

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

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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.

Index terms— real partnership data, simulation, revenue management, partnership, bid price exchange, true OD, code share itineraries.

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 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 ?? 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]

44 /Bookings information for both the airlines (Vinod, 2005). This optimal "know-all" solution will be referred to as
 45 joint revenue management system. However, such a tight integration system might not be feasible for a multitude
 46 of reasons including alliance exit options available to the airlines. A Goda R. Doreswamy ? , Amrit Raj Misra
 47 ? & Kavitha Guddeti ? significantly less investment and risk (Vinod, 2005). The alliance between Northwest
 48 and KLM airlines in 1991 had shown how airlines can benefit from strategi marketing partnerships. Northwest's
 49 connecting traffic with KLM increased by 115% from 1991 to 1994 adding Table ??: Key performance measures
 50 of Global Alliances A more realistic approach is to have a loosely coupled, decentralized system which allows
 51 real time information exchange enabling the individual systems to make decisions while being aware of the entire
 52 alliance network. In such an environment each airline will implement its own revenue management and inventory
 53 control system. However, a communications framework will allow the individual system to request and receive
 54 required information in real time, enabling decisions that are beneficial for the entire alliance network. The
 55 environment will prompt a shift in the decision making process from a greedy approach where each airline is
 56 focused on optimizing their own network to a more collaborative approach where the benefit of entire alliance is
 57 preferred. Fundamental operational requirement for airlines participating in an alliance is to facilitate code share
 58 bookings (where one airline sells tickets on a sector operated by the partner). Alliance partners need to exchange
 59 operational information like availability, PNR and baggage details in order to ensure code share bookings are
 60 appropriately handled. Further, alliance partners can exchange data like the current bid prices on various legs
 61 that can help an alliance-aware system make strategic decisions keeping in mind the entire alliance network.

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

70 The remainder of the paper has been organized as follows. Section 2 provides the details of prior work done in
 71 this area including some of the common practices already adopted by alliances. Section 3 lays down the foundation
 72 for the motivation and the need for conducting simulation studies on real alliance data to compliment prior work.
 73 Section 3 also deep dives into the details of various integration mechanisms and explains the choices behind
 74 the scenarios that are simulated and outlines an integration maturity order within these scenarios. Section 4
 75 provides an overview of Airline Planning and Operations Simulator (APOS), the tool used for simulation. Section
 76 5 provides an overview of the combined alliance network that is simulated and presents some key statistics
 77 describing the network. Section 6 gives the details of each scenario that is simulated including the information
 78 exchange, forecasting and optimization techniques and the revenue sharing mechanism used in each simulation
 79 study. Section 7 first presents the results from each individual simulation study and then moves on to provide
 80 a consolidated outline of revenue gain. Section 8 concludes with a recommendation for airlines on integration
 81 areas that need to be addressed first. Section 9 provides a glimpse of future simulation work that can be done
 82 and some of the gaps with the present study that need to be addressed

83 1 II. Prior Work

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

88 Alliance Revenue Management (Vinod, 2005) provides an in-depth discussion on challenges faced when trying
 89 to synchronize decision making across an airline alliance in order to maximize revenue across the % RPK [3] Flown
 90 (%age of total) # Of Destinations Flown alliance network. The paper underlines the fact that alliances will remain
 91 the prevalent mechanism of cooperation between international airlines due to sovereignty and nationalist issues.
 92 An optimal environment for combined revenue management of the alliance is outlined i.e. a single inventory
 93 control environment for all partners in an alliance which is aware of the details of the combined network. The
 94 paper further establishes the fact that such an optimal environment is far from reality due to several factors
 95 like alliance exit options, revenue sharing and anti-trust immunity considerations. A more realistic approach
 96 is defined where the alliance partners exchange inventory availability and bid prices in real time on a need
 97 to know basis in order to maintain network equilibrium. A detailed treatment of operational and strategic
 98 challenges for alliance partners is provided including alliance pricing, through check-in, PNR-synchronization
 99 across partners and combined overbooking policy. Simulation results from PODS [6] simulation framework
 100 showcasing the benefits from sharing of bid prices between the partner airlines and using the bid price of the
 101 partner airline within the optimization have been presented (Belobaba & Jain, 2013). Two important aspects of
 102 Alliance Revenue Management are covered. The first being determination of seat availability based on revenue
 103 benefit and opportunity cost for the alliance using shared bid price from the alliance partner. The second is using
 104 information (bid prices) about the current state of the alliance partner during the optimization process in order
 105 to set the optimal controls that will optimize the entire alliance network.

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

117 **2 III. Motivation**

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

121 **3 a) Inventory Information Exchange**

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

125 **4 b) Decision making**

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

132 **5 c) Revenue sharing**

133 The alliance partners need to decide on revenue sharing for code share itineraries so that the individual airline
134 revenue maximization goals are aligned with the alliance revenue maximization goal. Dynamic proration
135 mechanisms suggested in prior work require the airlines to exchange bid price information in order to allow
136 revenue split based on the state of the airline at the time of sale. This is the final stage of maturity in integration
137 as it requires a major level of trust among partners and deeper level of integration like between Lufthansa and
138 Swiss or between KLM and Air France (Hu, Caldentey, and Vulcano, 2013) The motivation for this study is to put
139 a realistic estimate on the revenue gain that practitioners can expect by adopting the integration mechanisms
140 described in prior work. The earlier studies either did not perform a simulation to measure the impact of
141 suggested strategies or performed it on a sample artificial network. The main contribution of this study would be
142 to estimate the revenue impact after running simulation on a large realistic network created from data obtained
143 from actual partner airlines and also provide a path of maturity in integration to follow that can help close
144 the revenue opportunity gap between completely decentralized and centralized systems. Airline Planning and
145 Operations Simulator (APOS) is used for the simulation studies.

146 There are two sets of variations introduced in the simulation:

147 Maturity of integration: Several mechanisms that represent maturity of integration are simulated. These
148 mechanisms have been defined in the further sections Code share Factor: The code share factor controls what
149 percent of the total traffic is on code share. This variation is used for analyzing sensitivity of revenue impact to
150 the level of code share traffic carried by the network Based on the three aspects of systems integration discussed
151 in this section, three stages of integration maturity are defined as shown in Figure 1: The speech stage addresses
152 the operational aspects of the systems integration within an airline alliance which primarily revolves around the
153 mechanism of sharing availability information. This is referred to as the speech stage because this is primarily the
154 way IT systems talk to each other and convey information. The sight and split stages address the more strategic
155 issues related to setting of inventory controls and the mechanism of sharing revenue on ticket sales on code share
156 itineraries. The sight stage covers strategies related to forecasting and optimization in the individual revenue
157 management systems of the alliance partners and whether these individual systems are aware of the partner and
158 code share itineraries. The split stage covers the mechanisms of revenue sharing. These stages are described in
159 more detail using the code share itinerary example in Figure 2: In a partnership scenario, one airline is allowed
160 to market tickets on another airline and also sell code share itineraries where different segments of the itinerary
161 are operated by different airlines (See Figure 2). While evaluating such requests, the marketing airline needs to
162 know the status of the seats available on the operating airline. The operating airline can share different levels of
163 data with the marketing airline regarding status on whether a seat is available on the requested flight and how

164 valuable those seats are. The different kinds of inventory information exchange mechanisms that are simulated
 165 are: AVS: AVS stands for Availability Status Message or Availability Inventory Status message which is an IATA
 166 standard Teletype message transmitted from one airline to another or to a CRS [8] /GDS [9] in order to update
 167 its Flight’s availability on other airline or GDS core availability. Operating airline would exchange AVS message
 168 with the marketing airline(s) which processes the AVS messages and stores the availability matrix of on the flights
 169 operated by their partners (see Figure ??). When the code share sale request is received by an airline, it will refer
 170 to this locally stored availability matrix before accepting or rejecting the request (see Figure 4). AVS messages
 171 are usually transmitted as a result of changes in status when availability crosses pre-defined level of availability
 172 threshold. Due to these thresholds and lag in transmission of AVS message, code share requests can get rejected
 173 even when seats are available on the operating carrier or lead to unintended over sales for the operating carrier.
 174 Bid Price Exchange: Carriers can make more optimal inventory decisions at the O&D level if they evaluate the
 175 availability using the O&D fare and the bid prices of all the underlying legs (including that of the operating
 176 carrier). This will enable right availability value to be used at the time of sale in an O&D environment. Bid
 177 price exchange allows operating carriers to push bid price vectors of the legs operated by them to the marketing
 178 airlines. These bid price vectors are stored and processed by the marketing airlines at the time of availability
 179 determination. Figure 6 and Figure 7 outlines the details of the exchange mechanism and request evaluation.
 180 The experiment design moves along each stage keeping everything else constant and just varying the options
 181 available in the given stage. There is an inherent order in the stages defining a chain of maturity which is speech,
 182 sight and then split. As the experiments move into the higher stage of maturity, the ‘best case’ settings from the
 183 previous stage are retained. This is done in order to isolate the impact of variations in each stage.

