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Assessing the Impact of information Exchange, Forecasting and Revenue Sharing Agreements in Partnership Revenue Management: An Application of Airline Planning and Operations Simulator (APOS)

By Goda R. Doreswamy, Amrit Raj Misra & Kavitha Guddeti

Abstract- Airline partnerships have become one of the major trends in the recent years with the primary motivation of increasing revenues and decreasing costs for alliance partners. A major advantage comes through increase in the number of destinations served by an airline at little incremental costs. The total benefit of partnership can be achieved when partners in an alliance operate and take decisions as a single virtual entity. Various systems of the partner airlines need to interface and exchange information to achieve the benefit in a decentralized world. This paper provides a path to maturity in collaboration between partners from current state to joint revenue management leveraging simulation studies run on real data from two airline partners. The results from simulation studies quantify the revenue impact of incremental steps in maturity of collaboration along stages of information exchange, true origin and destination demand forecasting and revenue sharing agreements.

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ASSESSINGTHEIMPACTOFINFORMATIONEXCHANGEFORECASTINGANDREVENUESHARINGAGREEMENTSINPARTNERSHIPREVENUEMANAGEMENTANAPPLICATIONOFAIRLINEPLANNINGANDOPERATIONSSIMULATORAPOS

Strictly as per the compliance and regulations of:

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Goda R. Doreswamy [α], Amrit Raj Misra [σ] & Kavitha Guddeti [ρ]

Abstract- Airline partnerships have become one of the major trends in the recent years with the primary motivation of increasing revenues and decreasing costs for alliance partners. A major advantage comes through increase in the number of destinations served by an airline at little incremental costs. The total benefit of partnership can be achieved when partners in an alliance operate and take decisions as a single virtual entity. Various systems of the partner airlines need to interface and exchange information to achieve the benefit in a decentralized world. This paper provides a path to maturity in collaboration between partners from current state to joint revenue management leveraging simulation studies run on real data from two airline partners. The results from simulation studies quantify the revenue impact of incremental steps in maturity of collaboration along stages of information exchange, true origin and destination demand forecasting and revenue sharing agreements.

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I. Introduction

Alliances between airlines on international markets has been a dominant feature of the industry, with alliances carrying more than 60% of the total scheduled traffic (IATA[1] WATS[2] report 2016). Global demand data shows that code share traffic has increased by more than 40% between the years 2010 and 2014.Multi-airline marketing partnerships are important in a modern airline's strategic toolkit. By joining a large airline alliance an airline can vastly expand the network where it provides services, in addition to the benefits of getting more flow passengers on its operating network from the alliance partners. Code sharing alliances can produce 50 percent or more of the full revenue benefits of an actual merger with significantly less investment and risk (Vinod, 2005). The alliance between Northwest and KLM airlines in 1991 had shown how airlines can benefit from strategi marketing partnerships. Northwest's connecting traffic with KLM increased by 115% from 1991 to 1994 adding an estimated revenue of US$ 125 million for Northwest and US$ 100 million for KLM in 1994 (Vinod, 2005).

Alliances have been expanding their reach by covering destinations not covered by own network through alliance partners. Table 1 summarizes the key performance measures of global alliances. Even more tightly integrated than alliance members are airlines in equity partnerships and Joint Ventures that involve antitrust immunity and make it possible for partners to engage in highly coordinated pricing, marketing and revenue accounting practices (Ratliff & Weatherford, 2012).

Operating in a partnership requires airlines to integrate their operations and systems in order to enable the seamless experience expected by the customers. State of the art technology focuses on integrating operations across alliance partners like interline ticketing, baggage handling and loyalty programmes. Academia and the industry are now gearing up to address the challenges of integrating the strategic and tactical planning across the alliance partners. Optimal integration would need airlines to behave as a single virtual airline by sharing inventory control, network planning and capacity allocation. An optimal revenue management system would sit on a single combined source of information which provides schedules, fares, revenue accounting and PNR[5]/Bookings information for both the airlines (Vinod, 2005). This optimal "know-all" solution will be referred to as joint revenue management system. However, such a tight integration system might not be feasible for a multitude of reasons including alliance exit options available to the airlines.

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Table 1: Key performance measures of Global Alliances

	Star Alliance	Sky Team	One world	Other alliances and Individual Airlines
# Of Members	27	20	14	78
Annual Passengers (Million)	641.1	665.4	557.4	1706.1
% RPK[3] Flown (%age of total)	23	20	18	39
# Of Destinations Flown	1330	1062	1016	475

A more realistic approach is to have a loosely coupled, decentralized system which allows real time information exchange enabling the individual systems to make decisions while being aware of the entire alliance network. In such an environment each airline will implement its own revenue management and inventory control system. However, a communications framework will allow the individual system to request and receive required information in real time, enabling decisions that are beneficial for the entire alliance network. The environment will prompt a shift in the decision making process from a greedy approach where each airline is focused on optimizing their own network to a more collaborative approach where the benefit of entire alliance is preferred. Fundamental operational requirement for airlines participating in an alliance is to facilitate code share bookings (where one airline sells tickets on a sector operated by the partner). Alliance partners need to exchange operational information like availability, PNR and baggage details in order to ensure code share bookings are appropriately handled. Further, alliance partners can exchange data like the current bid prices on various legs that can help an alliance-aware system make strategic decisions keeping in mind the entire alliance network.

Prior work in the area of airline partnerships have suggested mechanisms for better integration of systems and decision making to achieve the revenue opportunity provided by a joint revenue management system. The inherent assumption here is that the overall alliance benefits are not biased and are beneficial for the participating airlines too. This paper leverages simulation as a tool to quantify the impact of the suggested mechanisms on real airline networks working in partnership. Scenarios simulated in the paper traverse the path of maturity that partnering airlines can take to capture the revenue opportunity space between current state of minimum integration and the optimal State of a joint revenue management system and quantify the revenue impact of every step along the path.

The remainder of the paper has been organized as follows. Section 2 provides the details of prior work done in this area including some of the common practices already adopted by alliances. Section 3 lays down the foundation for the motivation and the need for conducting simulation studies on real alliance data to compliment prior work. Section 3 also deep dives into the details of various integration mechanisms and explains the choices behind the scenarios that are simulated and outlines an integration maturity order within these scenarios. Section 4 provides an overview of Airline Planning and Operations Simulator (APOS), the tool used for simulation. Section 5 provides an overview of the combined alliance network that is simulated and presents some key statistics describing the network. Section 6 gives the details of each scenario that is simulated including the information exchange, forecasting and optimization techniques and the revenue sharing mechanism used in each simulation study. Section 7 first presents the results from each individual simulation study and then moves on to provide a consolidated outline of revenue gain. Section 8 concludes with a recommendation for airlines on integration areas that need to be addressed first. Section 9 provides a glimpse of future simulation work that can be done and some of the gaps with the present study that need to be addressed

II. Prior Work

Prior work has addressed different aspects of Partnership Revenue Management, including the need for synchronized decision making, the infeasibility of a centralized revenue management system (Vinod, 2005), impact of various revenue sharing methods on the overall profitability of the alliance (Belobaba & Jain, 2013) and strategies for real time information exchange in a decentralized environment (Ratliff & Weatherford, 2012).

Alliance Revenue Management (Vinod, 2005) provides an in-depth discussion on challenges faced when trying to synchronize decision making across an airline alliance in order to maximize revenue across the alliance network. The paper underlines the fact that alliances will remain the prevalent mechanism of co-operation between international airlines due to sovereignty and nationalist issues. An optimal environment for combined revenue management of the alliance is outlined i.e. a single inventory control environment for all partners in an alliance which is aware of the details of the combined network. The paper further establishes the fact that such an optimal environment is far from reality due to several factors like alliance exit options, revenue sharing and anti-trust immunity considerations. A more realistic approach is defined where the alliance partners exchange inventory availability and bid prices in real time on a need to know basis in order to maintain network equilibrium. A detailed treatment of operational and strategic challenges for alliance partners is provided including alliance pricing, through check-in, PNR-synchronization across partners and combined overbooking policy.

Simulation results from PODS[6] simulation framework showcasing the benefits from sharing of bid prices between the partner airlines and using the bid price of the partner airline within the optimization have been presented (Belobaba & Jain, 2013). Two important aspects of Alliance Revenue Management are covered. The first being determination of seat availability based on revenue benefit and opportunity cost for the alliance using shared bid price from the alliance partner. The second is using information (bid prices) about the current state of the alliance partner during the optimization process in order to set the optimal controls that will optimize the entire alliance network.

Codeshare and alliance revenue management best practices: AGIFORS[7] roundtable review(Ratliff & Weatherford, 2012) gives a practitioner-oriented review of the problems. Opportunities and best practices associated with code share and alliance revenue management have been presented based on a round table discussions with operations research experts and airline RM practitioners. The paper provides details on the code share inventory control mechanism, revenue sharing agreements in widespread use by the alliance partners along with the details of approaches used by airlines to curb the biases built in proration methods (for example mileage based proration favors the long haul carrier).The paper discusses the superiority of free-sell availability agreements which does not impose a pre-specified limit on the number of seats allocated to the marketing airlines, instead uses a dynamic approach for seats sharing. A section is dedicated to the alliance revenue management best practices with emphasis on dynamic proration mechanisms advocated by several authors and in early adoption stages by a few airlines.

III. Motivation

There are three major aspects of integration systems that come to the fore, based on a study of the previous work in the area of alliance revenue management and current practices at various airlines: inventory information exchange, decision making and revenue sharing.

a) Inventory Information Exchange

The alliance partners need to integrate their inventory systems and exchange availability information. This enables the partner airlines to sell tickets of on sectors operated by the other. This is typically the first level of maturity in integration without which the airlines will not be able to effectively sell code share itineraries.

b) Decision making

The revenue management systems should be enabled to consider the true origin and destination demand and revenue proration to make informed decisions while allocating seats in order to maximize the revenue. This requires all the alliance partners to exchange complete itinerary information with each other instead of sharing only the portion operated by the airline. Knowing the entire code share it inerary allows the alliance partners to estimate and forecast demand appropriately. This is the next level of maturity in integration after crossing the first level of inventory information exchange.

c) Revenue sharing

The alliance partners need to decide on revenue sharing for code share itineraries so that the individual airline revenue maximization goals are aligned with the alliance revenue maximization goal. Dynamic proration mechanisms suggested in prior work require the airlines to exchange bid price information in order to allow revenue split based on the state of the airline at the time of sale. This is the final stage of maturity in integration as it requires a major level of trust among partners and deeper level of integration like between Lufthansa and Swiss or between KLM and Air France (Hu, Caldentey, and Vulcano, 2013)

The motivation for this study is to put a realistic estimate on the revenue gain that practitioners can expect by adopting the integration mechanisms described in prior work. The earlier studies either did not perform a simulation to measure the impact of suggested strategies or performed it on a sample artificial network. The main contribution of this study would be to estimate the revenue impact after running simulation on a large realistic network created from data obtained from actual partner airlines and also provide a path of maturity in integration to follow that can help close the revenue opportunity gap between completely decentralized and centralized systems. Airline Planning

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and Operations Simulator (APOS) is used for the simulation studies.

