Lufthansa Aviation Standard: Developing an Open Group Reference Architecture for the Aviation Industry

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Abstract: Since March 2016, architects from Lufthansa and Capgemini have been collaborating on developing an Aviation Reference Architecture (RA), designed to serve as the basis of an Open Group Standard. Central to the development and description of the RA is an Architecture Definition Document (ADD), which explains the RA in its four TOGAF-specific architecture domains, namely the Business Architecture, Application Architecture, Data Architecture and Technology Architecture. In this paper, the RA will be presented in these four aspects, and the "Revenue Management & Pricing" business function has been selected to model and describe the core elements of the RA.

Keywords: Reference Architecture, Aviation, Lufthansa

1   Problem Statement and Motivation

As a complex organization, Lufthansa constantly explores and pursues various activities to improve, standardize and make and the architecture processes and its assets more effective. As part of the IT Management activities, the Architecture Board of Lufthansa decided to invest in drawing up and developing a RA to gain insights and capitalize on the potential a RA provides. Capgemini was chosen as a partner to assist with the development and publication of the RA.

On Lufthansa's side, the project has three business drivers: Firstly, Lufthansa intends to achieve process and time-to-market improvements by avoiding having to educate their relevant suppliers on the way it approaches, structures and deliverers selected IT services internally. Secondly, architects and/or companies new to the industry can utilize the knowledge and information inherent in the RA to achieve greater productivity in shorter periods of time. Thirdly, Lufthansa can generate a structured and cascading view on an aviation industry-specific EA that transparently describes, in a modularized fashion, various capabilities, including business capabilities, components/services, applications, interoperability, and creates the opportunity to develop combined capabilities and modules in a controlled fashion.

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Using the RA, Lufthansa and Capgemini aim to enable the architectural and delivery aspects leading to improved business efficiency and effectiveness to be pursued through the use of aviation industry standards.

The content and its structure published in this RA respects the boundaries of confidentiality, thereby protecting Lufthansa's unique competitive advantage achieved through proprietary means.

2   Introduction

Reference architectures are used as a checklist for modeling, they provide a procedure for project realization, and ideally they are an international standard [Sc99, S. 3]. A RA serves as a base template for the implementation of architecture in a particular industry context or in a specific application field, and it therefore acts as a design principle, recommendation and proven reference [BD10, S. 201]. The RA defines components and their relationships to each other, as well as between associated interfaces and components. Cloutier et al. define a RA as follows [CM10]:

> *"Reference Architecture provides a proven template solution for an architecture for a particular domain. It also provides a common vocabulary with which to discuss implementations, often with the aim to stress commonality. A Reference Architecture often consists of a list of functions and some indication of their interfaces (or APIs) and interactions with each other and with functions located outside of the scope of the Reference Architecture."*

TOGAF, is an Enterprise Architecture Framework (EAF) and an open international standard, which was first published in 1995 and is being continuously developed and maintained by the Open Group, a consortium of more than 500 member organizations. It is freely available for internal use in order to develop an EA. TOGAF provides a framework for creating a RA, which has been used for the Lufthansa project presented here. TOGAF enables the development of a unified architecture that reflects stakeholder needs and takes account of current and future business requirements. It distinguishes between four essential architecture domains; Business, Data, Application, and Technology.

The first architecture domain, business architecture covers the entire range from descriptions of corporate strategies to business processes. The second, data architecture covers entities with their relationships that are used to implement business processes – ultimately, the organizational data model is clearly and concisely described. The third architecture domain, application architecture, includes applications, interactions and the interfaces between them as well as the entire application landscape, within which business processes run. The fourth domain, the technology architecture, covers architectural elements for setting up, running and managing the IT infrastructure – it defines the basis on which applications are procured, integrated and operated.

These four architecture domains have been considered in modeling/creating the aviation RA and the "Revenue Management & Pricing" function as the initial business domain.