6 IV. APOS

184 The APOS framework enables simulation on top of real historical data provided by an airline. APOS modules
 185 are outlined in Table 2. The main modules of interest for this study are: f) Split: How the revenue from code
 186 share itineraries is split between the partners?
 187

188 Once a seat is sold on the code share itinerary, the involved airlines (marketing and operating) need to split the
 189 revenue between themselves. The revenue sharing agreement should ensure fair share for each airline. Following
 190 revenue sharing schemes are considered for the study: Static: Static methods split the revenue between the
 191 partners based on a pre-decided mutually agreed ratio. This could be based on local fares of partners, or cost
 192 weighted mileage. Airlines also sign a Special Proration Agreement (SPA) which defines the revenue split ratio.
 193 The static proration methods do not take into account the real time dynamics at the time when the sale request
 194 is confirmed. Proration ratios obtained from real data of the partner air lines are used for the study. Some key
 195 statistics about the airlines involved in the partnership are as shown in Table 3: The APOS framework simulates
 196 several streams of incoming passenger requests that mimic different instances of a typical 24-hour window of
 197 departures on the airline networks. APOS also has the capability to simulate higher demand on code share
 198 itineraries for sensitivity analysis.

7 V. Simulation Setup

199 Real data obtained from two alliance partners is used in simulation in order to have a realistic estimate of the
 200 revenue impact. For the sake of present study, the airlines will be called Airline1 and Airline2. Airline1 is a pure
 201 hub and spoke carrier which serves international markets. Major portion of Airline1 traffic is flow traffic moving
 202 through the hub to their eventual destination. Airline2 is a major regional player with only a few long haul
 203 routes. The partnership allows Airline1 to expand its network in the region where Airline2 operates and helps
 204 Airline2 provide several international connections from its regional airports.
 205

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

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

8 VI.

9 Experiment Setup

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

216 First the experiments move along the speech stage as it is the fundamental requirement for alliances to allow
 217 code share bookings. Once the best strategy to communicate inventory availability information is identified, the
 218 speech stage is fixed with the best strategy and the experiments move along the more strategic sight stage and
 219 measure gain from forecasting and optimizing true ODs as against forecasting and optimizing only the operated
 220 ODs. Finally the speech and sight stages are fixed at their best alternative and the experiments move along the
 221 split stage to find out the best mechanism of splitting the revenues amongst the partners and measure expected

222 gain from different revenue sharing mechanisms. Finally, the simulation of a virtual single airline that includes
223 the network of both the airlines where inventory decisions are made using centralized revenue management
224 and inventory systems provides an upper bound on the alliance revenue (Vinod, 2005) to assess the revenue
225 opportunity gap between centralized and decentralized systems that is captured by integration mechanisms.

226 In all the experiments conducted the following forecasting and optimization model sare used: Using the same
227 forecasting and optimization methods across ensures that the differences seen in the alliance revenues can be
228 attributed to changes in the integration and revenue sharing methods. The Table 5 shows all scenarios that
229 are simulated in the increasing order of maturity stages. The base case used for each stage is highlighted. It
230 is important to note that there is an inherent order in the way the experiments move through the stages from
231 operational to more strategic levels. The best case from each stage is retained when moving to a higher stage.
232 No integration mechanisms are required here, as the simulation treats the entire network as a single airline which
233 is aware of all information required The details of the three sets of experiments are as follows:

234 a) The Speech Stage

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

239 AVS exchange is treated as the as the base case and the revenue gain that can be achieved by implementing
240 seamless code share and bid price exchange is estimated. Table ?? outlines the request evaluation method in each
241 of the three information exchange mechanisms for the sample itinerary in Figure 9. The information available
242 to the forecasting and optimization methods is varied keeping the availability information exchange and revenue
243 sharing mechanisms constant. Availability information method is set at Bid Price Exchange which came out as
244 the best mechanism for the speech stage as can be observed in results section later. Revenue sharing mechanism
245 is set to static proration agreements which is the base case for split stage. There are the two cases simulated
246 for sight stage based on visibility of information of partner airlines and utilization of the same in forecasting
247 and optimization: Operated O&D: The airlines have information only about the portion of itineraries that is
248 operated by them. The fare of the operated O&D is used in optimization.

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

252 Operated O&D is considered as the base case here to estimate the gain that can be achieved by True O&D
253 forecasting and optimization. Price Exchange and sight stage constant at True O&D forecasting and optimization
254 that turned out to be the best mechanisms for the respective stages as can be observed in results section later. In
255 the split stage, Static SPAs are considered as the base case, as it is a fixed proration across the market and does
256 not consider the situation of the flights at the time of sale for splitting the revenue between the airlines. This
257 method might not be a win scenario for the airline which is running at a higher load factor and thus giving up a
258 more valuable seat for the code share. The other two cases consider the current bid prices of the leg cabins over
259 which the itinerary is flying and split the revenue per code share seat sold, instead of applying a flat proration
260 rate.

261 The combination of base cases of each stage with AVS used for availability information exchange, operated
262 O&D used for decision making and static revenue sharing scheme for splitting the revenue represents the base state
263 of decentralized systems. An imaginary centralized system where partner airlines operate and control inventory
264 as a single air line is also simulated to assess the revenue opportunity gap between centralized and decentralized
265 systems that the steps in maturity of integration help capture. In addition to the experiments represented in
266 the above cases, sensitivity analysis with respect to percentage of code share bookings carried by the network
267 is also conducted. This section can be divided into two subsections. First subsection presents the simulation
268 results from the experiments conducted as described in the experiment setup section. The second subsection
269 consolidates the results from various experiments and provides an overview of the revenue gain that alliance
270 partners can expect by adopting better integration mechanisms with partner airlines. The results are presented
271 for the entire alliance and each individual airline in order to study whether the entire alliance is benefiting from
272 the integration mechanism, and whether benefits accrued are biased towards a singular airline.

273 The possible reasons for revenue gain (or loss) observed are explained through small sample examples. Effects
274 of higher code share traffic flying on the alliance network is also presented.

275 10 i. The Speech Stage

276 Significant revenue gain is observed as the systems mature from AVS exchange method for sharing seat availability
277 to bid price exchange for code share request evaluation. The revenue gain is not biased and benefit both the
278 airlines individually, while adding to the revenue of the overall alliance. The seamless code share method produces
279 marginal gain (0.05%) for the overall alliance, while losing revenue (-0.26%) for Airline1 and gaining similar
280 amount of revenue (0.26%) for Airline2.

281 The bid price exchange method shows a significant gain of 1.71% over AVS for the overall alliance. Both Airline1
282 (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.

11 Results for Each Maturity stage a)

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

12 A B C

Airline 1 -Ticketing Airline Proration Factor = 60%

BidPrice: 500

BidPrice: 550 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. Revenue gain of about 0.57% is observed for the overall alliance when the visibility of the revenue management system for the individual 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. The revenue gain can be explained by looking at the sample itinerary in Figure 18. The demand and fares for the various service classes flying over segment A-B in the sample itinerary are shown in Table 9. 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 ??1. 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. 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. 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. 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

343 which leads to a feedback loop in case of Dynamic Additive proration. Lower estimates on code share revenue
344 share for operating airline leads to dilution as well as an expectation that the revenue from code share does not
345 increase with time. This leads to rejection of code share demand leading to drop in code share percentage as well
346 as revenue loss for the overall partnership.

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

351 **13 b) Consolidated Results**

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

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

359 Joint Centralized System (Best Case): This refers to a very tightly integrated "know-all" virtual entity that
360 has complete information about both the airline network and makes the inventory control decisions as a single
361 airline. As previously described such a centralized system is not quite realistic due to several factors including
362 the option of the airlines to exit an alliance.

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

368 Results in Figure 25 show that 88%(2.35% incremental revenue) of the total revenue opportunity can be
369 achieved by upgrading to bid price exchange for availability computation and True O&D forecasting and
370 optimization. Bid price exchange for availability calculation covers 66% of the total revenue opportunity (1.77%
371 incremental revenue). True OD forecasting and optimization covers an additional 21% (0.58% incremental
372 revenue) of the revenue opportunity. The overall gain for the partnership is achieved without penalizing any
373 single airline. The individual airlines in the partnership as well tend to gain from these steps in the direction
374 of closer integration and maturity as shown in Figure 26 and Figure 27. Airline1 achieves more than 95% of
375 the total opportunity, while Airline2 achieves more than 80%. This shows that the revenue gain roots from a
376 win-win situation that aligns individual airline revenue goals with the overall partnership goals. This revenue
377 gain can be achieved by partner airlines by upgrading to better information exchange mechanisms and decision
378 making like bid price exchange with true O&D demand forecasting and optimization within the practical realms
379 of decentralized systems.

