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Passenger Behavior on Revenue Management Systems of Inter-city Transportation

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Abstract

Nowadays, the birthrate is declining and the proportion of senior citizen is increasing in Japan. The trend of new transportation infrastructure investment is decreasing while the trend of operation and maintenance cost is increasing. Therefore, it is necessary to increase the utilization of the existing transportation facilities, such as high-speed rail (HS-rail) by using Revenue Management (RM). The management may include (1) increasing the number of use if the utilization is low, and (2) optimization of seat allocation if the existing seat allocation system is suboptimal. To increase the number of use, transportation firm may decrease average ticket price by introducing discounted ticket. However, the total revenue may decrease if discounted ticket is introduced. Therefore, the accurate demand forecast system is necessary.

The demand forecast in RM systems nowadays, in major airline companies, employ dependent demand models, such as time series analysis and smoothing exponential, to forecast demand successfully. However, dependent demand models cannot forecast demand when passenger choice is affected by the change of ticket contracts (including ticket price, mileage credit, and restrictions) of their own company or competitors. In chapter 3, demand forecast methods using passenger behavior was employed. Moreover, the model of passenger ticket choice was created and simulated in the competition between HS-rail and airlines. Then, the discounted ticket contracts (including price, advance purchase length, and cancellation charge of the ticket) which can increase number of use and revenue of HS-rail could be decided by using the model of passenger ticket choice. However, HS-rail was assumed as single-line-non-stop system in the model of passenger ticket choice by the limitation of the model, while HS-rail is single-line-multiple-stop in real operation. Therefore, the model of passenger ticket choice cannot be applied with HS-rail directly. It must be applied together with seat allocation, and the combination of seat allocation and the model of passenger ticket choice was discussed in chapter 5.

The other way to increase the utilization of existing transportation facilities is seat allocation optimization. Nowadays, HS-rail employs First-come-first-serve (FCFS) in ticket distribution and it seems to be an inefficient method in facility utilization. The seat allocation should be optimized in order to improve average passenger load factor (APLF). However, the revenue and number of passenger rejection may become worse. In chapter 4, real demand data of HS-rail, from 434 trains of 1 month, was simulated whether seat allocation optimization can improve all 3 index of efficiency (APLF, total revenue, and number of passenger rejection) together. The results showed that seat allocation can improve 3 index of efficiency together in most trains. Therefore, it is concluded that seat allocation is useful system in HS-rail.

In chapter 5, the combination between implementation of discounted ticket (using the model of passenger ticket choice in chapter 3) and seat allocation on single-line-multiple-stop

(chapter 4) was discussed. The input of optimization in chapter 5 was different from chapter 4. Real HS-rail demand was modified by the model of passenger ticket choice as if discounted ticket was available on HS-rail system. Then, the optimization procedures were the same as chapter 4. Then the results show that implementation of discounted ticket perform the best on off-peak trains. While on intermediate train, discounted ticket perform the best on APLF.

It was found that employing (1) demand forecasting by using the model of passenger ticket choice and (2) seat allocation can increase the utilization of existing transportation infrastructure of HS-rail. Moreover, the other aspects can also be improved including customer surplus (cheaper average ticket price), transportation firm’s revenue, and level of service (number of passenger rejection).

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Chapter 1

Introduction

As passenger demand change seasonally, when high demand come, airlines can sell high price to earn more revenue, but when demand is low, airline better sell low price better than leave empty seats on departure. Therefore, in practice, airlines use historical data to forecast when high demand and low demand occur, in order to set price. But using only historical data cannot include customer behavior in forecasting. For example, passengers choose ticket of which transportation company depend whether other choice is available. The share of each ticket type (full fare or discounted fare) can change when details in contract, such as advance purchase length and cancellation fee, change. If advance purchase restriction is shorter, more passenger from full fare move to advance purchase ticket type, even though no price change.

1.1 What is revenue management?

Revenue management (RM from now on) is a method to manage business that selling product or service with facing with uncertainty of market conditions, including most favorable conditions, right price which is not too high or not too low as a state "*to maximize passenger revenue by selling the right price to the right customers at the right time*" (from American Airlines, 1987). For example, leisure trip passengers can have low valuation of air fare ticket and normally decide trip schedule in advance, while business trip passengers have high valuation and cannot decide schedule in advance. Therefore, airlines offer discounted ticket with advance purchase restrictions for leisure trip passengers, while offer full fare ticket with out advance purchase restrictions to business trip passengers. Moreover, all the decisions in setting of price or quantity of tickets must be made by scientific methods.

In fact, revenue management was originally created in airline business but the concept is employed widely in other business which as characteristics as (1) product or service cannot be stored, (2) fixed number of unit, and (3) possible to segment price sensitive customers, for example passenger railways, hospitality services, tour operators, air cargo, freight.

1.2 Origin of RM

When US Civil Aviation Board (CAB) loosened control price of airline price in 1978, low cost airlines entered the business in 1981 and growth rapidly until 1984 by getting share from the major airlines. Then, major airline such as American airlines competed with low cost airlines by starting the combination of “purchase restrictions” and “capacity controlled fares”, as to separate business trip passengers and leisure trip passengers by using purchase restrictions and separated compete with low cost airline without damaging own business by limiting number of discounted ticket. After that, American airline considered that the patterns of demand were different by time so Dynamic Inventory Allocation and Maintenance Optimizer system (DINAMO) was employed in 1985. Finally, the low cost airline went bankrupt in 1986.

1.3 RM in Japan

In Japan, there are 2 main modes of medium and long inter-city transportation (around 500 km to 700 km); airlines and high speed rail (HS-Rail or Shinkansen). Each of them has its own service characteristics. Airlines have advantages on short line haul time and frequent flyer program (FFP). While the advantages of HS-Rail are short access and egress time as most of train stations are located in city centers rather than most of the airports are located further form city areas. Moreover, HS-Rail also has advantages on punctuality, safety, frequency of departure, luxury and less weather dependent. Comparing the market share, HS-Rail takes the higher share than Airlines; however, passengers of HS-Rail decreased from 1997 to 1999 while the passengers of airline increased as they were shown in figure 1.1. Since 1997, airlines have started to sell special discounted tickets (Toku-wari in Japanese) which have maximum 35% discount rate with restriction of advance purchase, e.g. 21 days, 7 days and 1 day. The discounted tickets of airlines was effective as the number of airline passenger between Keihanshin area (Kyoto, Osaka and Kobe) increase from 1997 to 1999 continually while the number of HS-rail passenger decrease in the same time period. Since HS-rail provided no typical discounted ticket, some passengers who used to ride HS-rail shifted to airlines discounted ticket if they could meet the advance purchase restriction.

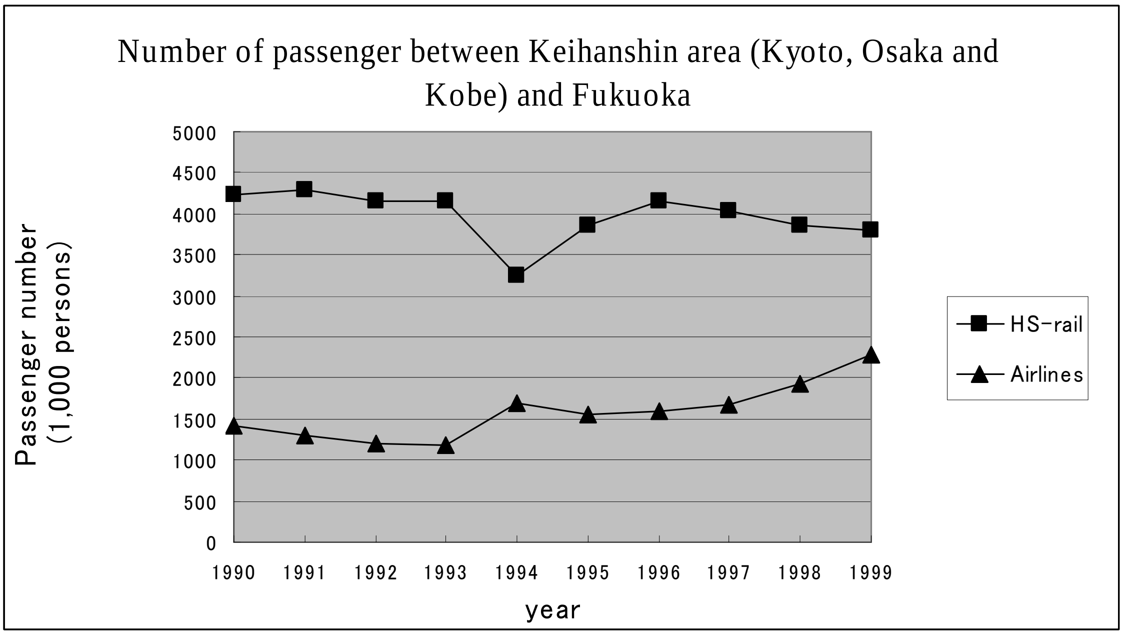

Figure 1.1: The number of passengers of both modes (data from Ministry of Land, Infrastructure and Transport), note: sudden drop in 1995 caused by the great Hanshin earthquake in Jan 1995

HS-Rail has 3 kinds of typical tickets; (1) *reserved seat*, seat position is fixed, passengers are guaranteed that they can sit along the trip, (2) *non-reserved seat*, around 5% cheaper than reserved seat, seat position is not fixed, passenger may sit anywhere if it is available and s/he has to stand if seats are fully occupied, sometime the firm sell non-reserved seat ticket more than the seat capacity (the firm allow passengers to stand along the trip) during peak hours and (3) *green car*, or business class, around 30% more expensive than reserved seat with more luxury service. All of these tickets provide no discount for advance purchase. HS-Rail seem to be a ready-to-go transit mode comparing with airlines when consider about the availability of non-reserved seat, check in time and security check at airport. In order to compete with airline discounted tickets, HS-rail company (Japan Railways) should consider discounted ticket strategies to increase passenger number. However, HS-Rail may lose some revenue when HS-Rail discounted tickets are available because some passengers who use to buy full fare may shift to buy HS-rail discounted ticket.

1.4 Motive

As far as we know, RM has been employed in inter-city transportation in both USA and Europe, but not in Asia. For example, in Japan, RM has been employed in airlines less than 10 years ago and has not been employed with railways yet. We also want to find the difficulty of introducing RM in other countries and we expect that RM is applicable with inter-city transportation in other countries also.

1.5 Contribution to society

Using RM in inter-city transportation can promote non-business trip; including retired senior citizen, college student going back home town, visiting family, leisure traveling, which usually has lower willingness to pay than business trip, by the cheaper average ticket price. Moreover, RM can increase utilization of the existing facility (rail or air transportation) by decreasing empty seat at departure.

1.6 Originality

We employ passenger behavior in RM in order to increase capability of RM. Nowadays, RM forecast future demand by time series analysis methods, e.g. exponential smoothing, which mainly depends on historical data. These traditional methods have some limitation when price structure of their own company or competitors change. Moreover, the methods cannot include competition in the forecasting, while this research can include competition in forecasting, including competition between high-speed railways and airlines.

1.7 Objective

To develop the passenger demand forecast method by using passenger choice behavior, including passenger choice model, into real applications.

1.8 Structure of research

The summary of structure of this research is shown in figure 1.2. In chapter 2, we review the research fields of RM, from the past to present, including practical methods in airline business. Chapter 3, we introduce using passenger behavior in RM, and study how passenger tradeoff between discount rate and restrictions, including choosing mode of transportation. Then, we make passenger choice model to forecast demand for 1 leg case. In chapter 4, we show how possible railway can apply RM without loosing goodwill from passenger and society. In one leg multiple stops network problem, including high-speed railway networks, some passengers may be rejected in order to optimize revenue. Therefore, in chapter 4, we prove that overall benefit is improved when high speed railways employ RM. In chapter 5, passenger behavior model (of chapter 3) and seat allocation of single line multiple stop problem (of chapter 4) are combined. Finally, chapter 6 is the conclusion of this research. The details of research flow are described in next section.

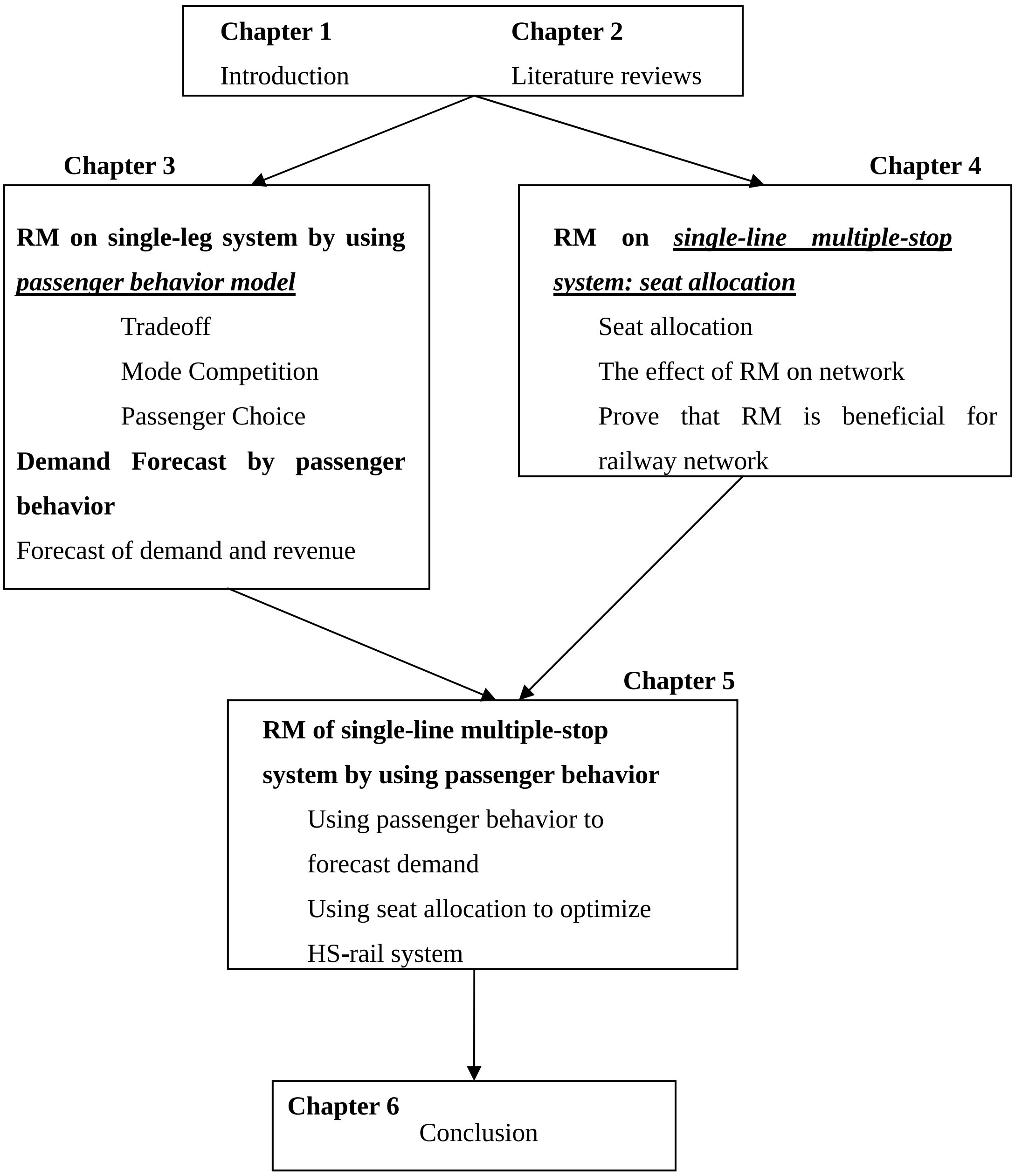

Figure 1.2: Summary of structure of this research in summary

1.9 Research flow

Research flow is shown in figure 1.3 to 1.6. The flow of backgrounds is shown in figure 1.3. Nowadays, the birthrate is declining and the proportion of senior citizen is increasing. The trend of trend of new transportation infrastructure investment is decreasing while the trend of operation and maintenance cost is increasing. Therefore, it is necessary to increase the utilization of the existing transportation facilities by (1) optimize seat allocation if the existing seat allocation system is suboptimal, which is discussed in chapter 4, and (2) increase the number of use if the utilization load is low. To increase the number of use, transportation firm may decrease average ticket price by introduce discounted ticket. However, the total revenue may change if discounted ticket is introduced. In chapter 3, the topic of forecasting demand if discounted tickets are introduced is discussed in details.

Next, in figure 1.4, the flow of chapter 3 is described by starting at “how to set discounted ticket price and restrictions” problem. Traditional forecast method, which mainly based on historical data, cannot forecast demand when ticket price and restriction change. Therefore, in chapter 3, passenger behavior model is employed in demand forecasting. A simulation case study of the competition between HS-rail and airlines on route Keihanshin – Fukuoka is selected and passenger behavior data is collected via web-based survey. For the ease of calculation, both transportation systems are considered as single-line-non-stop. The results of forecast show that at some price and restriction of discounted ticket, revenue of HS-rail does not decrease. However, this study cannot be applied with real situation because HS-rail system is single-line-multiple-stop. Therefore, the study of discounted ticket on single-line-multiple-stop is further discussed in chapter 5.

Then, in figure 1.5, the flow of chapter 4 is described. First-come-first-serve, which is employed in HS-rail, is considered as inefficient method. The seat allocation should be optimized in order to improve total revenue, average passenger load factor (APLF), and number of passenger rejection. However, optimizing one objective may lead to suboptimal of the others, e.g. optimize revenue on HS-rail system may reduce APLF and increase number of passenger rejection. The objective of this chapter is to simulate whether seat allocation optimization can improve all 3 index of efficiency (APLF, total revenue, and number of passenger rejection) together by using real data of demand from 434 trains. The results show that seat allocation can improve 3 index of efficiency together. Therefore, it is concluded that seat allocation is useful system in HS-rail.

Then, in figure 1.6, the flow of chapter 5 is described. This chapter is the combination between implementation of discounted ticket in chapter 3 and seat allocation on single-line-multiple-stop of chapter 4. The input of optimization in chapter 5 is different from chapter 4 as the demand is modified if discounted ticket is available on HS-rail system, while the optimization procedure are the same as chapter 4. Then the results show that implementation of discounted ticket perform the best on off-peak trains. While on intermediate train, discounted ticket perform the best on APLF.

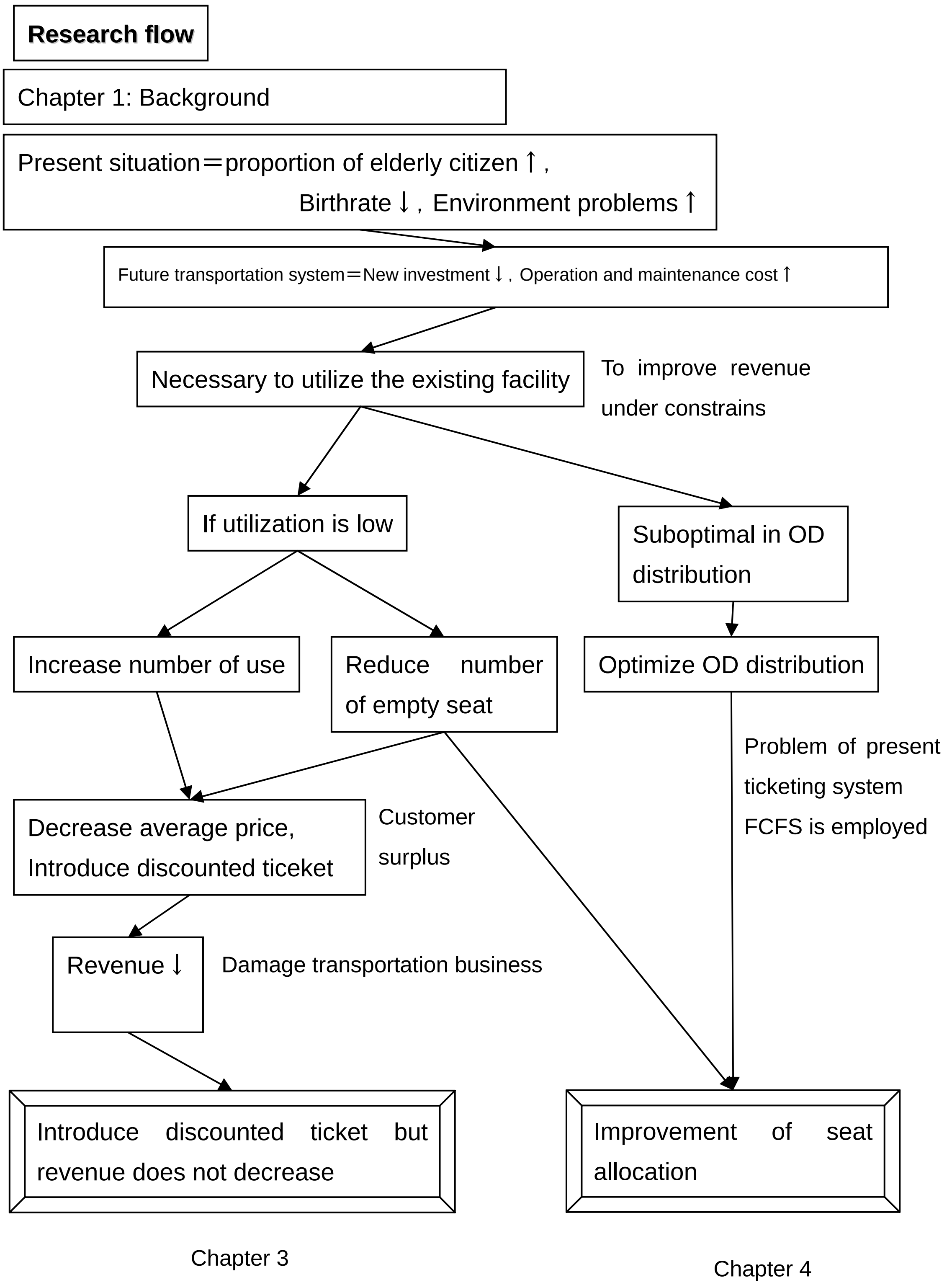

Figure 1.3: Research flow in background

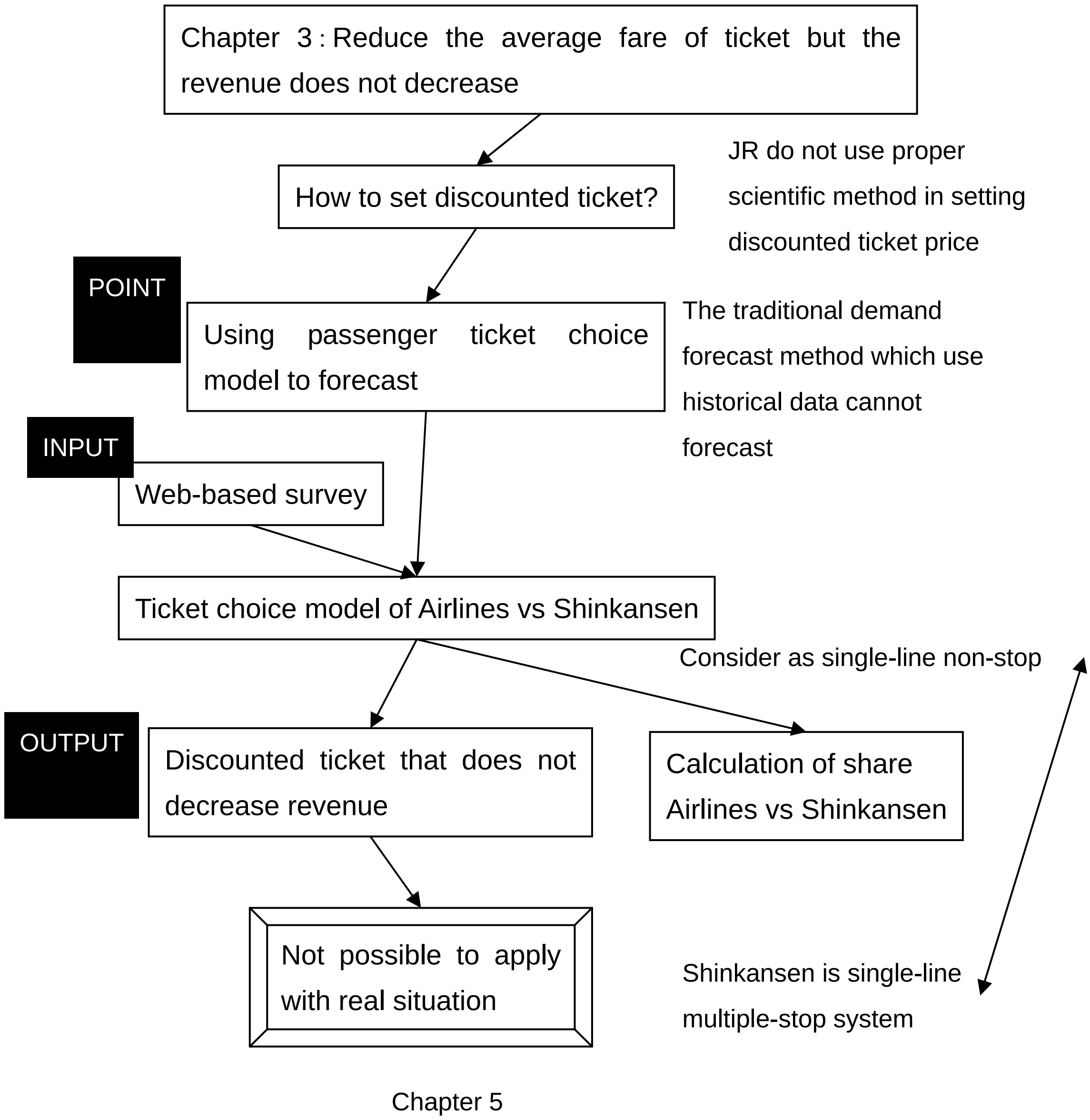

Figure 1.4: Research flow of chapter 3

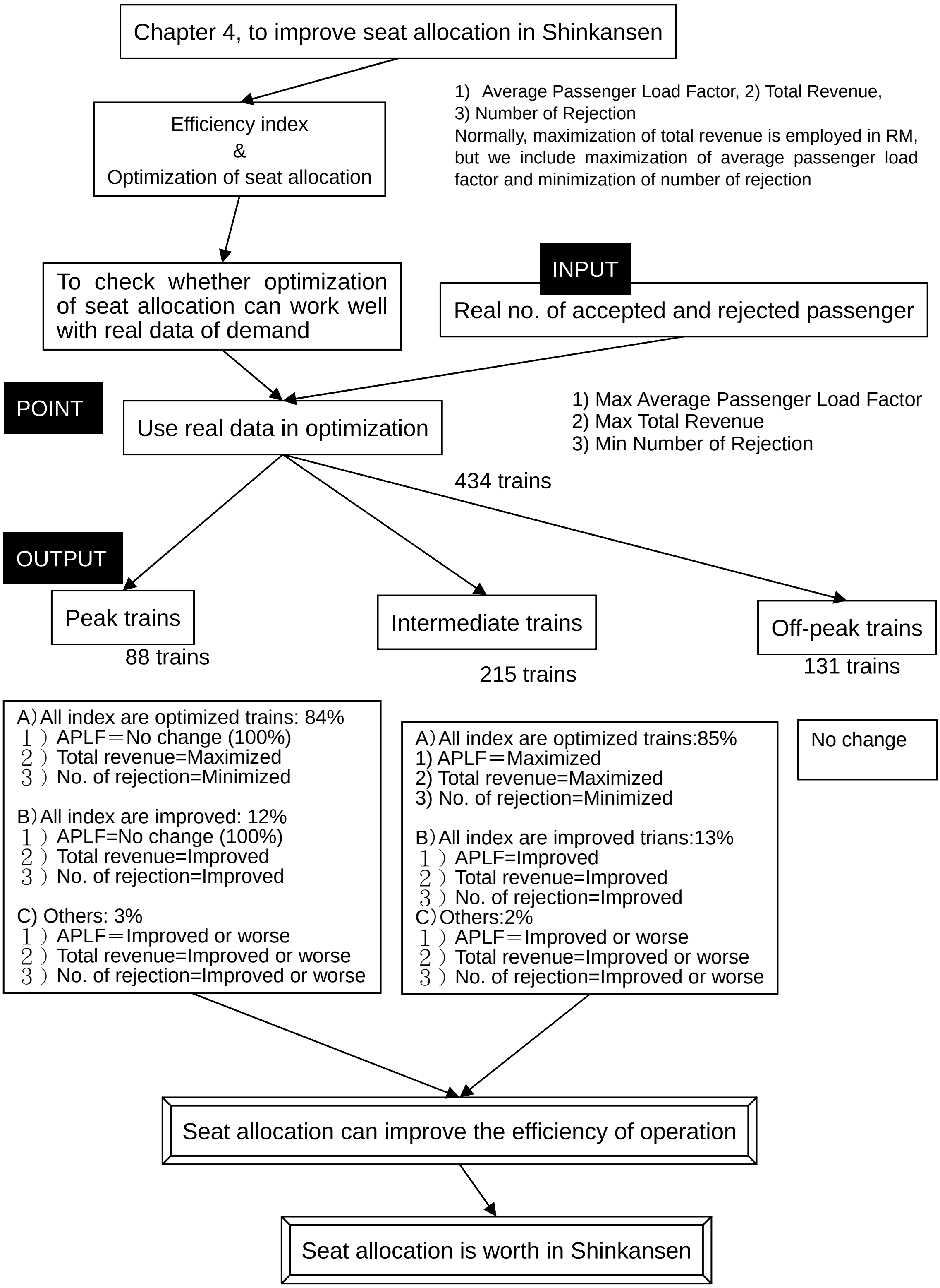

Figure 1.5: Research flow of chapter 4

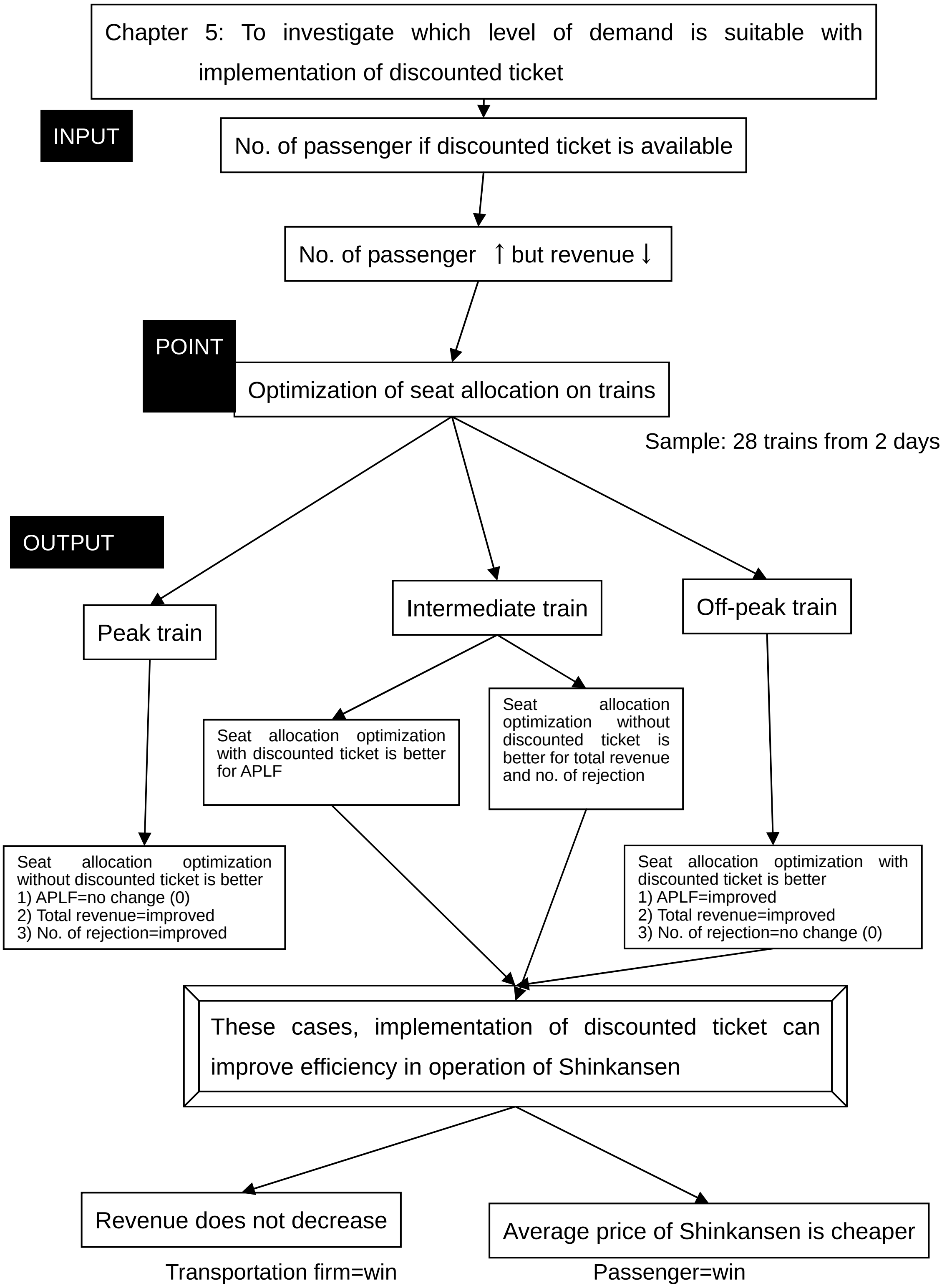

Figure 1.6: Research flow of chapter 5

1.10 Position of the research

Position of the research is shown in figure 1.4. This research begins at forecasting of demand in side the common elements. The demand forecasting methods which are employed in airlines industries nowadays are demand dependent model, the forecasting model which is based on historical data. However, in this research, forecasting by using passenger behavior model is selected. Moreover, the equation of passenger ticket choice model is created (see more details in chapter 3).

