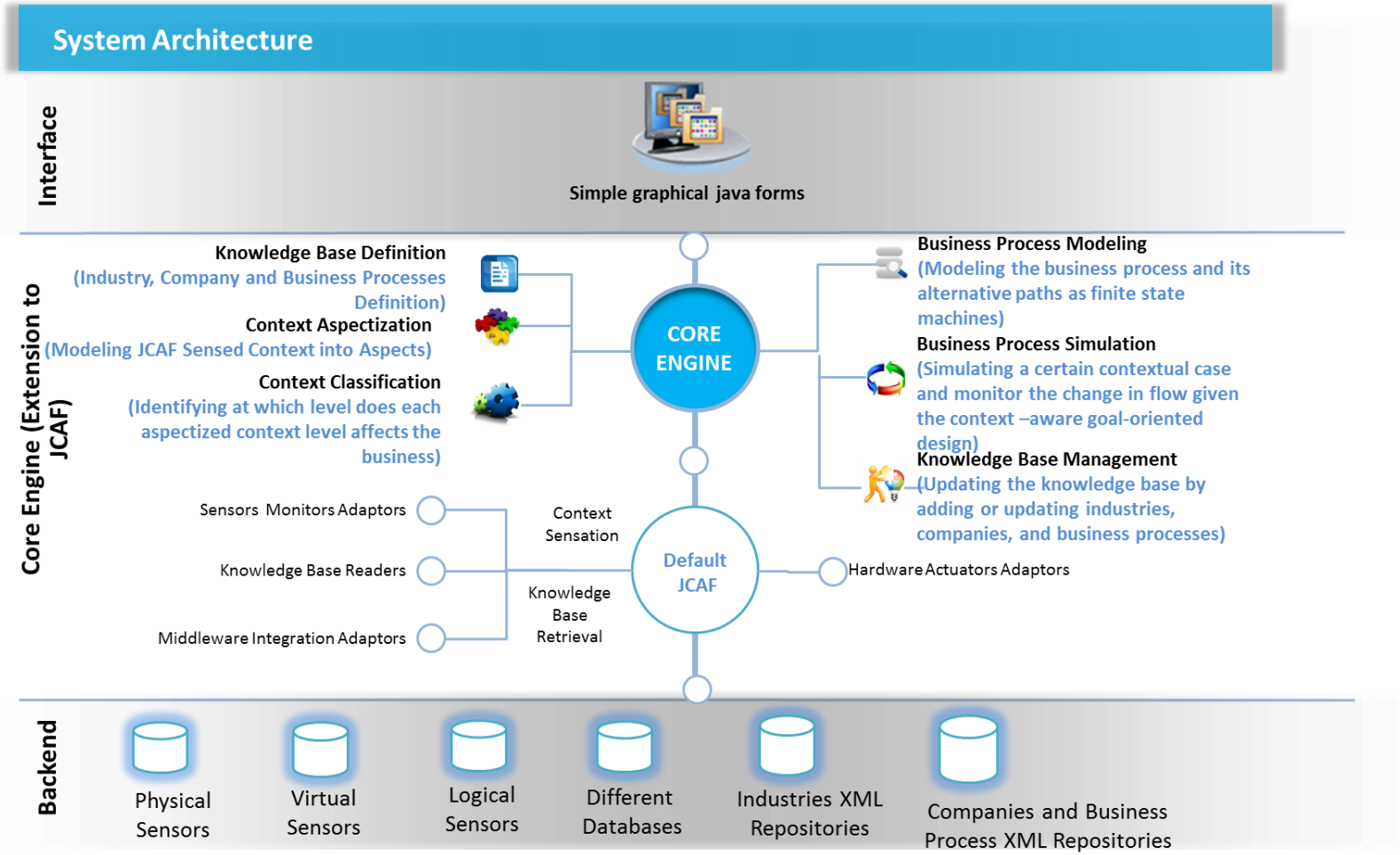

Figure 10: The Prototypical Framework Architecture

As depicted in the system architecture diagram, the system interfaces the users through simple graphical java forms. The core engine of the system which we developed as an extension to JCAF consists of the following main modules:

a. Knowledge Base Definition Module: this module is responsible for enabling the business experts to:
    i. Define information about their industry(industry name, the contextual aspects of interest to the industry, the classification of the contextual aspects on the different contextual layers and the context elements under each contextual aspect (e.g. Material utilization aspect belongs to the immediate layer and has the check-in counters number as a context element under it)
    ii. Define information about their company (company name, the parent industry, the company goals matrix, the relationship between those and the different contextual layers)
    iii. Define information about their business processes (business process name, the parent company, the parent industry, the business process goals, the business process steps and alternative paths)
b. Context Aspectization Module: this module models the different context items related to a specific industry in terms of Aspects for the sake of reusability across the different industries
c. Context Classification Module: this module classifies the contextual aspects related to a specific industry and consequently the contextual items under these aspects into the four main contextual layers identified in the solution methodology (immediate, internal, external and environmental context). The classification is retrieved from the knowledge base of the industry and is already defined by the industry expert at the industry definition phase.
d. Business Process Modeling Module: this module models the business process in terms of a finite state machine that can cater for concurrent finite state machines running together and can take more than one contextual event at a time as an input to do its configuration based on those events.
e. Business Process Simulation Module: this module generates a certain contextual case and simulates how the business process will alter its path according to the given contextual situation. The business process listens through JCAF listeners to the contextual items of interest to this business process and according to the contextual state the most appropriate recommendation, which is modeled as a finite state machine transitional condition, is chosen. The link between the context items and a business process is a goal-oriented link. During the industry definition the industry expert defines the contextual

items that are related to his/her industry and identifies the contextual aspect and contextual layer to which they belong (e.g. check-in counters items belong to the material utilization aspect under the immediate layer) and during the company definition phase the company expert links the contextual layers with company goals through these two links. A context item can be directly linked to a specific goal. Hence, the context items that the business process listens to and according to which takes its decision are the ones related to the goals that the business process contributes in achieving.

f. Knowledge Base Management Module: is responsible for retrieving, updating and deleting all the data in the knowledge base of an industry, a company or a specific business process

The default JCAF part of the system is responsible for sensation of context through different types of context sensors. We added to this set some additional readers to read from the knowledge bases of the different industries, companies and business processes.

The system can be integrated with different types of back-ends shown in the diagram above which currently provide, or may provide in the future, important data for any application that will implement our solution methodology.

3.2. Framework Specifications

This section details the specification of the Context-aware Aspectized Goal Driven Business Process Modeler Framework which was developed in this research as a proof of concept for the solution methodology that was described in the above section. The main features and design elements of the framework are listed below.

3.2.1. Knowledge Base

This section describes how the framework entails accumulating knowledge about new industries, new companies, new business processes, and new contextual aspects so that it can apply the idea of modeling context of business processes in terms of aspects and goal-driven modeling of business processes and configuration as described in the solution methodology. The knowledge accumulation incorporates the following;

- Industry Definition
- Industry Contextual Aspects and Variable Definition
- Industry Contextual Classification Suggestion
- Company Definition
    - Company Goal Matrix Definition
    - Company Goals and Context Association
    - Business Processes Definition

3.2.1.1. Industry Definition

The business process expert can simply define a new industry through a simple graphical user interface (depicted in figures 11, 12 and 13)

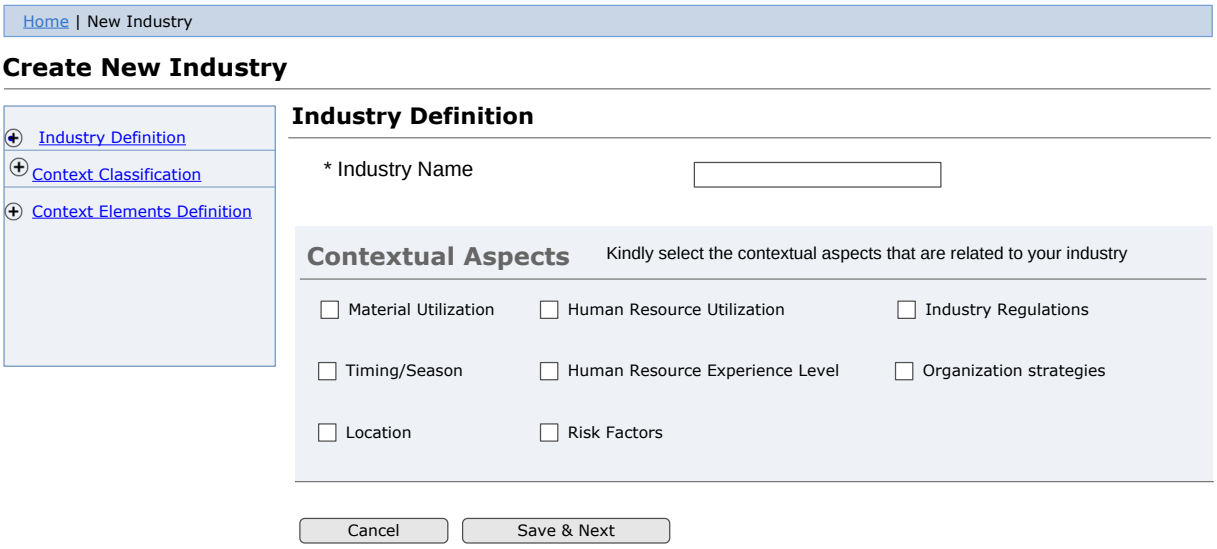

Figure 11: Industry Definition Initial Form

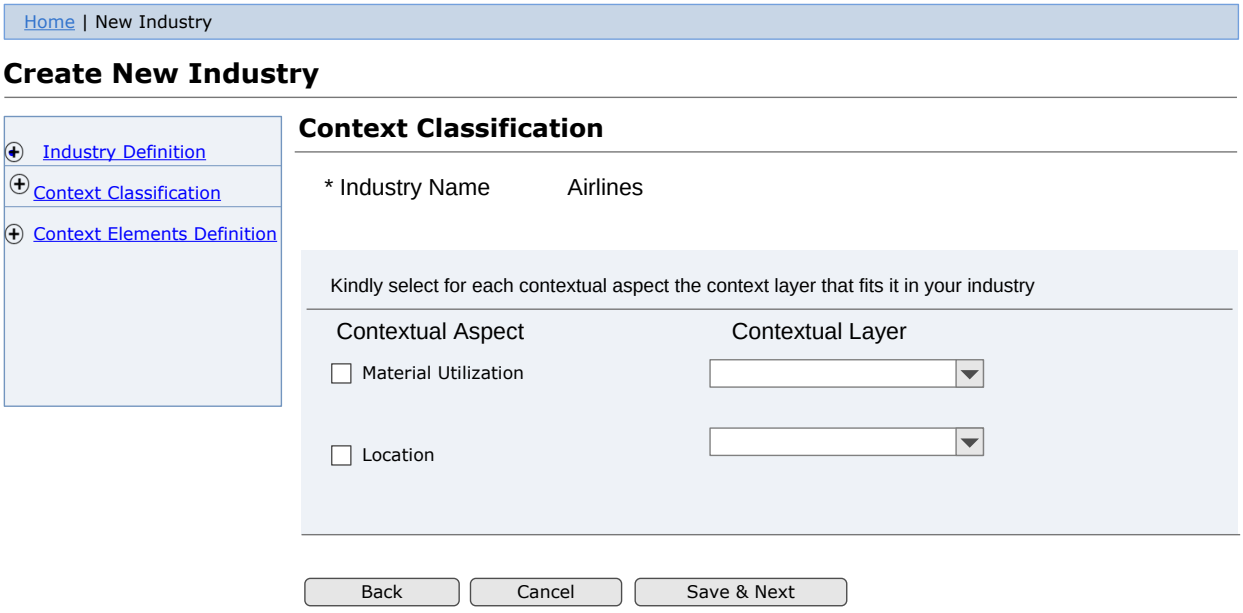

Figure 12: Industry Context Classification

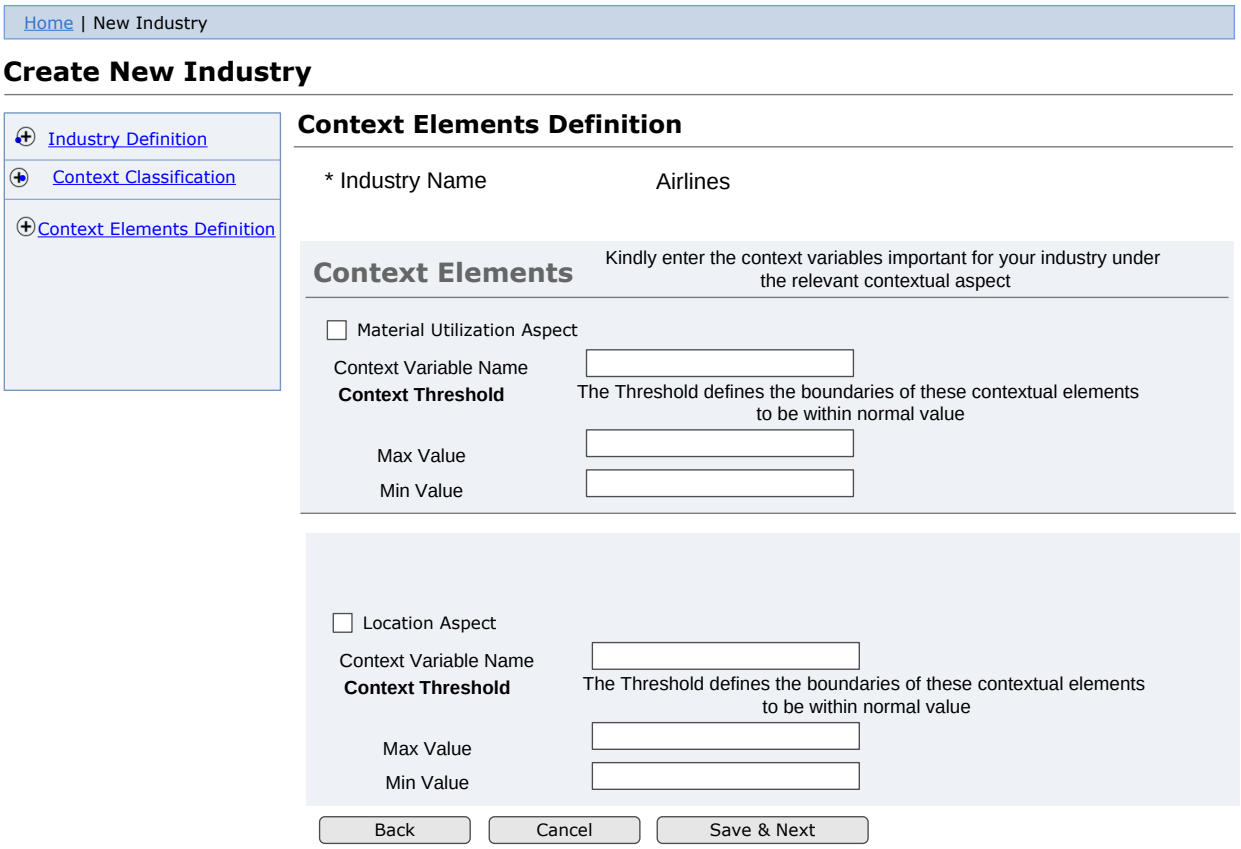

Figure 13: Industry Contextual Variables

First the business expert just enters the industry name and this action triggers the creation of an industry folder which will allow all the data files related to this industry to be loaded whenever the system runs a business process related to this industry.

3.2.1.2. Industry Contextual Aspects Definition

The second step is defining the contextual aspects that are relevant to this industry. From our study of business processes and our business modeling experience we identified the contextual aspects that are relevant to the industry and hence are generally relevant for all companies within the industry. This is why we ask the business expert to define the relevant contextual aspects on an industry level and not a company level as per the form in figure 11. The implemented framework focuses on certain contextual aspects as described earlier yet it is flexible and can apply to

more contextual aspects. Once this step is completed we move to the next step which is defining exact contextual variables under the above mentioned contextual aspects as depicted in figure 13. For example if in the airlines industry the business expert chose the material utilization aspect as an important contextual aspect for the industry, s/ he can define contextual variables like Check-In Counters, Luggage Loaders as contextual variables under this contextual aspect. The framework requests the business expert to enter threshold values (minimum and maximum values) for those context variables so that whenever the contextual sensors that sense the items detect out-of-boundaries values they trigger an alteration that needs to apply to the business process and in that case, it shouldn't flow in the normal flow scenario.

3.2.1.3. Industry Context Classification

The classification of the industry contextual aspects into the four layers of Rosemann is important to identify the level at which the contextual aspects affect the business processes for a specific company under the defined industry. As explained earlier in the solution methodology section, this cannot be an automatic classification as it varies with industry so only the industry experts are the ones allowed to define this classification on the form depicted in figure 12 above.

3.2.1.4. Company Definition

The company definition is the process of adding companies that have specific goals and specific business processes under a specific industry that is already defined by the business experts. The company is simply composed of a name, goals list (i.e. list of strategic goals, e.g. Increase profit) along with their sub goals (operational goals that will increase profit) and a list of goal-oriented business processes. The company definition is reached by accumulating the above mentioned knowledge through a series of graphical user interfaces (depicted in figures 14, 15, 16, 17, 18, and 19);

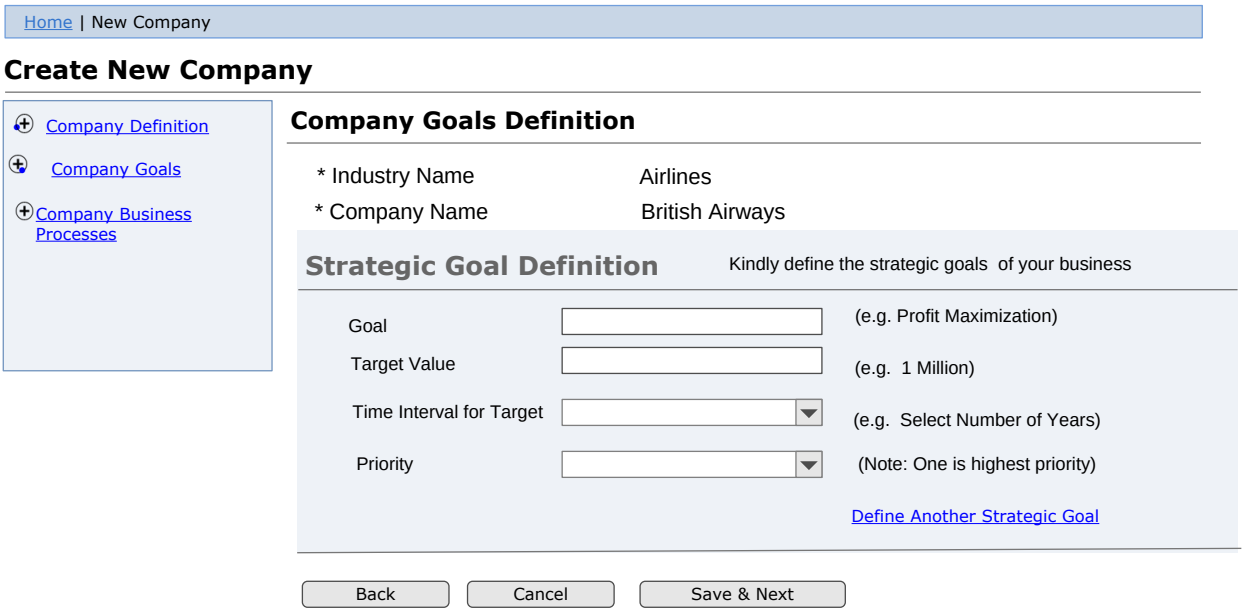

Figure 14: Company Initial Definition

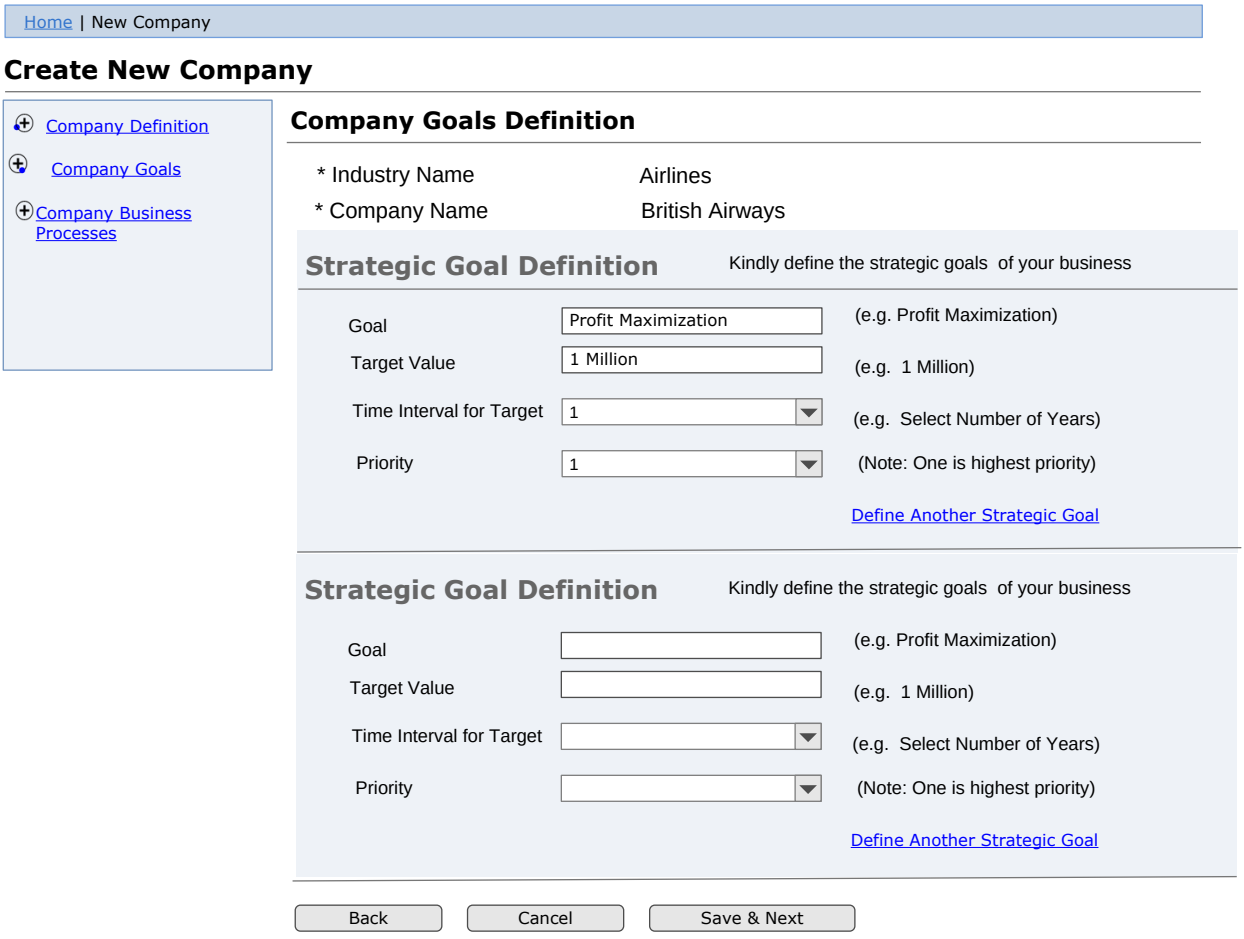

Figure 15: Company Strategic Goals Definition

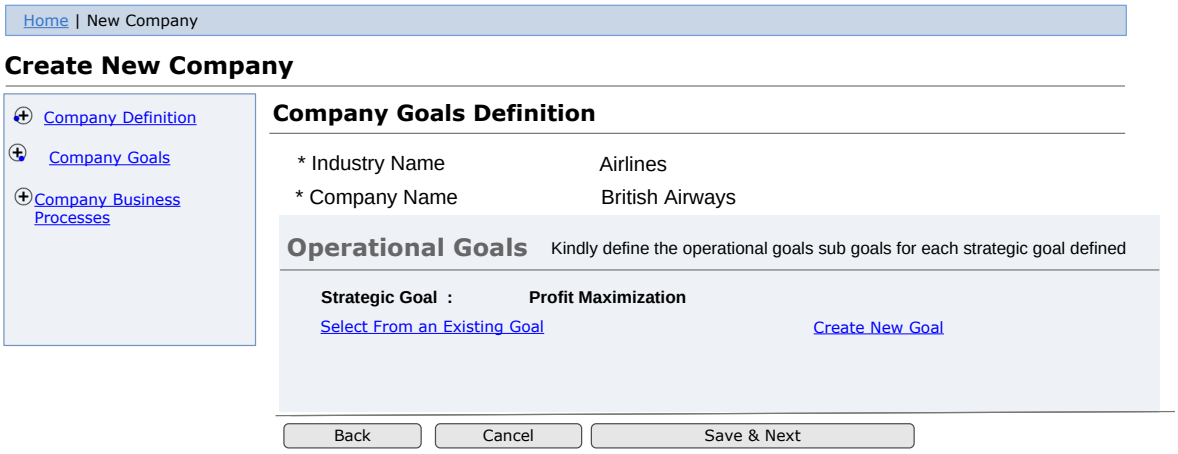

Figure 16: Company Operational Goals Definition

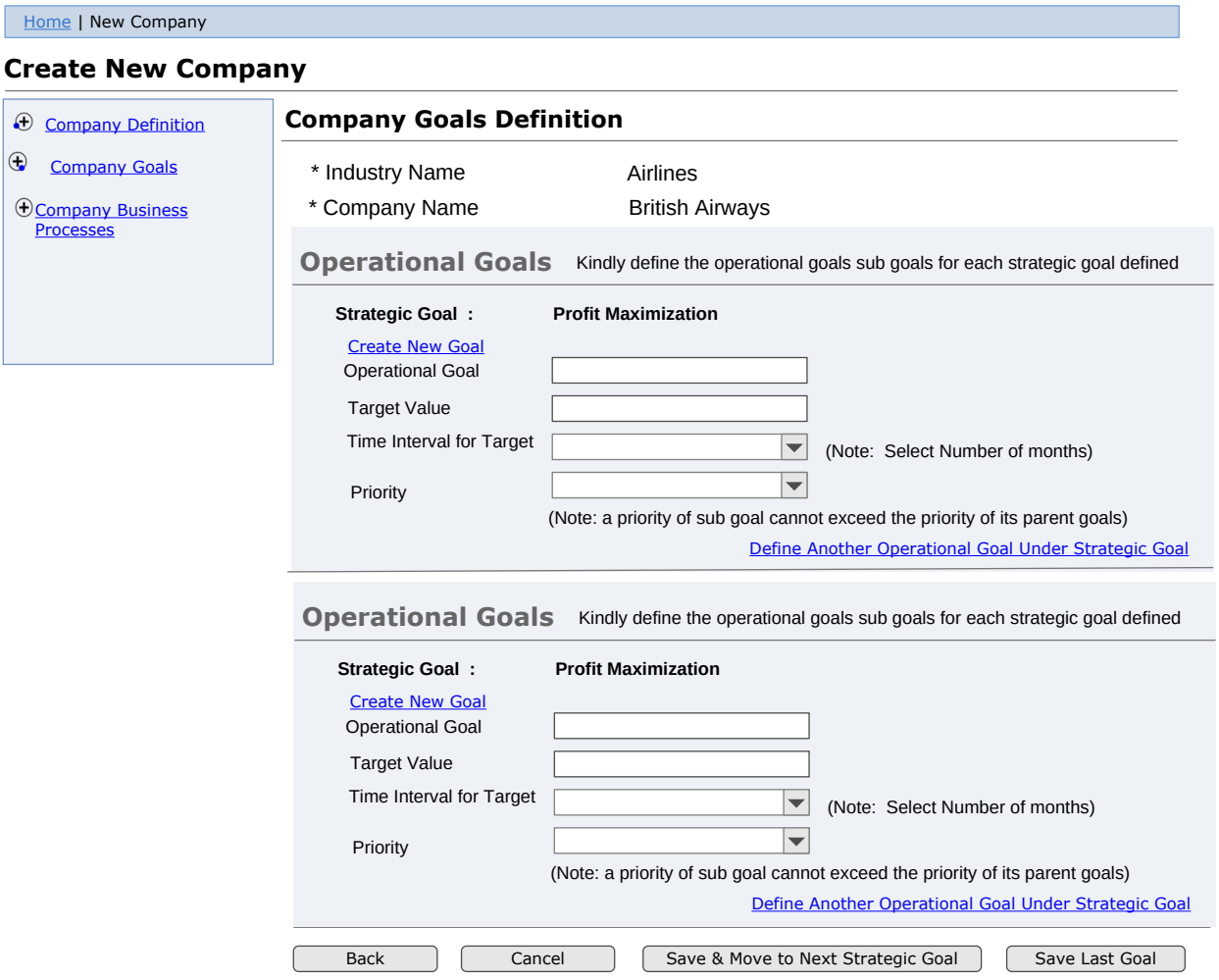

Figure 17: Company Strategic Goals Definition

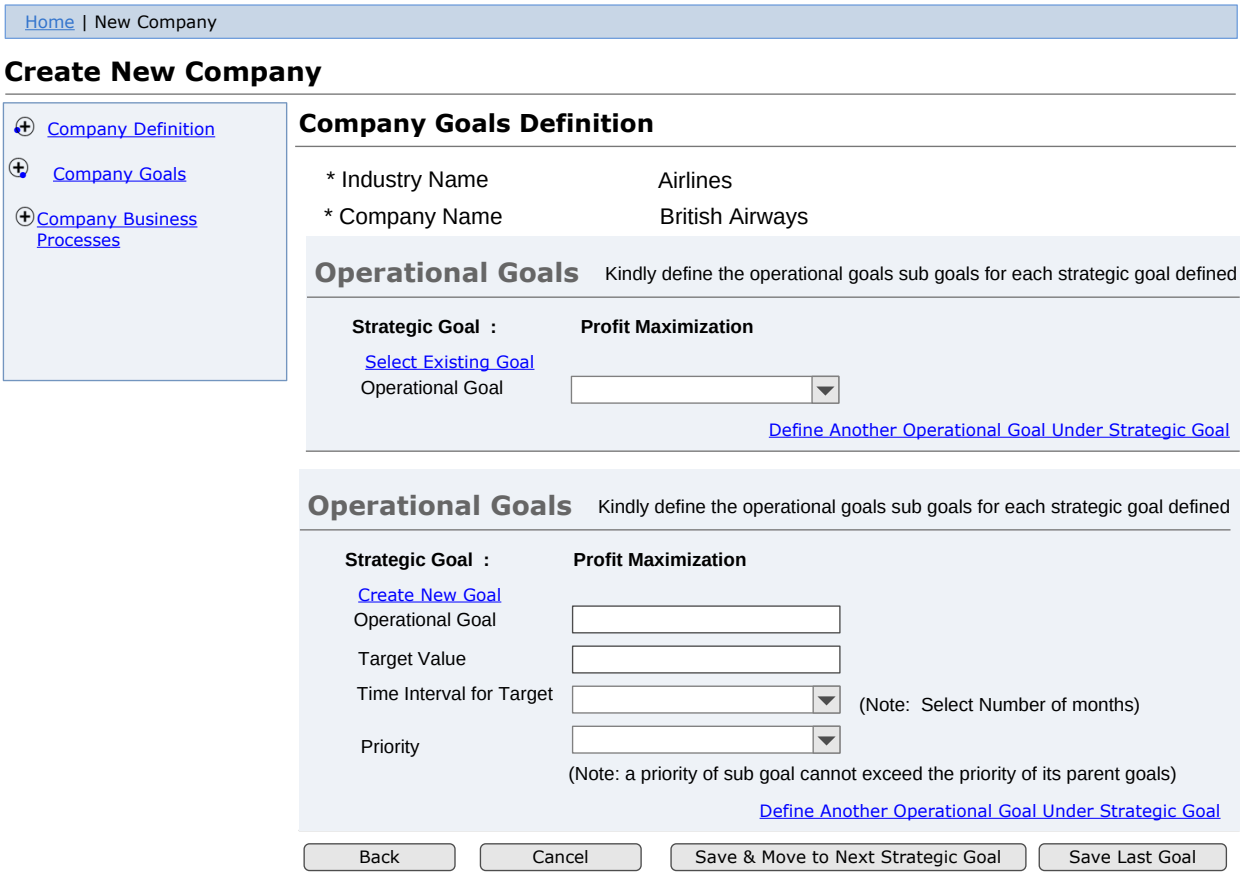

Figure 18: Ability to re-use predefined goals

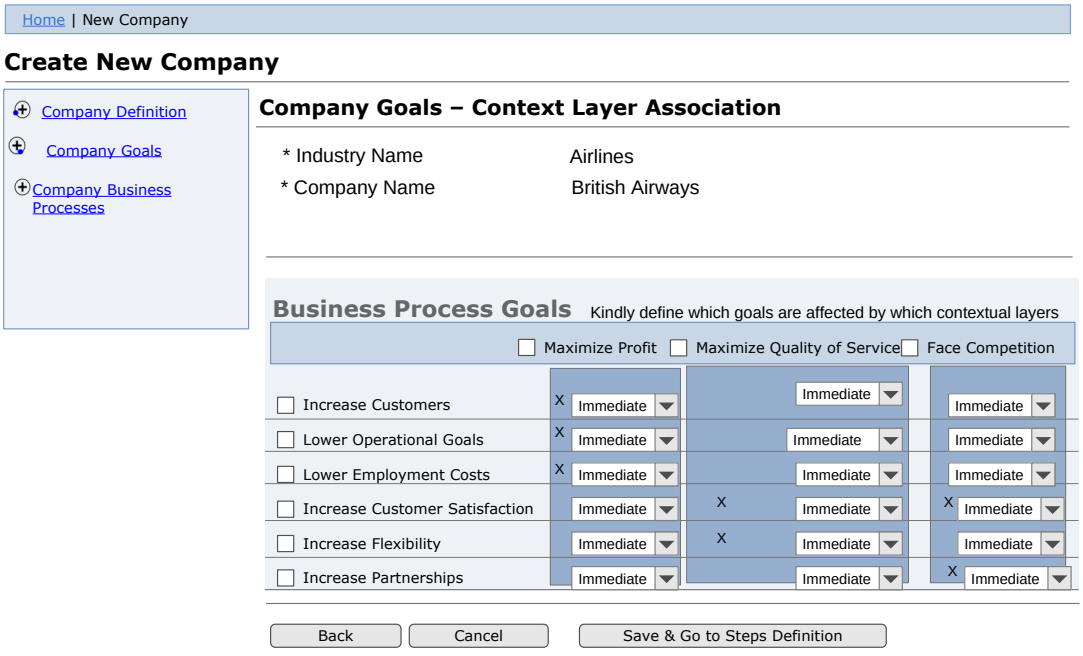

Figure 19: Goals to Contextual Layers Association

3.2.1.5. Company Structure Architecture

The company knowledge structure architecture is represented in figure 20 and a specific example is shown in figure 21.

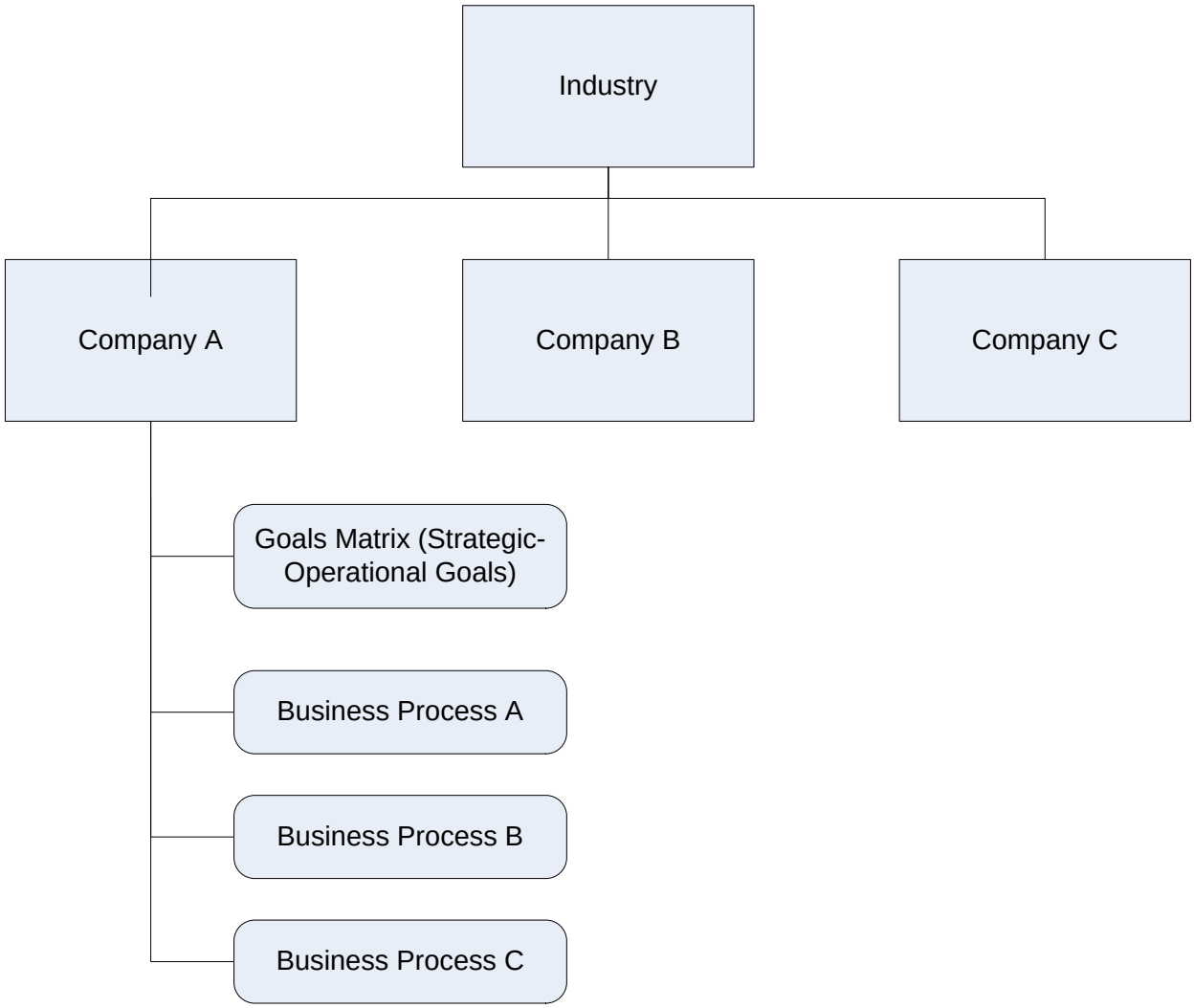

Figure 20: Company General Structure

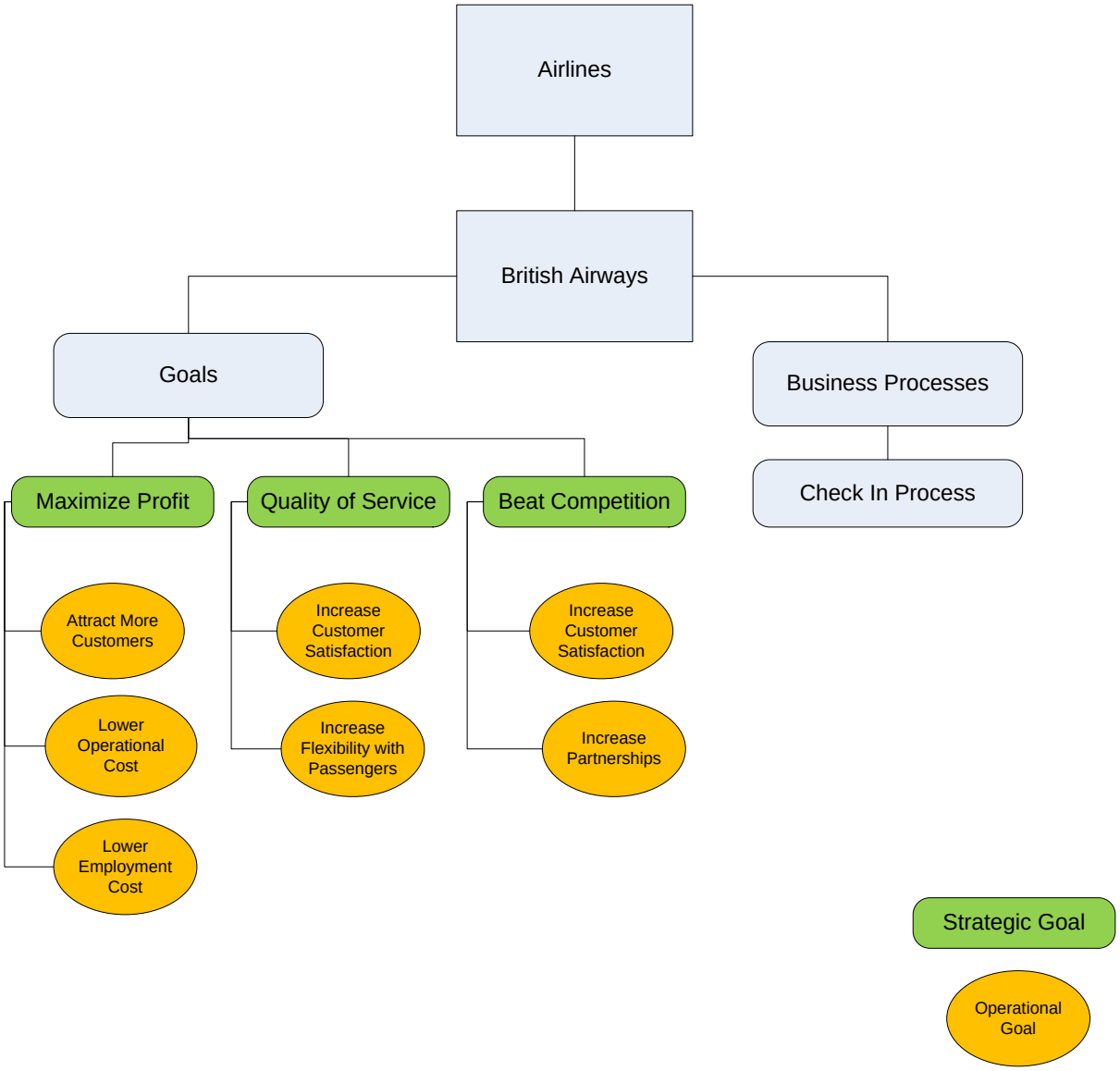

Figure 21: Company Example

The company structure should consist of the following;

- **Parent Industry;** it is essential that a company belongs to one of the predefined industries in the framework so that we can identify the contextual aspects, layers and variables that will be considered and monitored for the business processes running for this company
- **Company name;** this is just a company identification that should be unique within each industry

- **Company Goals Matrix;** this matrix shows the strategic goals important to a company and the operations that achieve them. It is represented in our framework as 2 dimensional matrixes as depicted in Table 1.