There are two sets of variations introduced in the simulation:

Maturity of integration: Several mechanisms that represent maturity of integration are simulated. These mechanisms have been defined in the further sections

Code share Factor: The code share factor controls what percent of the total traffic is on code share. This variation is used for analyzing sensitivity of revenue impact to the level of code share traffic carried by the network

Based on the three aspects of systems integration discussed in this section, three stages of integration maturity are defined as shown in Figure 1:

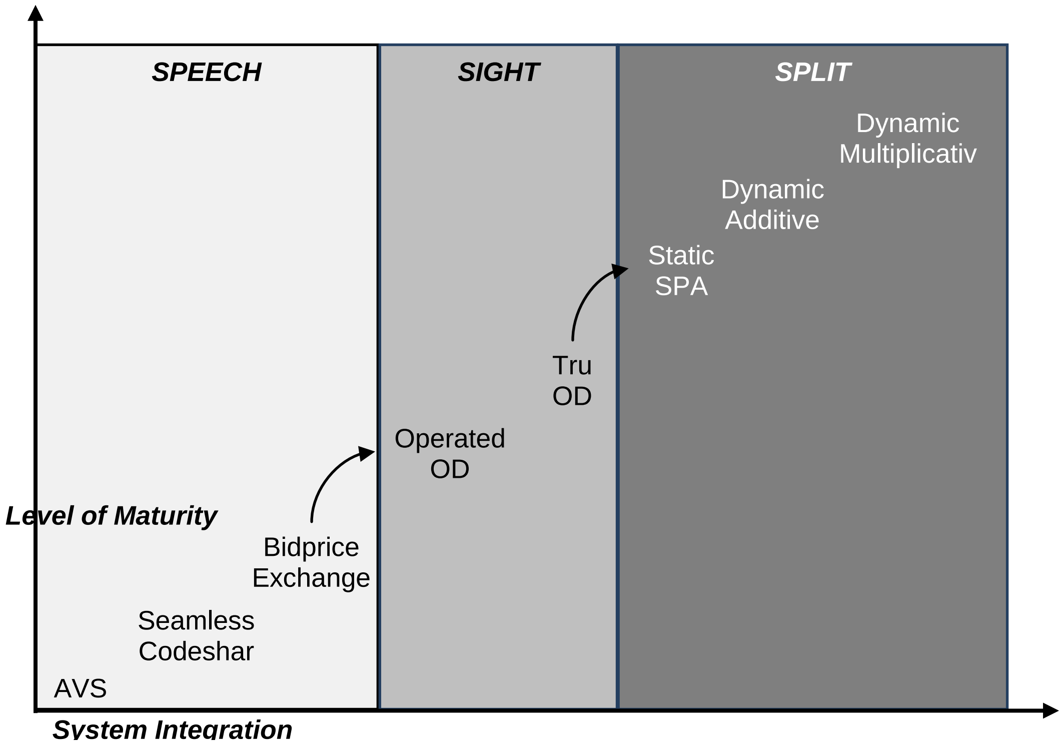

Figure 1: Partner systems synchronization –Levels of maturity

The speech stage addresses the operational aspects of the systems integration within an airline alliance which primarily revolves around the mechanism of sharing availability information. This is referred to as the speech stage because this is primarily the way IT systems talk to each other and convey information. The sight and split stages address the more strategic issues related to setting of inventory controls and the mechanism of sharing revenue on ticket sales on code share itineraries. The sight stage covers strategies related to forecasting and optimization in the individual revenue management systems of the alliance partners and whether these individual systems are aware of the partner and code share itineraries. The split stage covers the mechanisms of revenue sharing. These stages are described in more detail using the code share itinerary example in Figure 2:

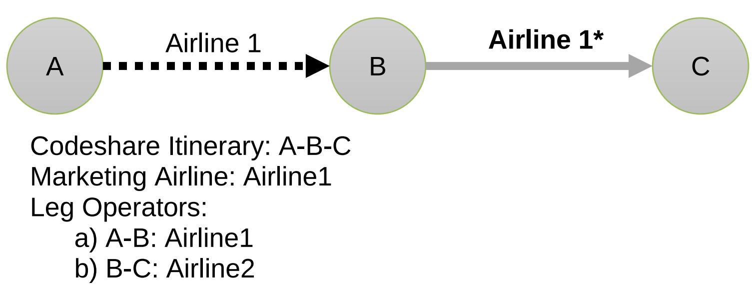

Figure 2: Sample code share itinerary

d) Speech: How do partners communicate their availability status to each other?

In a partnership scenario, one airline is allowed to market tickets on another airline and also sell code share itineraries where different segments of the itinerary are operated by different airlines (See Figure 2). While evaluating such requests, the marketing airline needs to know the status of the seats available on the operating airline. The operating airline can share different levels of data with the marketing airline regarding status on whether a seat is available on the requested flight and how valuable those seats are. The different kinds of inventory information exchange mechanisms that are simulated are:

AVS: AVS stands for Availability Status Message or Availability Inventory Status message which is an IATA standard Teletype message transmitted from one airline to another or to a CRS[8]/GDS[9] in order to update its Flight's availability on other airline or GDS core availability. Operating airline would exchange AVS message with the marketing airline(s) which processes the AVS messages and stores the availability matrix of on the flights operated by their partners (see Figure 3). When the code share sale request is received by an airline, it will refer to this locally stored availability matrix before accepting or rejecting the request (see Figure 4). AVS messages are usually transmitted as a result of changes in status when availability crosses pre-defined level of availability threshold. Due to these thresholds and lag in transmission of AVS message, code share requests can get rejected even when seats are available on the operating carrier or lead to unintended over sales for the operating carrier.

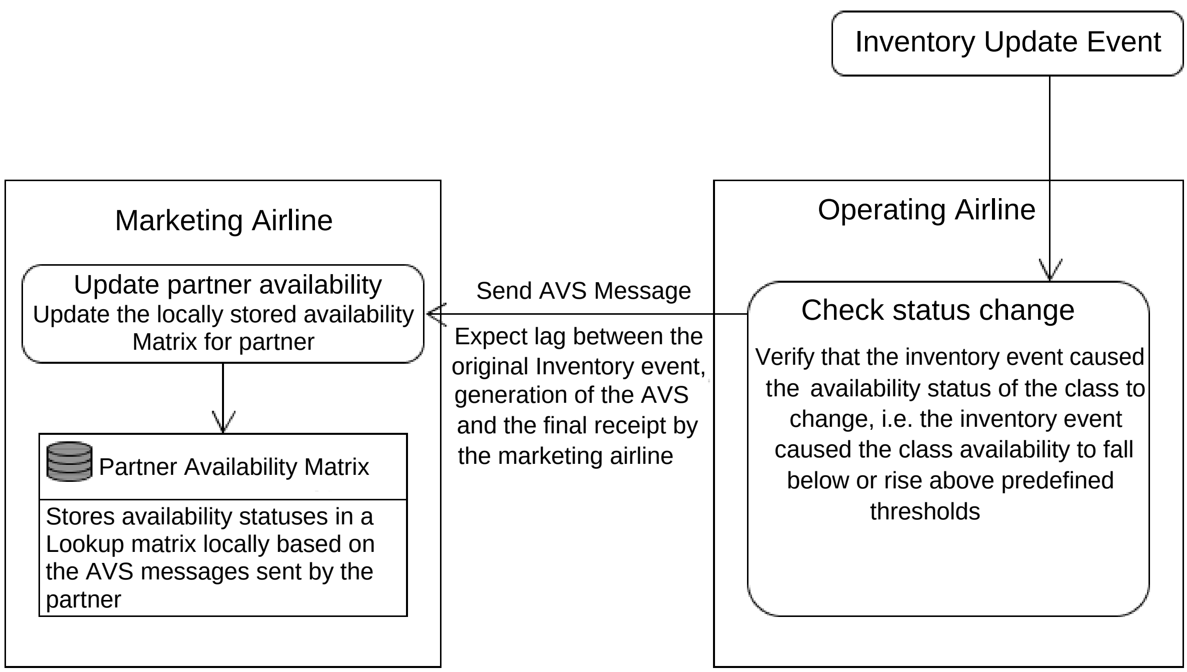

Figure 3: AVS Exchange

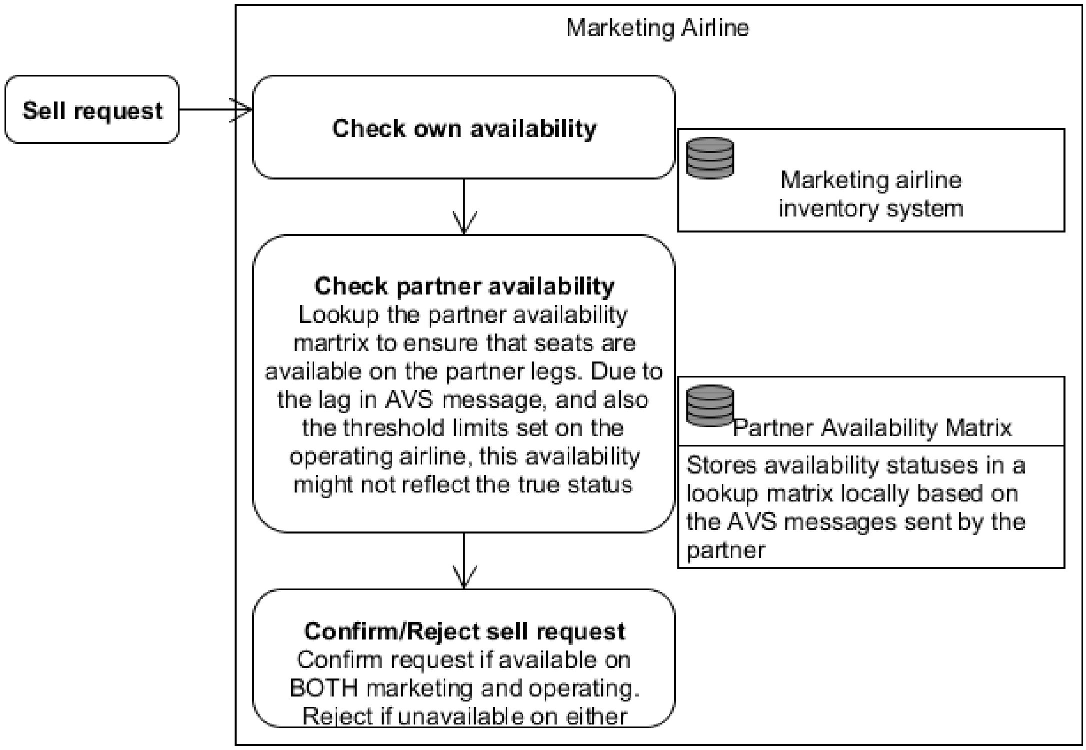

Figure 4: Code share evaluation based on AVS exchange

Seamless Code share: Seamless code share enables the carriers with interactive availability and sell capabilities with their partners hosted in other systems. It also provides code share partners with last seat availability and immediately decrements the sell rather than relying on AVS availability and code share guaranteed teletype sell action codes. Figure 5 outlines the code share request evaluation process in Seamless Code share. Seamless code share simulated in the study is cascading without journey data. This means the marketing airline has the entire O&D information and hence can evaluate availability of own leg by comparing bid price and prorated O&D fare but operating partner responds with leg class financial availability based on local fare.