Then, in the tools of RM, there are 2 kinds of RM control; (1) quantity-based RM and (2) price-based RM. The quantity-based RM is the RM that manage demand by controlling number of product, while price-based RM manage demand by controlling price of product. For example, in quantity-based RM, airlines manage demand by deciding mainly on the number of discounted ticket to be sold. While in price-based RM, airlines manage demand by deciding mainly on to increase of decrease ticket price. In this research, we focus on quantity-based RM on network. Generally, the objective of RM is to maximize total revenue, but we add other objectives, minimization number of rejection and maximization average passenger load factor. These 2 objectives are ignored in other research of RM. Especially, passenger railways are monopoly in many countries, focusing only on revenue may lead to loss of goodwill. This subject is discussed in chapter 4.

Finally, in chapter 5, forecasting by passenger behavior model and RM on network are combined. Usually, forecasting by using historical data is employed in quantity-based RM on network.

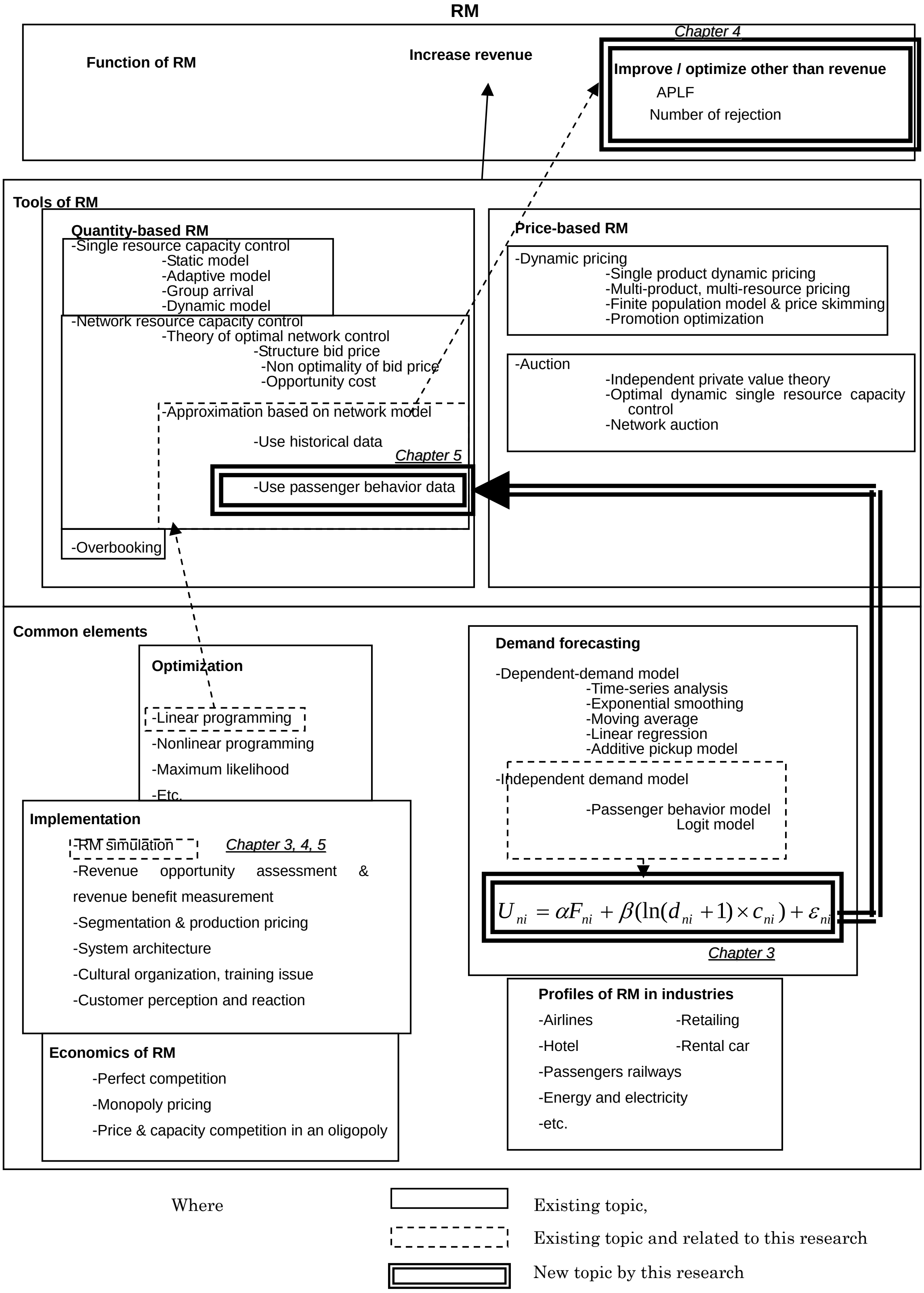

Figure 1.7: Position of the research

Chapter 2

Literature Reviews

2.1 RM from the past to present

In the airline industry, when US Civil Aviation Board (CAB) loosened control price of airline price in 1978, low cost airlines entered the business in 1981 and growth rapidly until 1984 by getting share from the major airlines. Then, major airline such as American airlines competed with low cost airlines by starting the combination of “purchase restrictions” and “capacity controlled fares”, as to separate business trip passengers and leisure trip passengers by using purchase restrictions and separated compete with low cost airline without damaging own business by limiting number of discounted ticket. After that, American airline considered that the patterns of demand were different by time so Dynamic Inventory Allocation and Maintenance Optimizer system (DINAMO) was employed in 1985. Finally, the low cost airline went bankrupt in 1986.

In research aspect, RM began earlier than in airline industry. Before 1972, most of the research focused on overbooking, which predict probability of passenger to appear on departure (go-show). The researches in this field are passenger cancellations, no-shows, and go-shows. In early 1970s, Littlewood proposed that request of discounted ticket should be accepted as long as it is higher than the expected future revenue of higher fare ticket, and seat inventory control was developed at that period. Littelwood’s rule is marked as the beginning of Revenue Management (or Yield Management at that time). Over last 20 years, there are a lot of development on single leg control, segment control and origin destination control. In 1999, most of world’s major and many smaller airlines were able to use RM in some levels, while other small and international airlines began development. A lot of success in airline RM were reported which stimulate development of RM in other industries, including passenger railways, hospitality, automobile rental.

2.2 Study fields in RM

In RM research, there are 4 main research fields; pricing, seat inventory control, overbooking, and forecasting.

2.2.1 Pricing

It is a kind of economics literature using to balance supply and demand and achieve an effective product allocation, including price discrimination, price competition, price dispersion, pricing under capacity restriction. In pricing, there are 3 kinds of market conditions; perfect competition, monopoly, and oligopoly. The works in this field deal with more theoretical than operational. For example, which explanation of pricing should be used in market condition, monopoly or competitive? One example of pricing research is DANA (1998). The study shows that airline pricing seems like monopoly price discrimination but the result shows that it is competitive market (see more details of this paper in chapter 3).

2.2.2 Seat inventory control

Seat inventory control is a system that controls the availability of seats of each fare class (in one leg control) and OD leg (in network control) in order to, normally, optimize revenue. There are 2 systems of optimization methods; single leg control, and network control.

Single leg control

Littlewood's rule is 1 of the first useful method in seat inventory control. It shows that class 1 (higher fare) should be protected as long as the condition is satisfied

$$f_2 \geq f_1 \Pr[X_1 \rangle \Theta_1] \qquad (2.1)$$

Where f_i is the average revenue from the ith fare class and $f_1 \rangle f_2$, Pr[.] is probability, X_1 is the demand of class 1, and Θ_1 is the protection level for fare class 1. For example, there are fare levels of demand; 10,000 yen (f_2) of low fare demand, and 20,000 yen (f_1) of high fare demand. If there is a seat left and a request of 10,000 yen, the ticket should be sold as 10,000 yen if the probability of a request of 20,000 yen is lower than 0.5, or otherwise. The figure 2.1 shows example of Littlewood's rule.

In Expected Marginal Seat Revenue (EMRS), Littlewood's rule is more generalized into more than 2 fare class. Protection levels are calculated by equating immediate revenue of accepting lower fare request with expected revenue of protection for a higher fare request as

$$f_2 = EMRS_1(\Theta_1) = f_1 \Pr[X_1 \rangle \Theta_1] \qquad (2.2)$$

where Θ_1 is the protection level for the highest value fare class, $EMRS_1(\Theta_1)$ is the expected marginal seat revenue of the Θ^{th} seat in fare class 1. Figure 1 shows the equating of immediate revenue and expected revenue in EMSR curves. The total protection Θ_2 for the total 2 highest class is

$$\Theta_2 = \theta_3^1 + \theta_3^2 \qquad (2.3)$$

where θ_3^1 and θ_3^2 are individual protection levels as

$$f_3 \geq f_1 \Pr[X_1 \rangle \theta_3^1] \qquad (2.4)$$

$$f_3 \geq f_2 \Pr[X_1 \rangle \theta_3^2] \qquad (2.5)$$

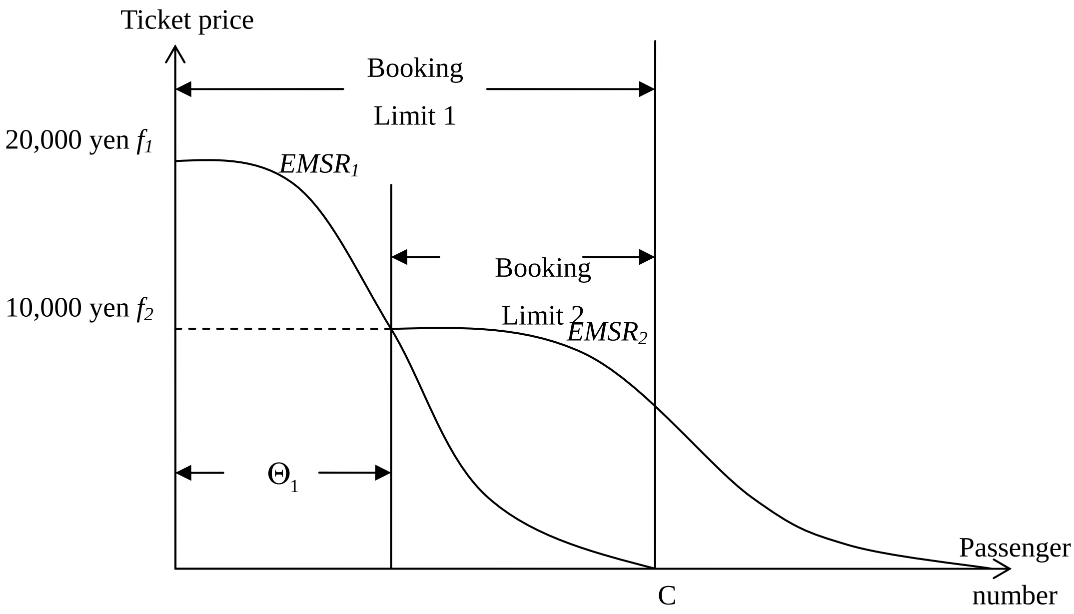

Figure 2.1: Example of EMSR curves

Network formulations

While EMSR works well on single leg control, it is not suitable for network formulations. Mathematical programming models are more appropriate. From Williamson's study, there are 2 concepts to consider passenger demand; (1) as deterministic and (2) as probabilistic.

Deterministic Linear Program

$$Maximize \sum_{ODF} f_{ODF} \cdot x_{ODF} \tag{2.6}$$

s.t.

$\sum_{ODF} x_{ODF} \leq C_j$ for all ODF's on flight leg j and flight legs j

$x_{ODF} \leq D_{ODF}$ for all ODF's

where f_{ODF} is the OD fare class (ODF) fare, x_{ODF} is the number of seats allocated to the ODF itinerary. C_j is seat capacity of flight j, and D_{ODF} is the deterministic estimated of demand for the ODF.

The formulation shows that the constraints are capacity and demand estimations are obtained from objective function. A set of seat allocation for each ODF is produce as maximizing total revenue of the network. However, the weakness of this formulation is considering passenger demand as deterministic while the nature of passenger demand is probabilistic.

Probabilistic Nonlinear Program

$$Maximize \sum_{ODF} f_{ODF} \cdot x_{ODF} \cdot \overline{P}(x_{ODF}) \tag{2.7}$$

s.t.

$\sum_{ODF} x_{ODF} \leq C_j$ for all ODF's on flight leg j and flight legs j

$x_{ODF} \geq 0$ for all ODF's

where $\overline{P}(x_{ODF})$ is the probability of selling x or more seats on each ODF itinerary, and x_{ODF} is the number of seats allocated to the ODF itinerary. This formulation can consider passenger demand as stochastic as its nature.

2.2.3 Overbooking

Overbooking is different from other fields in RM. While RM is mainly concerned with optimization of customer mix, overbooking focuses on improving capacity utilization in reservation-base system which has significant cancellations. Overbooking has the longest history in RM research. Moreover, it is the most successful in RM practice and considered as a mature field. The simplest and most widely used of overbooking is "static overbooking models", as shown in figure 2.2. The overbooking limit is high at the beginning and decrease as time close to departure, T. Therefore, reservation systems accept requests more than capacity until reaching overbooking limit. Finally, the number of show passengers is ideally close to capacity. Without overbooking, number of show passengers at departure becomes less than capacity, as shown in the lower curve.

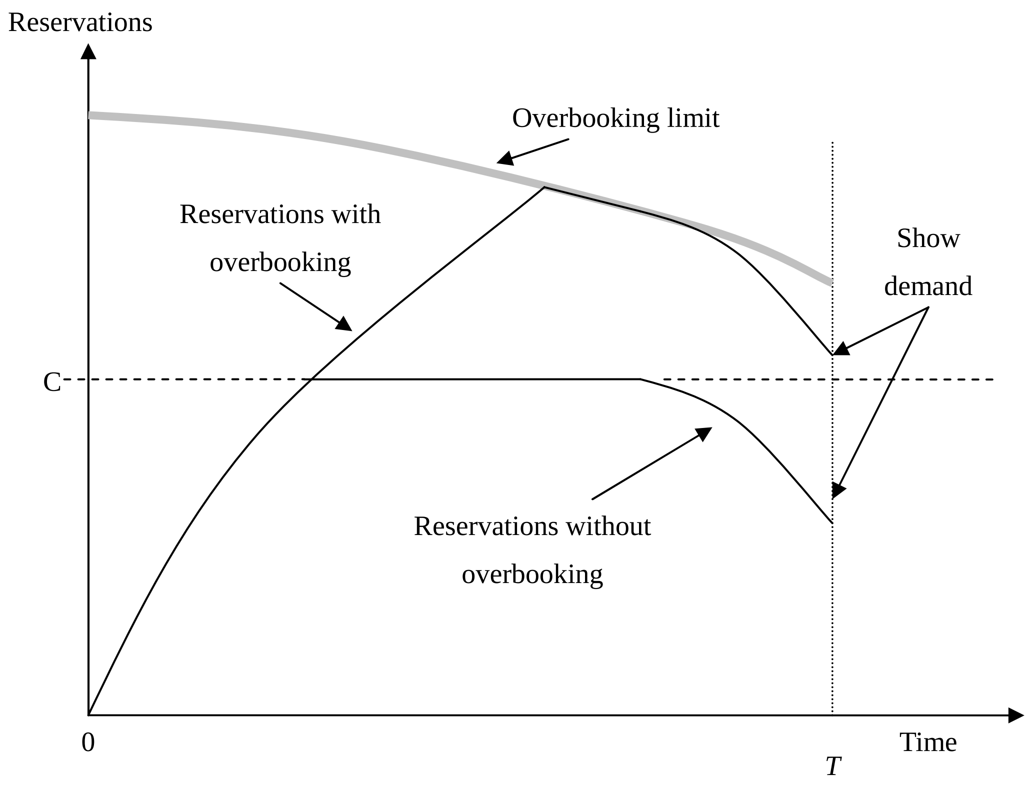

Figure 2.2: Overbooking limits overtime

2.2.4 Forecasting

Forecasting is an important component in airline RM because it directly influences on booking limit of airline revenue. There are 3 types of forecasting used in airline RM; macro level, micro level and passenger behavior.

Macro and micro level forecasting

Macro level forecasting is the forecast of aggregate level for total demand passenger of airline, while micro level forecasting is the forecasting that specify on disaggregate level, such as a specific flight, using historical data, booking profiles, of booking in the same flight. The objective of this method is to forecast demand at departure by given current reservations arrive at time of forecast.

In airline RM systems today, these methods are used mainly in RM as McGill and Van Ryzin (1999) stated that " *As far as we know at this time, most disaggregate forecasting systems depend on relatively simple moving average and smoothing techniques augmented with careful analysis of recent booking profiles*.". Furthermore, we survey the leaders of RM specialist service providers; Lufthansa Systems, Pros Revenue Management, and Sabre Airline Solutions, all of them optimize airline revenues by using historical data. One of them, at least, is developing share forecasting program using passenger behavior in forecasting. Until now, there are no companies using passenger behavior in RM.

There are 5 methods of micro level forecasting which are employed in airline industries (Weatherford, 1999); (1) Exponential smoothing (time series analysis), (2) Moving average, (3) Linear regression, (4) Additive pickup model and, (5) Multiplicative pickup model.

(1) Exponential smoothing

Exponential smoothing is one of time series analysis method which applies with decreasing weights to observation. It is simple as only 1 smoothing parameter is needed which can be described as

$$Forecast_{t+1} = \alpha \times Actual_t + (1-\alpha) \times Forecast_t \qquad (2.8)$$

The value of forecast at $t+1$ is produced by historical data at t ($Actual_t$) and forecast value at t ($Forecast_t$). Therefore, necessary data is only recent observation. For low α, the forecast value response is not sensitive to the change in historical data. While in high α, the forecast value response is sensitive to the change in historical data.

(2) Moving average

Similar to exponential smoothing, moving average is simple to understand. Future demand is forecasted by averaging the *n* most recent historical observations, and the calculation can be described as

$$Forecast_{t+1} = \frac{1}{n}\sum_{k=t}^{t-n+1} Actual_k \qquad (2.9)$$

(3) Linear regression

The calculation of this method is based on assumption that a linear trend between the bookings at departure and various day before depart. In the model, number of parameters and their weights can be decided by ordinary least square method or some other procedure. The calculation can be described as

$$Bookings_{DP0} = B_0 + B_1 Bookings_{DP7} + B_2 Bookings_{DP21} \tag{2.10}$$

where $Bookings_{DP0}$ is the total number of bookings at departure, $Bookings_{DP7}$ is the total number of bookings at 7 days prior departure, and $Bookings_{DP21}$ is the total number of bookings at 21 days prior departure.

(4) Additive pickup model

In this method, demand at departure can be forecasted by adding historical incremental bookings to the current booking at a given day prior to departure. It means that the final bookings are functions of current bookings on hand and on the amount picked up between the current day and departure. For example, the relationship between final bookings and bookings on 7 days prior departure can be described as

$$Bookings_{DP0} = Bookings_{DP7} + PU_{DP(7,0)} \tag{2.11}$$

where $Bookings_{DP0}$ is the total number of bookings at departure, $Bookings_{DP7}$ is the total number of bookings at 7 days prior departure, and $PU_{DP(7,0)}$ is the average number of bookings on hand at day prior 14 and the departure date.

(5) Multiplicative pickup model

Similar to additive pickup model, future bookings are forecasted by historical pickup observation. However, multiplicative pickup model multiply current bookings with average pickup ratio, while additive pickup model adds current bookings. The average pickup ratio for day prior x is given by

$$\overline{PUR}_{DP(X,0)} = \frac{\overline{Bookings}_{DP(0)}}{\overline{Bookings}_{DP(x)}} \tag{2.12}$$

where $\overline{Bookings}_{DP(x)}$ is the average number of current bookings at day prior x. A forecast of final bookings at departure can be described as

$$Forecast_{DP(0)} = \overline{Bookings}_{DP(x)} \times \overline{PUR}_{DP(x,0)} \tag{2.13}$$

All the forecasting models in micro level use historical data as input to forecast future demand. There is no other input such as passenger behavior, how passengers consider ticket fare, restriction conditions of ticket, and offers from competitors. Therefore, the methods in micro level forecast cannot give accurate results when the factors which are related passenger behavior e.g. fare and restrictions of ticket, change.

Passenger behavior

Passenger behavior model is adopted from discrete-choice analysis (Ben-Akiva and Lerman, 1985). In RM, it has not been studied much, both academic research and real world business. We explain passenger behavior in RM and discuss the different between using passenger behavior and historical data (micro-level and macro-level forecasting) in chapter 3.

Chapter 3

Forecasting share of each ticket type by using passenger choice behavior

3.1 Independent-demand model *vs.* Customer behavior

Most of the traditional concepts of RM are *independent-demand model*, e.g. EMSR (Belobaba, 1987) and Littlewood's model (Littlewood, 1972), as mentioned in chapter 1 and 2. The model is based on assumption that demand of each product is independent to stochastic process itself. However, Talluri and Van Ryzin (2004) state that consumer's behavior is ignored in *independent-demand model*. It does not consider customer's behavior neither choice behavior nor purchasing-time behavior. Moreover, they further state that, in fact, demand also effect by individual-choice behavior, for example the probability of purchasing full-fare ticket may depend on the availability of discounted ticket at the time. Customer's behavior can improve the limitation of RM. In this chapter, we concentrate on customer behavior method.

Therefore, understanding passenger ticket choice behavior is a powerful tool to find suitable prices and restrictions for discounted ticket to increase the revenue. In this study, the objectives of this study are (1) to model behavior of passengers, how they consider price, length of advance purchase and cancellation charge (or partial refund) to select the most preferred available ticket type and (2) show how a firm can adjust ticket characteristics to increase market share and revenue.

This chapter explains function of how passengers consider particular items of ticket and how the function can be implemented in transportation firm. The sections of this paper are ordered by starting form *related previous studies in passenger behavior.* Next, the details of how passengers choose ticket type are explained in *passenger ticket choice model* section. Then, in *Case studies* section, 2 case studies are showed how the model is applicable with the data. And finally, the last section is *Discussion, conclusion and future research.*

3.2 Random-Utility Models

They are based on probabilistic model of individual passenger utility. Let the n alternatives be denoted $j = 1,\dots, n$. A passenger has a utility for alternative j, denoted U_j, which can be separated into 2 parts; observable utility u_j, and error term ε_j (mena-zero randon component) as

$$U_j = u_j + \varepsilon_j \tag{3.1}$$

The probability that an individual selects alternative j from a subset S of alternatives is given as

$$P_j(S) = P(U_j \geq \max\{U_i : i \in S\}) \tag{3.2}$$

Normally, u_j represents various observable attributes and can be written as

$$u_j = \beta^T x_j \tag{3.3}$$

Where β is a vector of parameters and x_j is a vector of attribute values for alternative j, which conclude parameters such as price and others which effect decision making. Refer to multinomial-logit mode (MNL), probability of alternative j to be chosen can be calculated as

$$P_j(S) = \frac{e^{u_j}}{\sum_{i \in S} e^{u_i}} \tag{3.4}$$

Where $0 \leq P_j(S) \leq 1$.

3.3 Related previous studies in passenger behavior on RM

3.3.1 Advance purchase

Dana (1998) shows that a low valuation passenger (e.g. leisure type), who is certain to travel, buys ticket in advance as her value is adequate for ticket price at advance purchase only. While a high valuation passenger (e.g. business type), uncertain demand type, buys ticket at the site as her net surplus utility at the site is higher than at the advance purchase one. In his example, he shows calculation of utility of business passengers in case of advance purchase and on site purchase. Passengers gain benefit from discount but the probability of showing up reduce utility in total. While on site tickets are more expensive but the passengers are certainty of showing up. In his example, he shows that all business passengers buy on site tickets as the expected surplus is higher. The showing up probability of business passengers is calculated from probability that number of passengers reach each level. We summarize expected surplus of business type passenger from Dana's study as follows. Assume that valuation of business type passenger is 20$ and advance purchase ticket is 6$, and the summary of business type demand is shown in table 3.1. For Advance purchase case, unconditional probability = (1/3)$\times$0 + (1/3)$\times$(100/300) + (1/3)$\times$(300/300) = (4/9); therefore, the expected surplus of business type passenger = (4/9)$\times$20 – 6 = 2.9$, while the expected surplus of business type passenger at on site purchase = (1/3)$\times$(20 – 9) + (1/3)$\times${20 - (100/300)$\times$9 – (200/300) $\times$18} = 5.9$

Business type demand situation	Probablity	Number of Business type passenger	Spot price
Low	1/3	0	6$
Middle	1/3	100	9$
High	1/3	300	18$

Table 3.1: Summary of Business type demand: probability, number of passenger and spot price.

Gale and Holmes (1992) propose that a passenger learns their preference of selection between 2 flights over time from the day of advance purchase until departure date. If a passenger buy advance purchase ticket, her net surplus is equal to

$$s = r - p_0 - \frac{1}{2} y \tag{3.5}$$

where s is net surplus, r is reservation price, p_0 is price of advance purchase ticket and y is the disutility (in monetary term) of choosing the less preferred flight. Therefore, a consumer has to tradeoff between a cheaper price and likelihood that she will depart the non-preferred flight if she buys in advance. Otherwise, she will wait to buy her real preferred flight at spot site.

3.3.2 Cancellation charge

Even though the 2 studies above assume that reselling is prohibited and tickets are non-refundable, partial refund can reduce the risk of a consumer who buys ticket in advance. Courty and Li (2000) show the mechanism which screen passengers who learn valuation over time with partial refund contract under monopolist market. Ringbom and Shy (2004) provide the theory to calculate profit rate of partial refunds on customer no-show and cancellation. They claim that passengers earn more profit if the partial refund is higher.

Comparing to Dana's study, he assume showing up probability as the probability of passenger number reach each level, while we will access to passengers' self estimation of showing up probability. Comparing to both Dana, and Gale and Holms, we consider the length of advance purchase effects utility of passenger as it can change showing up probability in Dana research and the value of y in Gale and Holms. In our passenger ticket choice model, we include ticket price, advance purchase length, cancellation charge and other items function that possibly effect passenger ticket choice.

3.3.3 Passenger ticket choice models

In our previous chapter, we propose that a passenger has to trade off among 3 variables; ticket fare, length of advance purchase and cancellation charge. Multinomial Logit Model and Nested Logit Model (Ben Akiva, 1985) are employed to estimate passenger utility and the share of each choice.

$$U_{in} = \alpha F_{in} + \beta A_{in} + \gamma C_{in} + \varepsilon_{in} \tag{3.6}$$

Where; U is utility, F is fare of ticket (Japanese-yen), A is advance purchase (days), C is cancellation charge (Japanese-yen), ε is unobserved utility, i is altenative, n is respondent, and α, β *and* γ are coefficient. However, this model cannot reflex some disutility to the customer, e.g. the cancellation charge of on site purchase or the advance purchase without cancellation charge. We assume that the disutility is independent function of both advance purchase length and cancellation charge as in these following examples.