Several standardization initiatives have been attempted in the past by non-profit organizations and governmental institutions. For example, the *International Air Transport Association (IATA)* has started to develop and publish the *New Distribution Capability (NDC)*, an open XML-based data transmission standard, which aims to enhance the capability of communications between airlines and travel agents [IATA14]. In a similar manner, the *International Civil Aviation Organization (ICAO)* develops infrastructures as well as binding standards for aviation, to enable the implementation by member countries. In addition, in 1999 the European Commission launched the *Single European Sky (SES)*, a European program targeting consistently higher safety standards, increased airspace capacity for air traffic and air navigation service providers that increase efficiencies for the future. This present RA project builds on and involves these standards adequately and at an appropriate level of abstraction. It takes into consideration that the aviation industry is undergoing change. For instance, new NDC and dynamic pricing approaches will have a significant impact on the aviation industry's architectural landscape.

3   Procedure

The approach to creating the RA is divided into 4 main steps; initiation (1), consolidation and analysis of existing material (2), transformation of existing material into an architecture definition document, abbreviated here as ADD (3), and submitting the ADD to the Open Group (4).

As part of the initiation step, the domain model has been extracted and clarified from Lufthansa's enterprise architecture, which is described by a collection of architectural artifacts bound together under the umbrella of the *Lufthansa Enterprise Architecture Framework (LEAF)*. The consolidated domain model encompasses the aviation business domains including various industry-specific subdomains.

The second step encompassed the collection, review and in-depth analysis of additional Lufthansa documents, which have been incorporated into the ADD.

The third step involves the actual transformation of all of the previously collected material into the ADD. Additional content-related discussions and exchanges between the architects developing the RA in meetings, video conferences, and other means took place. As part of these discussions and exchanges, additional information has been gathered that was relevant for editing and refining the ADD.

The last step includes the submission of the architecture definition document to the Open Group to enable the publication of a reference architecture standard for the aviation industry. Fig. 1 depicts one of the most fundamental and important preliminary results of this project, the overall domain model of aviation industry consisting of seven domains.

Highlighted here is the "Revenue Management & Pricing" business domain, which serves as the example to model the aviation reference architecture.

Fig. 1: Aviation Domain Model

4   Modeling the "Revenue Management & Pricing" Domain

In the following chapter, the creation of the ADD will be illustrated using the "Revenue Management & Pricing" business domain. Reference literature on airline ticket pricing and yield management in the aviation industry is provided by Boyd [Bo07], Lindenmeier [Li05] and Talluri/van Ryzin [TaRy04].

Basically, the mission behind "Revenue Management & Pricing" features the sale of the right ticket to the right passenger at the right time for the right price. Since this guiding concept has its origins in the early 70s, it is partially outdated. In fact even in today's systems this mission translates to: "Publish the right fares beforehand and manage the sales process by opening and closing 26 booking classes corresponding to letters in the alphabet".

However, the "Revenue Management & Pricing" business domain is undergoing significant change. These changes and the evolution of the overall domain are being progressed by most airlines in order to realize benefits by either:

- implementing an availability management solution outside an Airline Passenger Services Systems (PSS) and/or,
- moving away from the classical availability-based pricing to a more dynamic-based pricing scheme.

The models presented here focus on the enterprise architecture management views. They have been created to capture the content for each TOGAF-specific architecture domain. Hence, the aviation industry-specific model comprises the Business Architecture, Data Architecture, Application Architecture, and Technology Architecture. The domain "Revenue Management & Pricing" consists of four subdomains, "Group Bookings", "Availability Management", "Forecast & Optimization", and "Pricing".

Managing booking class availability derived from outputs of *Forecast & Optimization* (demand and no-show forecasts, bid prices), direct availability control (in case of irregularity management), decision support for revenue controlling and availability for ancillary and special services (advanced seat reservation, wheelchair, special meal, etc.) are within the scope of the *Availability Management* subdomain.

The second subdomain *Forecast & Optimization* covers forecasts of demand, bookings, cancellations, and buy-downs. In addition, no-show figures based on historical, special and expert data are also included in this domain. The domain also caters for the controlling of the forecast and optimization process, which are monitored here. The aim here is to optimize revenue (fare-mix, overbookings) to steer capacity based on average earnings, the management of availability, inventory and reservation data.

