福岡FIRにおける2013年から2030年の空港需要予測方法

Forecasting Airport Demand in the Fukuoka FIR based on a Traffic Growth Forecast from 2013 to 2030

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目的

- Analyse future air traffic demand in Fukuoka in 2030 as part of research into Trajectory-Based Operations.
  軌道ベース運用方式（TBO）に関する研究の一部として、将来のATM環境を把握するため、2030年の福岡FIRの交通需要を予測する。

- Identify potential bottlenecks, capacity shortfalls.
  ボトルネック、需要が容量を超える箇所及び時間帯等を特定する。

- Look at broad future airport demand (runway capacity, arrivals and departures).
  この発表では、将来の空港需要（交通量、滑走路容量）を予測する方法を紹介する。

対象空港

- Busiest eight airports in Fukuoka FIR
  福岡FIR内で最も交通量が多い8つの空港

Airport / 空港	都市・地域	2013年交通量
RJTT/HND Tokyo International (Haneda)	東京・関東	403,242
RJAA/NRT Narita International	東京・関東	223,388
RJFF/FUK Fukuoka	福岡	170,640
ROAH/OKA Naha	那覇・沖縄	147,302
RJOO/ITM Osaka International (Itami)	大阪・関西	136,132
RJCC/CTS New Chitose International	札幌・北海道	134,312
RJBB/KIX Kansai International	大阪・関西	131,930
RJGG/NGO Chubu Centrair International	名古屋・中部	88,578

空港需要予測方法

Simplest way to forecast annual airport traffic
年間交通量の予測方法

- Take 1 year historical data.
  1年間の空港交通記録
- Categorise flights by region.
  フライトを国内便と地域別国際便に分類する
- Multiply numbers of flights by regional growth factors and sum.
  地域別の予想交通量増加率を掛けて合計を取る

交通増加予測モデルの例

地域ペア	増加率
日本～日本	1.06
日本～中国	1.92
日本～韓国	1.86
日本～北米	1.74
…	

But needs complete traffic data
各空港の詳細記録情報が必要

- Our historical data were missing February.
  2013年の記録を利用（2月分のデータ欠如）
- No data on VFR traffic.
  VFRフライトに関する情報はない

We needed an alternative method based on incomplete data
不完全なデータから予測できる方法が必要である

不完全なデータからの空港需要予測方法

1. Historical data (flight data) baseline (2013)
   2013年の飛行記録をベースラインとする
   - Take two scenario days: summer and winter schedule seasons.
     二つのシナリオ日を選ぶ。（冬と夏の季節）
   - Assume these days are average.
     シナリオ日の交通量を平均的と想定する

2. Apply traffic growth model to baseline to create 2030 scenarios
   ベースラインに交通増加モデルを適用し、2030年シナリオを作成

3. Estimate annual traffic by extrapolating scenario days.
   シナリオ日の交通量から年間交通量を外挿
   - Correct for “missing” VFR traffic.
     実データとの比較で抜けているVFR交通量を予測、補正する

使用した情報

- FDMS data: all days in 2013, 2014, 2015 except 2013/2. (JCAB)
  FDMSのからの飛行情報: 2013年～2015年（2013/2を除く）
  - IFR flight information only
    IFRフライトのみの情報（VFRを除く）
  - Includes ATD, ATA at Japanese airports
    日本の空港における出発時刻、到着時刻を含む

- Annual landing statistics for each airport (JCAB)
  各空港の年間着陸回数（航空局　公表統計データ　空港管理状況）

- 2013-2030 traffic growth forecast (JCAB / NILIM / ICAO)
  2013～2030交通量増加予測（航空局、国総研、ICAO）

FDMS: Flight Data Management System

シナリオから年間交通量予測

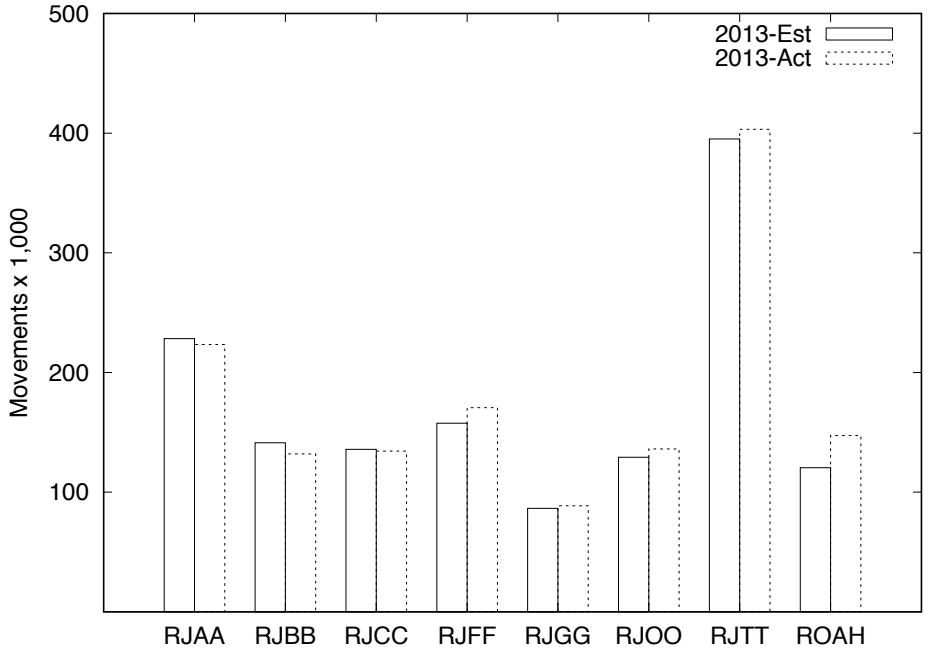
- Select IFR flight data for two days in summer & winter seasons with no significant WX
  ベースラインの1年から運用に及ぼす悪天の影響が少ない二つの日（夏と冬）のIFR飛行情報を選択する。
  - w^{2013} = 11 Jan 2013
  - s^{2013} = 6 Sep 2013.

- Annual traffic estimate $T_{est} = 365/2\ (\ w + s\ )$
  予測年間交通量
- Actual traffic counts $T_{act} = 2\ L$ (L = 着陸数)
  実年間交通量

- Assume difference between T_{act} and T_{est} mainly due to VFR traffic. Correct for VFR traffic by comparing estimates with actual landing statistics.
  T_{act} と T_{est} の差分はほとんどVFRフライトであることを想定し、
  年間交通量予測の補正に利用する。
  - Error $e = T_{act} - T_{est}$
  - Apply “VFR correction” if $|e| > 5\%$