Table 1, Company Goals Matrix

Strategic Goals/ Operational Goals	Maximize Profit	Quality of Service	Face Competition
Increase customers	√		
Lower Operational Costs	√		
Lower Employment Costs	√		
Increase Customer Satisfaction		√	√
Increase Flexibility with Passengers		√	
Increase Partner√ ships			√

In real business the relationship between the goals and other goals is many to many, however in our framework and for simplicity, we identify the sub operational goals that can contribute to more than one strategic goal. But we do not model the relationship between the strategic goals and each other (i.e. a strategic goal cannot be a sub goal to another strategic goal) and we maintain the goals at two levels of depth while in real business they can go to endless levels.

For each goal whether strategic or operational the company expert should define a target over time for the goal as well as for the goal priority. The target over the time is not currently utilized further in our framework but it should help future research work in an advanced assessment of the solution methodology's effectiveness. It could identify how appropriate modeling of context of business processes as aspects and binding them to other business processes

through goals-matching contributes to the achievement of targets. Goal priority is important as in some cases the contextual facts would reflect a perplexing situation where a certain business process recommendation/configuration maximizes a certain goal yet harms another goal. Hence, the decision in this case should be taken based on the priority of the goals. A logical constraint in our goal matrix model is that the priority of a sub goal should be equal or less than the priority of its parent goal.

- **Goals to Contextual Layers Association;**

  This association is essential as it defines which goals are associated with which contextual layers so the immediate layer that should be concerned with context related to the direct flow of the business processes would affect certain goals in the company goals matrix that fall on this level which affects the direct flow of the process. The association is done on this level also to identify the amount of impact the context would have on the business as probably more external goals related to industry new regulations might have a cross sectional impact of adding steps to all business process while immediate context would be most probably related to operational goals. Hence, linking the goals matrix to the contextual layers level is the easiest way for the business domain expert and for the framework to determine the level of impact that the aspects under this contextual layer would have on the different business processes.

- **Company Business Processes;**

Now the last part of the company representation is the list of business processes under the company. The business processes are represented in our framework in terms of a finite state machine as shown in the figure 22.

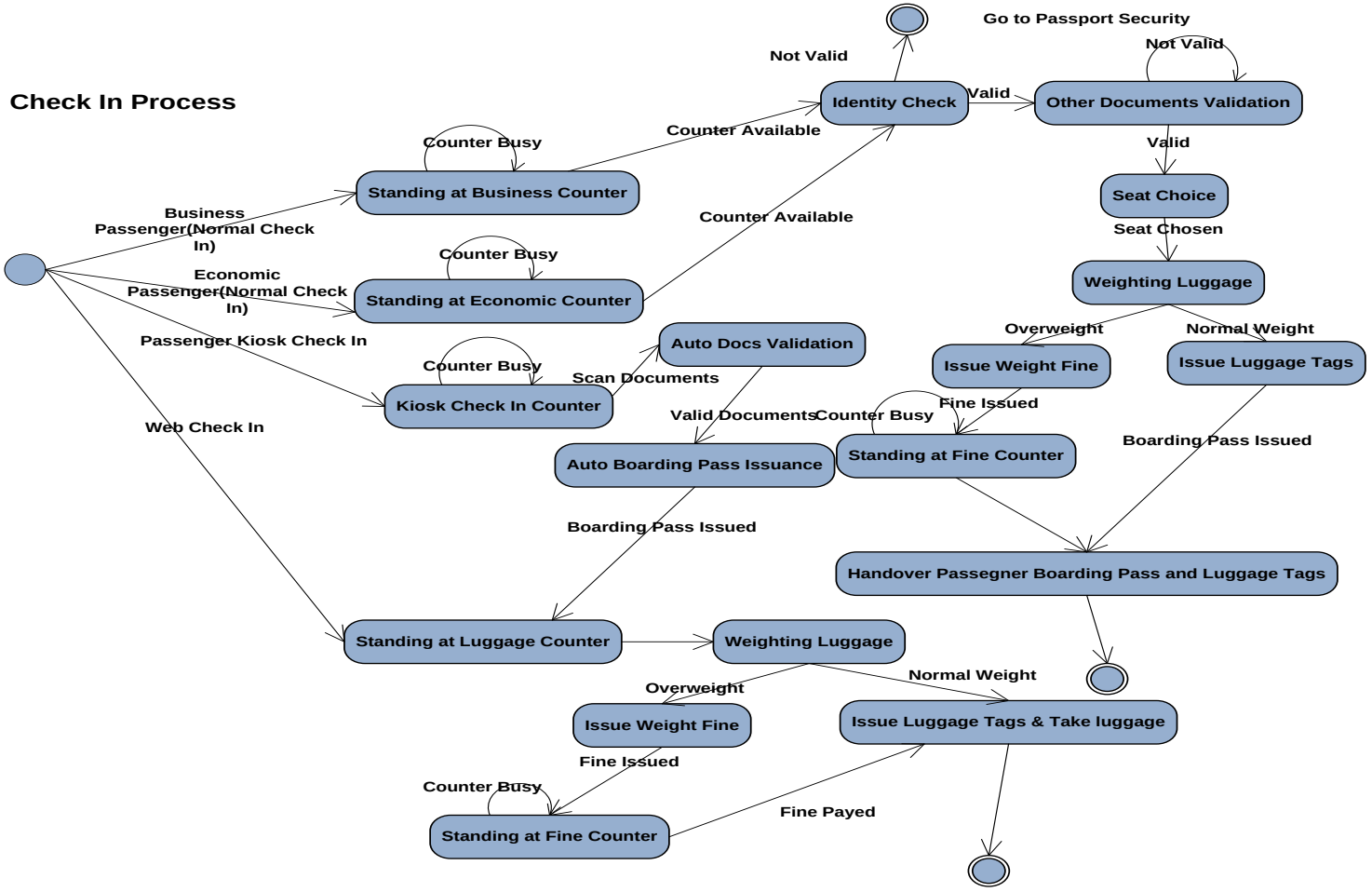

Figure 22: Check-in Business Process as Finite State Machine

The business processes are defined by business process experts inside the company through the following graphical user interfaces depicted in figures 23, 24 and 25

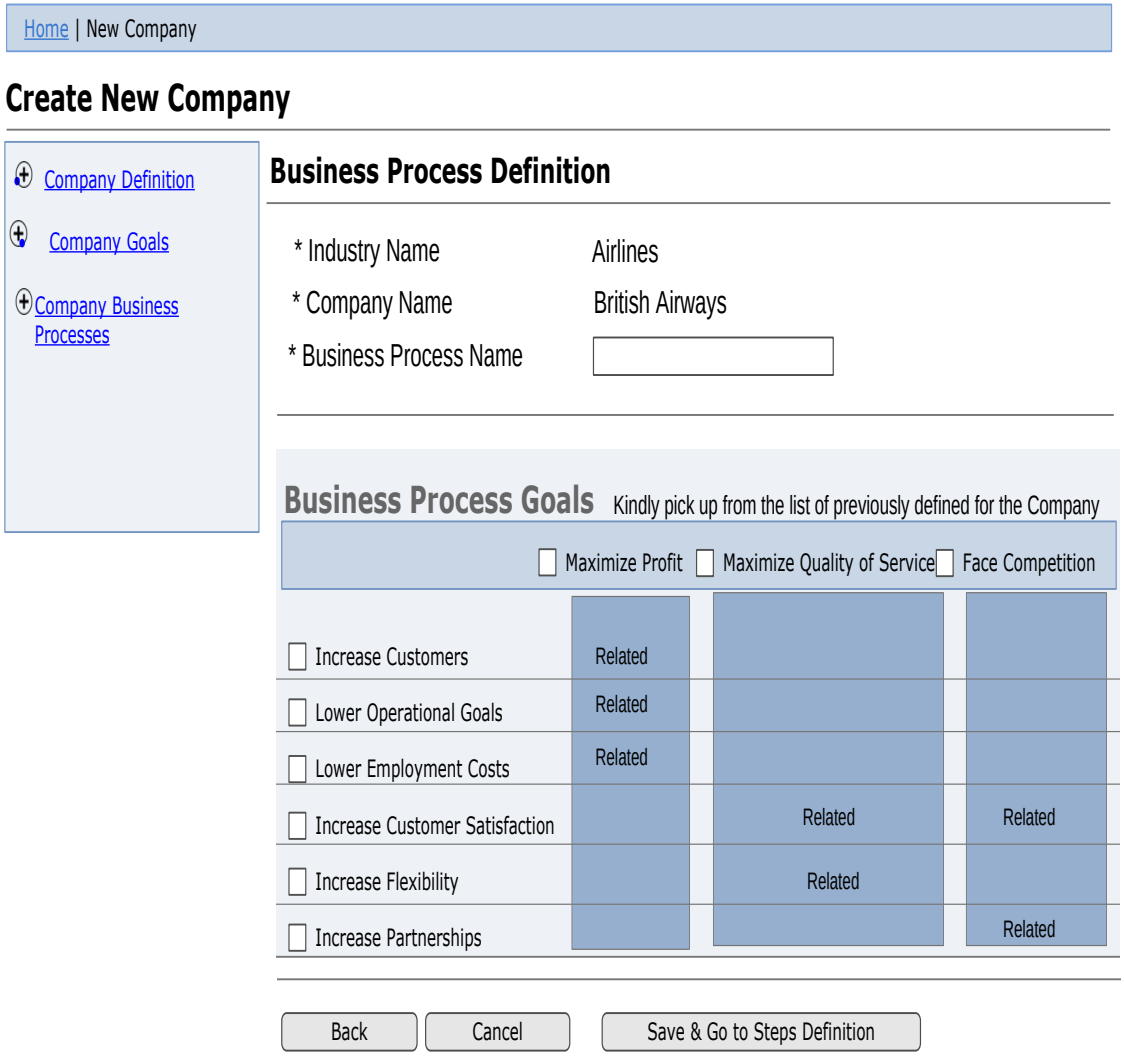

Figure 23: Business Process Definition - Goals Stage

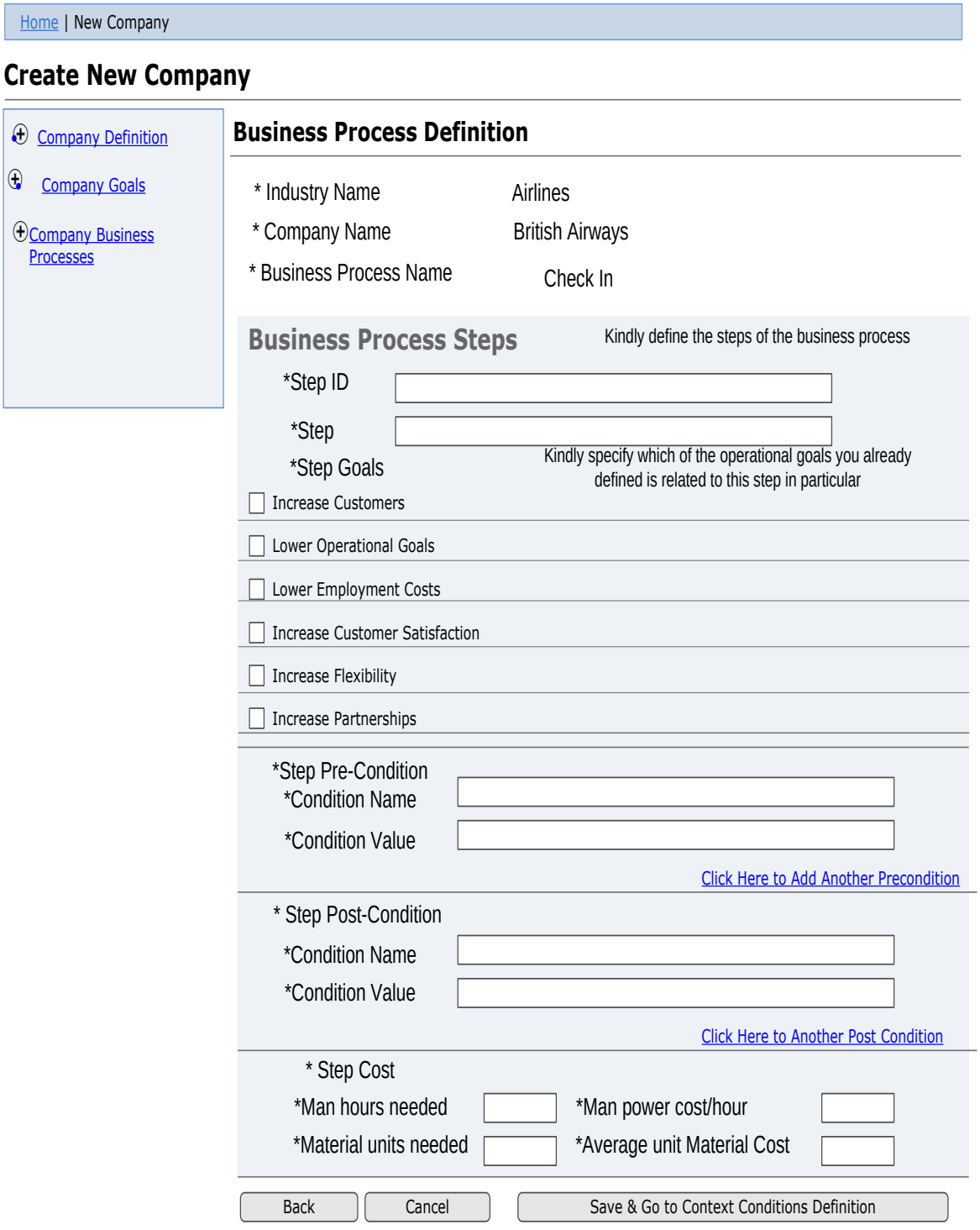

Figure 24: Business Process Definition - Steps Stage

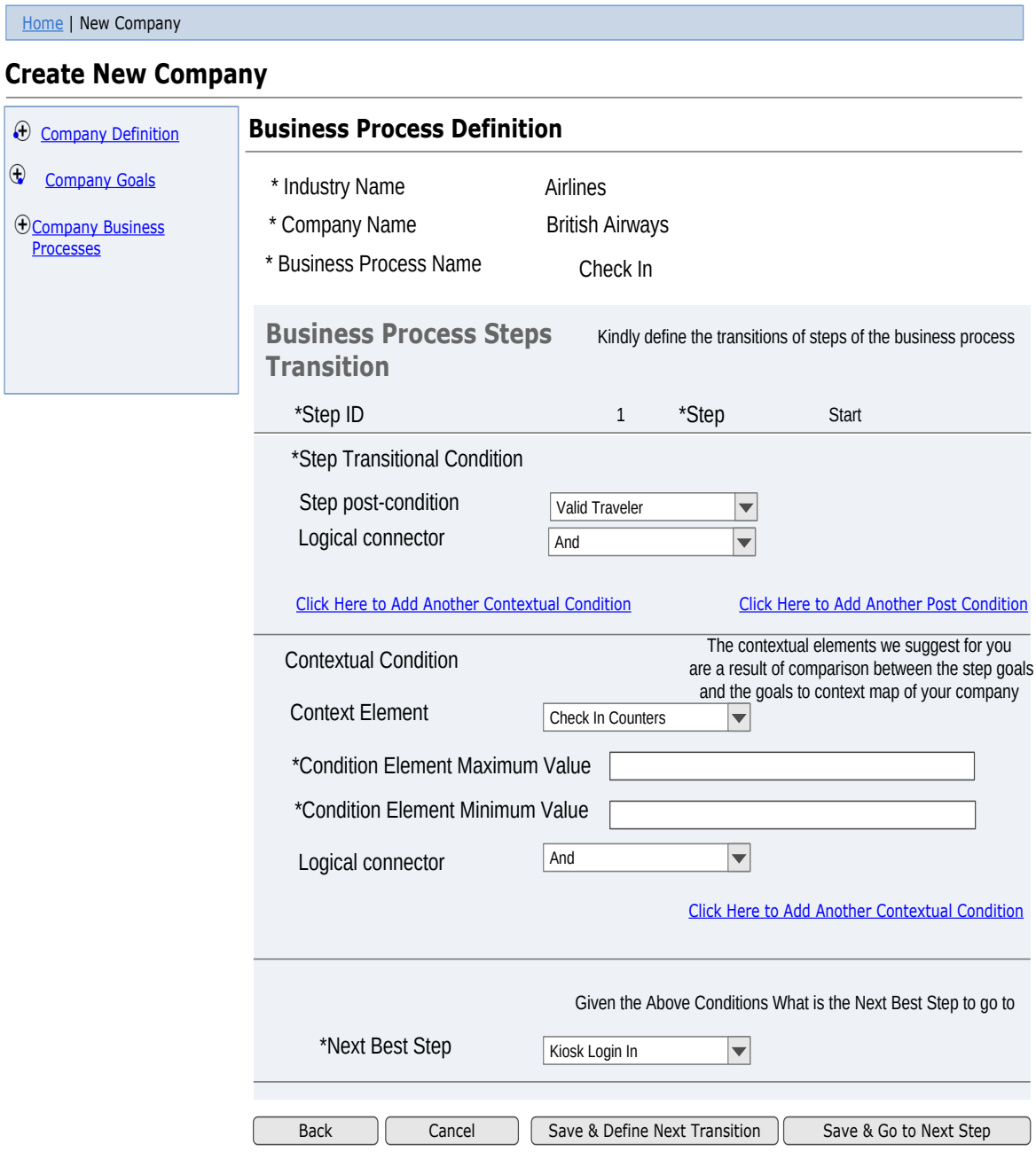

Figure 25: Business Process Transitional Conditions Definition

We have a goals matrix for each business process and for each step within the business process we define its relevant goals as well as its preconditions and post conditions, i.e. The conditions required before moving into this step and the conditions with which we exit the step, respectively. In addition, we define for each business process step, a cost parameter (which consists of the human resources cost and material cost needed for this business process step to execute properly). After defining all the steps we start the transition conditions definition phase, the transition

condition is used to define the post conditions and contextual situation under which the business process would move from one state to another state and it has a value and the next step identifier to define the next best move and in this way we incorporate the different possible alternative paths of a process based on the steps' goal-orientation and different contextual situations that could take place. [For example, in the check- in process on the condition that the passenger visa is not valid then the next step would be "validate with passport control" while if the condition value is valid, the business process would move into the next step of seat choice]. For the transition conditions, the system compares the business step goals and the contextual layers, aspects and elements related to these goals and for each contextual element the business process expert is asked to define ranges of values for it and the next best move in case of each range and this is defined in the form of a transitional condition as depicted in figure 25above.

3.2.2. Knowledge Base Architecture

The previous section described how the knowledge base is defined by business experts in an easily updatable format. This section describes how the framework saves the knowledge base of industries, companies, business processes and contextual aspects as well as their structure.

The overall structure can be best described through figure 26;

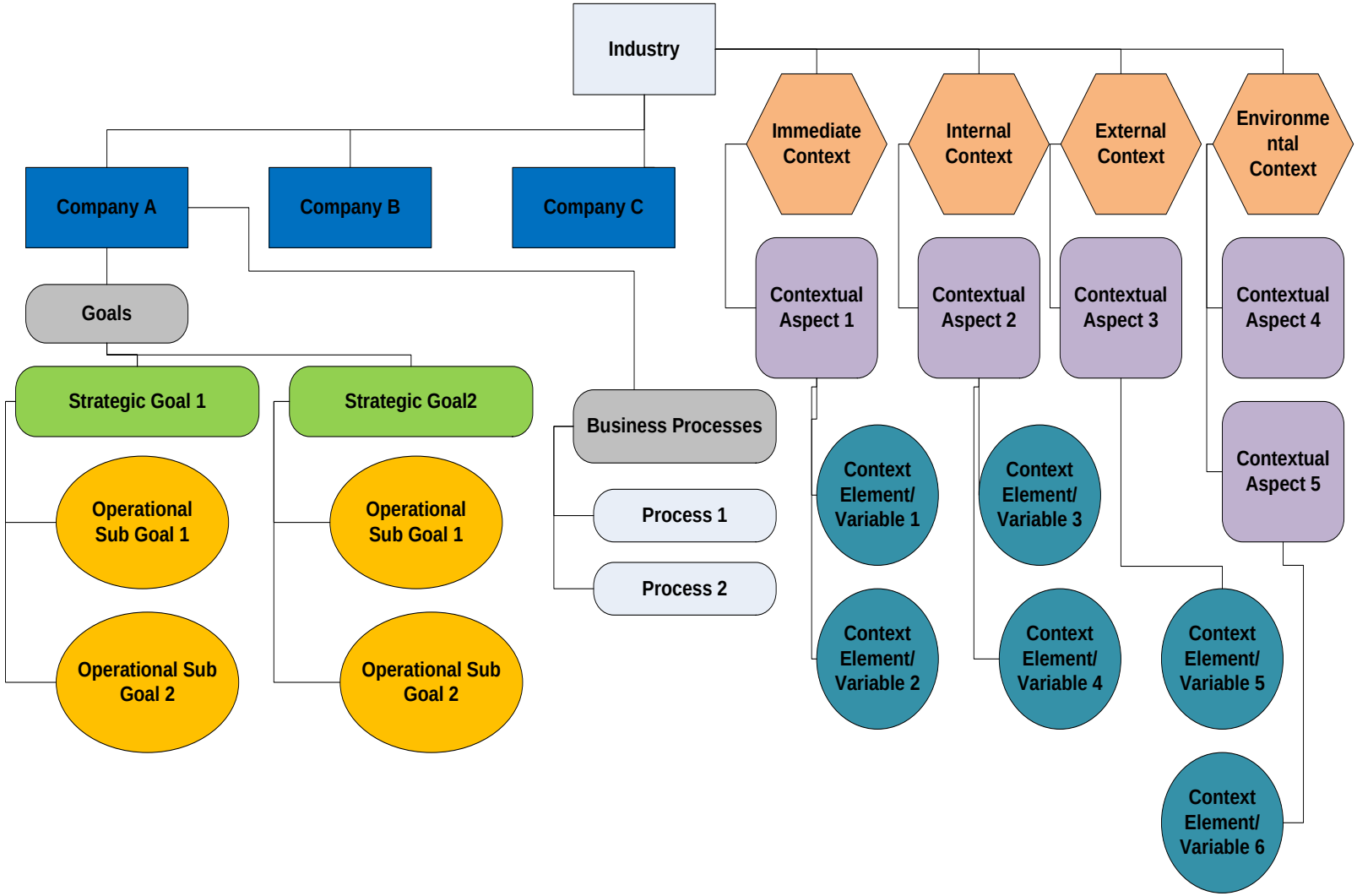

Figure 26: Knowledge Base Structure

3.2.2.1. Industry Repository

Each Industry defined by business domain experts will have a repository (a folder) created for it by the industry name. The industry folder shall have the following constituents;

- ***The Contextual definition XML file*** defines for each layer of the four layers of contextual layers (Immediate, Internal, External and Environmental Context), the list of contextual aspects that are under this layer. Each contextual aspect can belong to one and only one contextual layer. The contextual aspects that we focus in our solution methodology are as follows;
    - Non human resource utilization.
    - Human resource utilization.
    - Human resource experience level.
    - Organizational strategies (The strategies of the organization on which the business process is running (e.g. whether the strategy is cost cutting or quality focused).
    - The risk factors associated with a process.
    - Industry regulations and practices affecting a process.
    - Timing/Season

Each contextual variable under the contextual aspect is defined as explained earlier in the solution methodology. Hence, the non-human resource utilization can include a machine counter variable under it and the variables represent the measurable items that will be continuously monitored as they affect the different business processes under the defined industry. The contextual knowledge definition is saved in an XML file under the industry repository folder. The structure of the contextual knowledge XML file is described in Appendix I.

3.2.2.2. Company Repository

- ***Companies folders;*** whenever the business domain experts define a new company under a specific industry a company repository which is basically a company folder is created for this company; the company will have a number of constituents:
    - ***Company Goals Matrix;*** which is basically the list of strategic and operational goals and their associations with each other as well as what level of contextual layer should affect each goal

- The goals matrix XML file structure is described in Appendix II.
- ***Company Business Processes:*** which are basically XML files each XML file representing one of the business processes of the company

Table 2, an Example of a Company Goals Matrix

Strategic Goals/ Operational Goals	Maximize Profit	Quality of Service	Face Competition	Contextual layer
Increase customers	√			Immediate, Internal
Lower Operational Costs	√			Internal
Lower Employment Costs	√			External
Increase Customer Satisfaction		√	√	Immediate, Internal, External
Increase Flexibility with Passengers		√		Internal
Increase Partner√ ships			√	External, Environmental

3.2.2.3. Company Business Processes Repository

- ***Company Business Processes ;*** each company will have a repository of business processes which is a folder for company business processes and inside it each business process will have an XML file defining the details of the business process in terms of its goals and the steps that can be retrieved later on for running this business process. The Business process XML file structure is described in Appendix III.

3.2.2.4. Flexibility of the Knowledge base architecture

The way the knowledge base is structured in the form of repositories and XML files defining industries, companies, goals, contextual aspects and business processes makes it easy to add any new industry or company or goal or contextual aspects. Anything from industry definition to steps' transitional conditions could be edited at any point in

time through simple editing in the well-structured XML files described below or through requesting to edit from the graphical user interface provided for the business domain experts as an easy knowledge base definition and editing tool. According to the user's choice the appropriate information is fetched and presented in forms similar to the ones depicted earlier in the knowledge base definition section. Yet the forms are preloaded with the data that is already in the knowledge base and they are displayed in an editable format to allow the business experts to change them whenever they like as change is inevitable in today's business especially when related to company goals and business processes.

3.2.3. Context Detection and Business Process Configuration

So far the definition, structuring and update of the knowledge base that will enable us to model the context of business processes in terms of aspects and business processes in terms of configurable finite state machines that register their interest in certain context variables (according to a goal matching technique then alter their behavior according to contextual updates), were discussed. In this section we discuss in more details how the prototypical framework we built as a proof of concept caters for context detection and modeling, then business process modeling and configuration, in a manner that demonstrates the solution methodology discussed in the first part of this chapter.

1.2.3.1. Context Detection and Modeling

The context modeling and detection was implemented through JCAF (the Java Context-aware Framework). The JCAF has a generic context item class which represents the contextual items that can be detected through the JCAF monitor classes. The JCAF monitor and listener classes are classes that represent the different kinds of context monitors whether physical monitors (e.g. sensors monitoring temperatures, machines reading bar codes, etc….) or virtual monitors (e.g. monitors reading information from databases). New context monitors can be added to extend the abstract context monitor classes to detect any type of context and the listener classes to listen to specific contextual events. Within our framework we use the default monitors and simulate them as if these monitors are actually connected to sensors and databases by adding a randomly generated event feeding input into the context listener objects.

3.2.3.1.1. Context Detection

JCAF also has a context item abstract class which can be extended by adding new context item types to the context item package. Hence, our implemented framework extends the context item and defines the Context Item Generic class (depicted in figure 27) which can carry a contextual variable as defined in our knowledge base.

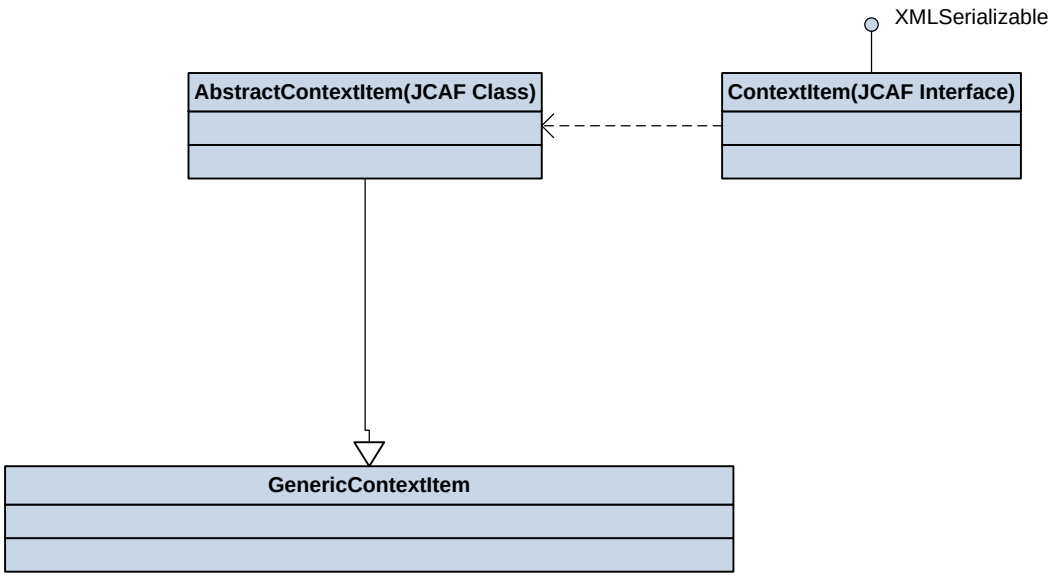

Figure 27: GenericContextItem Class

The new GenericContextItem class main functionality is to represent any contextual item that might be of interest to the industry as defined by the industry experts (For example in the airlines industry an object of the context could represent the check-in counter, another could represent luggage loaders, another could represent a certain airlines strategy). Hence, the class should have attributes flexible so that its instances can represent the various context items.

Table 3, Generic Context Item Class Attributes

Attribute	Type	Description
Name	String	This is the contextual element name (e.g. Counters Number)
Numerical Value	Int	This is the numerical value of the contextual element, it is used if the contextual element being represented can be measured by numbers
StringValue	String	This is the string value of the contextual element , it is used if the contextual element being represented value can be represented as text (For example human resource education will be measured as string and shall have high school, college, graduate studies)
MaxNumerical Value	Int	This is the maximum boundary of the numerical value after which any contextual items exceeding it must alter the flow of the business processes as it enters a critical zone and needs handling
MinNumerical Value	Int	This is the minimum boundary of the numerical value below which any contextual items exceeding it must alter the flow of the business processes as it enters a critical zone and needs handling
Apsect	String	This is the contextual aspect that the context item belongs to
Layer	String	This is the contextual layer that the context item belongs to

GenericContext Item Class Methods:

The methods of the GenericContext Item classes are simply constructors and getters of the different attributes of the whole object. The functionalities of communicating with different contextual monitors to monitor and simulate the generation of different values are implemented as calls of the JCAF monitor classes from the parent AbstractContextItem JCAF classes.

Table 4, Generic Context Item Class Methods

Method	Return	Description
getName	String	This returns the contextual element name (e.g. Counters Number)
getNumericalValue	Int	This returns the numerical value of the contextual element, it is used if the contextual element being represented can be measured by numbers
getStringValue	String	This gets the string value of the contextual element , it is used if the contextual element being represented value can be represented as text (For example human resource education will be measured as string and shall have high school, college, graduate studies)
getMaxNumerical Value	Int	This gets the maximum boundary of the numerical value after which any contextual items exceeding it must alter the flow of the business processes as it enters a critical zone and needs handling
getMinNumerical Value	Int	This gets the minimum boundary of the numerical value below which any contextual items exceeding it must alter the flow of the business processes as it enters a critical zone and needs handling
getAspect	String	This gets the contextual aspect that the context item belongs to
getLayer	String	This gets the contextual layer that the context item belongs to
GenericContextItem	Void	This is the constructor of the objects of the class
toXML	String	Returns the object value in form of XML
GetAccuracy	Double	Returns the accuracy level of the monitor sensing this contextual item, this a JCAF functionality inherited from the parent class. It is quite important to disregard the contextual item whose monitors have a low accuracy

3.2.3.1.2. Context Modeling

The contextual items in our framework are aspectized (i.e. represented in terms of aspects) which is our extension to JCAF. In our framework we use AJDT (AspectJ Java Development Tool) which is an add-on to java eclipse to support aspect development. Under the JCAF context items package we define the following nine aspects;

- Human Resources Experience Level
- Human Resources Utilization
- Industry Regulations
- Location
- Material Utilization
- Organization Strategy
- Risks
- Season
- Timing

The framework is extensible to add more aspects whenever needed. The aspect is simply associated with an industry, and the contextual layer it affects as well as a list of Generic Context Item objects which represents the contextual elements under this layer are included. For example the material utilization aspect belongs to the Airlines industry. It is classified (as per the industry knowledge base defined by business experts and described in the knowledge base section of this chapter) and has contextual items which are check-in counters and luggage loaders.

The aspect enables us to do calculations on the context item values and weighting averages for their values on the point cut of calling the context event listeners. These are called from the main simulation class (Context Tester class) which simulates the running of this framework. The context aspect class is depicted in figure 28 below.

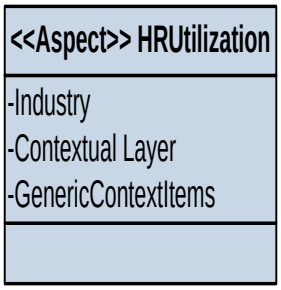

Figure 28 : Context Aspect Example

3.2.3.2. Context Classification

The classification of the contextual items depends on the industry and is defined by industry experts as per the knowledge base definition as depicted in figure 29. Thus, for every industry there is a different contextual classification instance. The connection between contextual layers and the goals take place on the company level as the goals and priorities matrix of each company vary. Hence, the second link of contextual layers to goals takes place as a part of the company modeling which will be described in the following sections;

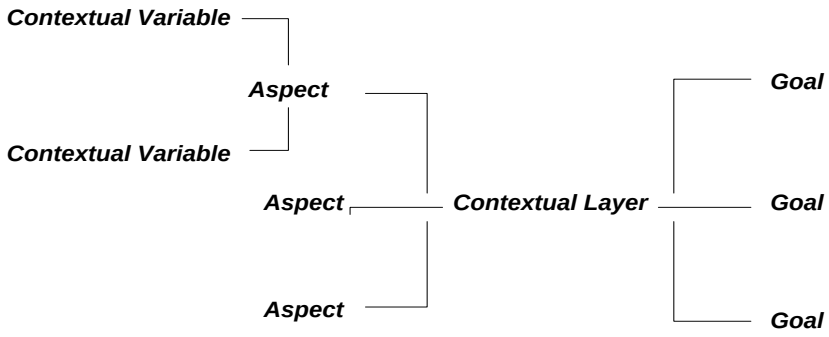

Figure 29: Contextual Layers Relationships

The nine contextual aspects (Human Resources Experience Level, Human Resources Utilization, Industry Regulations, Location, Material Utilization, Organization Strategy, Risks, Season, and Timing) that our prototype is focused on are distributed among the four contextual layers (Immediate, Internal, External and Environmental). The relationship between contextual aspects and contextual layers is many to many (i.e.

one contextual aspect can belong to more than one contextual layer and the contextual layer can be related to more than one contextual aspect) as shown in table 5 below;

Table 5, Contextual Aspects and Layers Matrix

	Immediate Layer	Internal Layer	External Layer	Environmental Layer
Material Utilization Aspect	√	√		
Human Resource Utilization aspect	√	√		
Human Resource Experience Aspect		√		
Organizational Strategies Aspect		√		
Risks Aspect			√	√
Industry Regulations Aspect			√	
Timing Aspect	√			
Season Aspect	√			
Location Aspect				

The relationship between contextual layers and goals is defined by business process experts as per the knowledge base definition and is a many to many relationship (i.e. one contextual layer might affect many business goals and one business goal can be affected by many contextual layers).