Pricing, the third subdomain, includes the provision and distribution of prices and conditions for each service and the booking class on each market. Maximizing the airline's revenue, monitoring competitor's prices and defining the price concept and strategy also fall within this domain.

Group Bookings, the last subdomain, deals with checking the availability for groups and the determination of group pricing. This is necessitated by the fact that the process for booking of groups slightly differs from the standard booking process.

4.1   Business Architecture

The business architecture offers a management oriented perspective onto the corporate structure, as it includes a business capability view that groups capabilities by subdomains. This includes a description of business capabilities, a business process that portrays the workflow, as well as the inputs and outputs of the relevant steps.
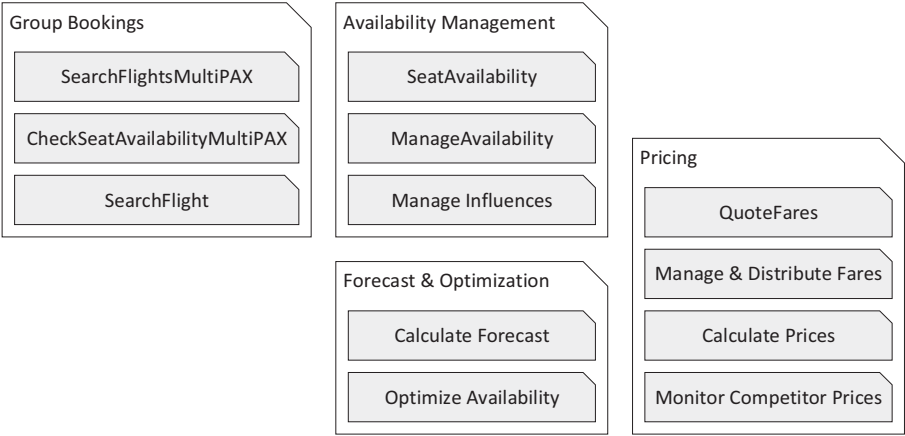

Fig. 2: Business Capability Map of the domain "Revenue Management & Pricing"

The business capabilities grouped by subdomains of the "Revenue Management & Pricing" domain are depicted in Fig. 2. The business capabilities belonging to the "Revenue Management & Pricing" domain are described in Table 1. Several of these have to be transformed into the definitions from the *NDC Implementation Guide* published by the *International Air Transport Association* [IATA14].

In general, business capabilities claim to be free of overlap, express abilities organizations require or offer and provided a logical grouping of these services. A business capability answers the question of "what" a service carries out, clearly distinguishing from the analogous question of "how" something is being carried out. All business capabilities, especially when introduced into a reference architecture, must conform to these principles.

Capability	Description
SearchFlightsMultiPAX	A flight search consist of search criteria including more than 9 passenger criteria and returns availability, fares and flight related ancillaries
CheckSeatAvailabilityMultiPAX	Check the availability of more than 9 seats for a specific flight and booking class

SearchFlight	If the user searches for flights with more than 9 passengers, the seat availability has to be checked first
SeatAvailability	A service to receive available seats by booking class
Manage Availability	(Re-)Calculates availabilities (to be presented to customers or published through the eCommerce channel) based on relevant settings and stored sold bookings
Manage Influences	Allows to adjust the influence settings, which are used as input to the calculation of availabilities and results therefore in a modified output
Calculate Forecast	Calculate the expected demand of seats based on historical bookings and current booking trend
Optimize Availability	Optimizes availabilities by utilizing forecasts and the current sold capacity to recalculate the inventory settings
FareQuote	A service to provide the fares fitting the search criteria (the available flights)
Manage & Distribute Fares	Provision and communication of the fare model including conditions to partners and fare filing
Calculate Prices	Calculate the prices to be provided for the various fares
Monitor Competitor Prices	Track and observe pricing models and current fares offered by competitors

Table 1: Description of *Revenue Management & Pricing* Business Capabilities

Business process models provide a means of developing a behavioral view of the system under investigation. The business process of the domain "Revenue Management & Pricing" is depicted in Fig. 3, which selectively illustrates the input and output of each activity.