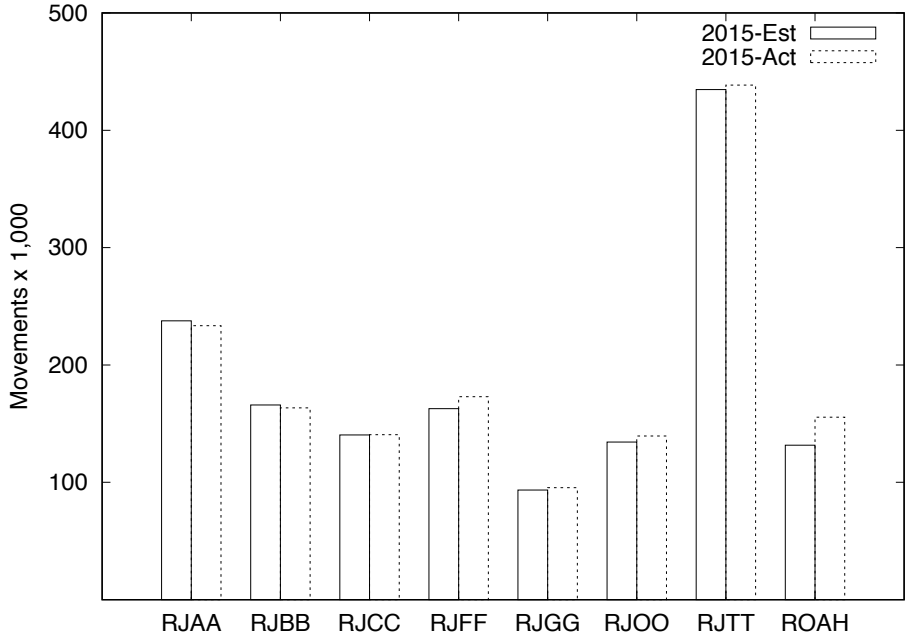
予測交通量と実交通量の比較

Comparison of annual traffic estimated from 2 scenario days vs. actual traffic
シナリオの二日から予測年間交通量と実年間交通量の比較



2013 T_{est} and T_{act}
w_{2013} 11 Jan s_{2013} 6 Sep

Significant errors (>5%):
RJBB 7.1% RJFF -7.6% RJOO -5.1% ROAH -18.2%



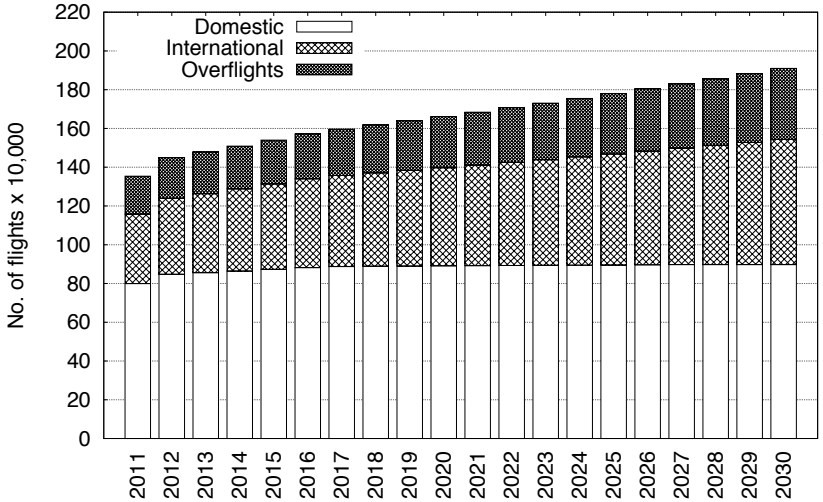
2015 T_{est} and T_{act}
w_{2015} 9 Jan s_{2015} 4 Sep

Significant errors (>5%):
RJFF -5.9% ROAH -15.4%

Comparing IFR flight records versus landing statistics for all days in 2014, 2015 show RJFF and ROAH have significant VFR traffic: RJFF ~6.6% ROAH ~18.5%
年間着陸数とIFR飛行記録の比較から、RJFFとROAHにおけるVFRフライトの比率は5%以上である

航空交通増加予測モデル

- From 2013 – 2030 in Fukuoka FIR.
  福岡FIRにおける、2013～2030の交通増加率
- Aggregate countries as Regions, forecast inter-regional growth factors.
  国内交通、地域・国ペア間毎の交通の増加率（フライトの数）



- Domestic growth relatively flat (<10%)
  国内増加率　　1割以下
- International traffic grows ~80%
  国際増加率　　約8割
- Overflight traffic grows ~70%
  上空通過便の増加率 約7割

- Long-range macroscopic forecast based on economic growth.
  経済発展に基づいた長期マクロ的予測。
- Models service frequencies (number of flights) between regions taking fuselage downsizing and Low Cost Carrier growth trends into account, but uses existing (2013) aircraft types.
  地域間のフライト数の増加率モデル。航空機の容量の変化トレンド、LCC増加のトレンドを含む。
- Based purely on inter-regional traffic growth factors, not airport pairs. Traffic keeps to existing (2013) routes. Additional growth traffic between 2013 and 2030 distributed evenly between all 2013 airport pairs.
  空港ペア・シティーペア間の交通ではなく、地域ペア間毎の交通増加率。
  交通増加は既存の空港ペアに分散される。

交通増加モデルの適用

地域ペア (R_{org}, R_{dest}) の 2013から2030年の増加率 = $c(R_{org}, R_{dest})$

From a baseline scenario set of flights S, derive forecast scenario S' by the following procedure: ("Clone and shift")

ベースラインシナリオ S から予測シナリオ S' を以下の方法で生成

- 各地域間フロー $F(R_A,R_B)$に対して、ベースラインの交通量と増加率から予測交通量を計算
- 予測交通量を満たすため、$F(R_A,R_B)$からランダムにフライトをコピーし、到着・出発時刻をランダムで+/-20分までずらして、予測シナリオS'に追加("Clone and shift")

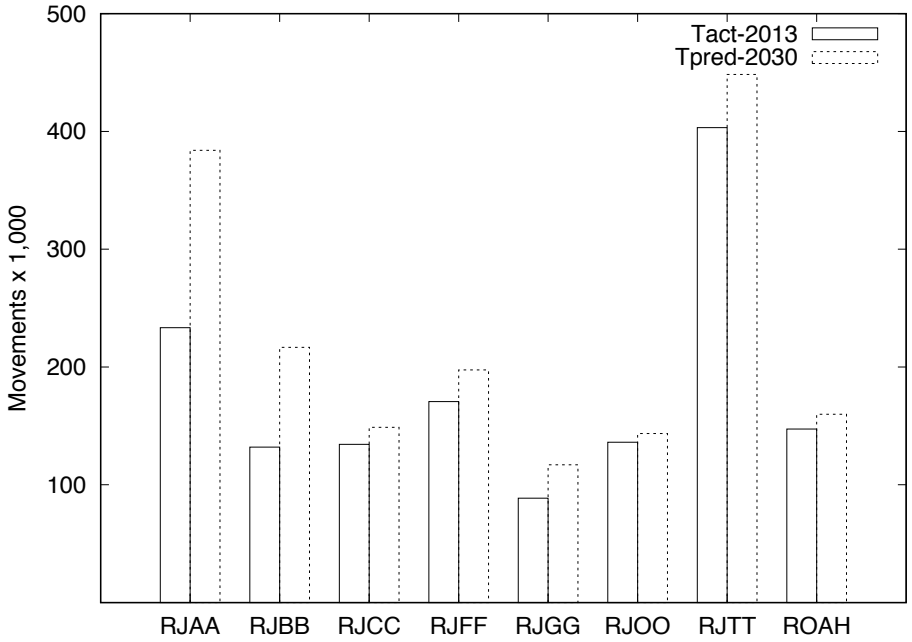
1. For each region pair (R_A, R_B), take the set of flights from R_A to R_B as
   $F(R_A,R_B) = \{f_1, f_2, \ldots f_n\} \in S$
2. Obtain the number of flights n' in corresponding forecast scenario F'(A,B) as
   $n' = \text{ceil}(n \cdot c(R_A,R_B))$
   where ceil(x) is the smallest integer greater than x.
3. Set the initial set of flights $F'(R_A,R_B) \in S'$ to F
4. Repeat the following process ($n' - n$) times:
   i. Select flight f_k from $F(R_A, R_B)$ where k = rand(0, q)
      where rand(0, q) gives a random integer in the interval (0, q)
   ii. Create flight f' = shift(f_k, rand(-20, 20))
      where the shift(q) function moves the arrival and departure times of a flight by q minutes
   iii. Add the flight f' to $F'(R_A, R_B)$