The context classification class is not the normal automatic classifier class that has one of the known classification algorithms. The classification class has a much simpler algorithm which is as follows;

1. Read from contextual aspect XML file the relationship between layers , aspects and contextual items under aspects
2. These are accumulated into lists in the classification class, thus we have four lists in the classification
    - Immediate Context List; consists of a list of aspects under immediate context layer and each aspect in the list consists of the list of contextual elements under this aspect as per the contextual aspect file which exists under the industry folder of the industry currently being examined as depicted in table 6 which represents the context classifier class attributes.
    - Internal Context List; consists of a list of aspects under the internal context layer and each aspect in the list consists of the list of contextual elements under this aspect as per the contextual aspect file which exists under the industry folder of the industry currently being examined as depicted in table 6 which represents the context classifier class attributes.
    - External Context List; consists of a list of aspects under the external context layer and each aspect in the list consists of the list of contextual elements under this aspect as per the contextual aspect file which exists under the industry folder of the industry currently being examined as depicted in table 6 which represents the context classifier class attributes.
    - Environmental Context List; consists of a list of aspects under the environmental context layer and each aspect in the list consists of the list of contextual elements under this aspect as per the contextual aspect file which exists under the industry folder of the industry currently being examined as depicted in table 6 and 7 which represents the context classifier class attributes and methods.

Table 6, Context Classifier Class Attributes

Attribute	Type	Description
Industry	String	This is simply the name of the industry that this context classification represent
Immediate Context	List of Strings	This is list of the names of the contextual aspects related to the immediate context layer as per Rosemann Onion model described in the solution methodology section
Internal Context	List of Strings	This is list of the names of the contextual aspects related to the internal context layer as per Rosemann Onion model described in the solution methodology section
External Context	List of Strings	This is list of the names of the contextual aspects related to the external context layer as per Rosemann Onion model described in the solution methodology section
Environmental Context	List of String	This is list of the names of the contextual aspects related to the environmental context layer as per Rosemann Onion model described in the solution methodology section

Table 7, Context Classifier Class Methods

Method	Return Type	Input	Description
GetImmediate Context	List of Strings	Industry Name	Returns list of the names of contextual aspects related to the immediate context layer as per Rosemann Onion model described in the solution methodology section
GetInternal Context	List of Strings	Industry Name	Returns list of the names of contextual aspects related to the internal context layer as per Rosemann Onion model described in the solution methodology section
GetExternal Context	List of Strings	Industry Name	Returns list of the names contextual aspects related to the external context layer as per Rosemann Onion model described in the solution methodology section
GetEnvironmental Context	List of Strings	Industry Name	Returns list of the names contextual aspects related to the environmental context layer as per Rosemann Onion model described in the solution methodology section
ContextClassifier	Constructor	Industry Name	This is the constructor of the class, which reads the XML file parse it and set it to the different class attributes
getContextClassifier	ContextClassifier Object	Industry Name	Return the whole context classifier object

3.2.3.3. Company Structure and Goals Modeling

The company under a specific industry should be well structured and modeled in our prototypical framework as it acts as the container for the business processes as well as the business goals which are the back bones of our business process modeling methodology. The company structure is depicted in figure 30 below.

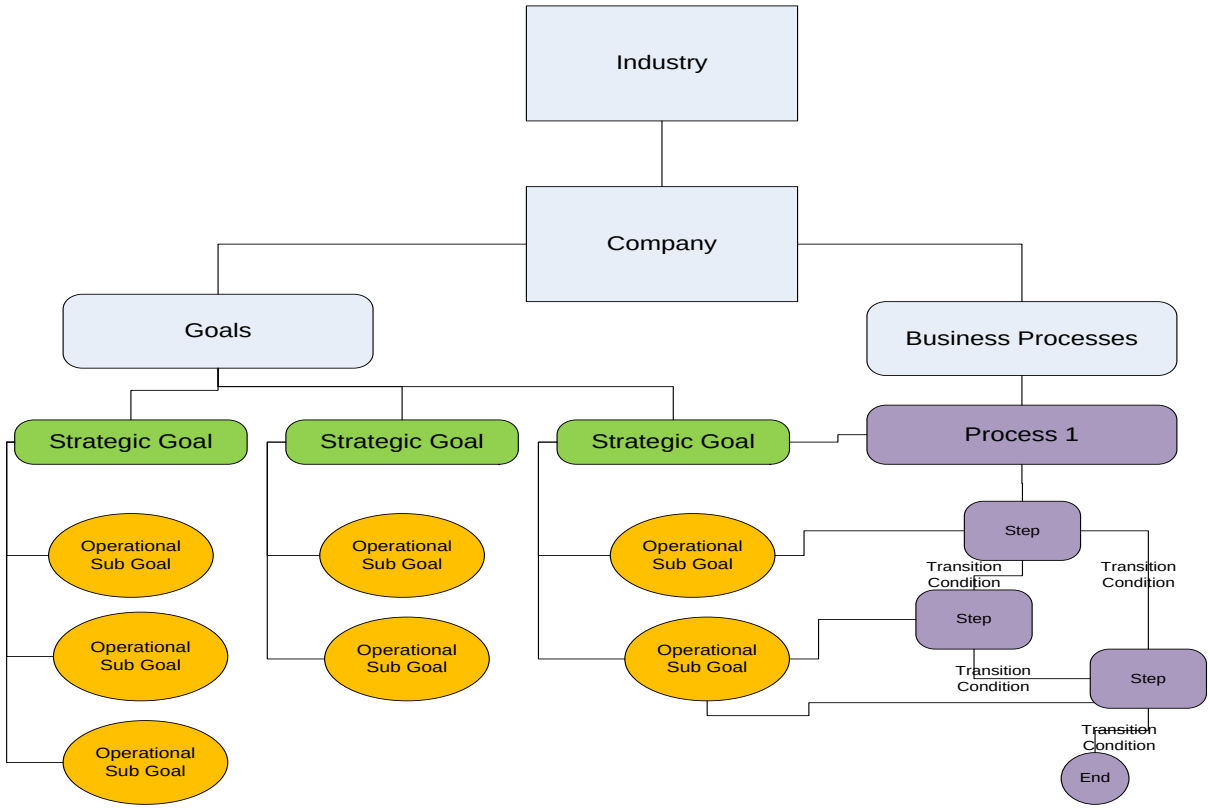

Figure 30: Company General Structure

In the prototypical framework that we designed, and in accordance with our solution methodology described earlier in this chapter, we have the following classes;

- **Company Class**

  The company class represents a specific company under a specific industry. It is a container that has other objects so that an instance of this class would represent the company with all its needed information. The information is available so that when we simulate a business process related to these companies all information related to the company would be there to help take the right decision related to the business process configuration. Table 8 and Table 9 below represents the company class attributes and methods.

Table 8, Company Class Attributes

Attribute	Type	Description
Company Name	String	This is the company name
Industry Name	String	This is the industry name, it will be used to retrieve the contextual layers and aspects related to this industry by calling the context classifier method and giving these methods the industry name as an input
Goal Matrix	A List of objects of the Goal Matrix Class	This represent the list of strategic goals and under them the operational sub goals of the industry
Business Processes	List of Business Processes	List of objects of type business processes which represent the business processes under this company

Table 9, Company Class Methods

Method	Return Type	Description
Company	None	This is the default constructor which parse the company repository, reads the company's goal matrix xml file and fill the goal matrix object and parse each business process xml file and populate the business processes object with the data accordingly
Company	None	This another constructor which takes the attributes as an input to its methods
getCompanyName	String	Returns the company name
getIndustry Name	String	Returns the industry name, it will be used to retrieve the contextual layers and aspects related to this industry by calling the context classifier method and giving these methods the industry name as an input
getGoal Matrix	An instance of the Goal Matrix Class	Returns list of strategic goals and under them the operational sub goals of the industry
getBusiness Processes	List of Business Processes	Returns List of objects of type business processes which represent the business processes under this company

- **Goals Matrix Class**

  The goals matrix class represents the strategic goals and their operational sub goals and the relationships between the goals and each other. For simplicity reasons the prototype focuses on one type of relationship between goals which is the parent child relationship and only one depth level of goals. The specific company under a specific industry is a container that has other objects so that an instance of this class would represent the company with all its needed information. This information is available so that when we simulate a business process related to these companies all the information related to the company would be

there to help take the right decision related to business process configuration. Figure 31 represents the goals matrix. Table 11 and Table 12 below represents the goal matrix class attributes and methods.

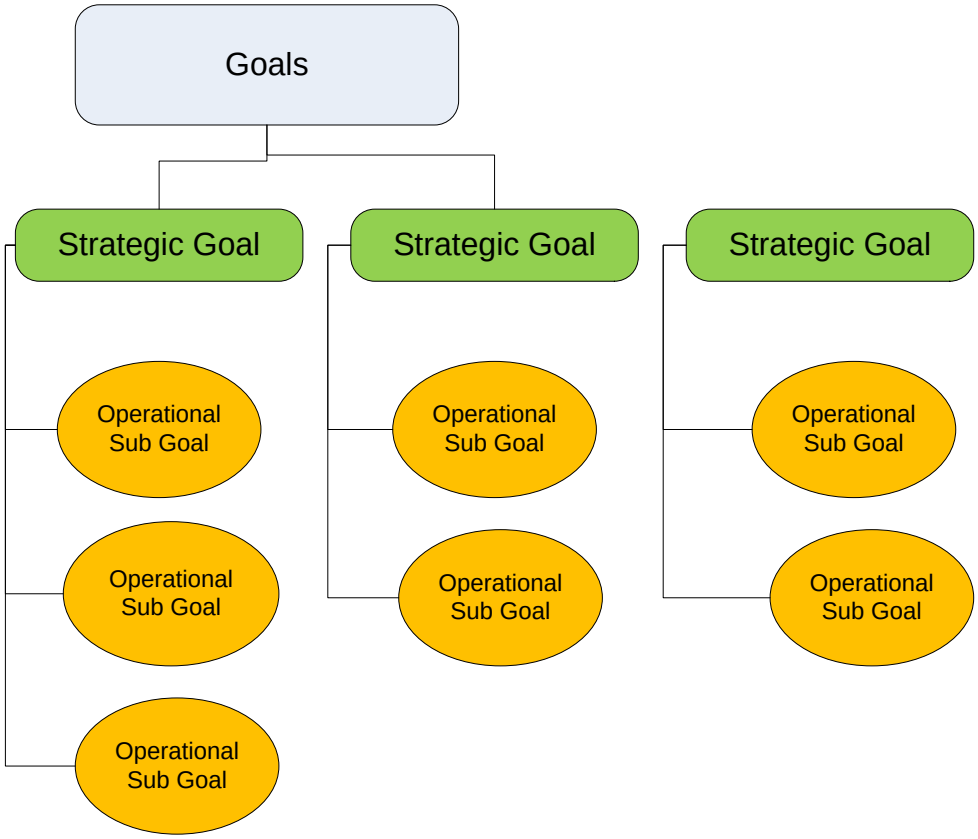

Figure 31: Graphical Representation of the Goals Matrix

Table 10, Goals Matrix Template

Strategic Goals/ Operational Goals	**Strategic Goal 1**	**Strategic Goal 2**	**Strategic Goal 3**
Operational Goal 1	√		
Operational Goal 2	√		
Operational Goal 3	√		
Operational Goal4		√	√

Table 11, Goals Matrix Class Attributes

Attribute	Type	Description
Company	String	This attribute represents the company to which this goals matrix belongs to
MainGoal	Goal	This represents the strategic goal
Related goals	List of Goals	This represents the operational goals under the strategic main goal

From the goals structure we realize that each company will have a list of goal matrix objects and each goal matrix represents only one strategic goal and its operational sub goals as depicted in table 10 above.

Table 12, Goals Matrix Class Methods

Method	Return Type	Description
GoalsMatrix	None	This is a constructor that parse XML files and get the objects
GoalsMatrix	None	This is a constructor that takes the attributes as input items to it
getGoalsMatrix	Goals Matrix object	This method returns the whole goals matrix

- **Goal Class**

  The Goal class simply represents one goal whether strategic or operational goals and is the basic element of the Goal Matrix Class. Tables 13 and 14 represent the goal class attributes and methods.

Table 13, Goal Class Attributes

Attribute	Type	Description
isStrategic	Boolean	This attribute defines whether the goal is strategic goal or operational goal
Id	Int	A unique identifier for the goal
Goal Name	String	This represents the goal (e.g. Increase profile)
Target	Int	This represents the target in a numerical value for simplicity
Time	Int	The time to achieve the target
Priority	Int	This represents the priority of the goal so that if we have conflicting goals we consider the higher priority one and try to achieve it

Table 14, Goal Class Methods

Method	Return Type	Description
Goal	None	This is a constructor
getGoal	Goal	Returns the whole goal
getId	Int	A unique identifier for the goal
Goal Name	String	This gets the goal name (e.g. Increase profile)
Target	Int	This gets the target in a numerical value for simplicity
Time	Int	This gets time to achieve the target
Priority	Int	This gets the priority of the goal so that if we have conflicting goals we consider the higher priority one and try to achieve it

- **Business Process Class**

  The Business Process Class represents the business process under a specific company under a specific industry. The business processes are tightly coupled to goals and are represented as finite state machines to make the simulation of the different alternative flows of a business process easy enough. We discuss in more details the business process modeling in the next section.

3.2.3.4. Business Process Modeling

The business process in our solution methodology within the prototypical framework that was developed as a proof of concept, is modeled as a finite state machine as depicted in figure 32.

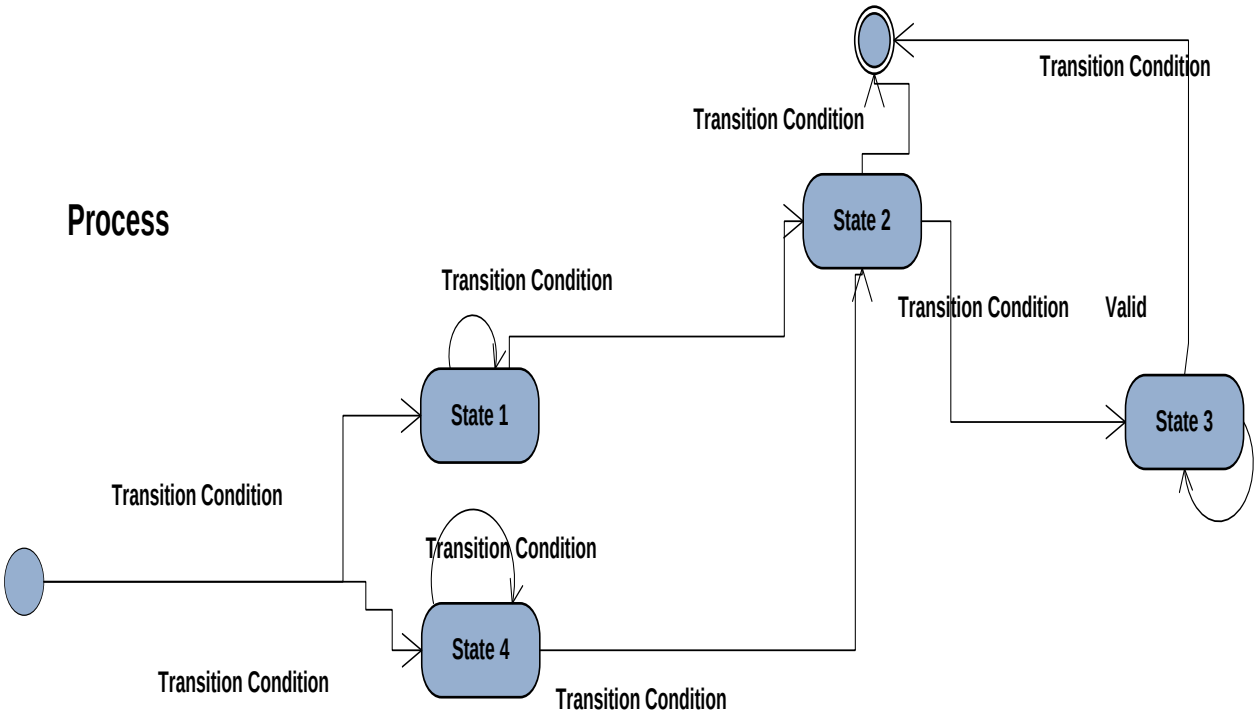

Figure 32: Business Process as Finite State Machine

The benefits of modeling a business process as a finite state machine in our solution methodology and framework may be stated as follows:

- Steps can be mapped directly as states in the finite state machine
- Transitional conditions to move from one step to another can be directly mapped to step pre-conditions and post conditions. In addition it makes it easy to define all the different alternative passes for the business process
- Transitional conditions can also incorporate contextual item values and thus depend on certain contextual item values as we move from one step to another

The Business Process Modeling Classes are as follows:

- **Business Process Class**

  This is a typical finite state machine representation, the only addition is having a goals matrix which will be used in the goals matching process to identify which contextual elements affect which process according to common goals to achieve the idea of context-aware goal-driven business process flexibility which is the core benefit behind our solution methodology. Tables 15 and 16 represent the business process class attributes and methods.

Table 15, Business Process Class Attributes

Attribute	Type	Description
BusinessProcessName	String	This is simply the name of the business process
Goals Matrix	List	Each Goals Matrix list represent a strategic goal related to the business process and the operational sub goals under it
Step State	List of Step State Objects	This is a list of step objects that represent all the steps that form the business process.

Table 16, Business Process Class Methods

Method	Return Type	Description
BusinessProcess	None	This is simply the default constructor of the business process and it takes as an input Business Process Name , Industry name and company name and parse the relevant XML file to generate the required Business Process object
BusinessProcess	None	Another constructor which takes the attributes of the business process object as input parameters
runBusinessProcess	List of step ids representing the sequence of steps taken in the run	This is the function that shall be called from the simulation class to run the business process given certain contextual evidence and it produces the best sequence of steps for which the business process is run. The algorithm and the input based on which the best sequence of steps is decided will be described in detailed in section V about Business Process Configuration
getBusinessProcess	BusinessProcess	This is a function that returns the business process instance
getBusinessProcessName	String	This is the function that retrieves the business process name
getGoal_Matrix	Goal_Matrix	This is the function that retrieves the goals matrix of the business process
getSteps	List of Business Process Steps	This is the function that returns a list of all the steps of the business process
contextChanged	ContextEvent	This is an override of the context change function in JCAF. The functionality is overridden to make objects of type business process listen to changes in Generic Context Items related to their goals as per the JCAF methodology of monitoring context of an entity.

- **Step State Class**

  This class represents the individual step within a business process. It is implemented as a typical state of the finite state machine. Each step has a name which also identifies what the step is about (e.g. Check Passenger Identity). Each step is tightly bound to one or more of the operational goals that were defined to be process goals. This is done to extend the goal orientation even on the step level to form a totally goal driven business process model. For each step there are three important conditions defined as follows:

  - A Precondition: It is a condition or list of conditions that must be true before step execution. It is used to double check that the transition was a correct transition (For example in the Check Passenger Identity, it could be that counter personnel are available)
  - A Post-condition: It is a condition or list of conditions that becomes true after the step execution (For example in the Check Passenger Identity, it could be that the passenger identity is valid)
  - A transition condition: It is list of conditions that is defined according to the current context surrounding the step execution and the step post conditions to determine the next best step that the finite state machine should move to. The definition of the transition condition is the trickiest part as it involves the context of the business process. The definition of the transition condition goes according to the following algorithm:

    1) After defining the list of steps that constitute a business process
    2) The system compares the goals of the business process step and the goals of the different contextual layers through a simple comparison function specifically designed for that purpose
    3) The system identifies the contextual aspects and elements affecting this step
    4) The system asks the business process expert to determine the transitional conditions for every step
    5) The system allows the business process expert to create several possible transitions for every step
    6) The systems asks the business process expert to choose one or more post condition to relate it to the transition

7) The system asks the business process expert to define the logical relationship between the different post conditions (they are either ANDed or ORed together or some conditions are ANDed and other conditions are ORed)
8) After finishing the choice of the post conditions that affect the transition, the system asks the user to define the contextual conditions that should be incorporated in this transition
9) The systems displays to the user the list of contextual items that are related to the step according to the goals comparison of step 2 of the algorithm
10) The business process expert can choose any subset of the contextual elements, give them ranges and/or add them to the transition conditions
11) The system asks the business process expert to define the logical relationship between the different contextual conditions (they may be ANDed or ORed together or some conditions may be ANDed and other conditionsmay be ORed)
12) After finishing the contextual conditions definition, the system asks the business process expert to set the ANDing or ORing on the post conditions and the transitional conditions.
13) The system displays the list of conditions that s/he has chosen to be the constituents of the transitions (e.g. The passenger document is valid and the check-in counters are from 1 to 200) for validation
14) The business process expert can edit the conditions during the validation step or directly confirm the condition
15) Finally given that condition, the system asks the user to choose from the list of steps that constitute the business process, the next best step to move to if the transitional condition turns out to be true
16) The system allows the user to define several transitional conditions for the same step
17) The system ensures that the user defines at least one transitional condition for every business process step with the exception of the terminal steps as the terminal steps cannot have any transitional conditions as they are final states
18) Each transitional condition is given a priority which is by default is equivalent to the average of the priorities of the goals that the contextual element that the condition is evaluating was

connected to. However, the business process expert can override this default value if s/he wishes with another priority. The importance of this step will be described in the next section when describing the business process configuration but it is mainly in case of conflicting recommendations from the transitional conditions that we take the transitional condition with the highest priority.

The algorithm is summarized in figure 33 below and the step state attributes and methods are described in details in tables 17 and 18 below.

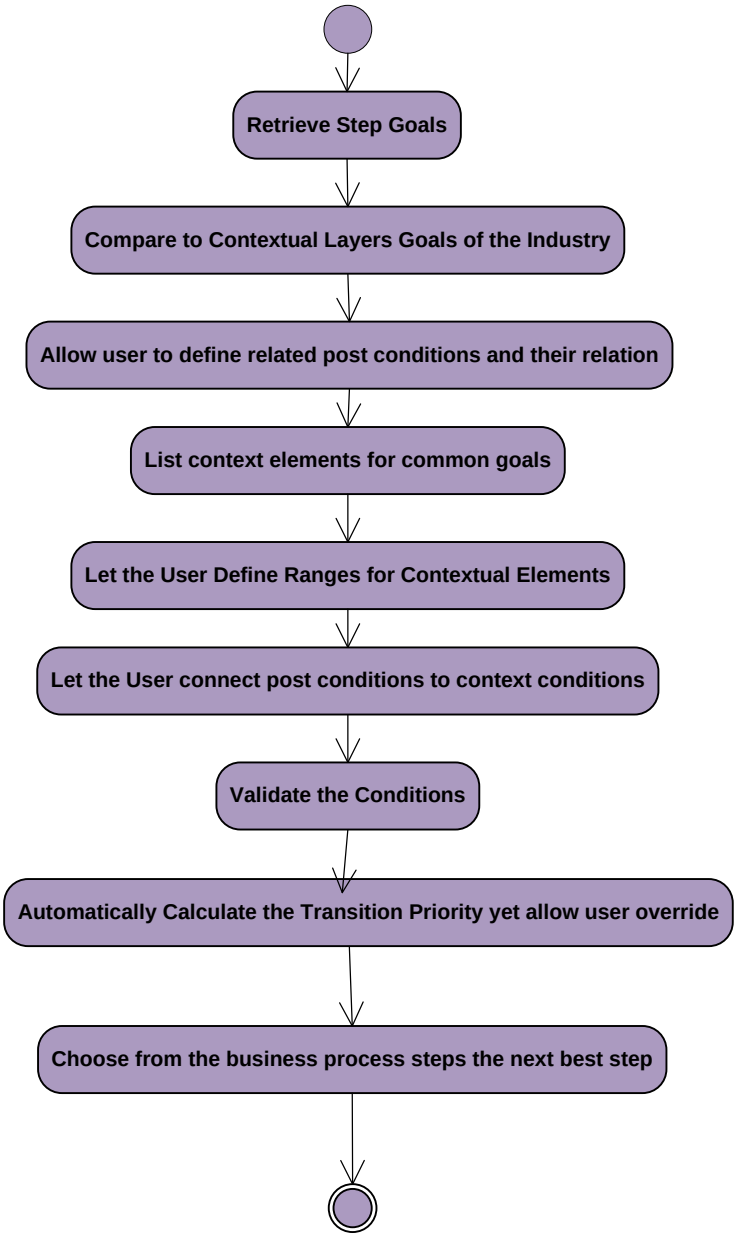

Figure 33: Contextual Transition Condition Definition

Table 17, Step State Class Attributes

Attribute	Type	Description
Step name	String	This is simply the name of the step and it also defines its description as we handle descriptions in a simple way in the prototypical framework (e.g. Check the Passenger Documents)
IsInitial	Boolean	This is simply an identifier for the initial state
IsTerminal	Boolean	This is simply an identified for the terminal state
Step id	Int	This is a unique identifier of the step (unique per business process)
Step goals	List of goals	This is a list of operational goals related to this step in particular, must be a subset of the goals associated with the whole business process
Step Precondition	A List of type condition	The class condition will be described in details shortly, however it is defining something that must be true before executing the step
Step Post condition	A List of type condition	The class condition will be described in details shortly, however it is defining something that must be true after executing the step
Step Transitional conditions	List of transitional conditions	This is a list of objects of type transitional conditions, the class transitional condition will be defined shortly, however the transitional conditions are related to contextual facts and ranges and according to their values incorporating within the business condition and context the next best step is defined
Step Cost	An object of type cost	This is an object of type cost defining the overall cost (financial cost and execution time as well) of the step

Table 18, Step State Class Methods

Method	Return Type	Description
Step	None	Constructor that reads the step information from XML file and load them to a step object
Step	None	Constructor that takes the step information and attributes as input to the constructor method
isInitial	Boolean	Returns true if this is an initial state/step
isTerminal	Boolean	Returns true if this is a terminal state/step
getStep	Step State	Returns the step object with all its information
getStepName	String	Returns the name of the step
getStepId	Int	Returns the id of the step
getStepPrecondition	A List of type condition	Returns the step precondition
getStepPostcondition	A List of type condition	Returns the step post condition
getStepTransitional conditions	List of transitional conditions	Returns list of objects of type transitional conditions, the class transitional condition will be defined shortly, however the transitional conditions are related to contextual facts and ranges and according to the values incorporated within the business condition and context the next best step is defined
getCost	Cost Object	Returns the overall cost (financial cost and execution time as well) of the step

- **Condition Class**

  This class is used to represent the pre-conditions and post conditions of execution of a business process step. It represents some non-contextual facts that must be true or false either before executing the business process step in case of pre-condition or after execution of a business process step in case of post-condition. A precondition of one step must be the post condition of its previous step for the transition from one step to another to be correct. The details of the class are depicted in tables 19 and 20 which describe the class attributes and methods.

Table 19, Condition Class Attributes

Attribute	Type	Description
Condition name	String	This is simply the name of the condition and it also defines its description as we handle conditions in a simple way in our prototype
Condition State	Boolean	This is whether the condition is now true or false
isPrecondition	Boolean	This is used to define whether this is a precondition or a post condition

Table 20, Condition Class Methods

Method	Return Type	Description
Condition	None	This is the condition constructor, it takes the attributes as an input to it
getConditionName	String	Returns the condition name
Condition State	Boolean	Returns the condition state
getConditionType	String	Returns whether the condition is pre-condition or post condition
getCondition	Condition	Returns the whole condition object

- **Transitional Condition Class**

  This class is quite important as it represents the transitional facts that allow a business process step to move to the best next step. As previously stated the business processes are defined as finite state machines to define all the alternatives of movement from one step to another so a business process is a collection of

steps/states. For the business process to determine the best sequence of steps to follow at a given contextual instance the process at each step must evaluate the surrounding conditions and decide on the next step and this is done by defining a list of transitional conditions at each step. One transitional condition is a composite of step post conditions (e.g. the traveler documents are valid) and contextual elements defined within a specific range (e.g. the checks in counters are from 4 to 6) the post conditions and contextual elements ranges are either Anded or Ored or a combination of both (some conditions Anded together then Ored with the rest of the conditions) then a best next step is defined. For example a transition condition could be representing the following situation:

If the traveler documents are valid (condition) and the check- in counters (contextual elements) are from 4 to 6 counters (range of values for contextual elements) go to step 10. The transitional condition is given a priority which is equivalent to the average of the priorities of the goals that are related to the contextual elements incorporated within the condition , yet the business process expert can still override this default priority if s/he wishes. The main benefit of the priorities happens in case the business process step is affected by more than one contextual element. If the contextual element values impose contradicting next step recommendations; we follow the next step whose transitional condition has the highest priority. The detailed attributes and methods of the transitional condition class are depicted in tables 21 and 22 below.

Table 21, Transitional Condition Class Attributes

Attribute	Type	Description
List of PostConditions	Condition object	This is the post condition, (e.g. the documents are valid)
List of PostCondition Logical connector	String	This string takes a value of either "and" or "or" and it represents the relationship of this post conditions with the next post condition
List of Contextual Elements	Generic Context Element	This is the contextual elements associated to this condition
List of Contextual Element Max Value	int	This is the upper boundary of the range of the contextual elements we want to associated with the transitional condition
Contextual Element Min Value	int	This is the lower boundary of the range of the contextual elements we want to associated with the transitional condition
ContextConditionLogical Connector	String	This string contains a value of either "and" or "or" and it represents the relationship between this the contextual condition and the next conditions condition in the list
TransitionalCondition Logical Connector	String	This string contains a value of either "and" or "or" and it represents the relationship between all the post conditions and all the contextual conditions (e.g. if the value coming out of all the post conditions evaluation (for example true) should be anded or ored with the value coming out of all the contextual conditions (for example false)
Next Step Id	int	This represents the next best step to go to given the current transitional condition
Priority	int	This is the priority of the transitional condition and it is equivalent to the average of the priorities of the goals that is related to the contextual elements associated with the current instance of the transitional condition and it can be overridden by the business process expert

Table 22, Transitional Condition Class Methods

Method	Return Type	Description
Transitional Condition	None	This is the constructor class of the transitional condition
Get Transitional Condition	Transitional Condition	This returns the whole transitional condition object
Get Priority	int	This returns the priority of the transitional condition and it is equivalent to the priority of the goal that is related to the contextual element associated with the current instance of the transitional condition
Get Next Step Id	int	This returns the next best step to go to given the current transitional condition

- **Cost Class**

  This cost class is a simple class that holds the different types of costs associated with a business process step and also the step execution time as a temporal cost. It was created with the purpose of having some measures that enable us to evaluate the effectiveness of our solution from cost and temporal perspectives. The detailed attributes and methods of the cost class are depicted in tables 23 and 24 below.

Table 23, Cost Class Attributes

Attribute	Type	Description
Man_hour_cost	double	This attribute represents the cost of man hour for human resources involved in this step
Hours_number	double	This attribute represents the time needed from the human resource to execute the step
Material_amount	double	This attribute represents the amount of all material in units required to execute the business process step
Material_cost_per_unit	double	This attribute represents the average cost of material per unit
Step_execution time	double	This attribute represents the total time a step takes to execute
Total_Financial cost	double	This attribute represents the total cost of the business process which is calculated as the (Man_hour_cost *Hours number) + (Material amount * Cost of Material per unit)

Table 24, Cost Class Methods

Attribute	Type	Description
Cost	none	This is the constructor class for the cost
getMan_hour_cost	double	Returns the cost of man hour for human resources involved in this step
getHours_number	double	Returns the time needed from the human resource to execute the step
getMaterial_amount	double	Returns the amount of all material in units required to execute the business process step
getMaterial_cost_per_unit	double	Returns the average cost of material per unit
getStep_execution time	double	Returns the total time a step takes to execute
calculateTotalFinancialCost	double	Returns the total cost of the business process which is calculated as the (Man_hour_cost *Hours number) + (Material amount * Cost of Material per unit)

3.2.3.5. Business Process Configuration

The business process configuration is one of the most crucial stages of our solution methodology and prototypical framework. The business process configuration stage is where a specific business process running within a specific context starts taking certain alternative paths to maximize the business process goals according to the contextual facts at hand. The configuration algorithm goes as follows:

1. The business process expert chooses the business processes under the selected company and selected industry to simulate
2. The system loads the industry related information which are the contextual layers, contextual aspects and contextual elements related to the defined industry as depicted in figures 34 and 35. (Note: the industry knowledge is accumulated by business domain experts using easily updatable graphical user interfaces and XML files as described earlier in this chapter in the knowledge base section).

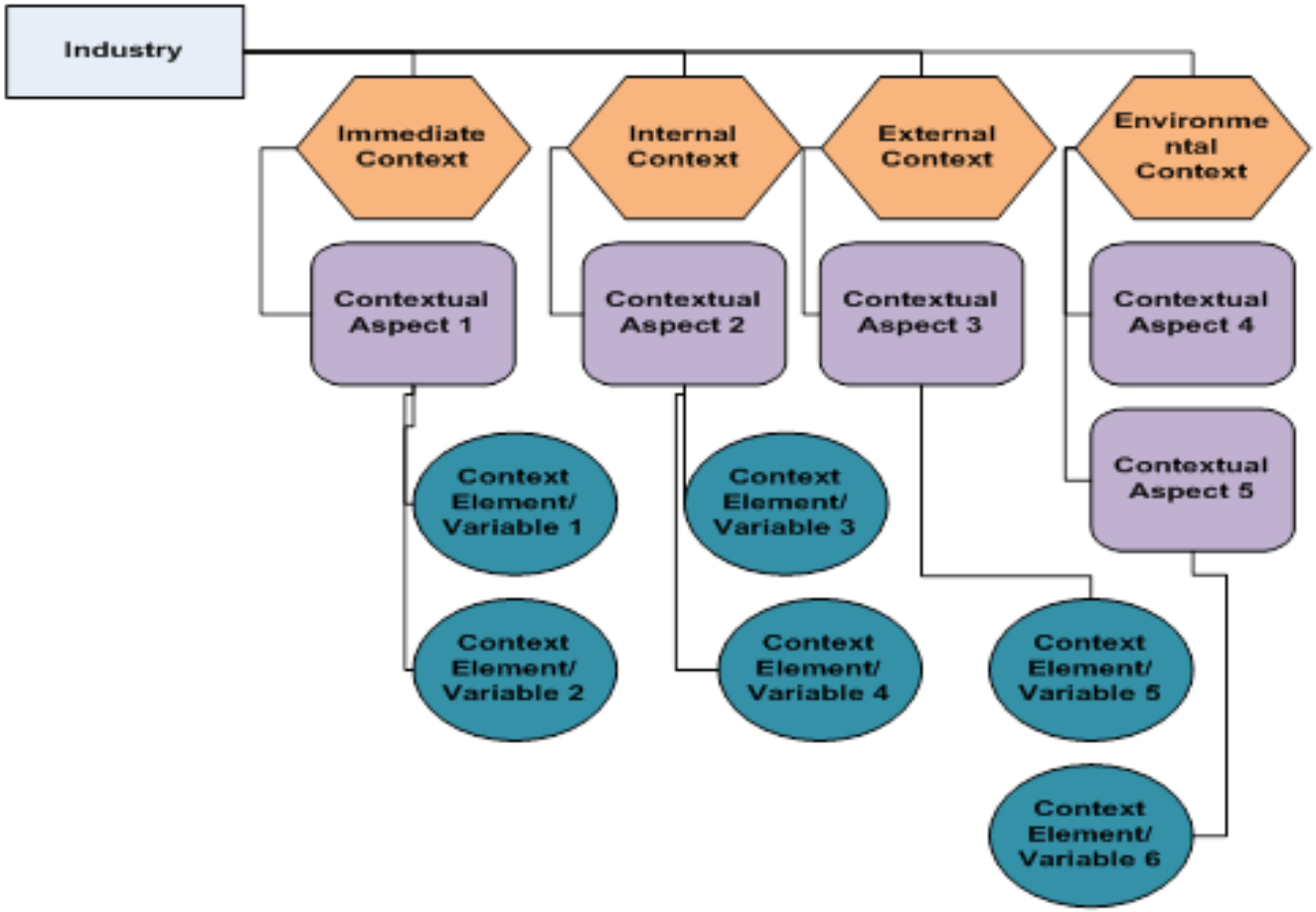

Figure 34: Industry Knowledge

3. The system loads the company related information which are the company goals matrix and the business process/es that will be simulated

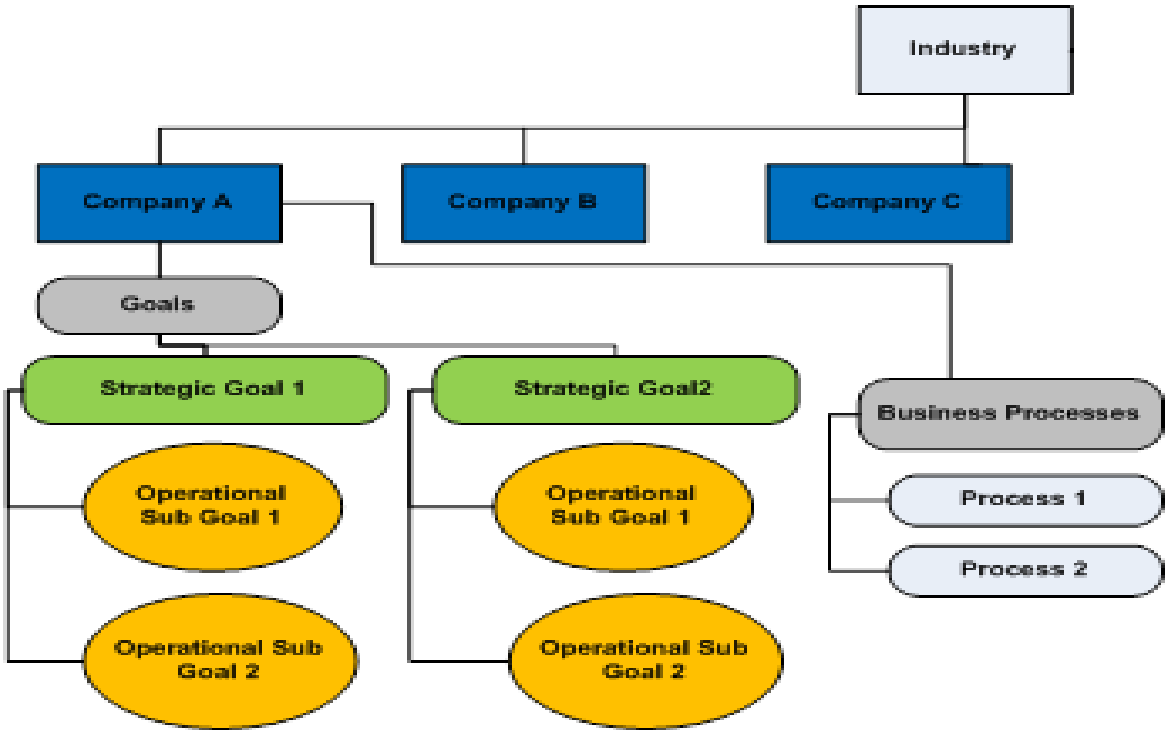

Figure 35: Company Goals Matrix

4. The system loads the business process related information which are :
    a. The business process goals
    b. The business process steps ; each step is associated with goal
5. The system compares the goals of the business process and the goal associated with each contextual layer and creates a list of contextual elements that are of interest to the business process and to each process step. The relationship between contextual layers, aspects and variables and the business goals is depicted below in figure 36.

