DAIKIN APPLIED - FORECASTING PROJECT

SENIOR DESIGN SPRING 2016

UNIVERSITY OF MINNESOTA

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Daikin Applied Overview

› Largest HVAC manufacturing company in the world

› Products: chillers, air handlers, rooftop systems, classroom unit ventilators, water source heat pumps, etc.

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Problem Overview

› Daikin would like to improve their booking (sales) forecasts for each month

› Current forecasts are heavily based on intuition and have room for improvement

› Daikin would like to develop a more data driven and systematic method to forecast their bookings

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Project Objective

- Design a forecasting algorithm
- Predict bookings for AAH, ATS & CHL business units for February, March & April.
- Total of 9 outputs

Forecast	February	March	April
AAH	?	?	?
ATS	?	?	?
CHL	?	?	?

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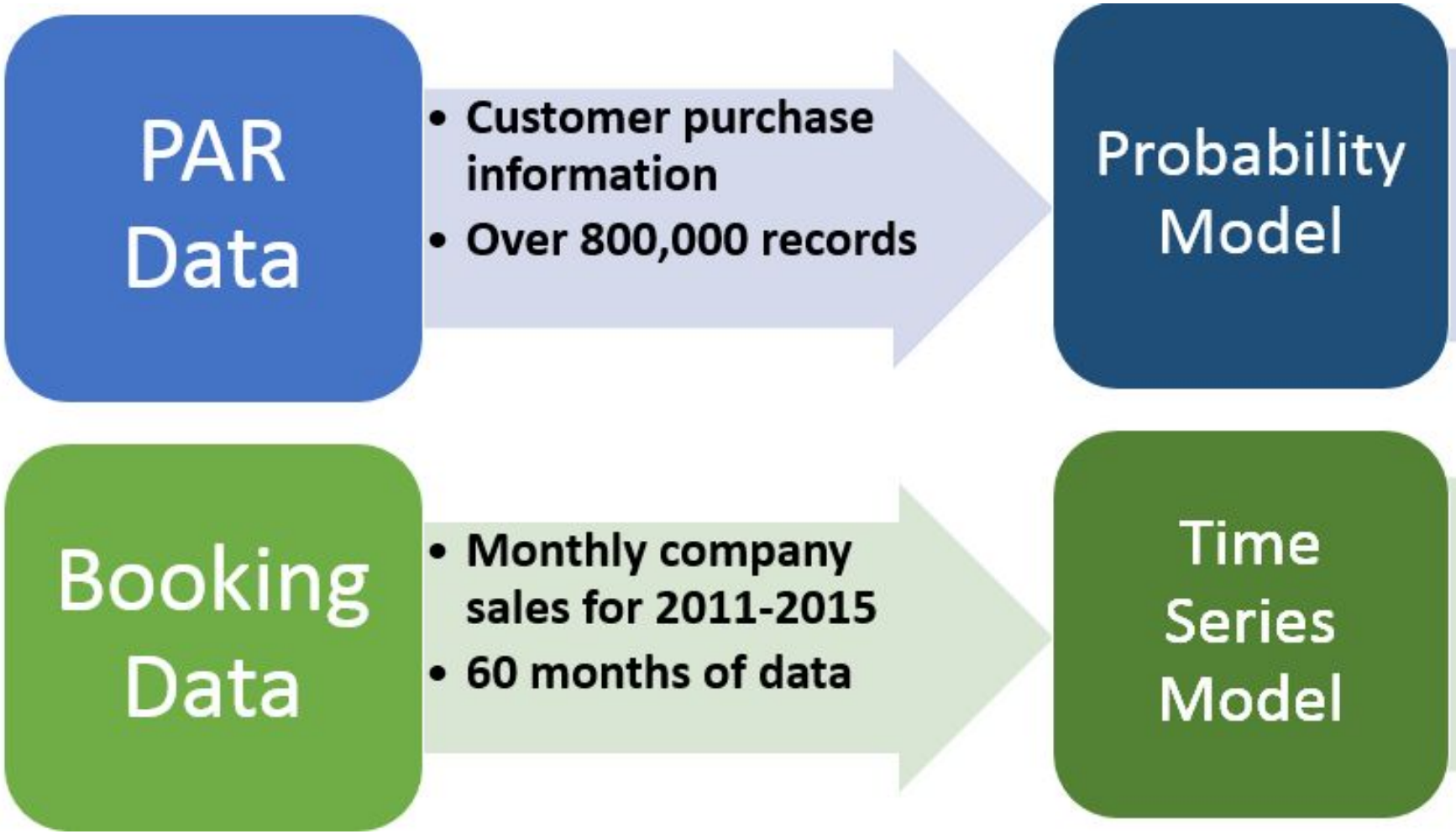
Value of Opportunity

- Opportunity to save Daikin up to $20 million
- Make better business decisions, minimize operating cost
- Recommendations on employee management
- Reducing lead times

Problem Approach

› Where do we start?

