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Impacts of Low Cost Carriers on Intercity Passenger Demand in Japan

総合研究部
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Contents

- Model Structure
- Model Calibration
- Model Validation

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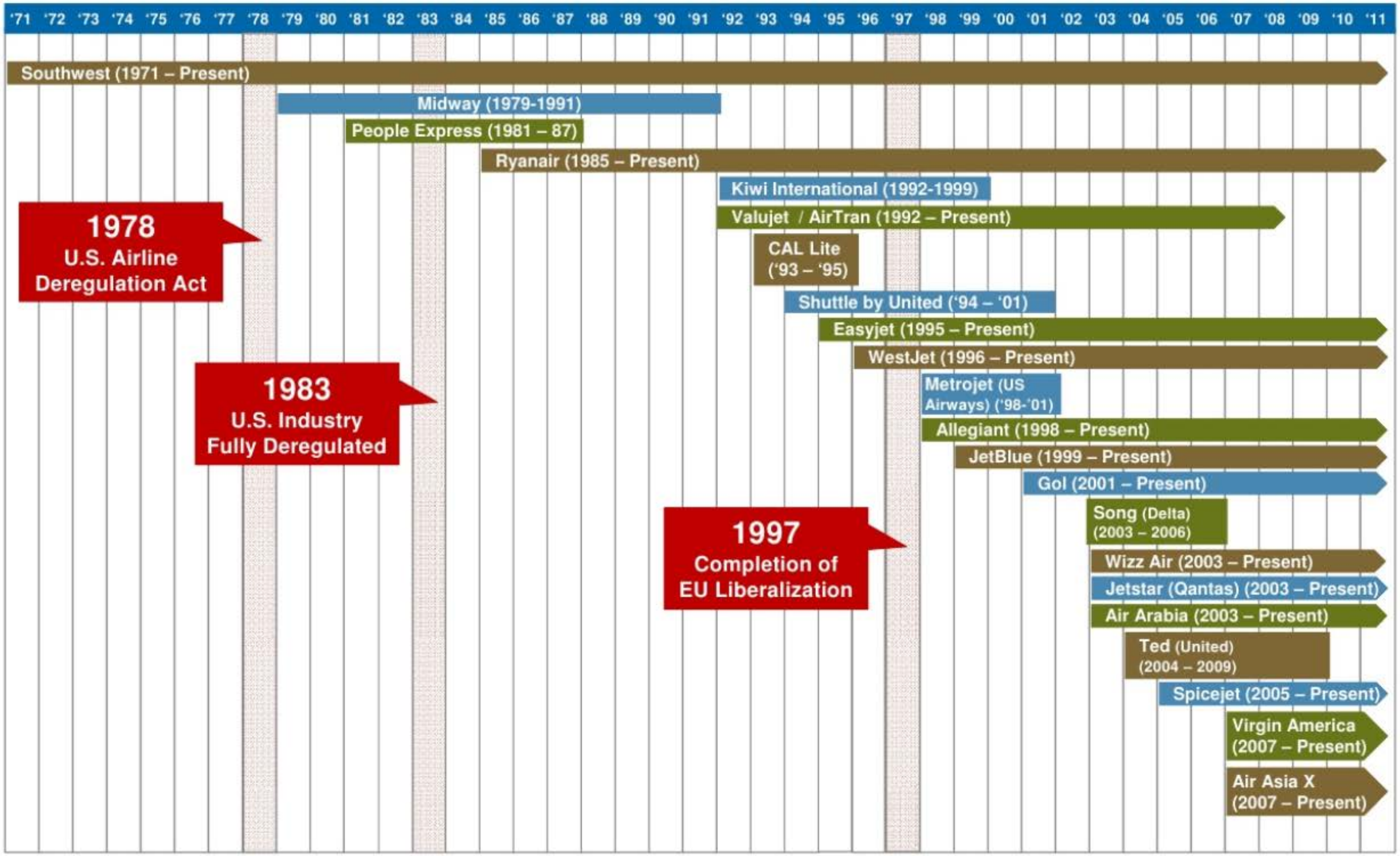
Introduction

- A Low Cost Carrier is an airline that generally has <u>lower fares</u> with <u>less comforts</u>
- To increase revenue, they may charge for extras (food, baggage, etc.)

Introduction

- LCCs first appeared in US in 1970s, then spread to Europe in 1990s and started operations in Asia after 2000.

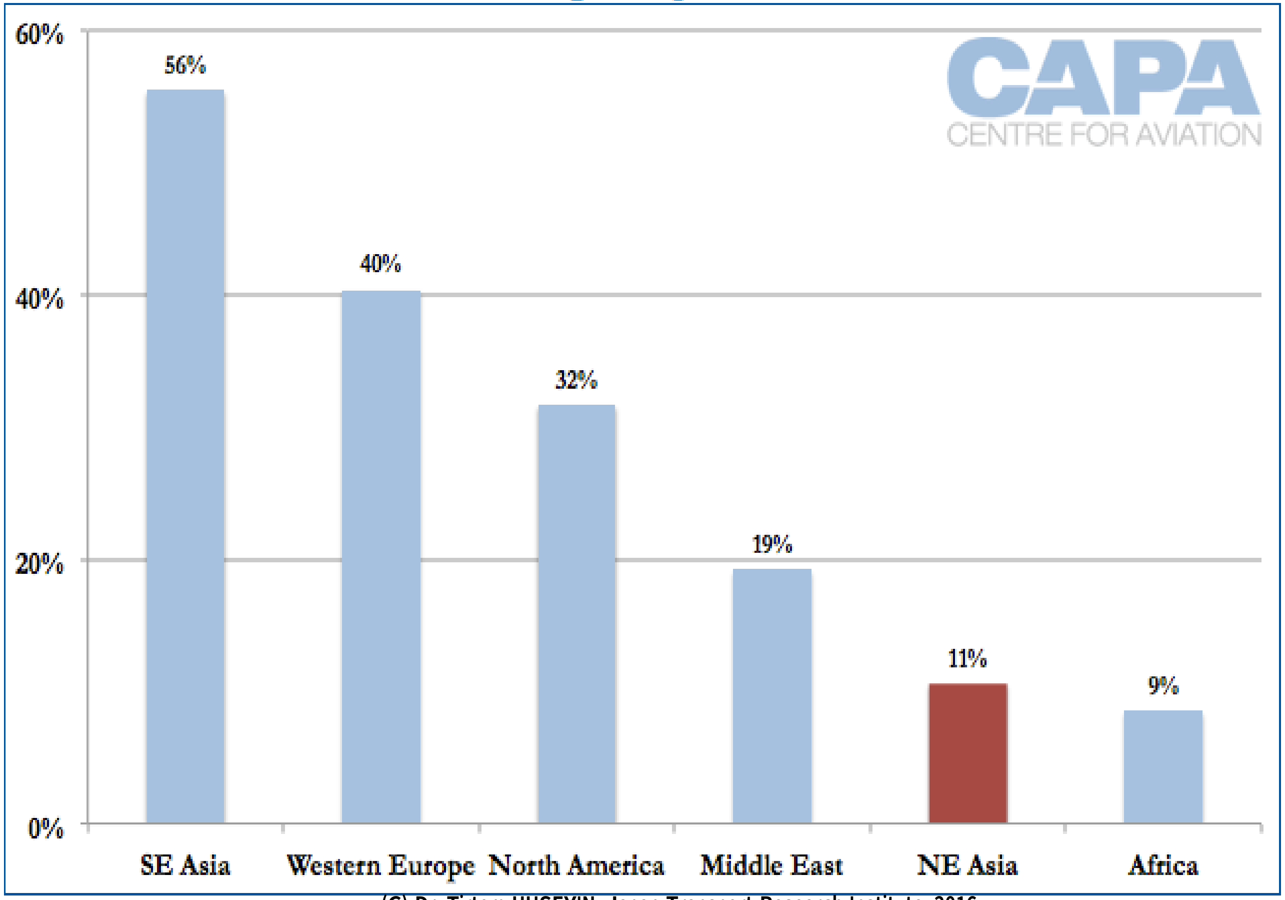


Source: Mark Diamond, ICF, SH&E

Introduction

- LCCs reached high market shares in South East Asian countries where transport networks are still developing.
- LCCs also reached significant market shares in US and Europe which already have developed transport networks

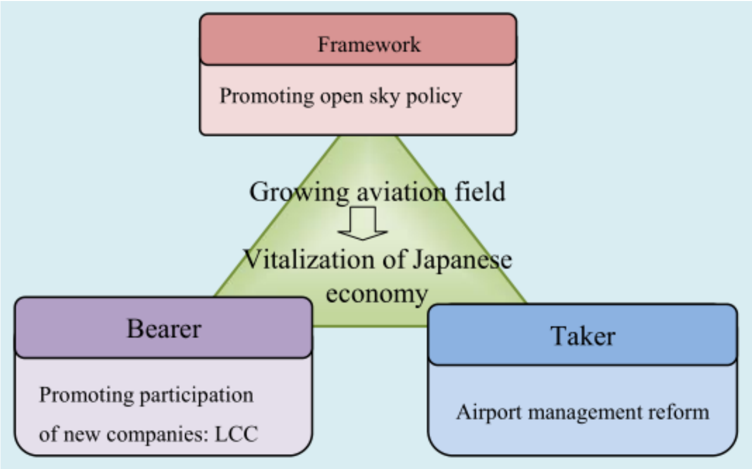
LCC share of available seats within a region: 05-Jun-2016 to 11-Jun-2016



Source: CAPA- Centre for Aviation and OAG

Japanese Government`s Aviation Policy:

1. Open sky agreements
2. Airport management reform
3. Promoting new entries (LCC)
   - Easing technical regulations
   - Preparing dedicated terminals
   - Providing discounts
   - Allocating airport capacity



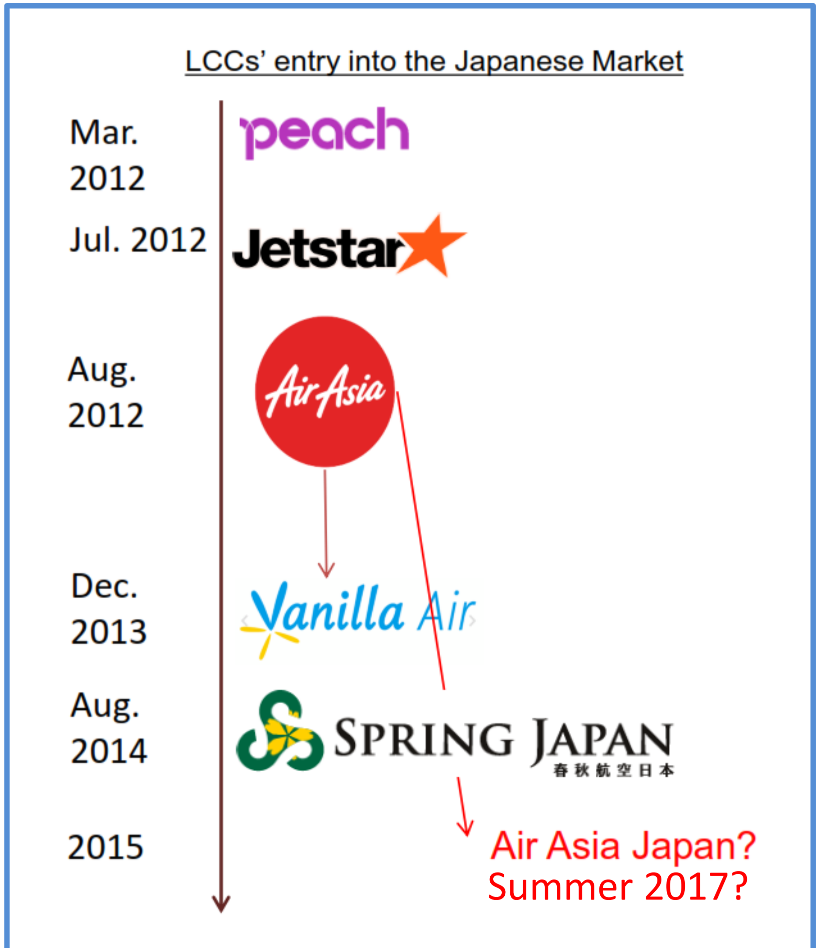
Source: 国土交通省国土技術政策総合研究所

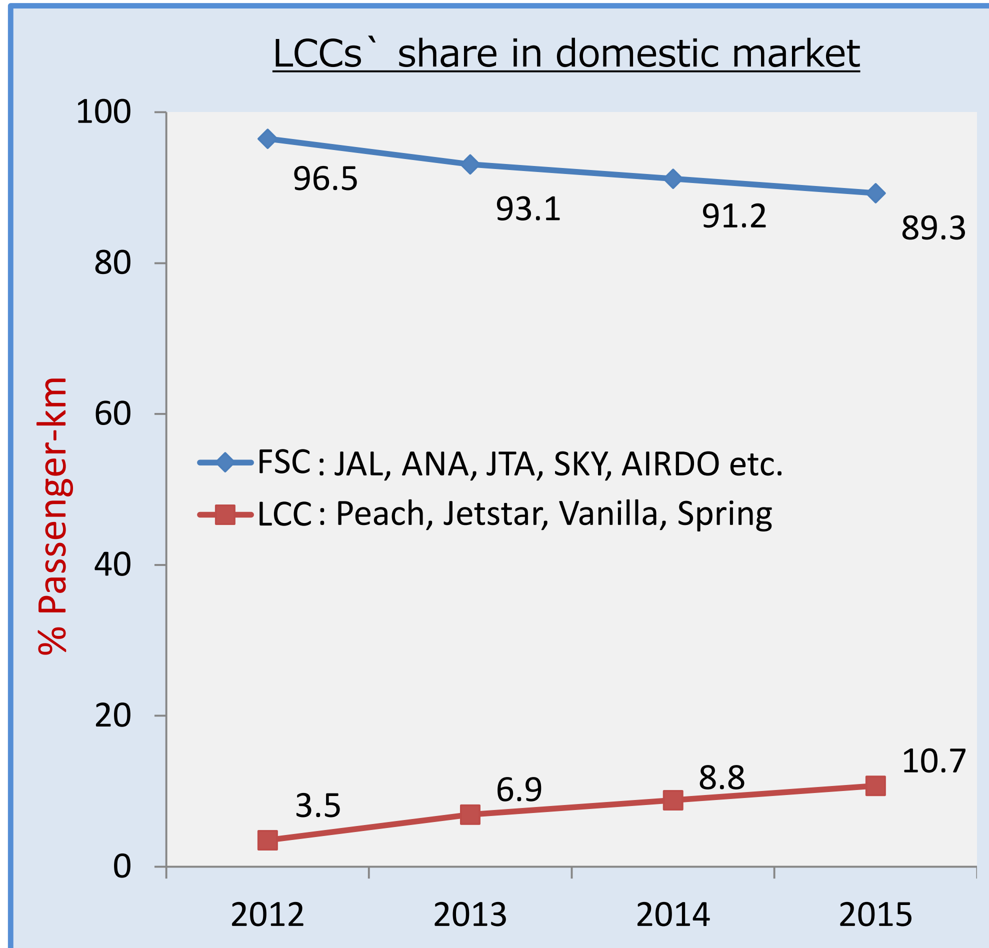
※ Government aims 14% domestic LCC share by 2020*.

交通政策基本計画（2015年）

Introduction

- In Japan, LCCs started as late as 2012, but managed a high growth rate and gained ~10% market share in just 4 years.