Example 1

$$\begin{array}{ccc} Ticket\,1 & & Ticket\,2 \\ U[100\$,\ 0days,\ 20\$] & \langle & U[100\$,\ 0days,\ 0\$] \end{array}$$

Where U[100$, 0 day, 0$] is expected utility of 100$ ticket fare, 0 day of advance purchase and 0$ cancellation charge. This model (eq. 2) shows that the 2 tickets – which are purchased on the departure date (advance purchase is zero) with the same price, different cancel fee (e.g. one is zero yen and the other is five thousand yen) – have different expected utility to a passenger. In fact, both ticket types have the same utility to a passenger because she has no probability to cancel a ticket if she buys on the departure date (usual case). Therefore, the cancellation charge, 20$, of the ticket 2 is not disutility to a passenger.

Example 2

$$\begin{array}{ccc} Ticket\,3 & & Ticket\,4 \\ U[100\$,\ 28days,\ 0\$] & \langle & U[100\$,\ 21days,\ 0\$] \end{array}$$

The model (eq. 2) shows that utility of ticket3 is lower that ticket4. As we discuss in example 1 that cancellation charge is considered as disutility only if a passenger have probability of cancellation higher than 0. Same as advance purchase, it is not disutility if there is no punishment for no-show such as cancellation charge (except last minute passengers, who cannot expect trip in advance, which are excluded in this study). Without cancellation charge, a passenger can make many reservations as she wants because she may cancel or no-show without any punishment. From 2 examples, we conclude that only 1 term alone of restrictions: advance purchase or cancellation charge, cannot be considered as disutility. We assume that disutility of restrictions can be model as the combination of advance purchase and cancellation fee.

In our new model, we propose that a passenger should trade off between utility and disutility of tickets. We assume that utility of tickets is discount rate, which is the difference between full fare and discounted rate (full fare – discounted fare), while the disutility of tickets is derived from advance purchase and cancellation charge. Cancellation charge is considered as disutility if a passenger cancel his/her ticket; therefore, we conclude that disutility of ticket is the product of the probability of cancellation and cancellation charge (risk of cancellation × cancellation charge).

For risk of cancellation, we assume that risk of cancellation is a function of advance purchase length, $R = f(A)$, where: *R* is risk of cancellation and A is advance purchase (day). Risk of cancellation should be between 0 and 1 as the passenger will travel for sure (risk = 0) and will not go for sure (risk = 1). Risk of cancellation is 0 when advance purchase is 0 day (purchasing on departure date), because a passenger has no probability to cancellation (as she purchase on site), and the risk increases with advance purchase length as she learn from received information or her experience. Moreover, we assume that the risk should increase rapidly from $A = 0$, then the gradient of risk decrease when the length of advance purchase increase and the function of risk is shown in the figure 3.1.

From those assumptions, we assume that the risk of cancellation function is: Risk $= \frac{\ln(A+1)}{C}$; where *C* is a constant, may change by group or person. To improve the passenger ticket choice model, we propose new model as

$$U_{in} = \alpha D_{in} + \beta[\ln(A_{in} + 1) \times C_{in}] + \varepsilon_{in} \qquad (3.7)$$

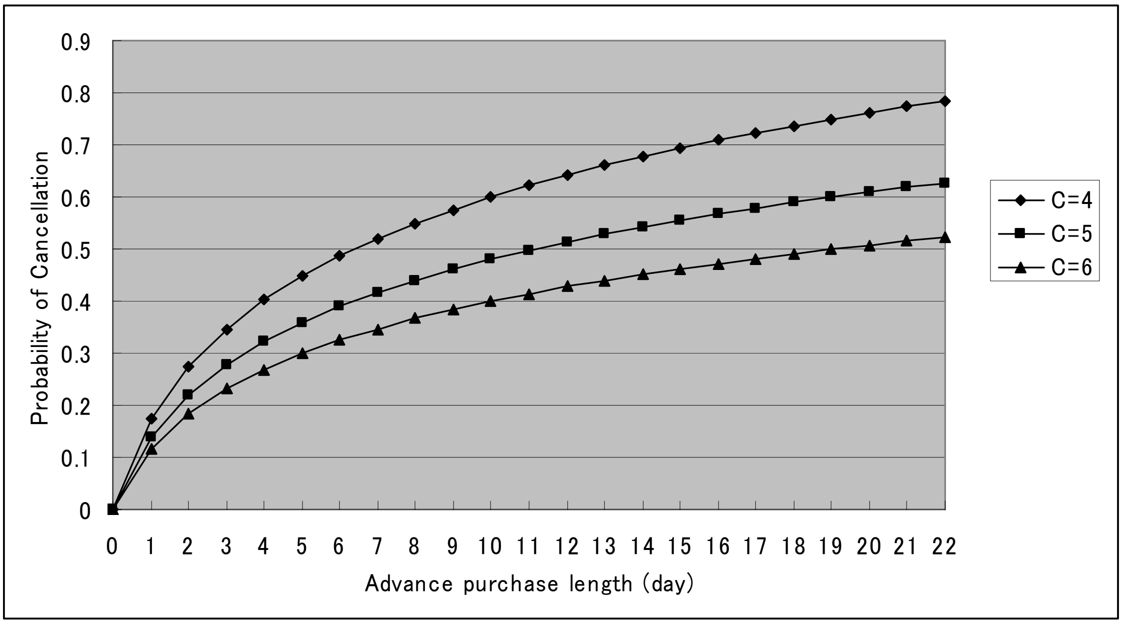

Figure 3.1: Function of risk at different constant

In this study, we assume that passengers are screened by ticket choice into 3 segments as "advance purchasing passengers", "restrictions & discount trade-off passengers" and "last minute passengers". Advance purchasing passengers: Most of passengers in this segment prefer to buy the available cheapest ticket. Comparing with other segments, the passengers in this group have lower willingness to pay but higher certainty to go (lower risk to cancel). Examples of this segment are leisure trip, going back to home town. In this study, we assume as this segment as *leisure passengers*. Restrictions & discount trade-off passengers: The passengers in this segment can have expected schedule in advance; however, their risk of trip cancellation is higher than the first segment, because, possibly, she is business trip passenger who may have risk to buy in advance. She is able to meet the full fare but, still, consider discount rate as surplus. Therefore, we assume that she tradeoffs between restrictions & discount in ticket purchase. In this study, we assume this group as *business trip*. Last minute passengers: The passengers in this segment are able to meet full fare ticket price. They are screened by advance purchasing (AP) restriction because they do not know trip schedule in advance. She cannot buy earlier than her trip is informed or expected. This segment is *excluded* in our study as the passengers cannot choose choices other than on-site purchase. Therefore, there are only 2 segment of passengers; (1) leisure trip passengers and (2) business trip passengers.

3.4 Case studies

In these case studies we assume that when a passenger know their expected future trip, base on these segmentations, all types of ticket, discounted and full fare, are available for a customer at the time of ticket selection, and the passenger chooses the choice that maximize her utility. In this paper, we show results from 2 surveys: case study 1 and 2. In case study 1, ticket type choosing behaviors of 1 transportation mode are examined but in case study 2, both ticket type and transportation mode choice choosing behaviors are examined.

3.4.1 Case study 1: passenger ticket choice in 1 transportation mode

This case study prove the applicability of the model in one transportation mode choice (monopoly market), HS-rail. The survey was conducted in 2001 with the cooperation of Japan Railway East, form around 1,000 respondents from 3 distances of origin-destinations (OD); long (700 km), middle (500 km) and short (300 km), with 2 trip purposes; business trip and leisure trip. Each respondent was asked 8 questions, 3 alternatives each, to choose HS-rail ticket that she prefer the most. After that, coefficients, as in eq (3.3), were estimated by Multinomial Logit Model (MNL). The objective of this survey is to confirm the existing of the coefficients. The results are shown in the table 3.2.

Distance 300km

parameter	unit	value			
		business		leisure	
		Coefficient	t-stat	Coefficient	t-stat
Discount	per1,000yen	0.296	17.755	0.788	33.244
Restrictions	per1,000yen	-0.243	-24.331	-0.088	-10.317
ρ^2		0.299		0.511	
hit ratio		0.652		0.832	
No. of sample		233		247	

Distance 500km

parameter	unit	value			
		business		leisure	
		Coefficient	t-stat	Coefficient	t-stat
Discount	per1,000yen	0.242	18.587	0.702	32.984
Restrictions	per1,000yen	-0.174	-23.189	-0.069	-9.565
ρ^2		0.292		0.588	
hit ratio		0.643		0.871	
No. of sample		223		250	

Distance 700km

parameter	unit	value			
		business		leisure	
		Coefficient	t-stat	Coefficient	t-stat
Discount	per1,000yen	0.196	20.602	0.616	34.297
Restrictions	per1,000yen	-0.144	-23.251	-0.056	-9.294
ρ^2		0.272		0.625	
hit ratio		0.626		0.886	

Table 3.2: Parameters of coefficients and goodness of fit

The results are shown in table 3.2 that coefficients of all ODs and purposes exist (as t-stat reach ± 1.96, at p = 0.05) and ρ^2 were around 0.3 for business and 0.5-0.6 for leisure passengers. Therefore, the eq (3) was proven for reliability. Moreover, all OD show that the ratios of discounts over restrictions of business trips are higher than the leisure trips. It means that passengers in leisure segment prefer to buy the cheaper ticket rather than the business segment that have higher uncertainty of ticket cancellation.

3.4.2 Case study 2: passenger ticket choice in inter-city transit modes competition

This survey was conducted in 2004 March to prove the applicability of the model in 2 transportation mode choices (oligopoly market) as there are 2 main inter-city transit modes in Japan; HS-rail and airlines. This survey is different from the case study 1 that include only HS-rail mode. Keihanshin (Kobe, Osaka and Kyoto) area and Fukuoka OD (around 600 km distance) was selected for this study as they are competitive, as shown in figure 1.1. The table 3.3 shows the average parameters of the 330 samples.

parameter	shinkansen	airlines
line haul cost (full fare) (yen)	14,980	18,300
line haul time (min)	168	65
access cost (yen)	442	901
access time (min)	20	38
egress cost (yen)	252	558
egress time (min)	11	23
time outside vehicle (min)	29	61
Number of transfer	2	3
Total travel time (min)	228	187
Total travel cost (yen)	15,674	19,759

Table 3.3: Average value of 330 samples

The data was collected form 513 respondents who live in Keihanshin and Fukuoka area by web-base survey and 330 samples were completed. The questionnaire included 3 parts of questions mainly: (1) *Revealed Preference* (RP) data: door-to-door OD and transit modes including access and egress, (2) *Stated Preference* (SP) data: a passenger was asked 9 questions to choose the most preferred ticket type, and (3) another personal and transit related data, e.g. occupation, date and purpose of recent trip. 2 modes were considered: (1) HS-rail, and (2) airlines. In SP questions, there were 6 types of one-way ticket: 3 of airlines and 3 of HS-rail. The alternatives of airlines are (1) full fare ticket, (2) web discounted ticket, and (3) special discounted ticket (1 day advance purchase discount), while the alternatives of HS-rail are (1) existing full fare of reserved seat, (2) existing full fare of non-reserved seat (3) non-existing discounted ticket, which its fare, cancellation charge and advance purchase length were varied through 9 questions. The difference reserved and non-reserved seat is the position of reserved seat ticket is fixed, while the position of non-reserved seat ticket is not fixed so the ticket holder can have a seat anywhere /any train of the day if the seat is not occupied.

There were 2 different transit modes; HS-rail and airline, which have some different parameters such as travel time number of transfer; therefore, other parameters were added in to the utility equation as in eq 4.

$$U_{in} = \alpha(F_{in}) + \beta[\ln(d_{in} + 1) \times C_{in}] + \sum_{k=1}^{m} \gamma O_{ink} + \varepsilon_{in} \tag{3.8}$$

Where O_{ink} is k parameters, which passengers can distinguish HS-rail and airlines – e.g. time out side vehicle, access and egress time - of alternative i and n person, and γ is coefficient of O_{ink}. Moreover, the term discount rate is substituted by fare (F_{in}) of the ticket because the full fare prices of both modes are different, and Multinomial Logit Model was substituted by Nested Logit Model for the calculation as nest 1 (HS-rail) and nest 2 (airlines). The nest and alternatives tree are shown in the figure 3.2.

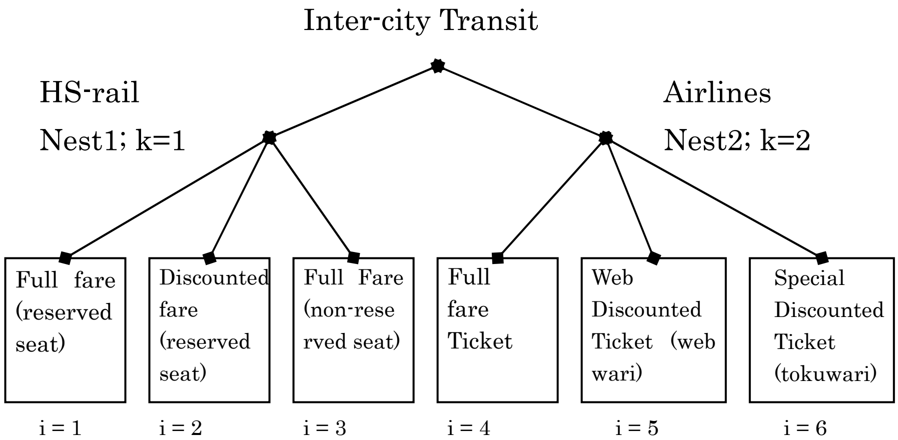

Figure 3.2, nest 1 is the nest of HS-rail (full fare and discounted fare), and nest 2 of airlines; i = alternative.

parameter	business		Leisure	
	Coefficient	t-stat	Coefficient	t-stat
Fare /1000yen	-0.260	-4.814	-0.134	-5.062
restrictions /1000yen	-0.076	-4.580	-0.013	-3.318
dummy of non-reserved	-0.963	-4.280	-0.307	-3.915
time outside vehicle /10 minutes	-0.163	-5.711	-0.257	-9.716
log-sum	0.457	4.743	0.210	5.228
ρ^2	0.237		0.436	
sample number	130		200	
Observation number	1170		1800	

Table 3.4: Coefficients and goodness of fit of study case 2

The results of case study 2 are shown in table 3.4. The t-stat values of all coefficients reached ± 1.96 (p =0.05) and ρ^2 were 0.24 for business passengers and 0.44 for leisure passengers. The coefficients of fare were negative as fare is disutility while the discount in case study 1 was positive. Similar to the case study 1, leisure trip passengers could tradeoff restrictions against fare better than business passengers as the ratio of fare over restrictions of leisure was 10.3 (as -0.260/-0.076) and business was 3.7 (as -0.134/-0.013). It means that leisure passengers preferred cheaper fare and they could accept restrictions better than business passengers. The additional variables from case study 1 were (1) dummy of non-reserved seat of HS-rail and (2) time outside vehicle, waiting and walking time during transfer. The results showed that passengers also considered the time during transfer or waiting vehicle as a factor of choosing transit mode (the longer time, the less probability to be chosen as the coefficients were negative), and reserved seat was preferable for HS-rail passengers (since the coefficients of non-reserved seat dummy were negative).

We calibrated the forecasting model (Nested Logit Model) by comparing estimated share with the real data. We conducted survey in March 2004 but the latest year available data is 2001. Therefore, we compared estimated share with survey data and the trend of latest 10 year available data (1992-2001). The figure 3.3 showed that the estimated share was 61.47% which close to our survey share (62.10%) in Mar 2004 and close to the real data in the year 1999. We concluded the model was successful to forecast share of HS-train passenger.

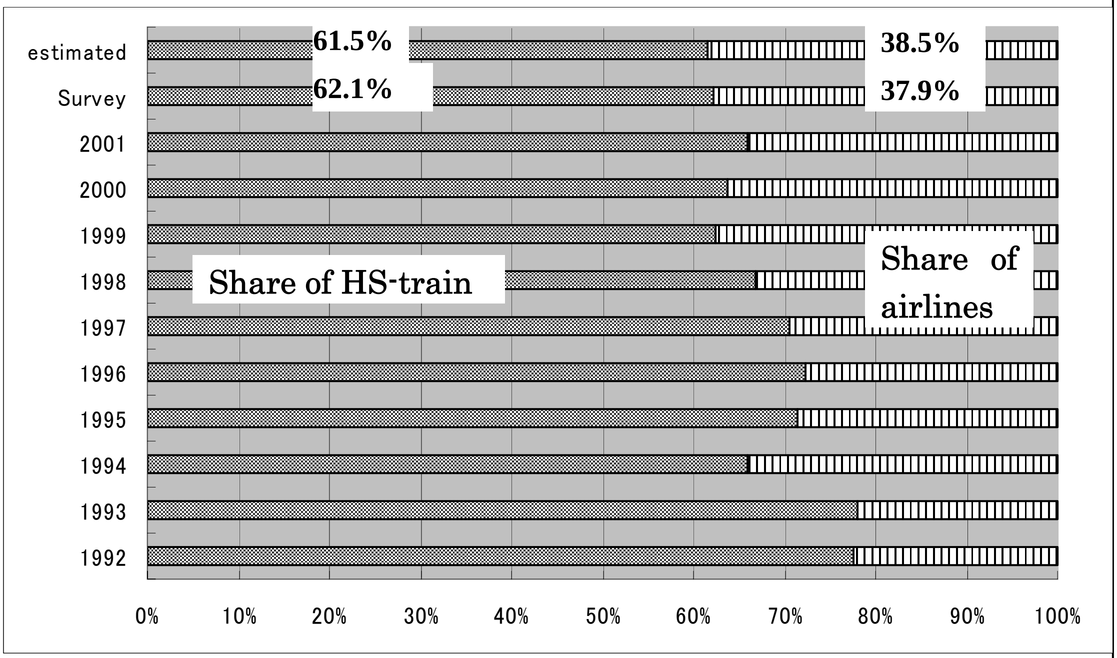

Figure 3.3: Comparison of real share and forecasted share; leisure trip 200 samples, business trip 130 samples

We illustrated how the advance purchase and cancellation charge were applicable with HS-rail in term of improving market share and revenue. The total number of passengers in figure 3.3 was based on total number of passenger in the year 1999 because the share was the closest to the share of our survey in 2004. In other words, this figure showed the expected revenue and market share if the discounted tickets of HS-train were available in the year 1999. Moreover, we assume that (1) the total number of passenger did not change and there was no booking limit, (2) no capacity constraint, (3) no booking limit and (4) no specific date or time preference.

Refer to figure 3.4, the situation 1 was the base situation, without discounted ticket. The latter situations were sorted by the price of discounted ticket with different cancellation charge and advance purchase length. The shares were calculated from Nested logit model calculation and the expected revenue of HS-rail were

$$\text{Revenue} = N\sum S_i F_i \tag{3.9}$$

where N is number of total passengers (6.1 million), S_i is the share of HS-rail ticket type i, F_i is the fare of ticket type i and i is ticket type, discounted or full fare of HS-rail. The share of total HS-rail (full fare and discount) increased as the price of discounted ticket was cheaper because passengers moved from airlines to HS-rail discounted ticket. However, the revenue of HS-rail may not increase as the share increased because some of passengers who used HS-rail full fare also moved to HS-rail discounted ticket which was cheaper. The figure 3.4 showed how the passenger behavior model helped the firm to increase their revenue by setting the price, cancellation charge and the length of advance purchase.

	Discount price	cancellation charge	advance purchase	HS-rail revenue total rev. 100M￥/y	HS-rail revenue revenue change 100M￥/y	HS-rail revenue revenue change percent	Market share
1	no	no	no	551.8	base	0.0%	
2	13400	5950	14	543.3	-8.5	-1.5%	
3	13400	5950	7	546.0	-5.8	-1.1%	
4	13400	5950	3	551.0	-0.8	-0.2%	
5	13400	2970	3	559.1	7.2	1.3%	
6	13400	2970	7	554.6	2.8	0.5%	
7	13400	2970	14	551.3	-0.5	-0.1%	
8	10420	2970	14	484.8	-67.0	-12.1%	
9	10420	2970	7	487.2	-64.6	-11.7%	
10	10420	2970	3	490.6	-61.2	-11.1%	
11	10420	5950	3	484.6	-67.2	-12.2%	
12	10420	5950	7	482.1	-69.7	-12.6%	
13	10420	5950	14	482.7	-69.1	-12.5%	
14	7440	2970	14	375.3	-176.5	-32.0%	
15	7440	2970	7	377.3	-174.5	-31.6%	
16	7440	2970	3	379.8	-172.0	-31.2%	
17	7440	5950	3	375.1	-176.7	-32.0%	
18	7440	5950	7	372.2	-179.6	-32.5%	
19	7440	5950	14	372.5	-179.3266	-32.5%	

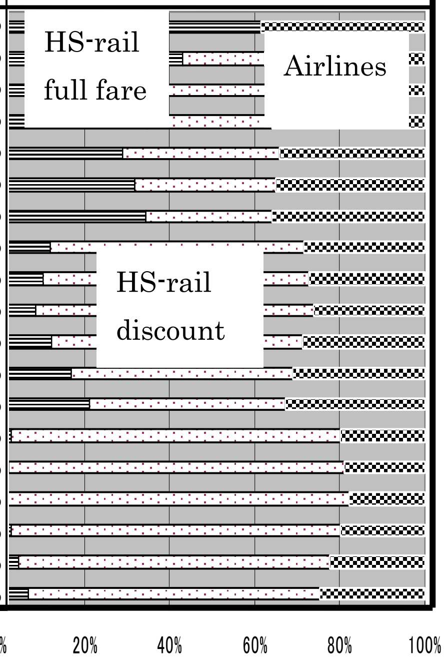

Figure 3.4: Expected share and revenue of HS-rail with different type of discounted ticket

3.5 Discussion and Conclusion

This chapter reported the forecasting model to incorporate the demand response to discounted ticket. As we illustrated in both case study 1 and 2, the eq 3 and 4 were applicable for modeling ticket choice behavior and forecasting share of passengers. This research showed that passengers, who can expect future trip, did tradeoff between restriction terms (advance purchase and cancellation charge) and discount rate, which is also beneficial to customers who can purchase ticket in advance as consumer surplus in our model. As our goal is to increase the revenue of HS-rail, we can apply the model to find the proper ticket price and restrictions.

Pricing is also important in revenue management. The application of this model is not only for inter-city transit firm, but also all perishable product business. For example, in competitive market nowadays, passengers have advantages to compare discounted price of services, e.g. rental car, from the internet. If a firm cannot offer lower price as the competitors, because of operation cost, the firm may persuade customers by decrease its restriction terms as passengers consider restrictions as disutility, especially the passenger who has high risk of cancellation such as passenger in business segment. Nowadays, ticket purchasing from internet is popular. The RP data of passenger ticket choice behavior can be collected from their real purchase. Later, the firm can use the records of passenger ticket chair to adjust their ticket fare, advance purchase length and cancellation charge to maximize their revenue.

For further study, passengers should be segmented by value and restrictions concern not by business or leisure (as some business passengers may have low valuation but some leisure passengers may have high valuation.). Some companies have advantage to access to FFP (frequent flyer program) to calculate valuation and restriction concern of individual passengers. Moreover, as the real time available seat data can be accessed online, some passengers may take advantage to delay their purchasing to reduce restriction concern. The behavior of these passengers may effects the accuracy of demand forecast if the number of these passengers is big enough. It is interesting to identify which segment they belong to, how big the segment is, and how to change their behavior.

Chapter 4

The benefit of using seat allocation in HS-railways networks

In Japan, HS-rail employs “first-come-first-serve” concept in reservation system. The “first-come-first-serve” concept seems fair to passengers but not effective in overall passenger load and revenue management. For example, long distance passengers cannot purchase tickets because seats are not available in some intervals, during the wanted O-D, which are purchased earlier by short distance passengers. Moreover, those empty seats are waste of opportunity at the departure. To eliminate the bottleneck, we propose using seat inventory control in HS-rail. Seat inventory control is a concept in revenue management, for example keeping some seats for long distance passengers who may come later, instead of selling to earlier-comer short haul O-D passenger. The network can earn higher revenue and improve serviceability (in passenger-km) and overall passenger load by maximizing the utility of existing facilities.

Even though seat allocation control seems to be beneficial to Railway Company, the company concern about the loss of passenger’s goodwill to the company because seat allocation control reject some passengers to accept other passengers in order to increase overall revenue. The objective of this study is to prove that seat allocation can improve not only overall revenue but also improve passenger load and rejection request. Finally, we show that the overall passenger goodwill does not decrease if seat allocation control is employed.

4.1 Related literatures

Revenue management (RM) or Yield Management is originally used in airline industries since 1970s (Belobaba, Littlewoods), while RM in Railways just has been being employed recently. Railway industries cannot adopt RM techniques from airline directly because most itineraries combine many legs (for example, Tokyo-Osaka O-D composes of Tokyo → Yokohama → Nagoya → Kyoto → Osaka) while airline itineraries compose of a single leg (for example, Tokyo-Osaka). Therefore, considering overall railway network is necessary.

Ciancimino (1999) improved mathematical program formulation by using historical data for seat inventory control, to accept or reject reservations. In the research, one class of fare level and one transportation mode (Italian Train) were considered.

There are some studies related to passenger behavior in network RM (airlines). Flexible products (or services) are the products which are indifferent to customers, including (1) routing control (Talluri) is a network of the same O-D pair with approximately same departure or arriving time but different place, waiting time and number of transfer, and (2) CORC study (CORC) is the same O-D direct flight with the different departure time.

All the previous studies focused on the improvement of revenue. In this study, we also include the improvement of other factors, passenger load factor and number of rejection, in order to improve the image of railway company that do not intend to improve their own benefit, but also consider the improvement of social benefit.

Objective functions

In our simulations, we set 3 objectives; passenger load maximization, revenue maximization and number of rejection minimization. The optimization in one objective may cause unwanted in other term, e.g. passenger load maximization may cause overall revenue decrease. Moreover, we summarize the features of each objective function as follows; (1) average passenger load factor (APLF) maximization, the firm may appeal that the improvement of passenger load which means serviceability improvement in term of passenger-km, which is beneficial to passengers. (2) Total revenue maximization: this objective is really beneficial to Railway Company but meaningless to passengers. Therefore, Railway Company such as JR may loss some goodwill form passengers if this objective is employed. (3) Number of rejection minimization: this objective should be beneficial to overall passengers, e.g. number of rejection decreases form 10% to 5%. However, it is still unclear whether the overall benefit of passenger improves, e.g. number of rejection decreases because a long distance ticket is rejected for 2 or more of shorter distance ticket.

What is the best answer for seat allocation optimization? The best answer must be the seat allocation that can maximize passenger load, maximize revenue and minimize number of rejection simultaneously. However, the simultaneous optimization of 3 objectives exists in some cases. Therefore, we conclude that the next best answer is the seat allocation that can maximize both passenger load and revenue simultaneously. The number of rejection maybe ignored if passenger load and revenue are optimized simultaneously. The optimization of each factor may occur simultaneously or separately depending on the patterns of passenger demand.

The objectives of this simulation are (1) to observe how many cases that optimization of 3 objectives occur simultaneously, 2 objectives occur simultaneously, and the characteristic of the rest and (2) to examine how seat allocation can improve revenue, passenger load and number of rejection simultaneously with the real passenger demand.

4.2 Simulation methodology

Data were taken from a railway company, route A to D during 2001 August 1st-31st, 14 trains a day. Each train, there are 195 seats for reservation seats. From station 0 to station 22, there are totally 23 stations and 22 sections. To simplify calculation, 23 stations were divided into 4 nodes; node 1 for station 0 to 4, Node 2 for station 5 to 10, Node 3 for station 11 to 17, and Node 4 for station 18 to 22. In this research, we adopt optimization method follows from Minami (2003). In the optimizations, we defined variables and assumptions as follows

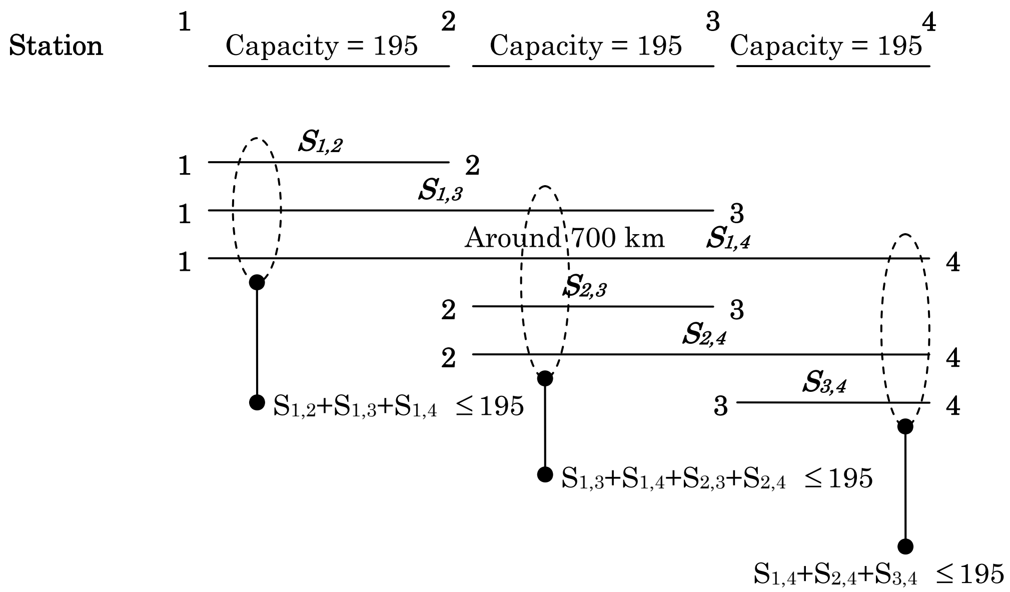

Figure 4.1 Network of HS-rail and its capacity

Variables

- Average passenger load factor $\overline{L}$
- Section l passenger load factor L_l
- Number of rejection R
- Revenue B
- Getting in station i getting off station j $(1 \leq i \leq j \leq n)$
- Operation cost OC
- Number of seat Z
- Ticket fare $P_{i,j}$
- Number of seat to be sold $S_{i,j}$
- Number of passenger demand $D_{i,j}$

- $\alpha_{i,j}$: ratio of ticket to be sold of arriving demand in i,j as $S_{i,j} = \alpha_{i,j} D_{i,j}$

Assumption

- Operation cost of JR high-speed railways is fixed
- Total number of seat is *Z*
- Number of station is *n*
- Overall section is divided into *n*-1 sections
- There is cancellation after purchase and no-show
- There is no group passenger
- *Z* = 195 seats of reserved seat.