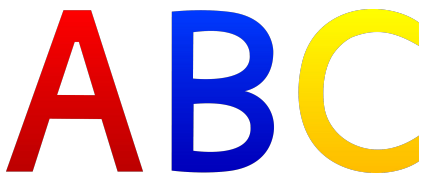
Data & Model Selection



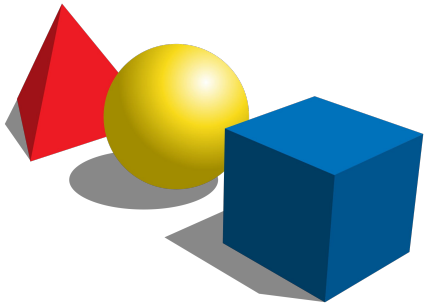
Probability Model Overview

› Parameters of Study

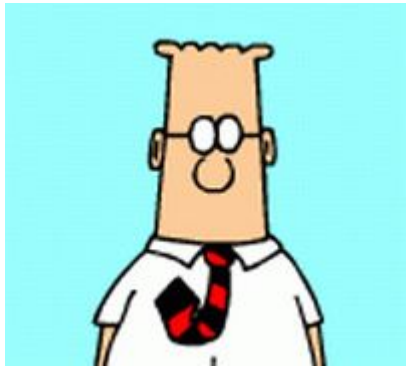
Design Type



Product Family



Sales Office



Model Type

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Probability Model 1 Methodology

- **Step 1:** Find the probabilities of a PAR becoming an order given the ***design type***, ***product family***, and ***sales rep***.
- **Step 2:** Average these probabilities to obtain a final probability.
- **Step 3:** Multiply the final probability with the PAR's net price.
- **Step 4:** Sum appropriate expected values of PARs for forecast.

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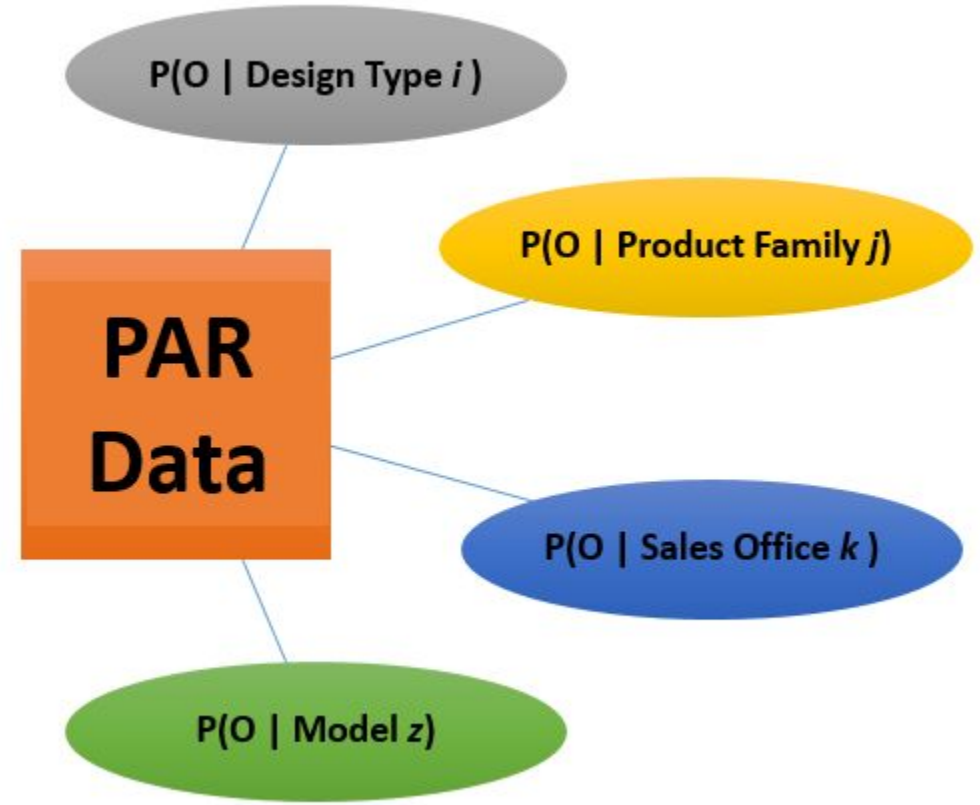
Probability Model 1 Methodology