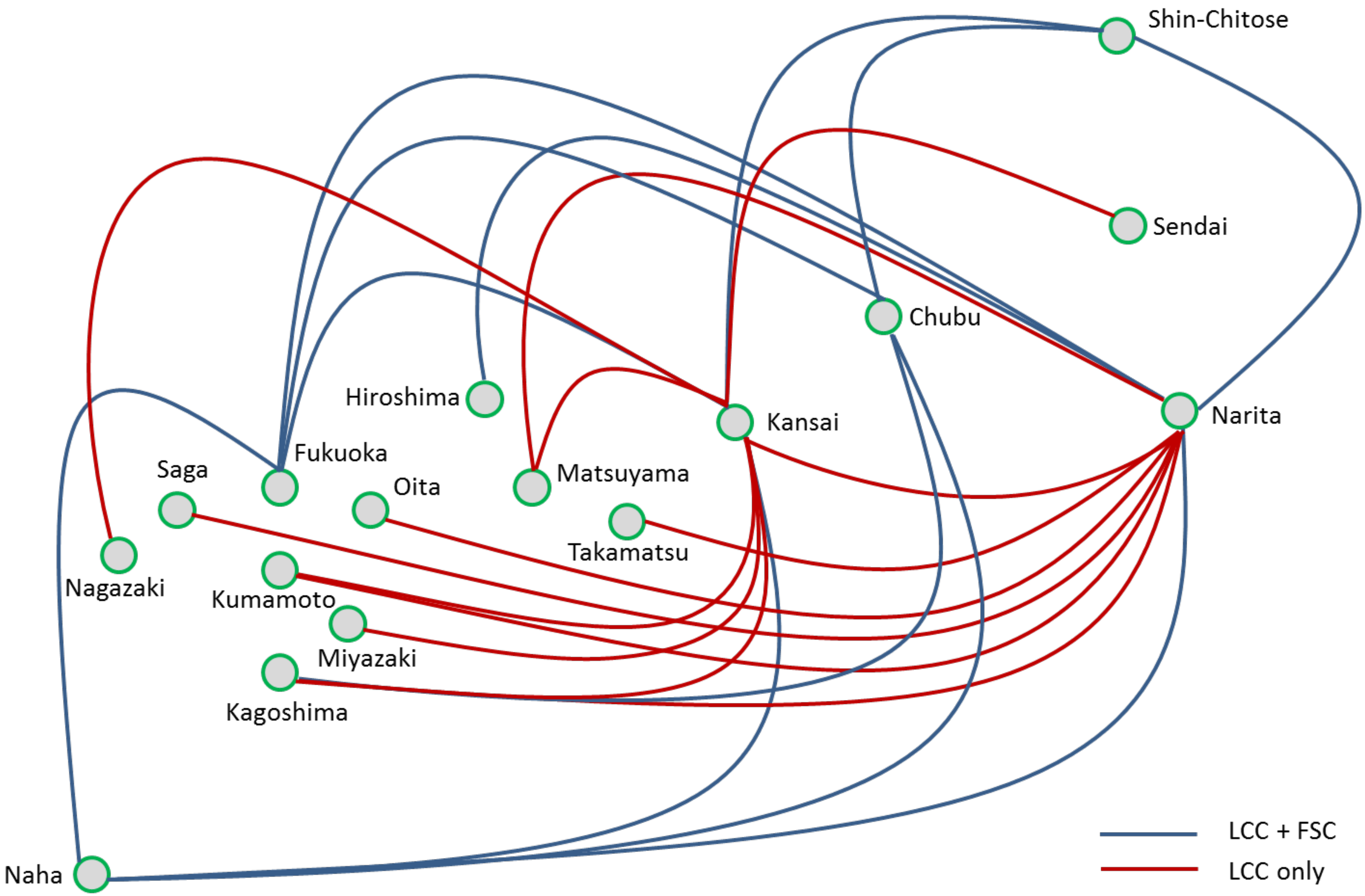


Source: Yoichi Hirotani, Development Bank of Japan

Source: Ministry of Land Infrastructure and Transport

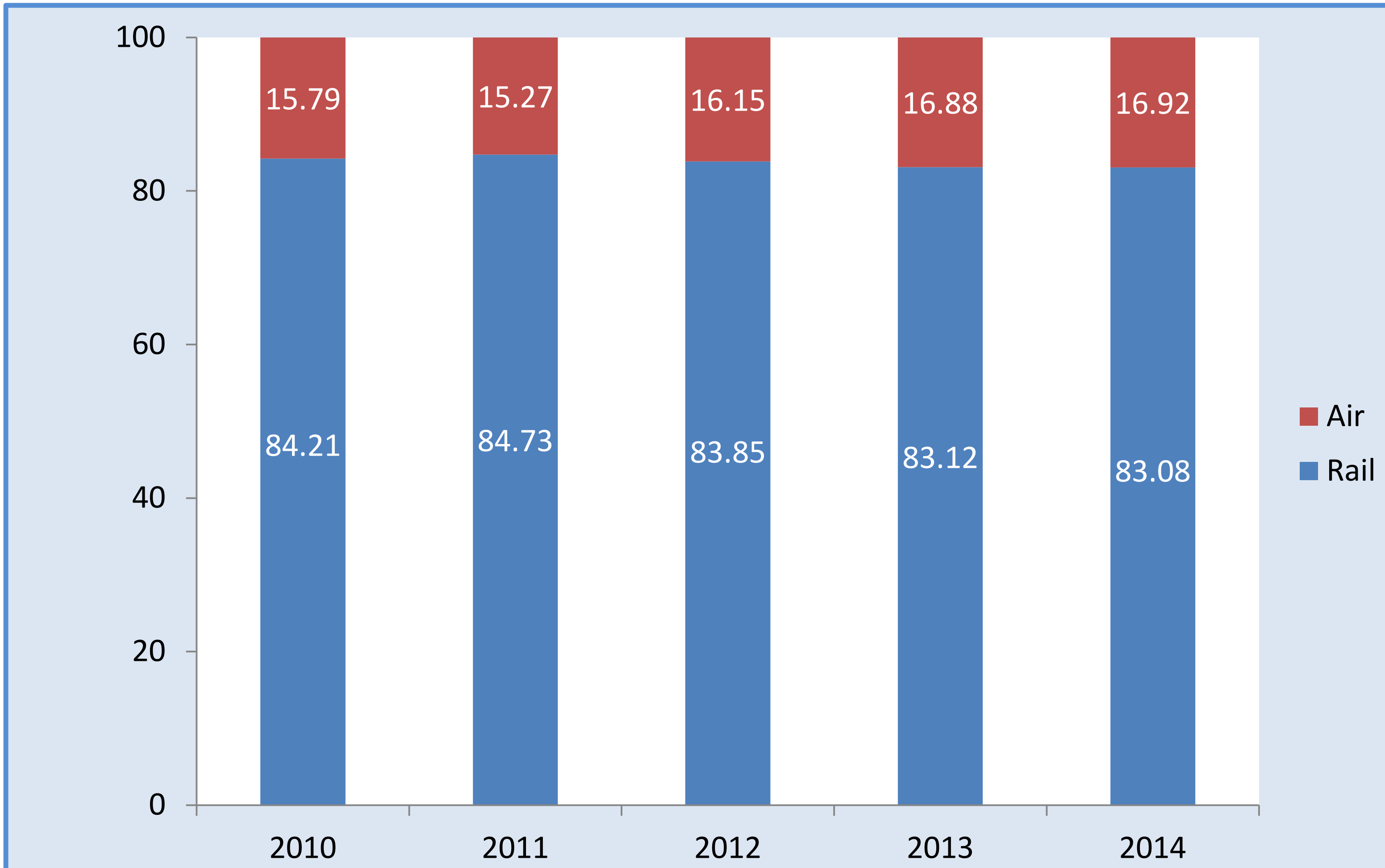
Introduction

- Now, 4 LCC airlines operate 184 domestic flights per day



Introduction Air Rail Market Shares

- Examples from Europe shows that LCC compete with rail, too.
- In Japan, rail market share against air shows a slightly decreasing trend
- Rail operators already being affected by LCC?



Source: 数字で見る鉄道 2016

Research Objective

Contents

- Model Structure
- Model Calibration
- Model Validation

Methodology

- Development of a demand forecasting model for FSC, LCC and rail modes

Growth Scenarios

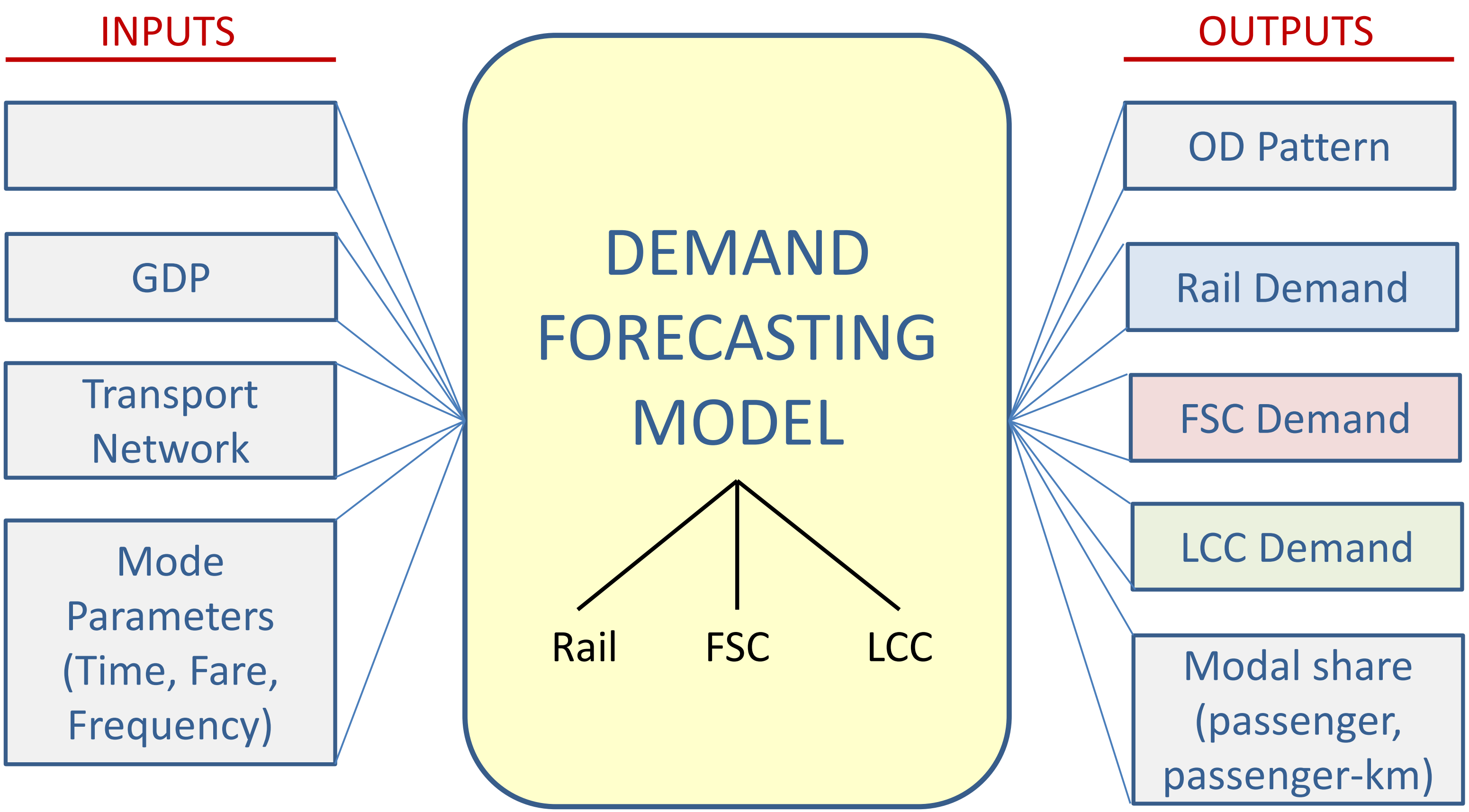
- Setting up LCC growth scenarios for 2020 (by assuming LCCs will increase flight frequencies to get higher market share, while other operators keep the frequencies and fares same)

Analysis

- Analysis of LCC impact by comparing users` benefits (consumer surplus) and operators` loss (revenue change)
- Analysis of slot distribution rule at congested airports

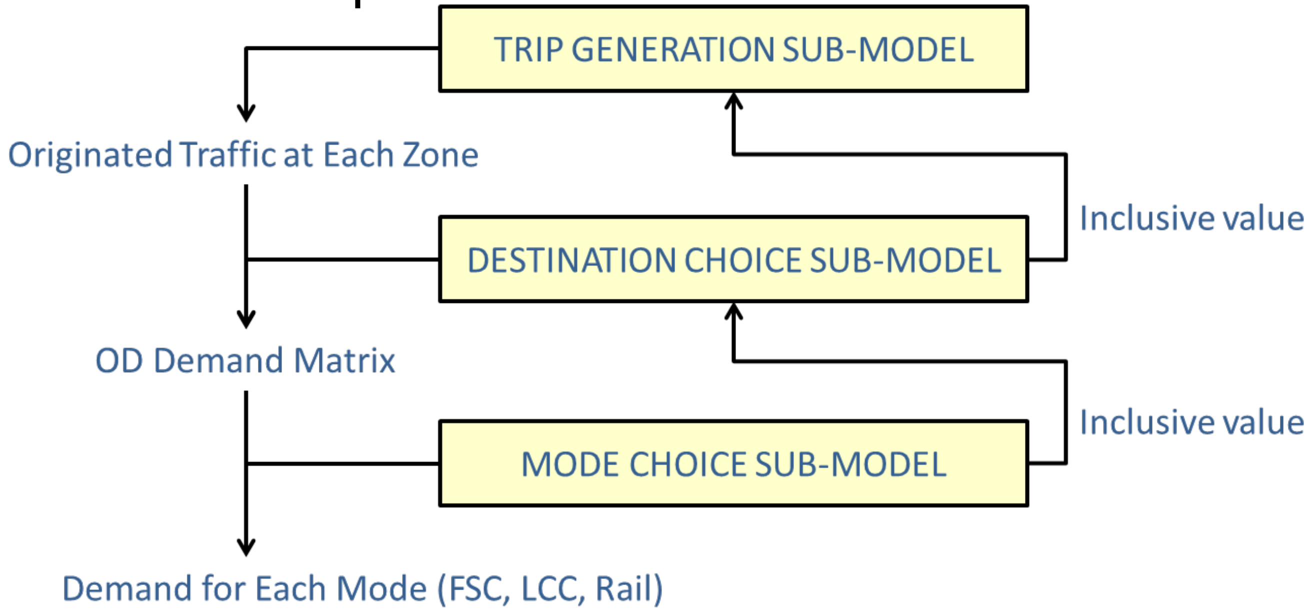
Model Structure

- This model forecasts passenger demand for each mode for each OD pair
- Inputs of the model are: Population, GDP, network structure and modal data such as travel time, fare, service frequency



Model Structure

- The model consists of three sub-models that are interconnected with inclusive values
- Trip generation sub-model forecasts total generated traffic in a zone (prefecture)
- Destination choice sub-model distributes generated traffic to destination zones
- Mode choice sub-model forecasts demand for FSC, LCC and rail for each OD pair



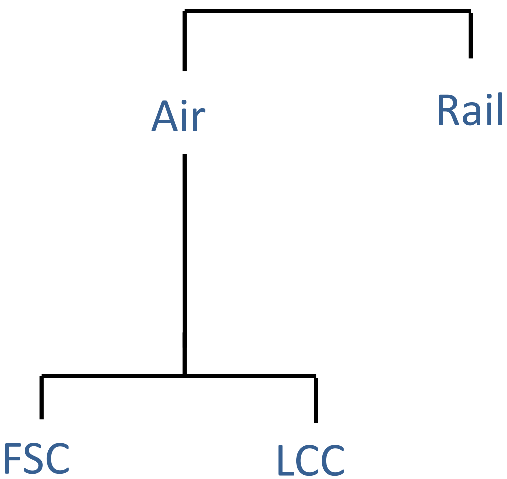
- This sub-model is formulated as a discrete choice model based on random utility theory
- Each individual chooses the mode that gives maximum utility
- In this model, utility of a mode is calculated according to mode attributes only

$$V_{Rail} = \beta_1 * Fare + \beta_{2\_rail} * Time$$

$$V_{FSC} = \beta_1 * Fare + \beta_{2_{air}} * Time + \beta_3 * Inverse\ Frequency + \beta_{4\_FSC}$$

$$V_{LCC} = \beta_1 * Fare + \beta_{2_{air}} * Time + \beta_3 * Inverse\ Frequency + \beta_{4\_LCC}$$

- Choice probabilities are calculated in a nested structure



$$P_i = \frac{e^{\lambda V_i}}{\sum_j e^{\lambda V_j}}$$ Probability of choosing mode i (Air vs Rail)

$$V_{Air} = \frac{1}{\gamma} \ln(e^{\gamma V_{FSC}} + e^{\gamma V_{LCC}})$$ Composite Air utility

$$P_k = PA_{ir} \frac{e^{\gamma V_k}}{\sum_l e^{\gamma V_l}}$$ Probability of choosing mode k (FSC vs LCC)

※ parameters of β and γ will be calibrated using survey data

- This sub-model is also formulated as a discrete choice model
- Each individual chooses a destination that gives maximum utility
- Utility of a destination is calculated according to zone GDP and inclusive value (LS)

$$V_{rs} = g_1 * GDP_s + g_2 * LS_{rs}$$

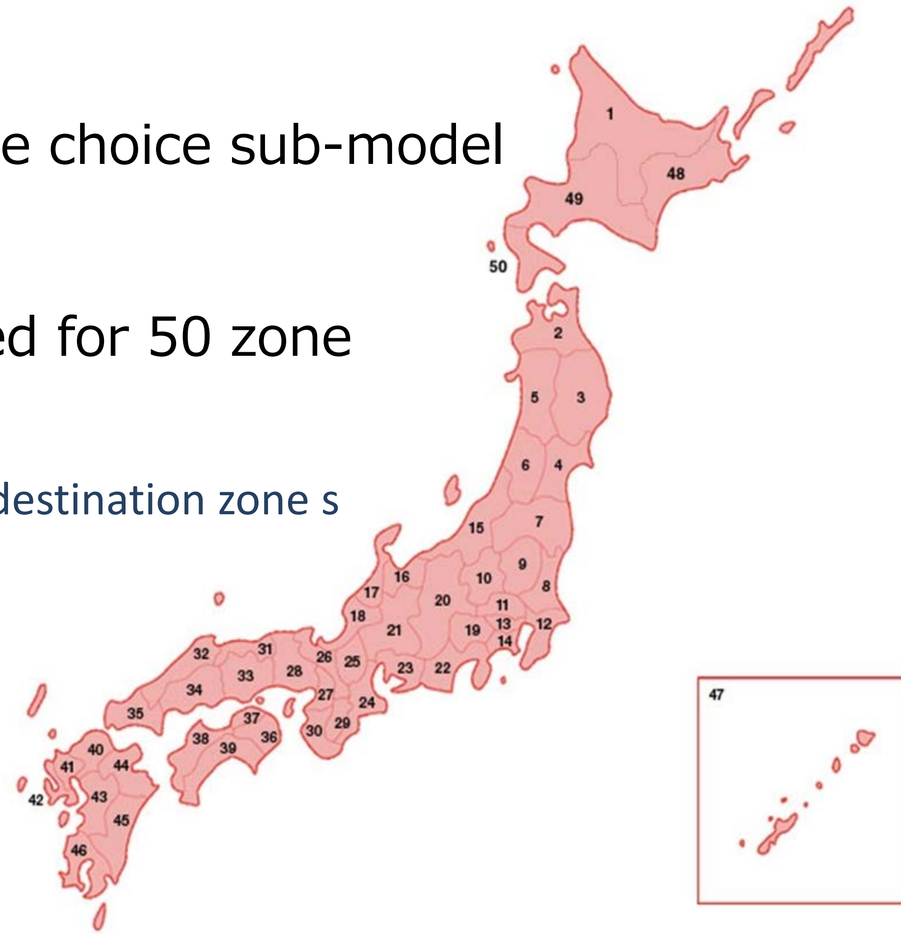
- Inclusive value comes from mode choice sub-model