4.2.1 Optimization formulas

(1) Maximization of average passenger load factor (APLF)

The maximization of average passenger load factor can be formulated as

$$\max_{\alpha,j} \bar{L} = \frac{1}{n-1}\left(\sum_{l=1}^{n-1} L_l\right) = \frac{1}{n-1}\left(\frac{1}{Z}\sum_{l=1}^{n-1}\left(\sum_{i=1}^{l}\sum_{j=l+1}^{n}\alpha_{i,j}D_{i,j}\right)\right) \tag{4.1}$$

(*s.t*)

$$\begin{cases} \sum_{i=1}^{l}\sum_{j=l+1}^{n}\alpha_{i,j}D_{i,j} \le Z \\ 0 \le \alpha_{i,j} \le 1 \end{cases} \tag{4.2}$$

Then the equation (4.1) and (4.2) can be explained as follows.

Get off station j

Get in station i

	1	2	3	…	L	l+1	…	n-1	n
1		S1,2	S1,3	…	S1,l	S1,l+1	…	S1,n-1	S1,n
2			S2,3	…	S2,l	S2,l+1	…	S2,n-1	S2,n
3				…	S3,l	S3,l+1	…	S3,n-1	⋮
⋮					…	⋮	…	⋮	⋮
l						Sl,l+1	…	Sl,n-1	Sl,n
l+1							…	…	Sl+1,n
⋮								⋮	⋮
n-1									Sn-1,n
n									

S1,2 is number of passengers who get in at 1 station and get off at 2 station

Table 4.1 OD matrix which compose of n stations, n-1 sections

From Table 4.1, the total number of passengers on section l+1 is equal to summation of all number in side the rectangle; therefore, the passenger load factor of section l is

$$L_l = \frac{1}{Z}\left(\sum_{i=1}^{l}\sum_{j=l+1}^{n} S_{i,j}\right) \tag{4.3}$$

Then, the average of passenger load factor can be calculated buy the summation of total passenger load factor divided by n-1 sections

$$\overline{L} = \frac{1}{n-1}\left(\sum_{l=1}^{n-1} L_l\right) = \frac{1}{n-1}\left(\frac{1}{Z}\sum_{l=1}^{n-1}\left(\sum_{l=1}^{l}\sum_{jz-l+1}^{n} S_{i,j}\right)\right) = \frac{1}{n-1}\left(\frac{1}{Z}\sum_{l=1}^{n-1}\left(\sum_{l=1}^{l}\sum_{j=l+1}^{n} \alpha_{i,j} D_{i,j}\right)\right) \tag{4.4}$$

In this study, we divided into 4 stations, 3 sections

$$\overline{L} = \frac{1}{3}\left(\sum_{l=1}^{3} L_l\right) = \frac{1}{3}\left(\frac{1}{Z}\sum_{l=1}^{3}\left(\sum_{i=1}^{l}\sum_{j=l+1}^{4} S_{i,j}\right)\right) = \frac{1}{3}\left(\frac{1}{Z}\sum_{l=1}^{3}\left(\sum_{i=1}^{l}\sum_{j=l+1}^{4} \alpha_{i,j} D_{i,j}\right)\right) \quad (4.5)$$

The constrains of this optimization are

- The number of passenger in each section must be less than seat capacity Z, 195 seats in this research.
- Ratio of accepted ticket of each section, $\alpha_{i,j}$, must be between 0 to 1.

(2) Maximization of total revenue

Revenue maximization can be formulated as

$$\max_{\alpha_{i,j}} B = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} S_{i,j}P_{i,j} = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \alpha_{i,j}D_{i,j}P_{i,j} \quad (4.6)$$

(s.t)

$$\begin{cases} \sum_{i=1}^{l}\sum_{j=l+1}^{n} \alpha_{i,j}D_{i,j} \le Z \\ 0 \le \alpha_{i,j} \le 1 \end{cases} \quad (4.7)$$

Since we simplified the network from 23 stations to 4 nodes, the ticket fare of $P_{i,j}$ is the average price of $S_{i,j}$. For example, $P_{1,3}$ can be calculated as the average of fare inside $S_{1,2}$. As we mentioned earlier that node 0 to 4 is simplified as node 1, and station 11 to 17 is simplified as node 3. If $S_{A,C}$ composes of $S_{0,17}$, 100 passengers with fare 13,840yen, and $S_{1,17}$, 20 passengers with fare 13,640yen, $P_{A,C}$ can be calculated as

$$P_{A,C} = \frac{13840\times100 + 13640\times20}{100+20} = 13800\,yen \quad (4.8)$$

and constrains are the same as earlier.

(3) Minimization of number of rejection

The number of rejection minimization can be formulated as

$$\min_{\alpha_{i,j}} R = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(D_{i,j} - S_{i,j}) = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(D_{i,j} - \alpha_{i,j}D_{i,j}) \quad (4.9)$$

(s.t)

$$\begin{cases} \sum_{i=1}^{l} \sum_{j=l+1}^{n} \alpha_{i,j} D_{i,j} \le Z \\ 0 \le \alpha_{i,j} \le 1 \end{cases} \tag{4.10}$$

where the number of rejection of passenger get in at i node and get off at j node is

$$D_{i,j} - S_{i,j} = D_{i,j} - \alpha_{i,j} D_{i,j} \tag{4.11}$$

where the constrains are the same as earlier.

4.2.2 Optimization method

The optimizations were solved by using Qprog program in GAUSS software. Qprog program is a

$$\min 0.5 * x'Qx - x'r \tag{4.12}$$

$$s.t(s.t)\ Ax = b \quad Cx \ge d \quad bnds[.,1] \le x \le bnds[.,2] \tag{4.13}$$

Please see more information about Qprog in the reference (gauss manual). In this research, from (4.2), (4.7), (4.10) and (4.13), A and B are 0. C, as in (4.19), is the 9×6 constraint coefficient matrix which composes of number of passenger demand in each OD, $D_{i,j}$; table 4.2 shows OD table of passenger demand. D, (4.20), is 9×1 constraint coefficient matrix, which composes of seat capacity of 3 sections that each cannot exceed 195. The number of station, n =4 and number of seat capacity, Z=195.

$$C = \begin{Bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ -D_{1,2} & -D_{1,3} & -D_{1,4} & 0 & 0 & 0 \\ 0 & -D_{1,3} & -D_{1,4} & -D_{2,3} & -D_{2,4} & 0 \\ 0 & 0 & -D_{1,4} & 0 & -D_{2,4} & -D_{3,4} \end{Bmatrix} \tag{4.19}$$

$$d = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ -195 \\ -195 \\ -195 \end{Bmatrix} \quad (4.20)$$

Get off station j

	Train 1	Station 1	Station 2	Station 3	Station 4
	Station 1	0	$D_{1,2}$	$D_{1,3}$	$D_{1,4}$
Get in	Station 2	0	0	$D_{2,3}$	$D_{2,4}$
station i	Station 3	0	0	0	$D_{3,4}$
	Station 4	0	0	0	0

Table 4.2: OD table of passenger demand

Refer to (4.12), Q is equal to 0 as the objective functions are linear functions and r, model constant vector, varies with the objective function as follows;

- Maximization of average passenger load factor (APLF)

$$r = \begin{Bmatrix} \frac{D_{1,2,k}}{585} & \frac{2D_{1,3,k}}{585} & \frac{3D_{1,4,k}}{585} & \frac{D_{2,3,k}}{585} & \frac{2D_{2,4,k}}{585} & \frac{D_{3,4,k}}{585} \end{Bmatrix} \quad (4.21)$$

- Maximization of total revenue

$$r = \{P_{1,2,k}D_{1,2,k} \quad P_{1,3,k}D_{1,3,k} \quad P_{1,4,k}D_{1,4,k} \quad P_{2,3,k}D_{2,3,k} \quad P_{2,4,k}D_{2,4,k} \quad P_{3,4,k}D_{3,4,k}\} \quad (4.22)$$

- Minimization of number of rejection

$$r = \{D_{1,2,k} \quad D_{1,3,k} \quad D_{1,4,k} \quad D_{2,3,k} \quad D_{2,4,k} \quad D_{3,4,k}\} \quad (4.23)$$

4.3 Results of simulations

Sample of simulation results: train 1

Objective function: maximization of APLF

The requests of longest OD, OD 1-4, tend to be accepted while the request of shorter OD, 2-4 and 3-4, tend to be rejected. In maximization of total revenue, similar to maximizing APLF, the requests of OD 1-4 tend to be accepted as they are the most expensive, while the requests of shorter

OD tend to be rejected. For minimization of number of rejection objective, the requests of the longest OD tend to be rejected and the capacity tends to be occupied by the combination of shorter ODs. Since a seat for OD 1-4 passenger can be substituted by 2 or more of shorter OD passengers.

Table 4.5 shows demand and number of accepted passenger in FCFS method and optimizations by 3 objective functions of 14 trains on August 1st. The results of total revenue, number of rejection, and APLF are shown are also shown in the table. From general observations of the results, we conclude that level of demand can be divided into 3 types as peak, off-peak and intermediate train.

Peak train

Train 3 is selected as the representative of peak train. In maximization of APLF, it can be maximized to 100% by many ways as demand is higher than capacity. While in both maximization of total revenue and minimization of number of rejection, the matching of shorter OD requests, e.g. OD 1-2 and 2-4 tend to be accepted instead of the request of OD 1-4, because the summation of OD 1-2 and OD 2-4 ticket is more expensive than the price of OD 1-4 and it can reduce number of rejection.

Off-peak train

Train 14 is selected as the representative of the group. The optimization does not make any improvement because the demand is lower than the capacity.

Intermediate train

Train 5 is selected as the representative of the group. In maximization of APLF, the request of the longest OD, OD 1-4, tend to be accepted while the request of shorter OD, 2-4 and 3-4, tend to be rejected.

As discussed above, the characteristic of 3 types of demand are summarized as

1. *Peak-time train*. Peak-time train is the train that has demand higher than capacity. The requests of passenger are rejected because there is no available space for all OD. The trains in this case are train 3, 4 and 7 in August 1st.
2. *Off-peak train*. Off-peak train is the train that has demand less than capacity. The trains in this case are train 8, 9, 10, 11, 12, 14 in August 1st.
3. *Intermediate train*. Intermediate train is the train that has demand less than peak-time but higher than off-peak train. Most of the time, requests of long OD are rejected because seats are occupied by the shorter OD passengers. The trains in this case are train 1, 2, 5, 6, 13 on August 1st.

The reason of rejection in peak train and intermediate train are different. For example, there is a railway line of 1 – 2 – 3 – 4. A request in peak train of traveling from 1 to 4 are rejected because all seats are booked, 1 to 2, 2 to 3, and 3 to 4, while a request in intermediate train are rejected because only the seats from 2 to 3 are not available.

Comparison of first-come-first-serve (real situation) and seat allocation by 3 objective functions are shown in table 4.6. When seat allocation is optimized by 1 objective function, the factor in that function is optimized. Moreover, the other factors are improved, frequently, they are optimized. For example, in train 1 on August 1st (see simulation results from August 2nd to 31st in appendix 1) objective function 1 (maximize APLF) can optimize all 3 factors (APLF, revenue and number of rejection) simultaneously. When at least 1 objective function can optimized 3 factors at the same time, we count that all 3 factors are optimized simultaneously, and the percent of this happening is summarized as in table 4.3 which shows that 70% of all trains can be optimized for 3 objectives simultaneously. More than 90% of all trains were improved for all factors at the same time. Around 90% of all trains can be optimized at least 2 terms, passenger load factor and revenue.

Results	percentage
all 3 factors are optimized simultaneously	70.04
all 3 factors are improved simultaneously	92.16
2 factors (APLF and revenue) are optimized simultaneously	89.17
2 factors (APLF and revenue) are improved simultaneously	95.39

Table 4.3: Summary of percent of happenings occur during August 1st-31st (total 434 trains)

4.4 Discussion and conclusion

Seat allocation can improve not only revenue but also average passenger load factor and number of rejection, which is important to railways in order to get merit from society and passenger as Railway Company is monopoly (in Japan and some other countries). Therefore, it is worth to do seat allocation in JR high-speed railways. However, in extreme cases, optimization causes 100% rejection in some O-D which is unfair to those passengers. For example, as shown in table 4.4, in train 4 on August 26th, all 3 factors are improved by the optimization; however, all demand of OD 1-4, 4667 passengers, are rejected. It is unfair to 1-4 O-D passengers to be rejected all. For this reason, the firm should provide minimum number of seats to specific O-D for social fairness reason. The minimum number of seats can be decided by various policy of the firm, for example (1) whether the substitute modes are available in that O-D, (2) competitiveness in the route, (3) proportion of passenger demand, and (4) provide some proportion for first-come-first-serve (FCFS) and the rest for seat allocation.

OD demand

	Station 1	Station 2	Station 3	Station 4
Station 1		46	156	4667
Station 2			13	88
Station 3				830
Station 4				

FCFS

OD accepted request					measurement of factors	
	Station 1	Station 2	Station 3	Station 4		
Station 1		34	88	66		
Station 2			12	17	APLF	95.90%
Station 3				107	revenue	3185780
Station 4					rejection	5476

After optimization

OD accepted request					measurement of factors	
	Station 1	Station 2	Station 3	Station 4		
Station 1		46	149	0		
Station 2			13	33	APLF	100.00%
Station 3				162	revenue	3410857
Station 4					rejection	5397

Table 4.4: Total demand, accepted demand by F-C-F-S and optimization method of train 4 on August 26th

Train	OD	Demand	Accepted passeners (person)				Revenue (yen)				No. of passenger rejection (person)				Passenger load				
				Objective fuction				Objective fuction				Objective fuction					Objective fuction		
			FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	Line	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection
1	1,2	32	32	32	32	32	332800	332800	332800	332800	0	0	0	0	line 1to2	151	164	164	114
	1,3	23	23	23	23	23	312340	312340	312340	312340	0	0	0	0	line2to3	195	195	195	183
	1,4	109	96	109	109	59	1534648	1742465	1742465	943169	13	0	0	50	line3to4	195	195	195	195
	2,3	22	20	22	22	22	125800	138380	138380	138380	2	0	0	0	APLF	0.92	0.95	0.95	0.84
	2,4	79	56	41	41	79	515422	377362	377362	727113	23	38	38	0					
	3,4	57	43	45	45	57	125426	131259	131259	166262	14	12	12	0					
	total	322	270	272	272		2946435	3034606	3034606	2620064	52	50	50	50					
2	1,2	86	82	86	86	86	854471	896153	896153	896153	4	0	0	0	line 1to2	195	195	195	189
	1,3	76	51	46	46	40	698360	629893	629893	547733	25	30	30	36	line2to3	195	195	195	195
	1,4	63	62	63	63	63	1018544	1034973	1034973	1034973	1	0	0	0	line3to4	125	130	130	130
	2,3	36	30	30	30	36	188700	188700	188700	226440	6	6	6	0	APLF	0.88	0.89	0.89	0.88
	2,4	56	52	56	56	56	512635	552069	552069	552069	4	0	0	0					
	3,4	11	11	11	11	11	41160	41160	41160	41160	0	0	0	0					
	total	328	288	292	292		3313871	3342947	3342947	3298527	40	36	36	36					
3	1,2	43	43	43	43	43	449221	449221	449221	449221	0	0	0	0	line 1to2	188	195	195	195
	1,3	10	10	5	10	10	136778	68389	136778	136778	0	5	0	0	line2to3	195	195	195	195
	1,4	180	135	147	142	142	2117632	2305866	2227435	2227435	45	33	38	38	line3to4	190	195	190	190
	2,3	0	0	0	0	0	0	0	0	0	0	0	0	0	APLF	0.98	1.00	0.99	0.99
	2,4	59	50	43	43	43	441469	379663	379663	379663	9	16	16	16					
	3,4	5	5	5	5	5	17867	17867	17867	17867	0	0	0	0					
	total	297	243	243	243		3162967	3221006	3210964	3210964	54	54	54	54					

Table 4.5: simulation results of train 1 to train 14 on August 1st

Train	OD	Demand	Accepted passeners (person)				Revenue (yen)				No. of passenger rejection (person)				Passenger load				
			FCFS	Objective fuction			FCFS	Objective fuction			FCFS	Objective fuction			Line	FCFS	Objective fuction		
				Max APLF	Max total revenue	Min no. of passenger rejection		Max APLF	Max total revenue	Min no. of passenger rejection		Max APLF	Max total revenue	Min no. of passenger rejection			Max APLF	Max total revenue	Min no. of passenger rejection
4	1,2	45	39	45	45	45	405885	468328	468328	468328	6	0	0	0	line 1to2	195	195	195	194
	1,3	56	43	16	16	22	571092	212500	212500	294227	13	40	40	34	line2to3	195	195	195	195
	1,4	134	113	134	134	127	1787337	2119497	2119497	2006347	21	0	0	7	line3to4	163	190	190	183
	2,3	10	9	9	9	10	56610	56610	56610	62900	1	1	1	0	APLF	0.95	0.99	0.99	0.98
	2,4	36	30	36	36	36	288738	346486	346486	346486	6	0	0	0					
	3,4	20	20	20	20	20	107000	107000	107000	107000	0	0	0	0					
	total	301	254	260	260	260	3216663	3310421	3310421	3285289	47	41	41	41					
5	1,2	50	42	36	36	36	440860	377880	377880	377880	8	14	14	14	line 1to2	195	195	195	195
	1,3	73	51	33	33	73	691872	447682	447682	990327	22	40	40	0	line2to3	189	195	195	195
	1,4	126	102	126	126	86	1637029	2022213	2022213	1380240	24	0	0	40	line3to4	134	158	158	118
	2,3	11	11	11	11	11	69190	69190	69190	69190	0	0	0	0	APLF	0.89	0.94	0.94	0.87
	2,4	25	25	25	25	25	238340	238340	238340	238340	0	0	0	0					
	3,4	7	7	7	7	7	31500	31500	31500	31500	0	0	0	0					
	total	292	238	238	238	238	3108792	3186805	3186805	3087477	54	54	54	54					
6	1,2	53	33	48	41	53	347985	506160	432345	558885	20	5	12	0	line 1to2	195	195	195	195
	1,3	67	58	0	67	0	797148	0	920843	0	9	67	0	67	line2to3	195	195	195	194
	1,4	148	104	147	87	142	1668333	2358125	1395625	2277917	44	1	61	6	line3to4	140	195	135	190
	2,3	11	4	7	0	11	25160	44030	0	69190	7	4	11	0	APLF	0.91	1.00	0.90	0.99
	2,4	41	29	41	41	41	271890	384396	384396	384396	12	0	0	0					
	3,4	7	7	7	7	7	20560	20560	20560	20560	0	0	0	0					
	total	327	235	250	243	254	3131076	3313271	3153769	3310948	92	77	84	73					

Table 4.5: simulation results of train 1 to train 14 on August 1st (cont. 1)

Train	OD	Demand	Accepted passeners (person)				Revenue (yen)				No. of passenger rejection (person)				Passenger load				
				Objective fuction				Objective fuction				Objective fuction					Objective fuction		
			FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	Line	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection
7	1,2	44	39	22	38	44	377003.51	212669	367337	425337.3	5	22	6	0	line 1to2	195	195	195	195
	1,3	30	26	0	4	30	355713.91	0	54725	410439.13	4	30	26	0	line2to3	194	195	195	189
	1,4	173	130	173	153	121	2095330	2788401	2466042	1950268.7	43	0	20	52	line3to4	172	195	195	163
	2,3	2	2	0	2	2	16150	0	16150	16150	0	2	0	0	APLF	0.96	1.00	1.00	0.94
	2,4	36	36	22	36	36	358634.12	219165	358634	358634.12	0	14	0	0					
	3,4	6	6	0	6	6	17748	0	17748	17748	0	6	0	0					
	total	291	239	217	239	239	3220579.5	3220234.6	3280636	3178577.3	52	74	52	52					
8	1,2	25	25	25	25	25	264750	264750	264750	264750	0	0	0	0	line 1to2	164	164	164	164
	1,3	24	24	24	24	24	332160	332160	332160	332160	0	0	0	0	line2to3	184	184	184	184
	1,4	115	115	115	115	115	1910661.1	1910661	1910661	1910661.1	0	0	0	0	line3to4	175	175	175	175
	2,3	1	1	1	1	1	6290	6290	6290	6290	0	0	0	0	APLF	0.89	0.89	0.89	0.89
	2,4	44	44	44	44	44	426724.57	426725	426725	426724.57	0	0	0	0					
	3,4	16	16	16	16	16	65156.923	65157	65157	65156.923	0	0	0	0					
	total	225	225	225	225	225	3005742.6	3005742.6	3005743	3005742.6	0	0	0	0					
9	1,2	11	11	11	11	11	115450	115450	115450	115450	0	0	0	0	line 1to2	133	133	133	133
	1,3	8	8	8	8	8	109260	109260	109260	109260	0	0	0	0	line2to3	180	180	180	180
	1,4	114	110	114	114	114	1845535.6	1845536	1845536	1845535.6	0	0	0	0	line3to4	171	171	171	171
	2,3	7	5	7	7	7	44030	44030	44030	44030	0	0	0	0	APLF	0.83	0.83	0.83	0.83
	2,4	51	42	51	51	51	483164.29	483164	483164	483164.29	0	0	0	0					
	3,4	6	5	6	6	6	27000	27000	27000	27000	0	0	0	0					
	total	197	181	197	197	197	2624439.9	2624439.9	2624440	2624439.9	0	0	0	0					

Table 4.5: simulation results of train 1 to train 14 on August 1^{st} (cont. 2)

Train	OD	Demand	Accepted passeners (person)				Revenue (yen)				No. of passenger rejection (person)				Passenger load				
				Objective fuction				Objective fuction				Objective fuction					Objective fuction		
			FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	Line	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection
10	1,2	37	37	37	37	37	381670	381670	381670	381670	0	0	0	0	line 1to2	131	131	131	131
	1,3	24	24	24	24	24	327050	327050	327050	327050	0	0	0	0	line2to3	154	154	154	154
	1,4	70	70	70	70	70	1149450.7	1149451	1149451	1149450.7	0	0	0	0	line3to4	138	138	138	138
	2,3	0	0	0	0	0	0	0	0	0	0	0	0	0	APLF	0.72	0.72	0.72	0.72
	2,4	60	60	60	60	60	593420	593420	593420	593420	0	0	0	0					
	3,4	8	8	8	8	8	33220	33220	33220	33220	0	0	0	0					
	total	199	199	199	199	199	2484810.7	2484810.7	2484811	2484810.7	0	0	0	0					
11	1,2	37	37	37	37	37	386171.18	386171	386171	386171.18	0	0	0	0	line 1to2	119	119	119	119
	1,3	21	21	21	21	21	284380	284380	284380	284380	0	0	0	0	line2to3	140	140	140	140
	1,4	61	61	61	61	61	990904.33	990904	990904	990904.33	0	0	0	0	line3to4	118	118	118	118
	2,3	9	9	9	9	9	56610	0	0	0	0	0	0	0	APLF	0.64	0.64	0.64	0.64
	2,4	49	49	49	49	49	471687.67	471688	471688	471687.67	0	0	0	0					
	3,4	8	8	8	8	8	36000	36000	36000	36000	0	0	0	0					
	total	185	185	185	185	185	2225753.2	2169143.2	2169143	2169143.2	0	0	0	0					
12	1,2	58	58	58	58	58	612580	612580	612580	612580	0	0	0	0	line 1to2	189	189	189	189
	1,3	51	51	51	51	51	669460	669460	669460	669460	0	0	0	0	line2to3	181	181	181	181
	1,4	80	80	80	80	80	1314674.3	1314674	1314674	1314674.3	0	0	0	0	line3to4	133	133	133	133
	2,3	5	5	5	5	5	29080	0	0	0	0	0	0	0	APLF	0.86	0.86	0.86	0.86
	2,4	45	45	45	45	45	437778.41	437778	437778	437778.41	0	0	0	0					
	3,4	8	8	8	8	8	28440	28440	28440	28440	0	0	0	0					
	total	247	247	247	247	247	3092012.7	3062932.7	3062933	3062932.7	0	0	0	0					

Table 4.5: simulation results of train 1 to train 14 on August 1st (cont. 3)

Train	OD	Demand	Accepted passeners (person)				Revenue (yen)				No. of passenger rejection (person)				Passenger load				
				Objective fuction				Objective fuction				Objective fuction					Objective fuction		
			FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection	Line	FCFS	Max APLF	Max total revenue	Min no. of passenger rejection
13	1,2	89	89	81	81	89	934555	850550	850550	934555	0	8	8	0	line 1to2	195	195	195	195
	1,3	35	30	35	35	27	411878	480524	480524	370690	5	0	0	8	line2to3	124	132	132	124
	1,4	79	76	79	79	79	1245710	1294883	1294883	1294883	3	0	0	0	line3to4	98	101	101	101
	2,3	2	2	2	2	2	12580	0	0	0	0	0	0	0	APLF	0.71	0.73	0.73	0.72
	2,4	16	16	16	16	16	152500	152500	152500	152500	0	0	0	0					
	3,4	6	6	6	6	6	25610	25610	25610	25610	0	0	0	0					
	total	227	219	219	219	219	2782833	2804067	2804067	2778238	8	8	8	8					
14	1,2	49	49	49	49	49	516830	516830	516830	516830	0	0	0	0	line 1to2	137	137	137	137
	1,3	21	21	21	21	21	289910	289910	289910	289910	0	0	0	0	line2to3	115	115	115	115
	1,4	67	67	67	67	67	1107419	1107419	1107419	1107419	0	0	0	0	line3to4	95	95	95	95
	2,3	0	0	0	0	0	0	0	0	0	0	0	0	0	APLF	0.59	0.59	0.59	0.59
	2,4	27	27	27	27	27	258280	258280	258280	258280	0	0	0	0					
	3,4	1	1	1	1	1	3110	3110	3110	3110	0	0	0	0					
	total	165	165	165	165	165	2175549	2175549	2175549	2175549	0	0	0	0					

Table 4.5: simulation results of train 1 to train 14 on August 1st (cont.4)

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	92.48%	2,946	52	94.70%	3,035	50	94.70%	3,035	50	84.10%	2,620	50
change	−	−	−	2.22%	89	−2	2.22%	89	−2	−8.38%	−326	−2
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 2	88.04%	3,314	40	88.89%	3,343	36	88.89%	3,343	36	87.86%	3,299	36
change	−	−	−	0.85%	29	−4	0.85%	29	−4	−0.17%	−15	−4
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	97.95%	3,163	54	100.00%	3,221	54	99.15%	3,211	54	99.15%	3,211	54
change	−	−	−	2.05%	58	0	1.20%	48	0	1.20%	48	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 4	94.53%	3,217	47	99.15%	3,310	41	99.15%	3,310	41	97.75%	3,285	41
change	−	−	−	4.62%	93	−6	4.62%	93	−6	3.22%	68	−6
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 5	88.55%	3,109	54	93.68%	3,187	54	93.68%	3,187	54	86.84%	3,087	54
change	−	−	−	5.13%	78	0	5.13%	78	0	−1.71%	−22	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	90.60%	3,131	92	100.00%	3,313	77	89.74%	3,154	84	98.97%	3,311	73
change	−	−	−	9.40%	182	−15	−0.86%	23	−8	8.37%	180	−19
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized
train 7	95.90%	3,137	52	100.00%	3,220	74	100.00%	3,281	52	93.50%	3,179	52
change	−	−	−	4.10%	83	22	4.10%	143	0	−2.40%	41	0
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	89.40%	3,006	0	89.40%	3,006	0	89.40%	3,006	0	89.40%	3,006	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	82.74%	2,624	0	82.74%	2,624	0	82.74%	2,624	0	82.74%	2,624	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	72.31%	2,485	0	72.31%	2,485	0	72.31%	2,485	0	72.31%	2,485	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	64.44%	2,169	0	64.44%	2,169	0	64.44%	2,169	0	64.44%	2,169	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	85.98%	3,063	0	85.98%	3,063	0	85.98%	3,063	0	85.98%	3,063	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	71.28%	2,783	8	73.16%	2,804	8	73.16%	2,804	8	71.79%	2,778	8
change	−	−	−	1.88%	21	0	1.88%	21	0	0.51%	−5	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	59.32%	2,176	0	59.32%	2,176	0	59.32%	2,176	0	59.32%	2,176	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

Table4.6: Result of optimization on August 1st

whrere:

Do nothing: real situation, first-come-first-serve

Objective function 1: maximize average passenger load factor (APLF)

Objective function 2: maximize revenue

Objective function 3: minimize number of rejection

Train: there are 14 trains a day; 1, 3, …, 27

APLF: average passenger load factor

Revenue in thousand yen

Rejection: number of rejection

Optimized: the number of passenger is optimized for that factor.

No: the number of passenger is not optimized for that factor

Chapter 5

RM of single-line multiple-stop system by using passenger behavior

In previous chapter, we discussed the benefit of seat allocation on HS-railway, which can significantly improve average passenger load factor, revenue, and number of rejection. However, seat allocation can improve only high-demand trains, for example train 1 to train 9 in table 4.6. Comparing with the optimization results of off-peak trains, the improvement in train 10 and 14 are significantly less than the improvement in high-demand trains.

In off-peak trains, seat allocation cannot improve average passenger load factor, revenue, and number of rejection because seat capacity is not constrain, as the number of passenger is much lower than capacity. In off-peak trains, average passenger load factor and revenue may be improved by selling discounted ticket to create more demand. Refer to chapter 3, revenue and number of passenger were improved by selling discounted ticket and we discussed of using passenger behavior on single-leg problem revenue management. However, in this chapter, passenger behavior and seat allocation on one-line multiple-stops are combined.

The objectives of this section are to (1) implement RM of passenger behavior model on one-line multiple-stop system, such as HS-railway and (2) discuss the usefulness of discounted ticket on HS-railway system. In this chapter, original demand is modified by passenger behavior model as discussed in chapter 3. Then, the modified demand is optimized same as the methods in chapter 4.The differences between chapter 4 and chapter 5 are compared in figure 5.1. From here, the seat allocation method in chapter 4 is called optimization with no discounted ticket, and the seat allocation method in chapter 5 is called optimization with discounted ticket.