› Step 1: Find the conditional probabilities of a PAR becoming an order given the design type, product family, and sales rep.

$$P(O|D_i) = \frac{P(O, D_i)}{P(D_i)}$$

$$P(O|F_j) = \frac{P(O, F_j)}{P(F_j)}$$

$$P(O|R_k) = \frac{P(O, R_k)}{P(R_k)}$$



Probability Model 1 Methodology & Results

› Step 2: Average these probabilities to obtain a final probability.

$$P(O|D_i, F_j, R_k) = \frac{1}{3}\left(P(O|D_i) + P(O|F_j) + P(O|R_k)\right)$$

› Step 3: Multiply the final probability with the PAR's net price.

› Step 4: Sum appropriate expected values of PARs for forecast.

Error	AAH	ATS	CHL
Feb	13%	27%	10%
Mar	34%	20%	7%
Avg Error	**23%**	**23%**	**9%**

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Probability Model 2 Methodology

- Uses the ***Model Type*** instead of the ***Product Family*** parameter.
- Uses steps 1-4 of previous model.
  - Calculate probabilities
  - Average probabilities
  - Find and sum expected values for forecast
- Step 5: Use 2013-14 PAR data to forecast sales for 2014-15

Probability Model 2 Methodology & Results

› Step 6: Average 2014-15 forecasts to forecast 2016 sales

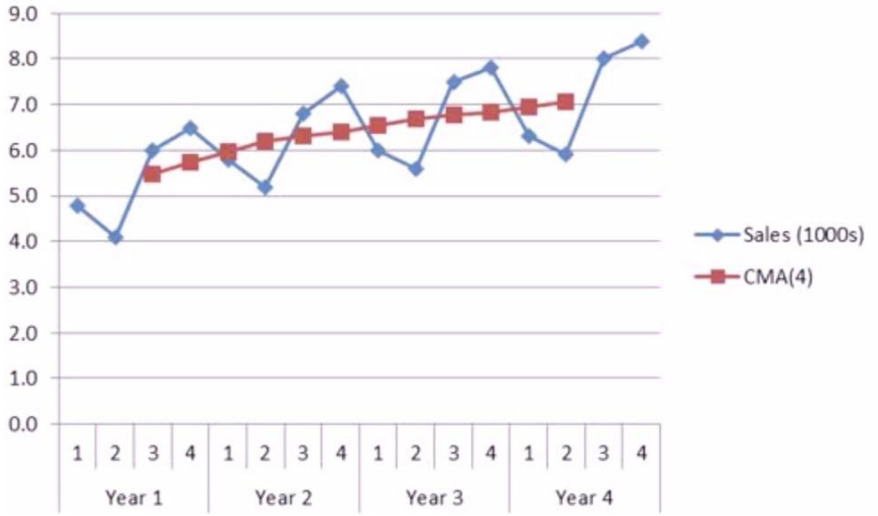
Error			
	AAH	ATS	Chiller
Feb	0.36%	6.65%	14.30%
Mar	-6.91%	17.87%	-10.34%
Apr	?	?	?

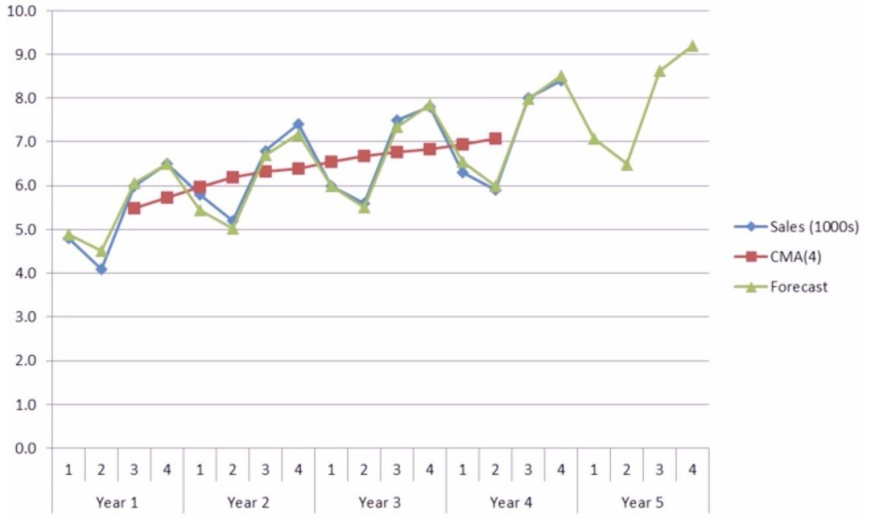
Time Series Model

Why a Time Series?