$$LS_{rs} = \ln(e^{V_{Rail}} + e^{V_{Air}})$$

- Choice probabilities are calculated for 50 zone system

$$P_{rs} = \frac{e^{V_{rs}}}{\sum_n e^{V_{rn}}}$$

Probability of choosing destination zone s from origin zone r



※ parameters of g1 and g2 will be calibrated using survey data

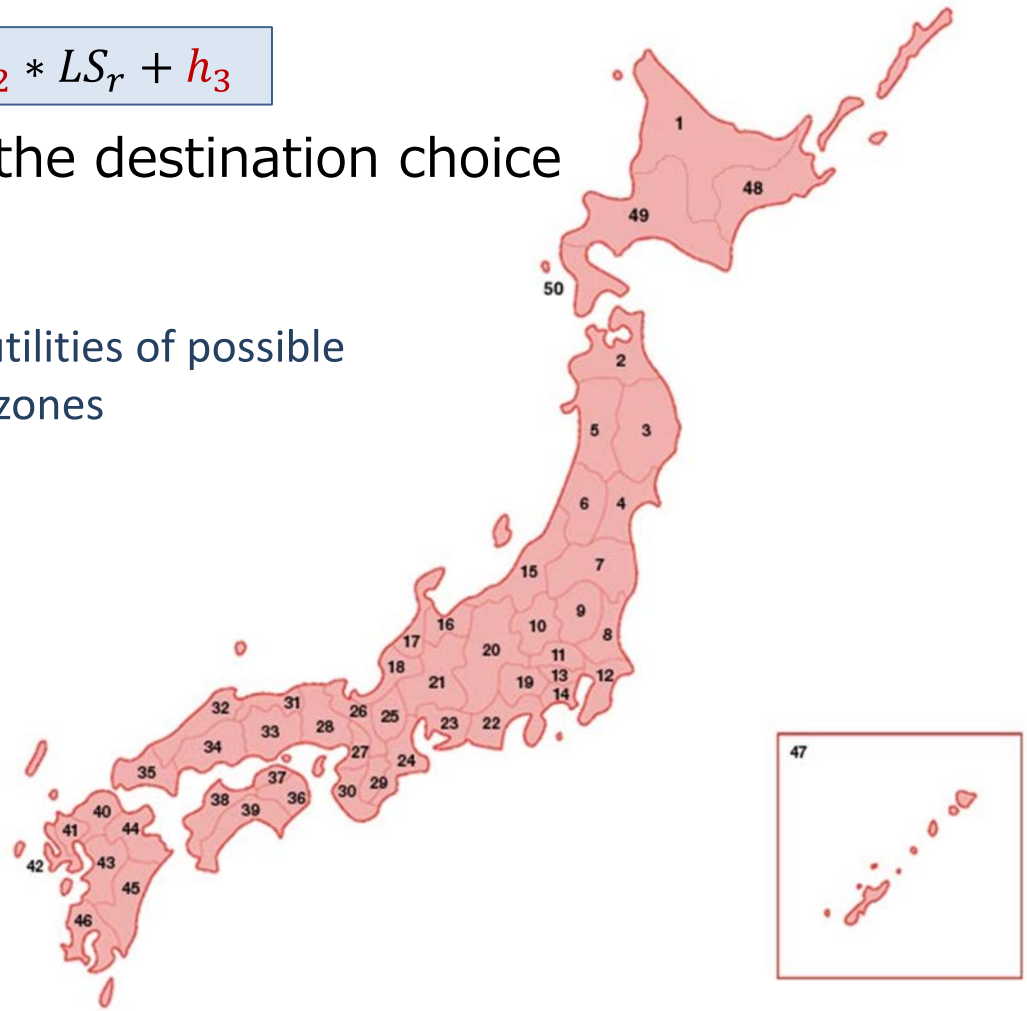
- This sub-model forecasts total generated traffic in a zone using a log-linear regression function
- Explanatory variables are zone population and inclusive value (LS)

$$\ln(G_r) = h_1 * \ln(Population_r) + h_2 * LS_r + h_3$$

- Inclusive value comes from the destination choice sub-model

$$LS_r = \ln\left(\sum_s e^{V_{rs}}\right)$$

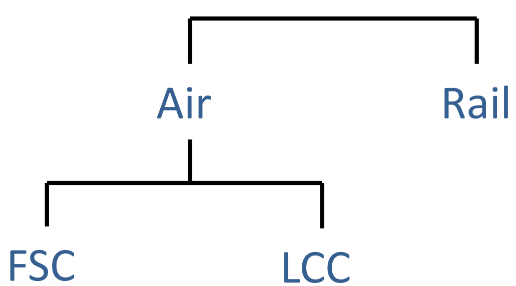
log-sum of utilities of possible destination zones

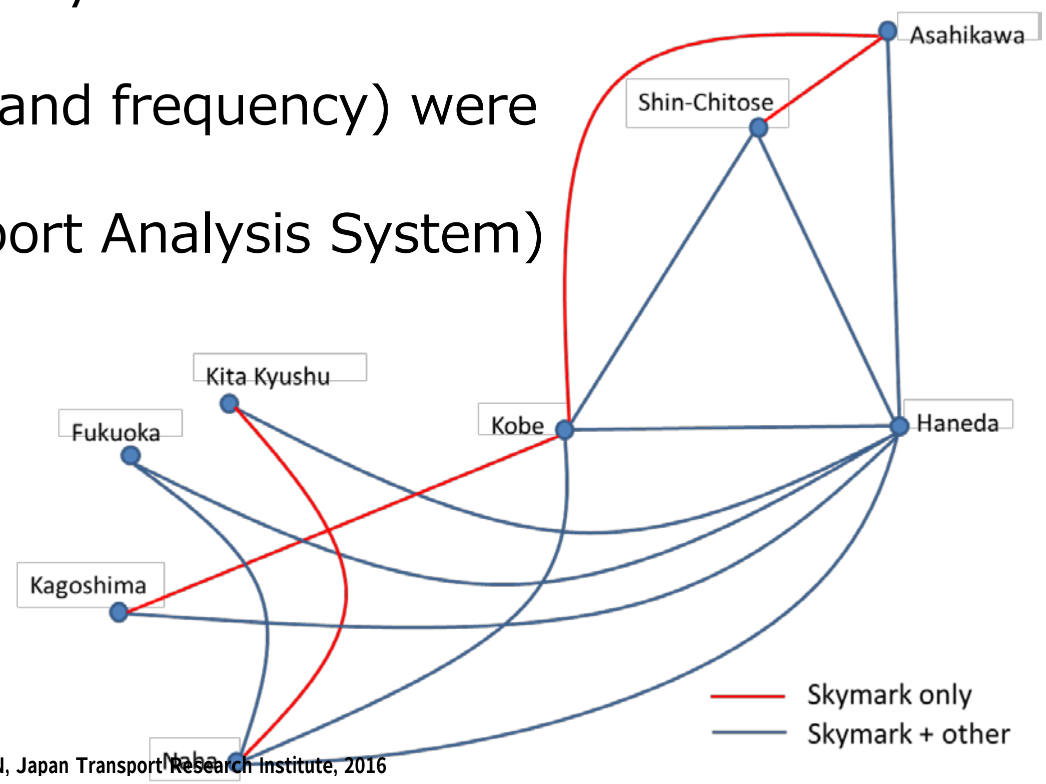


※ parameters of h_1,h_2 and h_3 will be calibrated using survey data

Contents

- The model parameters were calibrated using Inter-regional Travel Survey 2010 (幹線旅客純流動調査)
- This data set contains individual choice data for air, rail, sea, bus and car over 207 zone system covering entire Japan.
- But, there were no LCCs in 2010. As an approximation, Skymark was considered as an LCC as they provided lower ticket fares comparing to other airlines.
- Still, Skymark routes were very few which limited the available data.
- Mode attributes (time, fare and frequency) were obtained using NITAS (National Integrated Transport Analysis System)





Model Calibration (Mode Choice Sub-Model)

INDIVIDUAL Code	CHOICE	ORIGIN Code	DESTINATION code	PURPOSE	RAIL		FSC			LCC		
					TIME	FARE	TIME	FARE	FREQUENCY	TIME	FARE	FREQUENCY
1	FSC	491	11	Business	1.68	0.47	5.87	2.84	0.17	2.28	0.89	0.5
2	FSC	491	11	Business	1.68	0.47	5.87	2.84	0.17	2.28	0.89	0.5
3	FSC	233	461	Business	8.78	2.53	3.52	3.47	0.14	5.48	2.33	0.33
4	FSC	251	461	Other	7.5	2.26	3.47	2.92	0.09	3.77	1.56	0.33
5	LCC	251	461	Business	7.5	2.26	3.47	2.92	0.09	3.77	1.56	0.33
6	LCC	261	461	Business	7.42	2.25	3.3	2.87	0.09	3.67	1.52	0.33
7	LCC	271	452	Other	8.88	2.23	2.6	2.54	0.11	3.33	1.54	0.33
8	LCC	271	455	Business	11.03	2.26	2.83	2.62	0.11	3.3	1.53	0.33
9	LCC	271	461	Other	7.3	2.18	2.77	2.87	0.09	3.27	1.49	0.33
10	LCC	272	461	Other	7.63	2.2	2.93	2.87	0.09	3.3	1.49	0.33
11	LCC	281	432	Other	5.37	1.72	3.22	2.7	0.13	3.37	1.61	0.33
~	~	~	~	~	~	~	~	~	~	~	~	~
2667	RAIL	261	461	Business	7.42	2.25	3.3	2.87	0.09	3.67	1.52	0.33
2668	RAIL	491	13	Other	1.68	0.47	5.87	2.84	0.17	2.28	0.89	0.5

Calibration Result	Business Trip Purpose		Other Trip Purposes	
	Coefficient	t-stat	Coefficient	t-stat
β_1: Total Travel Cost (10,000 \)	-1.92	-4.04	-1.48	-5.37
β_{2_rail}: Total Rail Travel Time (Hours)	-0.427	-4.69	-0.814	-14.40
β_{2_air}: Total Air Travel Time (Hours)	-1.18	-6.27	-1.08	-10.49
β_3: Inverse Frequency	-5.68	-4.86	-3.21	-5.25
β_{4_FSC}: Constant (FSC)	4.30	4.64	0.209	0.34
β_{4_LCC}: Constant (LCC)	1.61	1.98	-1.77	-3.73
λ (constrained)	1			
γ	1.6	2.38	2.1	5.04
Rho-squared	0.773		0.738	
Initial log-likelihood	-2931.1		-6521.4	
Final log-likelihood	-665.1		-1707.1	
Number of Observations	2668		5936	
Value of Time (Air) (\/hour)	6,150		7,300	
Value of Time (Rail) (\/hour)	2,200		5,500	
Hit Ratio (%)	90.3		85.4	

- Model calibration was carried out separately for business purpose travelers and other purpose travelers.
- Test results show that coefficients are significant except FSC constant for other purpose travelers and signs of all coefficients are meaningful.
- But, Value of Time calculation gives contradictory results. Normally higher time values are expected for business purpose travelers compared to other purpose travelers.

※ Results indicate a poor model calibration due to the limited data. I hope to overcome this issue by using forthcoming Inter-regional Travel Survey 2015 data

- Test results show that coefficients are highly significant
- Rho-squared is acceptable considering large number of data

Calibration Result	Business Trip Purpose		Other Trip Purposes	
	Coefficient	t-stat	Coefficient	t-stat
g1: GDP of Destination Zone (10^ 13 \ )	0.351	559.76	0.316	621.45
g2: Inclusive Value of Transportation	0.478	308.52	0.303	381.75
Rho-squared	0.222		0.163	
Initial log-likelihood	-955027.4		-1578495.1	
Final log-likelihood	-743396.8		-1320418.7	
Number of Observations	249013		410285	

※ Results indicate good model calibration

- Test results show that coefficients are significant
- Zone GDP was used instead of Zone Population for other purpose travelers as it provided better results
- Inclusive Value of Transportation is not used for other purpose travelers as test results were insignificant
- Model fitness of R-squared is also high

Calibration Result	Business Trip Purpose		Other Trip Purposes	
	Coefficient	t-stat	Coefficient	t-stat
h1: Zone Population (million people)	1.17	20.55		
h1: Zone GDP (10^ 13 \ )			0.974	23.68
h2: Inclusive Value of Transportation	0.33	3.08		
h3: Constant	5.95	24.0	8.038	207.7
Dummy for Miyagi	0.60	2.69		
Dummy for Shikoku			-0.61	-4.21
R-squared	0.923		0.933	
Number of Observations	50		50	

※ Results indicate good model calibration

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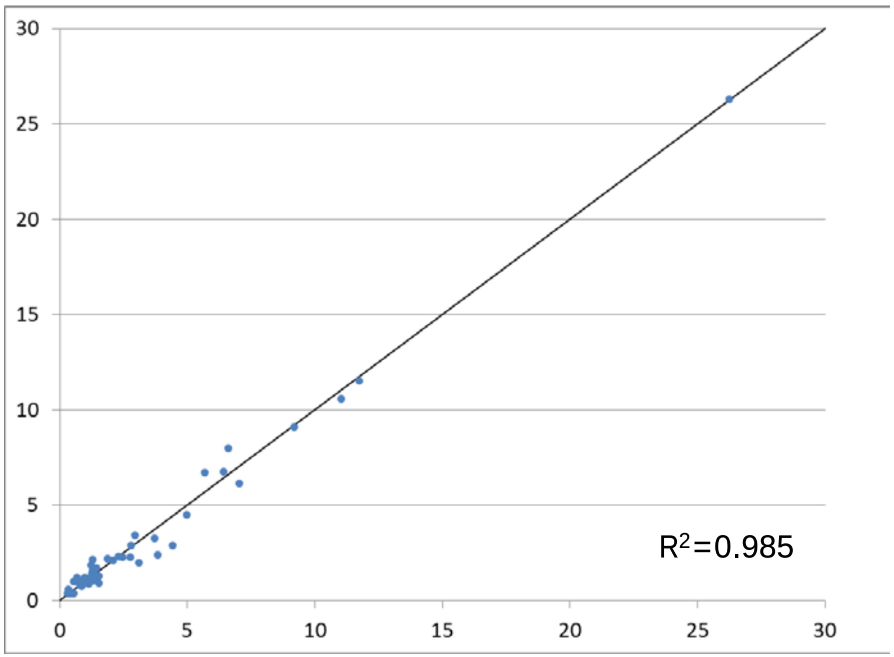
- Figures show observed demand vs estimated demand for each zone
- R-squared indicates that model fitness is high

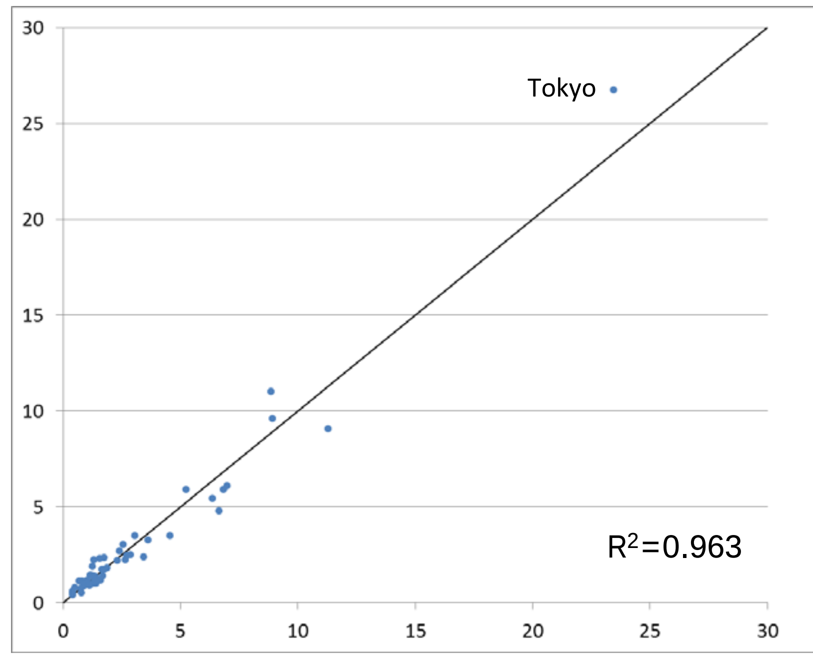
Business Purpose Travelers

Estimated demand



Observed demand (Million passengers per year)

Other Purpose Travelers

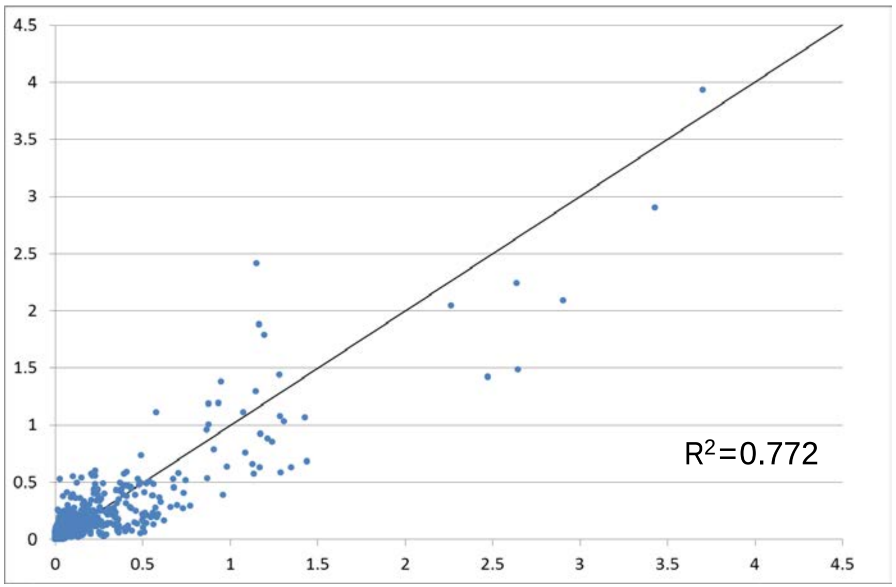


Observed demand (Million passengers per year)