交通増加モデルの適用（続き）

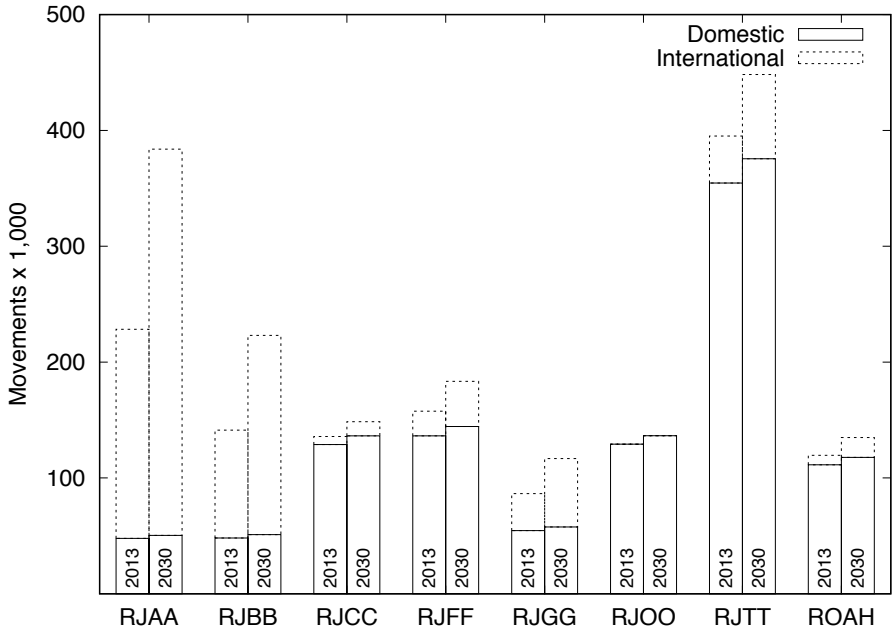
- “Clone and shift” selected to preserve traffic “peaks”.
  Assume that times of traffic peaks will not change.
  +/-20分の「clone and shift」の目的は交通「ピーク」を維持するため。ピークが変わらないと想定。

- Because each forecast scenario S’ is randomly generated, create 50 scenarios and take the average.
  予測シナリオS’はランダムで生成するため、50シナリオのセットを作成し、結果の平均を取る。

結果: 航空交通量予測(2030年)



T_{act}(2013) and T_{pred}(2030) annual movements
(corrected for VFR traffic)



T_{est}(2013) and T_{est}(2030) annual movements
(not corrected for VFR traffic)

Airport	T_{est}(2013)	T_{act}(2013)	Err	T_{est}(2030)	Corr.	T_{pred}(2030)	Growth
RJAA	228,308	233,388	2.2%	383,980	0	383,980	72%
RJBB	141,255	131,930	-7.1%	223,198	-7.1%	216,641	64%
RJCC	137,780	134,312	-2.6%	148,738	0	148,738	11%
RJFF	157,681	170,640	7.6%	183,595	+7.6%	197,548	16%
RJGG	86,505	88,578	2.3%	116,983	0	116,983	32%
RJOO	129,210	136,132	5.1%	136,510	+5.1%	143,472	5%
RJTT	395,113	403,242	2.0%	448,403	0	448,403	11%
ROAH	120,450	147,302	18.2%	135,233	+18.2%	159,845	9%

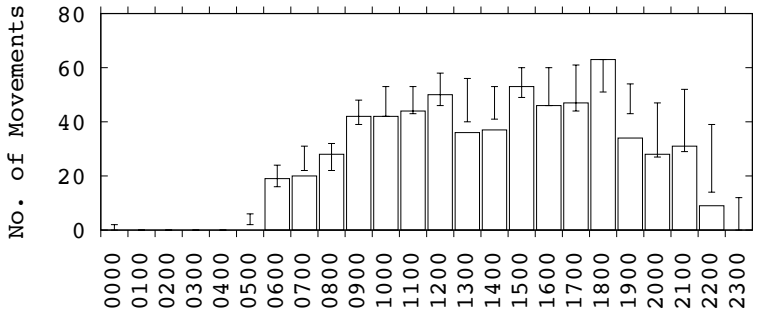
Airport	2013順位	2030 順位	Growth
RJTT	403,242 (1)	448,403 (1-)	11%
RJAA	223,388 (2)	383,980 (2-)	72%
RJFF	170,640 (3)	197,548 (4↓)	16%
ROAH	147,302 (4)	159,845 (5 ↓)	9%
RJOO	136,132 (5)	143,472 (7 ↓)	5%
RJCC	134,312 (6)	148,738 (6-)	11%
RJBB	131,930 (7)	216,641 (3↑)	64%
RJGG	88,578 (8)	116,983 (8-)	32%

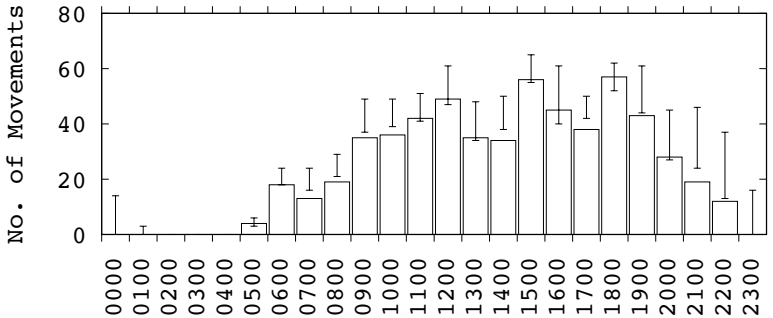
- Domestic traffic hardly changed, international traffic grows strongly.
  国内便の交通量はほとんど変わらない。国際便の率が高い空港の交通量は大きく増加する見込み。
- Largest percentage increases at RJAA, RJBB and RJTT.