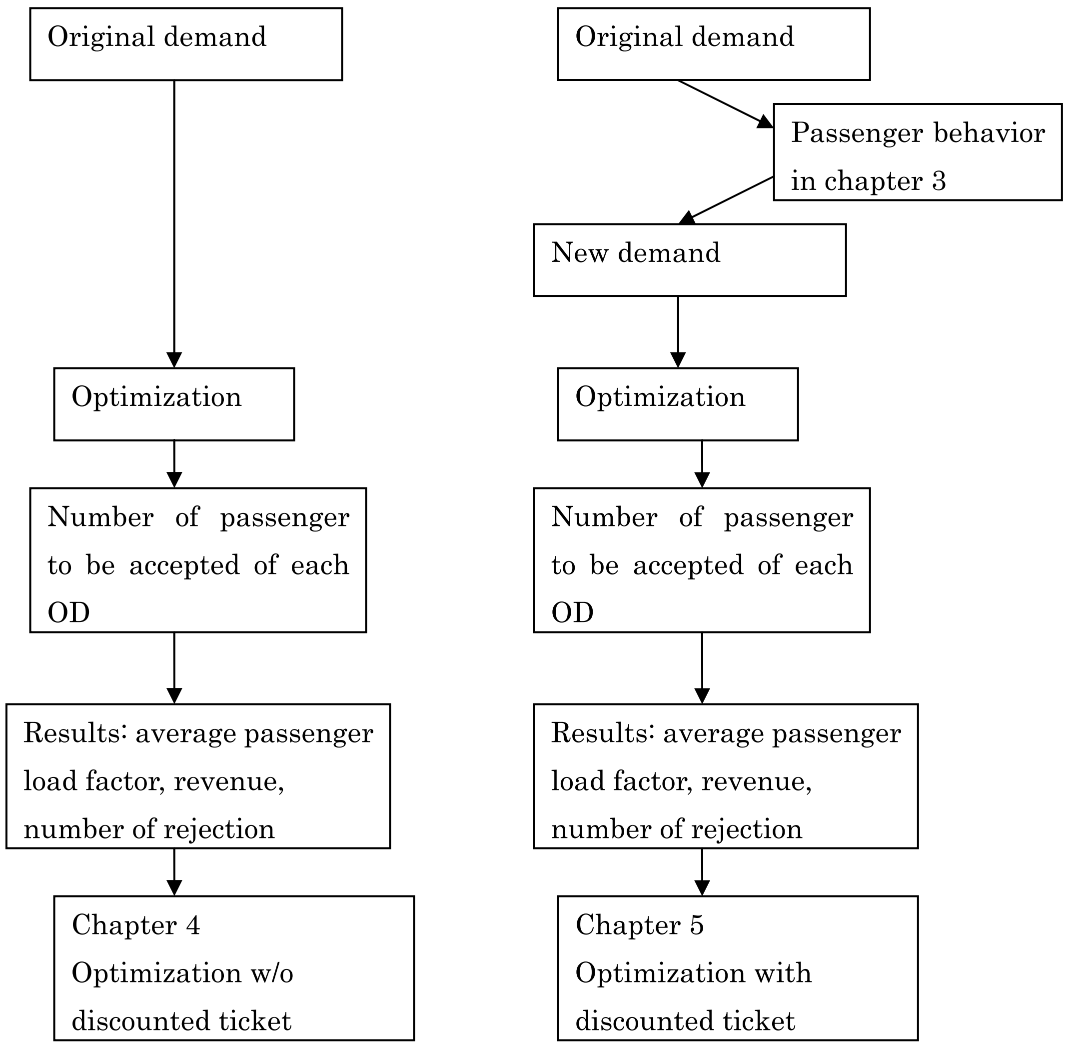

Figure 5.1: comparison of chapter 4 to chapter 5

5.1 Methodology

The procedure of simulations in optimization with discounted ticket are

1. The OD demand in chapter 4 (station 1 – 2 – 3 – 4, 2001 August 1^{st}-31^{st}) is used as base situation of demand.

2. Assume that demand of OD 1-4 change proportionally when discounted ticket is available. The change of demand by ticket characteristics is calculated by passenger behavior model as in chapter 3. In fact, SP data of passenger in this route are not available so we assume that passengers in this OD 1-4 have the same tradeoff valuation in chapter 3 (competition between HS-rail and airlines in Keikanshin – Fukuoka route). The change of demand and revenue are calculated and shown in table 5.1.

Situation		day prior (days)	cancellation charge (yen)	percent discount	share			total shinkansen demand expansion	average price	expansion of shinkansen revenue
					normal fare	discounted fare	total of shinkansen			
1	no discounted ticket	-	-	-	0.61	0.00	0.61	100%		
2	discouted [13400, 5950, 14]	14	5950	10%	0.43	0.19	0.62	101%	0.97	0.99
3	discouted [13400, 5950, 7]	7	5950	10%	0.40	0.23	0.63	102%	0.97	0.99
4	discouted [13400, 5950, 3]	3	5950	10%	0.35	0.29	0.64	104%	0.96	1.00
5	discouted [13400, 2970, 3]	3	2970	10%	0.29	0.37	0.66	107%	0.95	1.02
6	discouted [13400, 2970, 7]	7	2970	10%	0.32	0.33	0.65	105%	0.96	1.01
7	discouted [13400, 2970, 14]	14	2970	10%	0.34	0.30	0.64	104%	0.96	1.00
8	discouted [10420, 2970, 14]	14	2970	30%	0.12	0.59	0.71	116%	0.76	0.89
9	discouted [10420, 2970, 7]	7	2970	30%	0.10	0.62	0.73	118%	0.76	0.89
10	discouted [10420, 2970, 3]	3	2970	30%	0.09	0.65	0.74	120%	0.75	0.90
11	discouted [10420, 5950, 3]	3	5950	30%	0.12	0.59	0.71	116%	0.76	0.89
12	discouted [10420, 5950, 7]	7	5950	30%	0.17	0.52	0.69	112%	0.78	0.88
13	discouted [10420, 5950, 14]	14	5950	30%	0.21	0.46	0.67	109%	0.81	0.88
14	discouted [7440, 2970, 14]	14	2970	50%	0.03	0.77	0.80	130%	0.53	0.69
15	discouted [7440, 2970, 7]	7	2970	50%	0.02	0.79	0.81	132%	0.52	0.69
16	discouted [7440, 2970, 3]	3	2970	50%	0.02	0.80	0.82	134%	0.52	0.70
17	discouted [7440, 5950, 3]	3	5950	50%	0.03	0.77	0.80	130%	0.53	0.69
18	discouted [7440, 5950, 7]	7	5950	50%	0.05	0.73	0.78	126%	0.54	0.68
19	discouted [7440, 5950, 14]	14	5950	50%	0.07	0.68	0.75	123%	0.56	0.68

Table 5.1: the change of demand expansion, average price and revenue when the details of discounted ticket is changed

3. Optimize HS-rail system (all ODs in route 1 – 2 – 3 – 4) when discounted ticket available on OD 1-4. Hypothetic discounted ticket is established only on OD 1 - 4 because it is the only OD which is competitive with airlines, as in the figure 5.2. In this passenger behavior model, there is no change of demand in other OD because there is no switching demand from or to other modes (In fact, there are other transportation services in other OD, such as highway bus. However, in this study, we focus on competition between HS-rail and airlines only.).

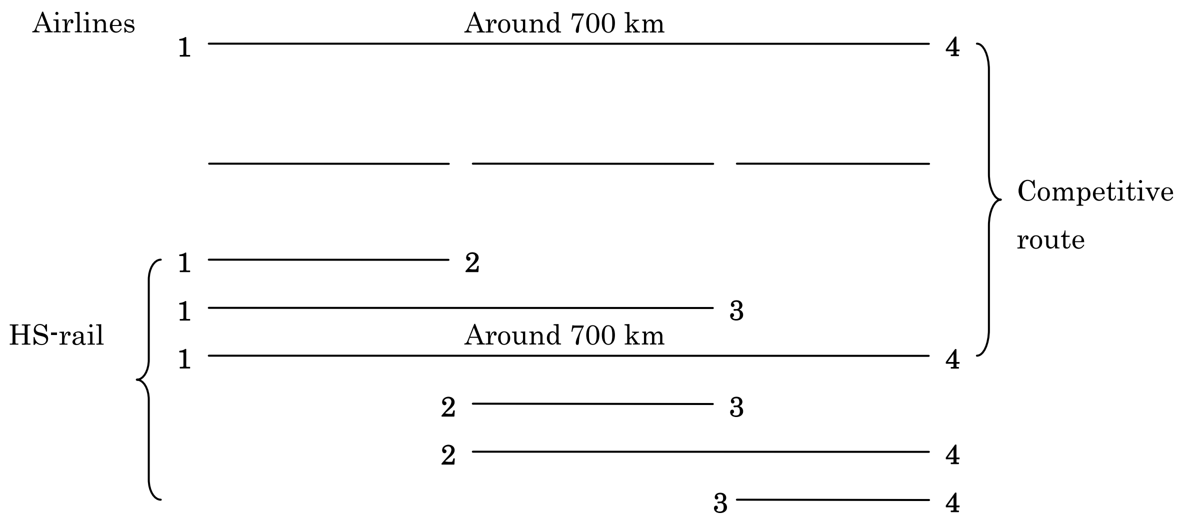

Figure 5.2: the competitive OD between airlines and HR-rail

4. In this study, the discounted ticket in situation 5 is selected (10% discount of ticket fare, 2970 yen of cancellation charge, 3 days prior) because it gives highest expansion of revenue.

5. The demand and revenue of FCFS (first-come-first-serve), when discounted ticket is available, are calculated by using the same number of accepted passenger in chapter 4. For example, in table 5.2, train 1 on August 1st, expansion of demand in OD 1-4 increase 7% (from situation 5 in the table 5.1), so it become 109 ×107% = 117 persons. The average price of ticket in OD 1-4 decreases to 95%; therefore, the new revenue in OD 1-4 is $\frac{1,486,690}{93} \times 93 \times 95\% = 1,419,194$ yen. In this section, 14 trains in August 1st are selected in the optimization and the rest trains are calculated in the same way as train 1. Then, FCFS with discounted ticket is used as input of optimization with discounted ticket.

	FCFS: w/o discounted ticket			FCFS: with discounted ticket		
Train 1	total demand (person)	accepted passenger (person)	revenue (yen)	total demand (person)	accepted passenger (person)	revenue (yen)
1,2	32	32	332,800	32	32	332,800
1,3	23	23	312,340	23	23	312,340
1,4	109	93	1,486,690	117	93	1,419,194
2,3	22	17	106,930	22	17	106,930
2,4	79	53	487,810	79	53	487,810
3,4	57	32	93,340	57	32	93,340
total	322	250	2,819,910	330	250	2,752,414

Table 5.2: comparing demand, and revenue FCFS when discounted ticket is available/unavailable of train 1 on August 1st

6. The results of optimization with demand can be obtained by optimization of FCFS with discounted ticket. The optimization methods are the same as in chapter 4 (maximization of revenue, maximization of APLF, and minimization of number of rejection).

5.2 Results

Results of optimization w/o discounted ticket and optimization with discounted ticket of all trains on August 1st are shown in table 5.4 and figure 5.3 – 5.5. Only the best optimization results of each train are shown (The best results is the results that optimize in all 3 factors simultaneously (maximize APLF, maximize total revenue, minimize number of rejection). If there is no such result in that train, the next best, such as improve all 3 factors, is shown.). Again, the patterns of results vary by 3 levels of demand. In this chapter, we selected 14 trains on August 1st as case study because they contain all 3 levels of demand.

5.2.1 Peak trains: e.g. train 3

The demand in this train is considered as peak time as the demand is higher than capacity. When discounted ticket is available, the demand of OD 1-4 increases from 180 to 193 passengers. However, number of accepted passenger in all ODs does not change. APLF also does not change; moreover, the APLF of optimization without discounted ticket is maximum, 100%. The number of rejection increase as the additional demand in OD 1-4, 13 passengers, cannot be allocated. Total revenue of the train decreases as the revenue of OD 1-4 decrease (no revenue change in other OD) because number of allocated seats is the same while the average fare decreases.

5.2.2 Off-peak trains: e.g. Train 10

The demand in this train is considered as off-peak time where capacity is higher than demand. The demand of OD 1-4 increases from 70 to 75 passengers when discounted ticket is available. The number of accepted passenger in OD 1-4 increases for 5 passengers, the same as the increase of demand. Therefore, APLF and revenue increase when discount ticket is available while number of rejection does not change from 0 as all demand can be accepted as the demand is still lower than capacity.

5.2.3 Intermediate trains

Sample train: train 1

From table 5.4, demand of OD 1-4 in train 1 increase from 109 to 117 when discounted tickets are available as new passengers switch from airlines to buy discounted ticket of OD 1-4. APLF increases from 94.70% to 96.07% when discounted ticket available, because the additional 8 passengers in OD 1-4 are substituted for the 8 passengers in OD 2-4. The number of rejection increase from 50 to 58 as the total demand increase 8 passengers but the number of accepted passengers is the same, 272 passengers. The changes of revenue occur in OD 1-4, as the number of accepted passenger increase, and OD 2-4, as the number of accepted passenger decrease. The increase of revenue in OD 1-4 is less than the decrease of revenue in OD 2-4. However, the overall revenue of optimization with discounted ticket is better than FCFS.

5.3 Discussion

Note that OD distribution fairness issue is not discussed in this chapter. From the results we summarize that there are 3 types of result patterns, same as in chapter 4, which are

5.3.1 Peak train

Peak train is the train that has demand higher than capacity. After optimization without discounted ticket, APLF becomes 100%. Therefore, optimization with discounted ticket cannot improve APLF, total revenue, and number of rejection from optimization without discounted ticket. In this case, seat allocation without discounted ticket gives the most advantage results. By the way, the results of APLF and revenue in optimization with discounted ticket are better than FCFS. The trains in this case are train 3, 4, 6 and 7.

5.3.2 Off-peak train

Off-peak train is the train that has demand less than capacity. After optimization with/without discounted ticket, the number of rejection becomes 0. Therefore, optimization with discounted ticket gives the most advantage results because the train has adequate capacity for additional demand, which switches from airlines. It means that if capacity is not constrain of seat allocation, HS-rail may sell discounted ticket to increase number of passenger and revenue. The trains in this case are train 8, 9, 10, 11, 12, 14.

5.3.3 Intermediate train

Intermediate train is the train that has demand less than peak-time but higher than off-peak train. Total number of accepted passengers in both with and without discounted ticket optimization are the same, so the rejected passenger number of without discounted ticket seat allocation is higher than with discounted one. In optimization with discounted ticket, the additional passengers in the longest OD, 1-4, are accepted while other shorter ODs in optimization without discounted ticket. It means that, in optimization with discounted ticket, additional passengers who switch from airlines occupy seats which can be allocated to the existing HS-rail demand. Even though optimization with discounted ticket gives the best APLF results, optimization without discounted ticket gives the best revenue results. The trains in this case are train 1, 2, 5, 13.

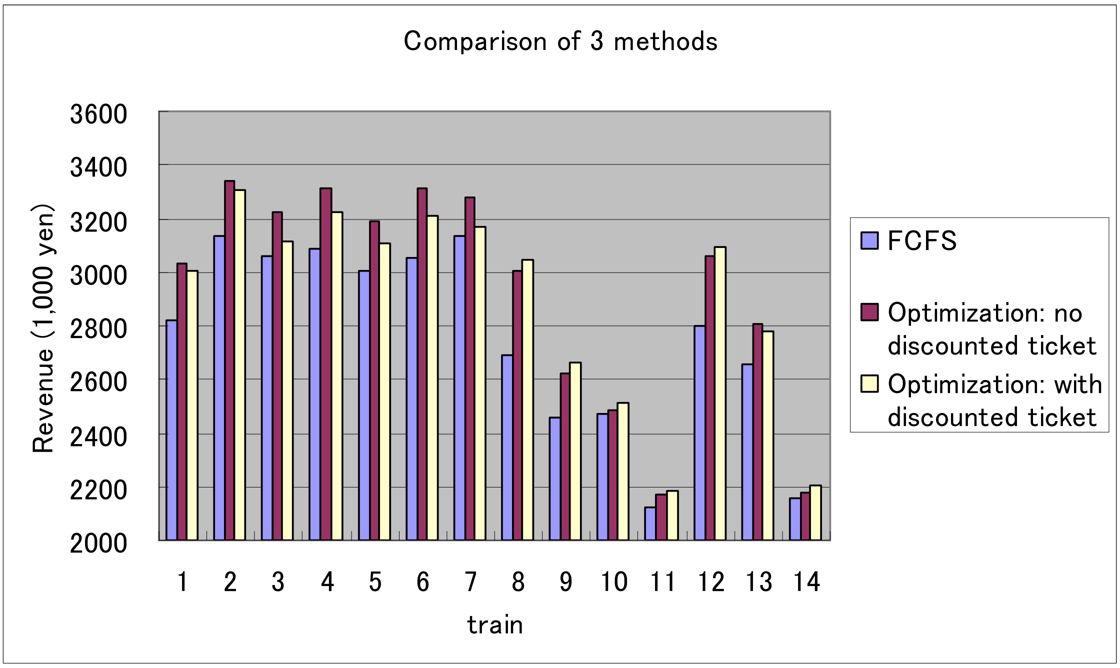

Figure 5.3: Comparing total revenue of 3 method (train 1-14 on August 1st)

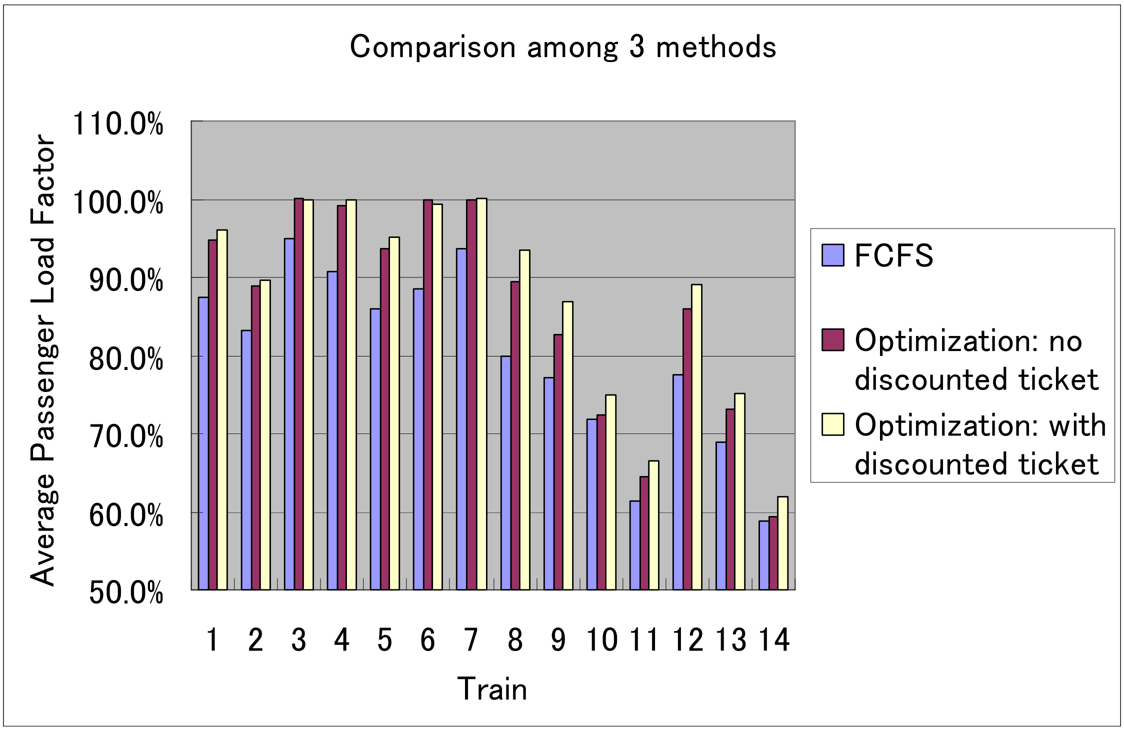

Figure 5.4: Comparing average passenger load factor of 3 method (train 1-14 on August 1st)

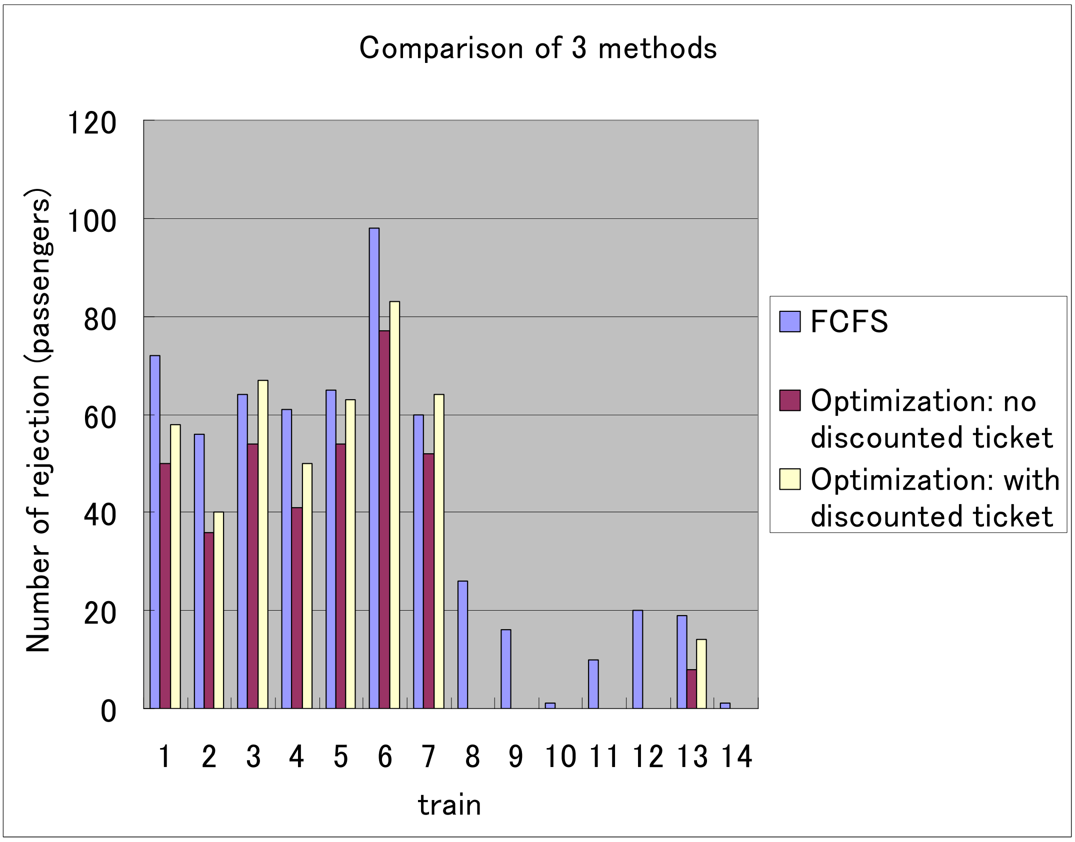

Figure 5.3: Comparing number of rejection of 3 method (train 1-14 on August 1st)

5.4 Conclusion

Passenger behavior can be implemented on single-line multiple-stop system of RM as well. Regardless of the fairness of seat allocation on ODs, each seat allocation method has different advantage on different demand situation. It is certain that optimization with discounted ticket is the best seat allocation method in off-peak train, and optimization without discounted ticket give the most advantage in peak train, while FCFS has no advantage at all. In intermediate trains, optimization with discount ticket have advantage in increasing APLF and total HS-rail demand, but optimization without discounted ticket give the highest total revenue and lowest number of rejection. Therefore, in intermediate train, there is no best seat allocation method for all-round purpose. Each seat allocation method is suitable for different policy. For example, optimization without discounted ticket is suitable for financial purpose, but optimization with discounted ticket is suitable for promotion campaign.

	Advantage of optimization with discounted ticket	Advantage of optimization without discounted ticket
Peak train	–	revenue, number of passenger rejection
Off-peak train	revenue, APLF	–
Intermediate train	APLF	revenue, number of passenger rejection

Table 5.3: Comparing advantages of optimization with and without discounted ticket

Train	OD	Demand		Number of accepted passenger (person)			Revenue (yen)			Number of passenger rejection (person)			Passenger load			
		w/o discount ticket	with discount ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket		FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket
	1,2	32	32	32	32	32	332800	332800	332800	0	0	0	line 1to2	151	164	172
	1,3	23	23	23	23	23	312340	312340	312340	0	0	0	line2to3	195	195	195
	1,4	109	117	96	109	117	1534648	1742465	1785438	13	0	0	line3to4	195	195	195
1	2,3	22	22	20	22	22	125800	138380	138380	2	0	0	APLF	92.5%	94.7%	96.1%
	2,4	79	79	56	41	33	515422	377362	303731	23	38	46				
	3,4	57	57	43	45	45	125426	131259	131259	14	12	12				
	total	322	330	270	272	272	2946435	3034606	3003948	52	50	58				
	1,2	86	86	82	86	86	854471	896153	896153	4	0	0	line 1to2	195	195	195
	1,3	76	76	51	46	42	698360	629893	575120	25	30	34	line2to3	195	195	195
	1,4	63	67	62	63	67	1018544	1034973	1050714	1	0	0	line3to4	125	130	134
2	2,3	36	36	30	30	30	188700	188700	188700	6	6	6	APLF	88.0%	88.9%	89.6%
	2,4	56	56	52	56	56	512635	552069	552069	4	0	0				
	3,4	11	11	11	11	11	41160	41160	41160	0	0	0				
	total	328	332	288	292	292	3313871	3342947	3303915	40	36	40				
	1,2	43	43	43	43	43	449221	449221	449221	0	0	0	line 1to2	188	195	195
	1,3	10	10	10	5	5	136778	68389	68389	0	5	5	line2to3	195	195	195
	1,4	180	193	135	147	147	2117632	2305866	2201180	45	33	46	line3to4	190	195	195
3	2,3	0	0	0	0	0	0	0	0	0	0	0	APLF	97.9%	100.0%	100.0%
	2,4	59	59	50	43	43	441469	379663	379663	9	16	16				
	3,4	5	5	5	5	5	17867	17867	17867	0	0	0				
	total	297	310	243	243	243	3162967	3221006	3116320	54	54	67				
	1,2	45	45	39	45	45	405885	468328	468328	6	0	0	line 1to2	195	195	195
	1,3	56	56	43	16	11	571092	212500	146093	13	40	45	line2to3	195	195	195
	1,4	134	143	113	134	139	1787337	2119497	2098767	21	0	4	line3to4	163	190	195
4	2,3	10	10	9	9	9	56610	56610	56610	1	1	1	APLF	94.5%	99.1%	100.0%
	2,4	36	36	30	36	36	288738	346486	346486	6	0	0				
	3,4	20	20	20	20	20	107000	107000	107000	0	0	0				
	total	301	310	254	260	260	3216663	3310421	3223285	47	41	50				
	1,2	50	50	42	36	36	440860	377880	377880	8	14	14	line 1to2	195	195	195
	1,3	73	73	51	33	24	691872	447682	325587	22	40	49	line2to3	189	195	195
	1,4	126	135	102	126	135	1637029	2022213	2068290	24	0	0	line3to4	134	158	167
5	2,3	11	11	11	11	11	69190	69190	69190	0	0	0	APLF	88.5%	93.7%	95.2%
	2,4	25	25	25	25	25	238340	238340	238340	0	0	0				
	3,4	7	7	7	7	7	31500	31500	31500	0	0	0				
	total	292	301	238	238	238	3108792	3186805	3110787	54	54	63				

Table 5.4: Comparing results of FCFS, optimization without and with discounted ticket

Train	OD	Demand		Number of accepted passenger (person)			Revenue (yen)			Number of passenger rejection (person)			Passenger load			
		w/o discount ticket	with discount ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket		FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket
6	1,2	53	53	33	48	52	347985	506160	548340	20	5	1	line 1to2	195	195	195
	1,3	67	67	58	0	0	797148	0	0	9	67	67	line2to3	195	195	195
	1,4	148	158	104	147	143	1668333	2358125	2189813	44	1	15	line3to4	140	195	191
	2,3	11	11	4	7	11	25160	44030	69190	7	4	0	APLF	90.6%	100.0%	99.3%
	2,4	41	41	29	41	41	271890	384396	384396	12	0	0				
	3,4	7	7	7	7	7	20560	20560	20560	0	0	0				
	total	327	337	235	250	254	3131076	3313271	3212299	92	77	83				
7	1,2	44	44	39	38	38	377004	367337	367337	5	6	6	line 1to2	195	195	195
	1,3	30	30	26	4	4	355714	54725	54725	4	26	26	line2to3	194	195	195
	1,4	173	185	130	153	153	2095330	2466042	2354084	43	20	32	line3to4	172	195	195
	2,3	2	2	2	2	2	16150	16150	16150	0	0	0	APLF	95.9%	100.0%	100.0%
	2,4	36	36	36	36	36	358634	358634	358634	0	0	0				
	3,4	6	6	6	6	6	17748	17748	17748	0	0	0				
	total	291	303	239	239	239	3220580	3280636	3168678	52	52	64				
8	1,2	25	25	25	25	25	264750	264750	264750	0	0	0	line 1to2	164	164	172
	1,3	24	24	24	24	24	332160	332160	332160	0	0	0	line2to3	184	184	192
	1,4	115	123	115	115	123	1910661	1910661	1950798	0	0	0	line3to4	175	175	183
	2,3	1	1	1	1	1	6290	6290	6290	0	0	0	APLF	89.4%	89.4%	93.5%
	2,4	44	44	44	44	44	426725	426725	426725	0	0	0				
	3,4	16	16	16	16	16	65157	65157	65157	0	0	0				
	total	225	233	225	225	233	3005743	3005743	3045880	0	0	0				
9	1,2	11	11	11	11	11	115450	115450	115450	0	0	0	line 1to2	133	133	141
	1,3	8	8	8	8	8	109260	109260	109260	0	0	0	line2to3	180	180	188
	1,4	114	122	114	114	122	1845536	1845536	1885380	0	0	0	line3to4	171	171	179
	2,3	7	7	7	7	7	44030	44030	44030	0	0	0	APLF	82.7%	82.7%	86.8%
	2,4	51	51	51	51	51	483164	483164	483164	0	0	0				
	3,4	6	6	6	6	6	27000	27000	27000	0	0	0				
	total	197	205	197	197	205	2624440	2624440	2664284	0	0	0				
10	1,2	37	37	37	37	37	381670	381670	381670	0	0	0	line 1to2	131	131	136
	1,3	24	24	24	24	24	327050	327050	327050	0	0	0	line2to3	154	154	159
	1,4	70	75	70	70	75	1149451	1149451	1175642	0	0	0	line3to4	138	138	143
	2,3	0	0	0	0	0	0	0	0	0	0	0	APLF	72.3%	72.3%	74.9%
	2,4	60	60	60	60	60	593420	593420	593420	0	0	0				
	3,4	8	8	8	8	8	33220	33220	33220	0	0	0				
	total	199	204	199	199	204	2484811	2484811	2511002	0	0	0				

Table 5.4: Comparing results of FCFS, optimization without and with discounted ticket (cont.)