As part of the initial step in this process, the strategy, objectives and methods are defined. During the second step, the market is analyzed and tactics are selected, followed by creating a proposal appropriately managed by the governance structures. The penultimate step is to govern capacity.
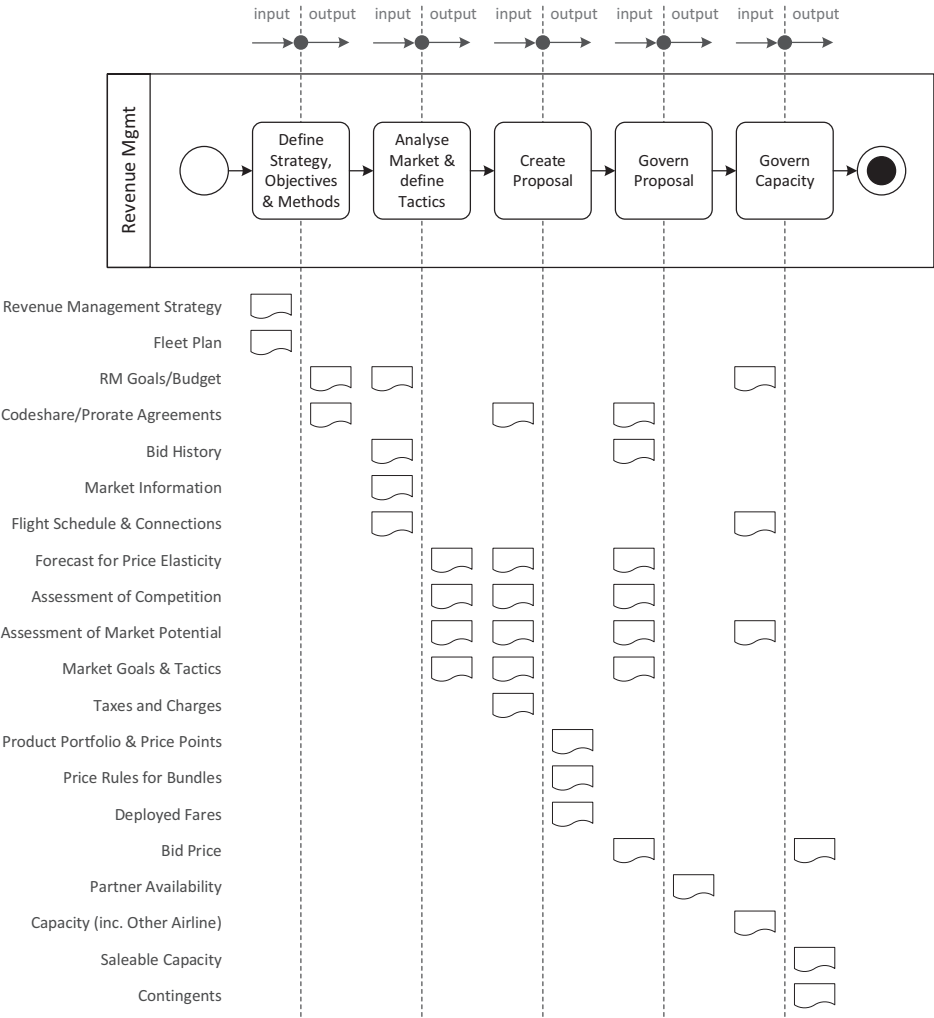
Fig. 3: *Revenue Management & Pricing* Business Process

4.2   Application Architecture

Fig. 4 depicts the mapping of business capabilities to applications. The main applications assigned to the domain *Group Bookings* are the *Group Offer Manager* and the *Group Sales* and *Reservation* Tool. A real-time-capable *Availability Calculator* represents the application, which forms core of the *Availability Management* subdomain. Similarly, a *Forecaster* is part of the *Forecast & Optimization* subdomain. The *Pricing* subdomain is covered by the *Fare Engine*, which calculates prices and distributes fares. Also part of the