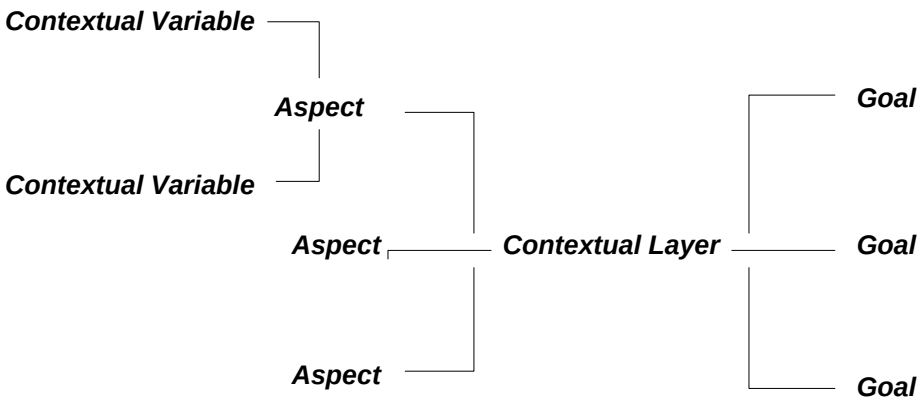

Figure 36: Relationship between Context and Goals

6. The system asks the user to define transitional conditions to move from one step to another and the transitional conditions of every step should incorporate the step's post conditions and ranges of values for the context items of interest Anded or Ored together
7. The system asks the business process expert to define a next best step for each transitional condition
8. The system models the business process as a finite state machine carrying all the alternatives of flow for the business process and the different transitions that might take place from one step to another as depicted in figure 37. (Note: the transitions are tightly bound to the business processes context elements and their values)
9. The system calculates the total financial cost of the business process alternative path taken versus the default path as well as the execution time of the business process alternative path taken versus the default path (the default path of the business process is the normal path without any configuration as if context-awareness doesn't exist in the model). This step is done for evaluation purpose and will be more clear in the results and analysis chapter.

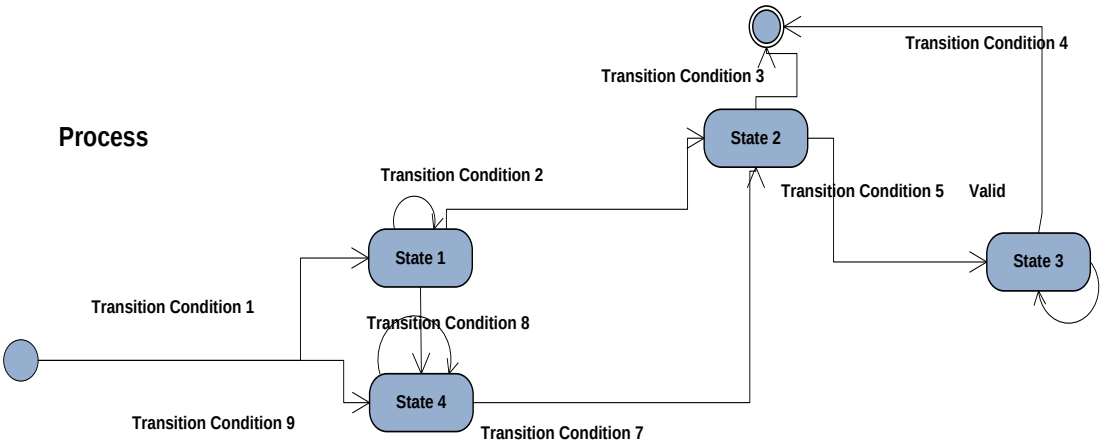

Figure 37: Business Process and Transitions

10. The system registers the interest of the running business process in the relevant contextual elements through the created JCAF entity listeners for each of the contextual elements
11. Entities (in our case business processes) in the context service simulation are notified when changes occur within their context. The entity container calls the contextChanged JCAF method
12. The changes in context are aggregated in a context event which has the values of contextual elements at a specific point in time
13. The system uses the run method that is defined in the business process class. The run method starts with the first step of the business process and for each move to the next step; the transition conditions are evaluated (i.e. the value of the post conditions and the value of the contextual condition is retrieved from the context event and compared to the ranges defined by the business process experts and accordingly the next step is determined)
    - In case the evaluation of two transitional conditions result in conflicting recommendations for the next best step to move to, we take the recommendation of the transitional condition with the highest priority

(Note: the priority of a transitional condition is the priority of the goals that the context of the condition is related to)

14. The run method keeps evaluating the next best step to move to until it reaches the final step of the business process. It then returns a list of the best steps sequence at this point in time which is a sequence of id of business process steps

    Example: For Check-in Business Process given the current context state; Step 1, Step 15, Step 16, Step 17, end

By using the above algorithm, the business process configuration takes place based on two pillars;

- Appropriate representation of business process context in terms of aspects
- Appropriate modeling of goal driven business process in terms of finite state machines

All configuration decisions are goals and context-aware conditions which should lead to better configuration and decision making regarding business processes flow and this what we proved in the results and analysis chapter.

i. Simulation

The simulation of a certain business process or business processes under a specific industry as a configurable goal and context driven finite state machine takes place in the ContextTester.java class which is the main simulation class that has the main loading functionalities of JCAF.

First, within the main function (the main running thread of the application) the system asks the user which business processes under which company and which industry he would like to run and set configurations.

Second, the load method of JCAF ContextTester class is used to add all the relevant simulation entities that will be used, namely:

- The industry entity with its contextual layers, aspects and elements which are initially input by the business domain experts as described in the knowledge base definition
- The company entity with its goals matrix and business process under inspection

Third, within test functionality which will be the service URI the business process goals and context goals are accumulated to decide on which contextual items the business process entity needs to listen to. It defines new instances of the different JCAF listener objects required to listen to the contextual items of interest. Then adds those listeners to the business process entity that needs to listen to them through the add entity listener JCAF functionality.

Fourth, the ContextTester constructor class passes the service URI as a test , adds appropriate listeners and uses the contextChanged JCAF functionality to make the business process entity listen to changes in the context values of its interest and calls the run method of the business process class to find the best configuration, given the contextual values of the listener. In this constructor class we add our simulation of contextual instance generator which feeds random values into a list of different contextual items of interest to the business process and whenever a new generation of the values list occurs the listener monitors this change and alerts the business process with the next context so that it can run accordingly and give us the best sequence of steps for the generated contextual instance. The context matrix generation is only done for the sake of the simulation and because this is a prototypical framework. In real life the APIs of the different sensors and databases that the context reads from should be connected to the JCAF monitors and real time data and the changes in them should be the trigger to a contextual event which in turn triggers a new business process run.

From the main class (main running thread call ContextTester construction and given test as service URI) the simulation will run as desired and as depicted in figures 38, 39 and 40.

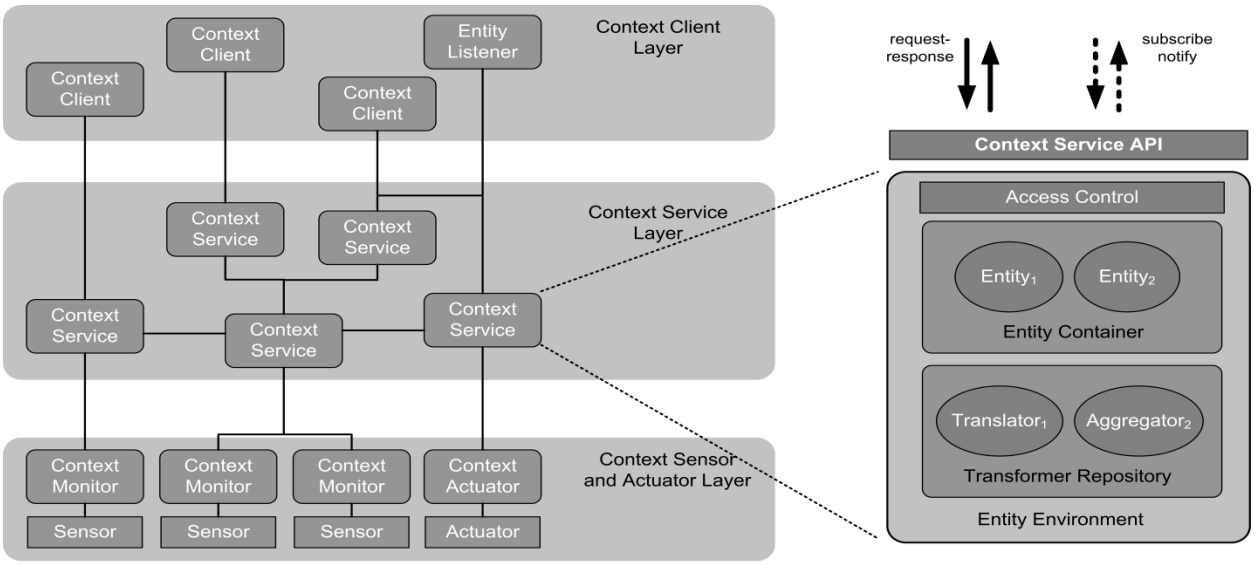

Figure 38: JCAF Architecture (Adapted from Bardram, 2005 [28])

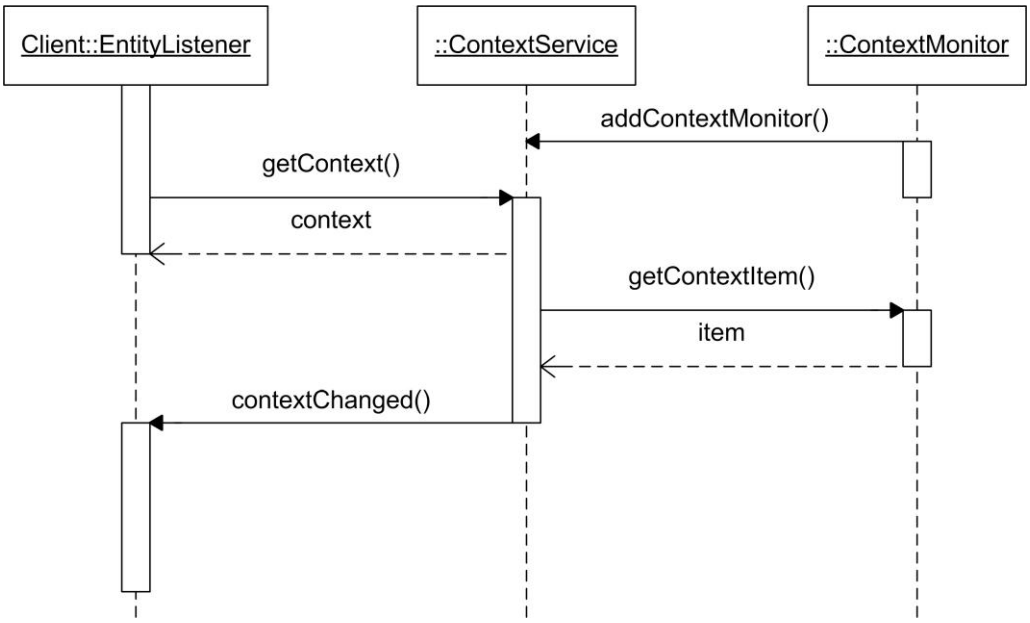

Figure 39: Context Acquisition in JCAF Architecture (Adapted from Bardram, 2005 [28])

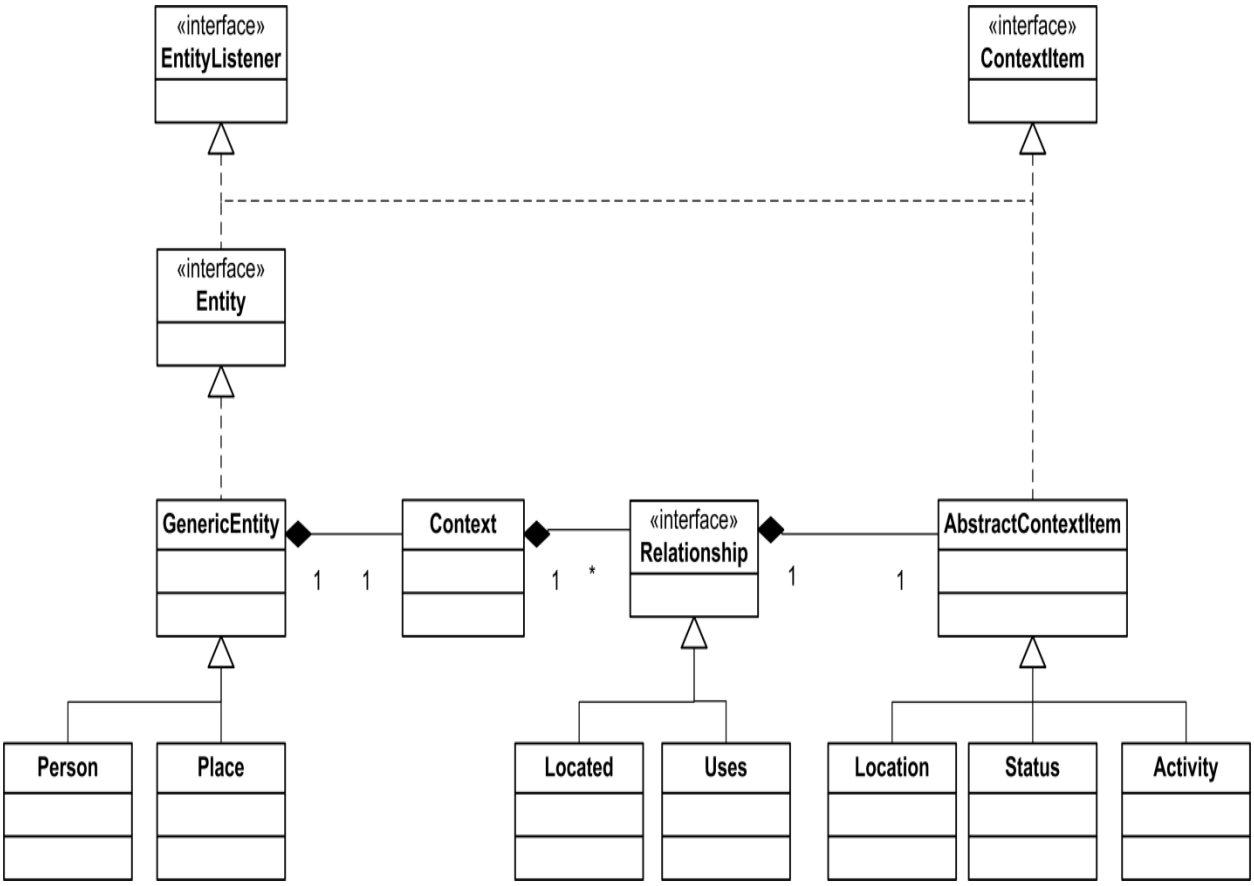

Figure 40: Entity and Context Relationship in JCAF Architecture (Adapted from Bardram, 2005 [28])

ii. Example

Figure 41 presents an example of the airlines check-in business process configuration steps which could take place using the above explained methodology.

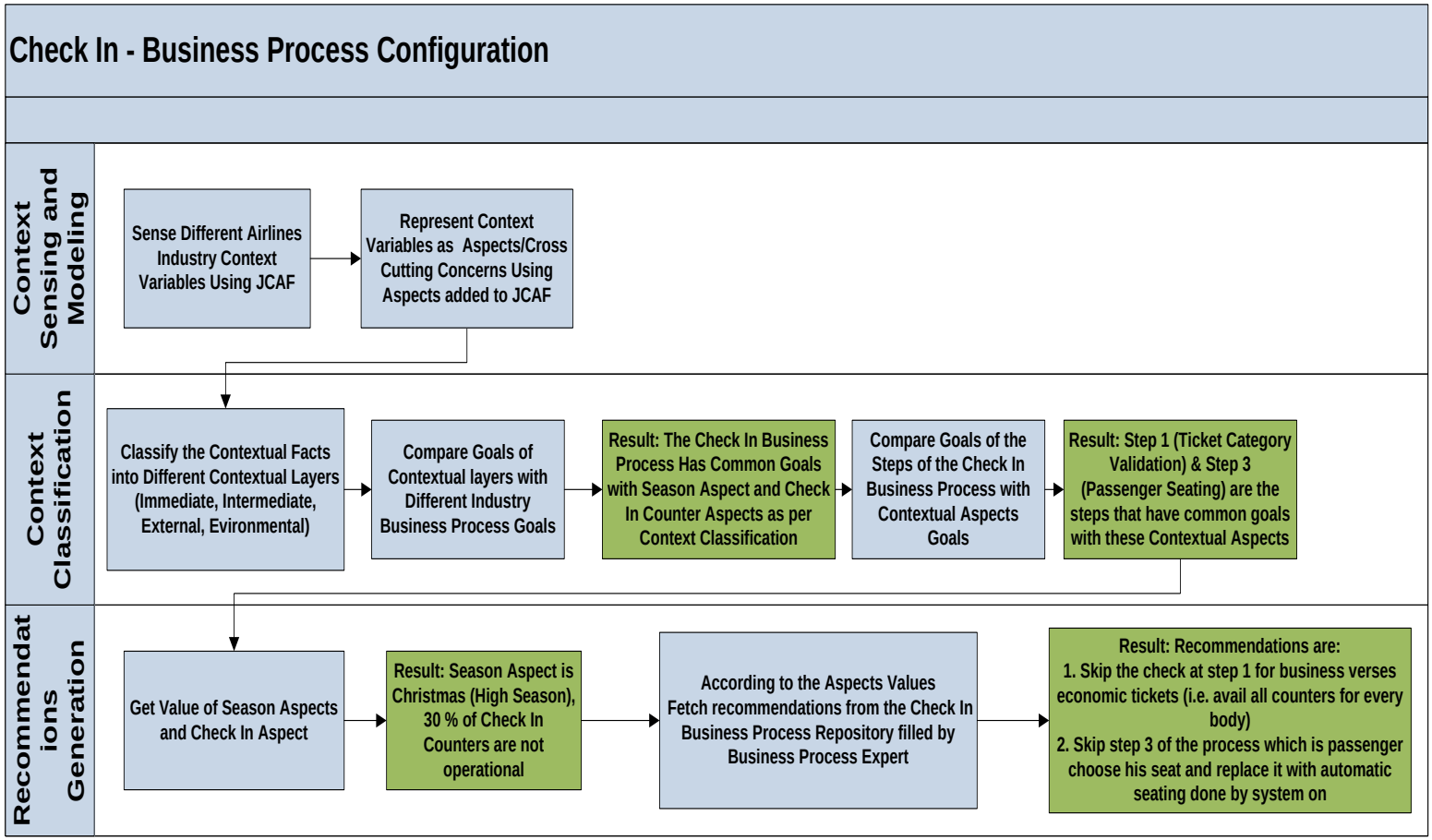

Figure 41: Business Process Configuration Example

In the above example the JCAF senses different contextual variables related to the airlines industry and represents them as open aspects. Classification of the contextual aspects takes place in the four contextual layers (immediate, internal, external, and environmental) defined earlier. According to this classification goals matching is done using additional goal matching classes added to JCAF and we discover that the season and number of check-in counters aspects affects step 1(Ticket Category Validation) and step 3 (Passenger Seating Choice) of the Check-In Business Process. The values of these two aspects are computed and recommendations for the ranges of values of these aspects are fetched from the business process repository (defined by the business process experts). The framework recommends skipping step 1 (thus availing all counters to everyone), skipping step 3 and making passengers seating automatic to speed up the process and avoid bottlenecks which resulted from the current contextual situation. This is just a simplified example, detailed examples and results are in our experimental work in the results and analysis chapter.

iii. Tools Used in building the prototypical framework

The following development tools were used in building the framework;

- JCAF: Java Context-aware Framework was used to detect and model context
- Eclipse 3.7 as the main development environment
- AJDT aspect j development tool added on Eclipse 3.7 to cater for modeling of context in terms of aspects
- JForm Builder : An add on for building forms in Eclipse 3.7

b. Sources of Flexibility in the Solution Methodology

The main source of the extensibility is finding an easy way for industry/business process experts to update information related to the business goals of the industry, its context variables, their classification as well as the different business processes and alternatives under the industry and their associated goals. This is achieved through a set of graphical user interfaces that enable the user to define a robust knowledge base for industries and companies and their business processes and the hierarchy of repositories and XML files that define the knowledge base. The business experts can easily use the framework for defining new industries and for defining their business goals, contextual layers and contextual variables and their associated list of business processes.

For each business process they can also define the business process and the recommendations according to contextual variables' threshold values that are defined by business process experts and advices to actions or best mitigation within each range of thresholds of contextual variables values. The solution methodology and framework are easily updatable by the knowledge of business expert which is a key source for strengthening the logic of the business processes decision-making as we incorporate all the human experience of experts using this methodology. In addition, driving contextual variables as aspects makes it easy in the future to apply after and before aspect advices complex reusable calculations about the contextual variables/elements values, to give them weighted averages and work more on the priority of context variables. Also, the weights could be related to the accuracy of context sensors sensing the contextual variables and this could be a separate research track within this area. Last but not least, having all the business processes and their steps tightly bound to business goals and the goals being prioritized makes it extremely easy to solve conflicting situations in which the contextual facts provide different recommendations. Also being goal-driven makes us sure that the configuration is tightly bound to achieving the business goals and maximizing their benefits.

c. Challenges Faced

We were faced by a number of challenges while working on our newly proposed methodology of aspectizing contextual elements, and the construction of the framework. Some of these have been addressed and some are still in progress. The main challenges were;

- Understanding the tools to be extended and changing their logic. This was resolved through cooperation with the owners of these tools.
- Extending JCAF to include aspectization especially that the JCAF framework never included in their roadmap the idea of aspects and their relation to contextual items. This was understandable as there is no substantial research in the area of aspectization of contextual elements.
- Researching and understanding about Aspect oriented development and how it could be merged with JCAF
- Finding an AspectJ development tool that could incorporate the normal JCAF java implementations and the aspect implementation and compile them in a homogenous manner

- Find a way to solve conflicting contextual situations where the input of one contextual item suggests a certain action while the input of another item that is also affecting the business process being simulated suggests another action.

Chapter 4: Results and Analysis

In this chapter we discuss the experimental work that we conducted on the prototypical framework developed as a proof of concept for our solution methodology on context-aware aspectized goal driven business process modeling. In this chapter we report on the experimental results, and analyze them and draw conclusions about them.

4.1. The Evaluation Methodology

Our evaluation methodology is depicted in the figures below. Figure 42 explains the knowledge definition process. Figure 43 explains the simulation of the defined business process and the evaluation of the effectiveness of context-awareness and goal orientation.

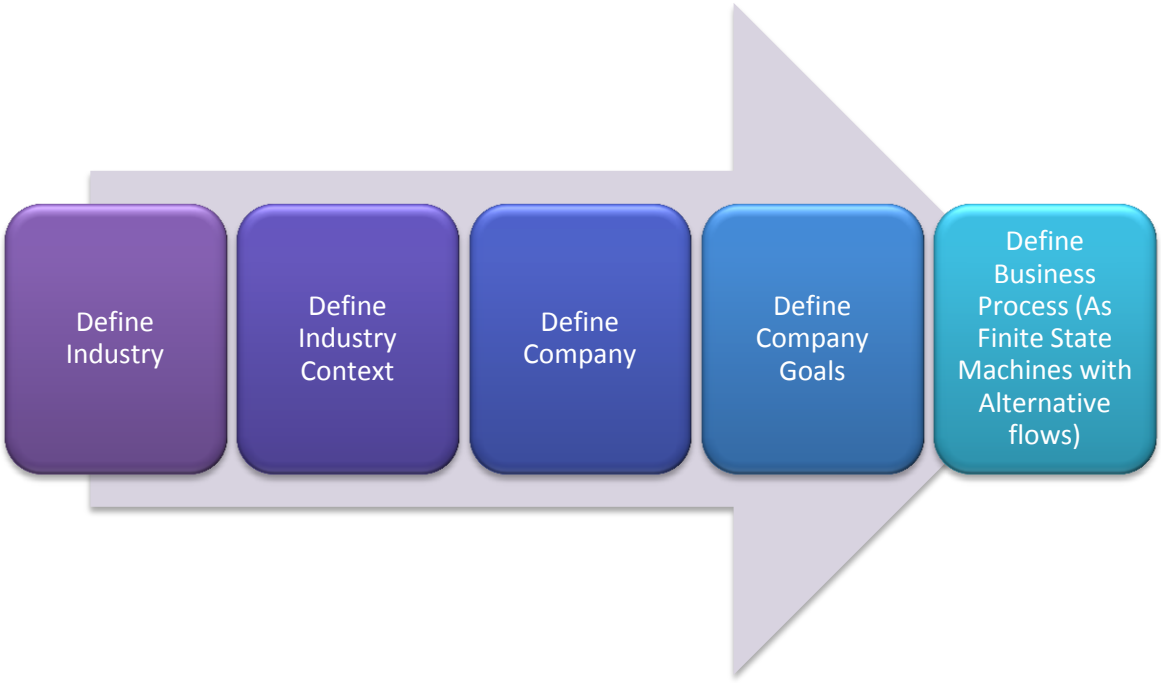

Figure 42: Knowledge Definition Process

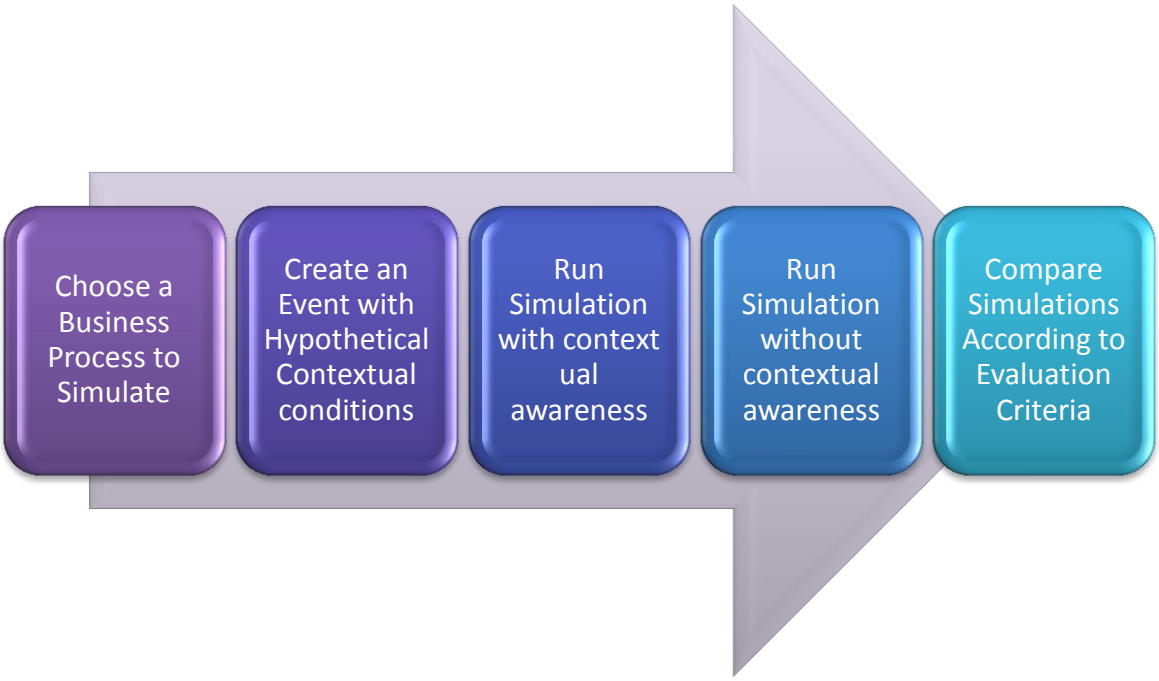

Figure 43: Business Process Simulation

In the first place the business expert defines the industry and the company information for the business process to be simulated. The industry is defined in terms of its name and the contextual aspects and elements under those aspects that are integral to the industry. The business expert also defines the classification of the different contextual aspects into the four contextual layers; immediate, internal, external or environmental according to the level of impact on the business under this industry. Secondly, the business process expert defines the goals of the company under which the prospective business process should run, and finally defines the business process itself as a finite state machine. The system guides the business expert through the business process definition by comparing the business goals of the process and the goals of the different contextual layers and guides the user to which contextual aspects and elements affect the process and guides him/her to define different contextual situations and the best decision per situation as explained earlier in the solution methodology chapter 3.

For the sake of evaluating the solution methodology, once the knowledge base is ready the system allows the business expert/user to pick any business process and to choose to simulate it. The system generates a hypothetical contextual situation using a contextual events generator that is added to the JCAF classes as explained earlier in the solution methodology, chapter 3. Then the business process is run and at every step the system evaluates the next

best step to move to according to the contextual elements in the contextual event generated. Hence, we have an output of a certain contextual situation with certain values of contextual elements and a sequence of steps which the business process decided to be the best sequence of steps to take given the current contextual situation. We run the business process simulation once more disregarding the contextual situation as if contextual awareness and modeling of business process context in terms of aspects doesn't exist and we record the sequence of steps that the business process flows into. We evaluate the effectiveness of the solution methodology by comparing the two simulations according to the evaluation criteria discussed in the next section of this chapter. For a single business process we simulate the process against a variant of contextual events and monitor the process configuration against each instance.

4.2. The Evaluation Criteria

One of the controversial areas in this research was finding a methodology through which the effectiveness of modeling the context of business processes can be evaluated. The evaluation is not easy and could be considered in more details in a separate research on its own. In general, business decisions may be evaluated on two levels: the ability to maximize profit on the long run and the ability to maximize profit on the short run. Several business decisions that are aimed at maximizing profit on the long run might increase costs and decrease profit on a short term. For example taking cost measures (discounts, very high level quality of service) to gain a wider customer base so that eventually on the long run the profit would be maximized. Such cases are valid in business and these cases make the evaluation of the business decision a harder process. However, there are business practices that make the evaluation of whether a certain business decision is on the right rack or not. One of these practices is making a short term audit to ensure that an indication of slight maximization of profit is happening in a certain time interval (short run). Hence, business decision makers are sure in the targeted time interval (long run) that the goal of profit maximization will be achieved to the extent they had planned to reach. We chose our evaluation criteria for the efficiency and correctness of business process configuration decisions based on the concept that for a measure to maximize a business profit in the long run it must at least provide slight profit maximization in the short run.

The purpose of our evaluation is to prove that appropriate context modeling and goal orientation enhanced the business process configurations and decision making. This is not a focal point nor a core part of the research but rather a preliminary step into trying to evaluate the effectiveness of context modeling and goal orientation within the

business process modeling domain from a cost perspective. It opens the door for future researches to further evaluate and investigate the effectiveness of context modeling and goal orientation within the business process modeling domain and its relation to cost. We proved this effectiveness by providing experimental evidence that the costs of business processes were reduced. Of course, measuring the effectiveness of context modeling is a more complicated task that goes beyond cost. As mentioned above, in some cases cost might increase after context modeling but there is more customer satisfaction or the cost increases now and decreases in the long run. There are many parameters and the process of measuring effectiveness should be a research project on its own, yet what was done in the course of this research is collecting simple and direct measures that can act as primary indicators of the effectiveness of context modeling in relation to business processes .

In our experimental work we established our evaluation criteria to be based on the following two types of cost:

4.2.1. Financial Cost of the Business Process

This aspect measures the cost of the business process if context wasn't taken into consideration versus the cost of the business process when context was modeled and accordingly certain configuration decisions were taken which modified the business process flow. The following calculation steps were taken to measure the financial cost aspect.

1) **FC** =HRC +MRC----------> ***(equation 1)***

Where

FC *is the financial cost of business process step*

HRC *is the human resource cost calculated as the man hour cost multiplied by the number of hours spent on the process step*

MRC *is the material resources cost to execute a step calculated as the material resources units multiplied by the cost of the material unit*

The cost of man power and resources, are configurable and defined by industry experts.

2) **TFC**= ∑FC----------> ***(equation 2)***

Where

TFC *is the Financial cost of the whole business process*

The cost of the business process is being calculated as the total cost of the number of steps that it includes. The steps vary according to the configuration decisions taken based on the contextual information provided (e.g. according to contextual element X being modeled, the configurable business process will take step M instead of step N) and this is where the cost variance comes from. The cost variance is calculated as follows;

3) **FCV** = (BPNC-BPCC)/BPNC ----------> ***(equation 3)***

Where

FCV *is the financial cost variance*

BPNC *is the cost of the business process when contextual facts are not taken into consideration while making the decision (calculated as per equation2)*

BPCC *is the cost of business process when contextual facts are taken into consideration while making the decision (calculated as per equation 2)*

4.2.2. Performance of the Business Process (Time/Throughput)

This aspect measures the cost of a business process in terms of time. It can be measured as the time taken to complete a business process without contextual consideration versus the time taken to complete a business process with context appropriately modeled. The following calculation steps are taken to measure the performance aspect.

1) **BPT=** ∑ST----------> ***(equation 4)***

Where

BPT *is the time of a business process*

ST *is the total time of a step in a business process*

The steps of a business process may vary according to the configuration decisions taken based on the context model and this will be the source of the time variance.

2) ***Time variance*** = (BPTNC-BPTC)/BPTNC ----------> ***(equation 5)***

Where

BPTNC *is the time of a business process without context modeling (equation 4)*

BPTC is *the time of business process after context modeling (equation 4)*

The time of every business process step is configurable so that the end user of the framework can change it and see the variance if s/he wants.

4.2.3. Measuring the Overall Effectiveness of the Solution Methodology

The evaluation criteria of the solution methodology adopted in this research includes the various aspects as described in the previous section. Now comes the important question which is : **how can these different aspects and concepts of quality and effectiveness be combined to reach one measure that could be the basis of judging the overall quality and effectiveness of context models produced by this research?** The answer is a combination of the above mentioned aspects which will be based on a weighted summation that gives each aspect a variable weight depending on its relative importance. The degree of importance depends on the industry/business domain in which the context model will be examined.

4.2.3.1. Calculation Method

Let Financial Cost Variance = F

Let Time Variance = TV

Let Number of Business Processes = N

Each of the above quality parameters is evaluated according to the business domain under investigation and is given a weight which ranges between 0 and 1 (a 0 means insignificant quality parameter and 1 means the most significant quality parameter). The summation of all the weights given should be equal to 1. The quality and effectiveness of a context model produced will be calculated as follows:

Quality/Effectiveness of the context model = (∑F/ N) * Weight of F + (∑TV/ N) * Weight of TV--------> ***(equation 6)***

The quality/effectiveness of the context model produced is proportional to the result of equation 6. The more the result moves near to 1 the better is the context modeling affecting the business goals and maximizing profit on the short run.

4.3. Effectiveness Guarantee

The main guarantee for the effectiveness of the solution is that the configuration decision is a result of the business process expert's recommendations and is not randomly generated by the framework. The identification of the best sequence of steps is based on the context of the business process and its goals. The following are the steps that take place:

1) Identifying which aspectized contextual variables/ elements affect which business processes and which steps to take within these processes. This is achieved by identifying the goals of the business process under investigation. It comes by studying the business behind the process and the wider picture that the business process fits in, which comes from the understanding of the overall business domain. As mentioned earlier, the goals of the company are placed in a goals repository within a certain industry repository. For each company repository that we have business processes defined under, the definition incorporates the goals of the process, the states (business process steps), the goals of each state (business process step) and the conditions to jump from one state to another (the conditions are of course related to the context of the process). These definitions are made through a simple graphical interface and are updatable by business experts.

2) Comparing the goals of the business process to the goals of the different aspects of contextual elements that are of interest to the company under which the business process falls and detecting any common goals. If common goals are found then the business process is affected by the context and through common goals we are able to identify which business process steps are affected.

3) For the contextual elements that are affecting a certain business process according to the goals matching, the business process experts must define a recommendation for the next best step based on ranges of values of these contextual elements

4) The business process registers its interest in contextual aspects of common goals and this is achieved through existing functionalities in JCAF. The business process runs and is triggered by changes in the contextual aspects

it is registered in. According to the changes in values of the contextual aspects and the conditions of jumping from one state/business process step to another (as per the business process definition), the business process decides on the best sequence of steps/states to take given a certain contextual input at a specific instance in time.

Hence, the business process expert is the main decision maker and the decisions are made based on business experience, as well as appropriate contextual sensation and modeling. The reason we try to calculate the financial and time cost effectiveness of the solution is to simulate an audit that would otherwise have been done by business process experts in real life, away from any simulation or software aids, to decide if their decisions were the right ones and in the direction of maximizing the business profit or not. If they found out that they are not in the right direction they can easily re-define the business process decision and the next best steps to move to according to their goals and the results would vary.

4.4. Experimental Results and Analysis

In this section we discuss the experiments done on the prototypical framework which prove the concept behind our solution methodology, the results of the experiments and our interpretation of these results.

4.4.1. Airlines Industry Experiments

These experiments were related to the Airlines Industry and in particular the check- in business process was chosen to be the business process to be experimented on from the Airlines industry. Its various contextual aspects which belong to various layers (immediate, internal, external and environmental) do affect this business process and it has a variety of configuration decision that can be taken. In addition, it is well known to researchers and readers from different backgrounds so the logic behind the configuration can be easily analyzed and criticized.

4.4.1.1. The Experimental Procedures

1. Industry Knowledge Definition

The following contextual knowledge about the Airlines industry was defined by the industry expert through a simple graphical interface. The industry expert defined the contextual aspect classification on the different contextual layers as well as the different elements related to the airlines industry under each aspect. Figures 44-48 depict the aspects at the various layers for the industry.