Train	OD	Demand		Number of accepted passenger (person)			Revenue (yen)			Number of passenger rejection (person)			Passenger load			
		w/o discount ticket	with discount ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket	FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket		FCFS	Optimized w/o discounted ticket	Optimized with discounted ticket
11	1,2	37	37	37	37	37	386171	386171	386171	0	0	0	line 1to2	119	119	123
	1,3	21	21	21	21	21	284380	284380	284380	0	0	0	line2to3	140	140	144
	1,4	61	65	61	61	65	990904	990904	1007945	0	0	0	line3to4	118	118	122
	2,3	9	9	9	9	9	56610	0	0	0	0	0	APLF	64.4%	64.4%	66.5%
	2,4	49	49	49	49	49	471688	471688	471688	0	0	0				
	3,4	8	8	8	8	8	36000	36000	36000	0	0	0				
	total	185	189	185	185	189	2225753	2169143	2186183	0	0	0				
12	1,2	58	58	58	58	58	612580	612580	612580	0	0	0	line 1to2	189	189	195
	1,3	51	51	51	51	51	669460	669460	669460	0	0	0	line2to3	181	181	187
	1,4	80	86	80	80	86	1314674	1314674	1349112	0	0	0	line3to4	133	133	139
	2,3	5	5	5	5	5	29080	0	0	0	0	0	APLF	86.0%	86.0%	89.1%
	2,4	45	45	45	45	45	437778	437778	437778	0	0	0				
	3,4	8	8	8	8	8	28440	28440	28440	0	0	0				
	total	247	253	247	247	253	3092013	3062933	3097371	0	0	0				
13	1,2	89	89	89	81	75	934555	850550	787546	0	8	14	line 1to2	195	195	195
	1,3	35	35	30	35	35	411878	480524	480524	5	0	0	line2to3	124	132	138
	1,4	79	85	76	79	85	1245710	1294883	1329976	3	0	0	line3to4	98	101	107
	2,3	2	2	2	2	2	12580	0	0	0	0	0	APLF	71.3%	73.2%	75.2%
	2,4	16	16	16	16	16	152500	152500	152500	0	0	0				
	3,4	6	6	6	6	6	25610	25610	25610	0	0	0				
	total	227	233	219	219	219	2782833	2804067	2776156	8	8	14				
14	1,2	49	49	49	49	49	516830	516830	516830	0	0	0	line 1to2	137	137	142
	1,3	21	21	21	21	21	289910	289910	289910	0	0	0	line2to3	115	115	120
	1,4	67	72	67	67	72	1107419	1107419	1136033	0	0	0	line3to4	95	95	100
	2,3	0	0	0	0	0	0	0	0	0	0	0	APLF	59.3%	59.3%	61.9%
	2,4	27	27	27	27	27	258280	258280	258280	0	0	0				
	3,4	1	1	1	1	1	3110	3110	3110	0	0	0				
	total	165	170	165	165	170	2175549	2175549	2204163	0	0	0				

Table 5.4: Comparing results of FCFS, optimization without and with discounted ticket (cont.)

Chapter 6

Conclusion

This research showed that HS-rail company can gain the benefit of implementation RM which are: (1) increase passenger surplus, as the average ticket price become cheaper, (2) increase the utilization of existing facility, as the average passenger load factor increase, and (3) the total revenue improvement.

This research focused on using passenger behavior for forecasting in revenue management. We found that forecasting by using passenger behavior can improve the ability of traditional forecasting in revenue management, which mainly relies on time series analysis that has limited capability. In this research, we showed that forecasting by using passenger behavior can predict the share, revenue and time of purchase (how many days do passengers buy ticket prior departure) based on passenger choice model. Then, the firms can design the suitable price and restrictions combination of each ticket type.

As RP data was used in this research, transportation firms have plenty of RP data as in passenger purchasing records, which is beneficial for the firms to forecasting by using passenger behavior in real business world.

We also proved that seat allocation, one of revenue management methods, can improve not only revenue of railways company, but also average passenger load factor and number of request rejection. The improvement can help railways company, which is monopoly in many countries, to maintain/increase goodwill of passengers and society when introducing revenue management. Moreover, we proved that seat allocation control and passenger behavior model can be combined together.

6.1 Further research

The future study should include the effect of the rejection of passenger request on future revenue. Base on passenger behavior aspect, a rejection of passenger request may result the reduction number of use in the future (also reduction of future revenue) because of the bad impression, as his/her request for a seat is rejected. The future revenue may relate to the number of passenger rejection; as the higher number of passenger rejection, the lower number of future revenue. Therefore, the present revenue, as in chapter 4 and 5, is not the whole index in revenue aspect. The overall revenue, which compose of present revenue and future revenue, should be considered in future research.

Furthermore, overbooking issues and competition with shorter OD, such as highway bus, should be included in RM of single-line multiple-stop systems.

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Appendix 1

Simulation results from August 2nd to August 31st

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	90.80%	2,856	71	98.12%	3,096	71	98.12%	3,096	71	95.56%	3,051	71
change	–	–	–	7.32%	240	0	7.32%	240	0	4.76%	195	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 2	86.00%	3,284	75	88.03%	3,328	74	88.03%	3,328	74	88.03%	3,328	74
change	–	–	–	2.03%	44	−1	2.03%	44	−1	2.03%	44	−1
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	98.30%	3,261	67	100.00%	3,170	102	100.00%	3,314	60	99.49%	3,304	60
change	–	–	–	1.70%	−91	35	1.70%	53	−7	1.19%	43	−7
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 4	88.20%	3,068	144	97.78%	3,258	138	97.78%	3,258	138	97.78%	3,288	129
change	–	–	–	9.58%	190	−6	9.58%	190	−6	9.58%	220	−15
optimized	–	–	–	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 5	90.60%	3,163	71	95.56%	3,245	71	95.56%	3,245	71	85.81%	3,085	71
change	–	–	–	7.52%	190	−11	7.52%	190	−11	−2.22%	29	−11
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	96.20%	3,328	54	100.00%	3,413	50	100.00%	3,420	47	95.21%	3,315	47
change	–	–	–	3.80%	85	−4	3.80%	92	−7	−0.99%	−13	−7
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 7	92.50%	3,238	78	98.80%	3,335	77	98.80%	3,335	77	89.06%	3,194	76
change	–	–	–	6.30%	97	−1	6.30%	97	−1	−3.44%	−44	−2
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 8	96.60%	3,288	24	100.00%	3,356	24	100.00%	3,356	24	100.00%	3,356	24
change	–	–	–	3.40%	68	0	3.40%	68	0	3.40%	68	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	95.20%	3,263	15	95.73%	3,273	15	95.73%	3,273	15	95.57%	3,217	15
change	–	–	–	0.53%	10	0	0.53%	10	0	0.37%	−46	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 10	85.81%	3,040	0	85.81%	3,040	0	85.81%	3,040	0	85.81%	3,040	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	92.99%	3,275	0	92.99%	3,275	0	92.99%	3,275	0	92.99%	3,275	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	83.60%	3,088	8	86.15%	3,132	8	86.15%	3,132	8	86.15%	3,132	8
change	–	–	–	2.55%	44	0	2.55%	44	0	2.55%	44	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	88.00%	3,164	18	92.14%	3,234	18	92.14%	3,234	18	89.27%	3,180	18
change	–	–	–	4.14%	70	0	4.14%	70	0	1.27%	16	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	71.10%	2,813	10	71.97%	2,829	10	71.97%	2,829	10	68.55%	2,769	10
change	–	–	–	0.87%	16	0	0.87%	16	0	−2.55%	−44	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA1-1: Result of optimization on August 2nd

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	92.30%	3,280	234	100.00%	3,388	234	100.00%	3,388	234	76.92%	2,645	234
change	–	–	–	7.70%	108	0	7.70%	108	0	−15.38%	−635	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 2	92.80%	3,379	590	100.00%	3,385	623	100.00%	3,497	585	96.75%	3,728	507
change	–	–	–	7.20%	6	33	7.20%	118	−5	3.95%	349	−83
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 3	89.60%	3,145	640	100.00%	3,423	611	100.00%	3,411	611	97.35%	3,358	611
change	–	–	–	10.40%	278	−29	10.40%	266	−29	7.75%	213	−29
optimized	–	–	–	optimized	optimized	optimized	optimized	no	optimized	no	no	optimized
train 4	85.10%	3,066	392	100.00%	3,229	421	97.61%	3,381	358	73.40%	3,018	358
change	–	–	–	14.90%	163	29	12.51%	315	−34	−11.70%	−48	−34
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 5	88.90%	3,133	772	100.00%	3,220	795	100.00%	3,264	795	77.61%	3,161	710
change	–	–	–	11.10%	87	23	11.10%	131	23	−11.29%	28	−62
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 6	87.40%	3,162	594	100.00%	3,420	578	97.09%	3,429	561	97.09%	3,429	561
change	–	–	–	12.60%	258	−16	9.69%	267	−33	9.69%	267	−33
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	optimized	optimized
train 7	93.00%	3,215	161	100.00%	3,212	188	100.00%	3,387	144	94.99%	3,210	138
change	–	–	–	7.00%	−3	27	7.00%	172	−17	1.99%	−5	−23
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 8	99.10%	3,372	43	100.00%	3,402	38	100.00%	3,350	53	100.00%	3,407	38
change	–	–	–	0.90%	30	−5	0.90%	−22	10	0.90%	35	−5
optimized	–	–	–	optimized	no	optimized	optimized	no	no	optimized	optimized	optimized
train 9	100.00%	3,273	42	100.00%	3,233	72	100.00%	3,273	42	100.00%	3,273	42
change	–	–	–	0.00%	−40	30	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 10	99.00%	3,446	23	100.00%	3,442	28	100.00%	3,468	23	100.00%	3,461	23
change	–	–	–	1.00%	−4	5	1.00%	22	0	1.00%	15	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	optimized	no	optimized
train 11	98.80%	3,431	23	100.00%	3,446	32	100.00%	3,453	23	99.14%	3,438	23
change	–	–	–	1.20%	15	9	1.20%	22	0	0.34%	7	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 12	94.90%	3,338	51	99.66%	3,454	44	99.66%	3,436	51	89.74%	3,272	44
change	–	–	–	4.76%	116	−7	4.76%	98	0	−5.16%	−66	−7
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 13	99.30%	3,395	133	100.00%	3,246	185	99.32%	3,450	118	100.00%	3,461	118
change	–	–	–	0.70%	−149	52	0.02%	55	−15	0.70%	66	−15
optimized	–	–	–	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 14	87.20%	3,132	38	92.14%	3,221	38	92.14%	3,221	38	84.44%	3,079	38
change	–	–	–	4.94%	89	0	4.94%	89	0	−2.76%	−53	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA!-2: Result of optimization on August 3rd

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	94.36%	3,262	221	100.00%	3,323	246	100.00%	3,323	246	98.29%	3,317	215
change	−	−	−	5.64%	61	25	5.64%	61	25	3.93%	55	−6
optimized	−	−	−	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 2	94.02%	3,334	602	100.00%	3,677	542	100.00%	3,667	539	81.20%	3,334	539
change	−	−	−	5.98%	343	−60	5.98%	333	−63	−12.82%	0	−63
optimized	−	−	−	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 3	100.00%	3,261	1,149	100.00%	3,183	1,179	92.65%	3,085	1,129	85.13%	2,831	1,086
change	−	−	−	0.00%	−78	30	−7.35%	−176	−20	−14.87%	−430	−63
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized
train 4	96.92%	3,352	1,990	100.00%	3,321	2,051	97.09%	3,565	1,927	84.44%	3,384	1,927
change	−	−	−	3.08%	−31	61	0.17%	213	−63	−12.48%	32	−63
optimized	−	−	−	optimized	no	no	no	optimized	optimized	no	no	optimized
train 5	98.97%	3,383	99	100.00%	3,189	1,256	100.00%	3,506	1,126	82.56%	2,946	1,098
change	−	−	−	1.03%	−194	1,157	1.03%	123	1,027	−16.41%	−437	999
optimized	−	−	−	optimized	no	no	optimized	optimized	no	no	no	optimized
train 6	92.31%	3,277	1,282	100.00%	3,644	1,212	100.00%	3,647	1,210	99.66%	3,640	1,210
change	−	−	−	7.69%	367	−70	7.69%	370	−72	7.35%	363	−72
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 7	90.94%	3,180	585	100.00%	3,257	607	84.44%	3,171	556	79.32%	3,019	556
change	−	−	−	9.06%	77	22	−6.50%	−9	−29	−11.62%	−161	−29
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 8	100.00%	3,476	177	100.00%	3,335	207	100.00%	3,523	156	98.46%	3,499	156
change	−	−	−	0.00%	−141	30	0.00%	47	−21	−1.54%	23	−21
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 9	100.00%	3,318	158	100.00%	3,354	164	100.00%	3,384	149	100.00%	3,408	137
change	−	−	−	0.00%	36	6	0.00%	66	−9	0.00%	90	−21
optimized	−	−	−	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 10	99.49%	3,406	116	100.00%	3,275	160	100.00%	3,434	122	100.00%	3,484	89
change	−	−	−	0.51%	−131	44	0.51%	28	6	0.51%	78	−27
optimized	−	−	−	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 11	99.49%	3,405	118	100.00%	3,264	156	100.00%	3,468	114	98.80%	3,527	83
change	−	−	−	0.51%	−141	38	0.51%	63	−4	−0.69%	122	−35
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 12	97.09%	3,441	114	100.00%	3,451	127	100.00%	3,558	99	90.60%	3,295	99
change	−	−	−	2.91%	10	13	2.91%	117	−15	−6.49%	−146	−15
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 13	100.00%	3,532	256	100.00%	3,206	355	100.00%	3,594	249	100.00%	3,627	227
change	−	−	−	0.00%	−326	99	0.00%	62	−7	0.00%	95	−29
optimized	−	−	−	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 14	86.67%	3,115	122	97.26%	3,305	122	94.19%	3,245	122	94.19%	3,245	122
change	−	−	−	10.59%	190	0	7.52%	130	0	7.52%	130	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	no	no	optimized

TableA1-3: Result of optimization on August 4th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	87.52%	2,820	72	94.70%	3,035	50	94.70%	3,035	50	84.10%	2,620	50
change	–	–	–	7.18%	215	−22	7.18%	215	−22	−3.42%	−200	−22
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 2	83.25%	3,138	56	88.89%	3,343	36	88.89%	3,343	36	87.86%	3,299	36
change	–	–	–	5.64%	205	−20	5.64%	205	−20	4.62%	161	−20
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	95.04%	3,062	64	100.00%	3,221	54	99.15%	3,211	54	99.15%	3,211	54
change	–	–	–	4.96%	159	−10	4.10%	149	−10	4.10%	149	−10
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 4	90.77%	3,085	61	99.15%	3,310	41	99.15%	3,310	41	97.75%	3,285	41
change	–	–	–	8.38%	225	−20	8.38%	225	−20	6.98%	200	−20
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 5	85.98%	3,006	65	93.68%	3,187	54	93.68%	3,187	54	86.84%	3,087	54
change	–	–	–	7.69%	181	−11	7.69%	181	−11	0.85%	81	−11
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	88.55%	3,055	98	100.00%	3,313	77	89.74%	3,154	84	98.97%	3,311	73
change	–	–	–	11.45%	259	−21	1.20%	99	−14	10.43%	256	−25
optimized	–	–	–	optimized	optimized	no	no	no	no	no	no	optimized
train 7	93.68%	3,137	60	100.00%	3,220	74	100.00%	3,281	52	93.50%	3,179	52
change	–	–	–	6.32%	83	14	6.32%	143	−8	−0.17%	41	−8
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	79.83%	2,693	26	89.40%	3,006	0	89.40%	3,006	0	89.40%	3,006	0
change	–	–	–	9.57%	313	−26	9.57%	313	−26	9.57%	313	−26
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	77.09%	2,457	16	82.74%	2,624	0	82.74%	2,624	0	82.74%	2,624	0
change	–	–	–	5.64%	167	−16	5.64%	167	−16	5.64%	167	−16
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	71.79%	2,468	1	72.31%	2,485	0	72.31%	2,485	0	72.31%	2,485	0
change	–	–	–	0.51%	16	−1	0.51%	16	−1	0.51%	16	−1
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	61.37%	2,120	10	64.44%	2,169	0	64.44%	2,169	0	64.44%	2,169	0
change	–	–	–	3.08%	49	−10	3.08%	49	−10	3.08%	49	−10
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	77.44%	2,800	20	85.98%	3,063	0	85.98%	3,063	0	85.98%	3,063	0
change	–	–	–	8.55%	263	−20	8.55%	263	−20	8.55%	263	−20
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	68.89%	2,658	19	73.16%	2,804	8	73.16%	2,804	8	71.79%	2,778	8
change	–	–	–	4.27%	146	−11	4.27%	146	−11	2.91%	121	−11
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	58.80%	2,159	1	59.32%	2,176	0	59.32%	2,176	0	59.32%	2,176	0
change	–	–	–	0.51%	17	−1	0.51%	17	−1	0.51%	17	−1
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-4: Result of optimization on August 5th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	89.06%	3,113	145	99.15%	3,255	149	99.15%	3,267	145	98.12%	3,223	145
change	–	–	–	10.09%	142	4	10.09%	154	0	9.06%	110	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 2	92.99%	3,277	110	99.83%	3,401	107	99.49%	3,398	107	99.83%	3,401	107
change	–	–	–	6.84%	124	−3	6.50%	121	−3	6.84%	124	−3
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	optimized	optimized	optimized
train 3	96.24%	3,211	312	100.00%	3,150	345	98.46%	3,284	301	99.78%	3,312	299
change	–	–	–	3.76%	−61	33	2.22%	73	−11	3.54%	101	−13
optimized	–	–	–	optimized	no	no	no	no	no	no	optimized	optimized
train 4	98.29%	3,337	612	100.00%	3,432	591	97.61%	3,337	605	88.38%	2,980	591
change	–	–	–	1.71%	95	−21	−0.68%	0	−7	−9.91%	−357	−21
optimized	–	–	–	optimized	optimized	optimized	no	no	no	no	no	optimized
train 5	92.65%	3,242	453	100.00%	3,153	521	99.15%	3,468	418	100.00%	3,484	418
change	–	–	–	7.35%	−89	68	6.50%	226	−35	7.35%	242	−35
optimized	–	–	–	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 6	89.91%	3,088	1,017	100.00%	3,268	1,009	100.00%	3,422	974	82.22%	2,730	974
change	–	–	–	10.09%	180	−8	10.09%	334	−43	−7.69%	−358	−43
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 7	99.49%	3,328	313	100.00%	3,304	342	95.04%	3,399	294	83.25%	2,864	294
change	–	–	–	0.51%	−24	29	−4.45%	71	−19	−16.24%	−464	−19
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 8	100.00%	3,565	247	100.00%	3,292	332	100.00%	3,594	230	98.46%	3,544	230
change	–	–	–	0.00%	−273	85	0.00%	29	−17	−1.54%	−21	−17
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 9	100.00%	3,349	139	100.00%	3,190	191	100.00%	3,346	144	94.70%	3,182	125
change	–	–	–	0.00%	−159	52	0.00%	−3	5	−5.30%	−167	−14
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 10	100.00%	3,421	201	100.00%	3,242	238	100.00%	3,498	197	88.72%	3,137	138
change	–	–	–	0.00%	−179	37	0.00%	77	−4	−11.28%	−284	−63
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 11	100.00%	3,355	229	100.00%	3,567	187	100.00%	3,516	209	96.07%	3,427	174
change	–	–	–	0.00%	212	−42	0.00%	161	−20	−3.93%	72	−55
optimized	–	–	–	optimized	optimized	no	optimized	no	no	no	no	optimized
train 12	100.00%	3,407	172	100.00%	3,276	202	100.00%	3,340	209	100.00%	3,511	133
change	–	–	–	0.00%	−131	30	0.00%	−67	37	0.00%	104	−39
optimized	–	–	–	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 13	96.41%	3,316	174	100.00%	3,200	231	99.32%	3,427	154	84.96%	3,206	154
change	–	–	–	3.59%	−116	57	2.91%	111	−20	−11.45%	−110	−20
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 14	89.74%	3,153	81	99.32%	3,315	83	97.26%	3,283	81	87.58%	3,117	81
change	–	–	–	9.58%	162	2	7.52%	130	0	−2.16%	−36	0
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized

TableA1-5: Result of optimization on August 6th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	98.80%	3,337	121	100.00%	3,397	114	100.00%	3,269	147	94.41%	3,322	107
change	−	−	−	1.20%	60	−7	1.20%	−68	26	−4.39%	−15	−14
optimized	−	−	−	optimized	optimized	no	optimized	no	no	no	no	optimized
train 2	99.32%	3,502	149	100.00%	3,580	134	100.00%	3,555	139	99.66%	3,574	134
change	−	−	−	0.68%	78	−15	0.68%	52	−10	0.34%	72	−15
optimized	−	−	−	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 3	100.00%	3,259	218	100.00%	3,316	216	100.00%	3,317	214	90.09%	3,013	177
change	−	−	−	0.00%	57	−2	0.00%	58	−4	−9.91%	−246	−41
optimized	−	−	−	optimized	no	no	optimized	optimized	no	no	no	optimized
train 4	100.00%	3,424	13,483	100.00%	3,418	13,500	94.36%	3,289	13,486	86.67%	2,957	13,453
change	−	−	−	0.00%	−6	17	−5.64%	−135	3	−13.33%	−467	−30
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized
train 5	99.49%	3,391	210	100.00%	3,452	204	95.90%	3,435	180	97.83%	3,460	180
change	−	−	−	0.51%	61	−6	−3.59%	44	−30	−1.65%	69	−30
optimized	−	−	−	optimized	no	no	no	no	optimized	no	optimized	optimized
train 6	98.46%	3,340	222	100.00%	3,225	284	94.36%	3,361	199	88.55%	3,259	199
change	−	−	−	1.54%	−115	62	−4.10%	21	−23	−9.91%	−81	−23
optimized	−	−	−	optimized	no	no	no	optimized	optimized	no	no	optimized
train 7	95.90%	3,241	183	100.00%	3,227	219	100.00%	3,213	219	99.67%	3,480	145
change	−	−	−	4.10%	−14	36	4.10%	−28	36	3.78%	239	−38
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 8	99.83%	3,434	82	100.00%	3,325	110	100.00%	3,424	98	100.00%	3,444	78
change	−	−	−	0.17%	−109	28	0.17%	−10	16	0.17%	10	−4
optimized	−	−	−	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 9	99.83%	3,332	83	100.00%	3,347	80	100.00%	3,313	101	100.00%	3,344	80
change	−	−	−	0.17%	15	−3	0.17%	−19	18	0.17%	13	−3
optimized	−	−	−	optimized	optimized	optimized	optimized	no	no	optimized	no	optimized
train 10	97.61%	3,339	91	100.00%	3,259	116	100.00%	3,395	87	95.38%	3,350	78
change	−	−	−	2.39%	−80	25	2.39%	57	−4	−2.22%	11	−13
optimized	−	−	−	optimized	no	no	optimized	optimized	no	no	no	optimized
train 11	95.73%	3,266	48	100.00%	3,374	44	100.00%	3,380	43	92.82%	3,195	43
change	−	−	−	4.27%	108	−4	4.27%	114	−5	−2.91%	−71	−5
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 12	91.45%	3,232	82	97.26%	3,345	82	97.26%	3,345	82	86.15%	3,130	82
change	−	−	−	5.81%	113	0	5.81%	113	0	−5.30%	−102	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 13	100.00%	3,390	65	100.00%	3,396	73	100.00%	3,396	73	97.26%	3,341	58
change	−	−	−	0.00%	7	8	0.00%	7	8	−2.74%	−48	−7
optimized	−	−	−	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 14	85.81%	3,126	0	85.81%	3,126	0	85.81%	3,126	0	85.81%	3,126	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-6: Result of optimization on August 7th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	90.94%	3,303	99	100.00%	3,384	121	98.12%	3,428	98	89.89%	3,291	98
change	−	−	−	9.06%	81	22	7.18%	124	−1	−1.05%	−13	−1
optimized	−	−	−	optimized	no	no	no	optimized	optimized	no	no	optimized
train 2	87.86%	3,150	346	98.12%	3,346	338	98.12%	3,390	323	60.87%	2,585	323
change	−	−	−	10.26%	196	−8	10.26%	241	−23	−27.00%	−564	−23
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 3	94.70%	3,130	113	100.00%	3,138	134	100.00%	3,104	138	99.83%	3,287	92
change	−	−	−	5.30%	9	21	5.30%	−25	25	5.13%	158	−21
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 4	88.72%	3,112	183	100.00%	3,270	192	100.00%	3,308	176	106.17%	3,443	169
change	−	−	−	11.28%	158	9	11.28%	196	−7	17.46%	331	−14
optimized	−	−	−	no	no	no	no	no	no	optimized	optimized	optimized
train 5	100.00%	3,377	149	100.00%	3,484	119	100.00%	3,253	176	94.70%	3,350	112
change	−	−	−	0.00%	107	−30	0.00%	−124	27	−5.30%	−27	−37
optimized	−	−	−	optimized	optimized	no	optimized	no	no	no	no	optimized
train 6	100.00%	3,354	160	100.00%	3,391	162	100.00%	3,392	156	99.11%	3,394	145
change	−	−	−	0.00%	37	2	0.00%	39	−4	−0.89%	41	−15
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 7	99.49%	3,337	147	100.00%	3,438	113	100.00%	3,418	143	93.33%	3,203	108
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	optimized	no	optimized	no	no	no	no	optimized
train 8	100.00%	3,419	73	100.00%	3,326	89	100.00%	3,391	95	99.66%	3,429	55
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 9	100.00%	3,280	96	100.00%	3,300	94	100.00%	3,300	94	99.15%	3,276	87
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 10	99.83%	3,413	62	100.00%	3,344	89	100.00%	3,443	62	98.80%	3,411	52
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	no	no	optimized	optimized	no	no	no	optimized
train 11	96.58%	3,234	49	100.00%	3,450	52	100.00%	3,483	44	99.10%	3,470	44
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 12	89.40%	3,238	34	92.82%	3,290	36	92.82%	3,297	34	92.82%	3,297	34
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 13	86.67%	3,157	36	89.74%	3,217	34	89.74%	3,217	34	78.12%	3,020	34
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	87.52%	3,134	8	89.91%	3,177	8	89.91%	3,177	8	88.55%	3,151	8
change	−	−	−	12.65%	236	−5	12.65%	248	−9	11.62%	204	−9
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA1-7: Result of optimization on August 8th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	93.68%	3,063	70	100.00%	3,288	77	100.00%	3,288	77	100.00%	3,294	70
change	–	–	–	6.32%	225	7	6.32%	225	7	6.32%	230	0
optimized	–	–	–	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 2	95.38%	3,296	87	100.00%	3,426	76	100.00%	3,381	88	92.31%	3,127	76
change	–	–	–	4.62%	130	−11	4.62%	85	1	−3.08%	−169	−11
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 3	99.32%	3,218	156	100.00%	3,275	159	99.83%	3,277	145	96.06%	3,129	145
change	–	–	–	0.68%	57	3	0.51%	59	−11	−3.25%	−89	−11
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 4	91.97%	3,134	119	100.00%	3,165	143	100.00%	3,243	123	92.48%	3,155	101
change	–	–	–	8.03%	30	24	8.03%	109	4	0.52%	20	−18
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 5	92.99%	3,116	169	100.00%	3,259	185	100.00%	3,196	185	99.83%	3,401	134
change	–	–	–	7.01%	143	16	7.01%	80	16	6.84%	285	−35
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 6	100.00%	3,290	168	100.00%	3,338	165	100.00%	3,176	210	90.26%	3,163	139
change	–	–	–	0.00%	48	−3	0.00%	−114	42	−9.74%	−127	−29
optimized	–	–	–	optimized	optimized	no	optimized	no	no	no	no	optimized
train 7	100.00%	3,251	137	100.00%	3,290	150	100.00%	3,174	186	88.38%	2,939	127
change	–	–	–	0.00%	39	13	0.00%	−77	49	−11.62%	−312	−10
optimized	–	–	–	optimized	optimized	no	optimized	no	no	no	no	optimized
train 8	100.00%	3,369	102	100.00%	3,246	132	100.00%	3,259	139	97.32%	3,384	85
change	–	–	–	0.00%	−123	30	0.00%	−110	37	−2.68%	16	−17
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 9	100.00%	3,272	172	100.00%	3,292	164	100.00%	3,292	164	100.00%	3,292	164
change	–	–	–	0.00%	20	−8	0.00%	20	−8	0.00%	20	−8
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	100.00%	3,373	123	100.00%	3,406	110	100.00%	3,369	129	100.00%	3,406	110
change	–	–	–	0.00%	34	−13	0.00%	−4	6	0.00%	34	−13
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	optimized	optimized	optimized
train 11	100.00%	3,381	58	100.00%	3,301	91	100.00%	3,379	70	100.00%	3,422	46
change	–	–	–	0.00%	−79	33	0.00%	−1	12	0.00%	41	−12
optimized	–	–	–	optimized	no	no	optimized	no	no	optimized	optimized	optimized
train 12	94.53%	3,259	165	100.00%	3,405	154	100.00%	3,290	186	69.91%	2,879	148
change	–	–	–	5.47%	147	−11	5.47%	31	21	−24.62%	−380	−17
optimized	–	–	–	optimized	optimized	no	optimized	no	no	no	no	optimized
train 13	97.44%	3,352	189	100.00%	3,326	207	95.56%	3,440	139	94.87%	3,428	139
change	–	–	–	2.56%	−26	18	−1.88%	88	−50	−2.56%	76	−50
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 14	80.68%	2,951	43	90.09%	3,115	43	90.09%	3,115	43	90.09%	3,115	43
change	–	–	–	9.40%	164	0	9.40%	164	0	9.40%	164	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-8: Result of optimization on August 9th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	100.00%	3,275	155	100.00%	3,208	180	100.00%	3,208	180	94.36%	3,201	147
change	–	–	–	0.00%	−67	25	0.00%	−67	25	−5.64%	−74	−8
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 2	92.31%	3,290	397	100.00%	3,485	383	95.73%	3,383	383	81.37%	3,024	383
change	–	–	–	7.69%	195	−14	3.42%	93	−14	−10.94%	−266	−14
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 3	100.00%	3,211	406	100.00%	3,177	410	100.00%	3,295	396	99.15%	3,353	366
change	–	–	–	0.00%	−34	4	0.00%	84	−10	−0.85%	142	−40
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 4	100.00%	3,279	654	100.00%	3,390	617	99.66%	3,384	617	81.54%	3,102	617
change	–	–	–	0.00%	111	−37	−0.34%	105	−37	−18.46%	−178	−37
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 5	100.00%	3,352	1,031	100.00%	3,389	1,037	89.57%	3,309	987	61.03%	2,809	987
change	–	–	–	0.00%	37	6	−10.43%	−43	−44	−38.97%	−543	−44
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 6	100.00%	3,270	667	100.00%	3,221	655	100.00%	3,388	637	97.53%	3,325	587
change	–	–	–	0.00%	−50	−12	0.00%	117	−30	−2.47%	55	−80
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 7	100.00%	3,248	339	100.00%	3,421	301	100.00%	3,422	296	98.12%	3,352	296
change	–	–	–	0.00%	173	−38	0.00%	174	−43	−1.88%	105	−43
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	100.00%	3,412	466	100.00%	3,510	431	98.97%	3,470	431	79.32%	2,778	410
change	–	–	–	0.00%	98	−35	−1.03%	58	−35	−20.68%	−634	−56
optimized	–	–	–	optimized	optimized	no	no	no	no	no	no	optimized
train 9	100.00%	3,281	1,535	100.00%	3,254	1,520	94.53%	3,189	1,520	90.77%	3,011	1,520
change	–	–	–	0.00%	−27	−15	−5.47%	−92	−15	−9.23%	−270	−15
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 10	100.00%	3,323	557	100.00%	3,206	582	100.00%	3,395	531	92.14%	3,244	531
change	–	–	–	0.00%	−116	25	0.00%	72	−26	−7.86%	−79	−26
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 11	100.00%	3,297	117	100.00%	3,181	158	100.00%	3,181	158	93.50%	3,134	98
change	–	–	–	0.00%	−116	41	0.00%	−116	41	−6.50%	−163	−19
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 12	100.00%	3,321	223	100.00%	3,406	213	100.00%	3,199	264	98.46%	3,408	168
change	–	–	–	0.00%	85	−10	0.00%	−122	41	−1.54%	87	−55
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 13	100.00%	3,393	235	100.00%	3,271	258	100.00%	3,412	241	97.44%	3,447	197
change	–	–	–	0.00%	−122	23	0.00%	19	6	−2.56%	54	−38
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 14	90.60%	3,114	102	100.00%	3,268	103	100.00%	3,268	103	99.83%	3,268	102
change	–	–	–	9.40%	154	1	9.40%	154	1	9.23%	154	0
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized

TableA1-9: Result of optimization on August 10th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	98.29%	3,278	224	100.00%	3,172	273	100.00%	3,335	216	94.04%	3,181	216
change	−	−	−	1.71%	−107	49	1.71%	57	−8	−4.26%	−98	−8
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 2	95.73%	3,274	1,053	100.00%	3,380	1,053	89.91%	3,255	1,031	89.91%	3,255	1,031
change	−	−	−	4.27%	106	0	−5.81%	−18	−22	−5.81%	−18	−22
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 3	98.46%	3,233	1,602	100.00%	3,276	1,609	80.00%	2,826	1,591	100.00%	3,293	1,591
change	−	−	−	1.54%	43	7	−18.46%	−406	−11	1.54%	60	−11
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 4	100.00%	3,246	1,829	100.00%	3,236	1,843	85.98%	3,125	1,800	100.00%	3,325	1,800
change	−	−	−	0.00%	−10	14	−14.02%	−121	−29	0.00%	79	−29
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 5	99.66%	3,300	1,615	100.00%	3,172	1,667	87.01%	3,201	1,586	82.22%	3,061	1,586
change	−	−	−	0.34%	−128	52	−12.65%	−99	−29	−17.44%	−239	−29
optimized	−	−	−	optimized	no	no	no	optimized	optimized	no	no	optimized
train 6	100.00%	3,267	2,187	100.00%	3,426	2,155	87.35%	3,253	2,136	87.35%	3,253	2,136
change	−	−	−	0.00%	159	−32	−12.65%	−14	−51	−12.65%	−14	−51
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 7	100.00%	3,292	1,801	100.00%	3,176	1,852	84.10%	2,876	1,774	90.89%	3,130	1,774
change	−	−	−	0.00%	−116	51	−15.90%	−417	−27	−9.11%	−162	−27
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 8	100.00%	3,416	1,151	100.00%	3,460	1,153	87.35%	3,002	1,123	86.15%	2,949	1,123
change	−	−	−	0.00%	45	2	−12.65%	−414	−28	−13.85%	−467	−28
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 9	100.00%	3,329	1,480	100.00%	3,451	1,465	100.00%	3,487	1,421	100.00%	3,487	1,421
change	−	−	−	0.00%	122	−15	0.00%	158	−59	0.00%	158	−59
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 10	100.00%	3,311	812	100.00%	3,354	808	88.21%	3,142	778	93.68%	3,164	778
change	−	−	−	0.00%	43	−4	−11.79%	−169	−34	−6.32%	−147	−34
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 11	100.00%	3,288	525	100.00%	3,183	592	96.75%	3,426	471	100.00%	3,492	471
change	−	−	−	0.00%	−105	67	−3.25%	138	−54	0.00%	204	−54
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 12	100.00%	3,405	898	100.00%	3,260	932	89.74%	3,395	843	100.00%	3,579	843
change	−	−	−	0.00%	−146	34	−10.26%	−11	−55	0.00%	174	−55
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 13	100.00%	3,375	1,262	100.00%	3,827	1,150	98.12%	3,795	1,135	100.00%	3,831	1,135
change	−	−	−	0.00%	453	−112	−1.88%	420	−127	0.00%	457	−127
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 14	95.73%	3,297	1,145	100.00%	3,543	1,105	84.96%	3,337	1,089	97.61%	3,517	1,087
change	−	−	−	4.27%	246	−40	−10.77%	40	−56	1.88%	220	−58
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized

TableA1-10: Result of optimization on August 11th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	100.00%	3,259	2,925	100.00%	3,390	2,875	87.86%	2,899	2,875	80.85%	3,113	2,875
change	–	–	–	0.00%	131	-50	-12.14%	-360	-50	-19.15%	-146	-50
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 2	100.00%	3,343	3,742	100.00%	3,471	3,690	78.80%	2,956	3,690	91.97%	3,160	3,690
change	–	–	–	0.00%	128	-52	-21.20%	-388	-52	-8.03%	-184	-52
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 3	100.00%	3,231	7,338	100.00%	3,059	7,250	90.77%	3,296	7,244	100.00%	3,433	7,244
change	–	–	–	0.00%	-173	-88	-9.23%	65	-94	0.00%	202	-94
optimized	–	–	–	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 4	100.00%	3,272	11,309	100.00%	3,172	11,182	86.15%	2,587	11,182	100.00%	3,232	11,116
change	–	–	–	0.00%	-100	-127	-13.85%	-685	-127	0.00%	-40	-193
optimized	–	–	–	optimized	no	no	no	no	no	optimized	optimized	optimized
train 5	100.00%	3,277	11,956	100.00%	3,676	11,815	98.80%	3,580	11,792	98.80%	3,580	11,792
change	–	–	–	0.00%	398	-141	-1.20%	302	-164	-1.20%	302	-164
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 6	100.00%	3,240	11,844	100.00%	3,240	11,669	94.02%	3,471	11,669	100.00%	3,240	11,669
change	–	–	–	0.00%	0	-175	-5.98%	230	-175	0.00%	0	-175
optimized	–	–	–	optimized	no	optimized	no	optimized	optimized	optimized	no	optimized
train 7	100.00%	3,270	12,741	100.00%	3,588	12,588	98.29%	3,457	12,588	99.83%	3,583	12,588
change	–	–	–	0.00%	318	-153	-1.71%	188	-153	-0.17%	313	-153
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 8	100.00%	3,338	8,241	100.00%	3,227	8,285	100.00%	3,381	8,241	2014.12%	59,195	2,209
change	–	–	–	0.00%	-111	44	0.00%	44	0	1914.12%	55,858	-6,032
optimized	–	–	–	no	no	no	no	no	no	optimized	optimized	optimized
train 9	100.00%	3,272	10,395	100.00%	3,322	10,404	84.44%	2,872	10,326	0.00%	0	10,642
change	–	–	–	0.00%	50	9	-15.56%	-400	-69	-100.00%	-3,272	247
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	no
train 10	100.00%	3,300	3,249	100.00%	3,558	3,116	81.88%	2,712	3,203	97.44%	3,549	3,116
change	–	–	–	0.00%	258	-133	-18.12%	-588	-46	-2.56%	249	-133
optimized	–	–	–	optimized	optimized	optimized	no	no	no	no	no	optimized
train 11	100.00%	3,313	1,303	100.00%	3,166	1,356	97.44%	3,256	1,282	98.12%	3,309	1,282
change	–	–	–	0.00%	-147	53	-2.56%	-57	-21	-1.88%	-4	-21
optimized	–	–	–	optimized	no	no	no	no	optimized	no	optimized	optimized
train 12	98.80%	3,261	2,233	100.00%	3,280	2,238	83.76%	3,020	2,217	100.00%	3,310	2,217
change	–	–	–	1.20%	19	5	-15.04%	-241	-16	1.20%	48	-16
optimized	–	–	–	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 13	99.49%	3,264	689	100.00%	3,345	678	92.48%	3,217	655	99.66%	3,322	655
change	–	–	–	0.51%	81	-11	-7.01%	-47	-34	0.17%	58	-34
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 14	96.41%	3,262	435	100.00%	3,378	422	85.64%	3,161	416	100.00%	3,389	416
change	–	–	–	3.59%	116	-13	-10.77%	-101	-19	3.59%	127	-19
optimized	–	–	–	optimized	no	no	no	no	optimized	optimized	optimized	optimized

TableA1-11: Result of optimization on August 12th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	100.00%	3,251	1,901	100.00%	3,109	1,903	94.70%	3,252	1,868	92.32%	3,260	1,730
change	−	−	−	0.00%	−142	2	−5.30%	1	−33	−7.68%	9	−171
optimized	−	−	−	optimized	no	no	no	no	no	no	optimized	optimized
train 2	96.92%	3,273	1,814	100.00%	3,167	1,872	95.56%	3,001	1,805	97.78%	3,038	1,805
change	−	−	−	3.08%	−106	58	−1.37%	−272	−9	0.85%	−235	−9
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 3	100.00%	3,219	4,893	100.00%	3,193	4,885	81.20%	2,758	4,855	83.25%	2,401	4,855
change	−	−	−	0.00%	−26	−8	−18.80%	−461	−38	−16.75%	−817	−38
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 4	100.00%	3,255	5,180	100.00%	3,300	5,053	100.00%	3,567	5,033	100.00%	3,010	4,951
change	−	−	−	0.00%	45	−127	0.00%	312	−147	0.00%	−246	−229
optimized	−	−	−	optimized	no	no	optimized	optimized	no	optimized	no	optimized
train 5	100.00%	3,322	4,102	100.00%	3,416	4,027	95.04%	3,224	3,986	100.00%	3,449	3,972
change	−	−	−	0.00%	93	−75	−4.96%	−99	−116	0.00%	127	−130
optimized	−	−	−	optimized	no	no	no	no	no	optimized	optimized	optimized
train 6	100.00%	3,250	3,017	100.00%	3,131	3,008	87.18%	3,178	2,940	100.00%	3,361	2,940
change	−	−	−	0.00%	−119	−9	−12.82%	−71	−77	0.00%	111	−77
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 7	100.00%	3,250	3,763	100.00%	3,415	3,617	78.46%	2,610	3,737	96.37%	3,288	3,611
change	−	−	−	0.00%	165	−146	−21.54%	−640	−26	−3.63%	38	−152
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized
train 8	100.00%	3,313	543	100.00%	3,185	578	95.38%	3,154	557	97.26%	3,516	470
change	−	−	−	0.00%	−128	35	−4.62%	−159	14	−2.74%	203	−73
optimized	−	−	−	optimized	no	no	no	no	no	no	optimized	optimized
train 9	100.00%	3,288	471	100.00%	3,206	477	96.07%	3,261	444	100.00%	3,352	444
change	−	−	−	0.00%	−83	6	−3.93%	−27	−27	0.00%	64	−27
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 10	97.95%	3,284	325	100.00%	3,360	318	100.00%	3,390	297	100.00%	3,390	297
change	−	−	−	2.05%	76	−7	2.05%	106	−28	2.05%	106	−28
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 11	96.58%	3,250	205	100.00%	3,327	204	98.80%	3,317	197	95.73%	3,265	197
change	−	−	−	3.42%	77	−1	2.22%	67	−8	−0.85%	15	−8
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 12	96.58%	3,236	120	100.00%	3,303	119	100.00%	3,294	130	99.63%	3,297	119
change	−	−	−	3.42%	66	−1	3.42%	58	10	3.05%	60	−1
optimized	−	−	−	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 13	96.24%	3,241	79	100.00%	3,274	79	100.00%	3,274	79	90.17%	3,105	79
change	−	−	−	3.76%	33	0	3.76%	33	0	−6.07%	−136	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	84.96%	2,999	27	92.48%	3,128	27	92.48%	3,128	27	89.37%	3,074	27
change	−	−	−	7.52%	129	0	7.52%	129	0	4.41%	76	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA1-12: Result of optimization on August 13th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	97.44%	3,221	61	100.00%	3,268	61	98.29%	3,157	86	94.70%	3,198	46
change	–	–	–	2.56%	46	0	0.85%	−64	25	−2.74%	−23	−15
optimized	–	–	–	optimized	optimized	no	no	no	no	no	no	optimized
train 2	95.38%	3,210	173	100.00%	3,289	171	94.53%	3,205	171	93.50%	3,169	165
change	–	–	–	4.62%	79	−2	−0.85%	−5	−2	−1.88%	−42	−8
optimized	–	–	–	optimized	optimized	no	no	no	no	no	no	optimized
train 3	100.00%	3,193	280	100.00%	3,088	325	100.00%	3,219	268	95.90%	3,074	268
change	–	–	–	0.00%	−105	45	0.00%	26	−12	−4.10%	−119	−12
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 4	100.00%	3,284	258	100.00%	3,187	259	99.66%	3,300	242	93.08%	3,155	242
change	–	–	–	0.00%	−97	1	−0.34%	16	−16	−6.92%	−129	−16
optimized	–	–	–	optimized	no	no	no	optimized	optimized	no	no	optimized
train 5	100.00%	3,270	410	100.00%	3,185	434	100.00%	3,185	434	77.56%	2,830	406
change	–	–	–	0.00%	−86	24	0.00%	−86	24	−22.44%	−440	−4
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 6	100.00%	3,306	1,166	100.00%	3,178	1,209	96.07%	3,225	1,154	99.48%	3,322	1,154
change	–	–	–	0.00%	−128	43	−3.93%	−81	−12	−0.52%	16	−12
optimized	–	–	–	optimized	no	no	no	no	optimized	no	optimized	optimized
train 7	100.00%	3,283	308	100.00%	3,157	344	100.00%	3,348	270	99.66%	3,336	270
change	–	–	–	0.00%	−127	36	0.00%	65	−38	−0.34%	52	−38
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	99.15%	3,318	138	100.00%	3,243	163	100.00%	3,332	137	99.49%	3,335	129
change	–	–	–	0.85%	−75	25	0.85%	14	−1	0.34%	17	−9
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 9	99.32%	3,266	520	100.00%	3,337	495	100.00%	3,277	530	100.00%	3,337	495
change	–	–	–	0.68%	71	−25	0.68%	11	10	0.68%	71	−25
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	optimized	optimized	optimized
train 10	100.00%	3,288	53	100.00%	3,185	87	100.00%	3,242	70	97.38%	3,250	53
change	–	–	–	0.00%	−103	34	0.00%	−46	17	−2.62%	−38	0
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 11	98.97%	3,241	32	100.00%	3,256	32	100.00%	3,240	49	100.00%	3,256	32
change	–	–	–	1.03%	16	0	1.03%	0	17	1.03%	16	0
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	optimized	optimized	optimized
train 12	89.74%	3,124	12	92.14%	3,159	12	92.14%	3,159	12	92.14%	3,159	12
change	–	–	–	2.39%	35	0	2.39%	35	0	2.39%	35	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	83.59%	2,957	0	83.59%	2,951	0	83.59%	2,951	0	83.59%	2,951	0
change	–	–	–	0.00%	−6	0	0.00%	−6	0	0.00%	−6	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	46.15%	1,648	1	46.67%	1,665	0	46.67%	1,665	0	46.67%	1,665	0
change	–	–	–	0.51%	16	−1	0.51%	16	−1	0.51%	16	−1
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-14: Result of optimization on August 14th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	89.91%	2,962	0	89.91%	2,962	0	89.91%	2,962	0	89.91%	2,962	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	95.56%	3,180	34	97.44%	3,212	34	97.44%	3,212	34	91.79%	3,070	34
change	−	−	−	1.88%	32	0	1.88%	32	0	−3.76%	−110	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	99.66%	3,127	60	100.00%	3,133	60	100.00%	3,125	68	99.66%	3,127	60
change	−	−	−	0.34%	6	0	0.34%	−1	8	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 4	96.58%	3,110	31	100.00%	3,166	31	99.66%	3,180	33	100.00%	3,180	31
change	−	−	−	3.42%	56	0	3.08%	69	2	3.42%	69	0
optimized	−	−	−	optimized	no	optimized	no	optimized	no	optimized	optimized	optimized
train 5	94.02%	3,146	69	100.00%	3,235	69	100.00%	3,235	69	96.03%	3,183	69
change	−	−	−	5.98%	89	0	5.98%	89	0	2.02%	37	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	96.92%	3,187	78	100.00%	3,222	87	100.00%	3,222	87	96.75%	3,194	78
change	−	−	−	3.08%	35	9	3.08%	35	9	−0.17%	6	0
optimized	−	−	−	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 7	98.63%	3,284	41	100.00%	3,227	61	100.00%	3,262	52	92.82%	3,148	41
change	−	−	−	1.37%	−57	20	1.37%	−22	11	−5.81%	−137	0
optimized	−	−	−	optimized	no	no	optimized	optimized	no	no	no	optimized
train 8	93.16%	3,183	1	93.50%	3,191	0	93.50%	3,191	0	93.50%	3,191	0
change	−	−	−	0.34%	8	−1	0.34%	8	−1	0.34%	8	−1
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	94.19%	3,132	25	98.29%	3,189	25	96.75%	3,160	25	98.29%	3,189	25
change	−	−	−	4.10%	57	0	2.56%	28	0	4.10%	57	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	optimized	optimized	optimized
train 10	77.44%	2,873	0	77.44%	2,841	0	77.44%	2,841	0	77.44%	2,841	0
change	−	−	−	0.00%	−32	0	0.00%	−32	0	0.00%	−32	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	53.16%	2,127	0	53.16%	2,127	0	53.16%	2,127	0	53.16%	2,127	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	67.69%	2,699	13	67.69%	2,693	13	67.69%	2,693	13	65.42%	2,656	13
change	−	−	−	0.00%	−6	0	0.00%	−6	0	−2.27%	−43	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 13	75.90%	2,848	10	78.97%	2,889	10	78.97%	2,889	10	78.97%	2,889	10
change	−	−	−	3.08%	40	0	3.08%	40	0	3.08%	40	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	49.40%	1,869	0	49.40%	1,869	0	49.40%	1,869	0	49.40%	1,869	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-14: Result of optimization on August 15th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	47.69%	1,553	0	47.69%	1,553	0	47.69%	1,553	0	47.69%	1,553	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	63.25%	2,171	0	63.25%	2,171	0	63.25%	2,171	0	63.25%	2,171	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	94.53%	3,080	99	100.00%	3,171	99	99.32%	3,161	99	99.32%	3,161	99
change	−	−	−	5.47%	90	0	4.79%	80	0	4.79%	80	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 4	92.14%	3,033	67	96.58%	3,089	69	95.56%	3,078	67	84.10%	2,921	67
change	−	−	−	4.44%	56	2	3.42%	46	0	−8.03%	−111	0
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 5	89.23%	3,081	47	95.56%	3,184	47	95.56%	3,184	47	91.62%	3,118	47
change	−	−	−	6.32%	103	0	6.32%	103	0	2.39%	37	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	98.29%	3,253	152	100.00%	3,187	188	100.00%	3,299	157	100.00%	3,290	138
change	−	−	−	1.71%	−66	36	1.71%	46	5	1.71%	38	−14
optimized	−	−	−	optimized	no	no	optimized	optimized	no	optimized	no	optimized
train 7	96.41%	3,288	29	98.12%	3,299	35	98.12%	3,299	35	98.12%	3,275	29
change	−	−	−	1.71%	11	6	1.71%	11	6	1.71%	−14	0
optimized	−	−	−	optimized	optimized	no	optimized	optimized	no	optimized	no	optimized
train 8	96.58%	3,253	29	107.69%	3,640	0	107.69%	3,640	0	107.69%	3,640	0
change	−	−	−	11.11%	387	−29	11.11%	387	−29	11.11%	387	−29
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	92.99%	3,154	0	92.99%	3,154	0	92.99%	3,154	0	92.99%	3,154	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	81.37%	2,989	19	86.15%	3,075	19	86.15%	3,075	19	79.66%	2,960	19
change	−	−	−	4.79%	85	0	4.79%	85	0	−1.71%	−29	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 11	72.82%	2,749	0	72.82%	2,749	0	72.82%	2,749	0	72.82%	2,749	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	73.50%	2,777	29	76.58%	2,826	29	76.58%	2,826	29	76.58%	2,826	29
change	−	−	−	3.08%	50	0	3.08%	50	0	3.08%	50	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	78.97%	2,904	10	81.37%	2,948	10	81.37%	2,948	10	81.37%	2,948	10
change	−	−	−	2.39%	44	0	2.39%	44	0	2.39%	44	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	48.55%	1,910	0	48.55%	1,910	0	48.55%	1,910	0	48.55%	1,910	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-15: Result of optimization on August 16th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	88.21%	3,011	0	88.21%	3,011	0	88.21%	3,011	0	88.21%	3,011	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	90.26%	3,249	55	90.26%	3,298	39	90.26%	3,298	39	87.69%	3,188	39
change	–	–	–	0.00%	49	−16	0.00%	49	−16	−2.56%	−61	−16
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	97.61%	3,159	33	100.00%	3,122	52	100.00%	3,189	33	100.00%	3,189	33
change	–	–	–	2.39%	−37	19	2.39%	30	0	2.39%	30	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 4	86.84%	2,986	74	95.38%	3,113	77	95.38%	3,105	74	78.12%	2,827	74
change	–	–	–	8.55%	127	3	8.55%	119	0	−8.72%	−159	0
optimized	–	–	–	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 5	84.10%	3,024	96	89.40%	3,082	96	82.74%	2,963	96	75.37%	2,860	96
change	–	–	–	5.30%	58	0	−1.37%	−60	0	−8.73%	−163	0
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 6	92.82%	3,140	38	99.32%	3,227	38	99.32%	3,227	38	99.32%	3,227	38
change	–	–	–	6.50%	87	0	6.50%	87	0	6.50%	87	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 7	91.97%	3,192	28	96.24%	3,235	37	96.24%	3,204	28	92.99%	3,136	28
change	–	–	–	4.27%	44	9	4.27%	12	0	1.03%	−56	0
optimized	–	–	–	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 8	68.55%	2,363	0	68.55%	2,363	0	68.55%	2,363	0	68.55%	2,363	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	75.21%	2,646	0	75.21%	2,646	0	75.21%	2,646	0	75.21%	2,646	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	68.03%	2,532	0	68.03%	2,513	0	68.03%	2,513	0	68.03%	2,513	0
change	–	–	–	0.00%	−19	0	0.00%	−19	0	0.00%	−19	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	48.72%	1,827	0	48.72%	1,827	0	48.72%	1,827	0	48.72%	1,827	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	74.02%	2,851	0	74.02%	2,820	0	74.02%	2,820	0	74.02%	2,820	0
change	–	–	–	0.00%	−31	0	0.00%	−31	0	0.00%	−31	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	50.09%	1,904	0	50.09%	1,897	0	50.09%	1,897	0	50.09%	1,897	0
change	–	–	–	0.00%	−6	0	0.00%	−6	0	0.00%	−6	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	27.35%	954	0	27.35%	954	0	27.35%	954	0	27.35%	954	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