380 **14 Conclusions**

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

389 **15 SPEECH**

390 SIGHT SPLIT

391 **16 SPEECH SIGHT SPLIT**

392 The information that can be shared between the airlines is categorized into three groups and incremental stages
393 of maturity of integration are defined -speech, sight and split. Speech: Availability information exchange between
394 the systems that allows airlines to better market and sell seats on code share itineraries Sight: Complete itinerary
395 (true origin and destination) information that allows the revenue management systems to better estimate demand
396 and estimate the revenue value of the same Split: Dynamic revenue sharing mechanisms that enable airlines to
397 make an informed decision about how to split the revenue from code share itineraries A roundtable discussion with
398 the real practitioners showed that some integration efforts are already being tried out with the major focus on the
399 speech dimension where inventory systems are integrated to share real time information about availability. Next
400 generation revenue management systems that consider true origin and destination demand and revenue proration

401 agreements are hitting the market (Doreswamy & Kulkarni, 2016). Dynamic proration mechanisms require a
 402 major level of trust among partners and deeper level of integration. Hence an inherent order is established in
 403 the stages of maturity that partner airlines can target to achieve and the simulation studies conducted on real
 404 airline alliance network data follow the path of maturity than a factorial design of experiments for the same.

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

408 Step 1: Use of bid price exchange for seats availability evaluation As shown in the consolidated results section,
 409 a lion's share of the expected revenue gain comes from upgrading to a bid price exchange based availability
 410 evaluation method. Bid price exchange between airlines for evaluating code share itineraries is already in a state
 411 where few airlines have adopted it, and the technology is in a mature state to allow this real time exchange
 412 (Ratcliff & Weatherford, 2012). Combining these two facts, bid price exchange for seats availability evaluation is
 413 clearly an area that airline alliances should address as it promises significant gain and technical feasibility has
 414 been established.

415 Step 2: Adopt true origin and destination revenue management system: True origin and destination revenue
 416 management is the second integration strategy that should be evaluated and implemented by the alliances. True
 417 OD forecasting and optimization promises an additional 22% capture of the total revenue opportunity.

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

422 17 IX.

423 18 Future Work

424 Few experiments can be perceived as a fall out of the present study and are in active consideration by the authors
 425 can be listed as follows: a) Dynamic revenue proration mechanisms for virtual code shares

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

429 19 b) Truthful information sharing between partners

430 The simulation studies conducted assume that the information (bid prices) shared by airlines for code share
 431 itinerary evaluation and revenue sharing are truthful and accurate. In case of dynamic proration mechanisms,
 432 there is incentive for the airlines to not share accurate bid prices and manipulate the system by bumping up the
 433 bid prices in order to extract bigger share of code share revenue. Research is being done in the area of mechanism
 434 design using game theoretic approaches that incentivize truthful information sharing (Hu, Caldentey, & Vulcano,
 435 2013). Simulation as a tool would be useful in validation and quantification of the impact of designed mechanisms.
 436 c) Use of partner information in optimization Dynamic valuation research (Belobaba & Jain, 2013) suggests that
 437 using partner bid prices in optimization can lead to better revenue mix and higher revenues. Simulation studies
 438 to estimate the gain from using partner information during optimization is a potential area of future research.

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

442 X.

443 20 Glossary of Terms

444 1 2 3 4 5

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²© 2017 Global Journals Inc. (US)

³() 2017 G Assessing the Impact of information Exchange, Forecasting and Revenue Sharing Agreements in Partnership Revenue Management: An Application of Airline Planning and Operations Simulator (APOS) operated O & D is considered as the revenue value of the demand in optimization.

⁴Assessing the Impact of information Exchange, Forecasting and Revenue Sharing Agreements in Partnership Revenue Management: An Application of Airline Planning and Operations Simulator (APOS)

⁵due to higher contribution of code share traffic and revenue to the total.© 2017 Global Journals Inc. (US)