- Figures show observed demand vs estimated demand for OD pair
- R-squared indicates that model fitness is acceptable

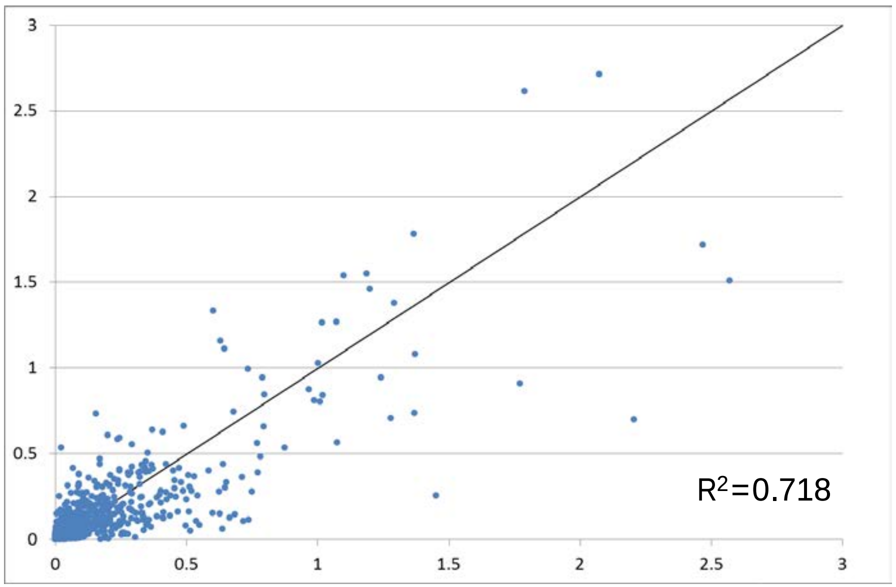
Business Purpose Travelers

Estimated demand



Observed demand (Million passengers per year)

Other Purpose Travelers

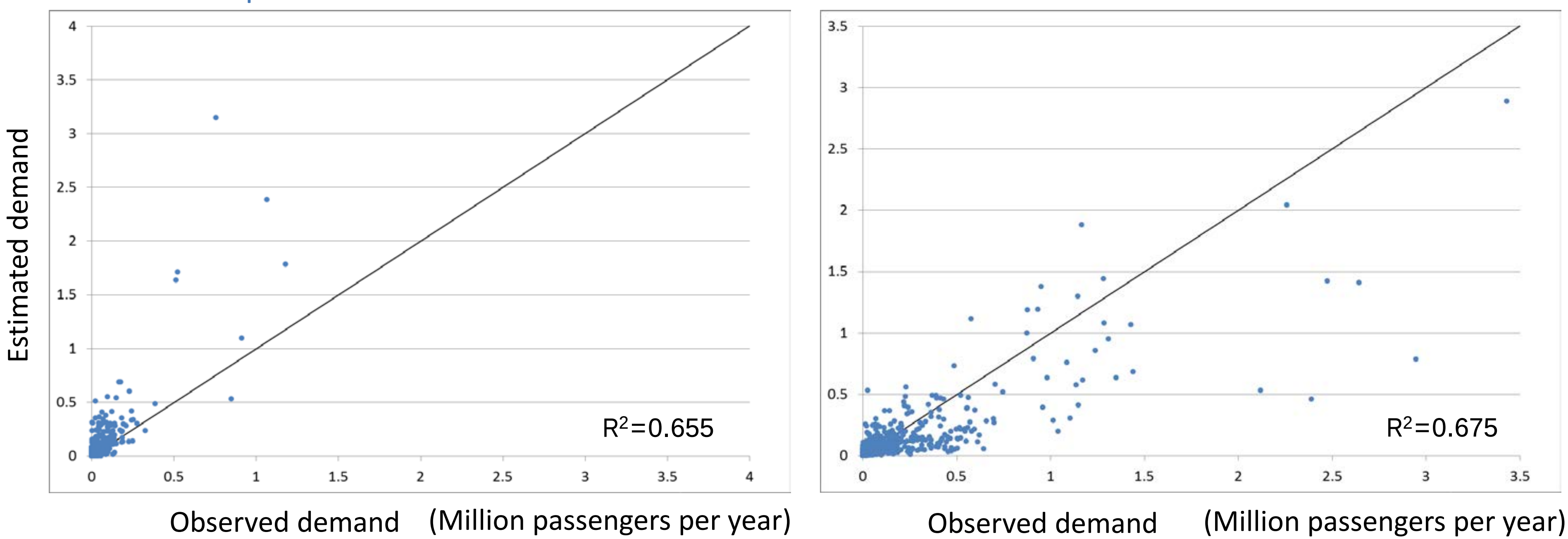


Observed demand (Million passengers per year)

- Figures show observed OD demand vs estimated OD demand for air and rail modes
- The model slightly overestimates air demand and underestimates rail demand
- Fitness of the model is poor and needs to be improved in future studies

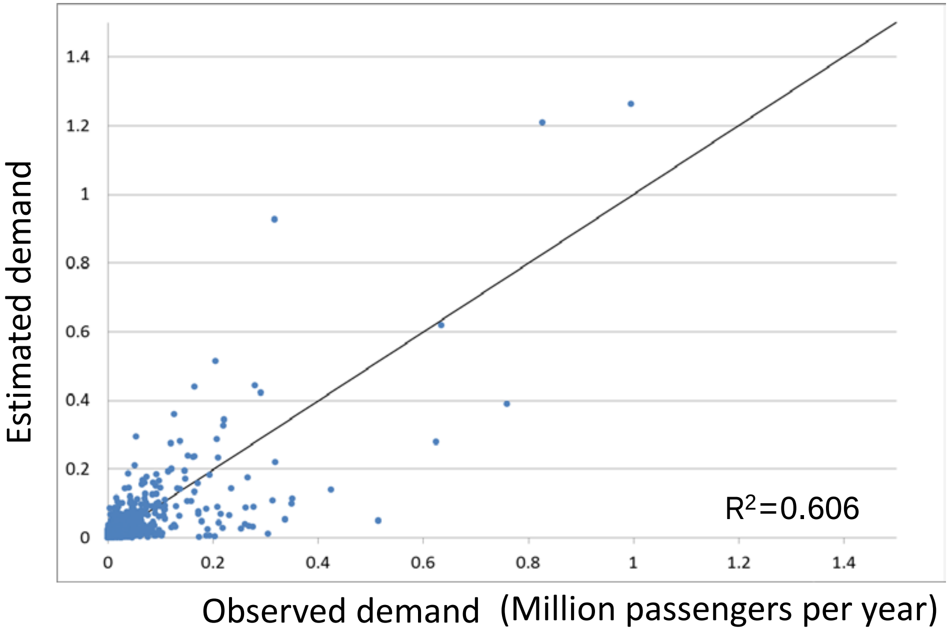
Business Purpose Travelers - Air

Business Purpose Travelers - Rail

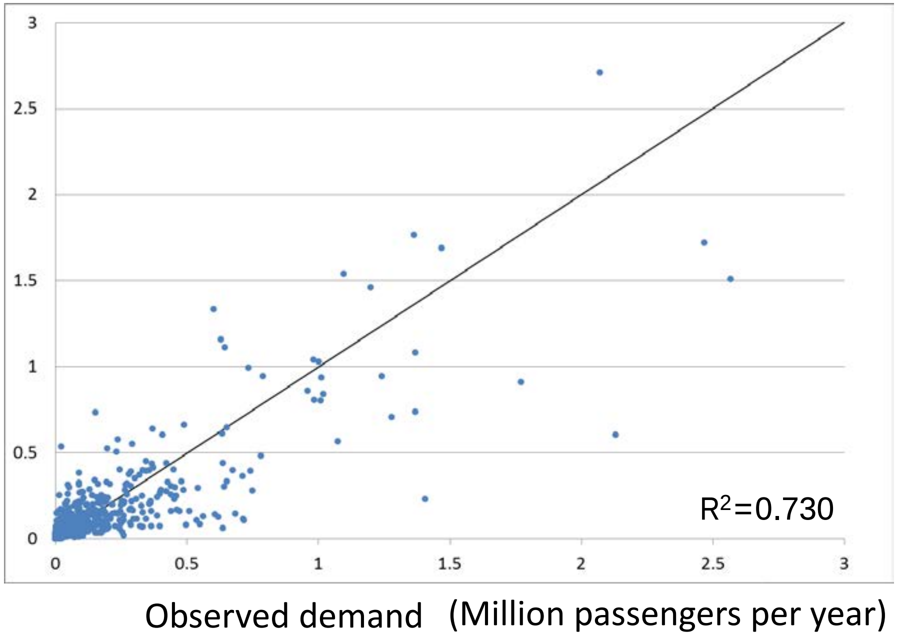


- Figures show observed OD demand vs estimated OD demand for air and rail modes
- R-squared is good for rail demand but low for air demand
- Fitness of the model is poor and needs to be improved in future studies

Other Purpose Travelers - Air



Other Purpose Travelers - Rail



- Fitness of Trip Generation Sub-model is high and fitness of Destination Choice Sub-model is acceptable.

- But, fitness of Mode Choice Sub-model is not sufficient, probably due to data limitation or other issues.

- Moreover, Value of Time calculation for other purpose travelers is higher than for business purpose travelers, which is inconsistent with existing literature. This must be improved in future studies

- I hope to improve model calibration using Inter-regional Travel Survey 2015 data because it contains LCC alternatives.

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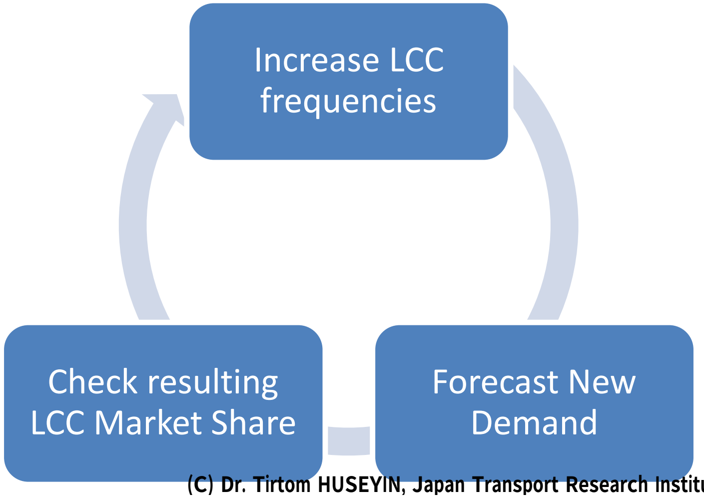
LCC Scenarios for 2020

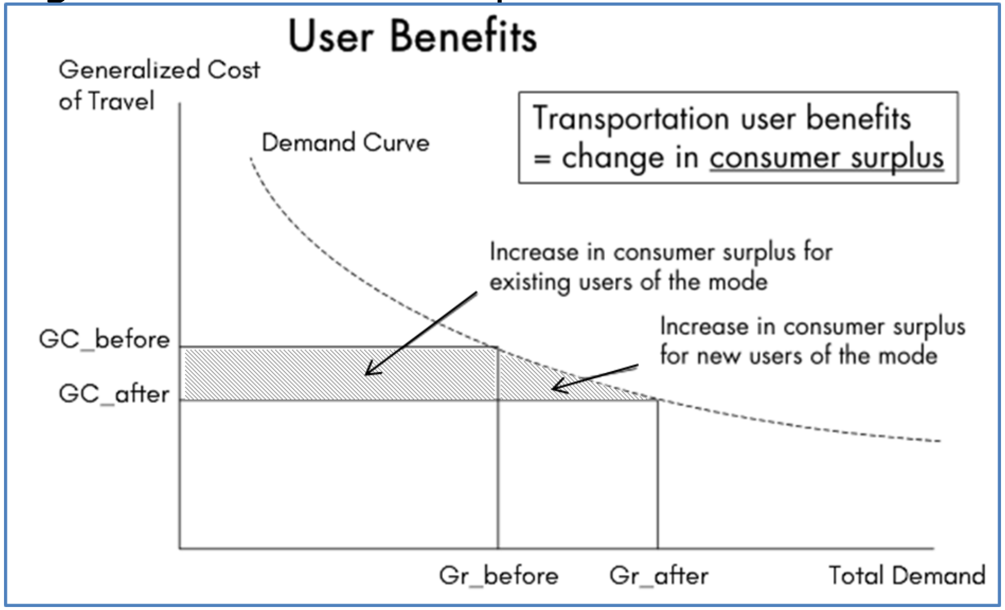


- Cost to operators: operators` revenue change
- Benefit to passengers: total consumer surplus
- Regional Disparity: Zone specific consumer surplus

※ Consumer Surplus is defined as the difference between what a group of users is willing to pay in terms of travel costs and what they actually pay.

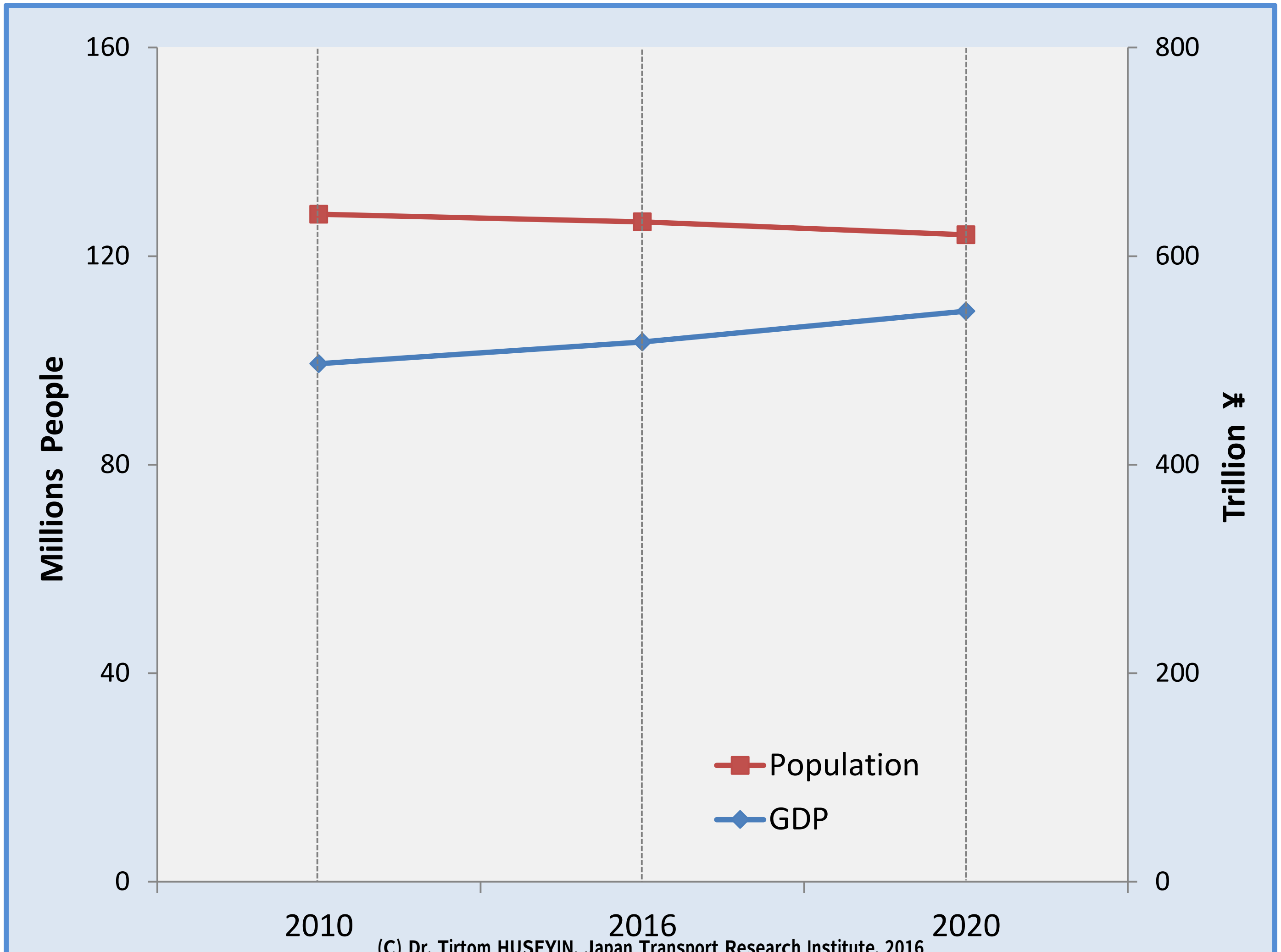
※ In a benefit cost analysis, the change in consumer surplus is attributable to a transportation improvement.