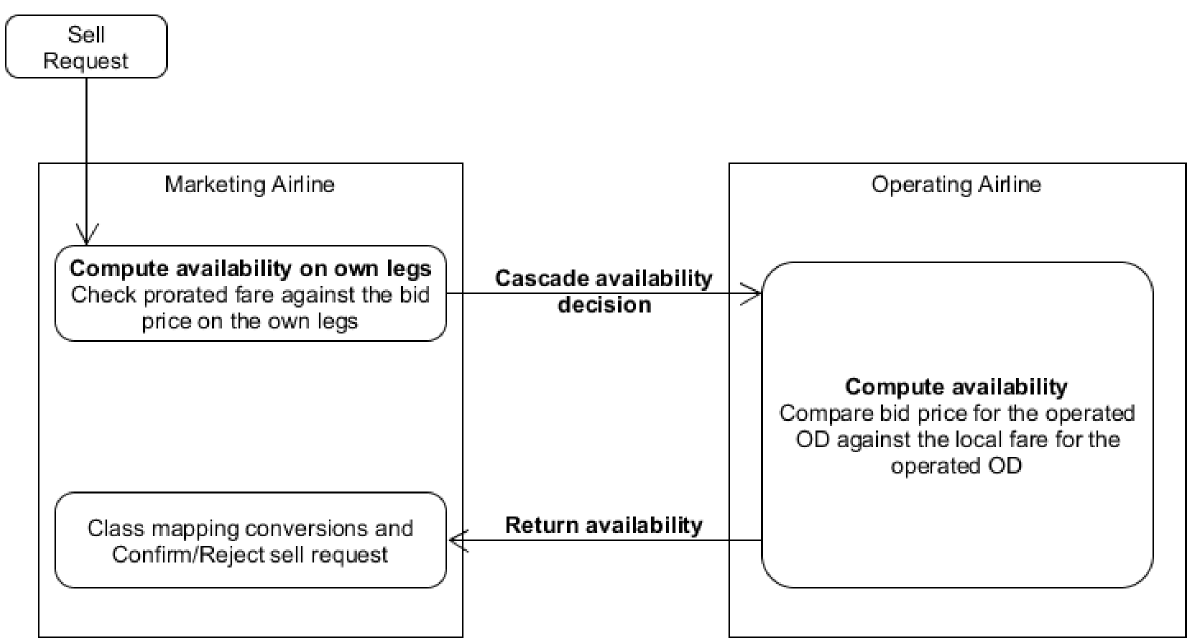

Figure 5: Seamless code share availability calculation

Bid Price Exchange: Carriers can make more optimal inventory decisions at the O&D level if they evaluate the availability using the O&D fare and the bid prices of all the underlying legs (including that of the operating carrier). This will enable right availability value to be used at the time of sale in an O&D environment. Bid price exchange allows operating carriers to push bid price vectors of the legs operated by them to the marketing airlines. These bid price vectors are stored and processed by the marketing airlines at the time of availability determination. Figure 6 and Figure 7 outlines the details of the exchange mechanism and request evaluation.

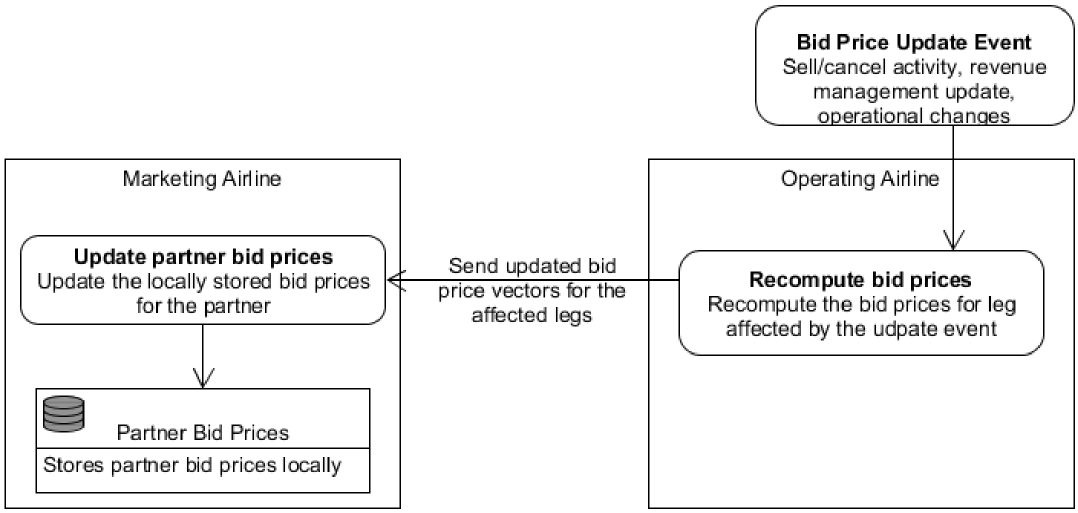

Figure 6: Bid price exchange mechanism

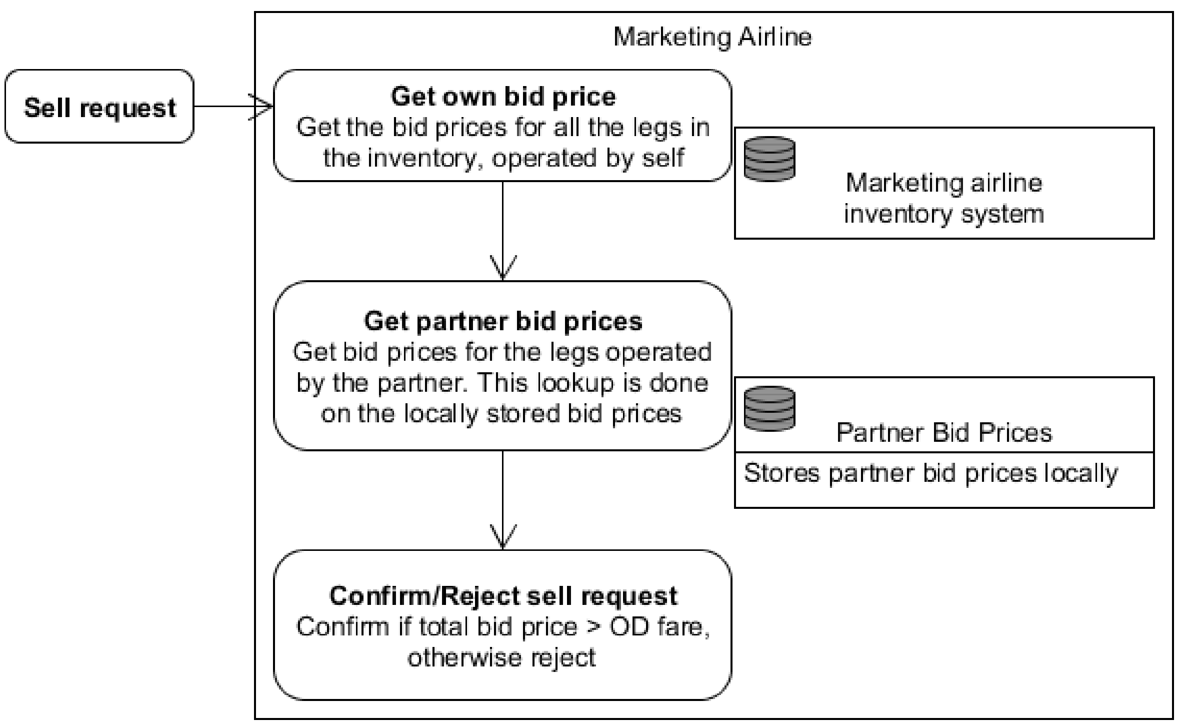

Figure 7: Code share itinerary evaluation using bid price exchange

e) *Sight: How far can the partner see during forecasting and optimization?*

The maturity of the partners in terms of information they are able to see determine whether the forecasted demand and revenue value of the demand is of the Operated O&D or True O&D.

Operated O & D: Each partner airline has information only about the operated portion of the code share it inerary. Hence the code share demand is forecasted as operated O&D demand and the fares filed for the operated O & D is considered as the revenue value of the demand in optimization.

True O&D: Here the airlines have complete information about the entire journey made by the passengers. Hence operated O&D passengers can be differentiated from code share passengers and forecasted separately. Information on revenue sharing agreements is used to estimate proration factor to be applied on True O&D fare to consider the right revenue value of the demand in optimization.

f) *Split: How the revenue from code share itineraries is split between the partners?*

Once a seat is sold on the code share itinerary, the involved airlines (marketing and operating) need to split the revenue between themselves. The revenue sharing agreement should ensure fair share for each airline. Following revenue sharing schemes are considered for the study:

Static: Static methods split the revenue between the partners based on a pre-decided mutually agreed ratio. This could be based on local fares of partners, or cost weighted mileage. Airlines also sign a Special Proration Agreement (SPA) which defines the revenue split ratio. The static proration methods do not take into account the real time dynamics at the time when the sale request is confirmed. Proration ratios obtained from real data of the partner air lines are used for the study.

Dynamic: Although static methods are the prevalent method of sharing mechanism between partners, academic research suggests dynamic revenue sharing schemes (Wright, Groenevelt, & Shumsky, 2008) as a more optimal way of splitting revenue between the partners. Dynamic methods vary the revenue proration ratios for each seat sold based on the state of the leg cabins on the code share itinerary at the time of the sale. Within dynamic revenue sharing schemes, two variants are used in the simulation.

a) *Additive:* The operating airline gets the current bid price at the time of sale, the rest goes to the marketing airline

b) *Multiplicative:* The revenue is shared between the airlines in the ratio of the bid prices

The experiment design moves along each stage keeping everything else constant and just varying the options available in the given stage. There is an inherent order in the stages defining a chain of maturity which is speech, sight and then split. As the experiments move into the higher stage of maturity, the 'best case' settings from the previous stage are retained. This is done in order to isolate the impact of variations in each stage.

IV. APOS

The APOS framework enables simulation on top of real historical data provided by an airline. APOS modules are outlined in Table 2. The main modules of interest for this study are:

Table 2: Main modules of the APOS framework

Reader	Event Generator	Models Engine	Evaluator	Reporter
Reads all the input files, including: 1. Historical demand 2. Network 3. Fares 4. Capacity	Generates randomized future event based on the historical events. This include: 1. Booking Requests 2. Demand Volume 3. Arrival Patterns	This is core of RM engine. It includes models for: 1. Network Optimization 2. Leg Optimization 3. Rules Engine Different models can be plugged here and APOS provided several pre-defined choices	Evaluator will process the request events and accept or reject them based on: 1. Economic and Physical control policies 2. Nesting structure of classes 3. Information exchange between partners Evaluator also simulates spill and recapture	Reporter writes out detailed information about each event that occurs within the simulation. This enables: 1. Analysis of simulation results 2. Drill-down reporting 3. KPI Reporting – RASK, Revenue, Load Factors

Event Generator: Incoming passenger requests are generated based on historical booking volume data of partner airlines. Arrival patterns are derived from industry data on markets simulated.

Models Engine: Average O&D demand forecasted by revenue management systems of individual airlines. Based on the maturity level of the revenue management system, this module can forecast only operated O&D

demand or true O&D demand. Each individual airline optimizes own revenue based on information available.

Evaluator: Request evaluation by the inventory systems of the airlines based on the information available on own and partner inventory.

Reporter: Accounts for Special proration and dynamic proration agreements in computing revenue achieved by each individual airline. Computes key performance indicators like Yield, Load factor, Code share and flow percentage

The APOS framework simulates several streams of incoming passenger requests that mimic different instances of a typical 24-hour window of departures on the airline networks. APOS also has the capability to simulate higher demand on code share itineraries for sensitivity analysis.

V. Simulation Setup

Real data obtained from two alliance partners is used in simulation in order to have a realistic estimate of the revenue impact. For the sake of present study, the airlines will be called Airline1 and Airline2.Airline1 is a pure hub and spoke carrier which serves international markets. Major portion of Airline1 traffic is flow traffic moving through the hub to their eventual destination. Airline2 is a major regional player with only a few long haul routes. The partnership allows Airline1 to expand its network in the region where Airline2 operates and helps Airline2 provide several international connections from its regional airports.