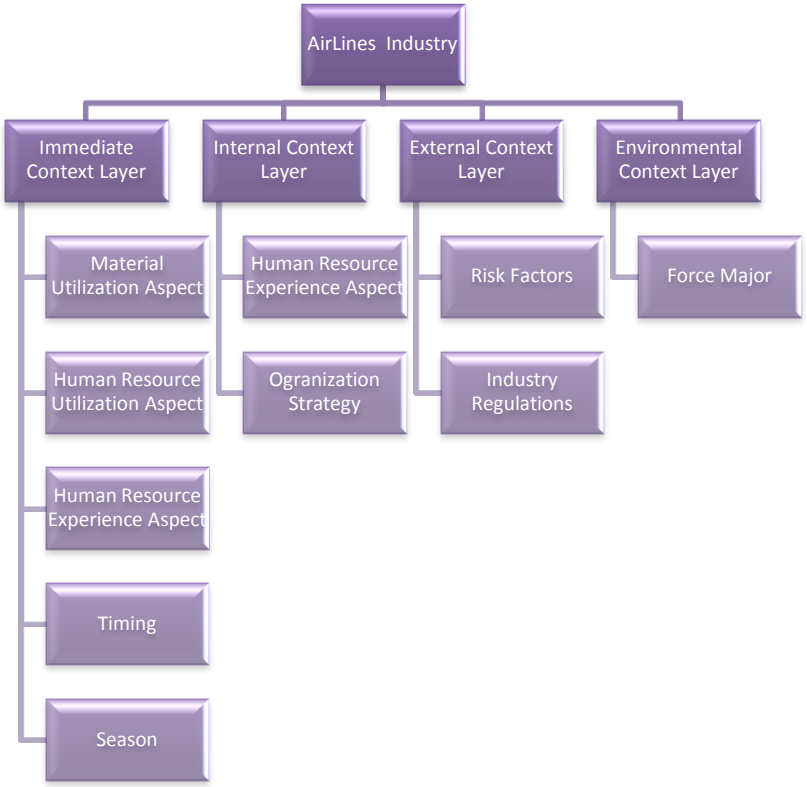

Figure 44: Context Aspects Classification

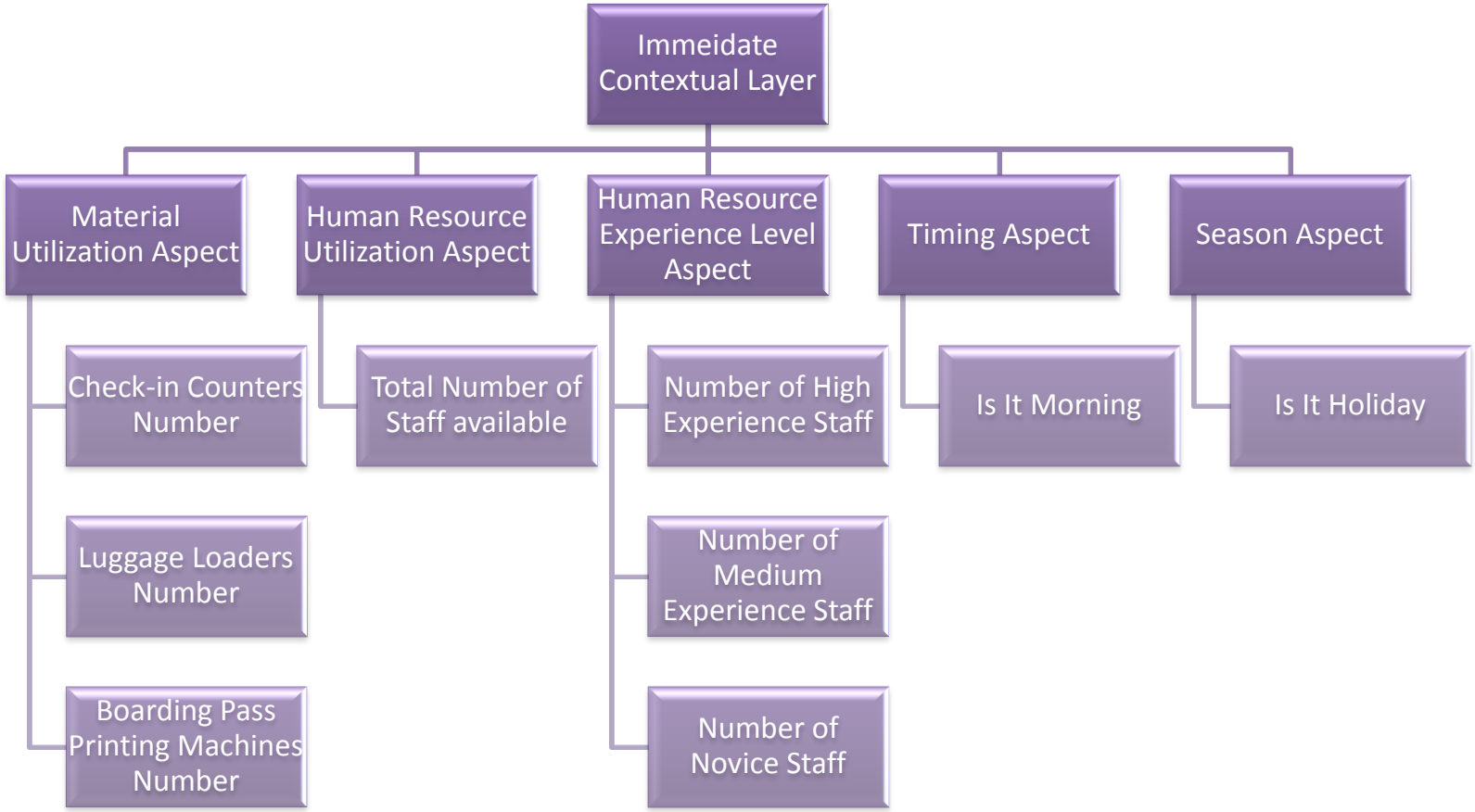

Figure 45: Immediate Context Layer Tree

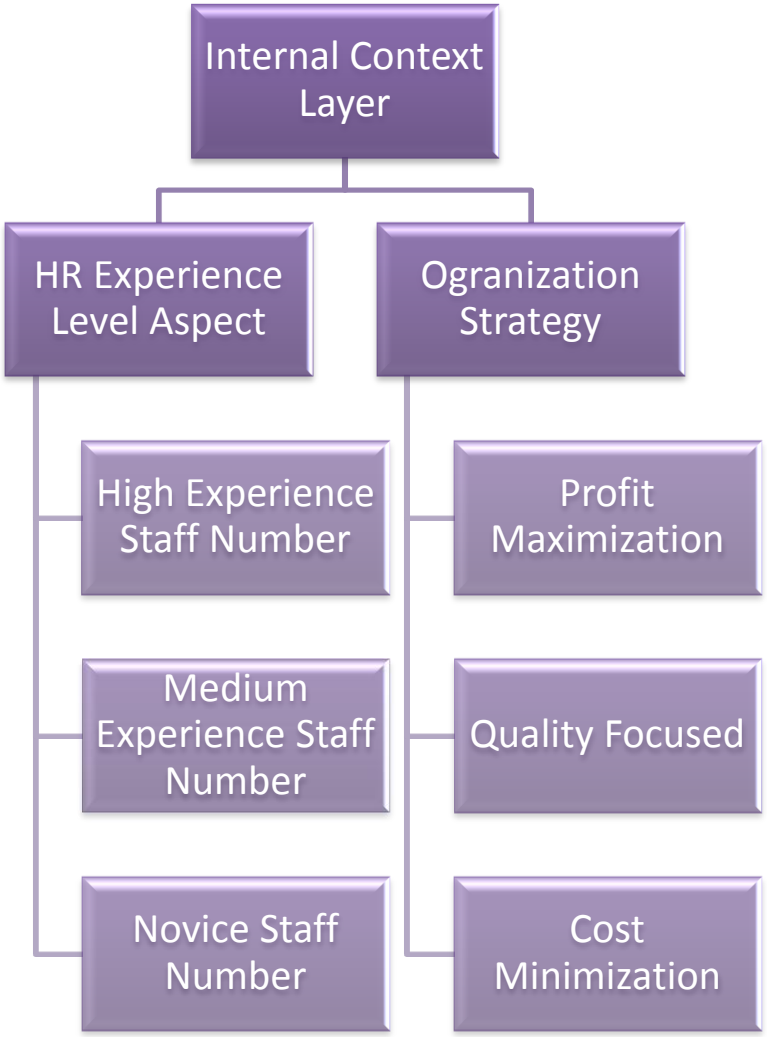

Figure 46: Internal Context Layer Tree

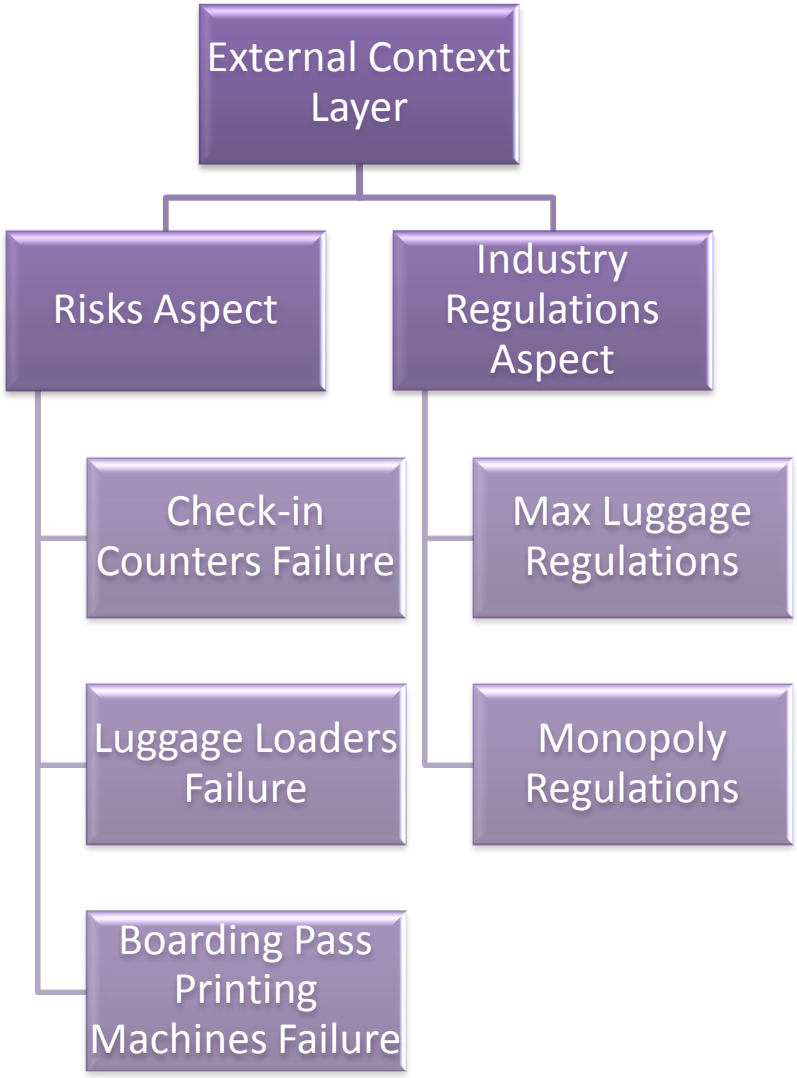

Figure 47: External Context Layer Tree

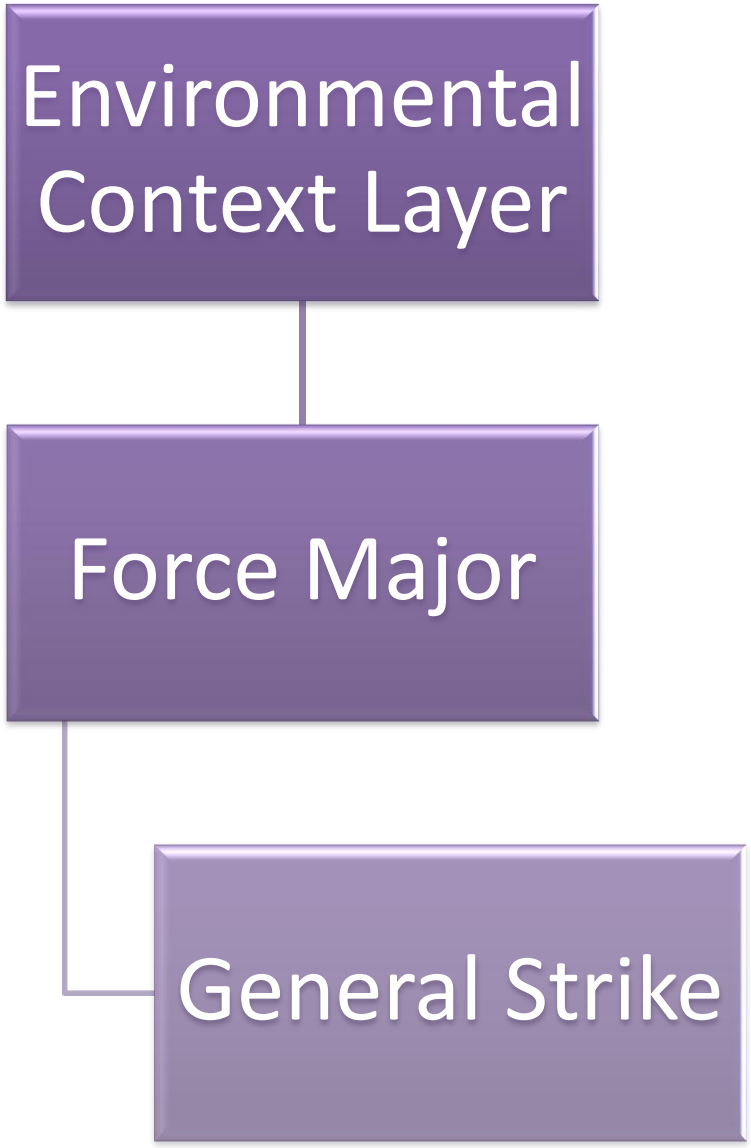

Figure 48: Environmental Context Layer Tree

2. Company Knowledge Base Definition

The company expert defined the company knowledge base starting with the company goals matrix (strategic goals and their operational sub goals) and for each goal a priority was defined as depicted in figure 49.

Priority 1 indicates the highest priority goals. Prioritization of goals is quite an important step in our solution methodology as it forms the focal point of conflict resolution whenever the business process is running in a controversial contextual situation where the values of some contextual elements under some contextual aspects suggest a certain path and configuration of business process steps and the other values of other contextual elements under other contextual aspects suggest another configuration. Such a situation is resolved by taking the recommendation of the contextual aspects that are related to goals (through contextual layers segmentation) with the highest priority.

P1 indicates the goal is of highest priority. Each strategic goal has a priority and its operational sub-goals have a priority, the priority of a sub goal should be as high as the priority of the strategic parent goal or less , however, it should not exceed the priority of the parent goal. All the priorities are defined by business experts and the logic behind the ratio between the sub-goals and parent goals is that the sub-goals help in achieving the parent goals so their priority should be according to how much they contribute to achieve the parent goal and thus can't be higher than the parent goal. For goals that have a fractional priority like p 1.5 this means the goal contributes to achieving a parent goal of priority 1 but its contribution is not that major. This is why its range is at 1.5. The same goes for goals given priority 2.5.

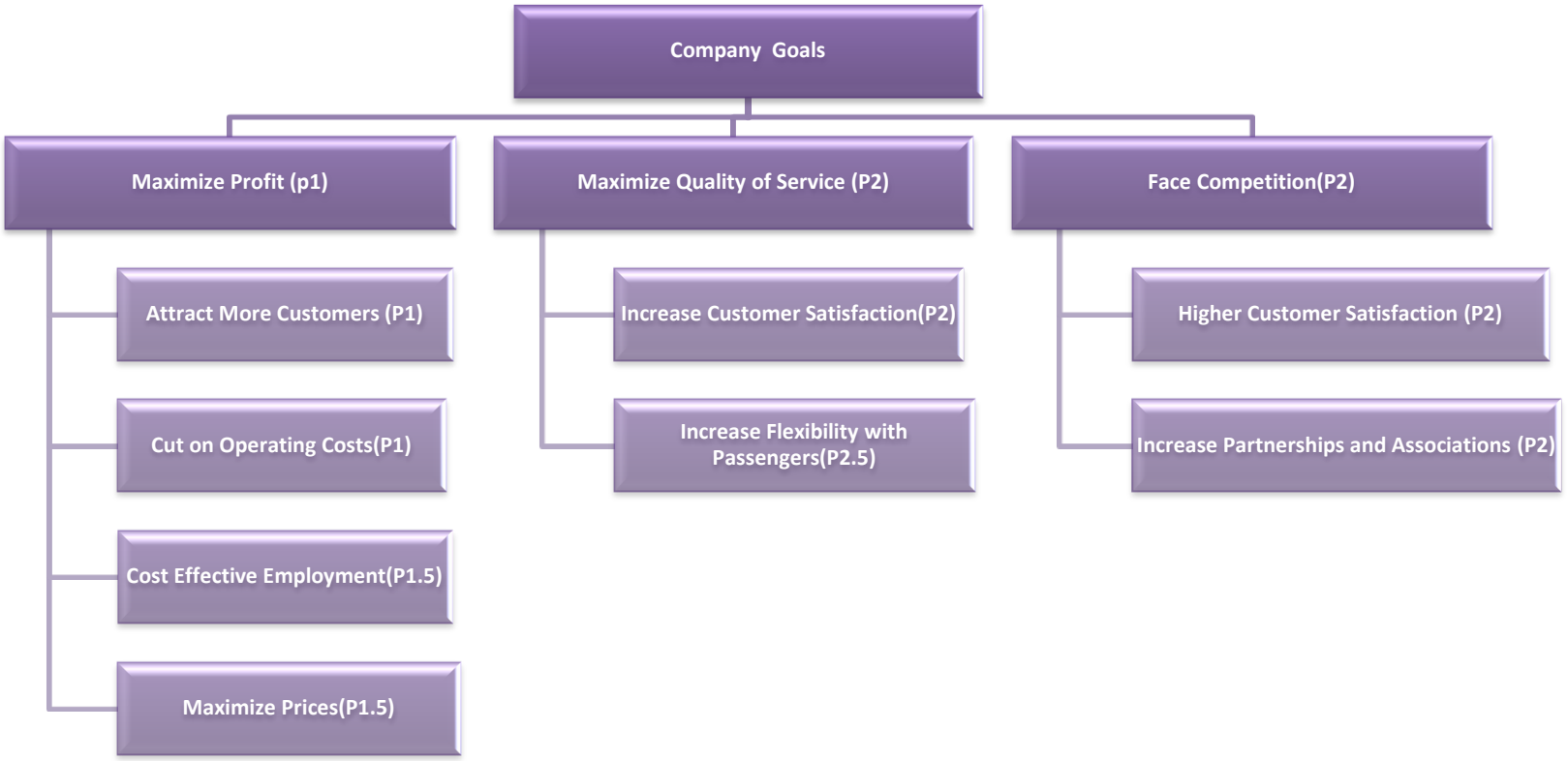

Figure 49: Company Goals Matrix

The company expert also defined the association between the different company goals and the four contextual layers (immediate, internal, external and environmental layers) as depicted below in figures 50, 51, 52, and 53, respectively.

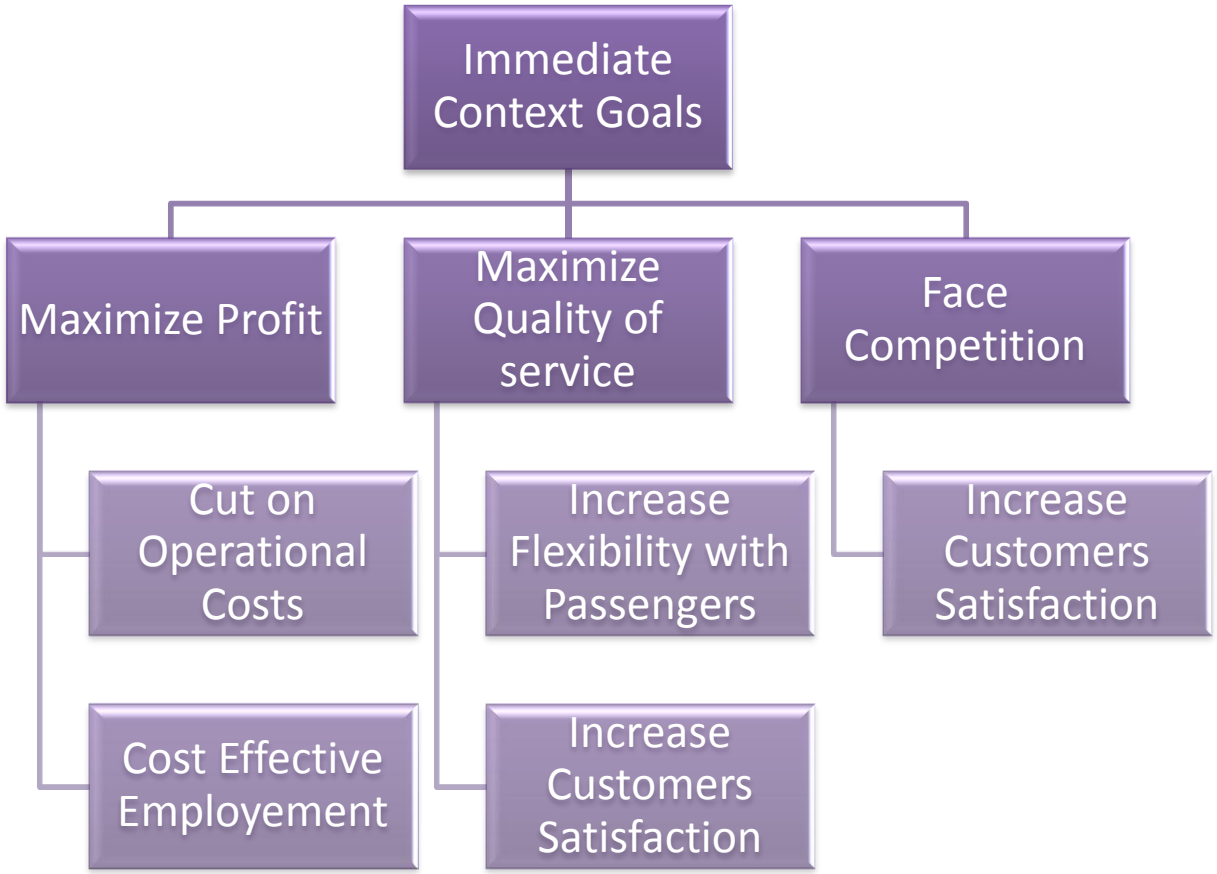

Figure 50: Immediate Context Goals

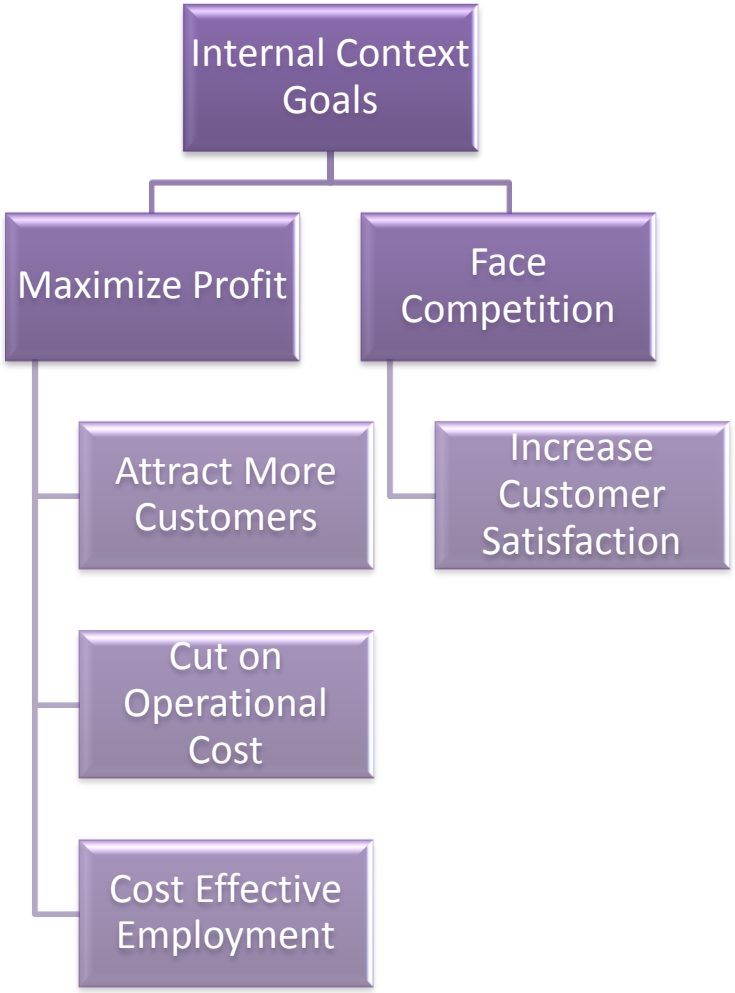

Figure 51: Internal Context Goals

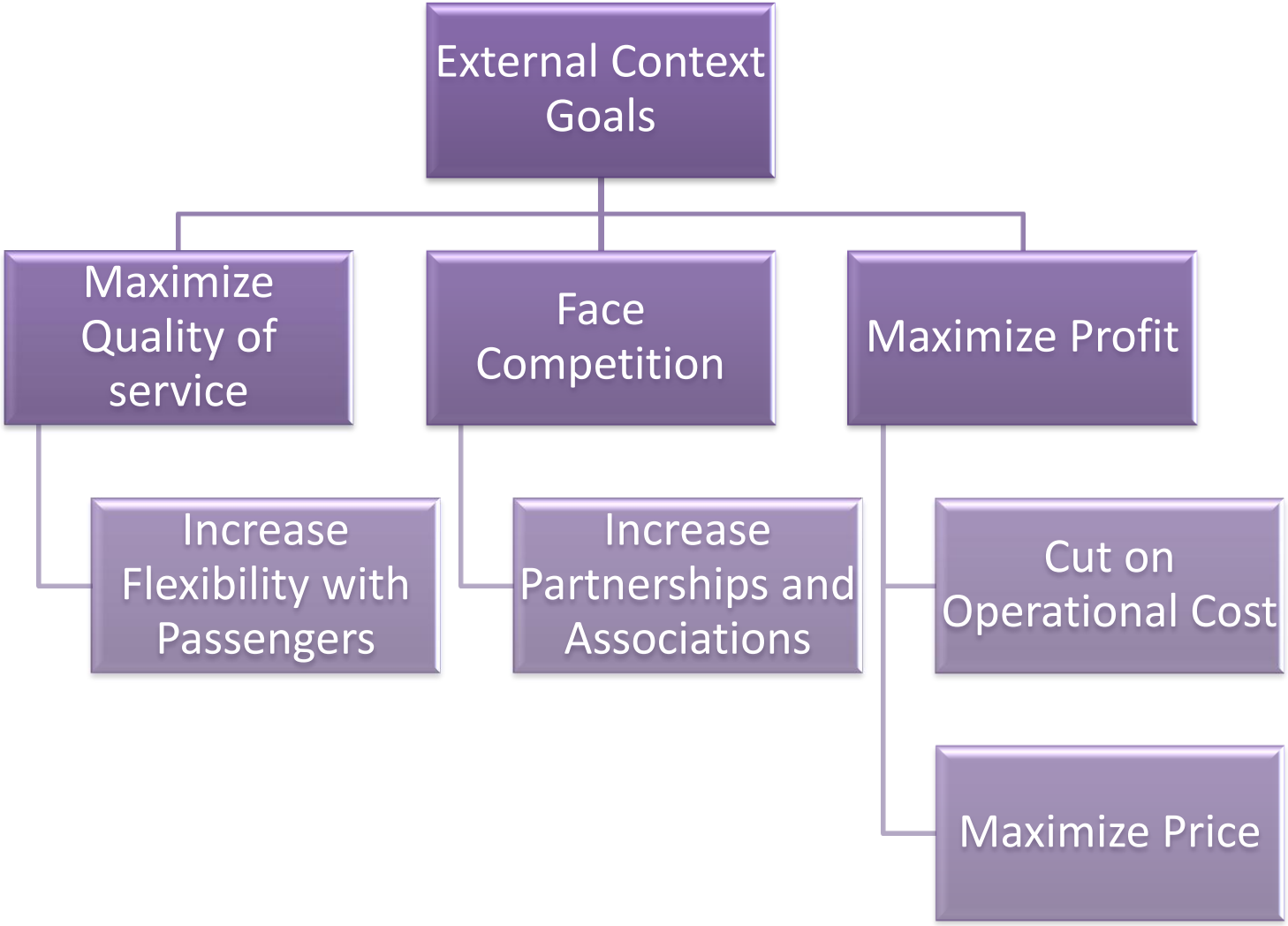

Figure 52: External Context Goals

Figure 53: Environmental Context Goals

The goals and their associated contextual layers are defined at the company level as goals that vary per company even if there are common company goals between companies operating within the same industry.

3. Business Process Definition

The business process expert defined the business process with the assistance of the system. First the business process goals which are a subset of the overall company goals were defined and they were as depicted in figure 54.

Figure 54: Business Process Goals

The business process expert defined the business process alternative flows in terms of a finite state machine as depicted in figure 55.

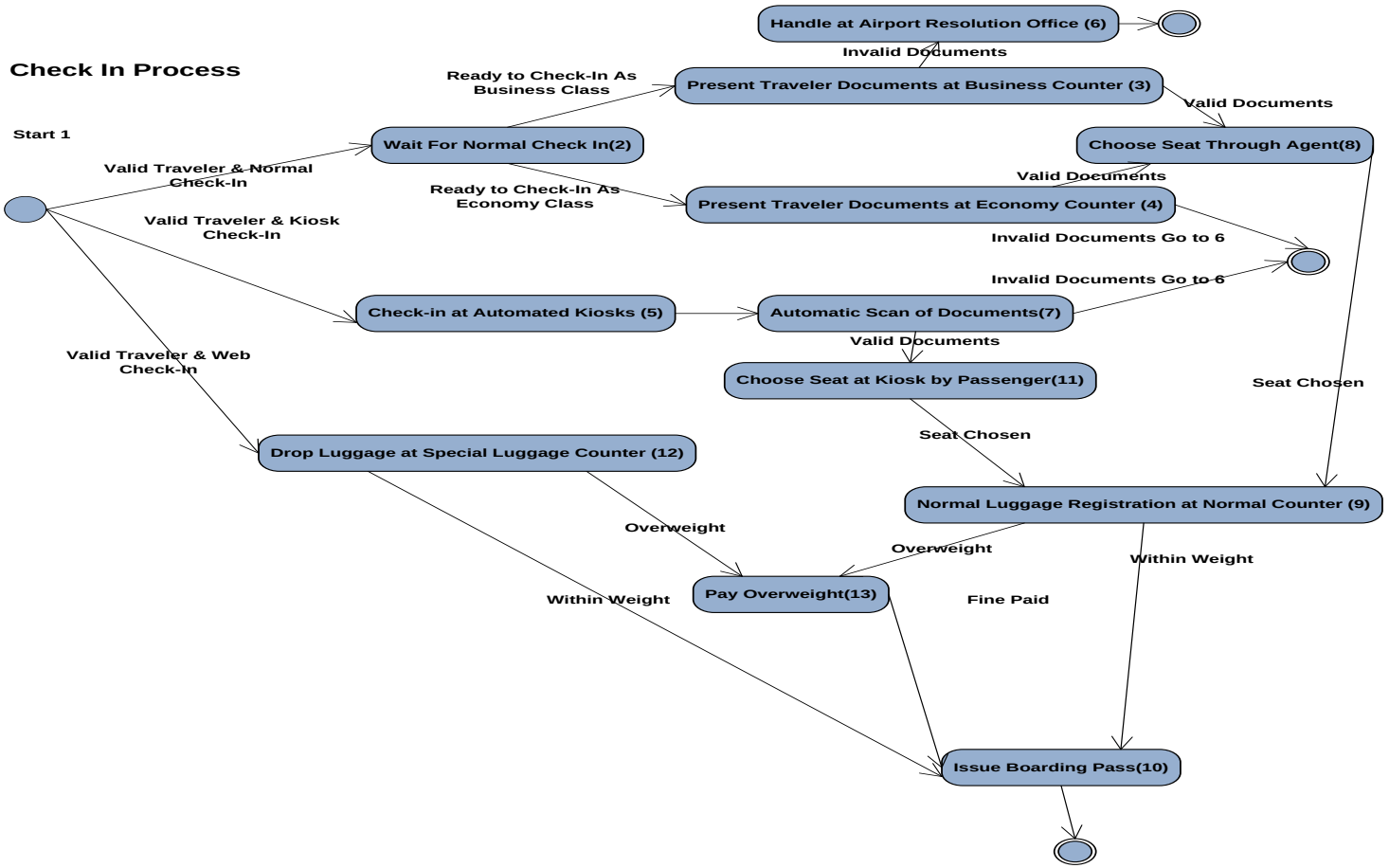

Figure 55: Check-in Business Process

The business process flow shown in figure 55 represents the direct flow of the contextual process (with pre and post conditions) and steps as finite state machine states. In addition to the above definition the business process expert defined (with the guidance of the system) how to reach different contextual situations by skipping steps or changing the flow. The guidance of the system is achieved through the following steps:

1. The system asks the user to choose a subset of the overall goals of the company to be selected as process goals

2. The system asks the user to define the business process steps

    2.1. For every step the system asks the user to choose a subset of the business process goals to be the step goals (i.e. the goals that the business process is expected to achieve)

    2.2. The system compares the goals of the step and the goals of the different contextual layers and identifies the context aspects and elements under them which should be considered while executing this step and moving to the next step , skip it or go for an alternative one.

    2.3. The system helps the user to define the conditions to move to the next best step by enabling him to define different kinds of conditions logically Anded or Ored together and their next best step. For example in Step 2 while waiting for normal check- in, if the number of economy counters is small or there is a shortage in staff and the passenger is an economy passenger open next step is 4 (open for the passengers the business counters till the bottleneck gets better).

3. The user defines all the steps and marks if they are initial or terminal states

Table 25 represents the business process goals and sub-goals while Table 26 represents the definition of step 1 of the check-in business process.

Table 25, Business Process Goals

Goals	Parent Goal	Sub Goal/s	Priority
Maximize Profit	This is the parent goal	Cut on Operational Cost Maximize Price Cost Effective Employment	1
Cut on Operational Cost	Maximize Profit	This is the sub goal	1
Maximize Price	Maximize Profit	This is the sub goal	1.5
Cost Effective Employment	Maximize Profit	This is the sub goal	1.5
Maximize Quality of Service	This is the parent goal	Increase Customer Satisfaction Increase Flexibility with Passengers	2
Increase Customer Satisfaction	Maximize Quality of Service	This is the sub goal	2
Increase Flexibility with Passengers	Maximize Quality of Service	This is the sub goal	2.5

Table 26, Business Process Definition & Recommendations Example

Step ID	Step Name	Goals	Pre-Conditions	Post Conditions	Recommendations
1	Start	Profit- Attract More Customers, Profit – Cut on operational cost, Quality of Service-Higher Customer Satisfaction, Face Competition-Higher Customer Satisfaction	Have E-Ticket, Have Been Checked at the gate, Is not a banned traveler	Valid Traveler & Normal Check-in, Valid Traveler & Kiosk Check-in , Valid Traveler & Web Check-in	If Valid Traveler & Normal Check-in & [Number of Check-in Counters is small (1 to 200) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on

					Strike Or Strategy is Profit maximization and cost cutting then Go to Step 5 Kiosk Check-in] Priority=1.64 If Valid Traveler & Normal Check-in& [Enough counters, &staff & normal season & quality maximization strategy Go to Step 2] Priority=1.64

As depicted in Table 26 the start step's goals were to maximize profit, attract more customers, cut on operational costs and increase quality of service and thus customer satisfaction. The step's pre-conditions and post-conditions are available in addition to the transitional recommendation conditions as shown in the recommendations column:

- if the traveler is a valid traveler and s/he is awaiting normal check-in
- **and** the number of check-in counters is small
- **or** the staff number is small or novice or the strategy is a cost cutting focus
- **and** the number of kiosk check-in counters is sufficient

Then the recommendation is to redirect passengers to the kiosk check-in. We note here that the recommendation has a priority which is equivalent to the priorities of the goals that the context elements in the recommendation condition are associated to.

For the details of the rest of the check-in business process steps, their goals, their pre-conditions, their post conditions and recommendations refer to Appendix IV.

4. Business Process Cost definition

Table 27 shows the details of the cost definition for all the business process steps as defined by the business expert.

Table 27, Business Process Cost

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
3	Present Documents at Business Counter	(0.13 time*10$ labor cost)=1.3	(3 resources number *5$ average cost of different resources) =15	16.5	0.13
4	Present Documents at Economy Counter	(0.2 time*10$ labor cost)=2	3 resources number *5$ average cost of different resources) =15	17	0.2
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
6	Handel Problem at Airport Security Office	(1 time* 20 $)=20	(3 resources number *5$ average cost of different resources) =15	35	1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
8	Choose your Seat by an Agent	(0.15 time *$10)=1.5	1 resource *5 average cost=5	6.5	0.15
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08
11	Choose your Seat Automatically at Kiosk by Yourself	0	1 resource * 5 average cost=5	5	0.1
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11
13	Pay Overweight Fine	(0.25 hour*10 cost)=2.5	2 resources* 5 average cost =10	12.5	0.25

5. Recommendations and Priority definition

All the business process definition and recommendations is done by the business process expert. The recommendation for the next step is done as a combination of post conditions and contextual conditions related to the step goals (as per the goals to context layer connection defined by the business expert as well). For every recommendation the business process expert must assign a priority to the recommendation to avoid the case where controversial contextual values put the system in a condition where there are two conflicting next steps. The system calculates by default the priority of one recommendation to be the average of the priorities of the goals connected to the contextual elements within that condition, however the system allows the business process expert to override this priority by a better value if s/he wishes.

4.4.2. Airlines Industry Experiments Results Summary and Analysis

This section illustrates the summary of the results done on various contextual cases and conditions of the Check-In business process under the airlines industry. For the details of the runs that were tested on our system and their exact output refer to appendix V.

The financial cost reduction for each of the 10 contextual cases is depicted in table 28 and the bar charts in figures 56 and 57 below summarize the cost reduction and time savings, respectively.

Benchmarking:

The benchmarking in our experiments is done through a contextual case where all the contextual conditions are within normal boundaries. Hence, the business process flows according to its default paths without any changes in flow due to any recommendations related to contextual conditions. We therefore take the financial cost and the execution time of the business process under this contextual case as the benchmark. We compare the cost of the different runs that take different alternative paths (according to the context-awareness and goal-orientation conditions) with this benchmark to identify the financial cost variance and the execution time variance.

Within this set of experiments on the Check-In business process the benchmark case is case 10.