- Figures show the demand curve of passengers. Area below the curve gives willingness-to-pay
- Area between demand curve and generalized cost line gives consumer surplus
- A decrease in generalized cost cause an increase in demand. Then shaded area gives change in consumer surplus

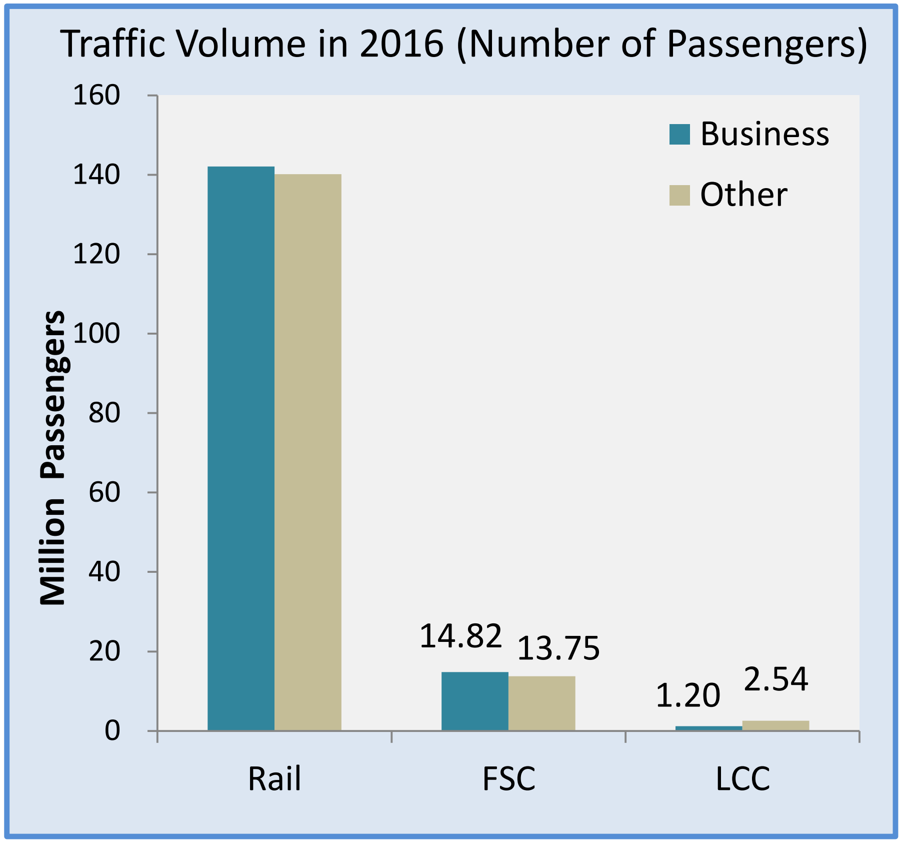


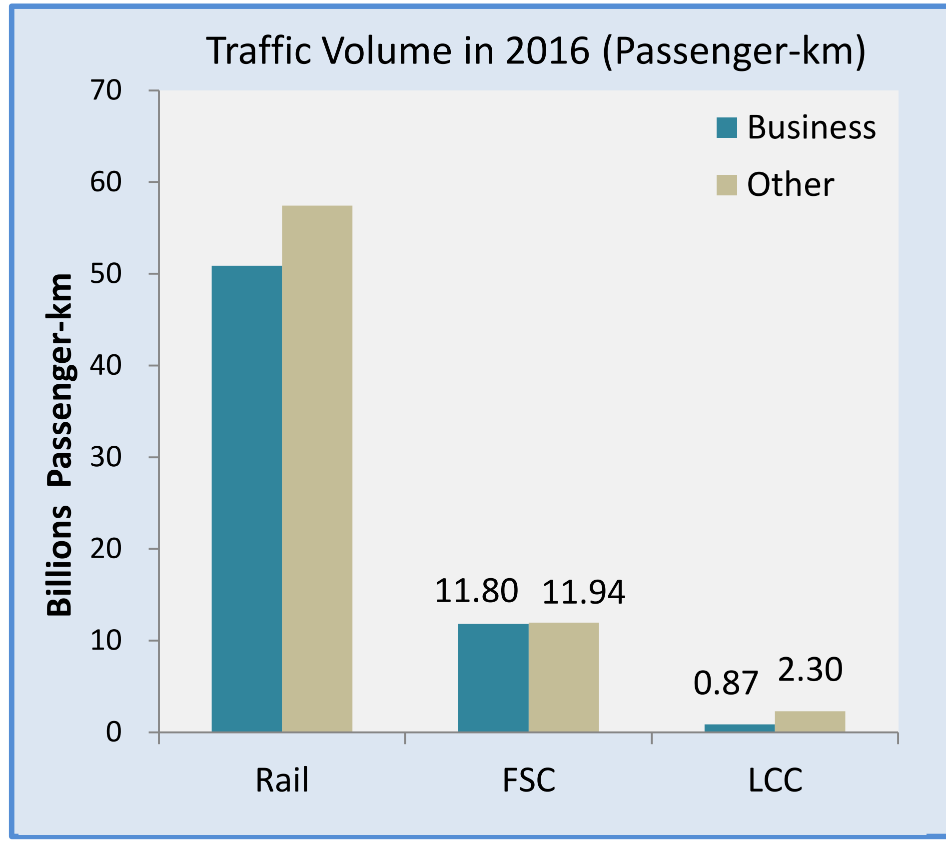
Consumer Surplus (for Zone r)	=	$\frac{1}{2}(G_{r\_after}+G_{r\_before})(GC_{after}-GC_{before})$
Generalized Cost (for Zone r)	=	$\frac{-1}{\beta_1}\ln\left(\sum e^{V_{rs}}\right)$

- Figure shows the population and GDP trends between 2010 and 2020
- It is expected that total population will decrease to 124 million, while GDP will increase to 547 trillion¥ until 2020



- Figures show the traffic volumes in 2016, forecasted by the model.
- Due to the issues in model calibration, air-rail share may not represent the actual situation. But, share between FSC and LCC is consistent with statistics.





Share within air sector	
FSC Share	LCC share
88.4 %	11.6%

Share within air sector	
FSC Share	LCC share
88.2%	11.8%

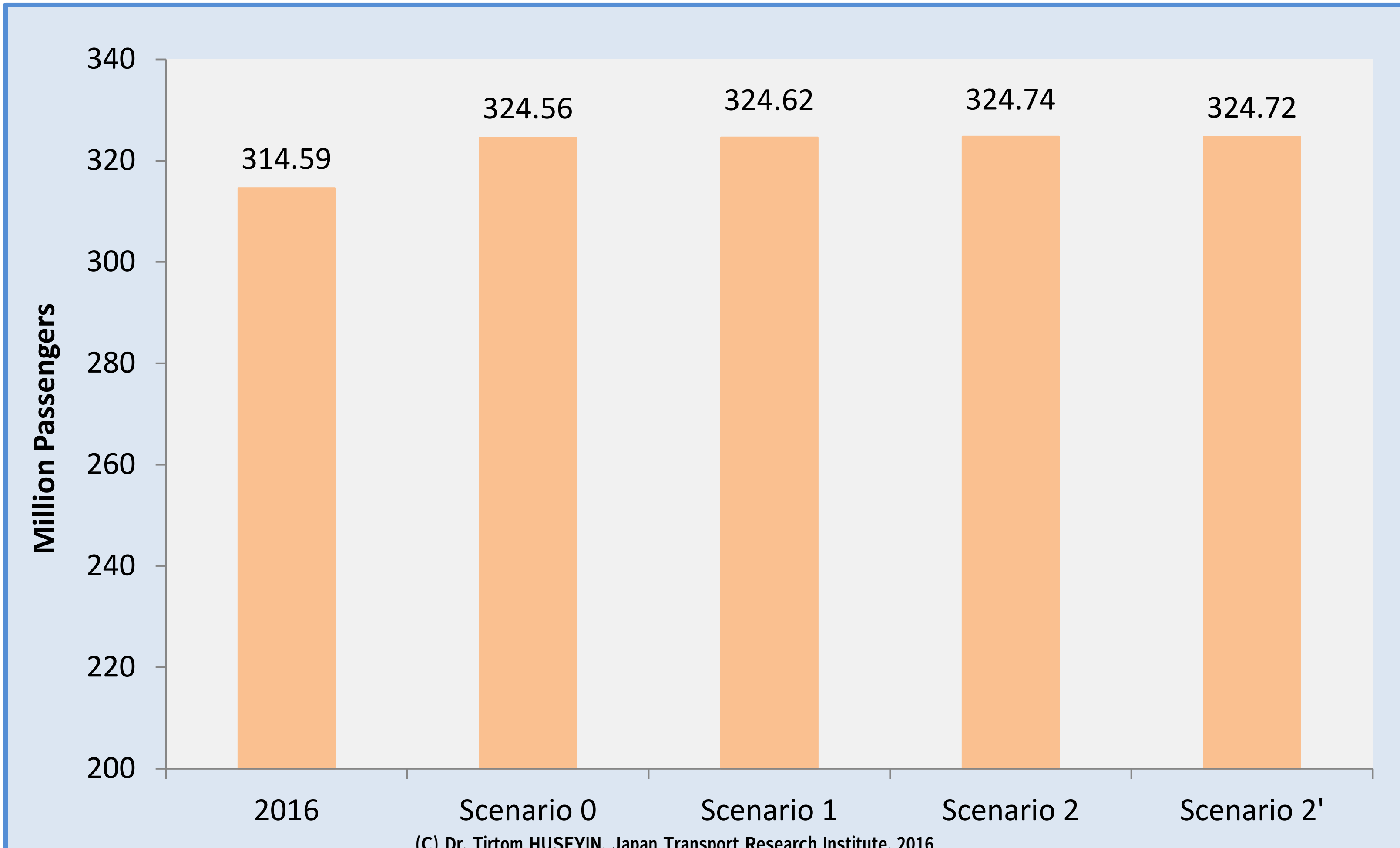
- Table shows the LCC routes frequencies and fares in 2016, in Scenario 1 and in Scenario 2
- 45% frequency increase is enough to reach 15% market share. But, 160% frequency increase is necessary to reach 20% market share
- In a more feasible case, 88% frequency increase combined with 5% fare discount is enough to get 20% market share (Scenario 2’)

Route		LCC Frequencies				LCC Fares			
Origin	Destination	2016	Scenario 1	Scenario 2	Scenario 2'	2016	Scenario 1	Scenario 2	Scenario 2'
Kansai	Shinchitose	7	10	18	13	19,000	19,000	19,000	18,050
Kansai	Fukuoka	5	7	13	9	12,000	12,000	12,000	11,400
Kansai	Naha	6	9	16	11	19,000	19,000	19,000	18,050
Fukuoka	Naha	2	3	5	4	15,700	15,700	15,700	14,915
Narita	Shinchitose	13	19	34	24	15,900	15,900	15,900	15,105
Narita	Kansai	8	12	21	15	12,600	12,600	12,600	11,970
Narita	Fukuoka	10	15	26	19	17,200	17,200	17,200	16,340
~	~	~	~	~	~	~	~	~	~
Kansai	Kagoshima	2	3	5	4	15,000	15,000	15,000	14,250
		Increase rate:	45%	160%	88%			Discount rate:	5%

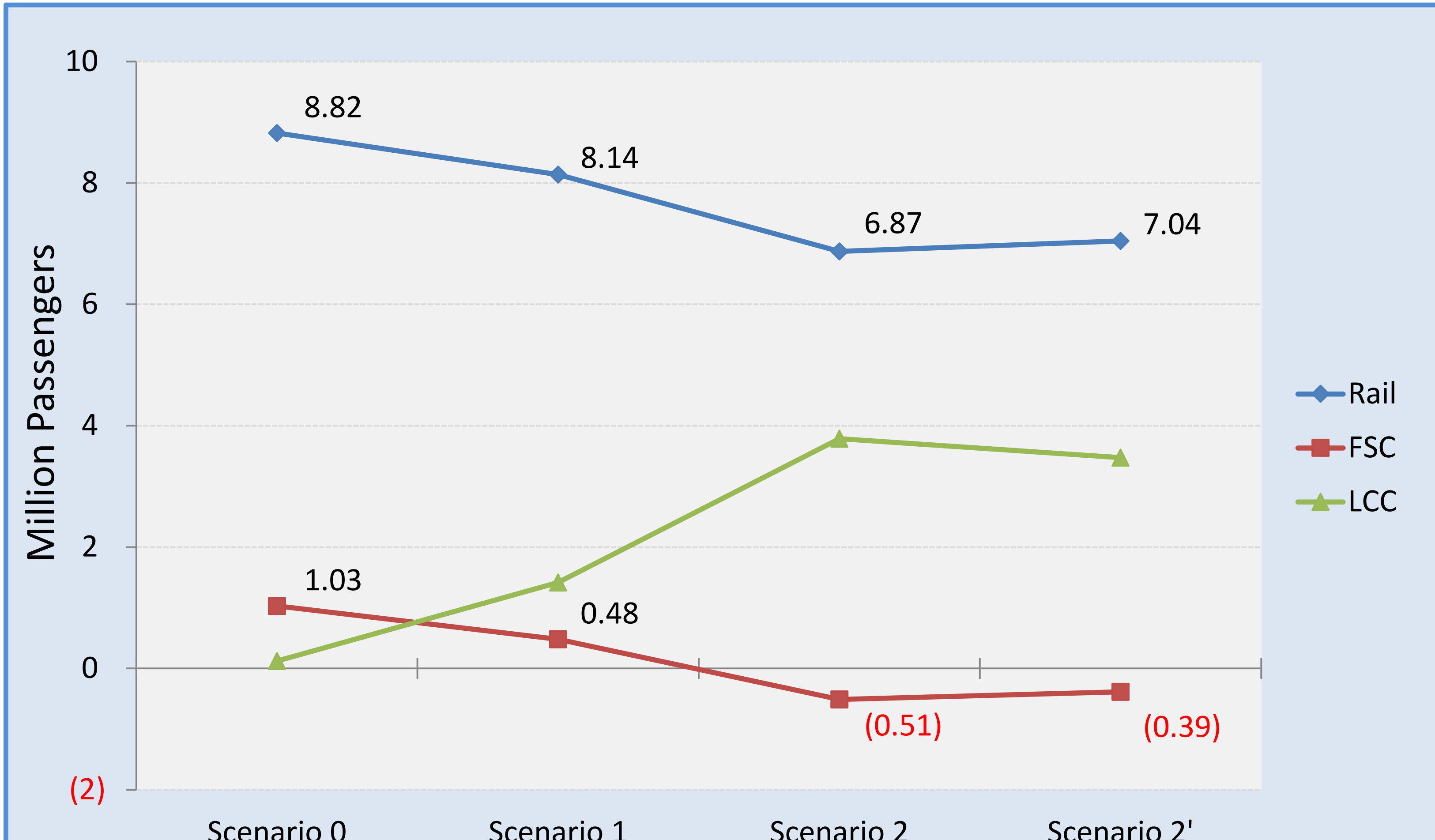
- Table shows the impact of increasing LCC frequency and decreasing fare on Kansai-Fukuoka route
- Scenario 0 case shows situation in 2020 assuming same mode parameters with 2016
- Both rail and FSC lose some passengers to LCC, but impact on FSC is higher
- Change in total passenger numbers indicate the amount of induced traffic by LCC growth

Kansai-Fukuoka	2016	2020 Scenario 0	2020 Scenario 1	2020 Scenario 2	2020 Scenario 2'
LCC Frequency	5	5	7	13	9
LCC Fare (\ )	12,000	12,000	12,000	12,000	11,400
Rail Passenges	342,418	353,683	350,714 (-2,969)	345,448 (-8,235)	346,437 (-7,246)
FSC Passengers	187,692	189,440	182,507 (-6,933)	170,599 (-18,841)	173,158 (-16,282)
LCC Passengers	21,924	22,238	34,548 (+12,310)	56,329 (+33,957)	51,505 (+29,267)
Total Passengers	552,034	565,361	567,769 (+2,408)	572,376 (+7,015)	571,100 (+5,739)

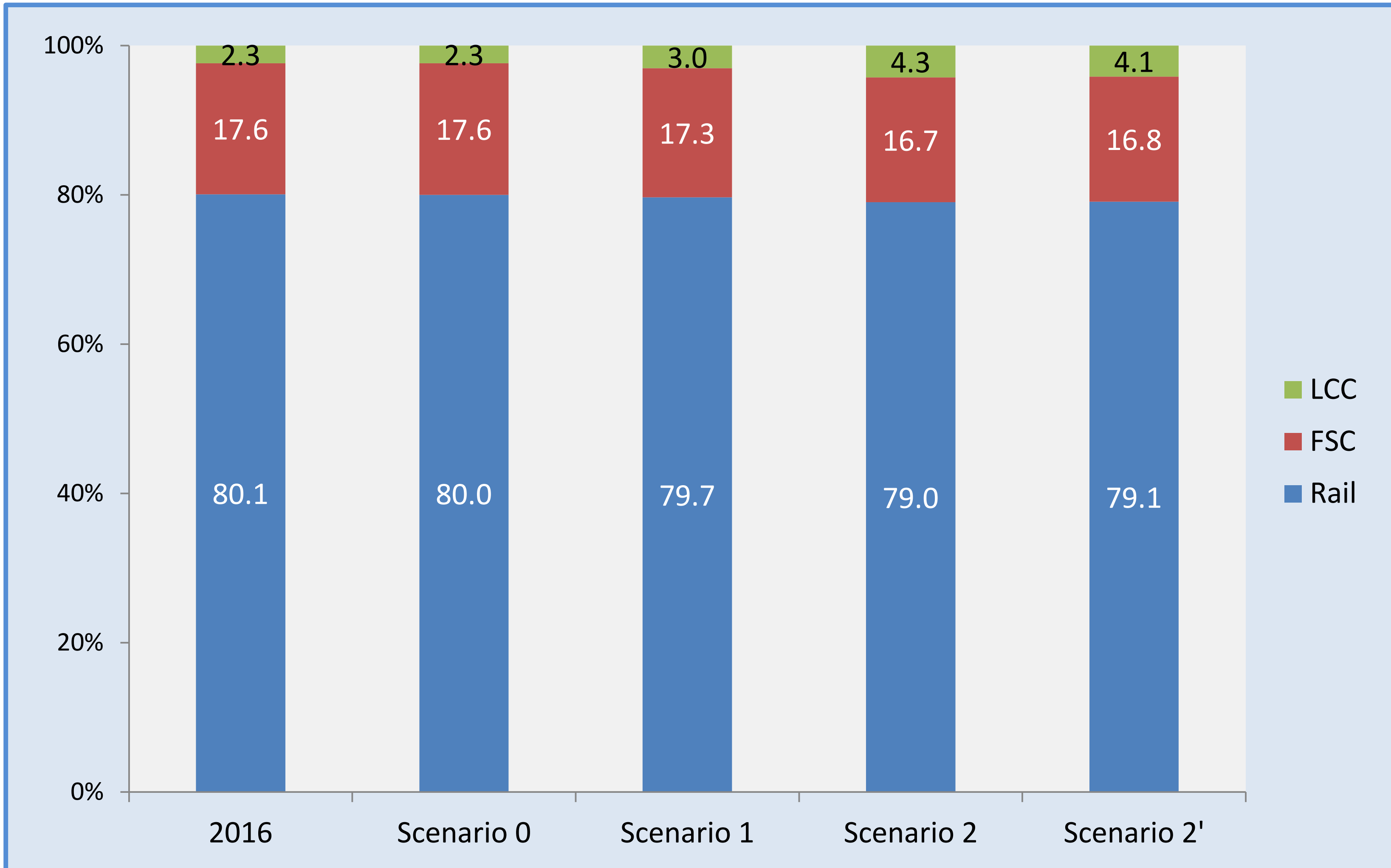
- Scenario 0 shows the combined impact of population decrease and GDP growth.
- Compared to Scenario 0, total demand is increased by 0.02% in Scenario 1 and 0.05% in Scenario 2'