A representative sketch of the combined network of the partners is as shown in Figure 8:

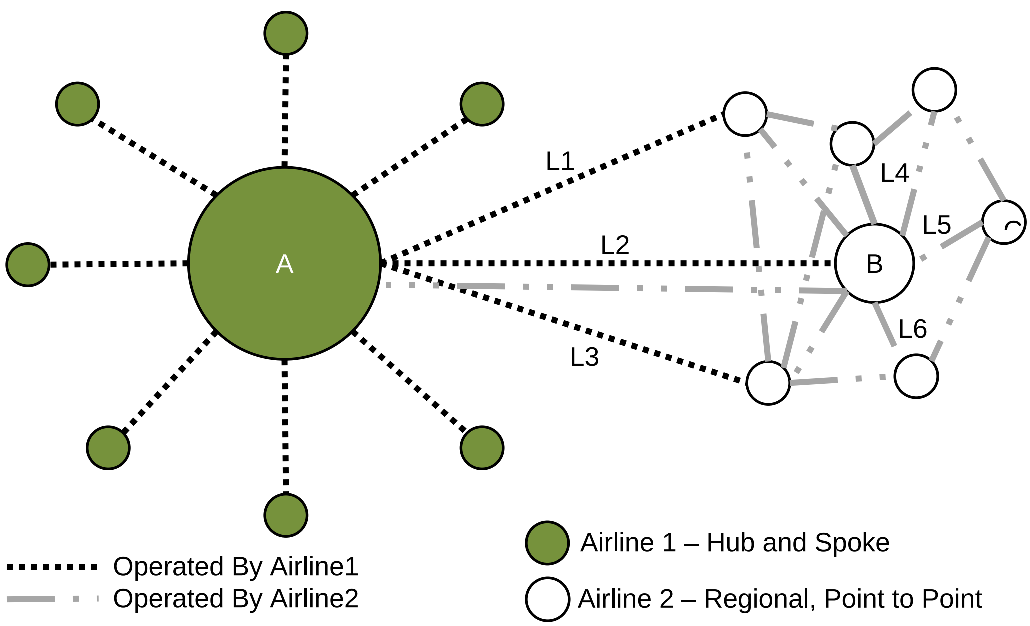

Figure 8: Combined network of the partner airlines

Some key statistics about the airlines involved in the partnership are as shown in Table 3:

Table 3: Key information about the airlines in the partnership

Airline1	KPI	Airline2
Hub and Spoke	Network Type	Point to point
200	Flights	700
800	Markets	1,200
1,000	Itineraries	2,500
22,000	Bookings	75,000
40,000	Capacity	100,000
16%	Code share Demand %	3%

The code share demand on the network can be divided into three different categories:

Table 4: Code share categories

Type	Representative Itinerary	Key features	Benefits
Parallel	A-B L2 Marketed by: Airline1 Operated by: Airline2 L2 Marketed by: Airline2 Operated by: Airline1	Code share on routes operated by both airlines (usually trunk routes). Entire itinerary operated by single airline. Sales agreement to allow partner to sell tickets Revenue sharing based on pre decided commission rates. In this sample both Airline1 and Airline2 offer services on the leg L2, however they allow each other to sell tickets on the shared sectors. Airline2 might not have many services offered on L2 while Airline1 might	Increased frequency on trunk routes
Complimentary	A-B-C L2 + L5 Marketed by: Airline1 Operated by:Airline1+Airline2	Itinerary is jointly operated by partners. Itinerary not serviceable by either airline alone. Revenue sharing based on the portion serviced. The sample itinerary L2+L5 creates a service from station A to C via B. This allows both the airlines to expand their network to stations that they are not able to service on their own network	Better network coverage
Virtual	B-C L5 Marketed by: Airline1 Operated by: Airline2	Entire itinerary operated by single airline. Service on non-shared routes. Revenue sharing based on pre decided commission rates. Here L5 sector is operated only by Airline2, however Airline1 is able to sell tickets on this sector because of the ticket sales agreement	Better network coverage

The sample network selected for the study contains code share itineraries of all the three types along with non-code share itineraries which are marketed and operated by a single airline. Airline1 has a large chunk of code share demand as can be seen in the key information about the alliance network in Table 3.

VI. Experiment Setup

Three sets of experiments are conducted, one along each stage of maturity as explained before. The experiments move along one stage, while keeping the previous stage constant at the best level in order to allow isolation of the effect of the variant stage.

First the experiments move along the speech stage as it is the fundamental requirement for alliances to allow code share bookings. Once the best strategy to communicate inventory availability information is identified, the speech stage is fixed with the best strategy and the experiments move along the more strategic sight stage and measure gain from forecasting and optimizing true ODs as against forecasting and optimizing only the operated ODs. Finally the speech and sight stages are fixed at their best alternative and the experiments move along the split stage to find out the best mechanism of splitting the revenues amongst the partners and measure expected gain from different revenue sharing mechanisms. Finally, the simulation of a virtual single airline that includes the network of both the airlines where inventory decisions are made using centralized revenue management and inventory systems provides an upper bound on the alliance revenue (Vinod, 2005) to assess the revenue opportunity gap between centralized and decentralized systems that is captured by integration mechanisms.

In all the experiments conducted the following forecasting and optimization model sare used:

Table 4: Experiment setup, forecasting and optimization

	Forecasting	Optimization	Inventory Control
Airline 1 Airline 2	Average The demand forecast is an average of historical OD demand	Network - DLP-OD Leg - EMSRb with displacement adjusted fares	Bid Price Control Request is evaluated based on financial controls

Using the same forecasting and optimization methods across ensures that the differences seen in the alliance revenues can be attributed to changes in the integration and revenue sharing methods. The Table 5 shows all scenarios that are simulated in the increasing order of maturity stages. The base case used for each stage is highlighted. It is important to note that there is an inherent order in the way the experiments move through the stages from operational to more strategic levels. The best case from each stage is retained when moving to a higher stage.

Table 5: Experiment sets in increasing order of maturity level along the three stages

Maturity Stage	Forecasting	Optimization	Evaluation	Revenue Sharing Mechanism
Speech	Operated OD	Operated OD No Proration	AVS	SPA
			Seamless Code share	
			Bid Price Exchange	
Sight	Operated OD True OD	Operated OD No Proration	Bid Price Exchange	SPA
		True OD No Proration		
Split	True OD	True OD Prorated Fares based on SPA	Bid Price Exchange	SPA
		True OD Prorated fares based on previous optimization bid prices	Bid Price Exchange	Dynamic Additive
				Dynamic Multiplicative
Joint Revenue Management	No integration mechanisms are required here, as the simulation treats the entire network as a single airline which is aware of all information required			

The details of the three sets of experiments are as follows:

a) The Speech Stage

The set of experiments in the speech stage study the value gained with higher level of integration and information exchange between inventory control systems of the partner airlines. The forecasting, optimization and revenue sharing between the partners is kept constant, while the availability information exchange methods are varied.

AVS exchange is treated as the as the base case and the revenue gain that can be achieved by implementing seamless code share and bid price exchange is estimated. Table 6 outlines the request evaluation method in each of the three information exchange mechanisms for the sample itinerary in Figure 9.

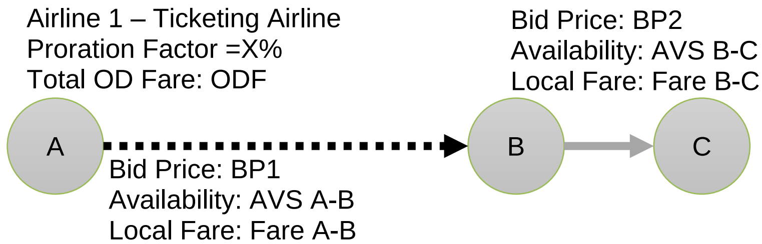

Figure 9: Sample code share itinerary

Table 6: Comparison of various inventory control integration methods

O&D Availability	AVS Exchange	Seamless Code share	Bid Price Exchange
✓	Both AVS A-B AND AVS B-C are true	ODF * X% >= BP1 AND Fare B-C >= BP2	ODF >= BP1 + BP2
✕	At least one of AVS A-B OR AVS B-C is false	ODF * X% < BP1 OR Fare B-C < BP2	ODF < BP1 + BP2

b) Sight Stage

The information available to the forecasting and optimization methods is varied keeping the availability information exchange and revenue sharing mechanisms constant. Availability information method is set at Bid Price Exchange which came out as the best mechanism for the speech stage as can be observed in results section later. Revenue sharing mechanism is set to static proration agreements which is the base case for split stage. There are the two cases simulated for sight stage based on visibility of information of partner airlines and utilization of the same in forecasting and optimization:

Operated O&D: The airlines have information only about the portion of itineraries that is operated by them. The fare of the operated O&D is used in optimization.

True O&D: The airlines can see the entire itinerary enabling them to appropriately allocate the passengers to the right O&D for demand estimation and also take proration into account in estimating the revenue value of the demand.

Operated O&D is considered as the base case here to estimate the gain that can be achieved by True O&D forecasting and optimization.

a) The Split Stage

Three different revenue sharing mechanisms are simulated: Static, Dynamic Additive and Dynamic Multiplicative keeping the speech stage constant at Bid Price Exchange and sight stage constant at True O&D forecasting and optimization that turned out to be the best mechanisms for the respective stages as can be observed in results section later. In the split stage, Static SPAs are considered as the base case, as it is a fixed proration across the market and does not consider the situation of the flights at the time of sale for splitting the revenue between the airlines. This method might not be a win scenario for the airline which is running at a higher load factor and thus giving up a more valuable seat for the code share. The other two cases consider the current bid prices of the leg cabins over which the itinerary is flying and split the revenue per code share seat sold, instead of applying a flat proration rate.

The combination of base cases of each stage with AVS used for availability information exchange, operated O&D used for decision making and static revenue sharing scheme for splitting the revenue represents the base state of decentralized systems. An imaginary centralized system where partner airlines operate and control inventory as a single air line is also simulated to assess the revenue opportunity gap between centralized and decentralized systems that the steps in maturity of integration help capture. In addition to the experiments represented in the above cases, sensitivity analysis with respect to percentage of code share bookings carried by the network is also conducted.

VII. Results

This section can be divided into two subsections. First subsection presents the simulation results from the experiments conducted as described in the experiment setup section. The second subsection consolidates the results from various experiments and provides an overview of the revenue gain that alliance partners can expect by adopting better integration mechanisms with partner airlines. The results are presented for the entire alliance and each individual airline in order to study whether the entire alliance is benefiting from the integration mechanism, and whether benefits accrued are biased towards a singular airline. The possible reasons for revenue gain (or loss) observed are explained through small sample examples. Effects of higher code share traffic flying on the alliance network is also presented.

a) Results for Each Maturity stage

i. The Speech Stage

Significant revenue gain is observed as the systems mature from AVS exchange method for sharing seat availability to bid price exchange for code share request evaluation. The revenue gain is not biased and benefit both the airlines individually, while adding to the revenue of the overall alliance.

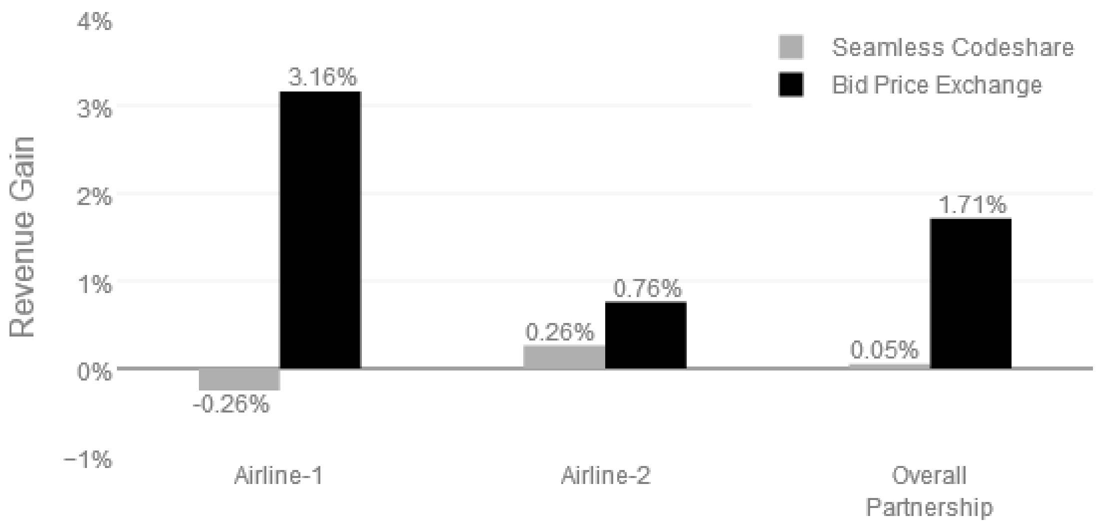

Figure 10: Speech stage, revenue gain over AVS

The seamless code share method produces marginal gain (0.05%) for the overall alliance, while losing revenue (-0.26%) for Airline1 and gaining similar amount of revenue (0.26%) for Airline2.