Table 28, Check-in Process Results Summary

Context Case	Run Situation	Financial Cost Reduction	Execution Time Reduction
The first case represents a high season while all other conditions are normal. The strategy is maximizing quality of service on the top of everything.	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in) Run 2(Business Passenger with valid documents and luggage within normal limit wishing to log in):	Run1 (16.6%) Run 2 (12.0 %)	Run 1(18.3%) Run 2 (47.8%)
The second case represents a high season while all other conditions are normal yet the strategy is cost cutting and profit maximization.	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in) Run 2(Kiosk Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1 (30 %) Run 2 (18.2%)	Run 1 (70 %) Run 2 (47.8 %)
The third case represents a high season, deficiency in overall staff number and experienced staff and the strategy is cost cutting and profit maximization.	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1 (30 %)	Run 1 (70%)
The fourth case represents a normal season, deficiency in overall staff number and the economy check-in counters and web-check-in counters, the strategy is quality focus strategy.	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1 (16.6%)	Run 1(18.3%)
The fifth case represents a high season, deficiency experience staff and the economy check-in counters and the business check-in counters and web check-in counters and the strategy is cost cutting strategy.	Run 1(Business Passenger with valid documents and luggage within normal limit wishing to check-in) Run 2(Economy Passenger with valid documents and luggage within normal limit wishing to check-in) Run 3(Web Check-in Passenger with valid documents and luggage within normal limit wishing to check- in)	Run 1 (12.0 %) Run 2(13.0%) Run 3 (-20.0%)	Run 1 (47.8%) Run 2 (50.8%) Run 3 (53.0%)
The Sixth case represents a high season, deficiency in overall staff number, deficiency in business counters and kiosk counters the strategy is cost cutting strategy.	Run 1(Kiosk Passenger with valid documents and luggage within normal limit wishing to log in) Run 2(Business Passenger with valid documents and luggage within normal limit wishing to log in)	Run 1 (18.2%) Run 2 (7%)	Run 1 (47.8%) Run 2 (68.14 %)
The seventh case represents a high season, deficiency in economy counters, the strategy is cost cutting strategy and there is a risk of strike of employees	Run 1(Economy Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1 (13 %)	Run 1 (50.8%)

so all employees who are working are novice.			
The eighth case represents a high season; deficiency in economy and business and kiosk counters, the strategy is quality focus.	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in) Run 2(Business Passenger with valid documents and luggage within normal limit wishing to check-in) Run 3(Kiosk Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1(30%) Run 2(7%) Run 3 (18.2)	Run 1 (70%) Run 2(68.14%) Run 3(47.8%)
The ninth case represents a high season; deficiency in normal luggage loaders, the strategy is cost cutting focus.	Run 1(Economy Passenger with valid documents and luggage within normal limit wishing to check-in)	Run 1 (6%)	Run 1 (5%)
The tenth case represents a normal situation where there is no deficiency in any resource and it is not a high season and it will be used as the benchmark for the default business process path verse the alternative paths take to cater for certain contextual situations	Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in) Run 2(Business Passenger with valid documents and luggage within normal limit wishing to check-in) Run 3(Web Check-in Passenger with valid documents and luggage within normal limit wishing to log in) Run 4(Kiosk Check-in Passenger with valid documents and luggage within normal limit wishing to log in		

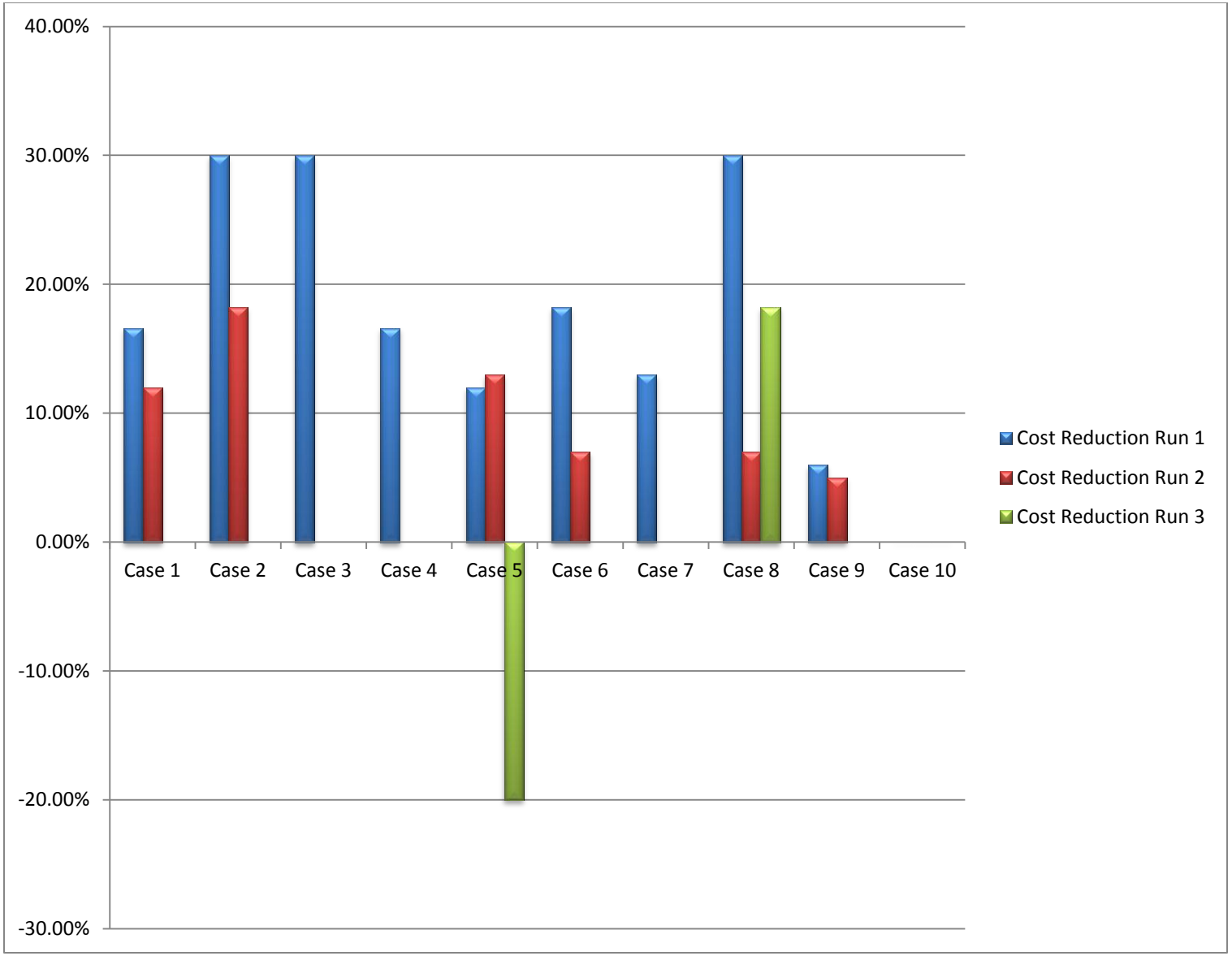

Figure 56: Airlines Cost Reduction Results Summary

In figure 56 we summarize the cost reduction results of the major runs simulated for the airlines check-in business process (the detailed runs are included in Appendix V). Not all the contextual cases were tested on 3 runs as sometimes the contextual situation would lead to the same recommendation whether the passenger is an economy passenger or a business passenger or a passenger who prefers a kiosk check-in so in these cases we only simulated one run like in case 4 (where the contextual situation that was tested on the check- in business process represented a normal season, deficiency in overall staff number and the economy check -in counters and web check- in counters, the selected strategy is the quality focus strategy). In case 4 it was sufficient to make only one run which was for an economy passenger as it would have been the same recommendation even if it is for a business passenger or kiosk passenger) .

Case 10 shows zero cost reduction as this is the benchmark case where there is no context-awareness of any kind being simulated.

For the financial cost reduction we see a strong fluctuation from an improvement of cost as high as 30% to an increase in cost of about 20%. However the run case that produced an increase in cost of about 20% was a case where there was a problem in the web check- in counters which is the cheapest kind of check-in within our simulation. So, in order to maintain the service quality which was the company strategy at this contextual instance, we had to substitute the web-check-in with another type of check- in which was using the kiosk check-in luggage loaders. This is more expensive but it was inevitable, so in some contextual situations according to the limitation of resources, the next best choice might move the expenses up. However, if we exclude these cases we find that the average of cost enhancements on the short run is 23 % which is a significant figure for cost enhancement given the millions of check-in business process runs taking place in one airport in one day.

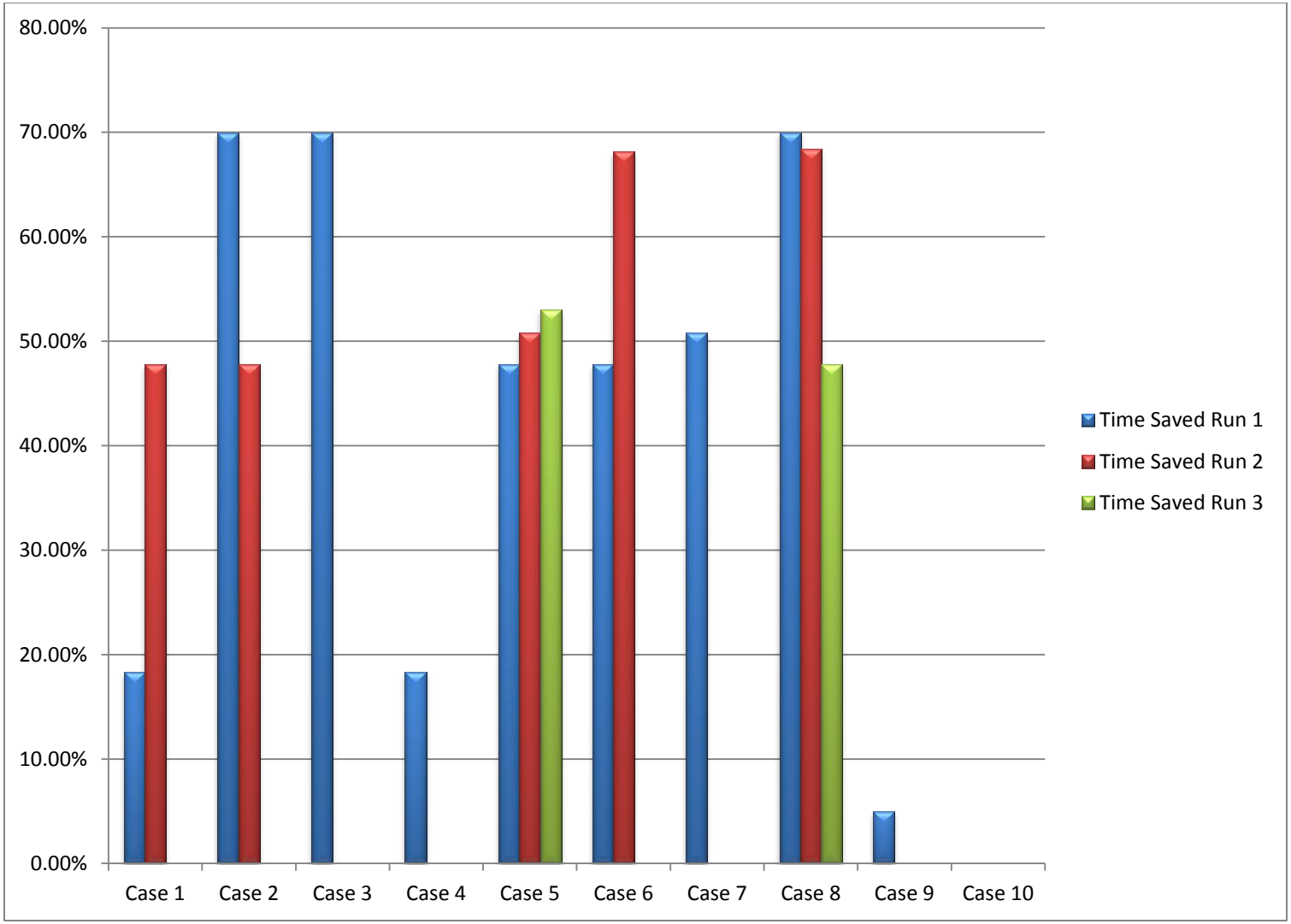

Figure 57: Airlines Industry Time Saving Results

In figure 57 we summarize the time saving results of the major runs simulated for the airlines check-in business process (the details of the runs are in Appendix V). Not all the contextual cases were tested on 3 runs as sometimes the contextual situation would lead to the same recommendation whether the passenger is an economy passenger or business passenger or a passenger who prefers the kiosk check-in. So, in these cases we only simulated one run like in case 4 (where the contextual situation that was tested on the check-in business process represented a normal season, deficiency in overall staff number and in the economy check-in counters and web check-in counters. The selected strategy is the quality focus strategy. In case 4 it was sufficient to make only one run which was for an economy passenger as it would have been the same recommendation even if it is for a business passenger or kiosk passenger .

Case 10 shows zero time saving as this is the benchmark case where there is no context-awareness of any kind being simulated.

For the execution time reduction we see an even better improvement than the financial cost reduction where the time of execution of the business process runs were enhanced at a higher rate. In some case it is as high as 70 % and in some case the enhancement is as small as 6%. But the latter are minor cases and the reason is again the resource limitations. If there is a situation where all the contextual variables are at crucial levels (risk of strike, novice people on counters, small counters numbers (economy, web check- in and kiosk counters) whatever could be done will still be slow or improve the execution time at a slight percentage like 6%. However, these cases, as compared to other less complex cases, form a small proportion in daily business life. Hence, gaining an average of 34 % time reduction for the check- in business process means maximizing the throughput for such a business process and maximizing the profit of the company that utilizes the context-aware goal-oriented business process modeler.

The General Average of Financial Cost Reduction of all the runs = Summation of Cost Reductions of all runs/number of runs = 12 %

The General Average of Execution time saved in all runs = Summation of Execution times Reductions of all runs/number of runs=34%

The Overall Quality/Effectiveness of the model as per equation 6 in section 1.1.3 (Evaluation Criteria) =

(Summation of Financial cost reduction/ the number of business processes runs that Financial cost reduction was calculated for) * Weight of F

+ (Summation of Time reduction/ the number of business processes that Time reduction was calculated for) * Weight of TV

Assuming the we give equal weight to the financial cost as well as the time cost (each 0.5 as the total of all weights should be one), the overall results of the model is that given the tests done on the Airlines check–in process, it improved the effectiveness of decision-making based on goal-orientation and appropriate modeling of context by (12%*0.5+34%*0.5) = 23 % . This is a significant percentage given that in real life and across the airports of the world, the check- in process executions takes place millions of times every day so an enhancement of 23% means millions of savings only on the short run.

From the above results we tend to appreciate the appropriate sensation and modeling of a business process context in terms of contextual aspects segmented into contextual layers. Each layer has a business-oriented goal and models a business process in the form of a finite state machine that decides on the best next move according to recommendations defined by business process experts and related to context of the step. The step goals have a significant positive effect on reducing the financial cost of the business processes and enhancing the throughput (the number of business process that could be executed within certain time period or time frame).

From both results of financial cost reduction and execution time reduction on the short run, we see promising results for the context-aware goal-oriented business process modeler on the long run. Definitely, there are more complex and detailed ways of measuring the effectiveness of the proposed solution methodology but this is quite diversified and needs a detailed study on its own.

4.4.3. The Telecom Industry Experiments

These experiments were related to the Telecom Industry and in particular the business process of payment of cellular phones postpaid plans (the postpaid plans are mobile tariff plans that allow the subscriber first to use the service then gets charged at the end of the month after actually using the service) bills. This business process from this industry was chosen due to my experience in the Telecom Industry and because it is a business processes that is affected by various contextual aspects belonging to various layers (immediate, internal, external and environmental). It has a variety of configuration decisions that can be taken. In addition, it is well known to researches and readers from different backgrounds so the logic behind the configuration can be more easily analyzed and criticized.

4.4.3.1. The Experimental Procedures

1. Industry Knowledge Definition

The contextual knowledge about the Telecom industry was defined by the industry expert through a simple graphical interface. The industry expert defined the contextual aspect classification on the different contextual layers as well as the different elements related to the Telecom industry under each aspect. Figures 58-62 represent the defined aspects for each of the respective layers.

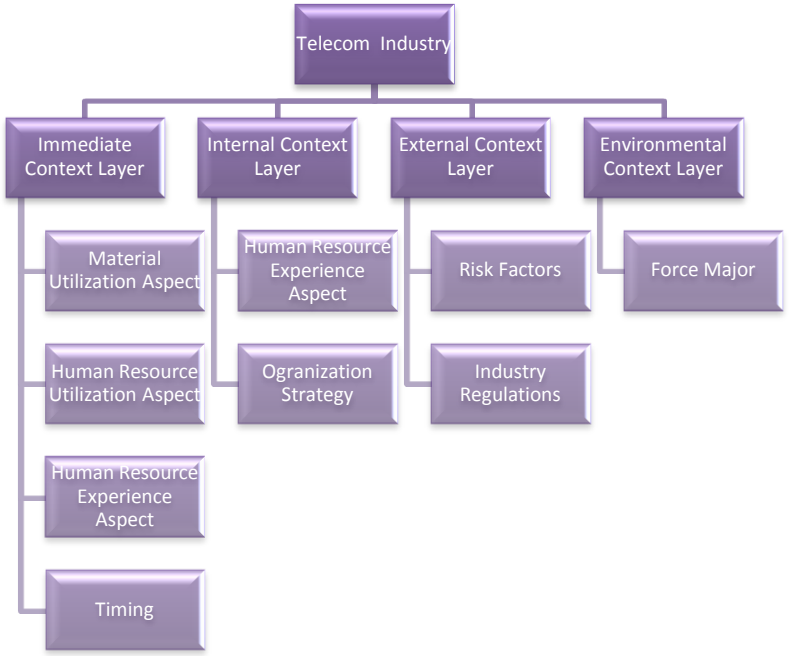

Figure 58: Telecom Industry Context

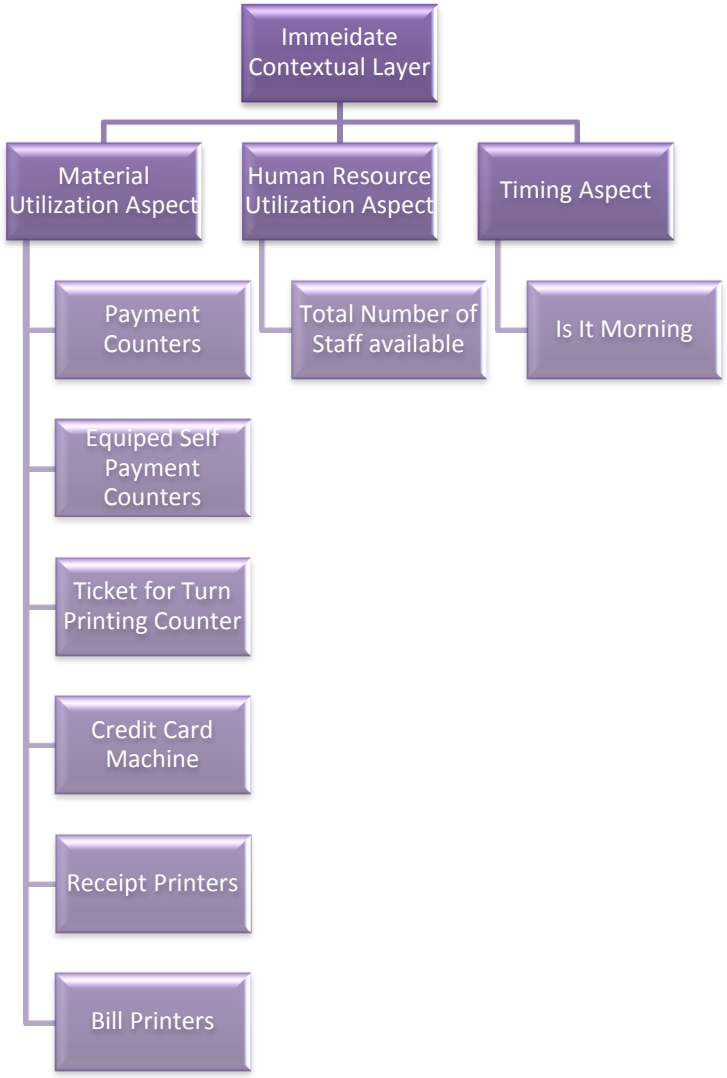

Figure 59: Telecom Industry- Immediate Context Layer Items

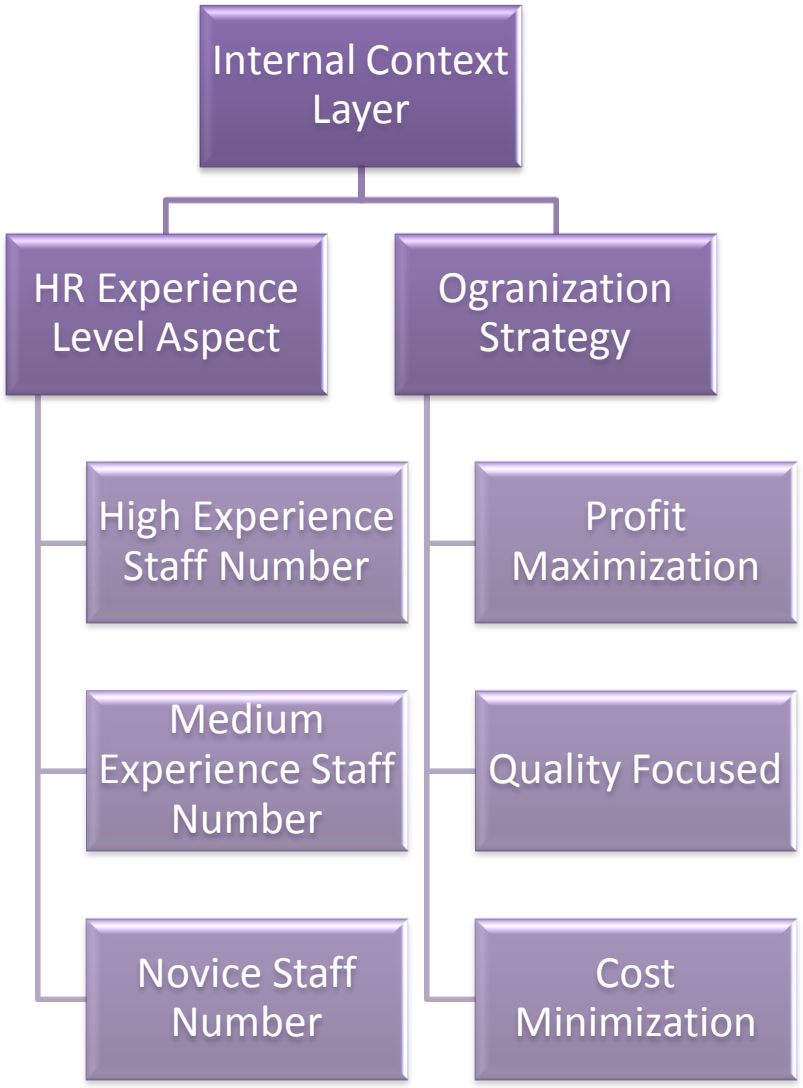

Figure 60: Telecom Industry- Internal Context Layer Aspects and Elements

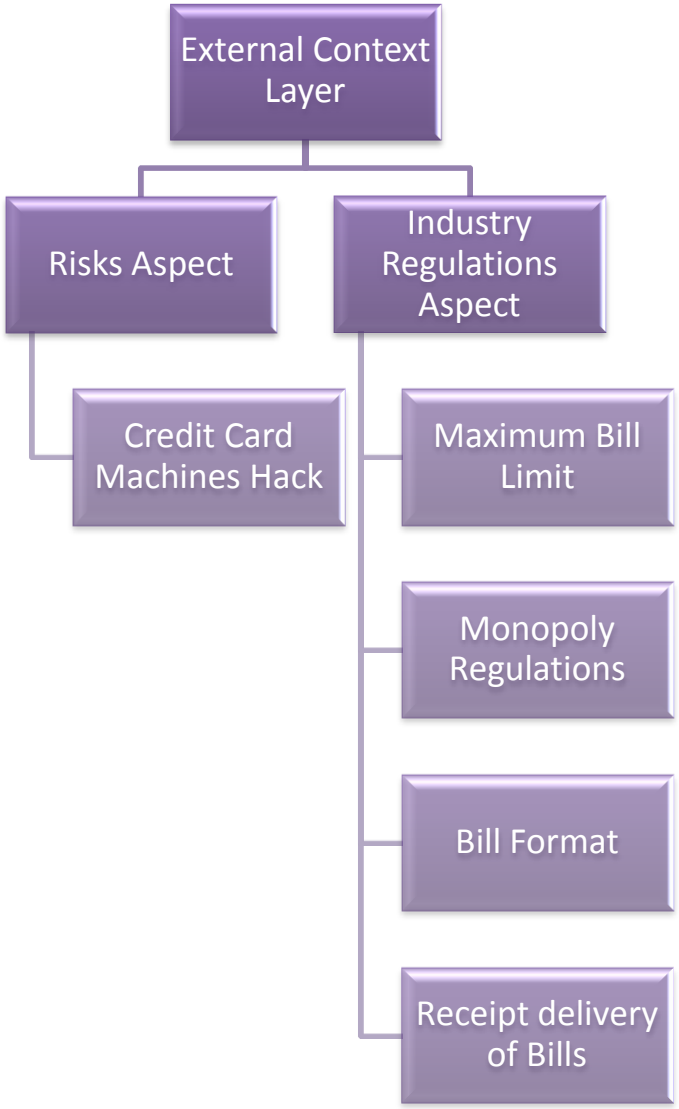

Figure 61: Telecom Industry- External Context Aspects and Elements

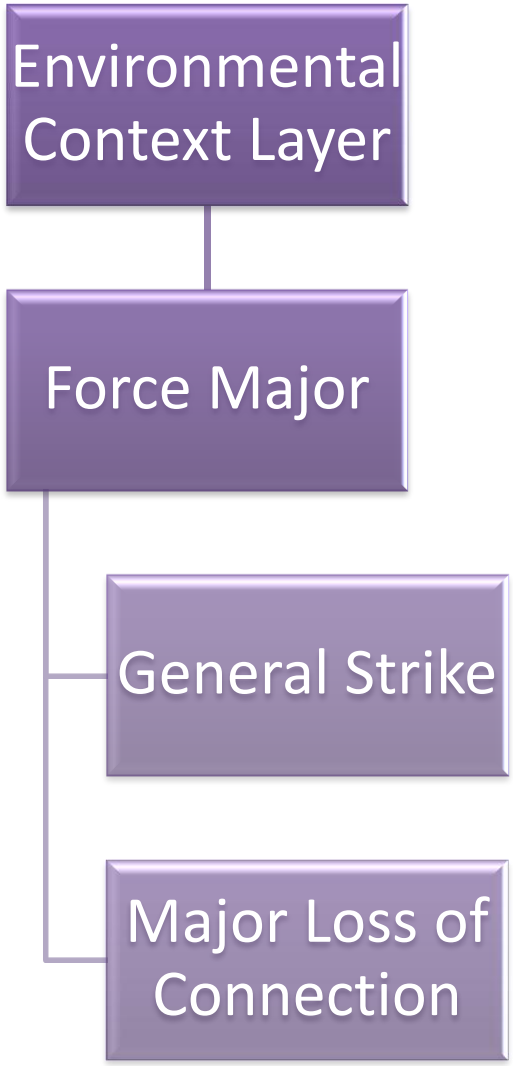

Figure 62: Telecom Industry Environmental Context Aspects and Elements

2. Company Knowledge Base Definition

The company expert defined the company knowledge base starting with the company goals matrix (strategic goals and their operational sub goals) and for each goal a priority was defined as depicted in figure 63.

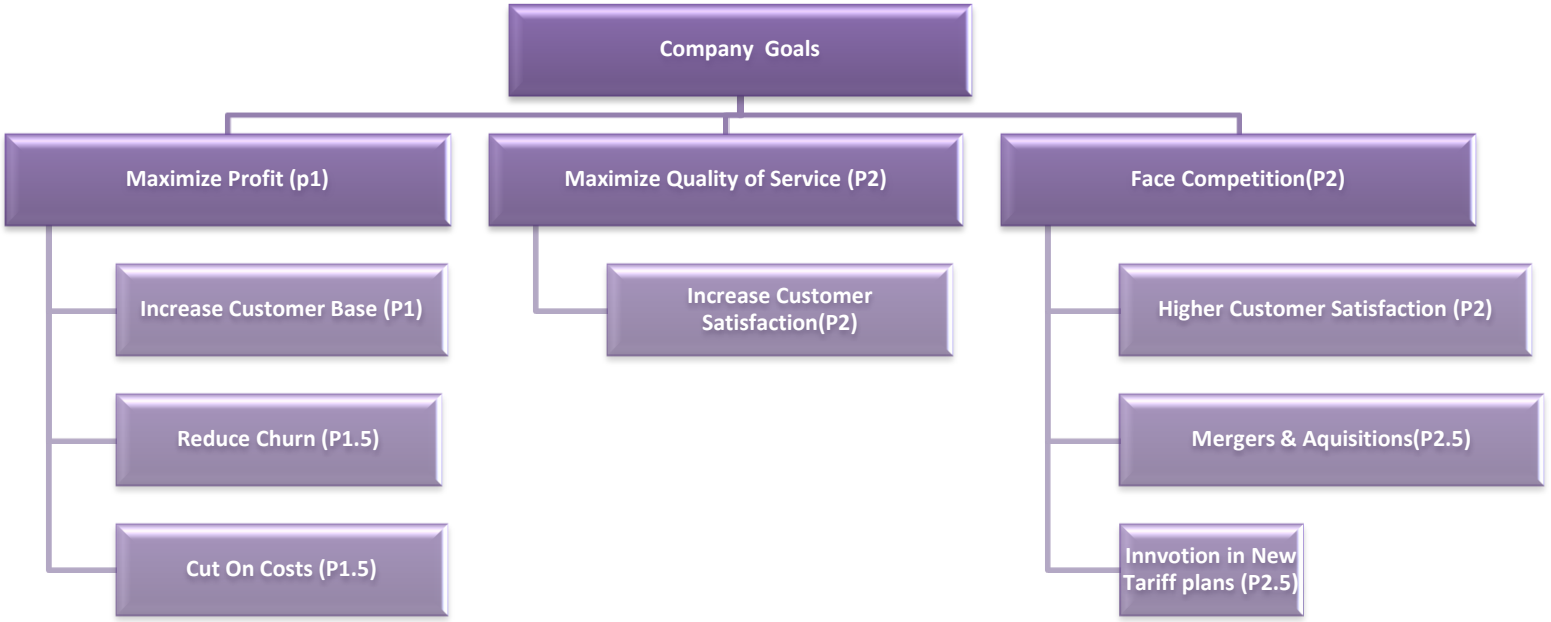

Figure 63: Telecom Company Goals Matrix

The company expert also defined the association between the different company goals and the four contextual layers (immediate, internal, external and environmental layers) as depicted below in figures 64, 65, 66 and 67.

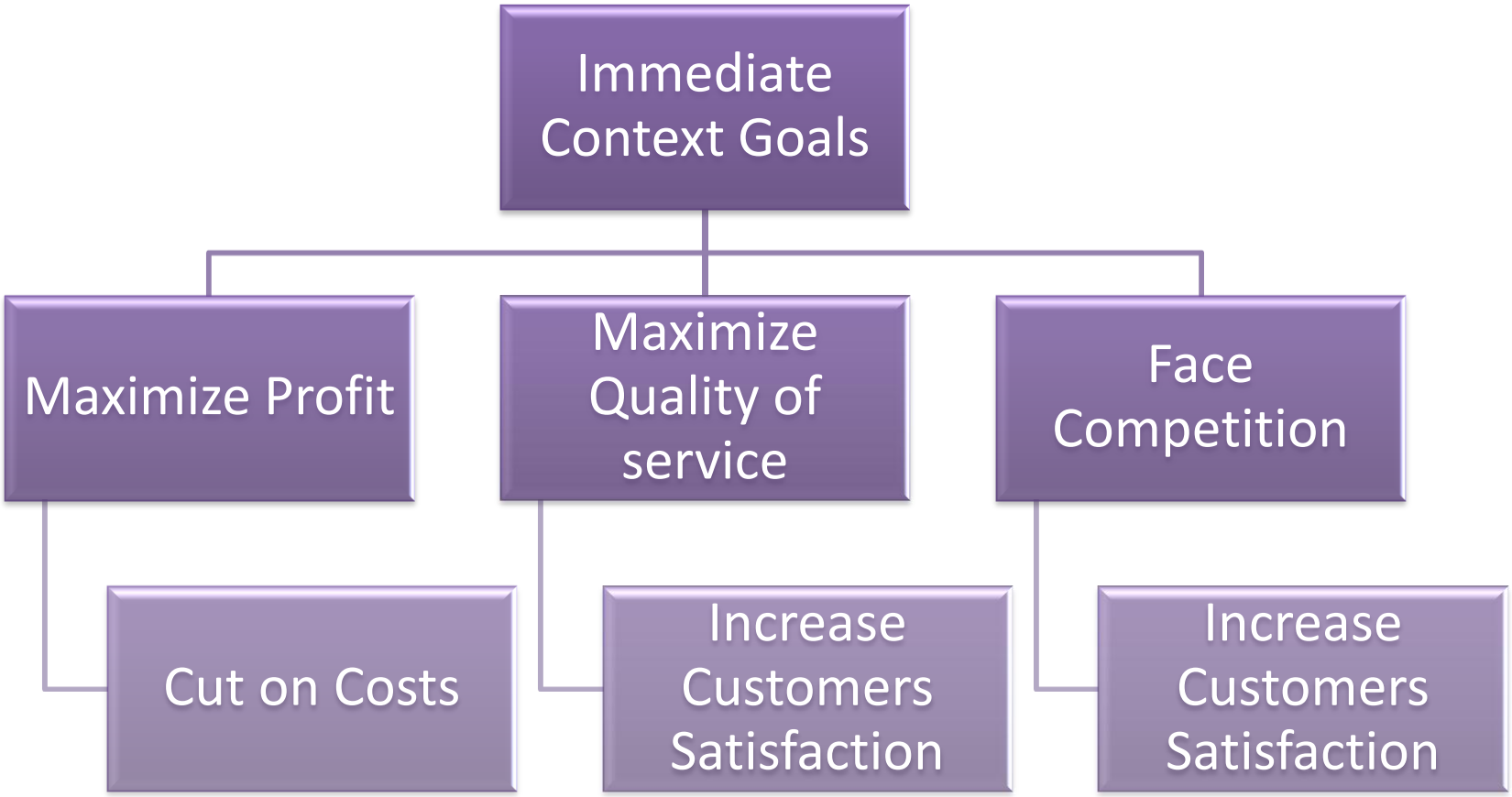

Figure 64: Telecom Immediate Context Goals

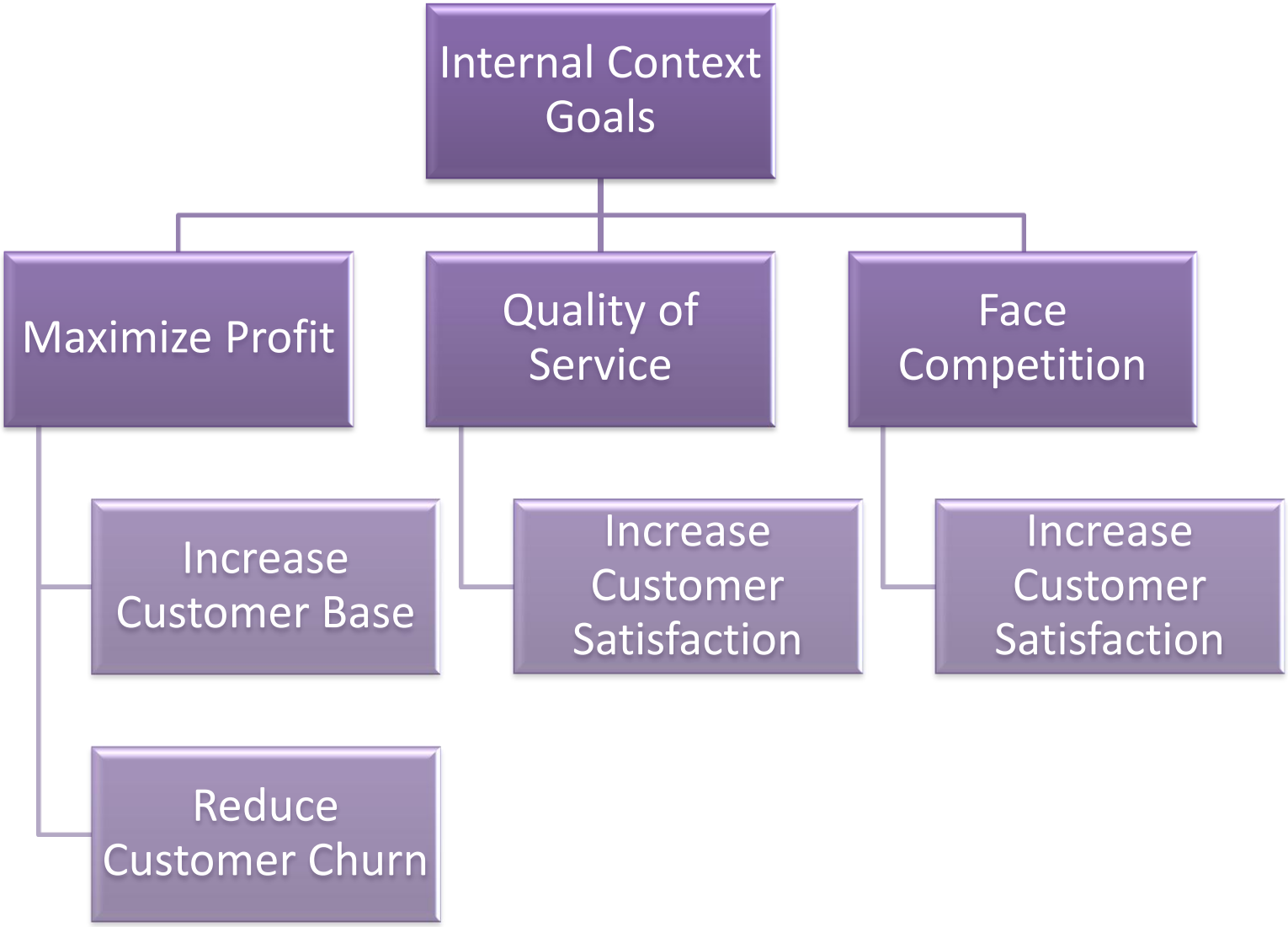

Figure 65: Telecom Internal Context Goals

Figure 66: Telecom External Context Goals

Figure 67: Telecom Environmental Context Goals

4. Business Process Definition

The business process expert defined the business process with assistance from the system. After defining the business process goals which in this case were similar to the company goals matrix listed earlier (excluding the innovation and merger goals), the business process expert defined the business process alternative flows which were represented in terms of a finite state machine (FSM) as depicted in figure 68.