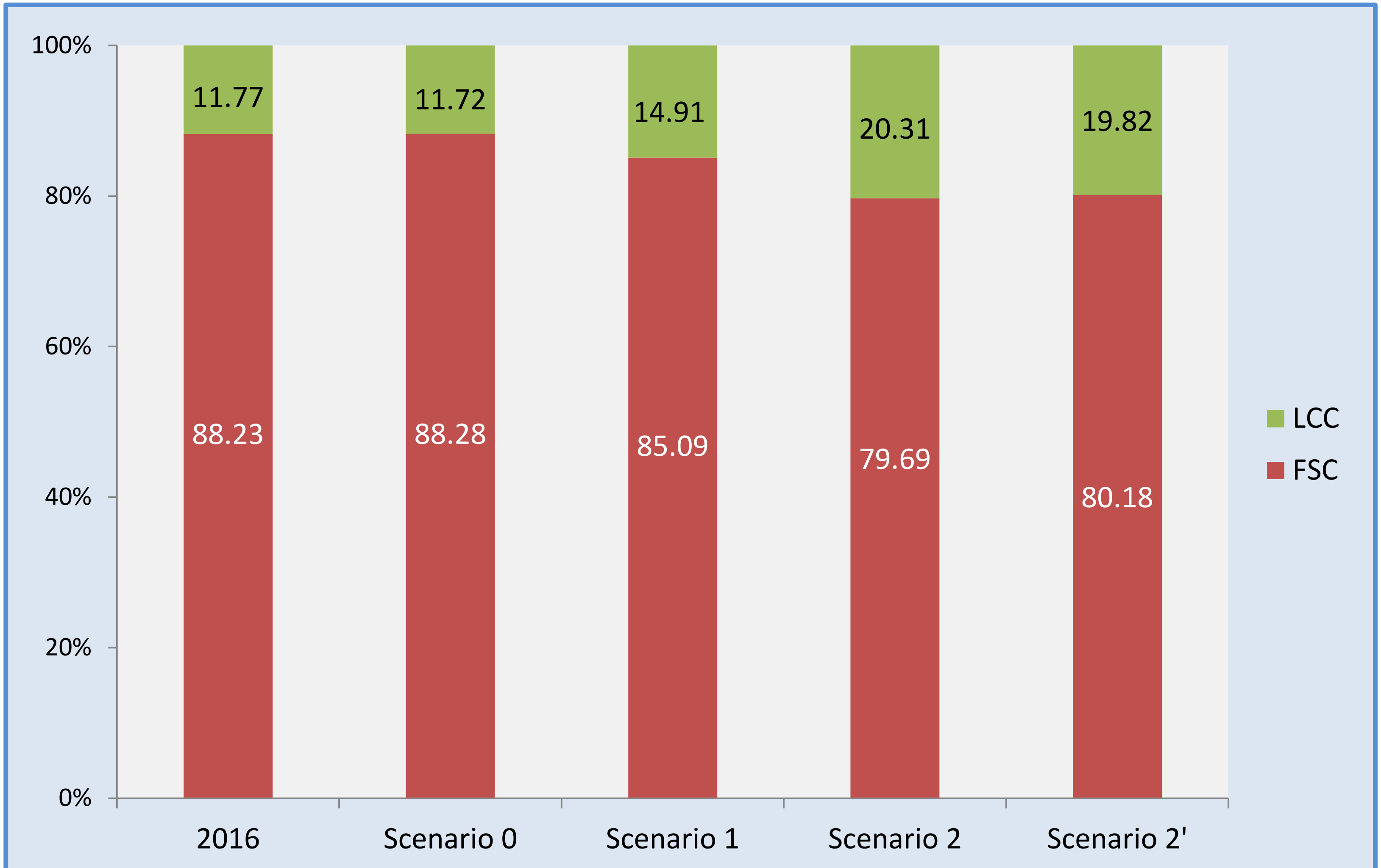
- Compared to Scenario 0, rail loses 0.2% passengers in Scenario 1 and 0.6% in Scenario 2', while FSC loses 1.8% and 4.8% respectively.
- LCCs passenger numbers increase by 34% in Scenario 1 and 87% in Scenario 2'



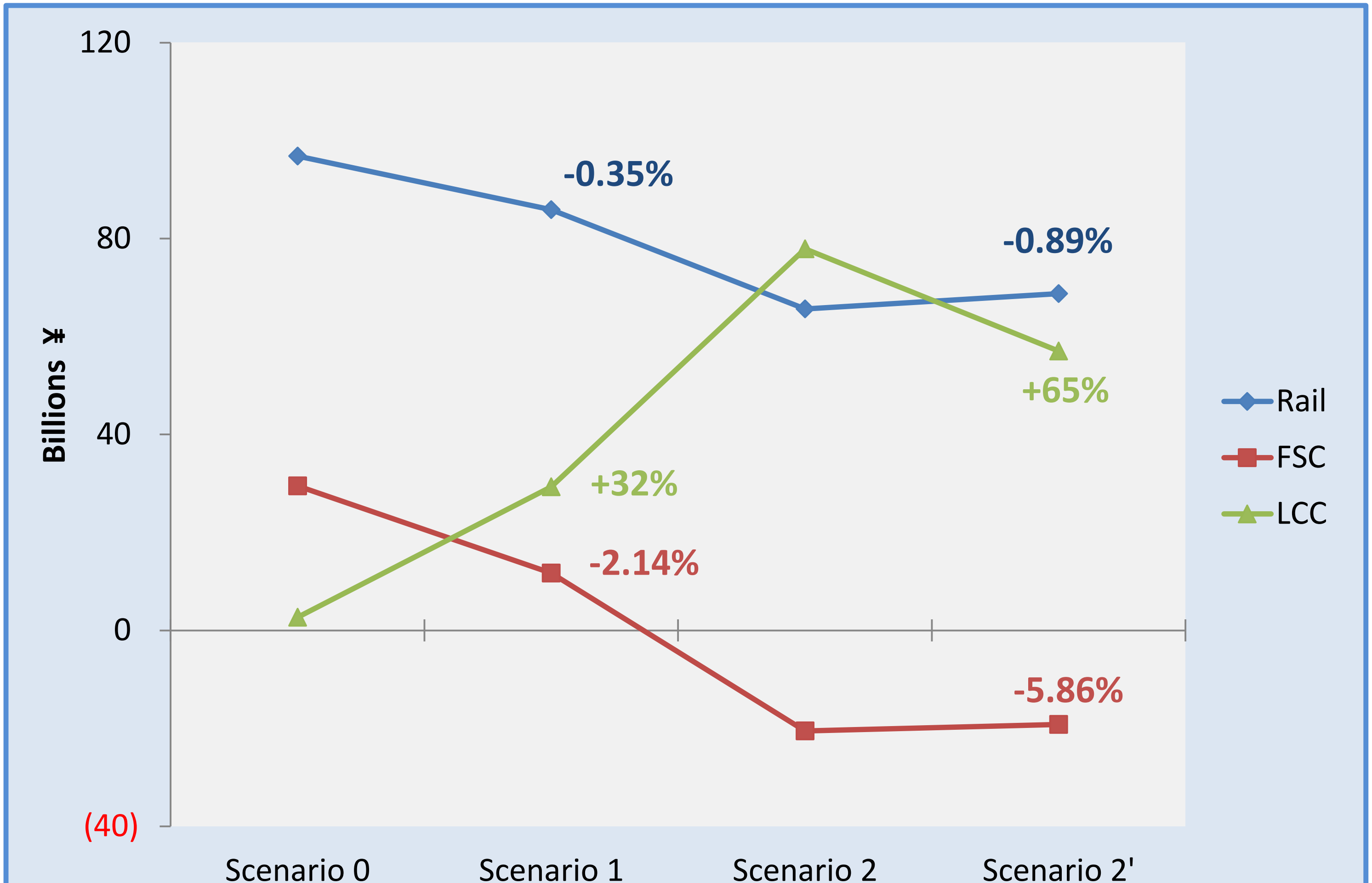
- Expectedly, rail market share slightly decreases while FSCs receive higher impact by the LCC growth



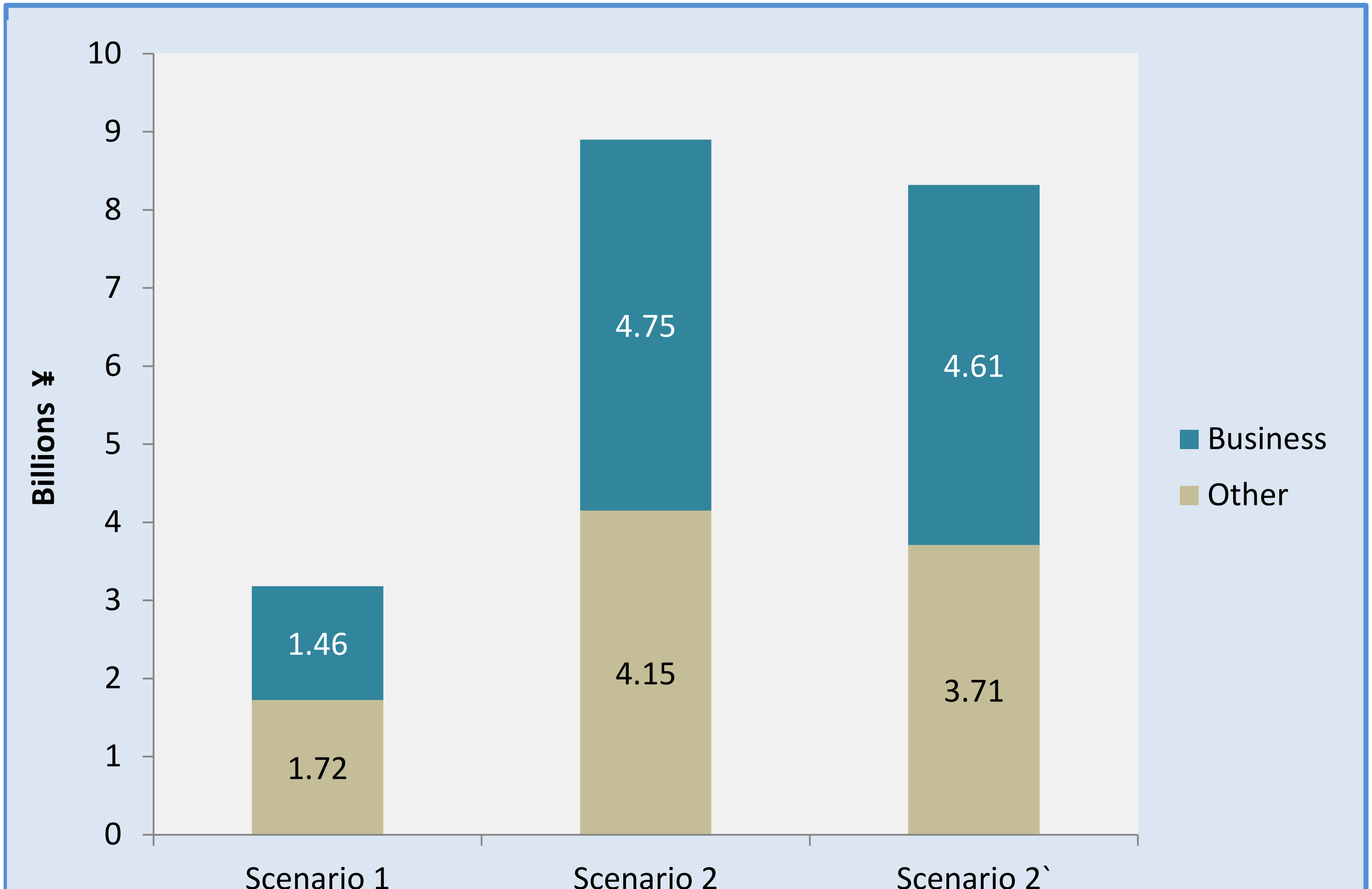
- Figure shows the market share between FSC and LCC in line with scenario settings



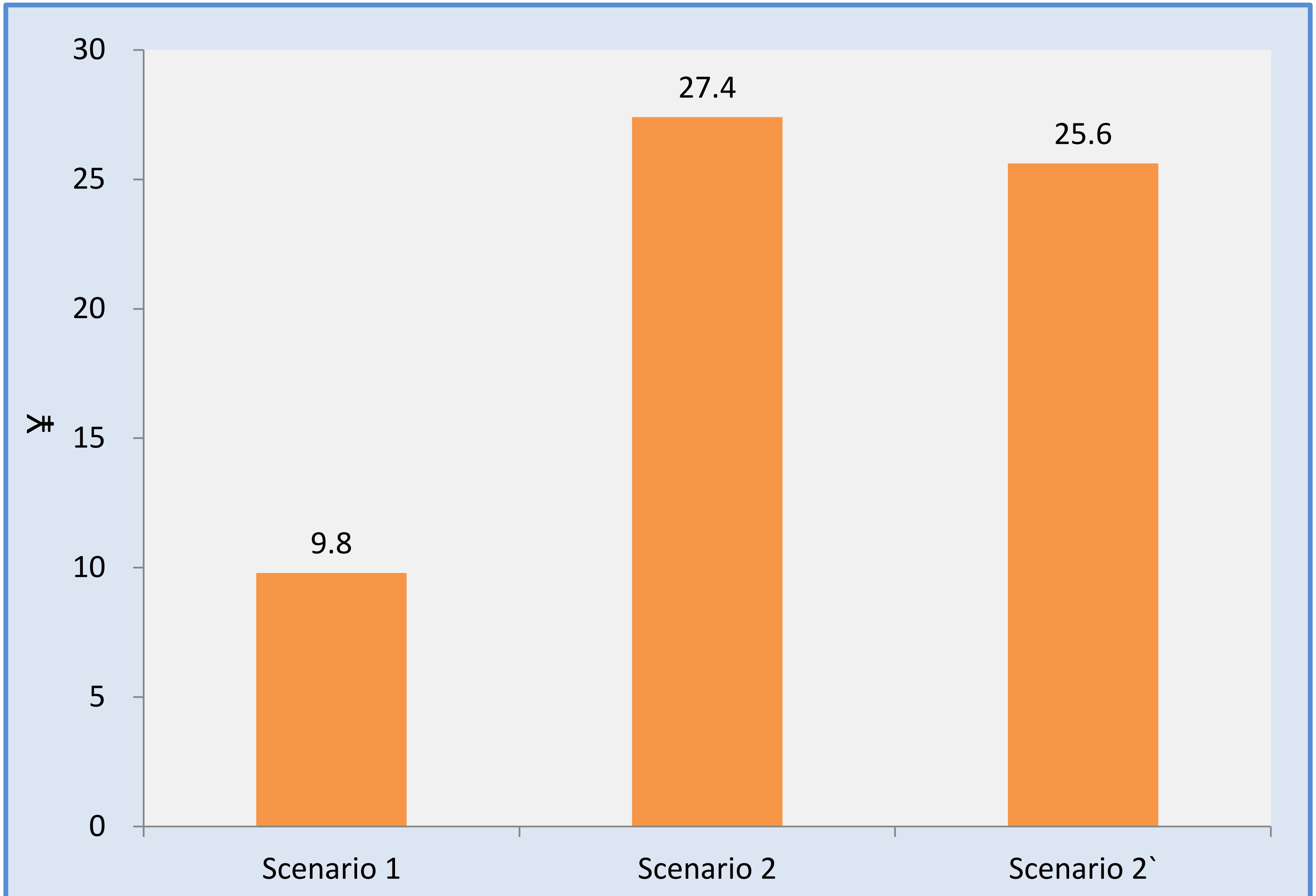
- Revenue change is used to measure LCC growth impact on other operators.
- Figure shows revenue losses in Scenario 1 are moderate, but reach to significant numbers in Scenario 2′, especially for FSCs