The bid price exchange method shows a significant gain of 1.71% over AVS for the overall alliance. Both Airline1 (3.16%) and Airline2 (0.76%) gain revenue by using bid price exchange for code share itinerary evaluation. The revenue gain can be attributed to the increase observed in the percentage of code share itinerary booking requests that are accepted. Figure 11 shows that the code share percent almost doubled in the entire network.

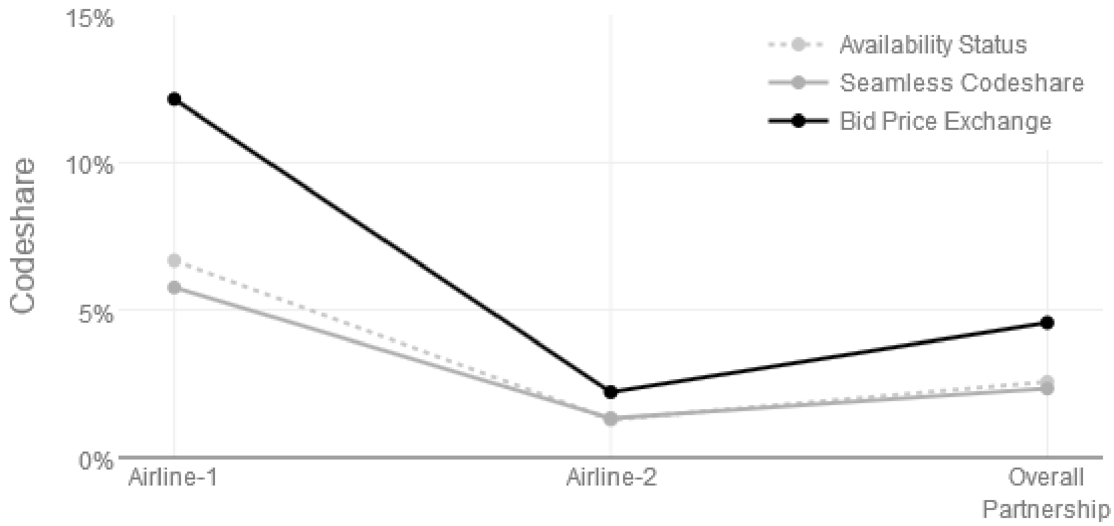

Figure 11: Speech stage, code share gain over AVS

An explanation of the observed increment in the code share traffic can be given by looking at the sample code share itinerary in Figure 12:

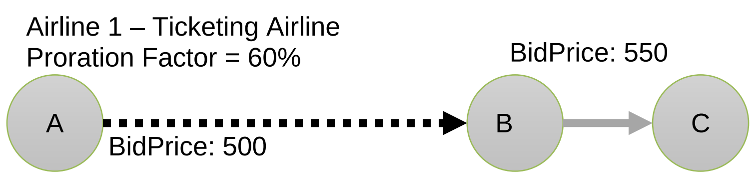

Figure 12: Sample code share itinerary for availability computation

This inter line code share itinerary flies on the market A-C, via station B. A-B is a long haul segment operated by Airline1. B-C is a short haul segment operated by Airline2. The details of availability of these segments is in Table 7.

Table 7: Availability computations for segment A-C

Fare Class	Physical Availability B-C	Fare B-C	Financial Availability B-C	Fare A-C	Airline1 Prorated Fare	Airline2 Prorated Fare
Y	5	700	✓	2000	1200	800
M	2	500	✓	1800	1080	720
B	✕	300	✕	1500	900	600

Availability decisions that will be taken for AC- B class itinerary by the different methods on the speech stage are shown in Table 8.

Table 8: Availability decisions from different evaluation methods

Evaluation Method	Availability Decision For A-C Itin	Reason
AVS	✕	Physical availability on segment B-C would lead to AVS close status, and hence the entire A-C itinerary will be rejected
Seamless Codeshare	✕	Financial availability on segment B-C is not there as the local fare for B-C segment in fare class B (300) is less than the B-C segment bid price (500). Hence the entire A-C
Bid Price Exchange	✓	Total bid price for A-C itinerary (500 + 550 = 1050) is less than the fare offered

The prorated fares for Airline1 and Airline2 (900 and 600 respectively) are more than the bid prices for local segments (500 and 550 respectively). Accepting this request is profitable for both the airlines. Bid Price Exchange enables the right tradeoff between operated O&D and code share requests to achieve better revenue for both the airlines and the overall partnership network.

Further, a trend is observed in the revenue gain when increased code share traffic is simulated on the network. This trend is linear gaining 0.6% revenue for each 1% increment in the code share percent.

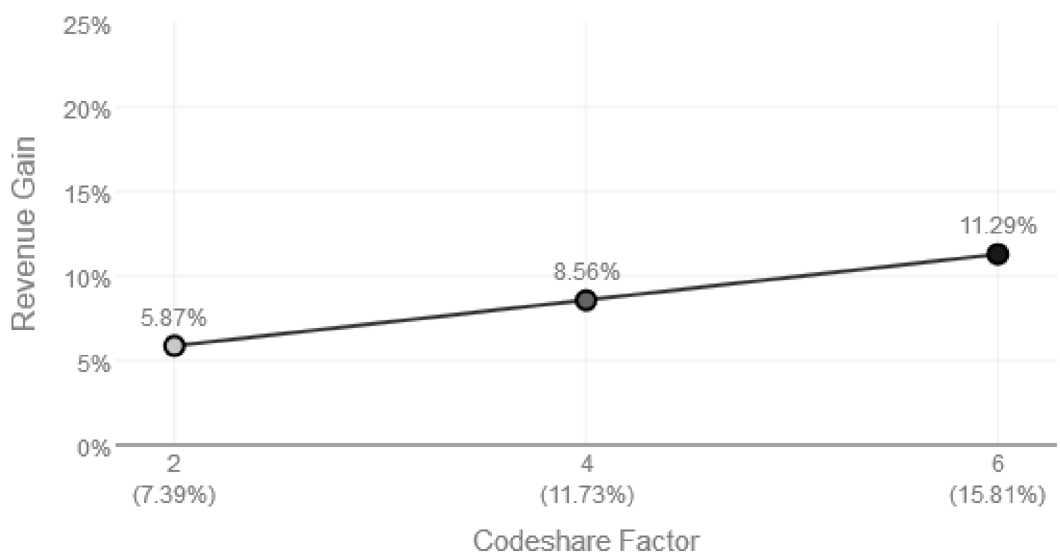

Figure 13: Speech stage, revenue gain trend over AVS for overall partnership

Similar linear trend is observed for the individual airlines. The gain for Airline1 is much higher than Airline 2 due to higher contribution of code share traffic and revenue to the total.

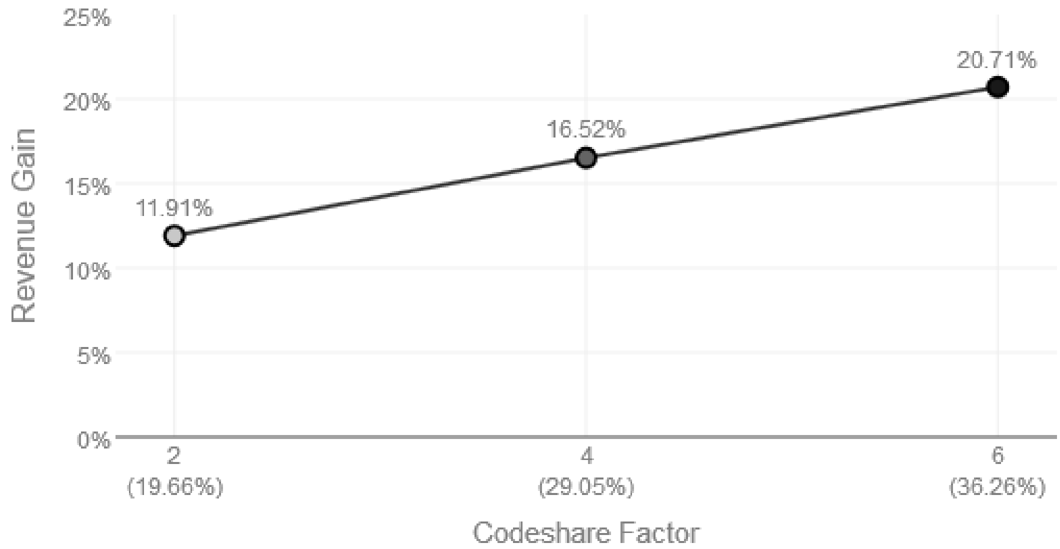

Figure 14: Speech stage, revenue gain trend over AVS for Airline1

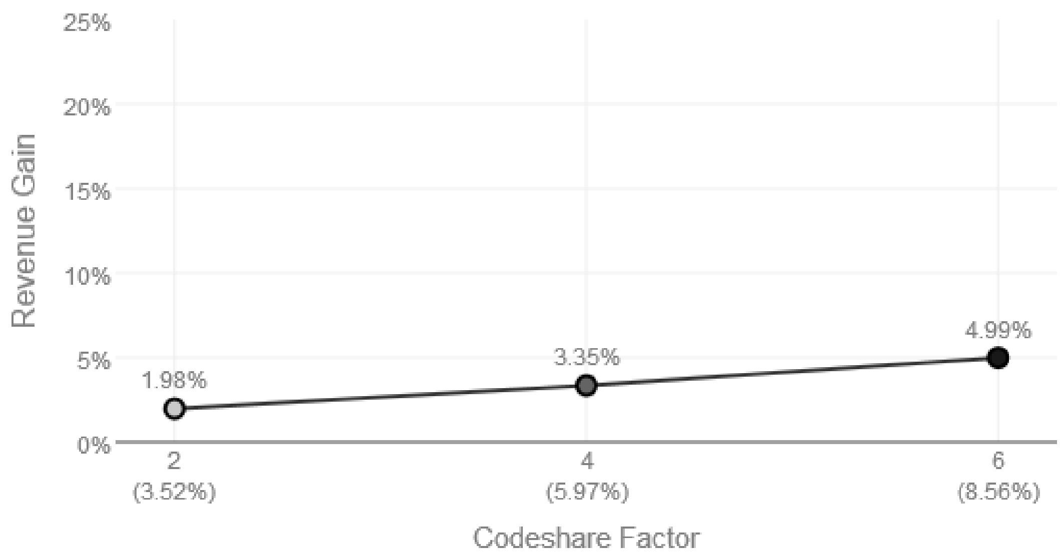

Figure 15: Speech stage, revenue gain trend over AVS for Airline2

ii. *The Sight Stage*

Revenue gain of about 0.57% is observed for the overall alliance when the visibility of the revenue management system for the in dividual airlines mature from Operated O&D to True O&D. Both the airlines also gain individually, Airline1 gains about 1.18% while Airline2 gains 0.16% revenue.