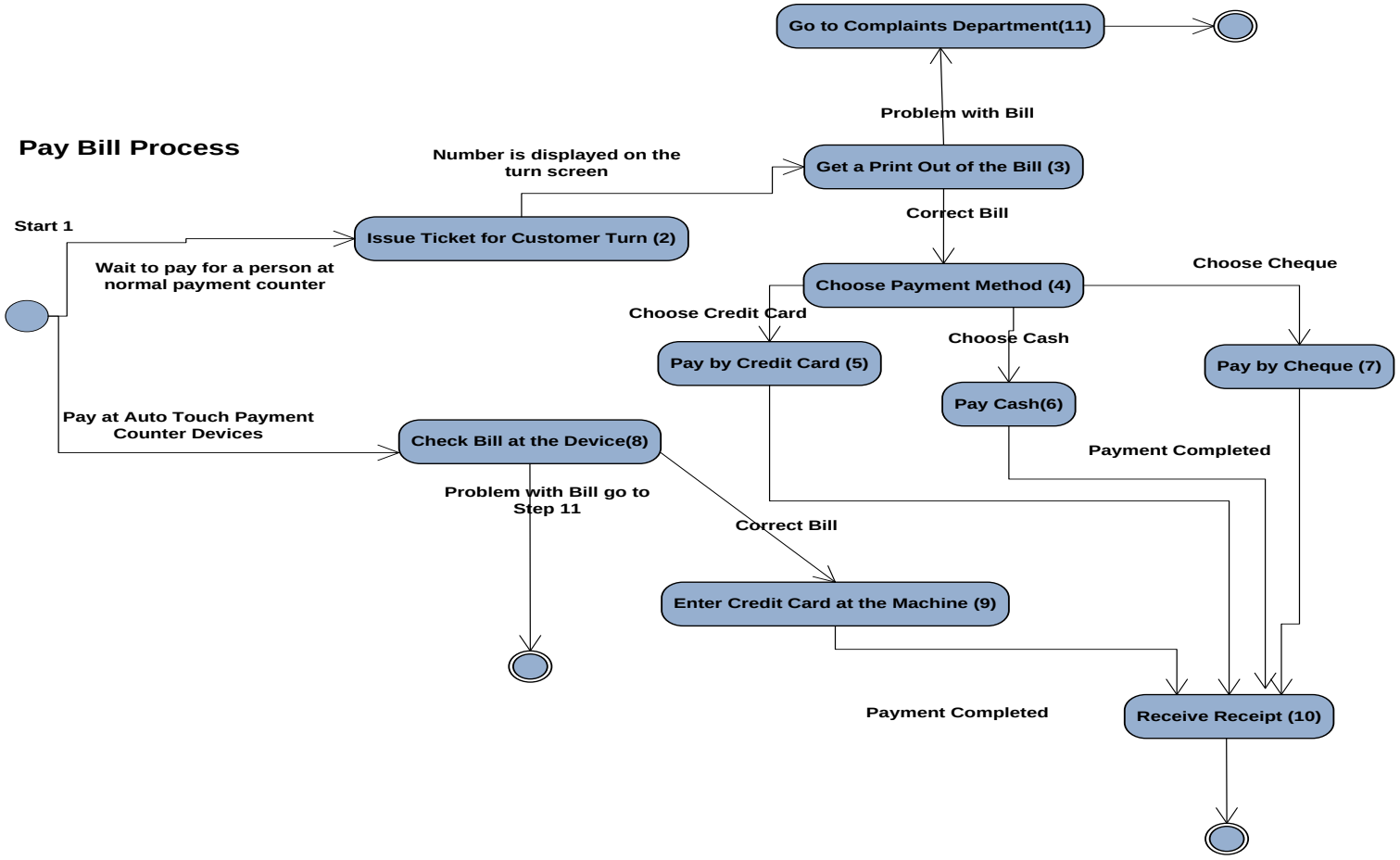

Figure 68: Bill Payment Business Process

The FSM is based on the pay bill business process steps and associated recommendations outlined in the pay bill business process definition table in Appendix VI.

6. Telecom Business Process Cost definition

Table 29 details the associated cost definition of all the business process steps in the pay bill finite state machine as defined by the business expert.

Table 29, Pay Bill Process Cost

Table 37: Telecom Business Process Cost

Step ID	Step Name	Man Power/$	Material Cost/$	Total Financial Cost/$	Total Execution time/hour
1	Start	0	0	0	0.17
2	Issue Turn Number	0	(1resources number *5$) =5	5	0.02
2'	Wait for your Turn	0	(2resource * 5 $ average cost of different resources	10	0.5
3	Get a print out of the bill	(0.17 time * man hour rate 10)=1.7	2resource * 7 $ average cost of different resources	14	0.25
4	Choose Payment Method	(0.17 time * man hour rate 10)=1.7	0	1.7	0.17
5	Credit Card Payment	(0.2 time * man hour rate 10)=2	1resource * 8 $=8	10	0.2
6	Cash Payment	(0.15 time * man hour rate 10)=1.5	0	0	0.15
7	Wait at Cheque counter for validation	(0.3 time * man hour rate 10) = 3	2 resources * 8=16	19	0.3
8	Check Bill at Self Service Device	0	1 resource * 7	7	0.08
9	Enter Credit Card at Self Service Machine & Pay	0	1resource * 8 $=8	8	0.2
10	Receive Receipt	(0.2* $10)=2	(1 resource * 8)	10	0.2
11	Go to Complaints Department	(1 * $10) =10	(2 resource * 8)	16	26

4.4.4. Telecom Experimental Results Summary and Analysis

In this section we illustrate the different contextual situations that the system automatically generated to simulate real life ones. For each contextual situation we show how the business process flows as well as the financial cost and time saved in each case. Table 30 summarizes the results from the 7 experiments (cases).

Benchmarking:

The benchmarking in our experiments is done through having a contextual case where all the contextual conditions are within normal boundaries. Hence, the business process flows according to its default paths without any changes in flow due to any recommendations related to contextual conditions. We therefore take the financial cost and the execution time of the business process under this contextual case as the benchmark. We compare the cost of the different runs that take different alternative paths (according to the context-awareness and goal-orientation conditions) with this benchmark to identify the financial cost variance and the execution time variance.

Within this set of experiments on the Pay Bill business process the benchmark case is case 7.

Table 30, Pay Bill Experimental Results Summary

Context Case	Run Situation	Recommended Business Process Execution path	Financial Cost Reduction (%)	Execution Time Reduction (%)
The first case represents a small number of counters while all other conditions are normal. The strategy is maximizing quality of service on the top of everything.	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay using credit card)	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive Payment Receipt (10) The main recommendation was redirecting bill self-service counters	Run 1 Cost with Context-awareness= $ 25 Run 1 Cost Without Context-awareness = $ 50.7 Cost Reduction = 50 %	Run 1 Execution Time with Context-awareness=0.65 hour Run 1 Execution Time without Context-awareness= 1.51 hour Execution Time Reduction = 60%
The second case represents a cost cutting strategy and a crowded while everything	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive	Run 1 Cost with Context-awareness= $ 25 Run 1 Cost Without	Run 1 Execution Time with Context-awareness=0.

else is normal	pay using credit card)	Payment Receipt (10) The main recommendation was redirecting bill self-service counters as it is the cheapest path to go with the cost cutting strategy	Context-awareness = $ 50.7 Cost Reduction = 50 %	65 hour Run 1 Execution Time without Context-awareness= 1.51 hour Execution Time Reduction = 60%
	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay by Cheque)	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive Payment Receipt (10) The main recommendation was redirecting bill self-service counters as it is the cheapest path to go with the cost cutting strategy	Run 2 Cost with Context-awareness= $ 25 Run 2 Cost Without Context-awareness = $ 59.7 Cost Reduction = 58 %	Run 2 Execution Time with Context-awareness=0. 65 hour Run 2 Execution Time without Context-awareness= 1.79 hour Execution

				Time Reduction = 63.7%
The third case represents a conditions were all resources are abundant and it is a crowded evening yet all human resources are novice	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay using credit card)	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive Payment Receipt (10) The main recommendation was redirecting bill self-service counters.	Run 1 Cost with Context-awareness= $ 25 Run 1 Cost Without Context-awareness = $ 50.7 Cost Reduction = 50 %	Run 1 Execution Time with Context-awareness=0.65 hour Run 1 Execution Time without Context-awareness= 1.51 hour Execution Time Reduction = 60%
	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay by Cheque)	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive Payment Receipt (10) The main	Run 2 Cost with Context-awareness= $ 25 Run 2 Cost Without Context-awareness = $ 59.7	Run 2 Execution Time with Context-awareness=0.65 hour

		recommendation was redirecting bill self-service counters .	Cost Reduction = 58 %	Run 2 Execution Time without Context-awareness= 1.79 hour Execution Time Reduction = 63.7%
Case 3 Continuation	Run 3 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cash)	Start (1), Redirect to Bill Self Payment Device (8), Enter Credit Card at Machine (9), Receive Payment Receipt (10) The main recommendation was redirecting bill self-service counters .	Run 2 Cost with Context-awareness= $ 25 Run 2 Cost Without Context-awareness = $ 40.7 Cost Reduction = 38.6%	Run 2 Execution Time with Context-awareness=0.65 hour Run 2 Execution Time without Context-awareness= 1.46 hour Execution Time Reduction =

				55.5%
The fourth case is a crowded evening, with everything normal except that some credit card machines are down	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay using credit card)	Start (1), Issue Turn Number (2) , Get a Bill copy (3), Use Credit Card Machine of Self Service Counter (9) Receive Payment Receipt (10) The main recommendation was using the credit card machines embedded in the bill self-service devices	Run 1 Cost with Context-awareness= $ 48.7 Run 1 Cost Without Context-awareness = $ 50.7 Cost Reduction = 4 %	Run 1 Execution Time with Context-awareness=0.65 hour Run 1 Execution Time without Context-awareness= 0.65 hour Execution Time Reduction = 0%
The fifth case is a crowded evening, with everything normal except that some bill printing machines are done	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay using credit card)	Start (1), Issue Turn Number (2) , See Bill at Self Service Counter (8), Pay using Credit Card (5) Receive Payment Receipt (10) The main	Run 1 Cost with Context-awareness= $ 43.7 Run 1 Cost Without Context-awareness = $ 50.7 Cost Reduction = 14	Run 1 Execution Time with Context-awareness=0.48 hour Run 1 Execution

		recommendation was check the bill at the self-service device then come back to the normal payment process	%	Time without Context-awareness= 0.65 hour Execution Time Reduction = 26%
Continuation of Case 5	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cash)	Start (1), Issue Turn Number (2) , See Bill at Self Service Counter (8), Pay in Cash (6) Receive Payment Receipt (10) The main recommendation was check the bill at the self-service device then come back to the normal payment process	Run 2 Cost with Context-awareness= $ 33.7 Run 2 Cost Without Context-awareness = $ 40.7 Cost Reduction = 14%	Run 2 Execution Time with Context-awareness=1.29 hour Run 2 Execution Time without Context-awareness= 1.46 hour Execution Time Reduction = 26%
Continuation of	Run 3 (A user who wanted to	Start (1), Issue Turn	Run 2 Cost with	Run 2

Case 5	start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cheque	Number (2) , See Bill at Self Service Counter (8), Pay in Cheque (7) Receive Payment Receipt (10) The main recommendation was check the bill at the self-service device then come back to the normal payment process	Context-awareness= $ 52.7 Run 2 Cost Without Context-awareness =$ 59.7 Cost Reduction = 14%	Execution Time with Context-awareness=1.62 hour Run 2 Execution Time without Context-awareness= 1.79 hour Execution Time Reduction = 26%
The sixth case is the company adopting cost cutting strategy, a crowded evening and self-service payment devices are few	Run 1 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cheque	Start (1), Issue Turn Number (2) , Get Bill Print out (3), Pay in Cash (6) Receive Payment Receipt (10) The main recommendation is enforcing people to pay cash to avoid extra cost and time or	Cost with context-awareness= $ 40.7 Cost without context-awareness= $ 59.7 Cost Reduction=31.8%	Execution time with context-awareness=1.46 hour Execution time without context-awareness= 1.79 hour Time

		cheque and credit card validations		Reduction=18.4 %
Sixth case continued	Run 1(A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Credit Card	Start (1), Issue Turn Number (2) , Get Bill Print out (3), Pay in Cash (6) Receive Payment Receipt (10) The main recommendation is enforcing people to pay cash to avoid extra cost and time or cheque and credit card validations	Cost with context-awareness= $ 40.7 Cost without context-awareness= $ 50.7 Cost Reduction=20%	Execution time with context-awareness=1.46 hour Execution time without context-awareness= 1.51 hour Time Reduction=4 %
The seventh case is the bench mark case were all conditions are normal so the business process moves in its default flow	Run 1 A user intended to user self-service payment	Start (1), Issue Turn Number (2) , See Bill at Self Service Counter (8), Pay using Credit Card (5) Receive Payment Receipt (10) There is no recommendations this is default path as per the user choice	Run 1 Cost Without/with Context-awareness = $ 25	Run 1 Execution Time without/with Context-awareness= 0.65 hour

Case Seven Continued	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cash	Start (1), Issue Turn Number (2) , Get Bill Print out (3), Pay in Cash (6) Receive Payment Receipt (10) There is no recommendations this is default path as per the user choice	Cost with/without context-awareness= $ 40.7	Execution time with/without context-awareness=1.46 hour
Case Seven Continued	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay in Cheque	Start (1), Issue Turn Number (2) , Get Bill Print out (3), Pay in Cheque (7) Receive Payment Receipt (10) There is no recommendations this is default path as per the user choice	Cost with/without context-awareness= $ 59.7	Execution time with/without context-awareness=1.79 hour
Case Seven Continued	Run 2 (A user who wanted to start a normal payment to a person , no self-service device is waiting, his bill is valid and he was intending to pay using credit card	Start (1), Issue Turn Number (2) , Get Bill Print out (3), Pay using Credit Card (5) Receive Payment Receipt (10)	Cost with/without context-awareness= $ 50.7	Execution time with/without context-awareness=1.51 hour

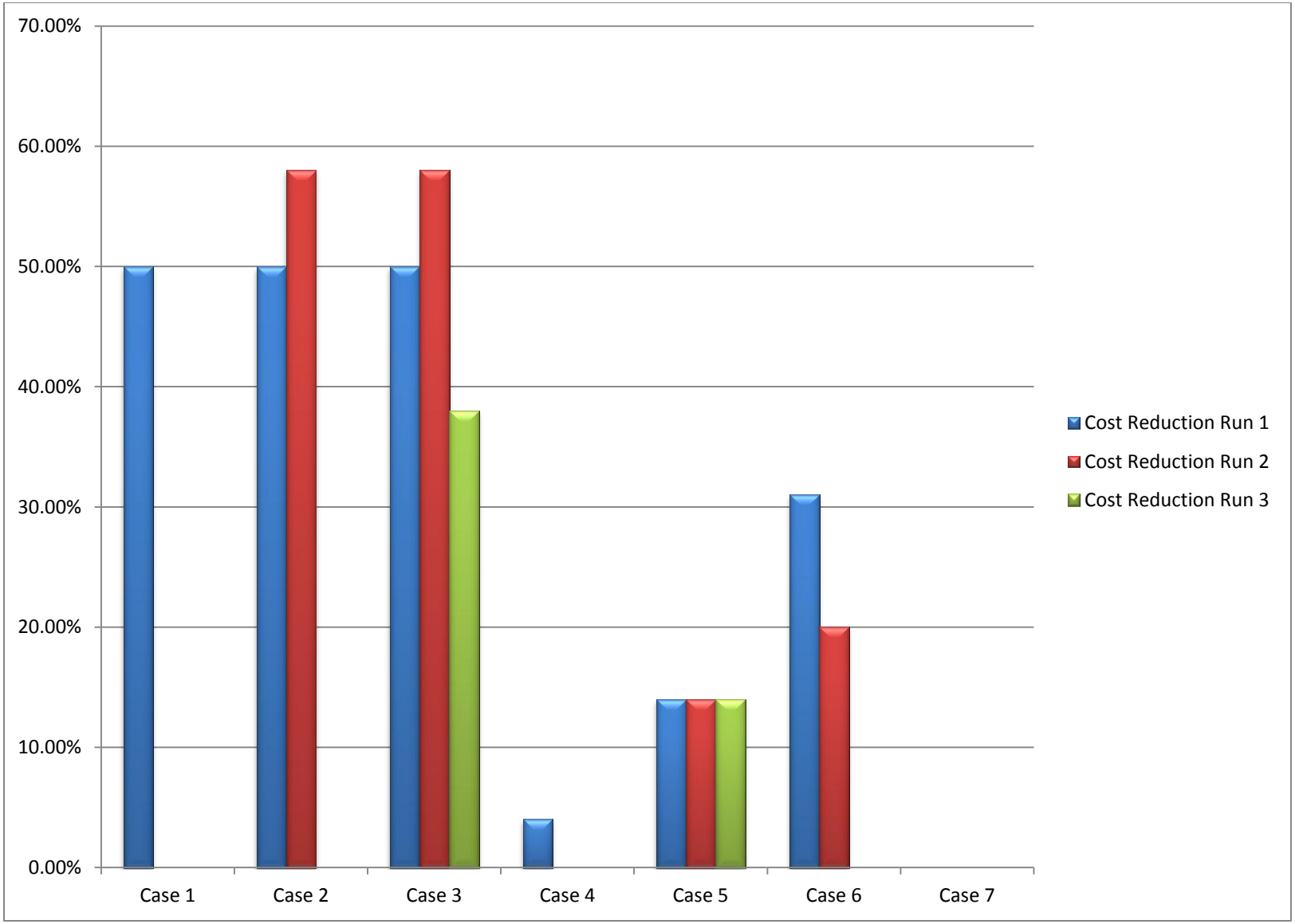

Figure 69: Telecom Business Process Cost Variance Summary

In figure 69 we summarize the cost reduction results of the major runs simulated for the Telecom pay bill business process. Not all the contextual cases were tested on 3 runs as sometimes the contextual situation would lead to the same recommendation whether the subscriber intended initially to pay in cash or cheque or by credit card like in case 1 (where the contextual situation that was tested on the pay bill business process represents a small number of counters while all other conditions are normal. The strategy is maximizing quality of service on top of everything.). In case 1 it was sufficient to make only one run which was for a user who wanted to start a normal payment to a person, i.e. no self-service device is waiting, his bill is valid and he was intending to pay using credit card.

Case 7 shows zero time saving as this is the benchmark case where there is no context-awareness of any kind being simulated.

For the financial cost reduction we note a strong fluctuation from an improvement of cost as high as 67% to only 4%. The reason is that in the case where there is a limitation of resources we have a limited number of alternative paths to take. So if we only apply a minor alteration to the process (whether we only need this minor alteration to achieve the process goals or whether we are limited because of resources or a complex contextual situation) we will get a small improvement like 4 %. Whereas when we decide on a major alteration such as redirecting the users to self -service payment devices we get a much higher cost reduction. However, even a 4 % reduction in cost given that this business process is repeated in different payment stores thousands of times a day, a 4 % means saving millions in the short run and of course more benefits on the long run.

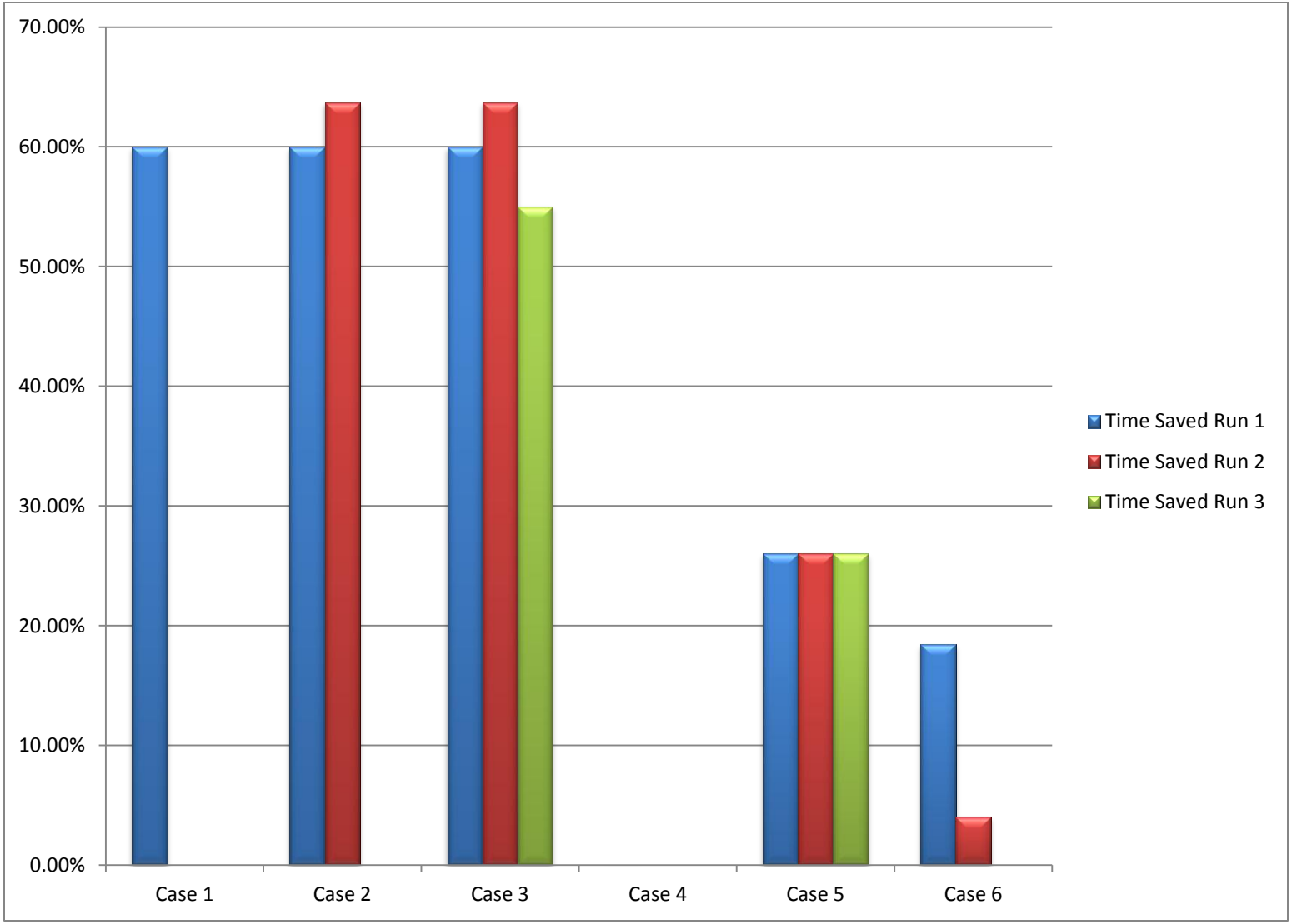

Figure 70: Telecom Business Process Execution Time Variance Summary

In figure 70 we summarize the time saving results of the major runs simulated for the Telecom pay bill business process. Not all the contextual cases were tested on 3 runs as sometimes the contextual situation would lead to the same recommendation whether the subscriber intended initially to pay in cash or cheque or by credit card like in case 1 (where the contextual situation that was tested on the pay bill business process represents a small number of counters while all other conditions are normal). The strategy is maximizing quality of service on the top of everything.. In case 1 it was sufficient to make only one run which was for a user who wanted to start a normal payment to a person, no self-service device is available, his bill is valid and he was intending to pay by credit card.

Case 7 shows zero time saving as this is the benchmark case where there is no context-awareness of any kind being simulated.

For the execution time reduction we note the same kind of fluctuation this time from 63 % to 0%. And the reason why we have extremely low or even no reduction in the execution time is that sometimes we are just solving a problem (e.g. lack of kiosk counters) but the alternative path does not save us time. It might be our only option or might save us some other financial cost or material cost but not time as in the contextual case four of our experimental results. Of course, the higher reduction in time which in many cases was around 60 % proves that the throughput would increase and the Telecom bill payment can take place with the contextual awareness and goal orientation of business process models. This in turn would also save millions and maximize the business profit in the short run and consequently on the long run.

The General Average of Financial Cost Reduction of all the runs = Summation of Cost Reductions of all runs/number of runs = 33.4 %

The General Average of Execution time saved in all runs = Summation of Execution times Reductions of all runs/number of runs=38.5%

The Overall Quality/Effectiveness of the model as per equation 6 in section 1.1.3 (Evaluation Criteria) =

(Summation of Financial cost reduction/ the number of business processes runs that Financial cost reduction was calculated for) * Weight of F

+ (Summation of Time reduction/ the number of business processes that Time reduction was calculated for) * Weight of TV

Assuming the we give equal weight to the financial cost as well as the time cost (0.5 each as the total of all weights should be one), the overall results of the model from the tests done on the Telecom bill payment–process showed

improvement in the effectiveness of the decision making based on goal orientation and appropriate modeling of context by (33.4%*0.5+38.5%*0.5) = 35.9 %. This is a significant percentage given that in real life and across different payment points in the process executions for millions of times every day an enhancement of 35.9% means millions of savings only on the short run.

Our experiments gave promising results with the appropriate sensation and modeling of a business process context in terms of contextual aspects segmented into contextual layers. When each layer has a well-defined business-oriented goal and models a business process in terms of a finite state machine that decides on the best next move (according to recommendations defined by business process experts and related to context of the step) the net result is a significant positive effect on reducing the financial cost of business processes and enhancement of the throughput (i.e. the number of business processes that get executed within a certain time period or time frame). The goal-oriented business process experimental results also show that our solution methodology proves to be a generic one (that is, not tailored for a specific business process or business processes within a certain industry) but that it can be adopted by any business process within any industry and that it can create significant enhancements in terms of cost and execution time as a result of the business process adaptation based on context-awareness and goal-orientation.

From both the financial cost reduction and execution time reduction on the short run and in various business processes from various industries, we foresee promising results for context-aware goal-oriented business process modelers on the long run. There are definitely more complex and detailed ways of measuring the effectiveness of the proposed solution methodology but that needs a detailed research on its own.

Chapter 5: Summary and Conclusion

5.1. Summary of the Research

In this research we proposed a methodology for sensation and identification of the different types of business contextual elements. Our solution models the contextual elements related to different business domains by building a library of aspects for each business domain embedded within an existing context-awareness framework. The framework we selected is the Java Context-awareness Framework (JCAF). The output of the extended Context-awareness framework is a set of apsectized contextual elements related to business processes for a specific industry. The aspectized contextual facts are represented as triggers to configure the affected business processes. The business processes themselves are modeled as goal driven finite state machines that take both goals and context into consideration when deciding on the next best state (business process step to move to). This leads to an intelligent decision-making process which is sensitive to the context of the business processes and their goals. The latter become dynamically updatable by business process experts to incorporate the constant changes in business environments. Our methodology of aspectizing context-awareness for business processes could be summarized in the following tasks:

5.1.1. Context Sensation, Identification and Modeling

Initially we focused on the following contextual aspects: Non human resource utilization, human resource utilization, human resource experience level, organizational strategies (i.e. the strategies of the organization on which the business process is running e.g. whether the strategy is cost cutting or quality focused), the risk factors associated with a process, industry regulations and practices affecting a process, timing, season, and location. Yet we designed our solution methodology to be extensible to cater for any other contextual aspects. We used the JCAF framework and extended it to support the representation of business process context in terms of aspects.

5.1.2. Context Classification

After appropriately extracting and sensing contextual information, we classify the contextual data on the four contextual layers: Immediate, internal, external and environmental.

The importance of context classification lies in the fact that the layer to which a contextual variable, or its constituent elements belong, defines the level of impact of this contextual variable or element on the

business. In more specific terms, each contextual layer would have a specific set of known goals (whether high level business goals or operational goals) that it impacts (i.e. the contextual variables or elements that belong to this contextual layer and would in turn impact the high level goals and operational goals that this contextual layer impacts). The goals that are impacted by each of the four contextual layers are defined but would differ for each industry considered within the scope of our framework. It is through these important links between the contextual variables and constituent elements and goals that we are able to identify which contextual variables affect which business process. As we link the goals of the business process with the goals of the contextual variables and detect the common goals, we identify which contextual variables and elements affect which business processes and consequently which business process steps to take.

The contextual variables/elements classification is not done automatically as it would differ from one industry to another and various industry experts may have their different views about them (e.g. weather could be an immediate context item in one industry while in another industry it could be an environmental context item). As a result, the most appropriate approach for classification that was adopted is to involve the industry (domain)/business process experts by allowing them to define their own classification in an easily updatable way. Hence we have two repositories, a repository for each industry/ business domain (where the business domain experts define in a near natural language syntax or using simple graphical forms the industry goals, the most important context elements related to the industry, the business processes under this industry) and another business process repository defined by business process experts (which stores the information related to the business process steps and alternatives, the business process specific goals as well as possible recommendations for the business process flow).

5.1.3. Business process modeling and configuration

The business process is represented in our framework as a sequence of states. Moving from one state to another is done by identifying certain conditions and according to these conditions the business process moves to the next best state. For the business process configuration to take place based on the context of the business process and its goals, the following steps are taken:

1) Identifying which aspectized contextual variables/ elements affect which business processes and which steps to take within these processes. This is achieved by identifying the goals of the business process under investigation. It comes by studying the business behind the process and the wider picture that the

business process fits in, which comes from the understanding of the overall business domain. As mentioned above, the goals of the company are to be placed in a goals repository within a certain industry repository. For each company repository that we have business processes defined for, the definition incorporates the goals of the process, the states (business process steps), the goals of each state (business process step) and the conditions needed to move from one state to another (these conditions are of course related to the context of the process). These definitions are made through a simple graphical interface and are updatable by business experts.

2) Comparing the goals of the business process to the goals of the different aspects of contextual elements that are of interest to the company under which the business process falls and detecting any common goals. If common goals are found then the business process is affected by the context and through common goals we are able to identify which business process steps are affected.
3) Matching the contextual elements that are affecting a certain business process according to the goals. The business process experts must define a recommendation for the next best step based on ranges of values of these contextual elements.
4) Registering the business process interest in contextual aspects of common goals and this takes place through existing functionalities in JCAF. The business process runs and is triggered by changes in the contextual aspects it registered in. According to the changes in values of the contextual aspects and the conditions of jumping from one state/business process step to another (as per the business process definition), the business process decides on the best sequence of steps/states to take given a certain contextual input at a specific instance in time.

5.2. Summary of Experimental Results

For the sake of proving our concept and the effectiveness of our solution methodology we created a prototypical framework extending the classes of JCAF on eclipse 3.7 and we tested the framework on two business processes coming from two different industries which are the check-in business process from the airlines industry and the cellular phone bill payment business process from the Telecom industry. The results were very promising.

For the check-in business process from the airlines industry the average financial cost reduction of all runs was around 12 % and the average reduction in execution time was around 34 % and the summation of the weighted reduction in all types of costs was around 23 %. These percentages are significant given that in real life and across world airports, the check -in process execution is done millions of times every day so an enhancement of 23% means millions of monetary unit savings only on the short run.

For the bill payment business process from the telecom industry the average financial cost reduction of all runs was around 33.4 % and the average reduction in execution time was around 38.5% and the summation of the weighted reduction in all types of costs was around 35.9% which is a significant percentage given that in real life and across different payment points in the process, executions are done for millions of times every day so an enhancement of 35.9% means millions of monetary unit savings only on the short run.

From the obtained results we deduce that the appropriate sensation and modeling of a business process context in terms of contextual aspects segmented into contextual layers is a very promising advancement in the field of business process modeling. By letting each layer have business oriented goals and modeling a business process in terms of a finite state machine that decides on the best next move (according to recommendations defined by business process experts and related to context of the step) we arrive at a significant positive effect on reducing the financial cost of business processes and enhancing the throughput (the number of business process that could be executed within a certain time period or time frame). In addition, we can deduce from experimental results that our solution methodology is a generic one as it is not tailored for a specific business process or business processes within a certain industry but can be adopted by any business process within any industry and it can create significant enhancements in terms of cost and execution time as a result of the informed business process adaptation that is both context-aware and goal-oriented.

5.3. Challenges Faced

In the course of this research we faced a number of challenges with our solution methodology, framework and testing results.

The first challenge was on how to represent the next best move from one state to another in our finite state machine. We solved this by enabling the business process expert to define transitional conditions as a combination of logically "anded" and "ored" post state conditions and contextual conditions (the contextual conditions are related to the context item related to the step goals as described above in section 5.1).

The second challenge was on how to handle controversial contextual situations that would create a perplexing situation where a certain business process recommendation/configuration maximizes a certain goal yet harms another goal. We addressed this challenge by placing a priority for every goal and this priority is configurable by the business process expert and hence whenever a controversial decision arises we resolve it by taking the recommendation that is related to the higher priority goals. If we have more than one goal at the same priority level, we take a weighted average of the goals and then take the recommendation in favor of the highest weighted average of the priority of goals.

The third type of challenge was related to the implementation details of our proof of concept framework. These may be summarized as follows:

- Understanding the tools to be extended and adapting their logic. This was resolved in cooperation with the owners of these tools.
- Extending JCAF to include aspectization especially that the JCAF framework never included in their roadmap the idea of aspects and their relation to contextual items. This was understandable as there is no substantial research in the area of aspectization of contextual elements yet.
- Researching and understanding about Aspect oriented development and how it could be merged with JCAF
- Finding an AspectJ development tool that could incorporate the normal JCAF java implementations and the aspect implementation and compiling them in a homogenous manner

The fourth and probably the most challenging part in this research was finding a methodology through which the effectiveness of modeling the context of business processes and modeling the business process as a goal

driven finite state machine and linking context to goals (to define which context affects which business decisions) could be measured. The evaluation was not easy and could be considered in more details in a separate research on its own. We believe that different business decisions can be evaluated on two levels: the ability to maximize profit on the long run and the ability to maximize profit on the short run. In our experimental work we relied on the fact that any measure that is taken even for the short run should have its impact assessed even if it is very mild on the short run. Hence, we established our evaluation criteria to two types of cost: the financial cost which is the human resource and material cost of a business process, and the execution time of the business process. We also added a third measure which is a weighted average of those two measures where each measure is given a weight (from 0 to 1) according to its relevance to the business and thus we end up with a single absolute number to measure the effectiveness of our model. In our case, we do not make the decision as the business process expert is the one who defines the recommendations however we do provide a tool for the business process expert to find out if his/her recommendations were in the right direction or not.

5.4. The Research Contributions

In this research we presented a new general purpose methodology for aspectized modeling of the context of business processes within the different business domains and also for modeling business processes as goal-oriented finite state machines. We envisioned how context may be conceptualized, how contextual elements may be distributed across business operational levels according to the goals of the business process, and how business process flow recommendations based on the aspectized contextual facts may materialize. We designed our methodology in a way that is practically usable, easily understandable and updatable by business domain experts. We designed a prototype framework as a proof of concept by extending the JCAF framework to allow us to take an experimental approach. We tested our framework within the Airlines and Telecom business domains and showed that higher business profits may be achieved by reducing financial cost and increasing throughput. The experimental results using this framework indicate the direction to be very promising and the framework itself to be a starting contribution to intelligent business decision making that is based on context-awareness and goal-orientation. In fact, the results assert the importance of further investigations in integrating context-awareness, context modeling and goal-orientation in the field of business process modeling as well as configuration and decision making. We summarize our major research contributions as follows:

- Conceptualizing the use of context-awareness within the field of business process modeling
- Extending the currently existing java context-awareness framework to cater for modeling of business processes context
- Making use of the advancement in context sensation and awareness research in a new field which is business process context-awareness
- Modeling context of the business process as aspects (cross cutting concerns) for the first time in aspect oriented research and applications
- Introducing a goal-oriented business process modeling technique that tightly bounds the business process context to the business goals and hence utilizes the context-awareness in achieving the different business goals according to their priority
- Defining a generic solution methodology and framework for context-aware goal-oriented modeling that could be easily adopted by various business/industrial domains
- Building our solution methodology on a business knowledge base that is fully defined by business experts and enabling business experts to update this business knowledge base in a simple manner
- Establishing a preliminary evaluation method for our solution methodology and framework. In this evaluation method the evaluation criteria are based on various aspects of financial cost as well as business process execution time which are among the main business profitability drivers.

We see this research as an addition to the adoption of context-awareness methodologies and modern technologies in business process modeling and we believe that it opens the door for more research in the area of intelligent business environments. We also foresee that there are more interesting research topics in this area that need the attention of the research community. Some of these research topics are listed below in the next section.

5.5. Future Work

The idea of aspectizing context-awareness within business processes and tightly binding the business process configurations to business goals and business context is a fairly new area of research and based on our literature review, very few researches were in fact conducted in this area. Hence, there are several future directions to go further. The most important future extensions to this research may be summarized as follows:

- In real business the relationship between goals is many to many. In our framework we identify a sub-operational goal that can contribute to more than one strategic goal but for simplicity, we do not model the relationship between the strategic goals and themselves (i.e. a strategic goal cannot be a sub-goal to another strategic goal) and we maintain the goals at two levels of depth while in real business they could go to endless levels. The goals' depth level and relationship to each other is an important area for future enhancement and research to make the solution methodology capable of simulating real complex business environments.
- The relationship between contextual aspects and each other and how they impact each other was not included in our investigations, yet in real business environments there may be a variety of relationships between the different contextual aspects. This is another area that needs further research.
- The prioritization of contextual aspects and their conflict resolution in association with the business goals is another part that needs further investigation in our framework. We handle it in a simple way and give priority to contextual aspects related to goals of higher priority but in real business environments the situation might be more complex to achieve a more robust, goal-oriented, context-aware prioritization scheme.
- The knowledge base for industries, companies and business processes information in our proposed solution methodology relies on the industry and company experts input and their updates. An important future direction is to develop this knowledge base to be a self -learning knowledge base that accumulates previous knowledge and learns from various cases and this could be done using neural networks or other artificial intelligence techniques. In this case the knowledge base will not only rely on the input from the industry and company experts but it will have its own guidelines for every industry so that it can even suggest decisions and guide the experts.

- Our solution methodology and prototypical framework concentrated on nine contextual aspects (Material utilization, Human resource utilization, Human resource experience level, Timing, Season, Strategy, Risk factors, and Industry regulation) and it provided an easy way to add new aspects An interesting area of research could be providing the business users with questions that help them identify the exact contextual aspects that they need to consider for their business in addition to those nine aspects.
- Our solution methodology classifies the contextual aspects into the four main contextual layers (immediate, internal, external and environmental) at the industry level. However, in some very special business cases the business process expert might need to re-define this classification on the business process level. Studying the impact of defining the contextual aspects classification on the business process level versus the industry level is an interesting future area of research.
- In our prototypical framework, the business process is modeled in terms of finite state machines. The modeling of more complex business processes could use petri-nets to represent the concurrently running objects as concurrency is sometimes considered an important requirement within the area of business process modeling.
- Our solution methodology focused on non-predictable contextual aspects that need to be sensed and accordingly the business process flow could change. However, there is an important set of predictable contextual aspects that are expected at certain timings or seasons. Hence, another future area of research could be analyzing those predictable contextual aspects for every industry and embedding pre-defined recommendations for business process flow that may be followed when those predictions become true.

- The evaluation methods in our proposed solution methodology could also pave the way for a separate track of future work. The first step in this research could be finding normalization criteria for the different types of costs of a business process. Also, discovering the correct measures and statistics of business improvement is a research area on its own. The future research needs to show detailed evidence that appropriate context modeling enhances the business process configurations and decision making. This was not a core part of the research as what we have done is only a preliminary step into trying to evaluate the effectiveness of context modeling within the business process modeling domain from a cost-effectiveness perspective. However, it opens the door for further work to evaluate and

investigate the effectiveness of context modeling within the business process modeling domain and relating it to financial cost. Of course, measuring the effectiveness of context modeling is a fairly complicated task that goes beyond cost. As in some cases cost might increase after context modeling but there is more customer satisfaction or it might be that the cost increases now and decreases in the long run. There are many parameters involved and the process of measuring their effectiveness might require more than one research effort on its own.