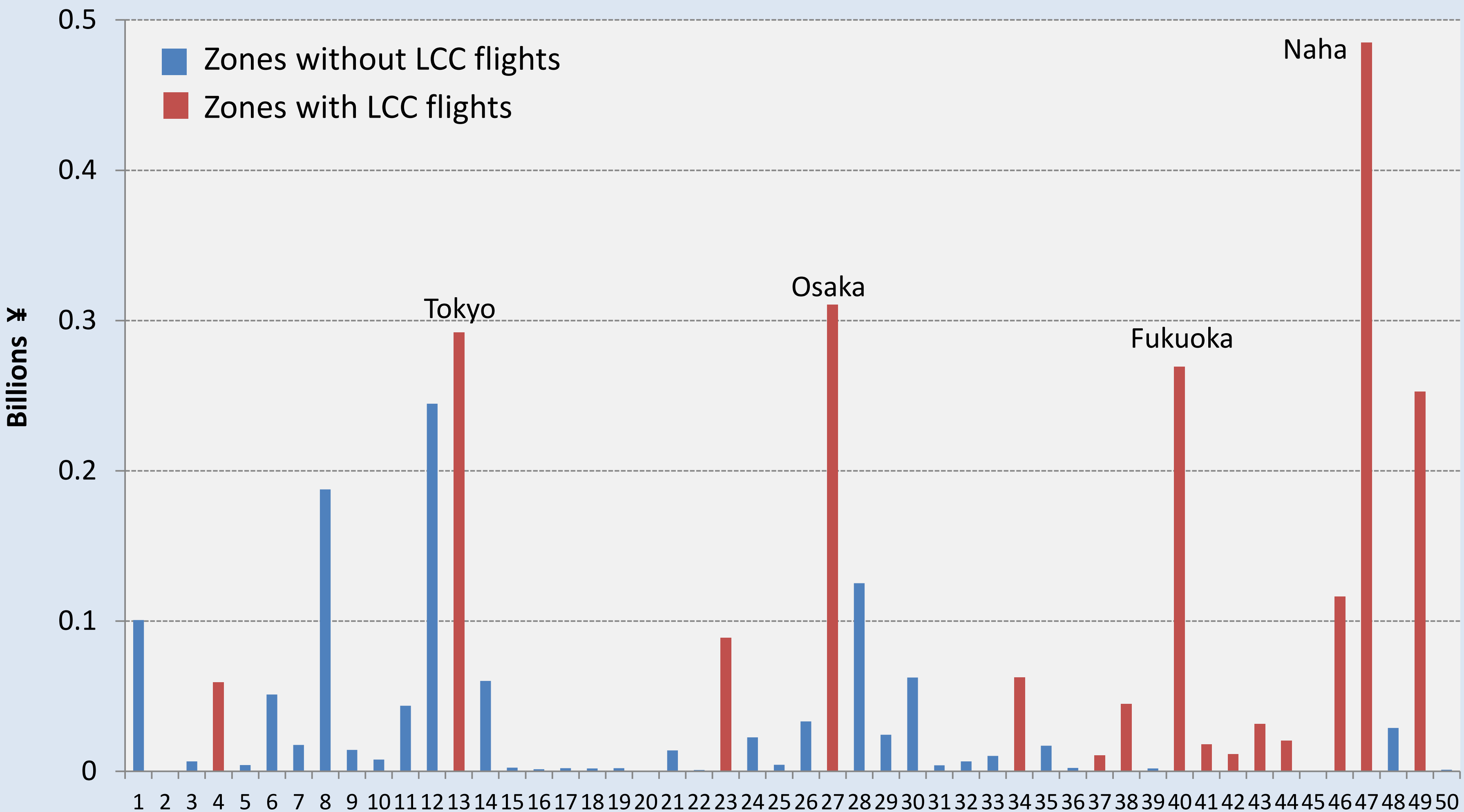
- Consumer Surplus is used to measure LCC growth impact on passengers.
- Figure shows that passengers gain a net benefit of 3.2 billion¥ in Scenario 1 and 8.3 billion¥ in Scenario 2′, compared to Scenario 0



- Figure shows the average benefit for one passenger thanks to the LCC growth



- Figure shows the consumer surplus of each zone in Scenario 1 compared to Scenario 0
- Expectedly, zones with high LCC flights gained most



- Table shows the preliminary results of the LCC growth impact on passengers and operators
- These results indicate that Government's 14% target might be moderate because of significant consumer surplus increase. But, a further growth may cause unpleasant situation for other operators.

Case	Scenario 1	Scenario 2'
Rail	Lose 0.35% revenue	Lose 0.89% revenue
FSC	Lose 2.14% revenue	Lose 5.86% revenue
LCC	Earn 32% revenue	Earn 65% revenue
Passengers	Gain 3.2 billion¥ benefit	Gains 8.9 billion¥ benefit

- Current scenarios assume frequency increase only on existing routes, which makes regional disparity worse. Future studies may consider introducing new routes to minimize regional disparity

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Airport Congestion Issue

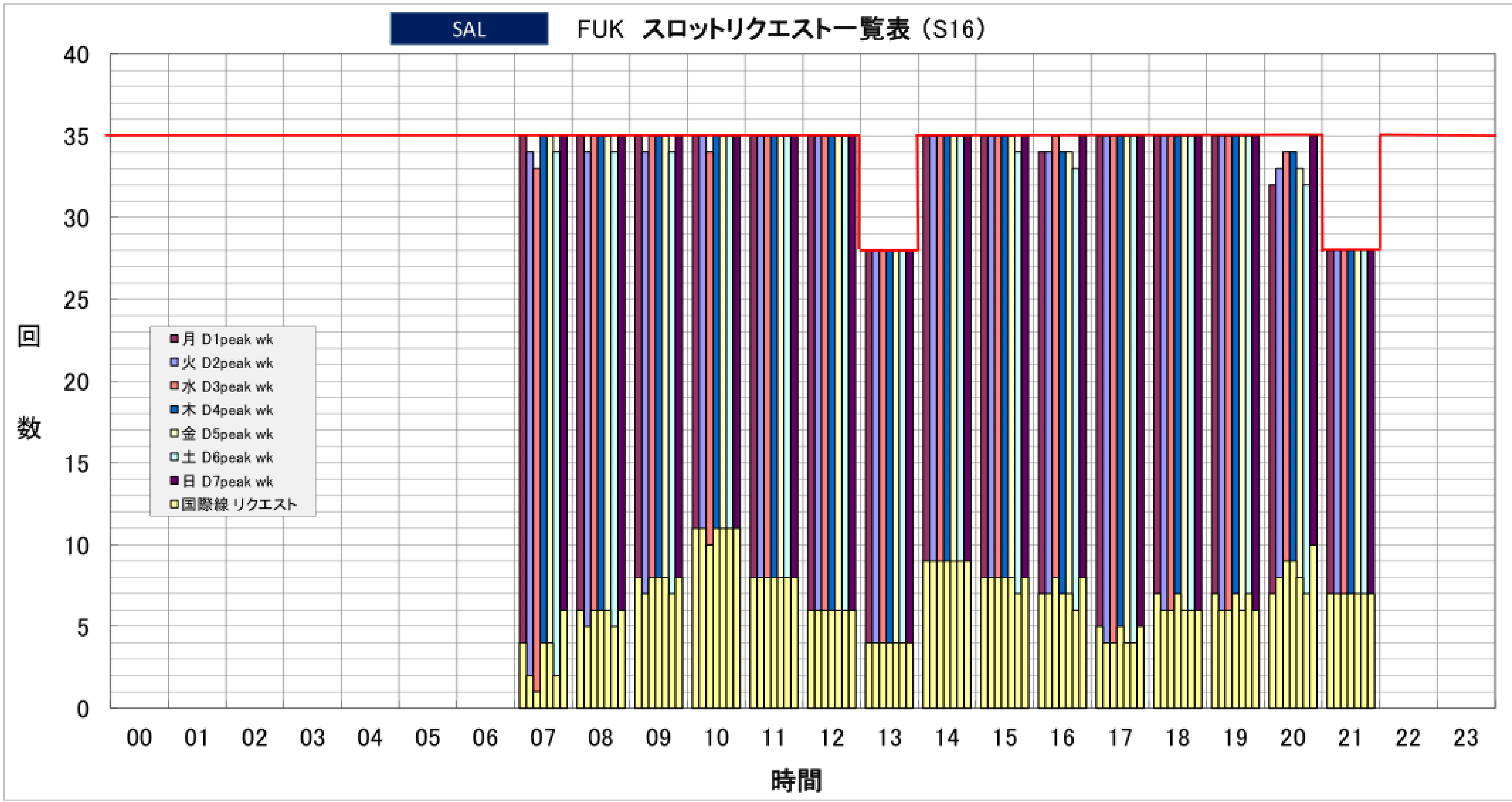
- In previous analysis, airport capacity limitations were not taken into account
- Currently, slot distribution of 5 airports are controlled by Japan Schedule Coordination:
  - Narita International Airport (NRT), Tokyo International Airport (HND), Fukuoka Airport (FUK) , Kansai International Airport (KIX) and New Chitose Airport (CTS)
- Among these, NRT, KIX and CTS have still available capacity, while there is no domestic LCC using HND
- But, in Fukuoka capacity is nearly full.

Route		LCC Frequencies	
Origin	Destination	2016	Scenario 1
Fukuoka	Kansai	5	7
Fukuoka	Naha	2	3
Fukuoka	Narita	10	15
Fukuoka	Chubu	3	4
Fukuoka Total		20	29

- According to previous analysis, 126 additional Fukuoka slots are necessary per week for LCCs to reach 15% market share in 2020.

Fukuoka Airport Congestion Issue

- Figure shows the weekly slot distribution of Fukuoka Airport in 2016
- There are only 25 slots/week available
- But, LCCs need 126 slots/week to reach 15% market share



- In the case of congestion, we assumed two scenarios:
- In Scenario 3 LCC frequencies will be the same as 2016 as there is no available slots
- In Scenario 4, FSC frequencies will be decreased to allow LCC growth

2 Options for Fukuoka LCC flights

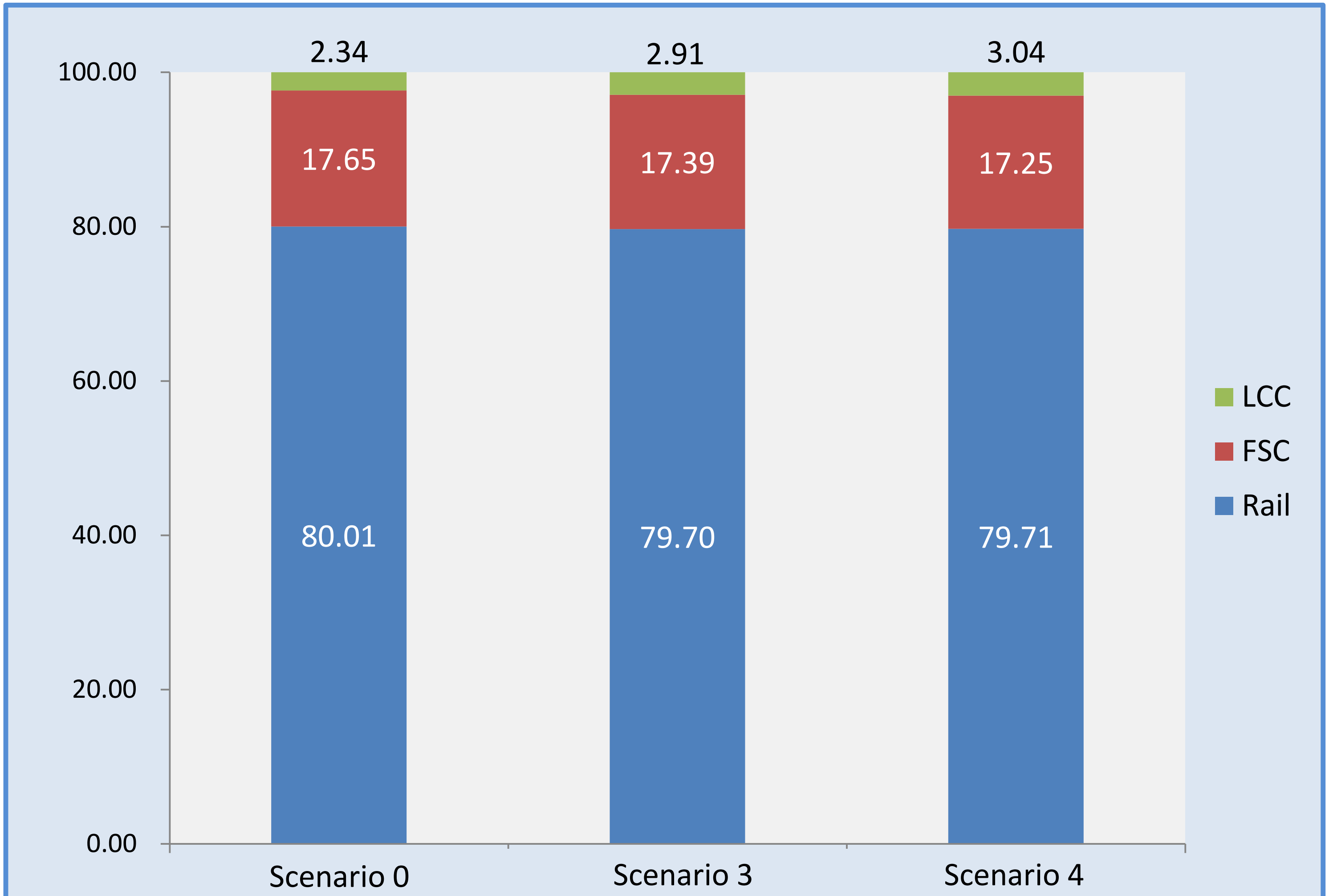
Priority to FSCs (No Increase for LCC)

Route		LCC Frequencies	
Origin	Destination	2016	Scenario 3
Fukuoka	Kansai	5	5
Fukuoka	Naha	2	2
Fukuoka	Narita	10	10
Fukuoka	Chubu	3	3
Fukuoka Total		20	20

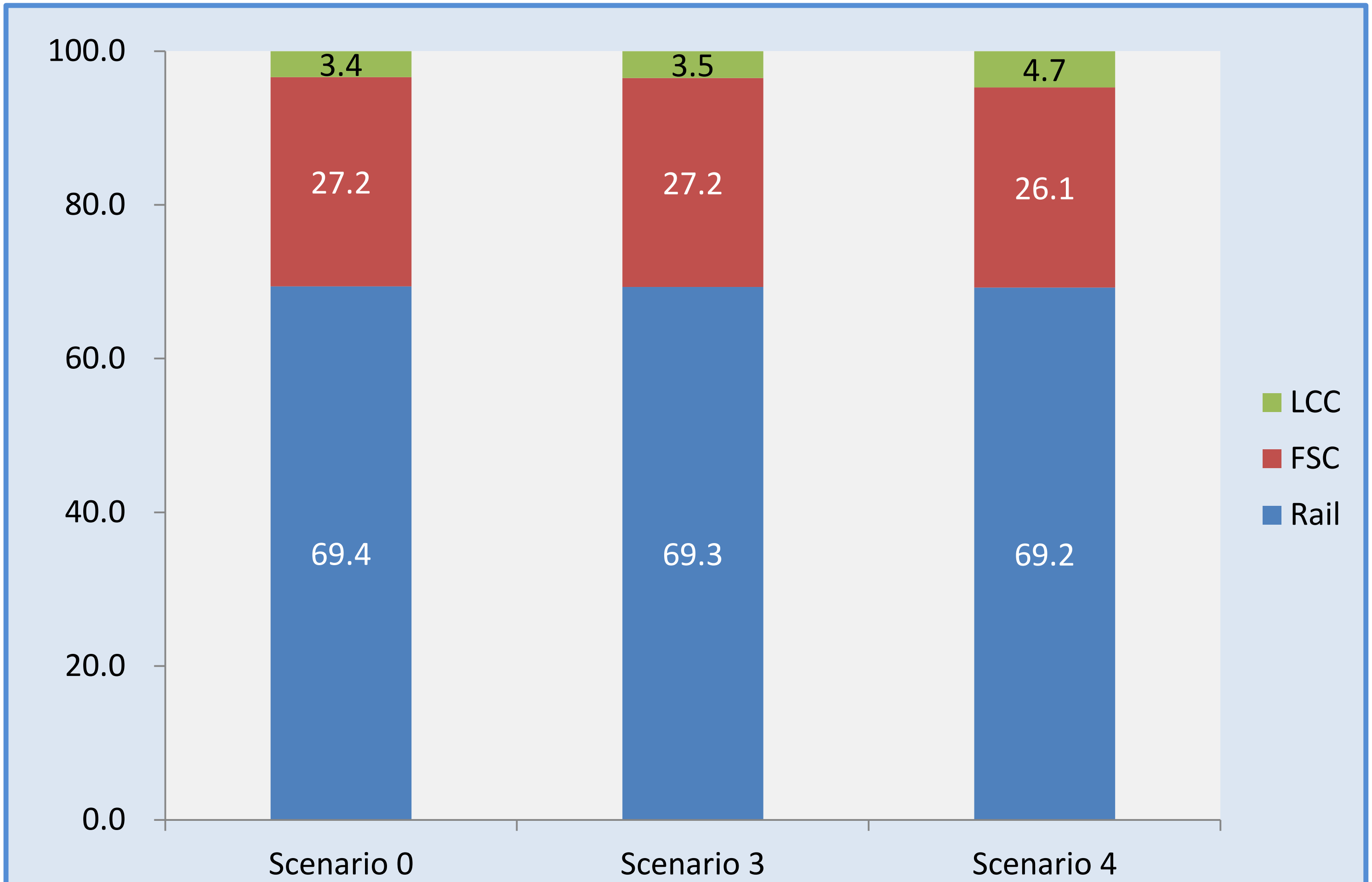
Priority to LCCs (LCC increases, FSC decreases)