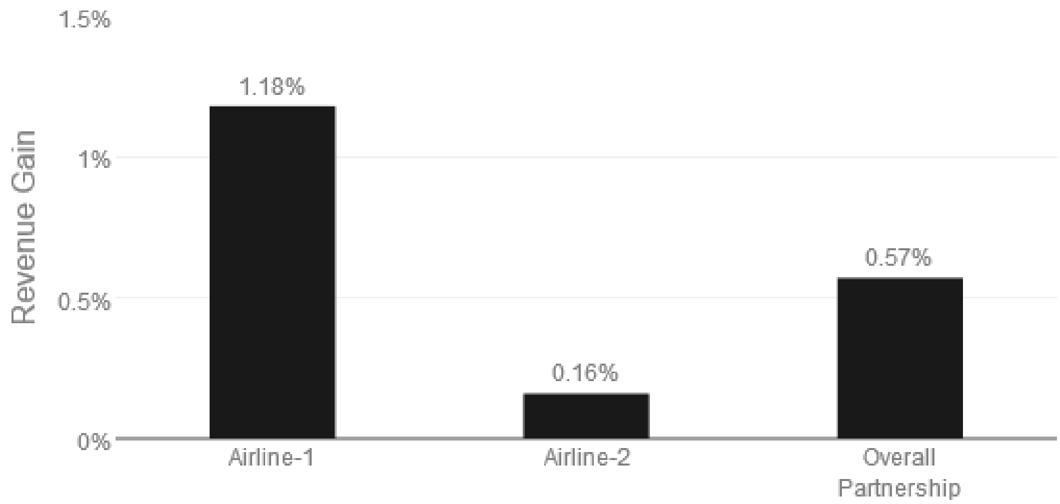

Figure 16: Sight stage, revenue gain over operated OD

Revenue gained over Operated O&D can be attributed to an increase in the number of code share Itineraries that are accepted. Since the revenue management systems at both airlines are aware of the True OD of each passenger serviced, the systems can perform an accurate estimation the demand and value of each sector they service. This allows the individual revenue management systems to make a better tradeoff between the online and code share demand.

Figure 17 shows the code share percentage gained by each airline and the overall alliance by using True O&D forecasting and optimization. The simulation results indicate that overall alliance code share percentage increases from 4.6 % to 4.9% but for Airline1 this leads to code share percentage going up from 12% to 13% when the revenue management systems mature from Operated O&D to True O&D forecasting and optimization.

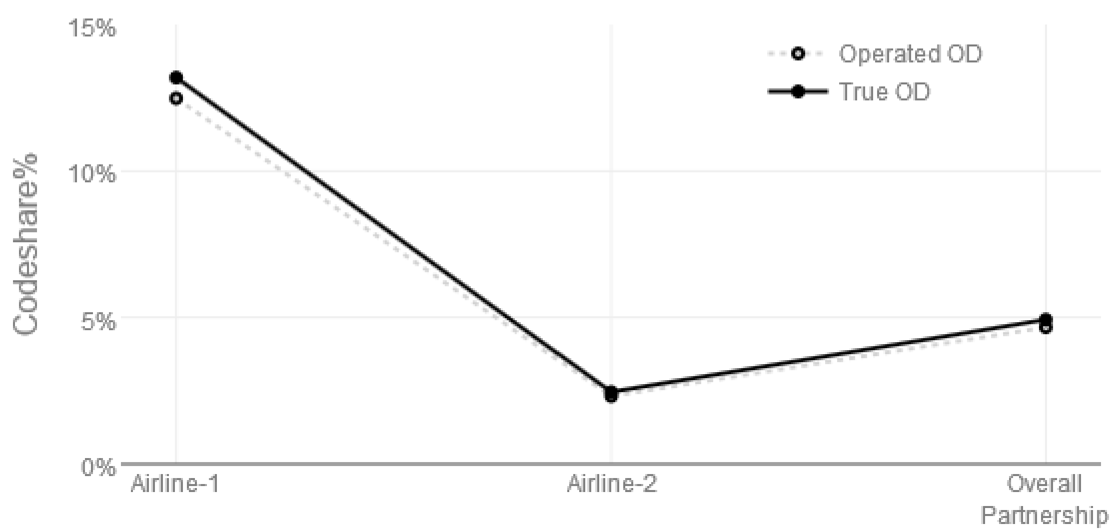

Figure 17: Sight stage, code share gain over operated OD

The revenue gain can be explained by looking at the sample itinerary in Figure 18.

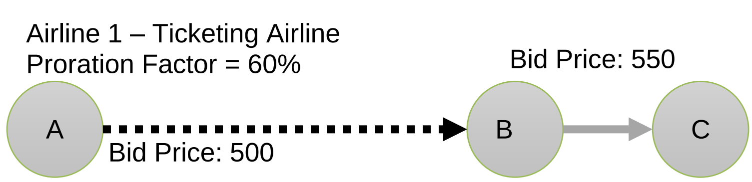

Figure 18: Sample code share itinerary for availability computation

The demand and fares for the various service classes flying over segment A-B in the sample itinerary are shown in Table 9.

Table 9: Fares and true demand for service classes flying over segment A-B

Fare Class	Demand	Fare	Airline1 Prorated Fare (60%)	Allocations
AC - Y	6	1800	1080	6
AC - B	10	1200	720	10
AB - Y	10	700	700	10
AC - M	15	1000	600	15
AB - B	15	500	500	9
AB - M	25	400	400	✕

It can be observed that the local fares for M class on segment AB is 400 against the prorated fare of 600 coming from M class on the service AC. In case of forecasting and optimization based on Operated O&D Airline1 would forecast demand and come up with seat allocations as shown in Table 10. The resulting revenue impact is explained in Table 11.

Table 10: Fares and demand considered by Operated O & D revenue management system for segment A-B

Fare Class	Demand	Fare	Airline1 Prorated Fare (60%)	Allocations
AB-Y	16	700	700	16
AB-B	25	500	500	25
AB-M	40	400	700	9

Table 11: Operated OD v/s True OD

Service - Class	Segment	Method	Revenue Estimate of Flow Demand
AC - M	AB	Operated O&D	Operated OD will estimate this demand at local fare 400. The optimization set lower bid prices and it will lead to dilution of revenue
AC- M	AB	True OD	True OD will estimate this demand using the prorated fare: 600, resulting in higher bid prices. Code share demand providing higher revenue share will be preferred over local demand. Hence true OD helps revenue management systems to increase yield by maintaining better mix of code share and operated market demand

Simulation of scenarios with higher code share demand showed that the benefits from True OD forecasting and optimization will increase linearly with higher code share demand.

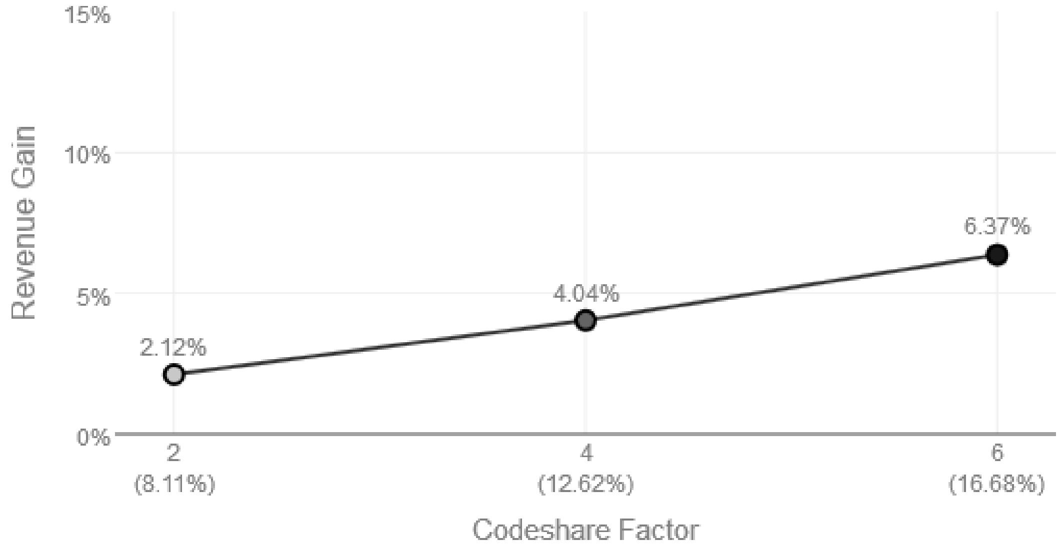

Figure 19: Sight stage, revenue gain trend over Operated O&D for overall partnership

Similar linear trend is found in the revenue gain for individual airlines as the code share demand increases as shown in Figure 20 and Figure 21. The trend is same for both the airlines. However, the gain observed for Airline1 is higher than Airline2 due to higher contribution of code share traffic and revenue to the total.

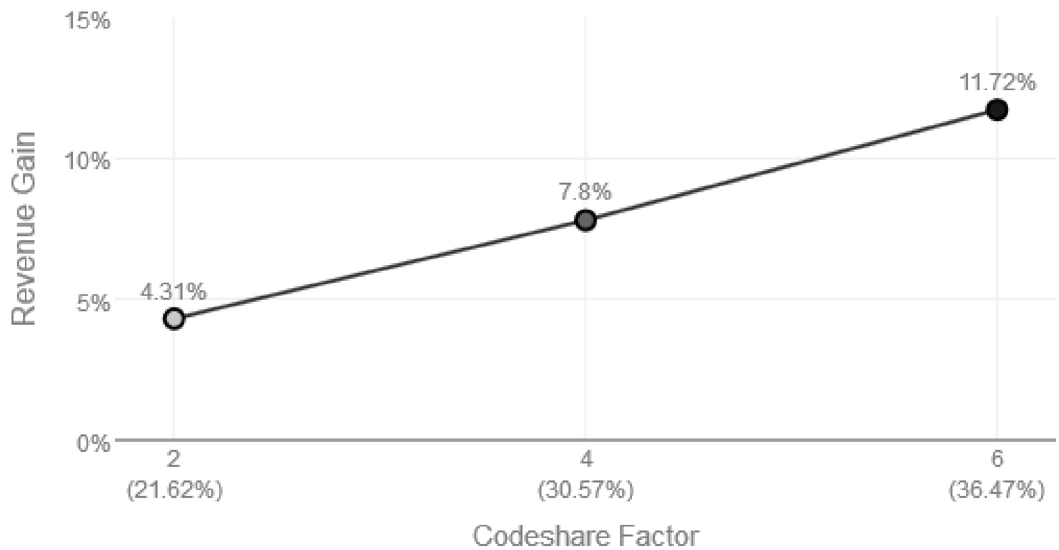

Figure 20: Sight stage, revenue gain trend over operated OD for Airline1

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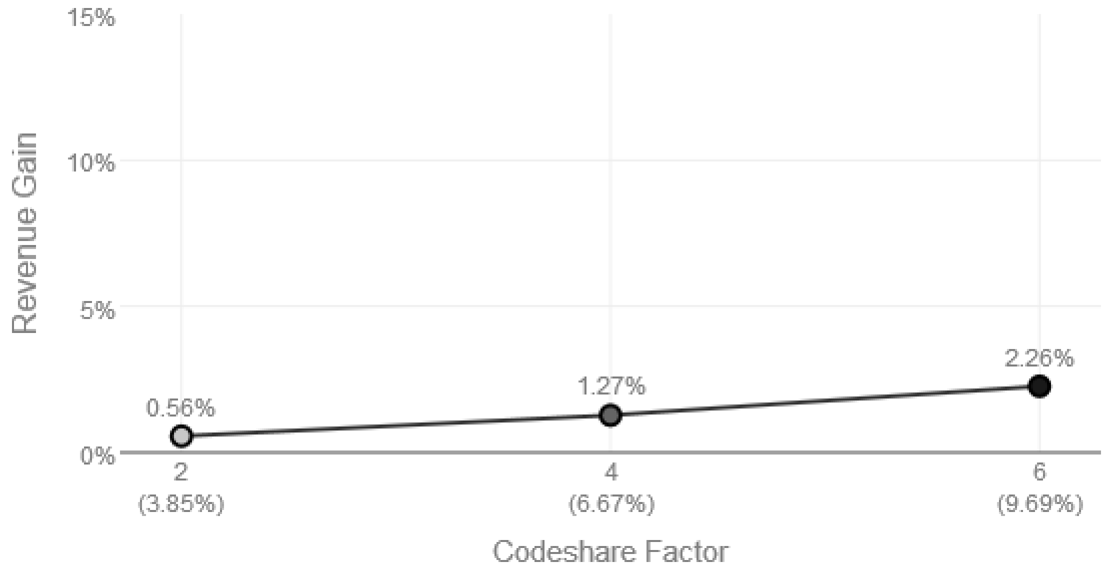

Figure 21: Sight stage, revenue gain trend over operated OD for Airline2

iii. *The Split Stage*

The results along the split stage provide insight on where dynamic proration methods help and where they do not. In the network considered for the study, the proportion of virtual, parallel and complementary code share demand out of the total demand of both airline networks is as shown in Table 12.