Appendices

Appendix I

In this appendix we show the structure of the contextual knowledge XML file that is available for each industry examined within our framework.

```
<Ontology xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.cs.aucegypt.edu /Context Definition
http://www.cs.aucegypt.edu/OntologySchema.xsd"
xmlns="http://www.cs.aucegypt.edu /Context VariablesValuesSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">

<!—Contextual Knowledge -->
<Industry>Airlines </Industry>
<Immediate Layer>
<Context Aspect name=”Human Resource Utilization”>
<Context Variable>
< name> Employee Number </name>
<max>10<max>
<min> 1<min>
<Context Variable>
</Context Aspect>
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<Context Aspect name=”Material Utilization”>
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<max>10<max>
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</Context Aspect>
</Immediate Layer>
<Internal Layer>
<Context Aspect name=”Risk Factors”>
<Context Variable>
< name>Counters Failure </name>
<max>10<max>
<min> 1<min>
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</Internal Layer>
```

Appendix II

In this appendix we show the structure of the company goals matrix XML file that is available for each industry examined within our framework.

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<Ontology xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.cs.aucegypt.edu /Context GoalsSchema
http://www.cs.aucegypt.edu/OntologySchema.xsd"
xmlns="http://www.cs.aucegypt.edu /Context GoalsSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">

<!—Context Layers Definition -->
<Industry>Airlines </Industry>
<Company> British Airways </Company>
<Strategic goal>
<goal name> Increase Profile</goal name>
<goal target> 1 million </goal target>
<goal time frame> 1 year </goal time frame>
<goal priority > 1 </goal priority>
<Operational goals list>
<Operational goal>
<goal name> Attract More Customers</goal name>
<goal target> 1 million </goal target>
<goal time frame> 4 months </goal time frame>
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</Operation goal>
<Operational goal>
<goal name> Cut on Operational costs</goal name>
<goal target> 1 million </goal target>
<goal time frame> 5 months </goal time frame>
<goal priority > 1 </goal priority>
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<goal layer> Internal </goal layer>
</Operation goal>
 </Operational goals list>
</Strategic goal>
```

Appendix III

In this appendix we show the structure of the business process XML file that is available for each industry examined within our framework.

```
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http://www.cs.aucegypt.edu/OntologySchema.xsd"
xmlns="http://www.cs.aucegypt.edu /BusinessProcess Schema"
elementFormDefault="qualified" attributeFormDefault="unqualified">

<!—Business Process Definition -->
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<business process name>  Check-in  </business process name>
<business process goals>
<Strategic goal>
<goal name> Increase Profit</goal name>
<goal target> 1 million </goal target>
<goal time frame> 1 year </goal time frame>
<goal priority > 1 </goal priority>
<Operational goals list>
<Operational goal>
<goal name> Attract More Customers</goal name>
<goal target> 1 million </goal target>
<goal time frame> 4 months </goal time frame>
<goal priority > 1 </goal priority>
<goal layer> Immediate </goal layer>
</Operation goal>
<Operational goal>
<goal name> Cut on Operational costs</goal name>
<goal target> 1 million </goal target>
<goal time frame> 5 months </goal time frame>
<goal priority > 1 </goal priority>
<goal layer> Immediate </goal layer>
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          </Operational goals list>
</Strategic goal>
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</Operation goal>
</step goals>
<Step PreCondition>
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<Condition value> <Condition value>
<next step> 15</next step>
</Condition>
</Step Transition>
</step>
</business process steps>
</step>

Appendix IV

The table in this appendix represents the full definition of the Airlines Check-In Process with all its steps, their pre-conditions, their post-conditions, their goals and the transitional recommendation conditions.

Step ID	Step Name	Goals	Pre-Conditions	Post Conditions	Recommendations
1	Start	Profit- Attract More Customers, Profit – Cut on operational cost, Quality of Service-Higher Customer Satisfaction, Face Competition-Higher Customer Satisfaction	Have E-Ticket, Have Been Checked at the gate, Is not a banned traveler	Valid Traveler & Normal Check-in, Valid Traveler & Kiosk Check-in , Valid Traveler & Web Check-in	If Valid Traveler & Normal Check-in & [Number of Check-in Counters is small (1 to 200) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit

					maximization and cost cutting then Go to Step 5 Kiosk Check-in] Priority=1.64 If Valid Traveler & Normal Check-in& [Enough counters, &staff & normal season & quality maximization strategy Go to Step 2] Priority=1.64 If Valid Traveler & Kiosk Check-in & [Number of Kiosk Counters is small (1 to 50) Or The season is Holiday Season Or The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then

					Go to Step 12 Web Check-in (Cheapest kind of check-in)] Priority=1.64 If Valid Traveler & Normal Check-in & [Luggage Loaders are few (1 to 200) Go to Step 12 Web Check-in] If Valid Traveler & Kiosk Check-in& [Enough counters, &normal season & quality maximization strategy Go to Step 5] Priority=2 If Valid Traveler & Web Check-in & [Luggage Loaders for web check are few (1 to 50) &

					Kiosk Counters are abundant >50] Go to Step 5 Kiosk Check-in] Priority=1.64 If Valid Traveler & Web Check-in& [Enough counters, &normal season & quality maximization strategy Go to Step12] Priority=2
2	Wait For Normal Check-in	Quality of Service-Increase Customer Satisfaction, Face Competition-Increase Customer Satisfaction,	Valid Traveler	Ready to Check-in as Economy Class, Ready to Check-in as Business Class	If Ready to Check-in As Economy Passenger & [Number of Economy Check-in Counters is small (50 to 150) Or Total staff is small (1 to 200) Or

		Quality of Service- Increase Flexibility with Passengers			Experiences staff ratio to novice staff ratio (10 %-50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Go to Step 4 redirect economy passengers to business counter (if business counters are abundant) till the bottle neck gets better, else go to step 5 (Kiosk log in) or 12 (Web log in)] Priority=1.64 If Ready to Check-in As Economy Passenger

					& [Number of Economy Check-in Counters is small (1 to 50) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<10 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Go to Step 5 (kiosk log in , if abundant number of kiosk counters) or Step 12 web log in (if small number of kiosk counters)

					] Priority=1.64 If Ready to Check-in As Economy & [Enough counters, &staff & normal season & quality maximization strategy Go to Step 4] Priority=1.64 If Ready to Check-in As Business Passenger & [Number of Business Check-in Counters is small (1 to 50) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or

					The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Go to Step 5 (kiosk log in , if abundant number of kiosk counters) or Step 12 web log in (if small number of kiosk counters)] Priority=1.64 If Ready to Check-in As Business & [Enough counters, &staff & normal season & quality maximization strategy Go to Step 3] Priority=1.64
3	Present	Quality of	Ready to	Either Valid	If Invalid documents redirect

	Papers at Business Counter	service-Increase Customer Satisfaction, Face Competition-Increase Customer Satisfaction, Maximize Profit-Cut on operation cost, Maximize Profit-Cost Effective Employment	Check-in as Business Passenger	documents or invalid documents	to step 6 –(Resolve the problem at Airport security office) If valid documents & [Number of Business Check-in Counters is small (1 to 50) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then

					Go to Step 9(luggage registration)i.e. skip the seat choice step] Priority=1.5 If valid documents & [Number of Business Check-in Counters is small (1 to 50) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit

					maximization and cost cutting then & Luggage Loaders are few(<50) Go to Step 12(direct the passengers to luggage loaders of web check-in] Priority=1.4 If valid documents & [Counters, staff are abundant & staff is experienced & normal season & strategy is maximize quality of service) Go to Step 8(Choose Seat Through Agent)] Priority=1.6
4	Present Papers at Economic	Quality of service-Increase	Ready to Check-in as Economy	Either Valid documents or invalid	If Invalid documents redirect to step 6 –(Resolve the problem at Airport security

	Counter	Customer Satisfaction, Face Competition-Increase Customer Satisfaction, Maximize Profit-Cut on operation cost, Maximize Profit-Cost Effective Employment	Passenger	documents	office) If valid documents & [Number of Economy Check-in Counters is small (1 to 150) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Go to Step 9(luggage registration)i.e. skip the seat

					choice step] Priority=1.5 If valid documents & [Number of Economy Check-in Counters is small (1 to 150) Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or The season is Holiday Season Or The Timing is a Morning Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then

					& Luggage Loaders are few(<50) Go to Step 12(direct the passengers to luggage loaders of web check-in] Priority=1.4 If valid documents & [Counters, staff are abundant & staff is experienced & normal season & strategy is maximize quality of service) Go to Step 8(Choose Seat Through Agent)] Priority=1.6
5	Check-in at Kiosk	Profit- Cut on operation costs, Profit-Cost effective employment,	Valid Traveler	Ready for Automatic document scan	If Invalid documents redirect to step 6 –(Resolve the problem at Airport security office)

		Quality- Increase Customer satisfaction, Face Competition- Increase Customer satisfaction			If valid documents & [The season is Holiday Season Or The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters Are Abundant>50 Go to Step 12(Skip Seat Choice & luggage registration at check-in counters)] Priority=1.4 If valid documents & [The season is Holiday Season Or The Timing is a Morning Time

					Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters Are Small>50 Go to Step 9(luggage registration at normal kiosk luggage loaders , yet skip Seat Choice)] Priority=1.4 If valid documents & [The season is Normal Season Or The Timing is not Morning Time Or Strategy is Quality Control & Go to Step 11(Automatic choice of seats)] Priority=1.4

6 (Terminal Step)	Handle Invalid documents at Airport Security Office		Invalid passenger documents	Invalid Passenger	No recommendations as this is a terminal step
7	Automatic Scan of Documents at Kiosk	Quality of service-Increase Customer Satisfaction, Face Competition-Increase Customer Satisfaction, Maximize Profit-Cut on operation cost, Maximize Profit-Cost Effective Employment	Ready for Automatic Document Scan	Either Valid documents or invalid documents	If Invalid documents redirect to step 6 –(Resolve the problem at Airport security office) If valid documents & [Number of Kiosk counters small (1 to 50) Or The season is Holiday Season Or The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters>50

					Go to Step 12(skip seat choice, and register luggage at web check-in loaders)] Priority=1.7 If valid documents & [Number of Kiosk counters small (1 to 50) Or The season is Holiday Season Or The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters<50 Go to Step 9(skip seat choice)] Priority=1.7

					If valid documents & [Counters, staff are abundant & staff is experienced & normal season & strategy is maximize quality of service) Go to Step 11(Choose Seat Through Kiosk Machines)] Priority=1.7
8	Choose Seat through Agent	Profit-Cut On Operation Cost, Profit-Cost Effective employment, Quality of Service- Higher Flexibility with Passengers, Quality of Service- Increase Customer Satisfaction	Valid documents	Seat Chosen	If Seat Chosen & [Number of counters small (1 to 200) Or The season is Holiday Season Or Total staff is small (1 to 200) Or Experiences staff ratio to novice staff ratio (<50 %) Or

					The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters>50 Go to Step 12(register luggage at web check-in loaders)] Priority=1.6 Otherwise, the only choice is to go to step 9(Normal luggage registration)
9	Normal Luggage Registration at Counter	Quality of Service-Increase Customer Satisfaction, Face Competition, Increase Customer Satisfaction	Seat Chosen	Overweight Fine Ticket Issued, or Luggage within weight &Loaded	If Overweight, go to step 13 (Pay fine) Else If Luggage within weight & Loaded , go to step 10 (Issue Boarding Pass)

10(Terminal)	Issue Boarding Path		Luggage Loaded	Boarding Pass Issued & Check-in Process Ended	No recommendations this is a terminal step
11	Choose Seat Your Self at Kiosk	Maximize Profit- Cut on operational costs, Maximize Profit-Cost Effective employment, Maximize Quality of service-High Flexibility with Passengers, Face Competition-High Flexibility with Passengers, Quality of service-Increase Customer Satisfaction	Valid documents	Seat Chosen	If Seat Chosen & [Number of kiosk counters small (1 to 50) Or The season is Holiday Season Or The Timing is a Morning Time Or Strategy is Profit maximization and cost cutting then & Web Check-in Counters>50 Go to Step 12(register luggage at web check-in loaders)] Priority=1.8 Otherwise, the only choice is to go to step 9(Normal

					luggage registration)
12	Drop luggage at web check-in special counters (for luggage only)	Quality of Service- Increase Customer Satisfaction, Face Competition, Increase Customer Satisfaction	The passenger did web check-in	Overweight and Fine issued, or within weight and luggage loader	If Overweight go to step 13 to pay fine Else If within weight go to step 10 to issue boarding pass
13	Pay overweight fine	Maximize Profit- Maximize Price	Overweight	Fine paid	If fine paid go to step 10 to issue boarding pass

Appendix V

In this appendix we illustrate the different contextual situations that the system automatically generates to simulate what takes place in real life and we show for each contextual situation how the business process flows as well as the financial cost and time saved in each case. We show all the major runs that we tested on our system and their output.

Contextual Case One

The following table describes the first contextual situation that was tested on the check-in business process. The first case represents a high season while all other conditions are normal. The strategy is maximizing quality of service on the top of everything else.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	300
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	355
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	355
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	155
Number of Medium Experience Staff	Human Resource Utilization	Immediate	100
Number of Novice staff	Human Resource Utilization	Immediate-Internal	100

Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	0.71 / 71 %
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Winter-Christmas Holiday
Is Profit Maximization	Organization Strategy	Internal	No
Is Cost Cutting	Organization Strategy	Internal	No
Is Quality Focused	Organization Strategy	Internal	Yes
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Luggage Loader failure	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 31, Context Case 1

Given the contextual situation described above in table 3, the business process' optimal flow suggested by the system is as follows:

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to log in):
The steps sequence and cost are shown in table 32:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
3	Present Documents at Business Counter	(0.13 time*10$ labor cost)=1.3	(3 resources number *5$ average cost of different resources) =15	16.5	0.13
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1

Table 32, Run 1 Case 1 Outcome

The main recommendations in this case were to open business counters for economy passengers' and to let the system automatically choose the seat for the passenger.

The total financial cost of business process with context-awareness= $ 35.05

The total financial cost of business process without context-awareness (calculated as the cost default flow of steps) = $ 42.05

The financial cost reduction =((42.05-35.05)/42.05)*100= 16.6%

The total execution time of the business process with context-awareness=0.98 hour

The total execution time of the business process without context-awareness (calculated as the time of the default flow of steps) =1.2 hour

The execution time reduction =((1.2-0.98)/1.2)*100= 18.3%

Run 2(Business Passenger with valid documents and luggage within normal limit wishing to check-in):

The steps sequence and cost are shown in table 33:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
9	Register Luggage at Normal Loaders	(0.17 time * $15)=2.55	2 resources* 5 =10	12.55	0.17
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08

Table 33, Case 1 Run 2 Results

The main recommendations in this case were to open direct business users to the kiosk check-in processes. It is a high standard and a quick service and seats are automatically assigned by the system for the passengers so we skip the seat choice step as well.

The total financial cost of business process with context-awareness= $ 35.05

The total financial cost of business process without context-awareness (calculated as the cost default flow of steps) = $ 36.55

The financial cost reduction = ((41.55-36.55)/41.55)*100= 12.0%

The total execution time of the business process with context-awareness=0.59 hour

The total execution time of the business process without context-awareness (calculated as the time of the default flow of steps) =1.13 hour

The execution time reduction =((1.13-0.59)/1.13)*100= 47.8

Contextual Case Two

Table 34 describes the second contextual situation that was tested on the check-in business process. This second case represents a high season while all other conditions are normal yet the priority strategy is cost cutting and profit maximization.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	300
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	355
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	355
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	155
Number of Medium Experience Staff	Human Resource Utilization	Immediate	100
Number of Novice staff	Human Resource Utilization	Immediate-Internal	100
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	0.71 / 71 %
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Winter-Christmas

			Holiday
Organization Strategy	Organization Strategy	Internal	Yes
Organization Strategy	Organization Strategy	Internal	Yes
Organization Strategy	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 34, Case Two Contextual Situation

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 35:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 35, Run 1 Case 2 Results

The main recommendation was to redirect the passengers to the web-check-in as it is the cheapest kind of check- in. The total financial cost of the business process with context-awareness= $ 17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $ 42.05

The financial cost reduction = ((42.05-34)/42.05)*100=30%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.2 hour

The total execution time variance= (1.2-0.36/1.2)*100= 70%

Run 2(Kiosk Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 36:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 36, Run 2 Case 2 Results

The main recommendation was to redirect the passenger to web check-in as it is the cheapest kind of check-in.

The total financial cost of the business process with context-awareness=$ 17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of business process without context-awareness (calculated as the cost default flow of steps) = $ 41.55

The financial cost reduction = ((41.55-34)/41.55)*100=18.2%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =0.69 hour

The total execution time variance= (0.69-0.36/0.69)*100= 47.8%

Contextual Case Three

Table 37 describes the third contextual situation that was tested on the check-in business process. The third case represents a high season, deficiency in overall staff number and experienced staff and the strategy is cost cutting and profit maximization.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	300
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	355
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	150

Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	20
Number of Medium Experience Staff	Human Resource Utilization	Immediate	30
Number of Novice staff	Human Resource Utilization	Immediate-Internal	100
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	0.33- 33 %
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Winter-Christmas Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	Yes
Is Quality Focused	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 37, Contextual Situation 3

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 38:

Table 38, Run 1 Case 3 Results

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

The main recommendation was to redirect the passenger to the web check-in as it is the cheapest kind of check-in and doesn't need any staff interaction.

The total financial cost of the business process with context-awareness= $17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of business process without context-awareness (calculated as the cost default flow of steps) = $42.05

The financial cost reduction = ((42.05-34)/42.05)*100=30%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.2 hour

The total execution time variance= (1.2-0.36/1.2)*100= 70%

Contextual Case Four

Table 39 describes the fourth contextual situation that was tested on the check- in business process. The fourth case represents a normal season, deficiency in overall staff number and the economy check -in counters and web check-in counters, the selected strategy is the quality focus strategy.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	150
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	30
Boarding Pass Printing Machines	Material Utilization	Immediate	355
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	150
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	50
Number of Medium Experience Staff	Human Resource Utilization	Immediate	50
Number of Novice staff	Human Resource Utilization	Immediate-Internal	50
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	66 %

Timing	Timing	Immediate	Morning
Season	Season	Immediate	Winter-Christmas Holiday
Is Profit Maximization	Organization Strategy	Internal	No
Is Cost Cutting	Organization Strategy	Internal	No
Is Quality Focused	Organization Strategy	Internal	Yes
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 39, Case 4 Contextual Situation

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 40:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
3	Present Documents at Business Counter	(0.13 time*10$ labor cost)=1.3	(3 resources number *5$ average cost of different resources) =15	16.5	0.13
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1

Table 40, Run 1 Case 4 Results

The main recommendations in this case were to open business counters for economy passengers' and to let the system automatically choose the seat for the passenger.

The total financial cost of the business process with context-awareness= $ 35.05

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $ 42.05

The financial cost reduction =((42.05-35.05)/42.05)*100= 16.6%

The total execution time of the business process with context-awareness=0.98 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.2 hour

The execution time reduction =((1.2-0.98)/1.2)*100= 18.3%

Contextual Case Five

Table 41 describes the fifth contextual situation that was tested on the check-in business process. The fifth case represents a high season, deficiency experience staff and the economy check- in counters and the business check- in counters and web check-in counters and the selected strategy is the cost cutting strategy.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	150
Business Check-in Counters	Material Utilization	Immediate	30
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	30
Boarding Pass Printing Machines	Material Utilization	Immediate	355
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	200

Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	50
Number of Medium Experience Staff	Human Resource Utilization	Immediate	0
Number of Novice staff	Human Resource Utilization	Immediate-Internal	150
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	33 %
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Winter-Christmas Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	Yes
Is Quality Focused	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 41, Contextual Situation Case 5

Run 1(Business Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 42:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08

Table 42, Run 1 Case 5 Results

The main recommendation in this case is to direct business users to the kiosk check-in process. It is a high standard and a quick service and seats assigns automatically for the passengers so we skip the seat choice step as well.

The total financial cost of the business process with context-awareness= $ 35.05

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $36.55

The financial cost reduction = ((41.55-36.55)/41.55)*100= 12.0%

The total execution time of the business process with context-awareness=0.59 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.13 hour

The execution time reduction =((1.13-0.59)/1.13)*100= 47.8%

Run 2(Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 43:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08

Table 43, Case 5 Run 2 Results

The main recommendations in this case are to redirect to kiosk log in as well as automatically assigning seats by the system for the passengers so we skip the seat choice step as well.

The total financial cost of the business process with context-awareness=$ 35.05

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $36.55

The financial cost reduction = ((42.05-36.55)/ 42.05)*100= 13 %

The total execution time of the business process with context-awareness=0.59 hour

The total execution time of the business process without context-awareness (calculated as the time of the default flow of steps) =1.2 hour

The execution time reduction =((1.2-0.59)/1.2)*100= 50.8%

Run 3(Web Check-in Passenger with valid documents and luggage within normal limit wishing to check- in):
The steps sequence and cost are shown in table 44:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
9	Register Luggage at Luggage Loaders of Kiosks	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17

Table 44, Run 3 Case 5 Results

The main recommendation is to use the kiosk luggage loaders instead of the web check -in luggage loaders counters to load the luggage. There are no more steps as the user had already done all the steps online 24 hours before hand at the company website.

The total financial cost of the business process with context-awareness= $12.55

The total financial cost of business process without context-awareness (calculated as the cost of the default flow of steps) = $ 10

The financial cost decrease = ((-2/ 42.05)*10= -20 % (Here the cost has increased but we can't help it as there isn't enough web check- in counters)

The total execution time of the business process with context-awareness=0.33 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =0.2 + Extra Weight time due to lack of counter 0.5 hour

The execution time reduction = ((0.7-0.33)/0.7)*100= 53%

Contextual Case Six

Table 45describes the sixth contextual situation that was tested on the check- in business process. The Sixth case represents a high season, a deficiency in overall staff number, and a deficiency in business counters and kiosk counters. The selected strategy is the cost cutting strategy.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	205
Business Check-in Counters	Material Utilization	Immediate	30
Kiosk Check Counters	Material Utilization	Immediate	30
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	250
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	100
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	50
Number of Medium Experience Staff	Human Resource Utilization	Immediate	0
Number of Novice staff	Human Resource Utilization	Immediate-Internal	50
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	50 %
Timing	Timing	Immediate	Morning

Season	Season	Immediate	Summer- Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	Yes
Is Quality Focused	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 45, Contextual Situation 6

Run 1(Kiosk Passenger with valid documents and luggage within normal limit wishing to log in):
The steps sequence and cost are shown in table 46:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 46, Run 1 Case 6 Results

The main recommendation was to redirect the passengers to the web check-in as it is the cheapest kind of check-in and since there is a deficiency in Kiosk counters.

The total financial cost of the business process with context-awareness= $17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $ 41.55

The financial cost reduction = ((41.55-34)/41.55)*100=18.2%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =0.69 hour

The total execution time variance= (0.69-0.36/0.69)*100= 47.8%

Run 2(Business Passenger with valid documents and luggage within normal limit wishing to log in):
The steps sequence and cost shall be as follows are shown in table 47.

Step Id	Step Name	Man Power Cost	Material Cost	Total Financial Cost	Total Execution
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 47, Run 2 Case 6 Results

The main recommendations in this case were to direct the passengers to web check -in.

The total financial cost of the business process with context-awareness= $17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $ 36.55

The financial cost reduction = ((36.55-34)/36.55)*100=7%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time of the default flow of steps) =1.13 hour

The execution time reduction = ((1.13-0.36)/1.13)*100= 68.14%

Contextual Case Seven

Table 48 describes the seventh contextual situation that was tested on the check -in business process. The seventh case represents a high season and deficiency in economy counters. The strategy selected is the cost cutting strategy and there is a risk of a strike of employees so all employees who are working are novice.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	250
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Luggage Loaders	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	305
Total Number of Staff	Human Resource Utilization	Immediate	300
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	0
Number of Medium Experience Staff	Human Resource Utilization	Immediate	0
Number of Novice staff	Human Resource Utilization	Immediate-Internal	300
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	0
Timing	Timing	Immediate	Morning

Season	Season	Immediate	Summer- Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	Yes
Is Quality Focused	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	Yes

Table 48, Contextual Case 7

Run 1(Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 49.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08

Table 49, Run 1 Case 7 Results

The main recommendations in this case are to redirect the passengers to kiosk check-in as well as automatically assign seats by the system for the passengers so we skip the seat choice step as well.

The total financial cost of the business process with context-awareness= $ 35.05

The total financial cost of business process without context-awareness (calculated as the cost of the default flow of steps) =$ 36.55

The financial cost reduction = ((42.05-36.55)/ 42.05)*100= 13 %

The total execution time of the business process with context-awareness=0.59 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.2 hour

The execution time reduction =((1.2-0.59)/1.2)*100= 50.8%

Contextual Case Eight

Table 50 describes the eighth contextual situation that was tested on the check-in business process. The eighth case represents a high season and a deficiency in the economy, business and kiosk counters. The strategy is quality focus.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	100
Business Check-in Counters	Material Utilization	Immediate	30
Kiosk Check Counters	Material Utilization	Immediate	30
Web Check-in Luggage Counters	Material Utilization	Immediate	80
Boarding Pass Printing Machines	Material Utilization	Immediate	200
Luggage Loaders	Material Utilization	Immediate	55
Total Number of Staff	Human Resource Utilization	Immediate	150
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	70
Number of Medium Experience Staff	Human Resource Utilization	Immediate	30
Number of Novice staff	Human Resource Utilization	Immediate-Internal	50
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	66%
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Summer- Holiday
Is Profit Maximization	Organization Strategy	Internal	No
Is Cost Cutting	Organization Strategy	Internal	No
Is Quality Focused	Organization Strategy	Internal	Yes
Check-in Counter failure	Risks	Internal	None
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 50, Contextual Case 8

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 51.

Step Id	Step Name	Man Power Cost	Material Cost	Total Financial Cost	Total Execution
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 51, Run 1 Case 8 Results

The main recommendation is to redirect the passengers to web check-in as it is the cheapest kind of check-in and it could be availed as there is a deficiency in all other types of counters.

The total financial cost of the business process with context-awareness= $17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of the business process without context-awareness (calculated as the cost of the default flow of steps) = $ 42.05

The financial cost reduction = ((42.05-34)/42.05)*100=30%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.2 hour

The total execution time variance= (1.2-0.36/1.2)*100= 70%

Run 2(Business Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 52.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/$
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 52, Run 2 Case 8

The main recommendation in this case is to direct the passengers to web check-in.

The total financial cost of the business process with context-awareness= $ 17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of business process without context-awareness (calculated as the cost of the default flow of steps) = $ 36.55

The financial cost reduction = ((36.55-34)/36.55)*100=7%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =1.13 hour

The execution time reduction = ((1.13-0.36)/1.13)*100= 68.14%

Run 3(Kiosk Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 53:

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 53, Run 3 Case 8 Results

The main recommendation was to redirect the passengers to the web check-in as it is the cheapest kind of check-in and it is the one where we can avail counters now.

The total financial cost of the business process with context-awareness= $ 17 (cost of process running) + $17 per process per time for availing extra laptops and their depreciation

The total financial cost of business process without context-awareness (calculated as the cost of the default flow of steps) = $ 41.55

The financial cost reduction = ((41.55-34)/41.55)*100=18.2%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time taken by the default flow of steps) =0.69 hour

The total execution time variance= (0.69-0.36/0.69)*100= 47.8%

Contextual Case Nine

Table 54 describes the ninth contextual situation that was tested on the check-in business process. The ninth case represents a high season and a deficiency in normal luggage loaders. The strategy is cost cutting focus.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	205
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	200
Luggage Loaders	Material Utilization	Immediate	55
Luggage Loaders	Material Utilization	Immediate	30
Total Number of Staff	Human Resource Utilization	Immediate	200
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	70
Number of Medium Experience Staff	Human Resource Utilization	Immediate	30
Number of Novice staff	Human Resource Utilization	Immediate-Internal	100
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	50%
Timing	Timing	Immediate	Morning
Season	Season	Immediate	Summer- Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	Yes
Is Quality Focused	Organization Strategy	Internal	Yes
Check-in Counter failure	Risks	Internal	No
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 54, Contextual Case 9

Run 1(Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 55.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
4	Present Documents at Economy Counter	(0.2 time*10$ labor cost)=2	3 resources number *5$ average cost of different resources) =15	17	0.2
8	Choose your Seat by an Agent	(0.15 time *$10)=1.5	1 resource *5 average cost=5	6.5	0.15
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1

Table 55, Run 1 Case 9 Results

The main recommendation was go in the flow normally, and yet use the luggage loaders of the web check- in counters.

The total financial cost of business process with context-awareness= $ 39.5

The total financial cost of business process without context-awareness (calculated as the cost default flow of steps) = $ 42.05

The financial cost reduction = ((42.05-39.5)/42.05)*100=6%

The total execution time of the business process with context-awareness=0.36 hour

The total execution time of the business process without context-awareness (calculated as the time of the default flow of steps) =1.2 hour

The total execution time variance= (1.2-1.14/1.2)*100= 5 %

Here we see the variance is minimal as we just replaced one step with another and all the flow is almost the same for the sake of lack of availability of luggage loaders. It will be almost the same case and variance for business passengers'.

Contextual Case Ten

Table 56 describes the tenth contextual situation that was tested on the check-in business process. The tenth case represents a normal situation where there is no deficiency in any resource and it is not a high season and it will be used as the benchmark for the default business process path. All the alternative paths taken to cater for certain contextual situations are compared to this benchmark.

Context Element	Context Aspect	Context Layer	Context Value
Economy Check-in Counters	Material Utilization	Immediate	205
Business Check-in Counters	Material Utilization	Immediate	55
Kiosk Check Counters	Material Utilization	Immediate	55
Web Check-in Luggage Counters	Material Utilization	Immediate	55
Boarding Pass Printing Machines	Material Utilization	Immediate	200
Luggage Loaders	Material Utilization	Immediate	55
Luggage Loaders	Material Utilization	Immediate	30
Total Number of Staff	Human Resource Utilization	Immediate	200
Number of High Experience Staff	Human Resource Utilization	Immediate-Internal	70
Number of Medium Experience Staff	Human Resource Utilization	Immediate	70
Number of Novice staff	Human Resource Utilization	Immediate-Internal	60
Ratio of Experience Staff to Novice Staff	Human Resource Utilization	Immediate-Internal	70%
Timing	Timing	Immediate	Evening
Season	Season	Immediate	Winter-Non Holiday
Is Profit Maximization	Organization Strategy	Internal	Yes
Is Cost Cutting	Organization Strategy	Internal	No
Is Quality Focused	Organization Strategy	Internal	No
Check-in Counter failure	Risks	Internal	Yes
Luggage Loader failure	Risks	Internal	None
Maximum Luggage and weight	Industry Regulations	External	1 piece on board-20 kg
Strike	Force Major	Environmental	No

Table 56, Contextual Situation 10

Run 1 (Economy Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 57.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
4	Present Documents at Economy Counter	(0.2 time*10$ labor cost)=2	3 resources number *5$ average cost of different resources) =15	17	0.2
8	Choose your Seat by an Agent	(0.15 time *$10)=1.5	1 resource *5 average cost=5	6.5	0.15
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1

Table 57, Run 1 Case 10 Results

There are no recommendations in this case based on contextual variance as this is the bench mark case where all conditions are normal and there is no need to change the path of the business process.

The total financial cost of the business process (calculated as the cost of the default flow of steps) =$ 42.05

The total execution time of the business process (calculated as the time taken by the default flow of steps) =1.2 hour

Run 2(Business Passenger with valid documents and luggage within normal limit wishing to check-in):
The steps sequence and cost are shown in table 58.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
2	Wait for Normal Check-in	0	0	0	0.42
3	Present Documents at Business Counter	(0.13 time*10$ labor cost)=1.3	(3 resources number *5$ average cost of different resources) =15	16.5	0.13
8	Choose your Seat by an Agent	(0.15 time *$10)=1.5	1 resource *5 average cost=5	6.5	0.15
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10	Issue Boarding Pass (normal)	(0.1 time * 10)= 1	1 resource *5 average cost=5	6	0.1

Table 58, Run 2 Case 10 Results

There are no recommendations in this case based on contextual variance as this is the bench mark case where all conditions are normal and there is no need to change the path of the business process.

The total financial cost of the business process without context-awareness (calculated as the cost of the default flow of steps) = $ 36.55

The total execution time of the business process (calculated as the time taken by the default flow of steps) =1.13 hour

Run 3(Web Check-In Passenger with valid documents and luggage within normal limit wishing to log in):
The steps sequence and cost are shown in table 59.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
10'	Web Check-in At Available Laptops at Airport & print boarding pass	0	1 resource * 7	7	0.09
12	Drop Luggage at Separate Web Check-in Luggage Loaders	0	2 resources* 5 average cost =10	10	0.11

Table 59, Run 3 Case 10 Results

There are no recommendations in this case based on contextual variance as this is the bench mark case where all conditions are normal and there is no need to change the path of the business process.

The total financial cost of the business process without context-awareness (calculated as the cost default flow of steps) = $ 17

The total execution time (without context-awareness) =0.36 hour

Run 4(Kiosk Check-in Passenger with valid documents and luggage within normal limit wishing to log in):
The steps sequence and cost are shown in table 60.

Step Id	Step Name	Man Power Cost/$	Material Cost/$	Total Financial Cost/$	Total Execution/hour
1	Start	0	0	0	0.16
5	Check-in at Kiosk	0	2 resources *6$=12	12	0.1
7	Automatic Scan of Documents	0	1 resource * 7	7	0.08
11	Choose your Seat Automatically at Kiosk by Yourself	0	1 resource * 5 average cost=5	5	0.1
9	Register Luggage at Normal Luggage Loaders	(0.17 time * $15)=2.55	2 resources* 5 average cost =10	12.55	0.17
10'	Issue Boarding Pass Kiosk	0	1 resource * *5 average cost=5	5	0.08

Table 60 , Run 4 Case 10 Results

There are no recommendations in this case based on contextual variance as this is the bench mark case where all conditions are normal and there is no need to change the path of the business process.

The total financial cost of the business process without context-awareness (calculated as the cost of the default flow of steps) =$ 36.55

The total execution time of the business process (calculated as the time taken by the default flow of steps) =0.6 9 hour

Appendix VI

The table in this appendix represents the full definition of the Telecom Pay Bill Process with all its steps, their pre-conditions, their post-conditions, their goals and the transitional recommendation conditions.

Step ID	Step Name	Goals	Pre-Conditions	Post Conditions	Recommendations
1	Start	Profit- Cut On Costs Profit- Reduce Churn Face Competition – Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Have Postpaid Line	Ready to Pay for Person, Ready to Pay at Self Service Device	If Ready to Pay to Person & [Counters for Payment is small (1 to6) Or Total staff is small (1 to6) And Experiences staff ratio to novice staff ratio (<50 %) Or The Timing is Evening Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Or Issue Turn Machines is down & Self Service Device >3 Go to Step 8 Self Service Payment] Priority=1.5 If Ready to Use Self Service Device & [Self Service Device <3 & Timing = Event Go to Step 2 Wait for Normal Counters] Priority=1.5 Otherwise go for Step 2 Priority =1.6
2	Issue Turn Number	Profit- Cut On Costs Face Competition– Increase Customer Satisfaction	Chose to pay to person	Turn Ticket Issued	If Turn Ticket Issued & [Counters for Payment is small (1 to6) Or Total staff is small (1 to6) And Experiences staff ratio to

		Quality – Increase Customer Satisfaction Competition			novice staff ratio (<50 %) Or The Timing is Evening Time Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then & Self Service Device >3 Go to Step 8 Self Service Payment] Priority=1.5 Otherwise go for Step 2' Priority =1.6
2'	Wait for your Turn	Profit- Cut On Costs Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Have a Ticket	Ticket Number is Displayed and Counter is Ready	If Counter is Ready & [Billing printing machines are few (1 to6) Or Strategy is Cost Cutting & Self Service Device >3 Go to Step 8 Check the Bill at the Device] Priority=1.5 Otherwise go for Step 3 Priority =1.6
3	Get a print out of the bill	Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	At Person payment counter	Bill is printed out	If Not Valid Go to Step 11 (Complaints Department) If Valid Go step 4
4	Choose Payment Method	Profit- Cut on Costs Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Bill is printed out	Payment method chosen (Cash, Credit Card or Cheque)	If Cash Payment Chosen go to Step 10(Receive Payment Receipt) If Cheque Payment Chosen & [Total staff is small (1 to6) And Experiences staff ratio to novice staff ratio (<50 %) Or The Timing is Evening Time

					Or A Portion of staff is on Strike Or Strategy is Profit maximization and cost cutting then Go to Step 6 Enforce Cash Payment] Priority=1.25 If Cheque is chosen and none of the above conditions is true go to Step 7 Priority=1.25 If Credit Card Payment Chosen & [Credit Card Machines are small <3) And The Timing is Evening Time And Strategy is Profit maximization and cost cutting then Go to Step 6 Enforce Cash Payment] Priority=1.25 If Credit Card Payment Chosen & [Credit Card Machines are small <3) Go to Step 9 Use Credit Card Machines of the Self Service Devices] Priority=1.5 If Credit Card is chosen and none of the above conditions is true go to Step 5 Priority=1.25
5	Credit Card Payment	Profit- Cut on Costs Face Competition–	Credit Card Chosen	Payment is Done	Go to Step 10 (Terminal step to receive receipt)]

		Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition			
6	Cash Payment	Profit- Cut on Costs Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Cash Chosen	Payment Done	Go to Step 10 (Terminal step to receive receipt)]
7	Wait at Cheque counter	Profit- Cut on Costs Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Cheque Chosen	Cheque Valid	Go to Step 10 (Terminal step to receive receipt)]
8	Check Bill at Self Service Device	Profit- Cut on Costs Face Competition– Increase Customer Satisfaction Quality – Increase Customer Satisfaction Competition	Self Service Chosen	Bill Valid or Invalid	If In Valid Bill Go to Step 11 (to Complaints Department) If Valid & [Credit Card Machines are few(1 to 3) of down go to Step 6 (enforce Cash collection] Priority 1.2 Otherwise go to step 9 (Enter credit and its info)
9	Enter Credit Card at Self Service Machine & Pay	Face Competition– Increase Customer Satisfaction Quality – Increase	Bill Valid	Credit Card Payment Successful or failure	If Credit Card Payment is Successful go to terminal step 10 to print receipt If Payment is failure redirect to Step 6 (Cash Collection

		Customer Satisfaction Competition			
10	Receive Receipt		Payment Successful	Process Ended with Payment Success	No Recommendations as this is a terminal step
11	Go to Complaints Department		Invalid Bill	Process Ended without Payment due to Complaint	No Recommendations as this is a terminal step

Table 61, Bill Payment Business Process Recommendations Details

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