滑走路需要予測

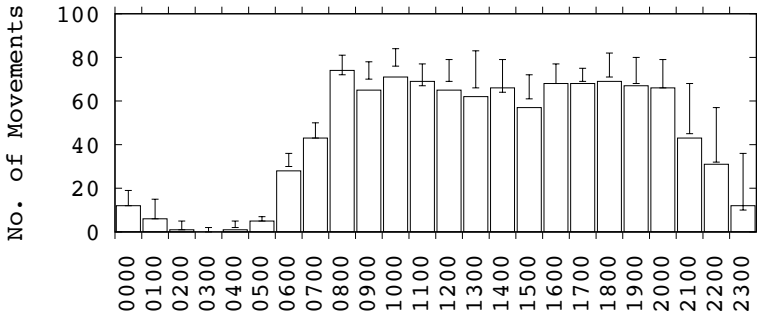
- Plot histograms of arrivals and departures at 60-minute intervals.
  出発時刻と到着時刻のヒストグラムを作成
- Assume baseline scenario days are typical.（Judge by looking at difference between scenario and median traffic over the season.）
  ベースラインシナリオの日は「平均」と想定
  （シナリオ日の交通量とベースライン年の各季節の一日交通量の中央値を比較）

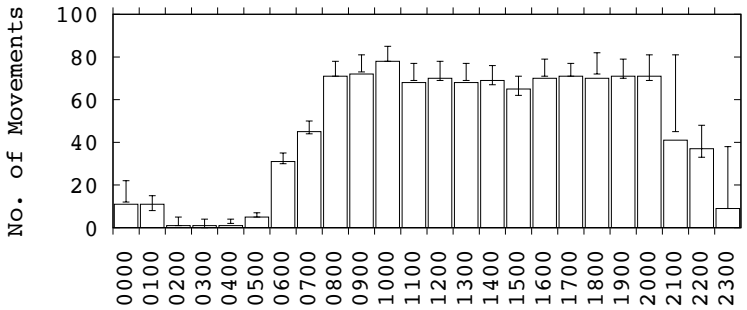
RJAA





RJTT



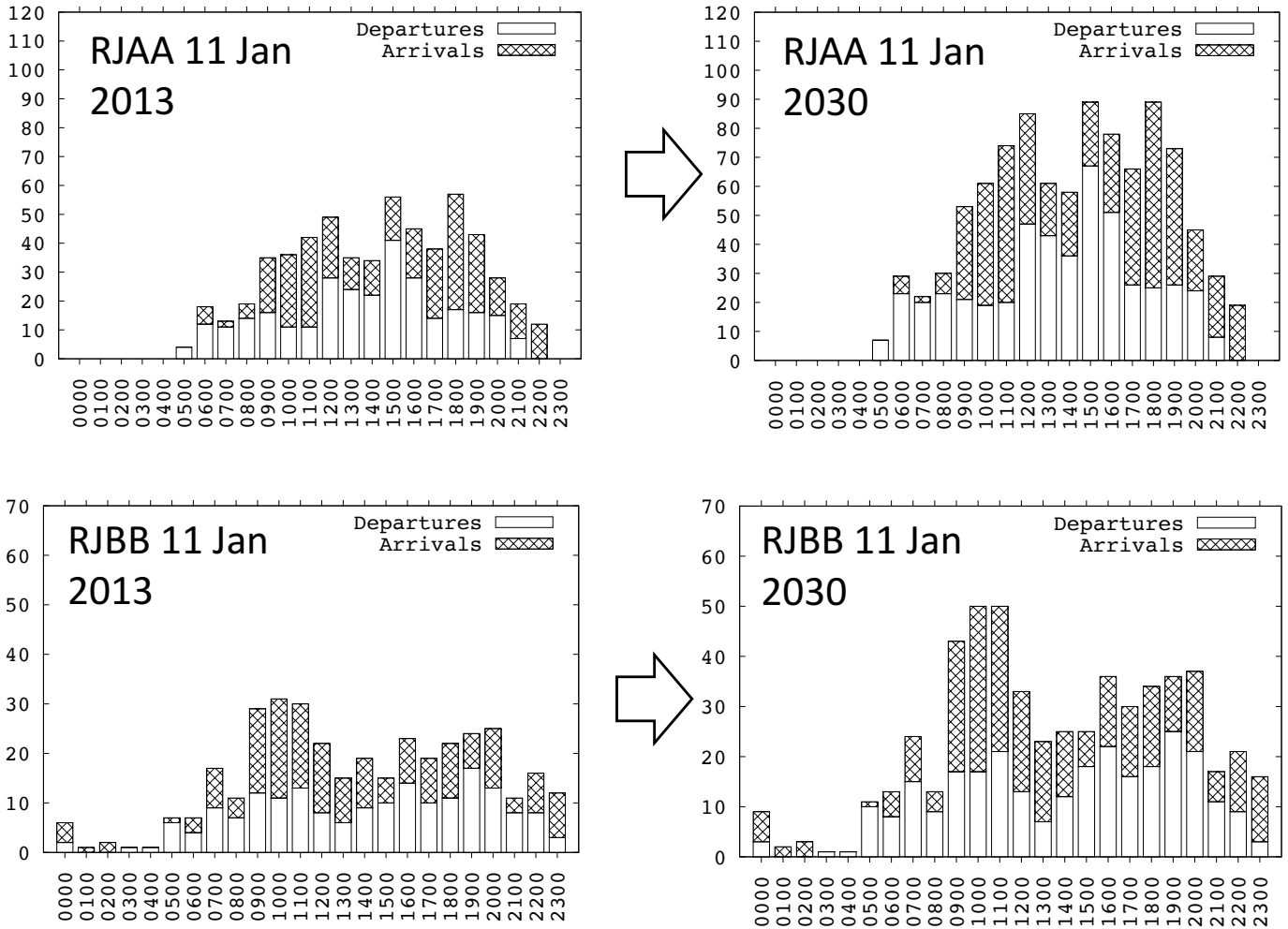


2013 11 Jan + Winter median/max

2013 9 Sep + Summer median/max

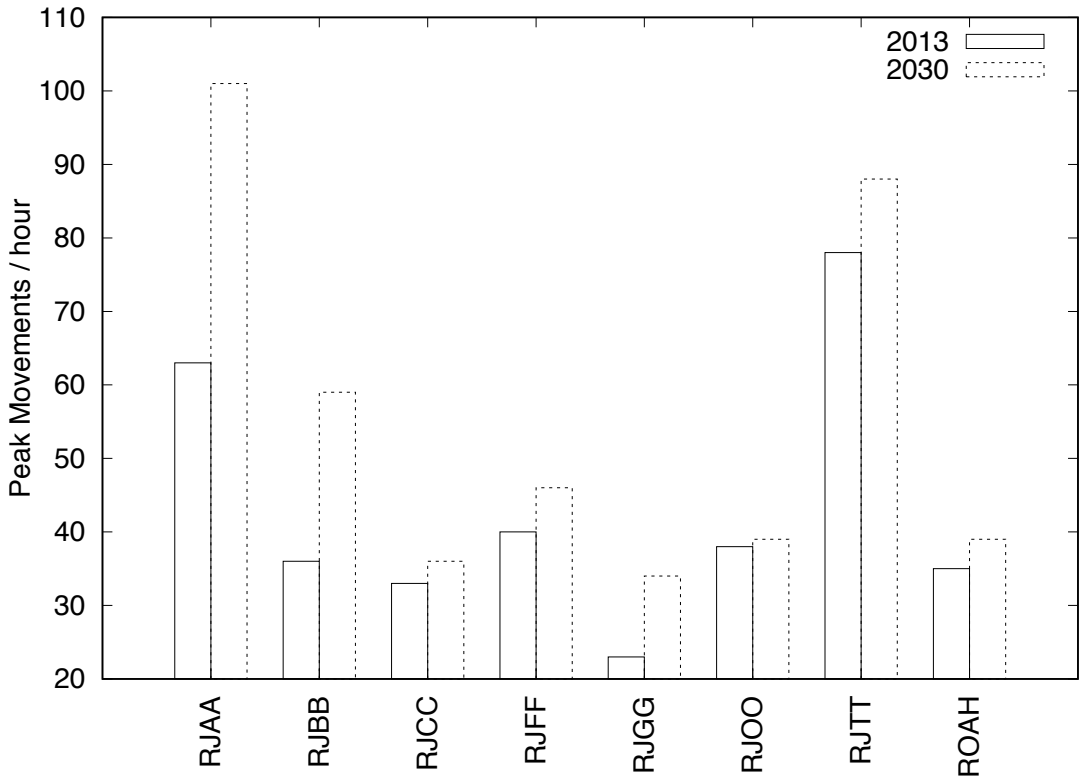
結果: 滑走路需要予測

- Compare averages of 50 random forecast scenarios with 2013 scenarios.
  2030年の50シナリオの平均ヒストグラムを2013年シナリオヒストグラムと比較