Table 12: Virtual, Parallel, Complementary code share percentages in the partnership network

	Marketing Airline	Operating Airline	Code share %
Virtual code share	Airline1	Airline2	1.5%
	Airline2	Airline1	4%
Parallel code share			0.1%
Complementary code share			0.1%
Total Operated		Airline1	21.7%
		Airline2	72.6%

Virtual code share and parallel code share are itineraries where the marketing airline does not operate any segment on the itinerary. However, the marketing airline benefits from selling such itineraries as it gets a marketing fees based on the proration agreement signed between the partners. The dynamic proration mechanisms based on bid prices used in simulation tend to get biased for virtual and parallel code shares without such marketing fees provisions. Dynamic additive proration tends to be biased towards the marketing airline, as it gives only the bid price to the operating airline and remaining revenue to the marketing airline. Dynamic multiplicative proration splits the revenue based on the bid price of the operated segment flown by each airline for a code share itinerary. For virtual and parallel code shares, the marketing airline does not receive any revenue.

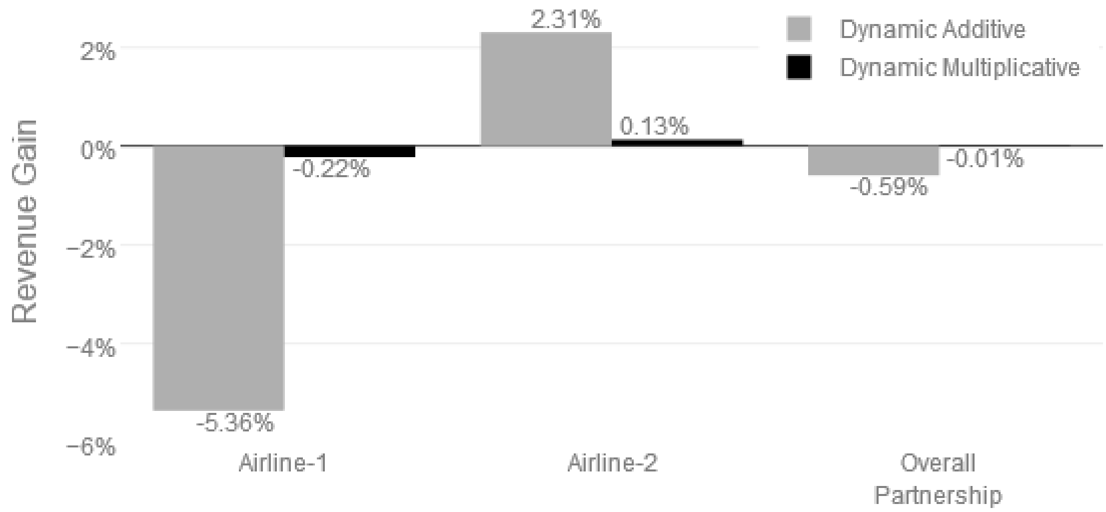

Figure 22: Revenue gain along split stage over static proration

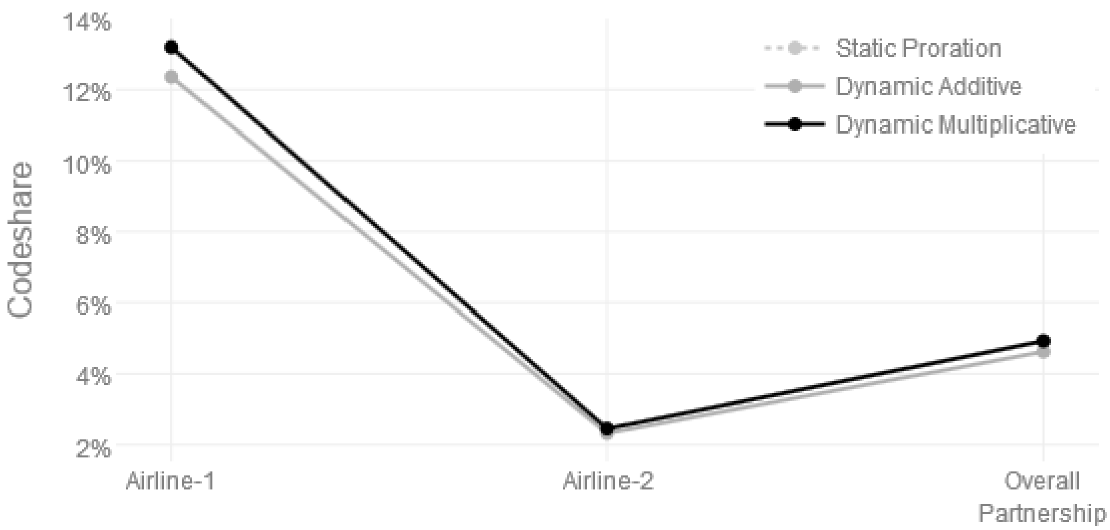

Figure 23: Code share gain along the split stage over static proration

Figure 22 outlines the revenue impact of dynamic proration methods vs static proration method that exists in reality. As observed in Figure 23, Dynamic multiplicative proration has the same percentage of code share traffic as static proration method while Dynamic additive has marginally lesser code share traffic. The observations in Figure 22 and Figure 23 are interesting due to two reasons.

First, the dynamic multiplicative proration redistributes revenue from Airline1 to Airline2 without impacting overall partnership revenue. Figure 24 makes it clear that proration ratio across markets in static agreements were favorable to Airline1 covering more than 50% of the area. Hence Dynamic Multiplicative proration corrects the proration ratios to the fair share of revenue in line with the bid prices of the legs of Airline1. Since the static proration agreements were good to begin with, this did not lead to any significant revenue gain for the overall partnership.

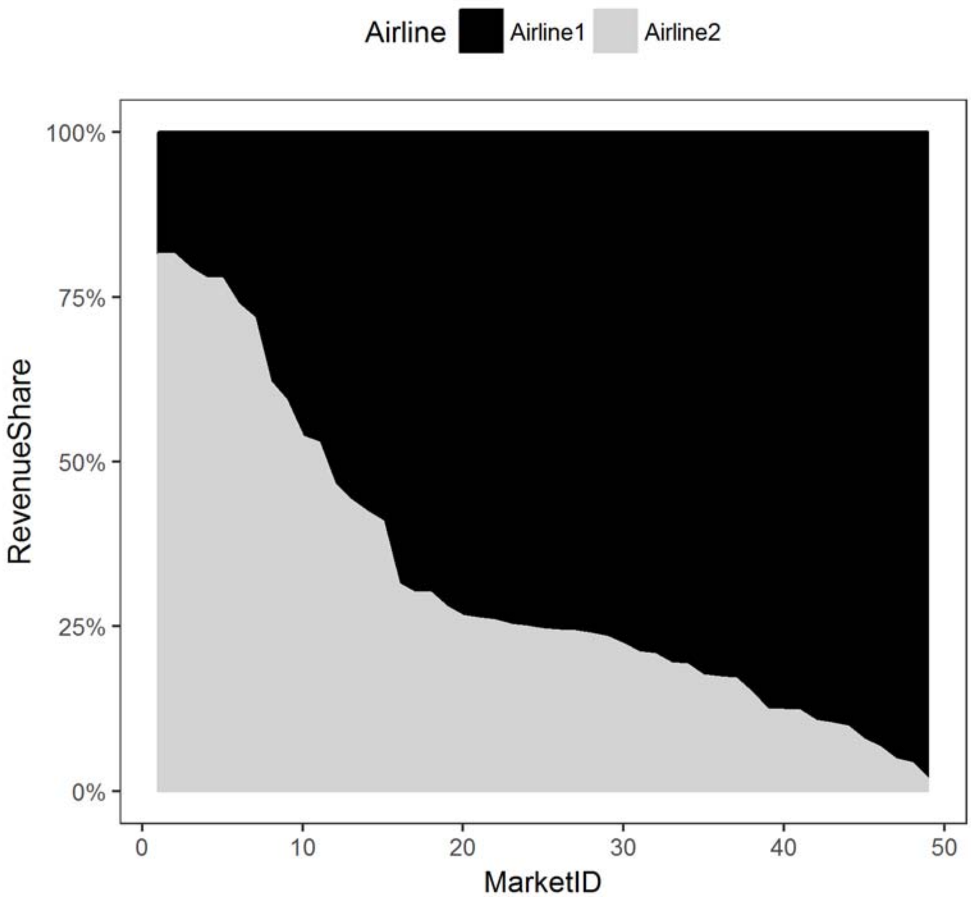

Figure 24: Market share by revenue held by the partners

Second, the dynamic additive proration leads to revenue loss for Airline1 and revenue gain for Airline2 but ends up with a loss for the overall partnership. There are two factors at play here. First, Airline2 has a higher share of virtual code share demand as the marketing airline. Dynamic additive proration provides operating airline only the bid price expected at the time of the sale and whenever the passenger pays a fare higher than bid price, it is favorable to the marketing airline. This causes Airline1 which originally claimed higher share in static proration agreements in comparison to bid prices to lose revenue. Second, True O&D optimization uses previous optimization bid prices as estimate for prorated revenue which leads to a feedback loop in case of Dynamic Additive proration. Lower estimates on code share revenue share for operating airline leads to dilution as well as an expectation that the revenue from code share does not increase with time. This leads to rejection of code share demand leading to drop in code share percentage as well as revenue loss for the overall partnership.

In addition to the above observations, the higher percentage of virtual code share traffic is not realistic and could have been caused by trip breaking logic used for breaking tickets into itineraries. A different trip breaking logic compounded with a better mechanism for handling virtual code share itineraries in case of dynamic proration could lead to different results. This will be a part of the future work in this area.

b) Consolidated Results

Previous subsection walked through the detailed simulation results along each stage of integration maturity. This subsection first defines the revenue opportunity that exists between two extreme scenarios and consolidates the results from the previous subsection within the opportunity space:

Completely Decentralized systems (Worst Case): Here the revenue management systems are unaware of the partnership and consider code share itineraries demand as operated O&D demand during forecasting and optimization. The availability computation is done using AVS messages exchange and static revenue sharing mechanism is used.

Joint Centralized System (Best Case): This refers to a very tightly integrated "know-all" virtual entity that has complete information about both the airline network sand makes the inventory control decisions as a single airline. As previously described such a centralized

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system is not quite realistic due to several factors including the option of the airlines to exit an alliance.

In this section, a consolidated overview of the expected revenue gain from each integration mechanism is sketched. The overview is provided for the entire alliance and for each airline as in the previous section. The total opportunity window available is defined by simulating the worst and best case scenarios as described above and taking the difference between the revenue of these scenarios. The revenue opportunity window that exists between these two scenarios is 2.67% of incremental revenue for the overall alliance network.

Results in Figure 25 show that 88%(2.35% incremental revenue) of the total revenue opportunity can be achieved by upgrading to bid price exchange for availability computation and True O&D forecasting and optimization. Bid price exchange for availability calculation covers 66% of the total revenue opportunity (1.77% incremental revenue). True OD forecasting and optimization covers an additional 21% (0.58% incremental revenue) of the revenue opportunity.