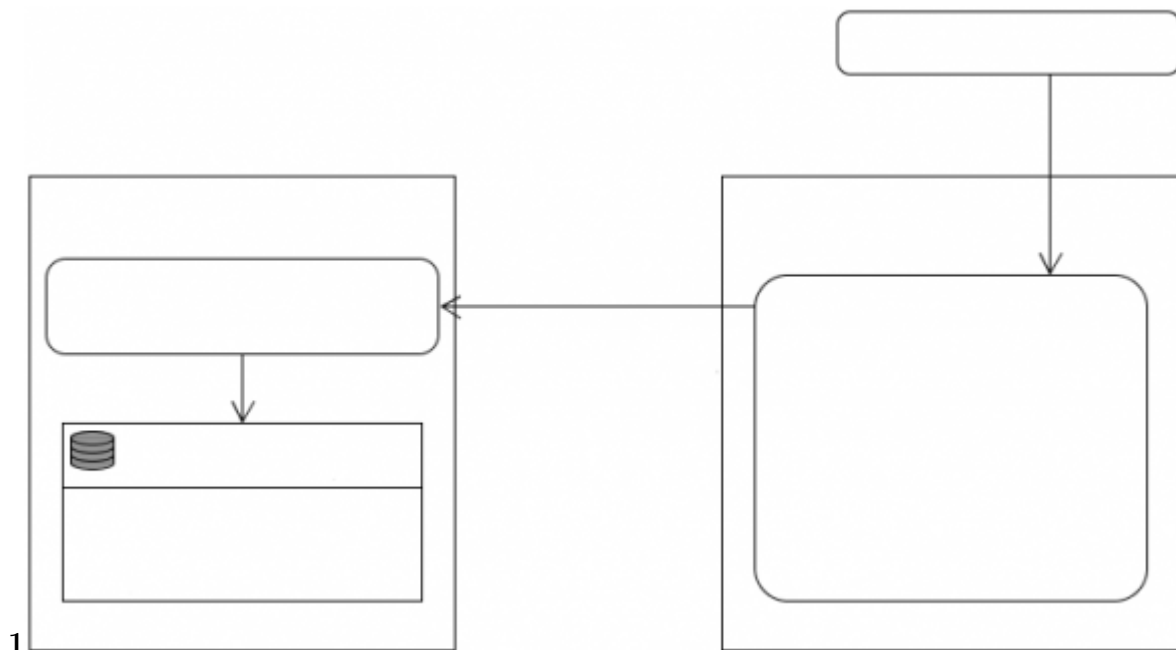


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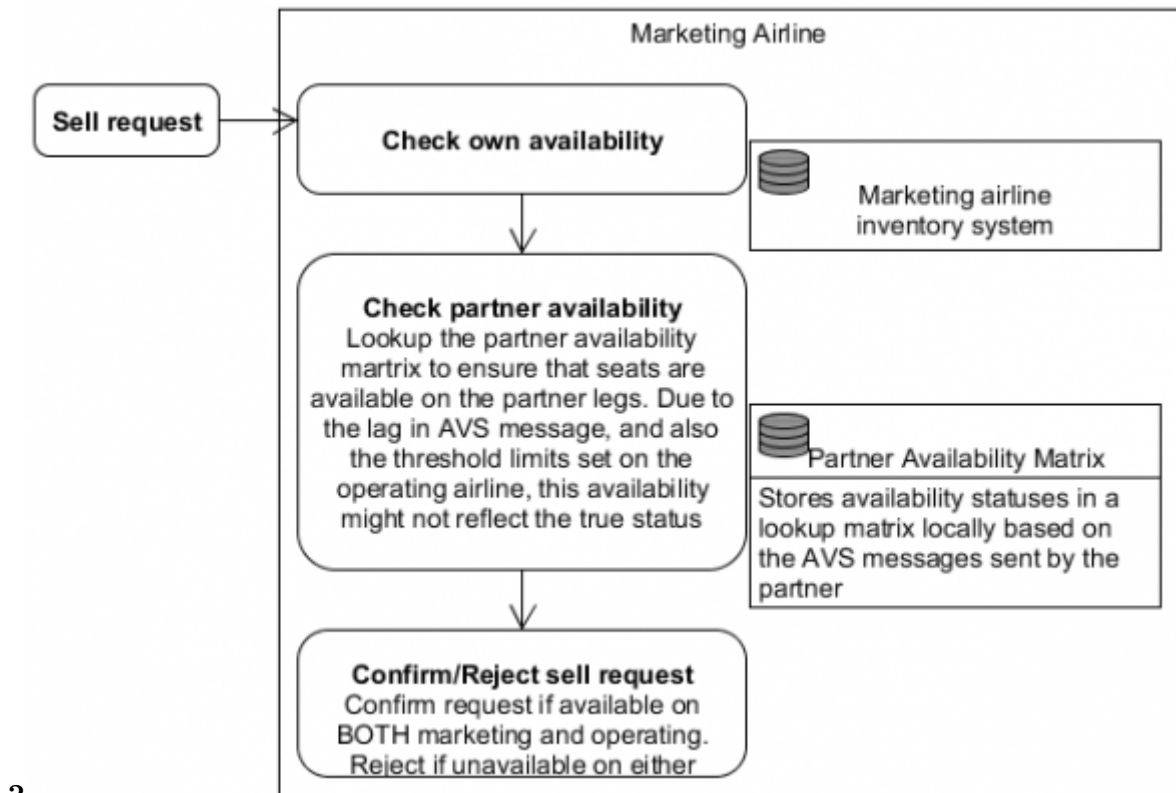
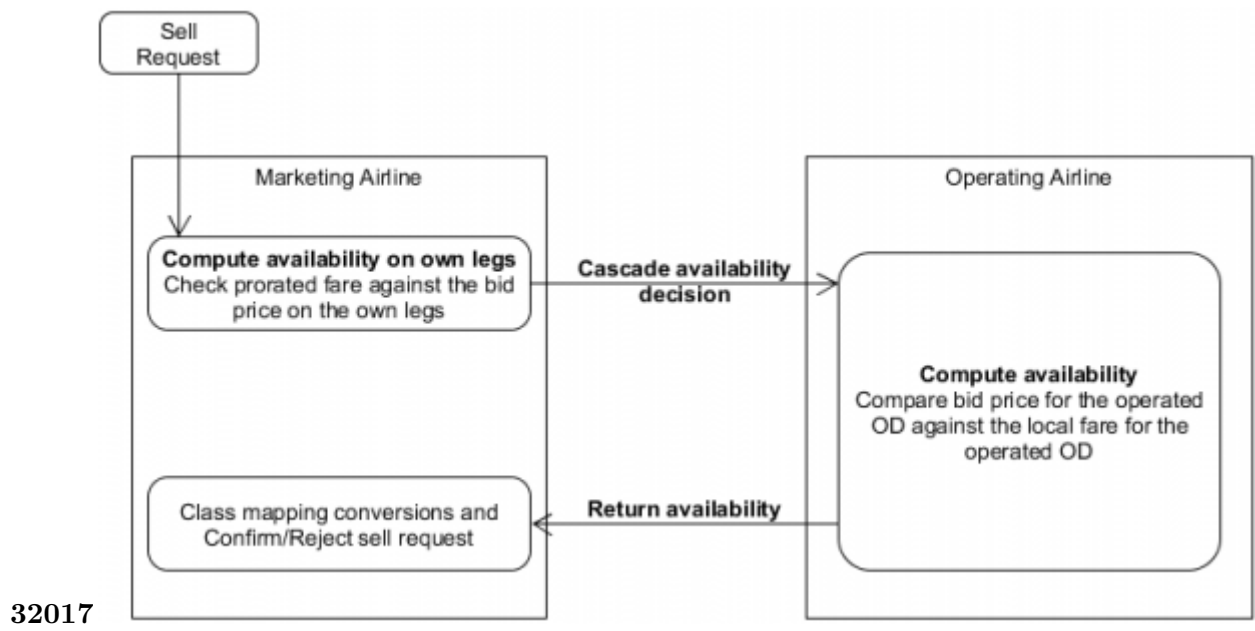
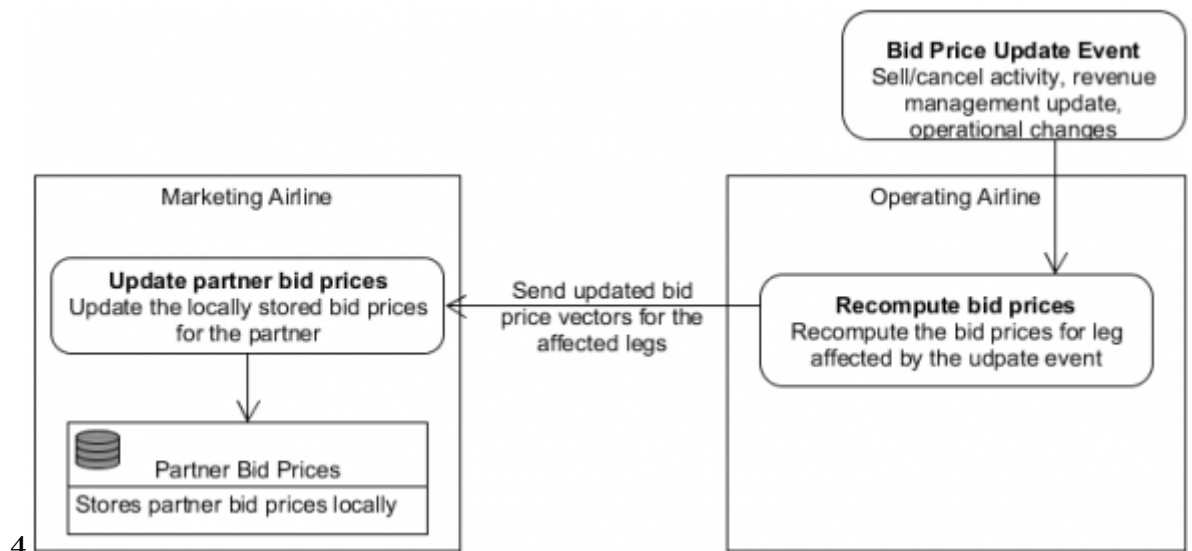


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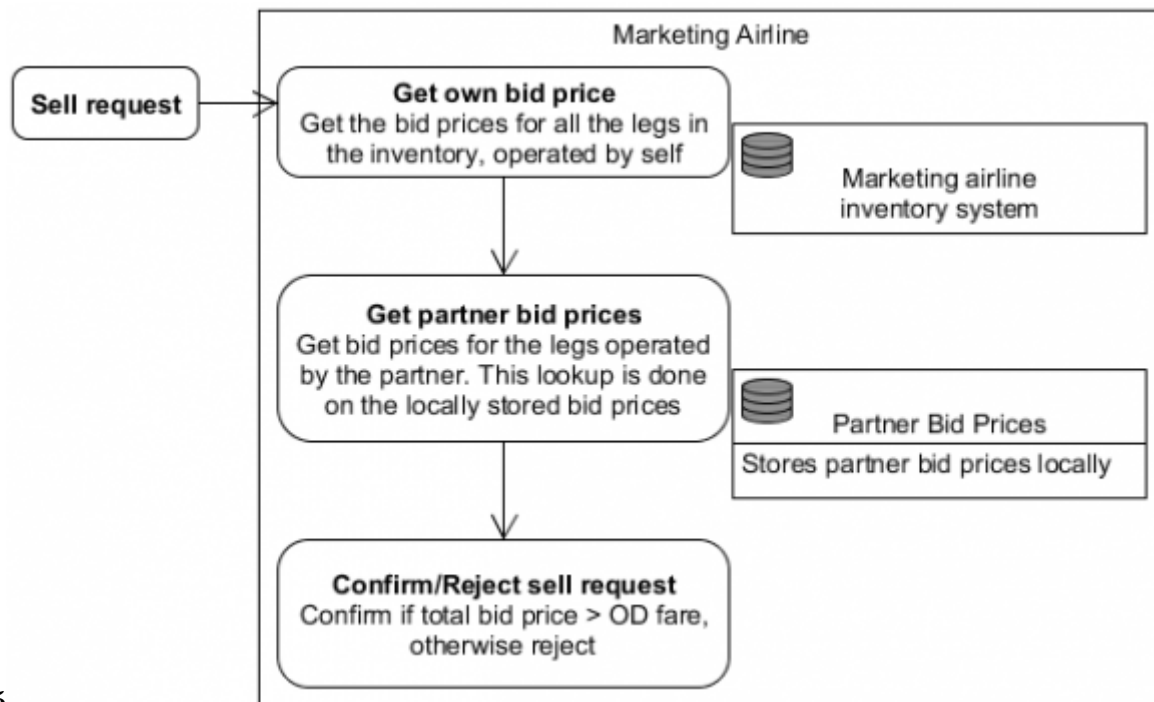
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Figure 3: Figure 3 :) 2017 G