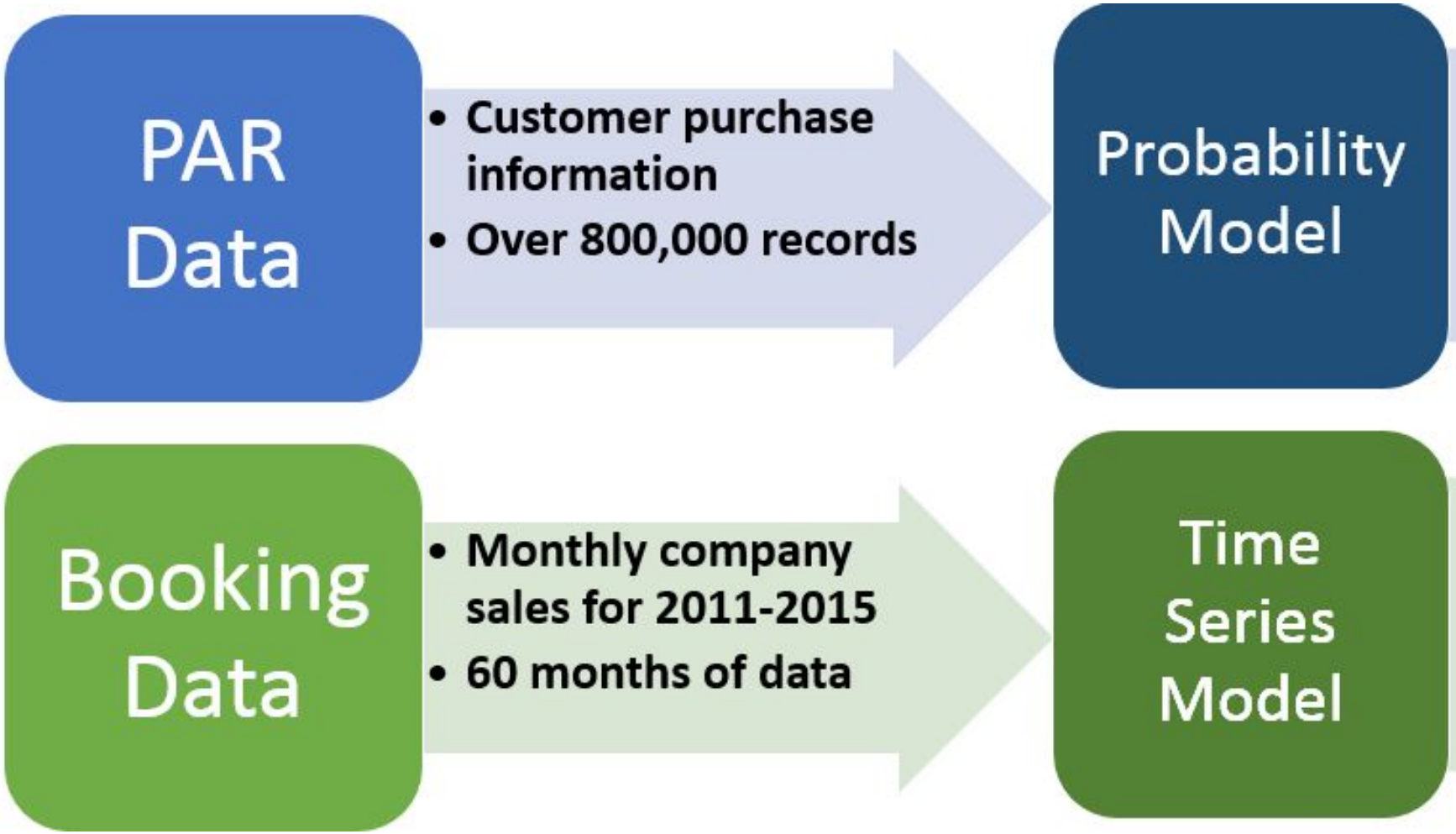
- Common method that is used when historical data is present

Example (non-Daikin data):





Data & Model Selection



Time Series Model - Overview

- Step 1: Choose Time Frame
- Step 2: Exploratory Data Analysis & Outlier Handling
- Step 3: Smooth & Deseasonalize data
- Step 4: Trend & Forecast
- Step 5: Go back to step 1 and repeat the process
- Step 6: Forecast Validation & Decision Making