結果: 滑走路需要予測

- Look at peak hourly movements, arrivals.
  ピーク1時間の離発着と到着



	2013年		2030年	
Airport	Mvmts	Arrivals	Mvmts	Arrivals
RJAA	63	46	101 (+38)	74 (+28)
RJBB	36	23	59 (+23)	39 (+16)
RJCC	33	18	36 (+3)	19 (+1)
RJFF	40	20	46 (+6)	24 (+4)
RJGG	23	16	34 (+11)	25 (+9)
RJOO	38	20	39 (+1)	20 (-)
RJTT	78	41	88 (+10)	46 (+5)
ROAH	35	20	39 (+4)	22 (+2)

結果のまとめ

Airport	2013		2030		Traffic	Runways	Operating
	T_{act}^{2013}	Peak/hr	Mvmts	Peak/hr	Growth		Time (JST)
RJAA	223,388	63	384,000	101	72%	2	06:00–23:00
RJBB	131,930	36	217,000	59	64%	2	24hr
RJCC	134,312	33	149,000	36	11%	2	24hr
RJFF	170,640	40	198,000	46	16%	1 (2 planned)	07:00–22:00
RJGG	88,578	23	117,000	34	32%	1	24hr
RJOO	136,132	38	143,000	39	5%	2	07:00–21:00
RJTT	403,242	78	448,000	88	11%	4	24hr
ROAH	147,302	35	160,000	39	9%	1 (2 planned)	24hr

Note: Based on 2013 forecast information.
Actual 2016 traffic grew more than expected!

予測手法のサマリー

- Forecast airport traffic growth based on historical data (flight scenarios) and a traffic growth model.
  ベースラインの年の飛行データと交通増加率の予測から空港交通量と滑走路需要を予測

- Estimated annual traffic from two scenario days (winter and summer schedule periods).
  １年間の交通量を2つのシナリオ日（夏と冬）から推定

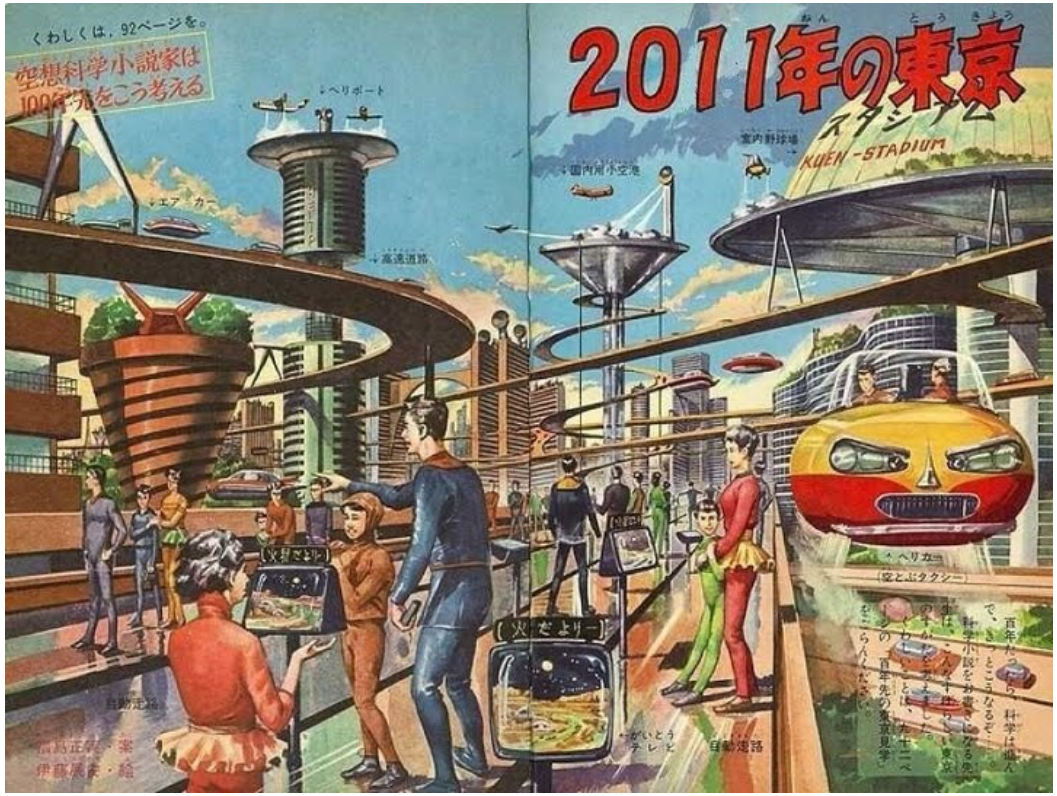
- Estimated demand peaks from traffic scenarios by histograms.
  滑走路需要をヒストグラムから推定

予測手法に関する課題

- Depends on choice of scenario days (how close to ”typical”)
  年間交通量予測はシナリオ日がどれくらい「平均」に近いかに依存

- Our growth model distributes additional traffic between existing city pairs; i.e. growth traffic distributed equally between airports. Does not model future traffic redistribution between airports as a result of competition, active growth promotion or government policy.
  予測シナリオの作成方法は既存の空港ペア間の交通増加を分散する。
  空港の間の競争、交通戦略などの影響を考慮しない。

- Might be useful as a “check” for other forecasts.
  他の予測の合理性の確認のために使えるだろう。



Det er vanskeligt at spaa, især naar det gælder Fremtiden.