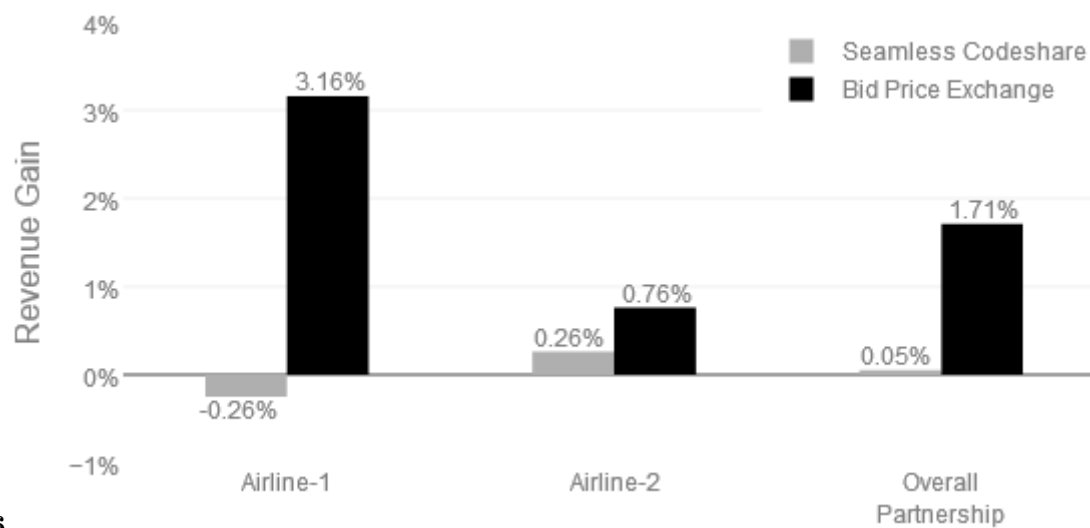
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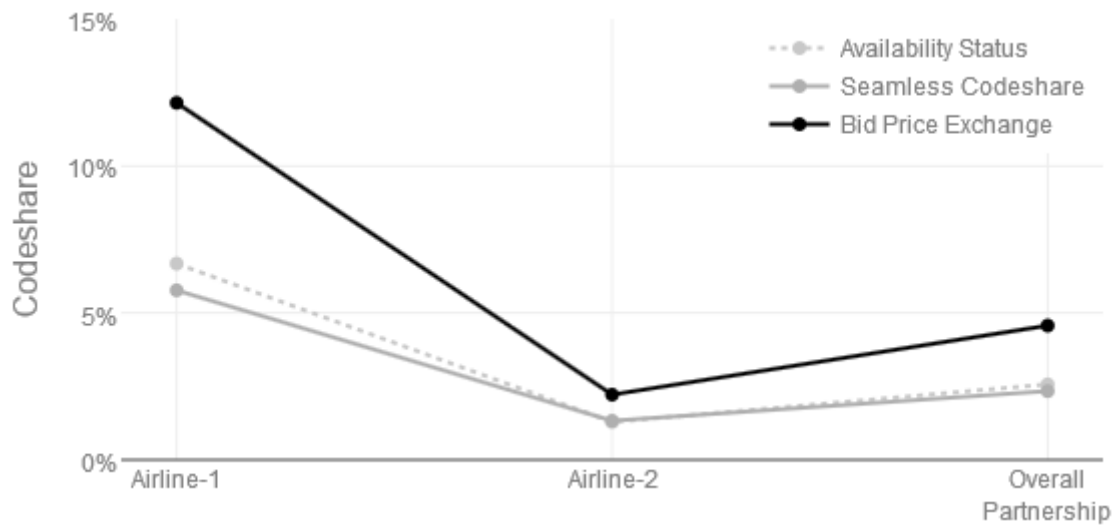
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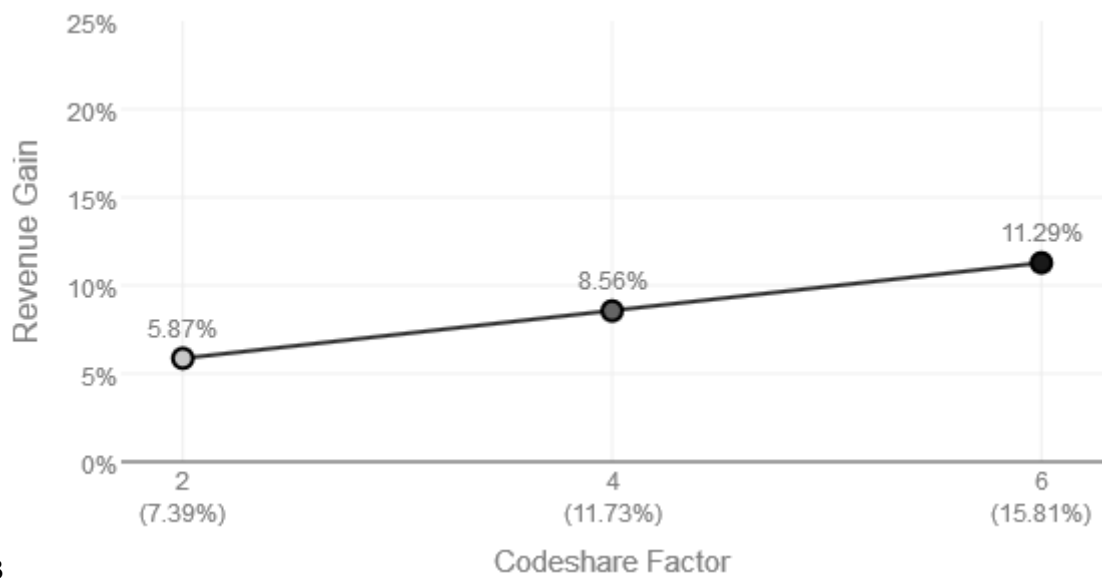
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Figure 6: Figure 6 :



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Figure 7: Figure 7 :



8

Figure 8: Figure 8 :

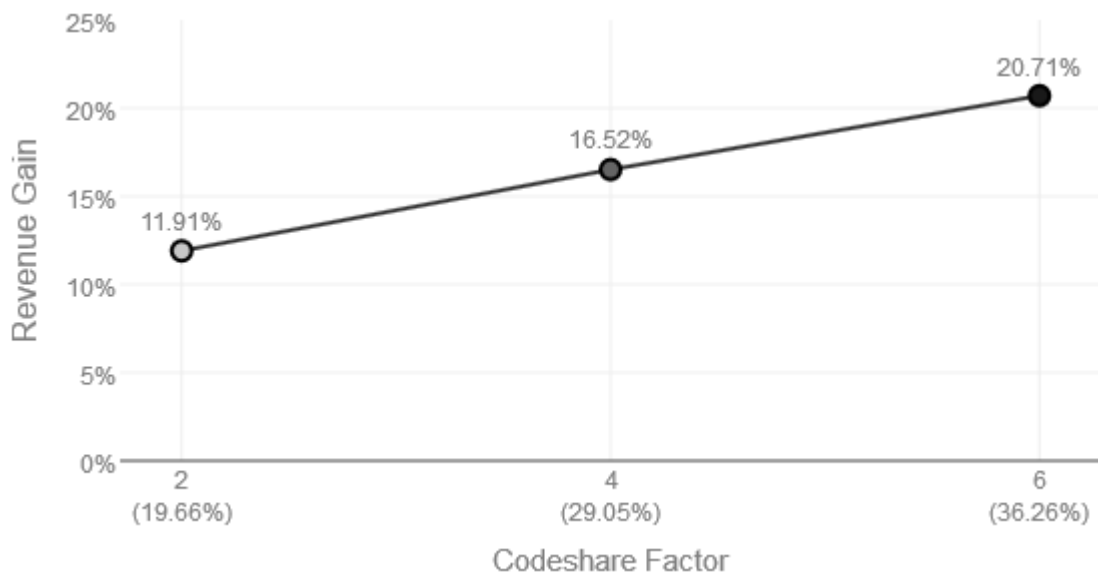
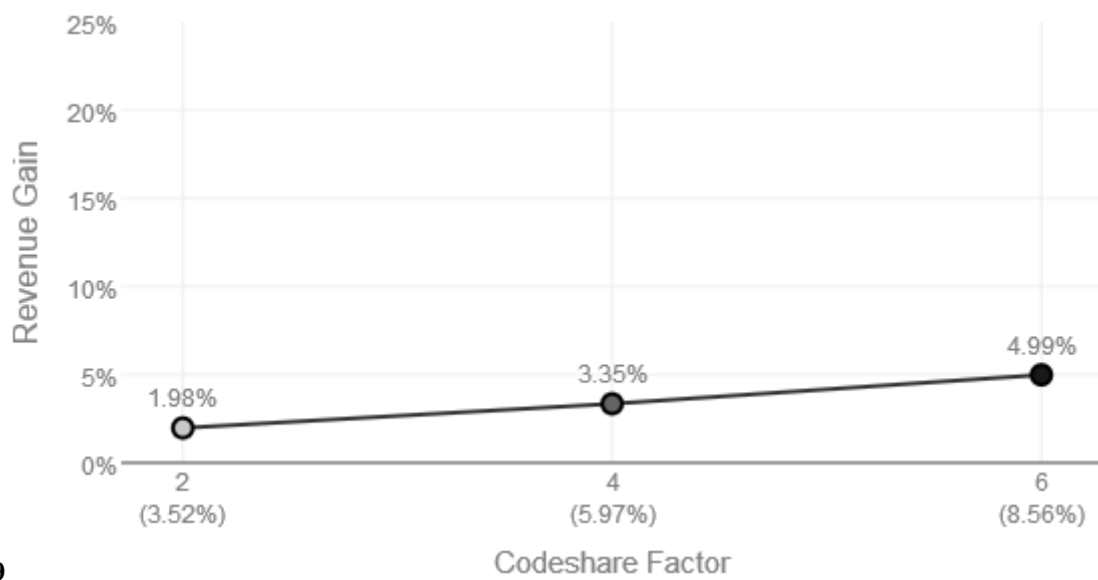