Pricing subdomain is the *Market Observation Engine* that monitors published offers by competitors. Such an assignment of applications to the business capabilities within the relevant subdomain clarifies what kind of functionality a new application must cater for if it is to be considered to replace an existing application in future.
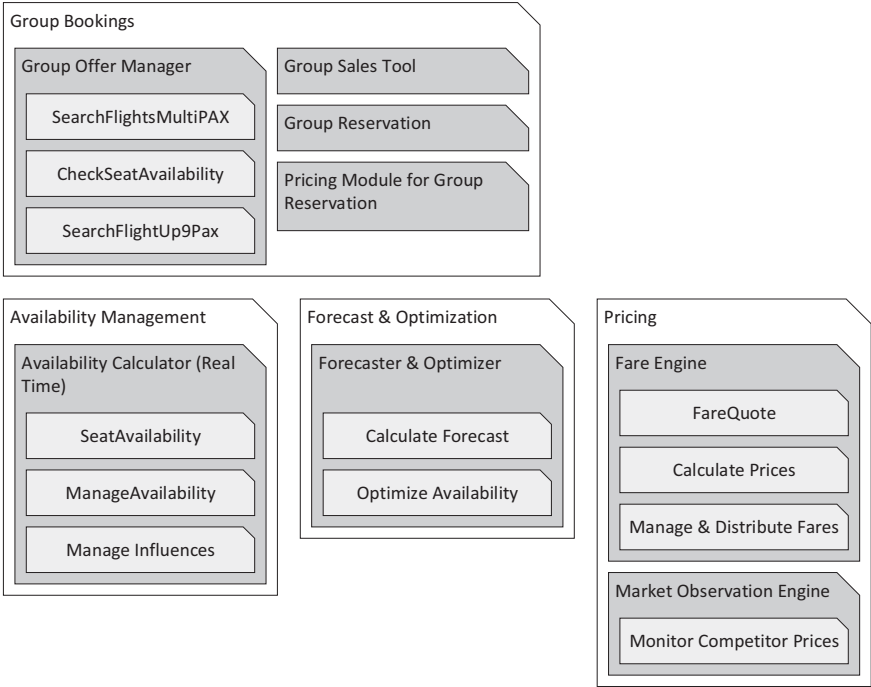