Route		FSC Frequencies	
Origin	Destination	2016	Scenario 4
Tokyo	Fukuoka	54	51
Fukuoka	Miyazaki	14	13
Osaka	Fukuoka	11	10
Fukuoka	Sendai	6	5
Fukuoka	Nagoya	5	4
Fukuoka	Shin Chitose	5	4
Fukuoka	Matsuyama	5	4
Fukuoka Total		106	97

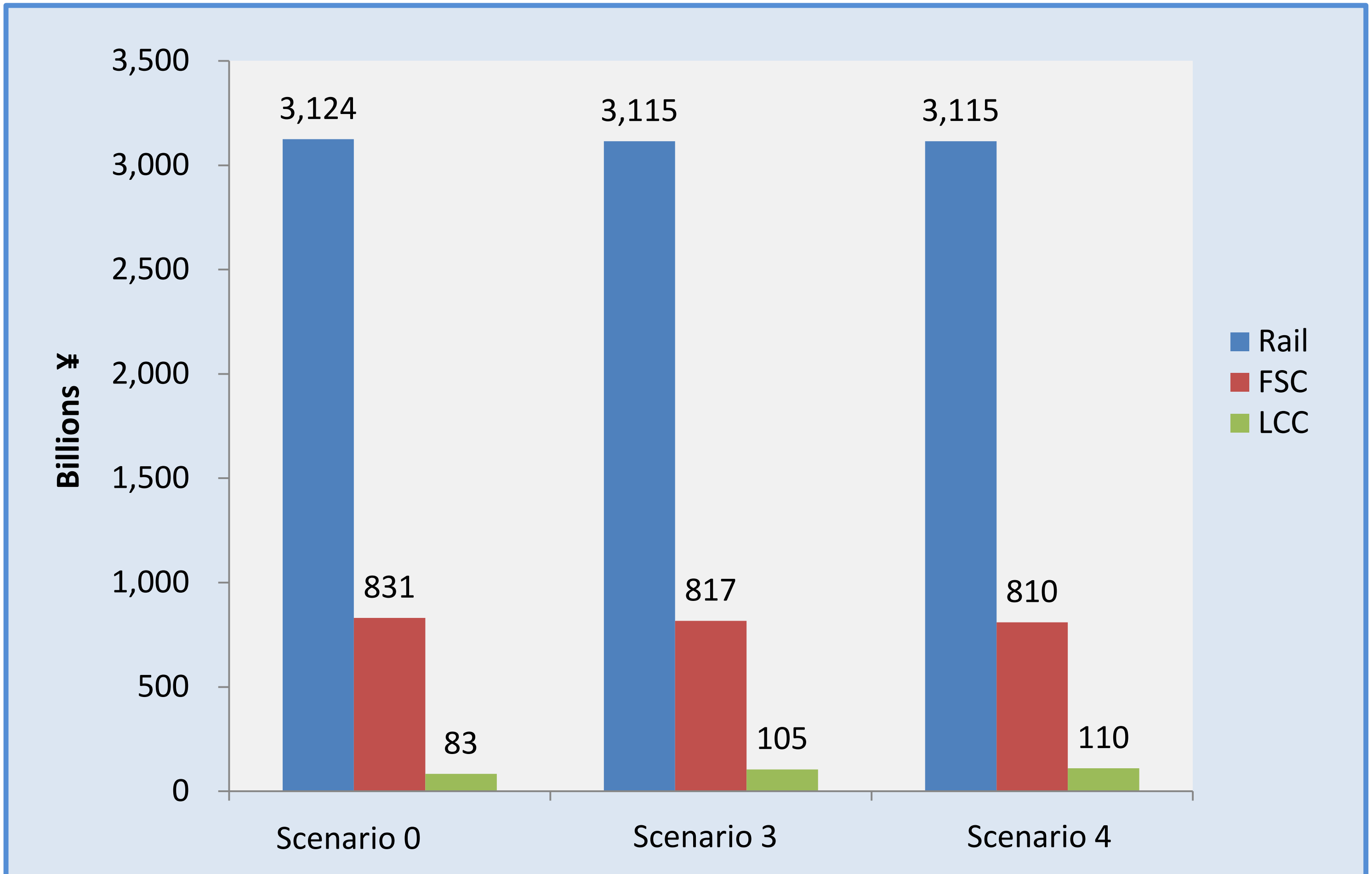
- Expectedly, giving priority to LCC decreases FSC market share further
- In priority to FSC case, LCC market share is reduced to 14%
- Figure shows that in both cases rail mode is not affected much



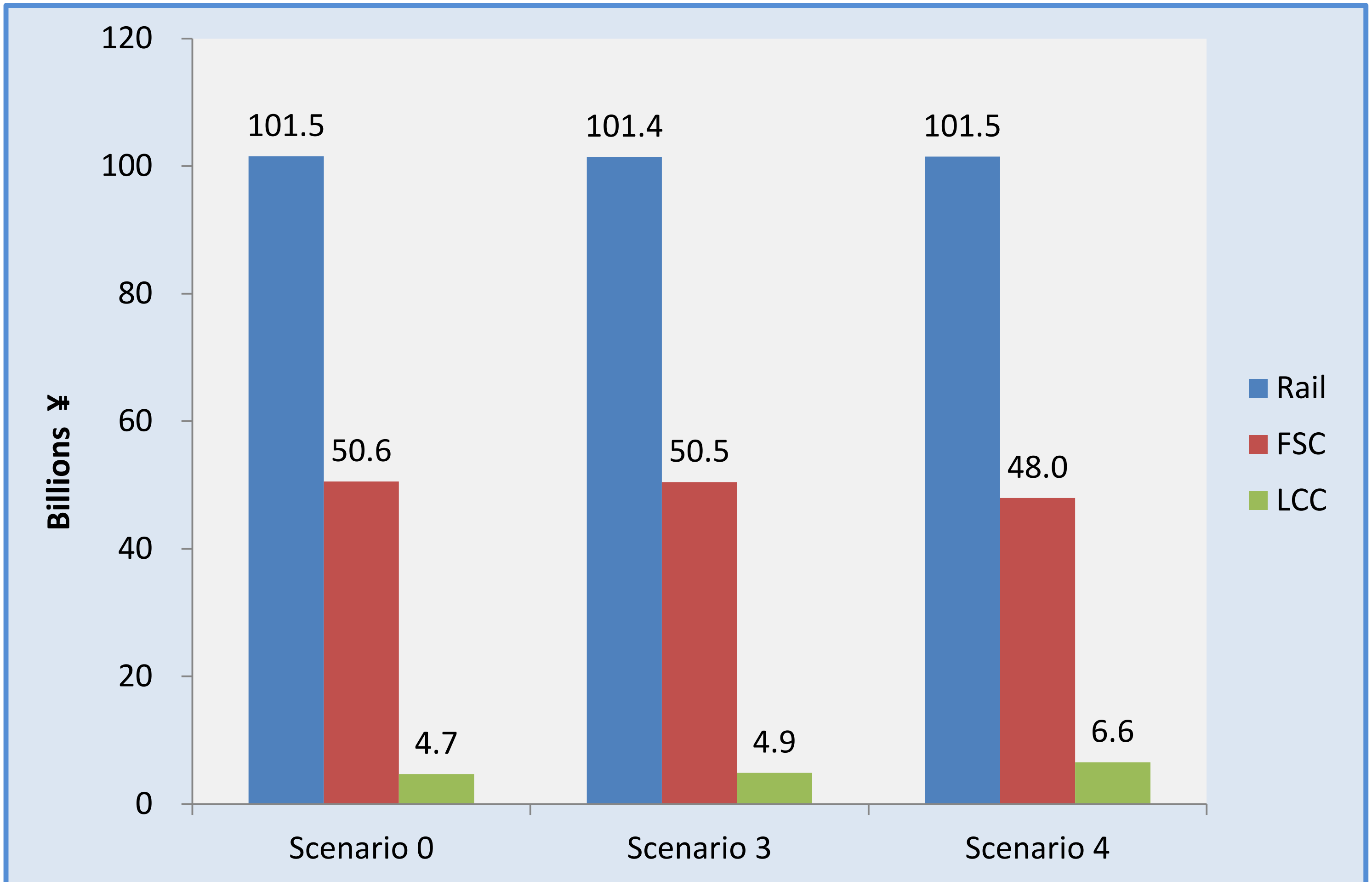
- Figure shows the modal share for Fukuoka zone only
- Expectedly, air share is higher in Fukuoka
- Similar to previous figure, rail mode is not affected from slot distribution choice



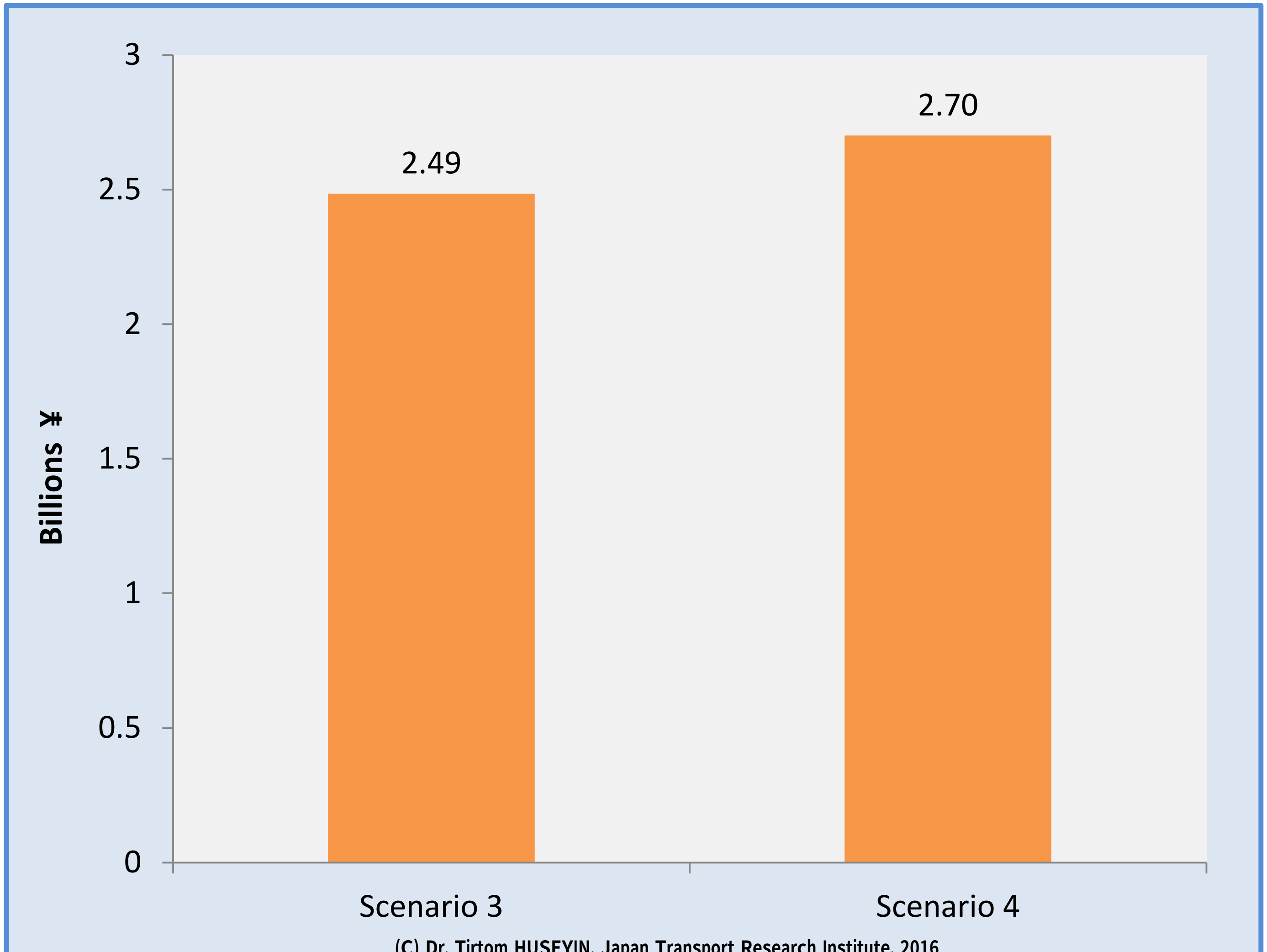
- Figure shows that LCCs will lose ~5 billions revenue if priority is given to FSCs
- On the other hand, FSCs will lose ~7 billions revenue if priority is given to LCCs



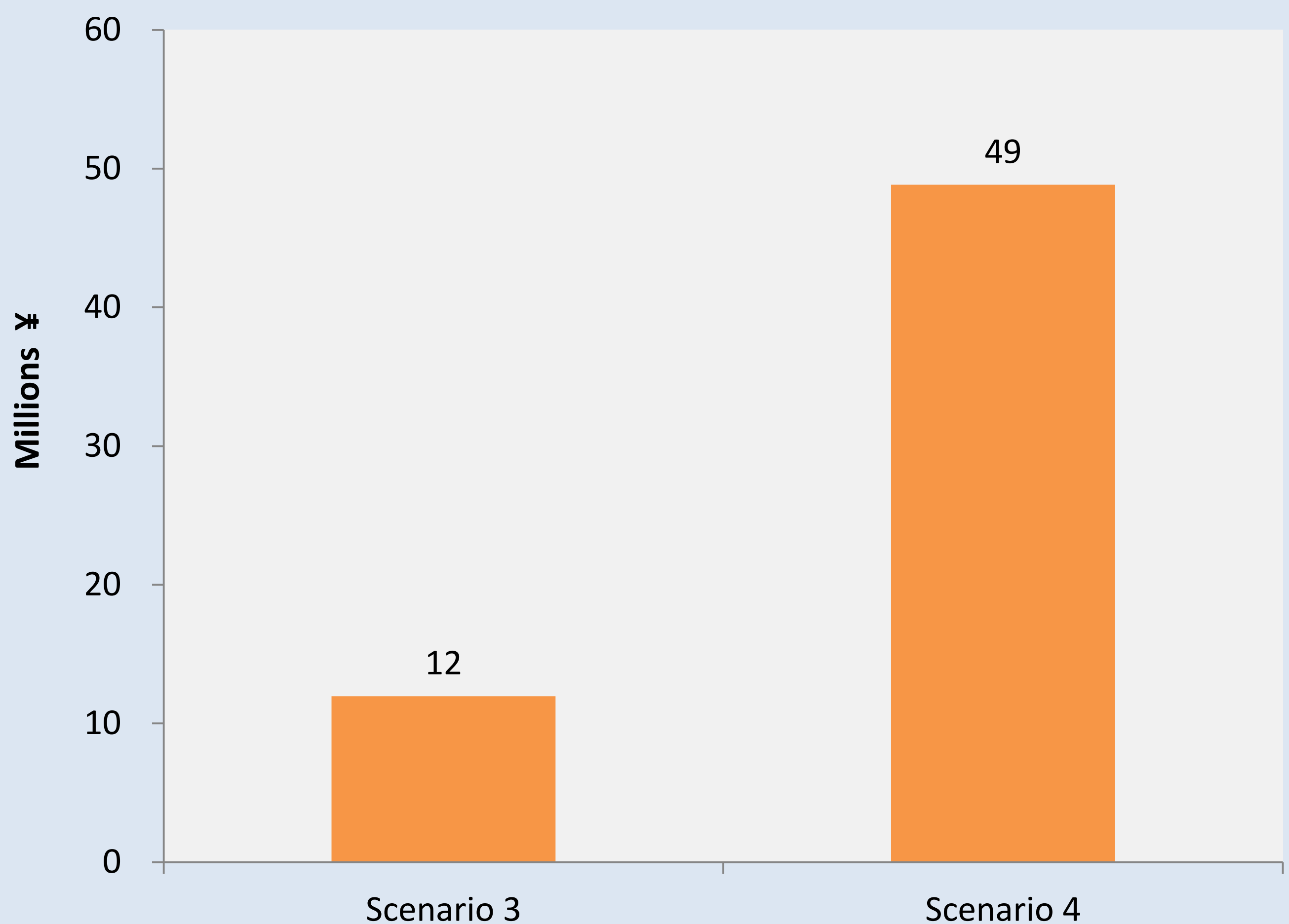
- Figure shows that LCCs will lose ~1.7 billions revenue if priority is given to FSCs
- On the other hand, FSCs will lose ~2.5 billions revenue if priority is given to LCCs



- Figure shows the consumer surplus change compared to Scenario 0
- Figure indicates that passengers will gain ~200 million¥ extra benefit if priority is given to LCC



- Figure shows the consumer surplus change for Fukuoka compared to Scenario 0
- Figure indicates that passengers from Fukuoka will gain ~37 million¥ extra benefit if priority is given to LCC



Contents

- Model Structure
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- I proposed a framework to measure impacts of LCC growth on intercity passenger demand pattern, passengers and other operators
- Preliminary results show that, LCC growth cause an improve in consumer surplus while ~0.4% revenue loss for rail and ~2% revenue loss for FSC.
- These results indicate that Government's 14% target might be moderate because of significant consumer surplus. But, a further growth may cause unpleasant situation for other operators.
- In the case of airport capacity limitation, giving priority to LCC causes a slight consumer surplus increase overall and a significant increase for Fukuoka. Therefore, it seems preferable to favor LCCs over FSCs in the case of congestion.

- The present analysis has several caveats to be improved in future studies:
  - First, data were limited to get a reliable model.
  - Second, no competition is considered between operators.

- Therefore, it is intended to improve the model using forthcoming Inter-regional Travel Survey 2015 data and to incorporate rail operators' and/or FSCs' strategic behavior

- Regarding airport congestion, current scenarios only consider increasing or decreasing frequencies on existing routes. Future studies may consider more detailed scenarios with redistribution of all slots.