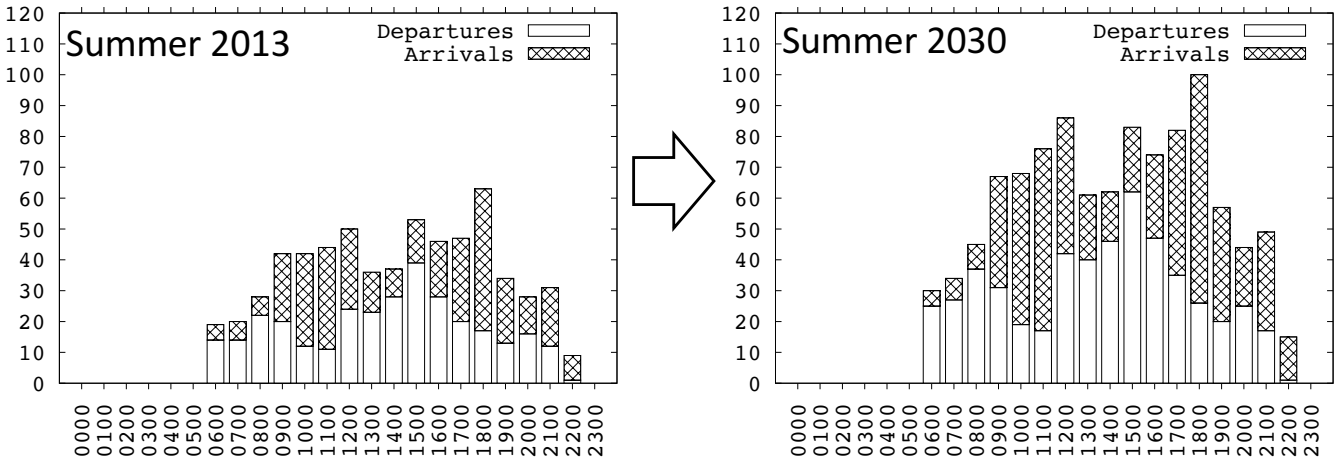
It is difficult to make predictions, especially about the future.

「予測することは難しい。特に未来は。」

-- Remark to Danish parliament, 1937-1938

RJAA

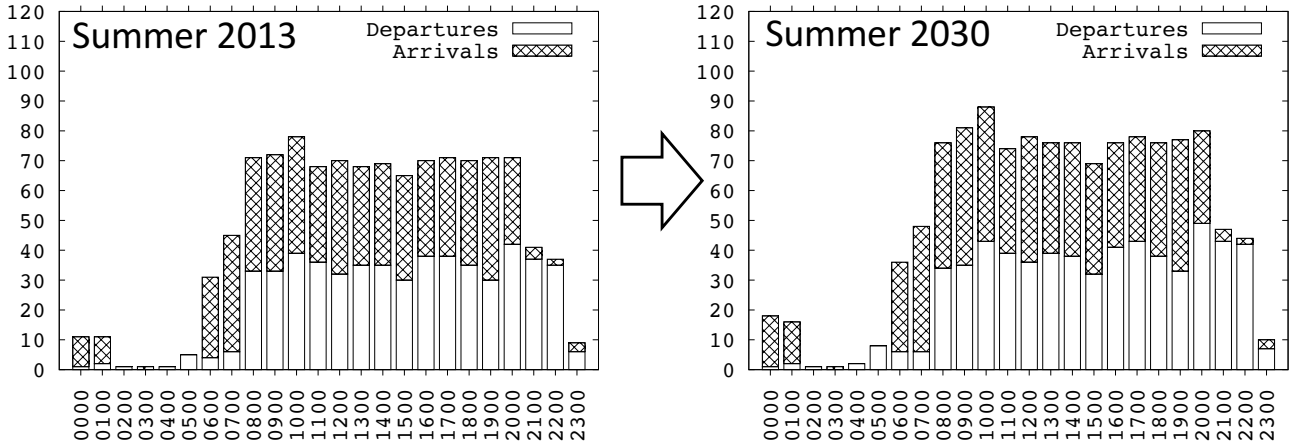
- Main int'l gateway to Japan, 2nd busiest airport
- 2 runways (4,000m, 2,500m)
- 3 terminals (one new)
- 72% growth from 223,388/year (2013) to ~384,000/year!



- Competition from RJTT for international traffic.
- Movements capped at 68/hour by local agreement but will need >100/hour by 2030.
- Proposals to construct 3rd runway.
- Need more stands.

RJTT

- Main domestic hub, busiest airport in Japan.
- Increasing int'l traffic.
- 24-hour operations.
- 4 dependent runways, 3 terminals.
- 11% growth from 403,242/year (2013) to ~448,000/year.



- Demand during day almost constant. ~80/hour in 2013 to ~90/hour in 2030.

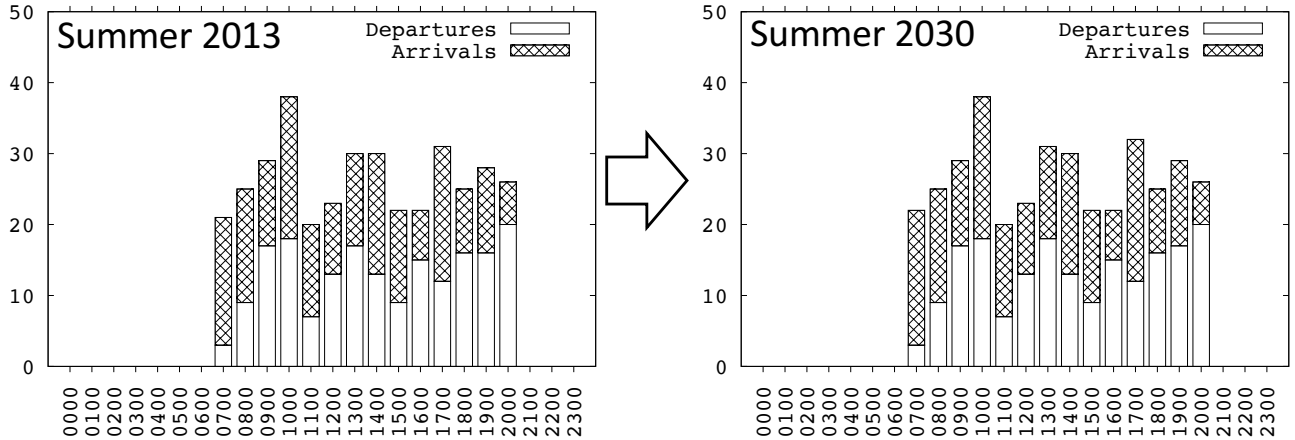
RJAA vs. RJTT

2016: RJTT capacity has failed to keep up with international traffic demand.

- Active promotion of international growth at RJTT, in competition with RJAA.
- RJTT more convenient for Tokyo, Yokohama & Kawasaki but maybe not overwhelmingly so.
- Fewer international flights to RJTT than RJAA and limited international terminal capacity but 24-hour op.
- Fewer domestic connections to RJAA than RJTT but more international connections between Asia-N. America.