Table A1-16: Result of optimization on August 17th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	66.32%	2,224	0	66.32%	2,224	0	66.32%	2,224	0	66.32%	2,224	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	73.68%	2,771	0	73.68%	2,771	0	73.68%	2,771	0	73.68%	2,771	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	99.32%	3,197	140	100.00%	3,184	149	98.97%	3,180	140	98.97%	3,180	140
change	–	–	–	0.68%	−13	9	−0.34%	−16	0	−0.34%	−16	0
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 4	99.15%	3,247	799	100.00%	3,210	832	91.62%	3,132	797	96.92%	3,213	797
change	–	–	–	0.85%	−37	33	−7.52%	−115	−2	−2.22%	−34	−2
optimized	–	–	–	optimized	no	no	no	no	optimized	no	optimized	optimized
train 5	91.11%	3,132	13	94.36%	3,185	13	94.36%	3,185	13	92.14%	3,149	13
change	–	–	–	3.25%	53	0	3.25%	53	0	1.03%	18	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	96.07%	3,157	28	99.32%	3,201	28	99.32%	3,198	29	90.94%	3,067	28
change	–	–	–	3.25%	45	0	3.25%	41	1	−5.13%	−90	0
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 7	91.11%	3,068	21	96.41%	3,203	21	96.41%	3,203	21	92.13%	3,073	21
change	–	–	–	5.30%	135	0	5.30%	135	0	1.02%	6	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 8	56.24%	1,928	0	56.24%	1,928	0	56.24%	1,928	0	56.24%	1,928	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	67.18%	2,360	0	67.18%	2,360	0	67.18%	2,360	0	67.18%	2,360	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	56.92%	2,236	0	56.92%	2,236	0	56.92%	2,236	0	56.92%	2,236	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	59.83%	2,219	0	59.83%	2,219	0	59.83%	2,219	0	59.83%	2,219	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	64.10%	2,480	0	64.10%	2,480	0	64.10%	2,480	0	64.10%	2,480	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	68.72%	2,795	0	68.72%	2,795	0	68.72%	2,795	0	68.72%	2,795	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	47.01%	1,875	0	47.01%	1,875	0	47.01%	1,875	0	47.01%	1,875	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-17: Result of optimization on August 18th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	69.40%	2,282	0	69.40%	2,282	0	69.40%	2,282	0	69.40%	2,282	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	83.42%	3,060	60	87.01%	3,123	62	83.42%	3,060	60	76.69%	2,952	60
change	–	–	–	3.59%	63	2	0.00%	0	0	-6.73%	-108	0
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 3	99.32%	3,224	81	100.00%	3,130	109	100.00%	3,111	119	97.90%	3,222	75
change	–	–	–	0.68%	-95	28	0.68%	-113	38	-1.42%	-2	-6
optimized	–	–	–	optimized	no	no	optimized	no	no	no	optimized	optimized
train 4	92.65%	3,181	37	98.97%	3,275	39	98.97%	3,269	37	94.36%	3,198	37
change	–	–	–	6.32%	94	2	6.32%	89	0	1.71%	17	0
optimized	–	–	–	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 5	99.66%	3,457	88	100.00%	3,413	106	100.00%	3,413	106	94.30%	3,280	77
change	–	–	–	0.34%	-43	18	0.34%	-43	18	-5.36%	-177	-11
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 6	90.94%	3,090	25	93.33%	3,151	36	93.33%	3,115	25	92.82%	3,108	25
change	–	–	–	2.39%	61	11	2.39%	26	0	1.88%	18	0
optimized	–	–	–	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 7	93.50%	3,213	0	93.50%	3,207	0	93.50%	3,207	0	93.50%	3,207	0
change	–	–	–	0.00%	-6	0	0.00%	-6	0	0.00%	-6	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	79.66%	2,611	0	79.66%	2,598	0	79.66%	2,598	0	79.66%	2,598	0
change	–	–	–	0.00%	-13	0	0.00%	-13	0	0.00%	-13	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	56.75%	1,974	0	56.75%	1,974	0	56.75%	1,974	0	56.75%	1,974	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	63.25%	2,396	0	63.25%	2,396	0	63.25%	2,396	0	63.25%	2,396	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	57.95%	2,123	0	57.95%	2,123	0	57.95%	2,123	0	57.95%	2,123	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	51.97%	2,038	0	51.97%	2,038	0	51.97%	2,038	0	51.97%	2,038	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	50.26%	1,834	0	50.26%	1,828	0	50.26%	1,828	0	50.26%	1,828	0
change	–	–	–	0.00%	-6	0	0.00%	-6	0	0.00%	-6	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	37.95%	0	0	37.95%	1,339	0	37.95%	1,339	0	37.95%	1,339	0
change	–	–	–	0.00%	1,339	0	0.00%	1,339	0	0.00%	1,339	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-19: Result of optimization on August 19th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	42.56%	1,338	0	42.56%	1,338	0	42.56%	1,338	0	42.56%	1,338	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	46.67%	1,689	0	46.67%	1,689	0	46.67%	1,689	0	46.67%	1,689	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	100.00%	3,063	509	100.00%	3,060	514	99.32%	3,041	509	92.99%	2,798	509
change	−	−	−	0.00%	−3	5	−0.68%	−22	0	−7.01%	−265	0
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 4	88.89%	3,025	52	94.87%	3,084	58	94.87%	3,103	52	94.01%	3,093	52
change	−	−	−	5.98%	59	6	5.98%	78	0	5.12%	68	0
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 5	95.21%	3,137	83	100.00%	3,076	118	95.90%	3,152	83	100.00%	3,199	83
change	−	−	−	4.79%	−61	35	0.68%	15	0	4.79%	62	0
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 6	99.15%	3,155	147	100.00%	3,052	172	99.15%	3,186	140	100.00%	3,195	140
change	−	−	−	0.85%	−103	25	0.00%	31	−7	0.85%	40	−7
optimized	−	−	−	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 7	100.00%	3,280	69	100.00%	3,214	88	100.00%	3,268	81	99.83%	3,274	69
change	−	−	−	0.00%	−65	19	0.00%	−12	12	−0.17%	−6	0
optimized	−	−	−	optimized	no	no	optimized	no	no	no	optimized	optimized
train 8	89.06%	2,950	0	89.06%	2,950	0	89.06%	2,950	0	89.06%	2,950	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	90.43%	3,092	0	90.43%	3,092	0	90.43%	3,092	0	90.43%	3,092	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	95.73%	3,379	22	97.61%	3,382	31	97.61%	3,411	21	97.61%	3,411	21
change	−	−	−	1.88%	3	9	1.88%	32	−1	1.88%	32	−1
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 11	82.22%	3,034	1	82.22%	3,034	1	82.22%	3,034	1	81.88%	3,028	1
change	−	−	−	0.00%	0	0	0.00%	0	0	−0.34%	−6	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 12	77.61%	2,947	48	83.25%	3,030	50	75.38%	2,911	48	75.38%	2,911	48
change	−	−	−	5.64%	84	2	−2.22%	−35	0	−2.22%	−35	0
optimized	−	−	−	optimized	optimized	no	no	no	optimized	no	no	optimized
train 13	75.56%	2,871	31	79.49%	2,910	31	79.49%	2,910	31	68.89%	2,759	31
change	−	−	−	3.93%	39	0	3.93%	39	0	−6.67%	−112	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 14	71.79%	2,743	10	73.16%	2,768	10	73.16%	2,768	10	71.45%	2,736	10
change	−	−	−	1.37%	26	0	1.37%	26	0	−0.34%	−7	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA1-19: Result of optimization on August 20th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	79.83%	2,988	18	84.44%	3,070	18	81.37%	3,012	18	84.44%	3,070	18
change	–	–	–	4.62%	81	0	1.54%	23	0	4.62%	81	0
optimized	–	–	–	optimized	optimized	optimized	no	no	optimized	optimized	optimized	optimized
train 2	87.01%	3,156	47	90.94%	3,216	50	90.94%	3,225	47	87.01%	3,149	47
change	–	–	–	3.93%	60	3	3.93%	69	0	0.00%	−7	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 3	99.83%	3,178	159	100.00%	3,185	159	100.00%	3,185	159	98.65%	3,133	159
change	–	–	–	0.17%	6	0	0.17%	6	0	−1.18%	−46	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 4	97.44%	3,281	100	100.00%	3,222	156	100.00%	3,222	156	88.03%	3,143	98
change	–	–	–	2.56%	−59	56	2.56%	−59	56	−9.40%	−138	−2
optimized	–	–	–	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 5	81.03%	2,928	38	88.55%	3,049	38	88.55%	3,049	38	88.55%	3,049	38
change	–	–	–	7.52%	121	0	7.52%	121	0	7.52%	121	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	94.53%	3,171	38	100.00%	3,240	52	98.97%	3,221	52	99.15%	3,249	38
change	–	–	–	5.47%	69	14	4.44%	50	14	4.62%	77	0
optimized	–	–	–	optimized	no	no	no	no	no	no	optimized	optimized
train 7	84.44%	2,921	0	84.44%	2,921	0	84.44%	2,921	0	84.44%	2,921	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	66.50%	2,200	0	66.50%	2,200	0	66.50%	2,200	0	66.50%	2,200	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	96.92%	3,161	97	100.00%	3,281	100	100.00%	3,282	97	97.95%	3,210	97
change	–	–	–	3.08%	120	3	3.08%	121	0	1.03%	49	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 10	75.04%	2,567	0	75.04%	2,567	0	75.04%	2,567	0	75.04%	2,567	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	47.86%	1,692	0	47.86%	1,692	0	47.86%	1,692	0	47.86%	1,692	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	60.51%	2,241	0	60.51%	2,241	0	60.51%	2,241	0	60.51%	2,241	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	72.82%	2,694	14	75.21%	2,733	0	75.21%	2,733	0	75.21%	2,733	0
change	–	–	–	2.39%	39	−14	2.39%	39	−14	2.39%	39	−14
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	33.16%	1,260	0	33.16%	1,260	0	33.16%	1,260	0	33.16%	1,260	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-20: Result of optimization on August 21st

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	64.62%	2,075	0	64.62%	2,075	0	64.62%	2,075	0	64.62%	2,075	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	85.64%	3,171	8	86.15%	3,181	8	86.15%	3,181	8	84.79%	3,155	8
change	–	–	–	0.51%	10	0	0.51%	10	0	−0.85%	−16	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	87.52%	3,061	0	87.52%	3,061	0	87.52%	3,061	0	87.52%	3,061	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 4	87.35%	3,149	74	90.77%	3,207	74	90.77%	3,113	102	71.11%	2,873	74
change	–	–	–	3.42%	58	0	3.42%	−36	28	−16.24%	−276	0
optimized	–	–	–	optimized	optimized	optimized	optimized	no	no	no	no	optimized
train 5	73.33%	2,790	0	73.33%	2,790	0	73.33%	2,790	0	73.33%	2,790	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	89.40%	3,095	21	94.19%	3,174	21	94.19%	3,174	21	91.65%	3,128	21
change	–	–	–	4.79%	78	0	4.79%	78	0	2.25%	33	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 7	78.80%	2,692	0	78.80%	2,692	0	78.80%	2,692	0	78.80%	2,692	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	54.87%	1,869	0	54.87%	1,869	0	54.87%	1,869	0	54.87%	1,869	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	70.09%	2,284	0	70.09%	2,284	0	70.09%	2,284	0	70.09%	2,284	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	69.91%	2,314	0	69.91%	2,314	0	69.91%	2,314	0	69.91%	2,314	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	59.83%	1,973	0	59.83%	1,973	0	59.83%	1,973	0	59.83%	1,973	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	81.88%	3,024	0	81.88%	3,024	0	81.88%	3,024	0	81.88%	3,024	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	79.32%	3,050	0	79.32%	3,050	0	79.32%	3,050	0	79.32%	3,050	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	58.12%	2,289	0	58.12%	2,289	0	58.12%	2,289	0	58.12%	2,289	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-21: Result of optimization on August 22nd

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	72.14%	2,348	0	72.14%	2,348	0	72.14%	2,348	0	72.14%	2,348	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	79.83%	3,105	1	79.83%	3,105	1	79.83%	3,105	1	79.66%	3,102	1
change	–	–	–	0.00%	0	0	0.00%	0	0	−0.17%	−3	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	97.44%	3,240	30	100.00%	3,263	45	100.00%	3,274	45	94.43%	3,188	30
change	–	–	–	2.56%	23	15	2.56%	34	15	−3.00%	−52	0
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 4	93.68%	3,238	78	96.92%	3,287	78	96.92%	3,287	78	88.55%	3,160	78
change	–	–	–	3.25%	49	0	3.25%	49	0	−5.13%	−78	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 5	81.37%	2,952	206	91.97%	3,124	206	91.97%	3,124	206	91.97%	3,124	206
change	–	–	–	10.60%	173	0	10.60%	173	0	10.60%	173	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	76.75%	2,773	0	76.75%	2,773	0	76.75%	2,773	0	76.75%	2,773	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 7	55.90%	1,963	0	55.90%	1,963	0	55.90%	1,963	0	55.90%	1,963	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	57.78%	1,949	0	57.78%	1,949	0	57.78%	1,949	0	57.78%	1,949	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	79.15%	2,694	0	79.15%	2,694	0	79.15%	2,694	0	79.15%	2,694	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	95.73%	3,356	2	96.07%	3,363	2	96.07%	3,363	2	96.07%	3,363	2
change	–	–	–	0.34%	7	0	0.34%	7	0	0.34%	7	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	72.82%	2,582	0	72.82%	2,582	0	72.82%	2,582	0	72.82%	2,582	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	93.85%	3,357	25	94.87%	3,377	25	94.87%	3,377	25	94.53%	3,370	25
change	–	–	–	1.03%	20	0	1.03%	20	0	0.69%	13	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 13	84.96%	3,128	20	89.23%	3,201	20	89.23%	3,201	20	89.23%	3,201	20
change	–	–	–	4.27%	73	0	4.27%	73	0	4.27%	73	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	64.62%	2,440	0	64.62%	2,440	0	64.62%	2,440	0	64.62%	2,440	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-22: Result of optimization on August 23rd

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	82.91%	2,828	2	83.25%	2,835	2	53.90%	1,918	95	54.34%	1,933	91
change	−	−	−	0.34%	7	0	−29.00%	−910	93	−28.57%	−895	89
optimized	−	−	−	optimized	optimized	optimized	no	no	no	no	no	no
train 2	91.11%	3,284	36	93.16%	3,344	29	93.16%	3,344	29	93.16%	3,344	29
change	−	−	−	2.05%	59	−7	2.05%	59	−7	2.05%	59	−7
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	98.63%	3,280	404	100.00%	3,161	438	96.58%	3,288	390	99.15%	3,327	390
change	−	−	−	1.37%	−119	34	−2.05%	8	−14	0.51%	47	−14
optimized	−	−	−	optimized	no	no	no	no	optimized	no	optimized	optimized
train 4	83.59%	3,026	341	100.00%	3,335	326	76.07%	3,021	320	73.63%	3,031	300
change	−	−	−	16.41%	309	−15	−7.52%	−5	−21	−9.96%	5	−41
optimized	−	−	−	optimized	optimized	no	no	no	no	no	no	optimized
train 5	90.94%	3,172	132	99.83%	3,378	132	99.83%	3,378	132	98.49%	3,346	132
change	−	−	−	8.89%	206	0	8.89%	206	0	7.55%	173	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	97.78%	3,318	31	100.00%	3,329	44	100.00%	3,370	26	100.00%	3,370	26
change	−	−	−	2.22%	10	13	2.22%	52	−5	2.22%	52	−5
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 7	96.24%	3,233	87	98.80%	3,326	90	98.80%	3,326	87	89.57%	2,986	87
change	−	−	−	2.56%	92	3	2.56%	93	0	−6.67%	−248	0
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	84.96%	2,706	3	85.47%	2,722	3	84.96%	2,706	3	85.47%	2,722	3
change	−	−	−	0.51%	17	0	0.00%	0	0	0.51%	17	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	optimized	optimized	optimized
train 9	67.52%	2,233	0	67.52%	2,233	0	67.52%	2,233	0	67.52%	2,233	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	79.66%	2,574	3	79.83%	2,579	3	79.83%	2,579	3	79.83%	2,579	3
change	−	−	−	0.17%	6	0	0.17%	6	0	0.17%	6	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	79.32%	2,655	0	79.32%	2,655	0	79.32%	2,655	0	79.32%	2,655	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	92.65%	3,372	40	95.21%	3,410	42	95.21%	3,416	40	92.65%	3,373	40
change	−	−	−	2.56%	37	2	2.56%	44	0	0.00%	0	0
optimized	−	−	−	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 13	93.85%	3,320	50	96.07%	3,306	45	96.07%	3,375	45	96.07%	3,306	45
change	−	−	−	2.22%	−14	−5	2.22%	55	−5	2.22%	−14	−5
optimized	−	−	−	optimized	no	optimized	optimized	optimized	optimized	optimized	no	optimized
train 14	63.93%	2,356	0	63.93%	2,356	0	63.93%	2,356	0	63.93%	2,356	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-23: Result of optimization on August 24th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	100.00%	3,340	130	100.00%	3,322	130	100.00%	3,348	128	100.00%	3,342	128
change	－	－	－	0.00%	−19	0	0.00%	8	−2	0.00%	2	−2
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	optimized	no	optimized
train 2	100.00%	3,447	110	100.00%	3,492	92	100.00%	3,467	132	94.36%	3,262	90
change	－	－	－	0.00%	45	−18	0.00%	20	22	−5.64%	−185	−20
optimized	－	－	－	optimized	optimized	no	optimized	no	no	no	no	optimized
train 3	100.00%	3,242	494	100.00%	3,107	541	97.78%	3,268	475	99.49%	3,289	475
change	－	－	－	0.00%	−134	47	−2.22%	26	−19	−0.51%	48	−19
optimized	－	－	－	optimized	no	no	no	no	optimized	no	optimized	optimized
train 4	100.00%	3,268	237	100.00%	3,225	245	100.00%	3,225	245	81.54%	2,896	210
change	－	－	－	0.00%	−42	8	0.00%	−42	8	−18.46%	−372	−27
optimized	－	－	－	optimized	optimized	no	optimized	optimized	no	no	no	optimized
train 5	100.00%	3,321	107	100.00%	3,380	75	100.00%	3,274	136	100.00%	3,407	75
change	－	－	－	0.00%	59	−32	0.00%	−47	29	0.00%	86	−32
optimized	－	－	－	optimized	no	optimized	optimized	no	no	optimized	optimized	optimized
train 6	100.00%	3,288	1,013	100.00%	3,166	1,045	91.28%	2,952	999	61.88%	1,914	999
change	－	－	－	0.00%	−122	32	−8.72%	−336	−14	−38.12%	−1,374	−14
optimized	－	－	－	optimized	optimized	no	no	no	optimized	no	no	optimized
train 7	95.73%	3,157	50	100.00%	3,304	66	100.00%	3,278	50	89.91%	2,902	50
change	－	－	－	4.27%	147	16	4.27%	121	0	−5.81%	−255	0
optimized	－	－	－	optimized	optimized	no	optimized	no	optimized	no	no	optimized
train 8	95.90%	3,149	57	100.00%	3,304	61	100.00%	3,308	59	100.00%	3,297	57
change	－	－	－	4.10%	155	4	4.10%	158	2	4.10%	147	0
optimized	－	－	－	optimized	no	no	optimized	optimized	no	optimized	no	optimized
train 9	99.83%	3,312	61	100.00%	3,294	61	100.00%	3,294	61	100.00%	3,294	61
change	－	－	－	0.17%	−18	0	0.17%	−18	0	0.17%	−18	0
optimized	－	－	－	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	99.66%	3,430	41	100.00%	3,321	53	100.00%	3,357	46	96.93%	3,312	36
change	－	－	－	0.34%	−109	12	0.34%	−73	5	−2.73%	−118	−5
optimized	－	－	－	optimized	no	no	optimized	optimized	no	no	no	optimized
train 11	99.66%	3,429	61	100.00%	3,444	59	100.00%	3,412	73	100.00%	3,433	57
change	－	－	－	0.34%	15	−2	0.34%	−17	12	0.34%	4	−4
optimized	－	－	－	optimized	optimized	no	optimized	no	no	optimized	no	optimized
train 12	96.75%	3,393	86	100.00%	3,366	96	100.00%	3,466	94	100.00%	3,366	96
change	－	－	－	3.25%	−28	10	3.25%	73	8	3.25%	−28	10
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	optimized	no	no
train 13	98.97%	3,371	215	100.00%	3,223	261	100.00%	3,179	274	75.21%	3,065	177
change	－	－	－	1.03%	−148	46	1.03%	−192	59	−23.76%	−306	−38
optimized	－	－	－	optimized	optimized	no	optimized	no	no	no	no	optimized
train 14	93.85%	3,209	118	100.00%	3,299	126	100.00%	3,296	122	97.79%	3,264	118
change	－	－	－	6.15%	90	8	6.15%	87	4	3.95%	54	0
optimized	－	－	－	optimized	optimized	no	optimized	no	no	no	no	optimized

TableA1-24: Result of optimization on August 25th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	100.00%	3,283	506	100.00%	3,258	534	100.00%	3,304	482	100.00%	3,258	534
change	－	－	－	0.00%	−25	28	0.00%	21	−24	0.00%	−25	28
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	optimized	no	no
train 2	100.00%	3,326	2,128	100.00%	3,426	2,034	100.00%	3,432	2,021	89.06%	3,041	2,021
change	－	－	－	0.00%	100	−94	0.00%	106	−107	−10.94%	−285	−107
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 3	100.00%	3,267	5,058	100.00%	3,174	5,122	100.00%	3,374	4,981	81.88%	2,722	4,981
change	－	－		0.00%	−93	64	0.00%	107	−77	−18.12%	−545	−77
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 4	99.15%	3,315	5,800	100.00%	3,303	5,559	100.00%	3,411	5,397	100.00%	3,411	5,397
change	－	－	－	0.85%	−12	−241	0.85%	96	−403	0.85%	96	−403
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	optimized	optimized	optimized
train 5	95.90%	3,269	7,702	100.00%	3,199	7,730	93.85%	3,262	7,641	84.79%	3,005	7,641
change	－	－	－	4.10%	−70	28	−2.05%	−7	−61	−11.11%	−264	−61
optimized	－	－	－	optimized	no	no	no	optimized	optimized	no	no	optimized
train 6	100.00%	3,368	5,322	100.00%	3,227	5,025	93.85%	3,230	4,947	100.00%	3,437	4,947
change	－	－	－	0.00%	−141	−297	−6.15%	−138	−375	0.00%	69	−375
optimized	－	－	－	optimized	no	no	no	no	optimized	optimized	optimized	optimized
train 7	100.00%	3,347	6,610	100.00%	3,313	6,634	100.00%	3,364	6,593	87.35%	2,860	6,593
change	－	－	－	0.00%	−34	24	0.00%	17	−17	−12.65%	−487	−17
optimized	－	－	－	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 8	68.55%	2,057	6,570	100.00%	3,203	6,618	75.73%	2,227	6,570	100.00%	3,203	6,618
change	－	－	－	31.45%	1,146	48	7.18%	170	0	31.45%	1,146	48
optimized	－	－	－	optimized	optimized	no	no	no	optimized	optimized	optimized	no
train 9	78.29%	2,460	5,227	100.00%	3,298	5,230	76.41%	2,341	5,230	47.18%	1,299	5,230
change	－	－	－	21.71%	838	3	−1.88%	−119	3	−31.11%	−1,161	3
optimized	－	－	－	optimized	optimized	optimized	no	no	optimized	no	no	optimized
train 10	87.01%	2,707	322	100.00%	5,529	338	100.00%	5,683	322	74.53%	6,035	322
change	－	－	－	12.99%	2,822	16	12.99%	2,976	0	−12.48%	3,328	0
optimized	－	－	－	optimized	no	no	optimized	no	optimized	no	optimized	optimized
train 11	81.54%	3,013	51	86.32%	3,146	51	86.32%	3,146	51	82.66%	3,038	51
change	－	－	－	4.78%	133	0	4.78%	133	0	1.12%	25	0
optimized	－	－	－	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 12	89.74%	3,093	0	89.74%	3,093	0	89.74%	3,093	0	89.74%	3,093	0
change	－	－	－	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	－	－	－	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	84.96%	3,143	114	100.00%	3,362	136	84.96%	3,131	114	90.77%	3,212	114
change	－	－	－	15.04%	219	22	0.00%	−12	0	5.81%	69	0
optimized	－	－	－	optimized	optimized	no	no	no	optimized	no	no	optimized
train 14	92.14%	3,086	361	100.00%	3,213	398	97.44%	3,257	365	99.66%	3,344	361
change	－	－	－	7.86%	127	37	5.30%	171	4	7.52%	258	0
optimized	－	－	－	optimized	no	no	no	no	no	no	optimized	optimized

TableA1-25: Result of optimization on August 26th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	69.57%	2,192	0	69.57%	2,206	0	69.57%	2,206	0	69.57%	2,206	0
change	–	–	–	0.00%	14	0	0.00%	14	0	0.00%	14	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	52.48%	1,829	0	52.48%	1,829	0	52.48%	1,829	0	52.48%	1,829	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	96.92%	3,073	287	100.00%	3,068	305	96.92%	3,073	287	244.10%	7,580	0
change	–	–	–	3.08%	−5	18	0.00%	0	0	147.18%	4,508	−287
optimized	–	–	–	no	no	no	no	no	no	optimized	optimized	optimized
train 4	82.22%	2,875	36	91.45%	3,003	42	89.74%	2,996	36	87.01%	2,941	36
change	–	–	–	9.23%	128	6	7.52%	121	0	4.79%	66	0
optimized	–	–	–	optimized	optimized	no	no	no	optimized	no	no	optimized
train 5	85.30%	2,918	0	85.30%	2,918	0	85.30%	2,918	0	85.30%	2,918	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	90.09%	2,846	1	90.09%	2,846	1	90.09%	2,846	1	89.74%	2,834	1
change	–	–	–	0.00%	0	0	0.00%	0	0	−0.34%	−12	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 7	64.79%	2,103	0	64.79%	2,103	0	64.79%	2,103	0	64.79%	2,103	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	71.97%	2,310	2,200	72.31%	2,324	2,199	72.31%	2,324	2,199	59.89%	1,904	2,199
change	–	–	–	0.34%	14	−1	0.34%	14	−1	−12.07%	−405	−1
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 9	100.00%	3,345	11	100.00%	3,341	14	100.00%	3,345	11	98.97%	3,310	11
change	–	–	–	0.00%	−4	3	0.00%	0	0	−1.03%	−35	0
optimized	–	–	–	optimized	no	no	optimized	optimized	optimized	no	no	optimized
train 10	100.00%	3,448	55	100.00%	3,307	89	100.00%	3,450	60	96.58%	3,324	53
change	–	–	–	0.00%	−141	34	0.00%	2	5	−3.42%	−124	−2
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 11	94.19%	3,358	188	100.00%	3,494	180	100.00%	3,494	180	84.62%	2,956	180
change	–	–	–	5.81%	136	−8	5.81%	136	−8	−9.57%	−402	−8
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 12	91.11%	3,314	224	100.00%	3,606	189	100.00%	3,606	189	95.71%	3,456	189
change	–	–	–	8.89%	292	−35	8.89%	292	−35	4.60%	142	−35
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 13	93.33%	3,337	112	100.00%	3,478	103	100.00%	3,504	95	85.13%	3,282	93
change	–	–	–	6.67%	141	−9	6.67%	167	−17	−8.21%	−55	−19
optimized	–	–	–	optimized	no	no	optimized	optimized	no	no	no	optimized
train 14	75.73%	2,861	30	80.51%	2,949	30	80.51%	2,949	30	78.04%	2,902	30
change	–	–	–	4.79%	88	0	4.79%	88	0	2.32%	41	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized

TableA1-26: Result of optimization on August 27th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	69.40%	2,527	0	69.40%	2,527	0	69.40%	2,527	0	69.40%	2,527	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	68.89%	2,540	0	68.89%	2,540	0	68.89%	2,540	0	68.89%	2,540	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	84.62%	2,766	0	84.62%	2,766	0	84.62%	2,766	0	84.62%	2,766	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 4	78.46%	2,881	18	80.68%	2,919	18	80.68%	2,919	18	75.87%	2,838	18
change	−	−	−	2.22%	38	0	2.22%	38	0	−2.59%	−43	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 5	76.07%	2,803	14	76.41%	2,813	13	76.41%	2,813	13	71.97%	2,742	13
change	−	−	−	0.34%	9	−1	0.34%	9	−1	−4.10%	−61	−1
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 6	95.73%	3,217	10	97.44%	3,243	10	95.90%	3,215	10	97.44%	3,243	10
change	−	−	−	1.71%	26	0	0.17%	−2	0	1.71%	26	0
optimized	−	−	−	optimized	optimized	optimized	no	no	optimized	optimized	optimized	optimized
train 7	40.85%	1,459	0	40.85%	1,459	0	40.85%	1,459	0	40.85%	1,459	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	40.17%	1,406	0	40.17%	1,406	0	40.17%	1,406	0	40.17%	1,406	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	76.58%	2,803	0	76.58%	2,803	0	76.58%	2,803	0	76.58%	2,803	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	59.15%	2,050	0	59.15%	2,050	0	59.15%	2,050	0	59.15%	2,050	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	56.07%	1,821	0	56.07%	1,821	0	56.07%	1,821	0	56.07%	1,821	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	71.97%	2,786	0	71.97%	2,786	0	71.97%	2,786	0	71.97%	2,786	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	57.61%	2,129	0	57.61%	2,129	0	57.61%	2,129	0	57.61%	2,129	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	40.34%	1,534	0	40.34%	1,534	0	40.34%	1,534	0	40.34%	1,534	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-27: Result of optimization on August 28th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	56.92%	1,834	0	56.92%	1,834	0	56.92%	1,834	0	56.92%	1,834	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	64.62%	2,370	0	64.62%	2,370	0	64.62%	2,370	0	64.62%	2,370	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	61.20%	2,148	0	61.20%	2,148	0	61.20%	2,148	0	61.20%	2,148	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 4	78.46%	2,880	32	81.88%	2,937	32	81.88%	2,937	32	76.41%	2,845	32
change	−	−	−	3.42%	57	0	3.42%	57	0	−2.05%	−35	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 5	55.21%	2,202	0	55.21%	2,202	0	55.21%	2,202	0	55.21%	2,202	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	53.33%	2,001	0	53.33%	2,001	0	53.33%	2,001	0	53.33%	2,001	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 7	54.02%	1,796	0	54.02%	1,796	0	54.02%	1,796	0	54.02%	1,796	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	36.58%	1,299	0	36.58%	1,299	0	36.58%	1,299	0	36.58%	1,299	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	51.11%	1,762	0	51.11%	1,762	0	51.11%	1,762	0	51.11%	1,762	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	42.05%	1,482	0	42.05%	1,482	0	42.05%	1,482	0	42.05%	1,482	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	54.02%	1,983	0	54.02%	1,983	0	54.02%	1,983	0	54.02%	1,983	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	61.71%	2,369	0	61.71%	2,369	0	61.71%	2,369	0	61.71%	2,369	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	46.67%	1,811	0	46.67%	1,811	0	46.67%	1,811	0	46.67%	1,811	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	36.92%	1,377	0	36.92%	1,377	0	36.92%	1,377	0	36.92%	1,377	0
change	−	−	−	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	−	−	−	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-28: Result of optimization on August 29th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	56.58%	1,814	0	56.58%	1,814	0	56.58%	1,814	0	56.58%	1,814	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	50.77%	1,880	0	50.77%	1,880	0	50.77%	1,880	0	50.77%	1,880	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 3	50.09%	1,657	0	50.09%	1,657	0	50.09%	1,657	0	50.09%	1,657	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 4	84.79%	3,071	17	89.06%	3,142	17	89.06%	3,142	17	89.06%	3,142	17
change	–	–	–	4.27%	71	0	4.27%	71	0	4.27%	71	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 5	63.08%	2,537	0	63.08%	2,537	0	63.08%	2,537	0	63.08%	2,537	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	61.20%	2,131	0	61.20%	2,131	0	61.20%	2,131	0	61.20%	2,131	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 7	47.69%	1,608	0	47.69%	1,608	0	47.69%	1,608	0	47.69%	1,608	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	45.30%	1,610	0	45.30%	1,610	0	45.30%	1,610	0	45.30%	1,610	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 9	47.35%	1,599	0	47.35%	1,599	0	47.35%	1,599	0	47.35%	1,599	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	52.82%	1,713	0	52.82%	1,713	0	52.82%	1,713	0	52.82%	1,713	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	49.91%	1,714	0	49.91%	1,714	0	49.91%	1,714	0	49.91%	1,714	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	59.83%	2,324	0	59.83%	2,324	0	59.83%	2,324	0	59.83%	2,324	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	72.82%	2,848	0	72.82%	2,848	0	72.82%	2,848	0	72.82%	2,848	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	48.72%	1,844	0	48.72%	1,844	0	48.72%	1,844	0	48.72%	1,844	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-29: Result of optimization on August 30th

train	Do nothing			Objective function 1			Objective function 2			Objective function 3		
	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection	APLF	revenue	Rejection
train 1	54.87%	1,745	0	54.87%	1,745	0	54.87%	1,745	0	54.87%	1,745	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 2	75.90%	2,765	18	75.90%	2,765	18	75.90%	2,765	18	72.82%	2,701	18
change	–	–	–	0.00%	0	0	0.00%	0	0	−3.08%	−65	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 3	51.97%	1,776	0	51.97%	1,776	0	51.97%	1,776	0	51.97%	1,776	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 4	51.97%	2,020	0	51.97%	2,020	0	51.97%	2,020	0	51.97%	2,020	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 5	62.74%	2,534	0	62.74%	2,534	0	62.74%	2,534	0	62.74%	2,534	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 6	52.99%	1,860	0	52.99%	1,860	0	52.99%	1,860	0	52.99%	1,860	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 7	41.71%	1,477	0	41.71%	1,477	0	41.71%	1,477	0	41.71%	1,477	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 8	27.52%	928	0	51.62%	1,562	1,039	51.62%	1,562	1,039	36.99%	1,060	1,039
change	–	–	–	24.10%	635	1,039	24.10%	635	1,039	9.47%	132	1,039
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	no	no	optimized
train 9	46.67%	1,623	0	46.67%	1,623	0	46.67%	1,623	0	46.67%	1,623	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 10	45.64%	1,520	0	45.64%	1,520	0	45.64%	1,520	0	45.64%	1,520	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 11	52.48%	1,855	0	52.48%	1,855	0	52.48%	1,855	0	52.48%	1,855	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 12	67.69%	2,549	0	67.69%	2,549	0	67.69%	2,549	0	67.69%	2,549	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 13	63.59%	2,394	0	63.59%	2,394	0	63.59%	2,394	0	63.59%	2,394	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized
train 14	35.90%	1,439	0	35.90%	1,439	0	35.90%	1,439	0	35.90%	1,439	0
change	–	–	–	0.00%	0	0	0.00%	0	0	0.00%	0	0
optimized	–	–	–	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized	optimized

TableA1-30: Result of optimization on August 31st