Figure 9: G



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Figure 10: Figure 9 :

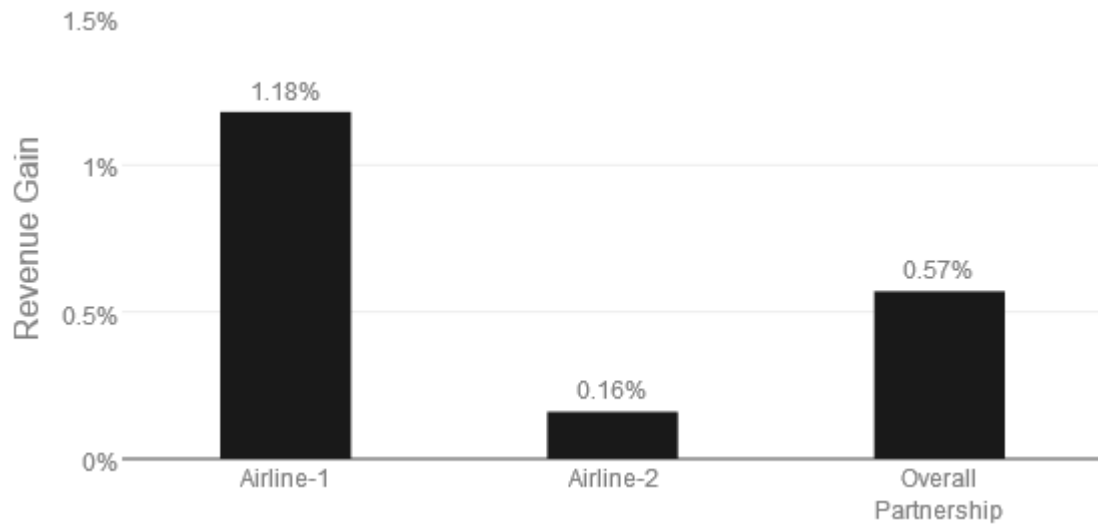
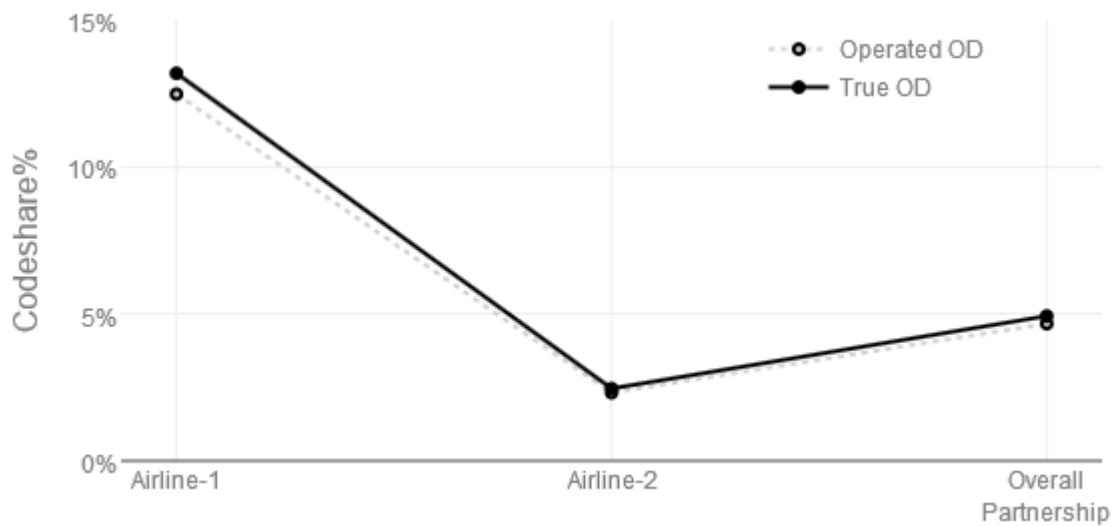


Figure 11:



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Figure 12: Figure 10 :