RJOO

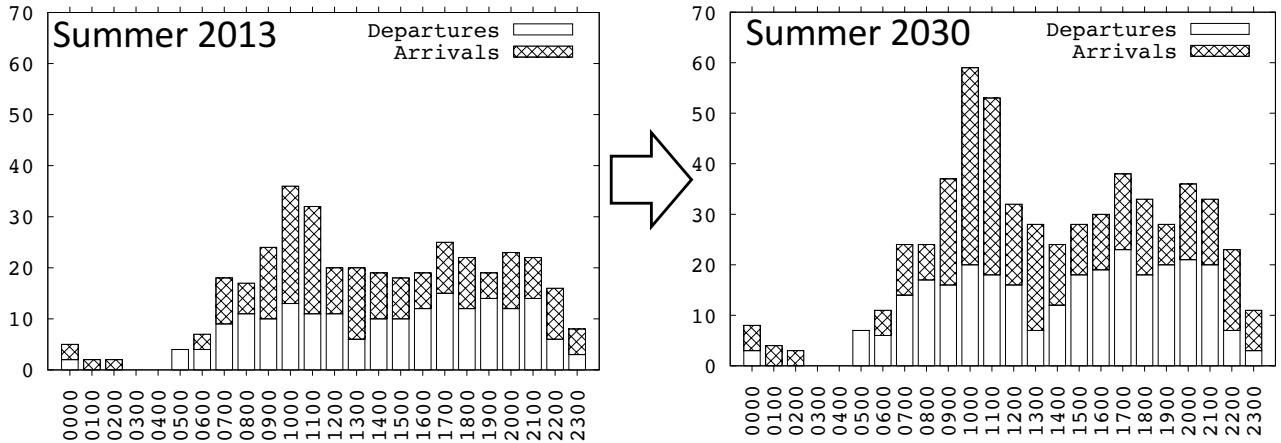
- Domestic hub for Osaka/Kansai region.
- Int'l traffic moved to RJBB in 1996.
- 07:00-21:00.
- 2 runways (3,000m + 1,800m).
- 5% growth from 403,242/year (2013) to ~448,000/year (2013).
- Expansion constrained by built-up areas.



- Peak demand in morning (~40/hour) hardly changes

RJBB

- Int'l hub for Osaka/Kansai region.
- Artificial island. Can create more surface by land reclamation.
- 24-hour ops.
- 2 runways (3,800m + 4,000m).
- 64% growth from 131,930/year (2013) to ~217,000/year (2030).

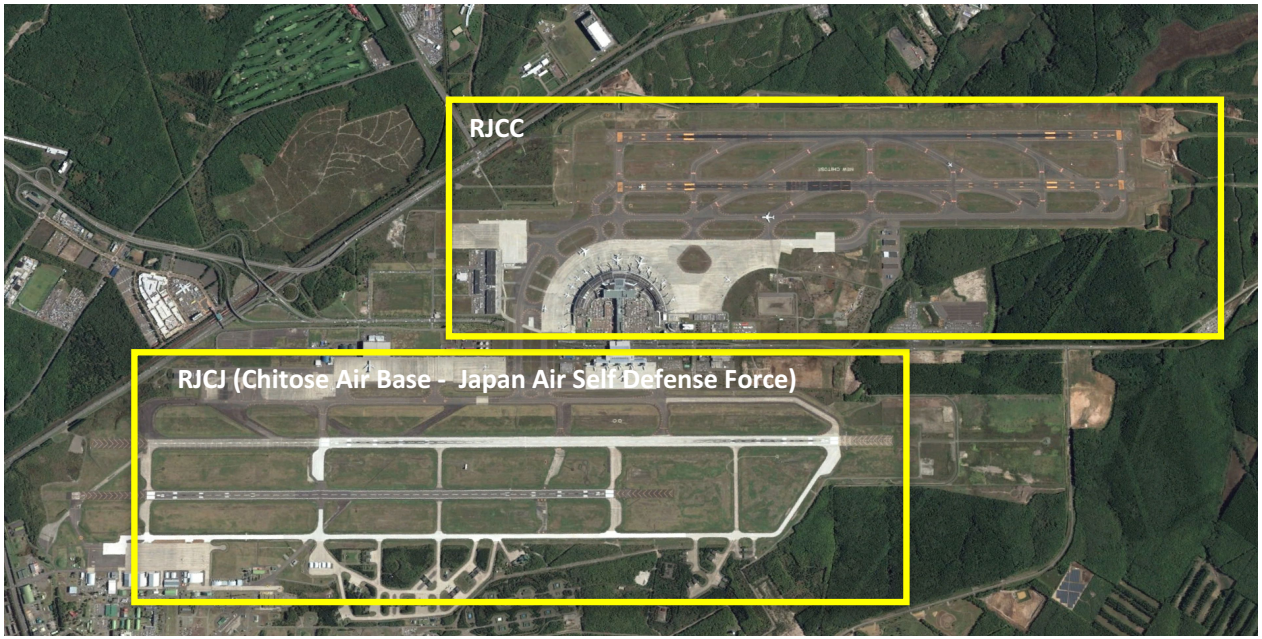


- Peak demand at 10:00-11:00 JST grows from ~36/hour to ~60/hour. Around 1/3 departures, 2/3 arrivals.

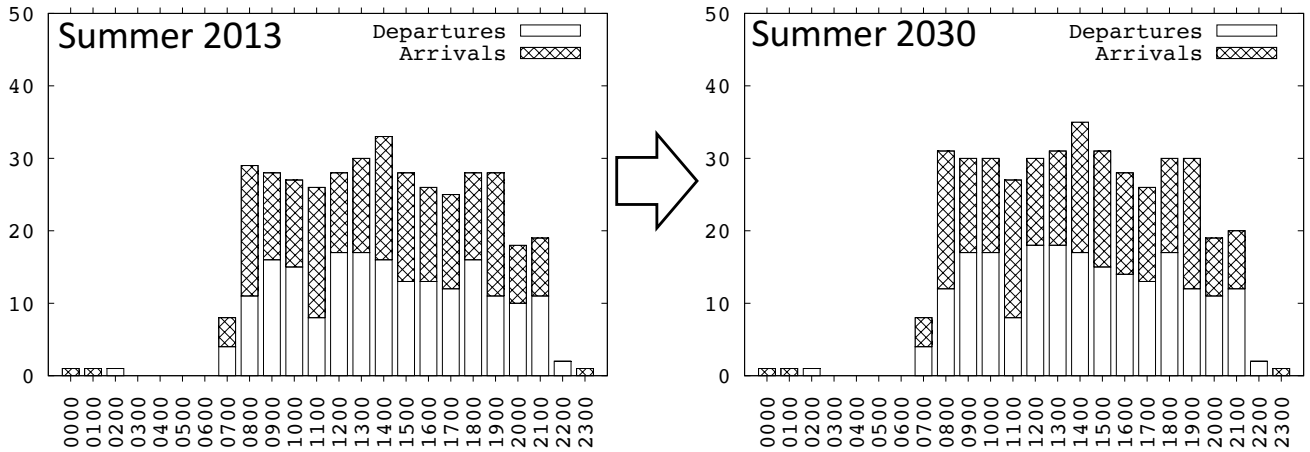
RJOO vs. RJBB

- RJBB opened in 1994 to relieve RJOO, which was then supposed to close.
- RJOO remains open partly due to sheer convenience.
- RJOO now domestic, RJBB mainly international.
- Increasing growth at RJBB driven by Asian LCCs.