Fig. 4: Mapping *Revenue Management & Pricing* Capabilities to Applications

4.3   Data Architecture

The data architecture offers an insight into the organizational data model. A suitable reference point for a data model fitting organizations of the aviation industry is the *IATA Airline Industry Data Model (AIDM)*. The AIDM data model facilitates the development and maintenance of messaging standards in the aviation industry [ThHo16]. The basis is a consistent model collaboratively developed and maintained by globally distributed industry working groups that use the Sparx Enterprise Architect tool, including the "industry-agreed vocabulary, data models, and message definitions, as well as the related business process context and requirements" [ThHo16]. Oracle provides a particularly detailed data model as well, the *Oracle Airline Data Model (OADM)*. It is "a standards-based, industry-specific, prebuilt data warehouse database schema with associated analytic models and dashboard" and a key component of the Oracle Passenger Data Management Industry Solution [Orac16].
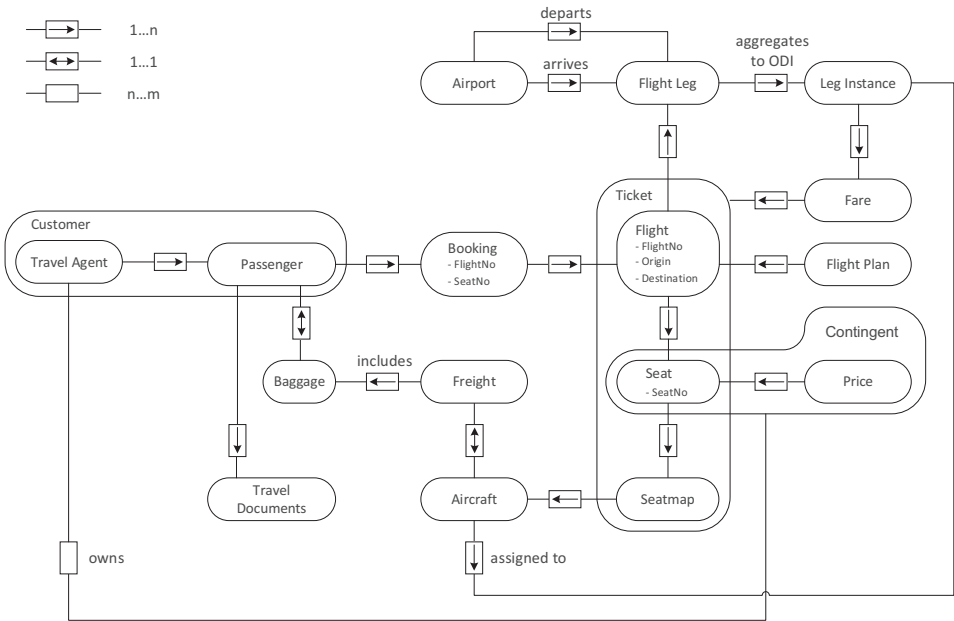
Fig. 5: Data Model including the *Revenue Management & Pricing* Domain

Here, a reasonably abstracted segment is displayed in Fig. 5 illustrating fundamental business entities of the *Revenue Management & Pricing* domain and their relationships.

4.4   Technology Architecture

The technology layer of the *Revenue Management & Pricing* domain is subdivided into four technological areas, *Bookings & Direct Sales* (1), *Forecast* (2), *Availability Optimization* (3), and *Availability Management* (4). The first area includes an E-Commerce Web Portal backed by a Shop System. Within the second area, namely the *Forecast* area, a data loader, integrator, store and analyzer are located, which corresponds to a typical *Business Intelligence (BI)* architecture. *Availability Optimization*, the third area, is technologically represented by a *Linear Optimization Problem Solver* such as *IBM CPEX*. An *Availability Request Processor*, which is high throughput-oriented, forms the core part of the last area: *Availability Management*. Here, the critical aspect is the ability to process as many requests in the shortest possible timeframe. Within this technology layer, essential platforms can be found, providing various services to applications, which are located in a layer above.

5   Concluding Summary

As a summary, we conclude that a project to design an industry-specific Reference Architecture and Standard is not only beneficial for organizations of this particular industry, but a valuable activity for organizations in general, such as suppliers of services or products.

Aviation industry service providers benefit from a generic framework that serves as a guideline or template for their enterprise architecture. In addition, actors share a common vocabulary when designing solutions, information systems or interfaces between them. Companies, peripheral to the aviation industry are able to create and deliver value through using the Reference Architecture by finding deeper insights into apparent processes and industry-specific realities.

The next step of this project will be to finalize the architecture definition document and refine the model and structures with various other aviation industry organizations to complete the Open Group Standards submission process.

6   Challenges and Outlook

The content, observations and analysis of this RA have been developed with the help of a group of people under the leadership of the Lufthansa CIO Dr. Roland Schütz and the Lufthansa Corporate CIO Josef Bogdanski, mainly in the team of the Lufthansa Director for Revenue Management Dr. Jutta Rockmann.

This paper was developed under the joint leadership of Carsten Breithaupt (Lufthansa Head of Domain Architectures) and Kai Schroeder (Capgemini Germany - Head of BTech SI Architecture), the coordinator and project manager Carsten Brockmann (Capgemini), and the lead architects Eldar Sultanow (Capgemini) and Christian Vollmer (Lufthansa). A team of eleven additional architects poured their combined knowledge and wisdom into this RA, protecting commercially sensitive information, while making the content for the reader as accessible and a meaningful as possible.

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