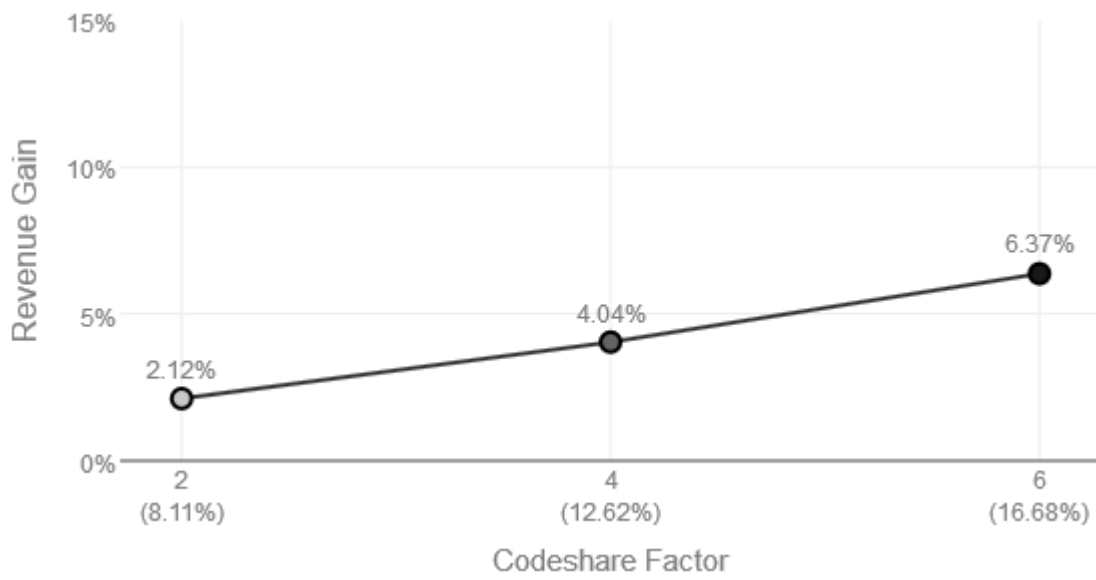


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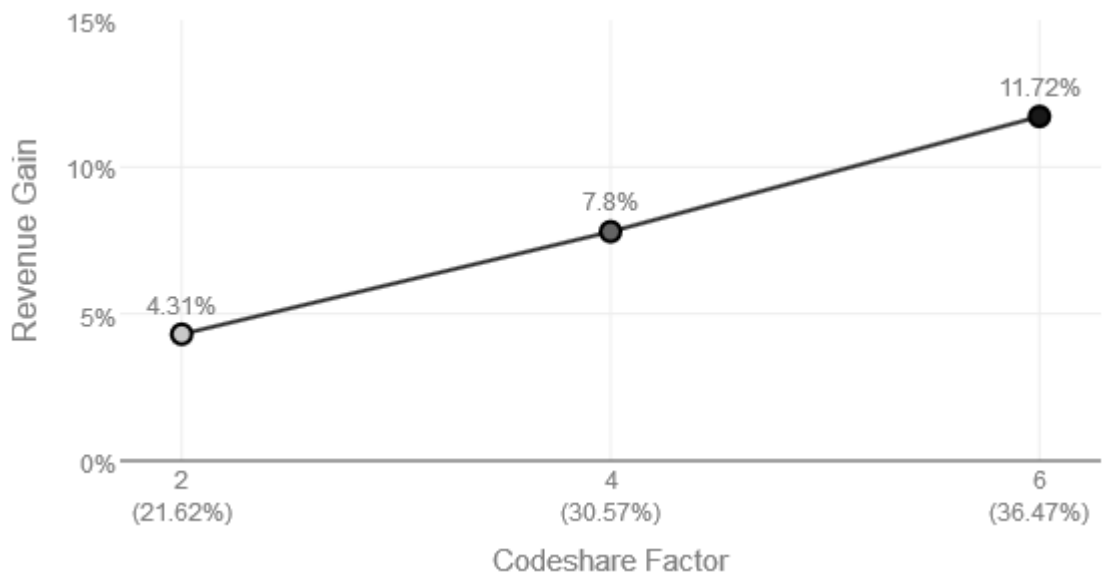
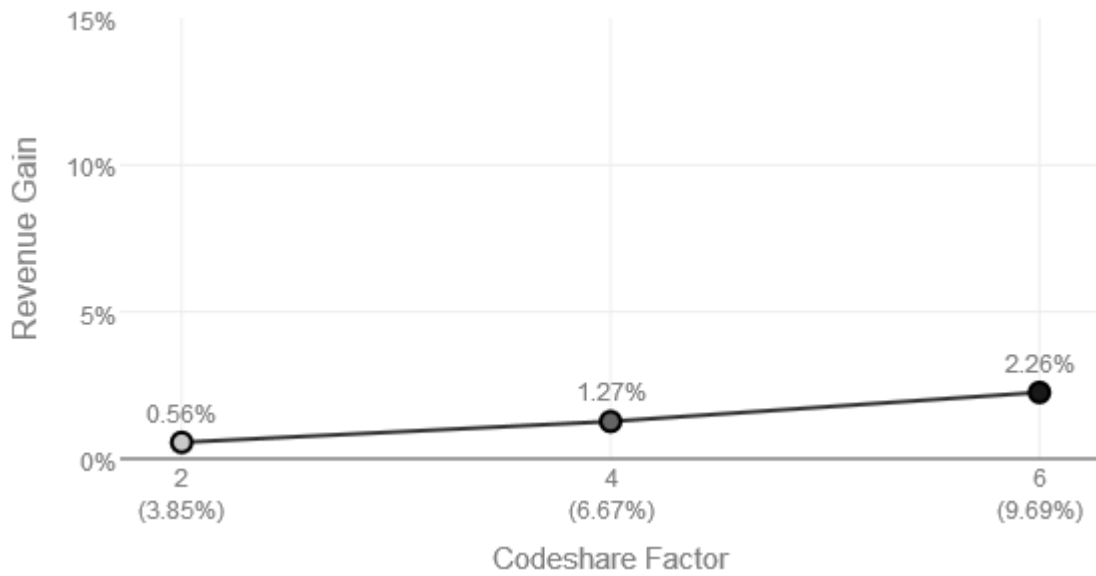
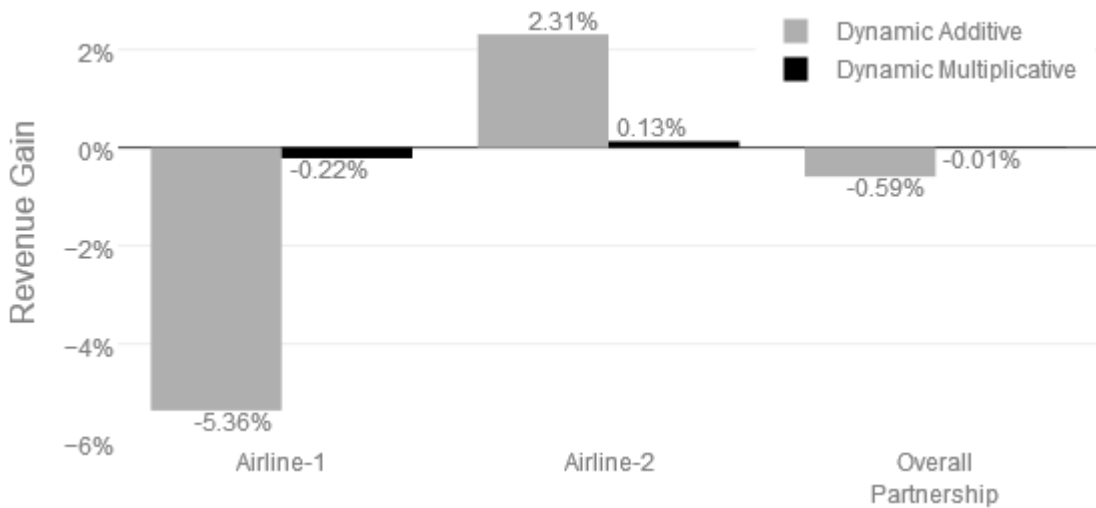


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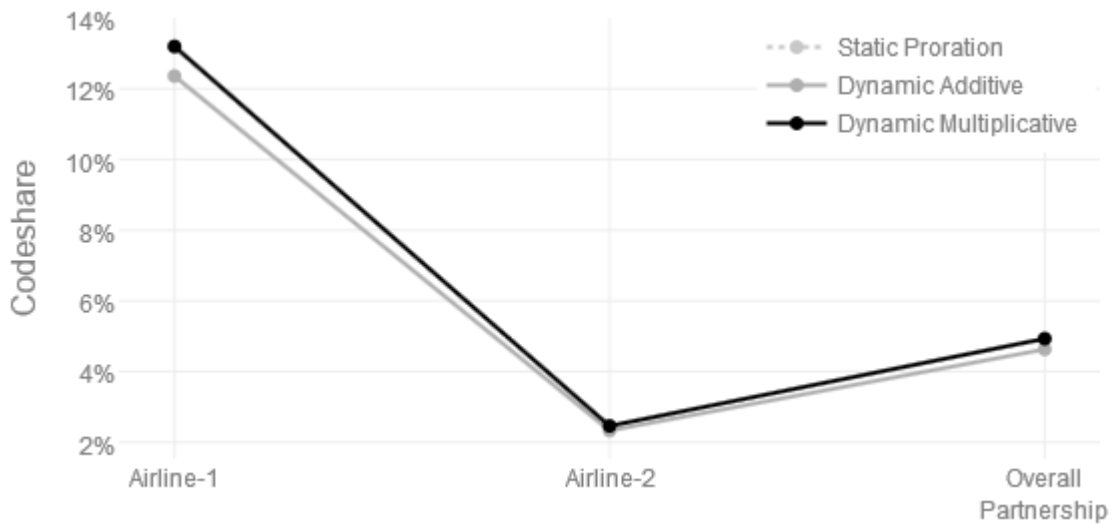
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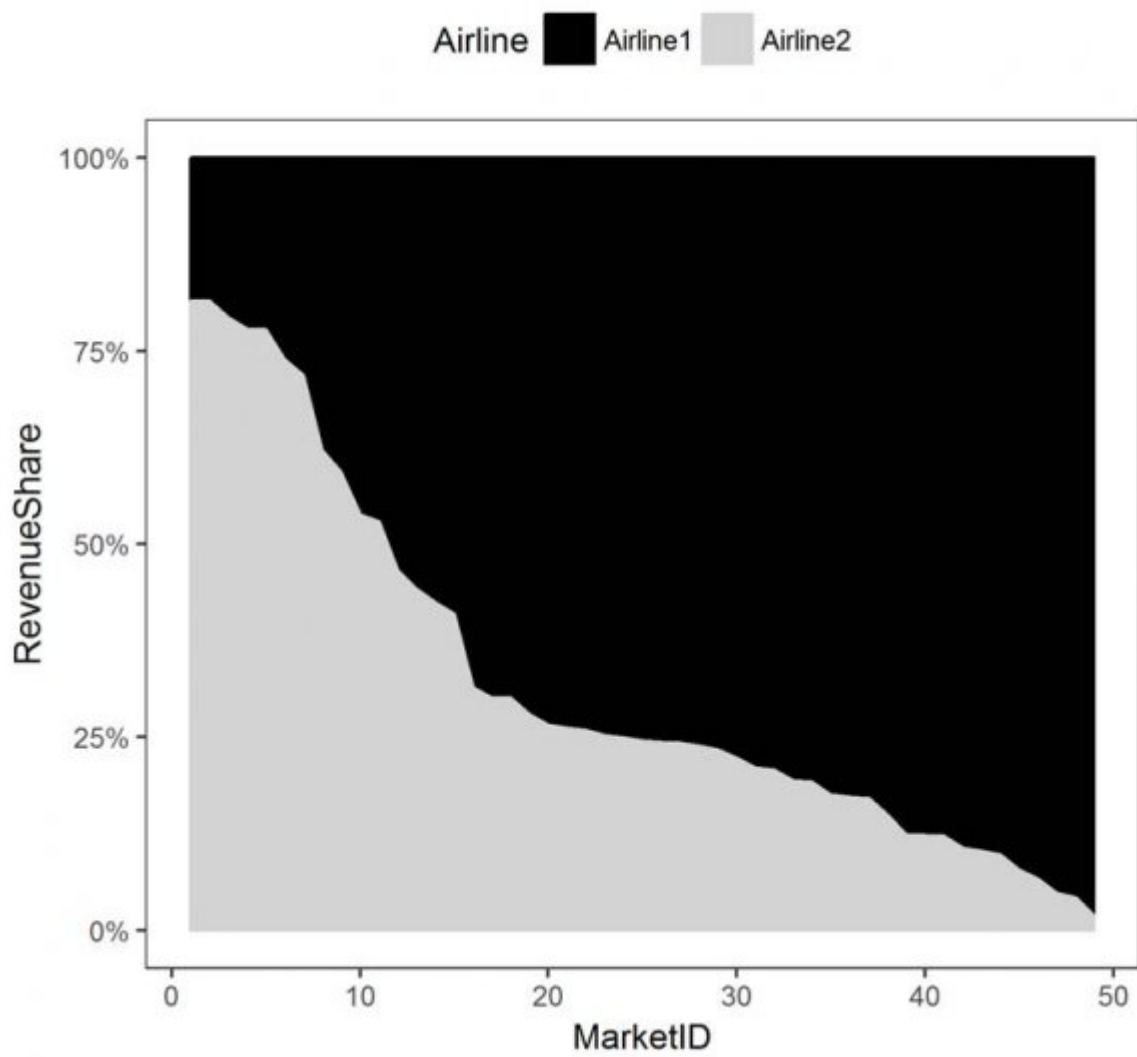
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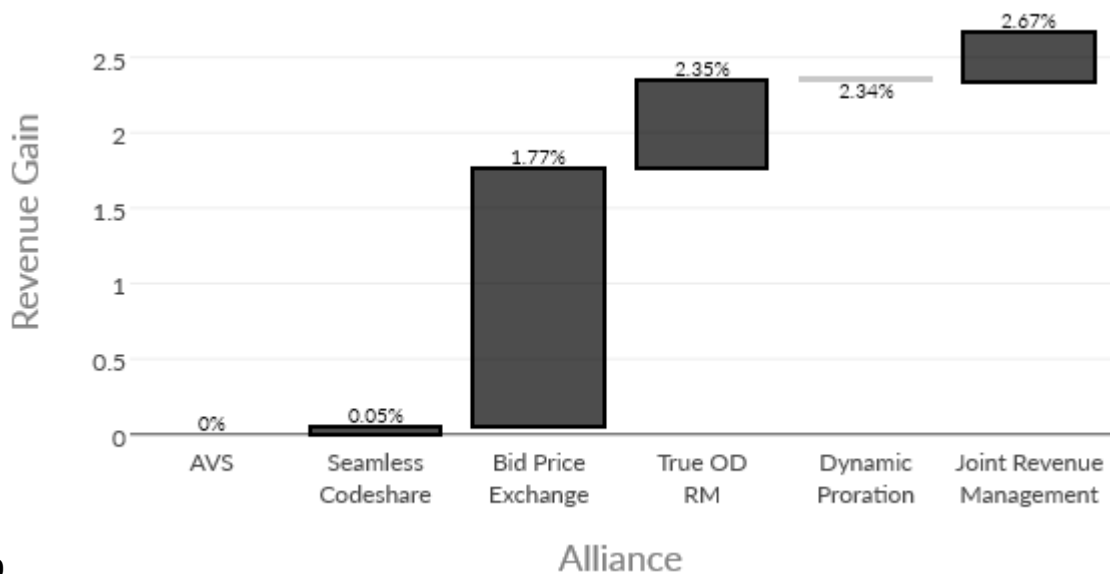
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Figure 17: Figure 18 :