RJCC



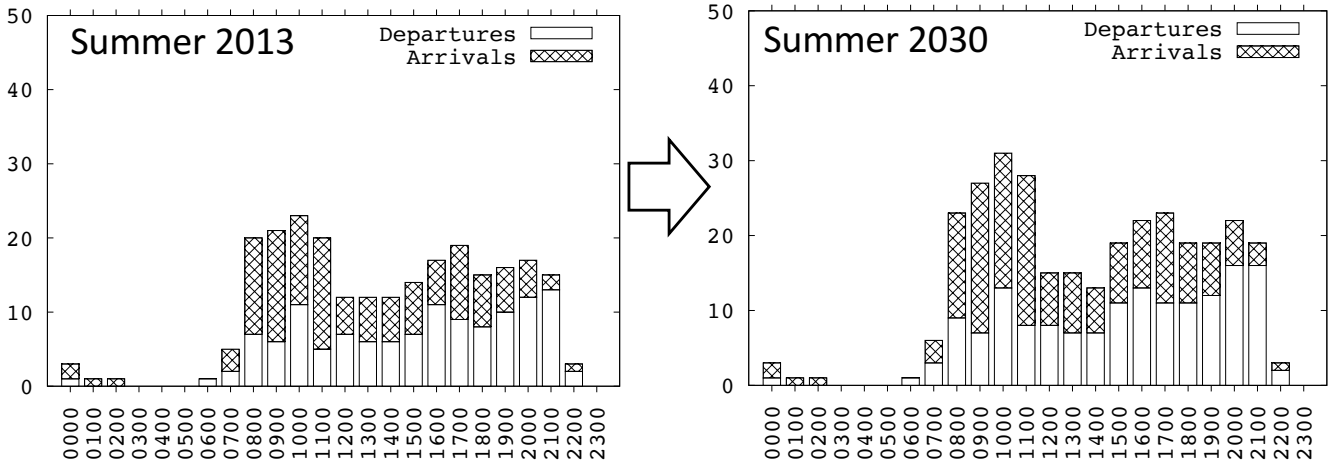
- Serves Sapporo (largest city on Hokkaido).
- 24-hour ops. but night restrictions (6 flights/day between 22:00 and 07:00)
- 2 runways (3,000m + 3,000m).
- 11% growth from 136,132/year (2013) to ~149,000/year (2030).



- Runway demand more or less constant from 08:00 to 20:00.
- Peak demand at 14:00-15:00 hardly changes. <40/hour.

RJGG

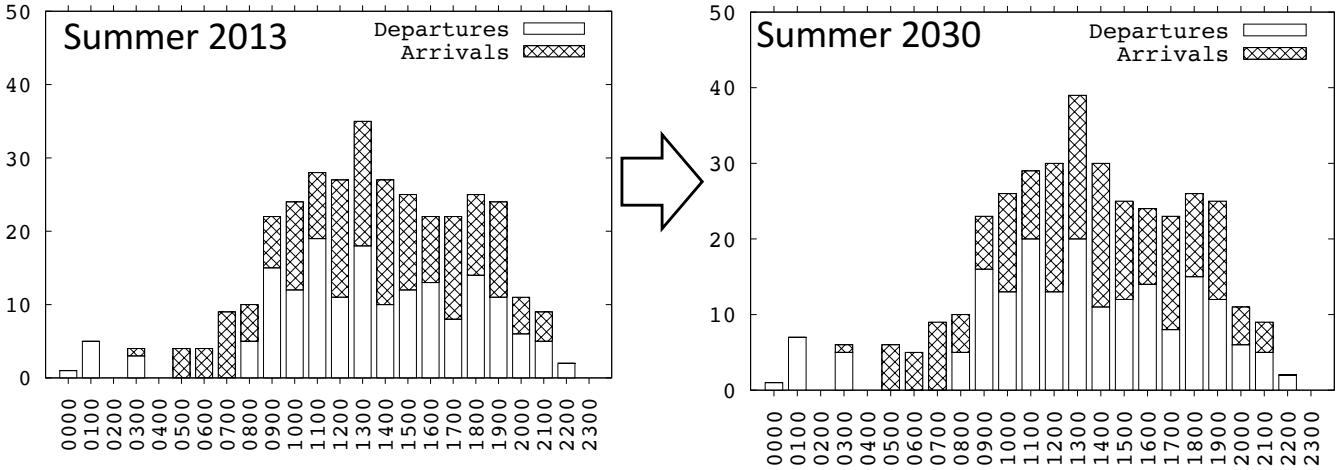
- Serves Nagoya/Chubu region.
- Artificial island. Intended to alleviate RJNA.
- 24-hour ops.
- 1 runway (3,500m).
- 32% growth from 88,578/year (2013) to ~117,000/year (2030).



- Morning peak 10:00-11:00.
- Peak demand changes from ~25/hour to ~35/hour. Easily within runway capacity.

ROAH

- Serves Naha city and hub for Ryukyu archipelago.
- Civil/SDF base.
- 24-hour ops.
- 1 runway (3,000m) + 1 planned.
- 4 terminals: domestic (1999), LCC (2012), International (2014), Cargo (2009).
- 9% growth from 147,302/year (2013) to ~160,000/year (2030).

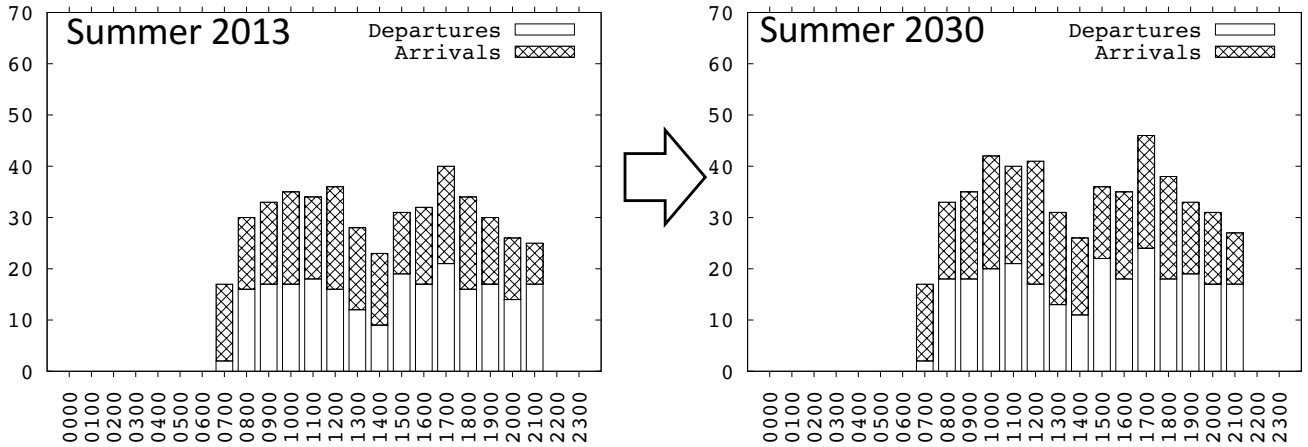


- Midday peak 13:00-14:00 grows from ~35/hour to ~40/hour.
- Does not include VFR (~20% of traffic).

Active expansion plans including international cargo hub not included in this projection.

RJFF

- Largest airport on Kyushu, serving Fukuoka.
- 07:00-22:00.
- 1 runway (2,800m) + 1 planned (closely-spaced, dependent).
- Expansion difficult as constrained by built-up areas and limited space within existing boundaries.
- 2 terminals: domestic, int'l, plus SDF base.
- 16% growth from 170,640/year (2013) to ~198,000/year (2030).



- Evening peak grows from ~40/hour to ~46/hour (winter).
- Does not include VFR (~6% of traffic).

RJFF vs. RJFR

- RJFF is extremely convenient (<10 mins to city centre) but expansion is highly constrained.
- Building another offshore airport costly and environmental problems.
- Capacity exists at RJFR but current journey times too great to attract RJFF traffic.