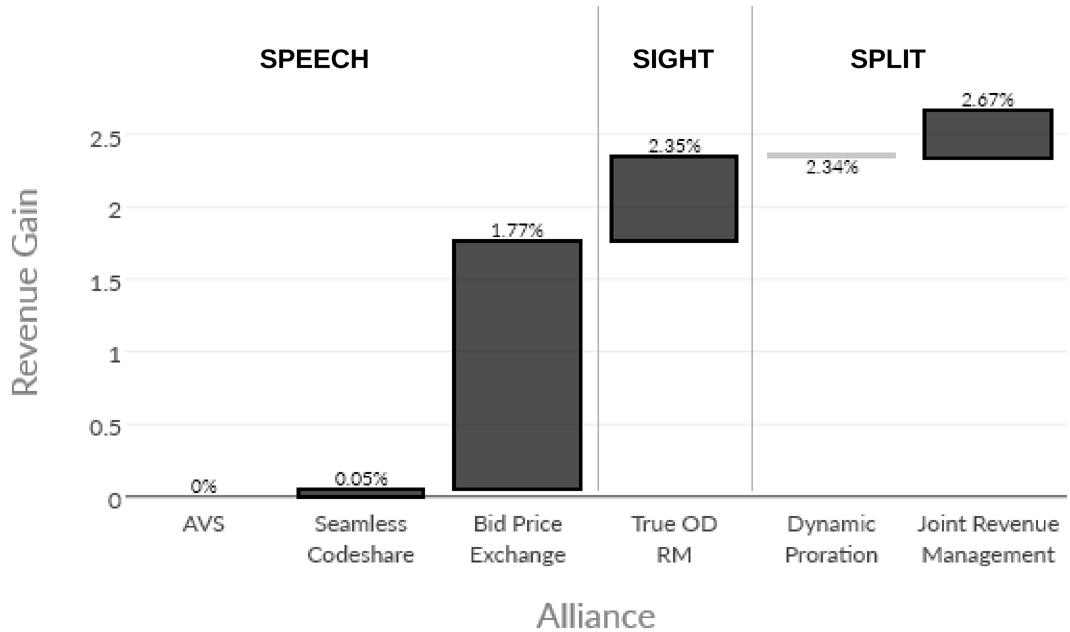

Figure 25: Revenue opportunity achieved for the partnership (>80%)

The overall gain for the partnership is achieved without penalizing any single airline. The individual airlines in the partnership as well tend to gain from these steps in the direction of closer integration and maturity as shown in Figure 26 and Figure 27. Airline1 achieves more than 95% of the total opportunity, while Airline2 achieves more than 80%. This shows that the revenue gain roots from a win-win situation that aligns individual airline revenue goals with the overall partnership goals. This revenue gain can be achieved by partner airlines by upgrading to better information exchange mechanisms and decision making like bid price exchange with true O&D demand forecasting and optimization within the practical realms of decentralized systems.

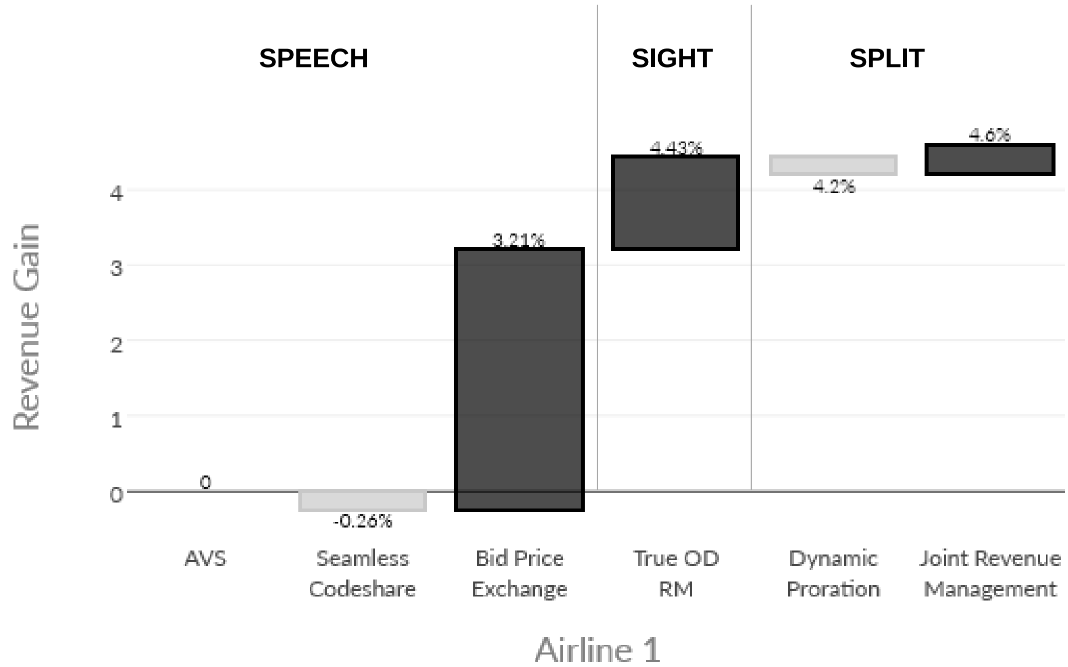

Figure 26: Revenue opportunity achieved for Airline 1 (>95%)

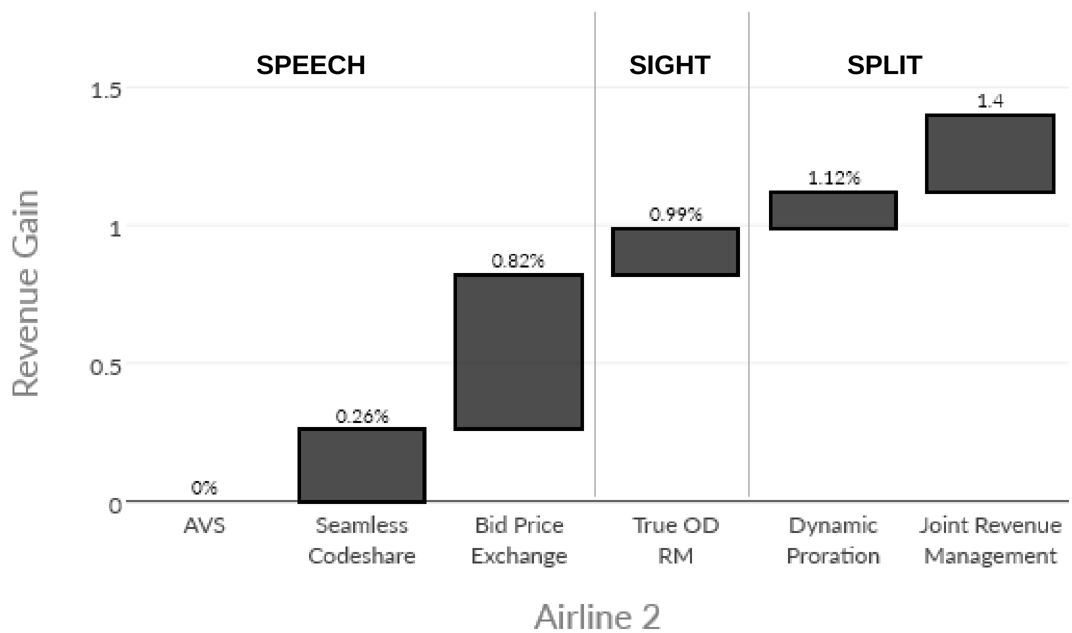

Figure 27: Revenue opportunity achieved for Airline 2 (>80%)

VIII. Conclusions

At this juncture, a quick recap of the sections on prior work and the motivation for present study is required. Prior work shows that alliance partners would not prefer a very tight integration of operations and information systems due to several legal, sovereignty and nationalistic issues. A joint revenue management system that has all the information required from all alliance partners is preferable but not realistic due to several factors outlined and thus mandates a loosely coupled approach to information exchange in systems integration. A realistic scenario under the given circumstances is to create an eco-system where the information systems at individual airlines collaborate by communicating with each other and exchange real time information for allowing informed decision making.

The information that can be shared between the airlines is categorized into three groups and incremental stages of maturity of integration are defined - speech, sight and split.

Speech: Availability information exchange between the systems that allows airlines to better market and sell seats on code share itineraries

Sight: Complete itinerary (true origin and destination) information that allows the revenue management systems to better estimate demand and estimate the revenue value of the same

Split: Dynamic revenue sharing mechanisms that enable airlines to make an informed decision about how to split the revenue from code share itineraries

A roundtable discussion with the real practitioners showed that some integration efforts are already being tried out with the major focus on the speech dimension where inventory systems are integrated to share real time information about availability. Next generation revenue management systems that consider true origin and destination demand and revenue proration agreements are hitting the market (Doreswa my & Kulkarni, 2016). Dynamic proration mechanisms require a major level of trust among partners and deeper level of integration. Hence an inherent order is established in the stages of maturity that partner airlines can target to achieve and the simulation studies conducted on real airline alliance network data follow the path of maturity than a factorial design of experiments for the same.

Based on the analysis of the consolidated results, there is a clear two step strategy that can be laid out for airlines in partnership to achieve more than 80% of the total revenue opportunity that exists with a win-win scenario for both airlines in partnership without penalizing individual airlines.

Step 1: Use of bid price exchange for seats availability evaluation

As shown in the consolidated results section, a lion's share of the expected revenue gain comes from upgrading to a bid price exchange based availability evaluation method. Bid price exchange between airlines for evaluating code share itineraries is already in a state where few airlines have adopted it, and the technology is in a mature state to allow this real time exchange (Ratliff & Weatherford, 2012). Combining these two facts, bid price exchange for seats availability evaluation is clearly an area that airline alliances should address as it promises significant gain and technical feasibility has been established.

Step 2: Adopt true origin and destination revenue management system:

True origin and destination revenue management is the second integration strategy that should be evaluated and implemented by the alliances. True OD forecasting and optimization promises an additional 22% capture of the total revenue opportunity.

An additional note on the dynamic revenue sharing mechanism is required. Although the revenue gain in the simulation of dynamic revenue sharing mechanism are not very significant due to a good initial state, they do tend to remove bias in revenue sharing and ensure that each partner gets a fair share of the revenue earned from the code share itineraries.

IX. Future Work

Few experiments can be perceived as a fall out of the present study and are in active consideration by the authors can be listed as follows:

a) *Dynamic revenue proration mechanisms for virtual code shares*

As seen in the analysis of the split stage, the results do not represent the true picture due tothe share of marketing airline being zero in dynamic multiplicative proration. Designing dynamic proration mechanisms that handle virtual code shares appropriately is an area of future research.

b) *Truthful information sharing between partners*

The simulation studies conducted assume that the information (bid prices) shared by airlines for code share itinerary evaluation and revenue sharing are truthful and accurate. In case of dynamic proration mechanisms, there is incentive for the airlines to not share accurate bid prices and manipulate the system by bumping up the bid prices in order to extract bigger share of code share revenue. Research is being done in the area of mechanism design using game theoretic approaches that incentivize truthful information sharing (Hu, Caldentey, & Vulcano, 2013). Simulation as a tool would be useful in validation and quantification of the impact of designed mechanisms.

c) *Use of partner information in optimization*

Dynamic valuation research (Belobaba & Jain, 2013) suggests that using partner bid prices in optimization can lead to better revenue mix and higher revenues. Simulation studies to estimate the gain from using partner information during optimization is a potential area of future research.

Further the authors will endeavor to continue integrating suggestions from academic work into the APOS framework in order to quantify the revenue impact that can be expected from implementing the suggested strategies.

X. Glossary of Terms

1. ATA: The *International Air Transport Association* is a trade association of the world's airlines.
2. WATS: World Air Transport Statistics is a comprehensive and up-to-date reference compendium of aviation statistics covering a wide range of key industry areas
3. RPK: Revenue Passenger Kilometers (RPK) is a measurement used in the aviation industry. Each kilometer a paying passenger has flown counts as an RPK
4. GDD: Global Demand Data

5. **PNR: Passenger name record (PNR)** is a record in the database of a computer reservation system (CRS) that contains the itinerary for a passenger, or a group of passengers travelling together
6. **PODS:** The Passenger Origin-Destination Simulator
7. **AGIFORS:** The Airline Group of the International Federation of Operational Research Societies
8. **CRS:** Computerized Reservation System
9. **GDS:** Global Distribution System

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