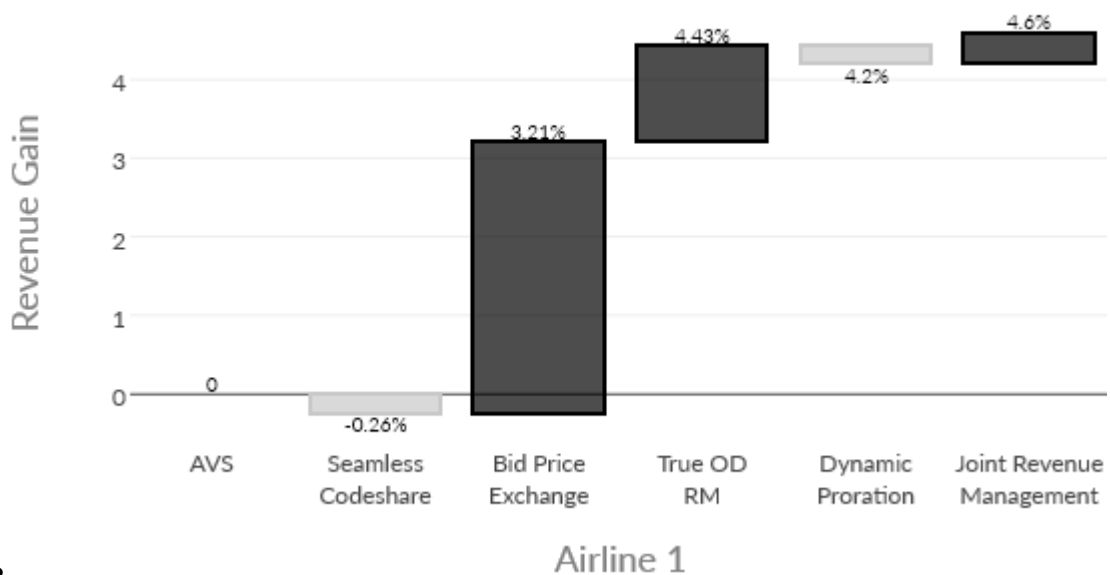
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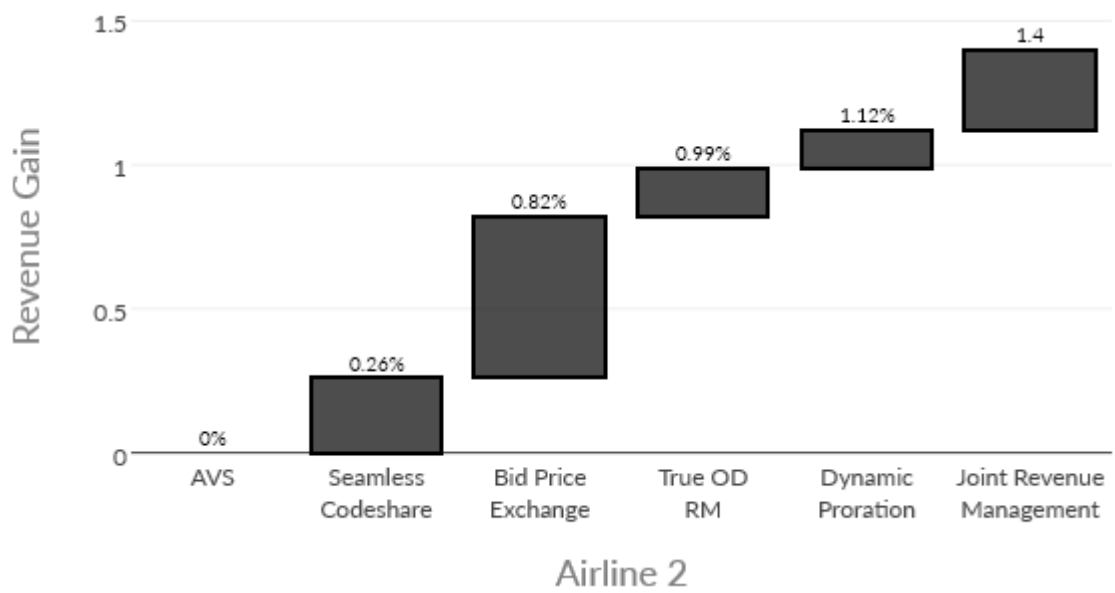
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Figure 19: Figure 20 :



22

Figure 20: Figure 22 :



25

Figure 21: Figure 25 :

2

Reader	Event Gen-erator	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 2. 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

Figure 22: Table 2 :

3

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%

Figure 23: Table 3 :

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

Figure 24: Table 4 :

4

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

Figure 25: Table 4 :

5

Maturity Stage Speech Sight Split Joint Revenue Management	Forecasting Operated OD Operated OD True OD True OD	Optimization Operated OD No Proration Operated OD No Proration True OD Prorated Fares based on SPA True OD Prorated fares based on previous optimization bid prices	Evaluation OD No Proration OD No Proration OD No Proration	Revenue Sharing Mechanism AVS Seamless Code share Bid Price Exchange Bid Price Exchange Bid Price Exchange Bid Price Exchange	Ex-SPA Ex-SPA Ex-SPA Ex-SPA Dynamic Additive Dynamic Multiplicative
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Figure 26: Table 5 :

7

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

Figure 27: Table 7 :

8

Evaluation Method	Availability Decision	Reason For A-C Itin
AVS	?	Physical availability on segment B-C would lead to AVS close status, and hence the entire A-C itinerary will be rejected
Seamless Code-share	?	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	â???	Total bid price for A-C itinerary (500 + 550 = 1050) is less than the fare offered

Figure 28: Table 8 :

9

Fare Class	Demand	Fare	Airline1 Prorated (60%)	Fare	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		?

Figure 29: Table 9 :

10

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
AC-M	AB	True OD	

Figure 30: Table 10 :

12

Marketing Airline	Operating Airline	Code share %
Airline1	Airline2	1.5%
Virtual code share		
Airline 2	Airline1	4%
Parallel code share		0.1%
Complementary code share		0.1%
Total	Airline1	
Operated	Airline2	72.6%

Figure 31: Table 12 :

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