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Time Series Model

Step 1: Choose Time Frame

› Choose training data (time frame of bookings)

› This is the data we are going to use to make the forecast

2011-2015 Bookings	2013-2015 Bookings	2014-2015 Bookings
• 60 data points	• 36 data points	• 24 data points

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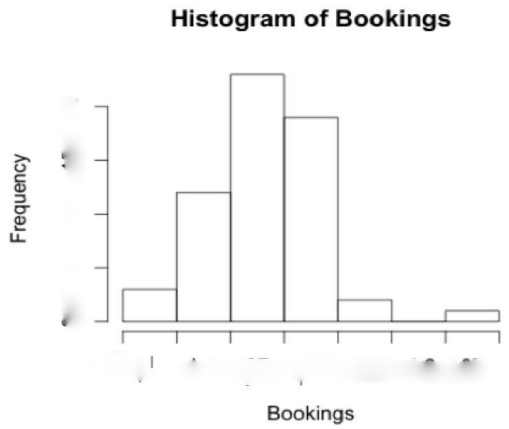
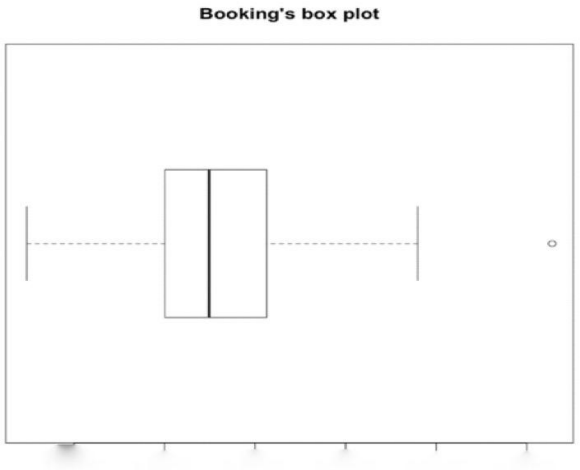
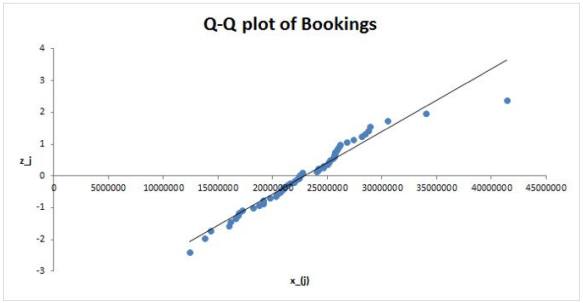
Time Series Model

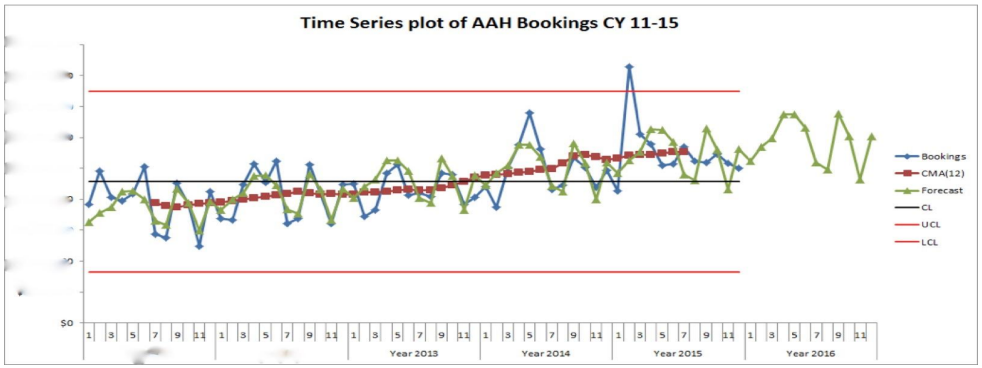
Step 2: Exploratory Data Analysis & Outlier Handling

› Verification of normality of data (bookings), and check for potential outliers with box plot, control chart, and input from sponsor









Time Series Model

Step 3: Smoothing & Deseasonalize

› Compute Moving Average of 6 or 12 months and then center it

$$CMA_t = \frac{1}{2}\left(\frac{1}{12}\sum_{j=t-6}^{t+5} b_j + \frac{1}{12}\sum_{j=t-5}^{t+6} b_j\right)$$

› Compute seasonal component, average it by month, and deseasonalize booking data

$$s_t = \frac{b_t}{CMA_t} \qquad D_t = \frac{b_t}{s_t}$$

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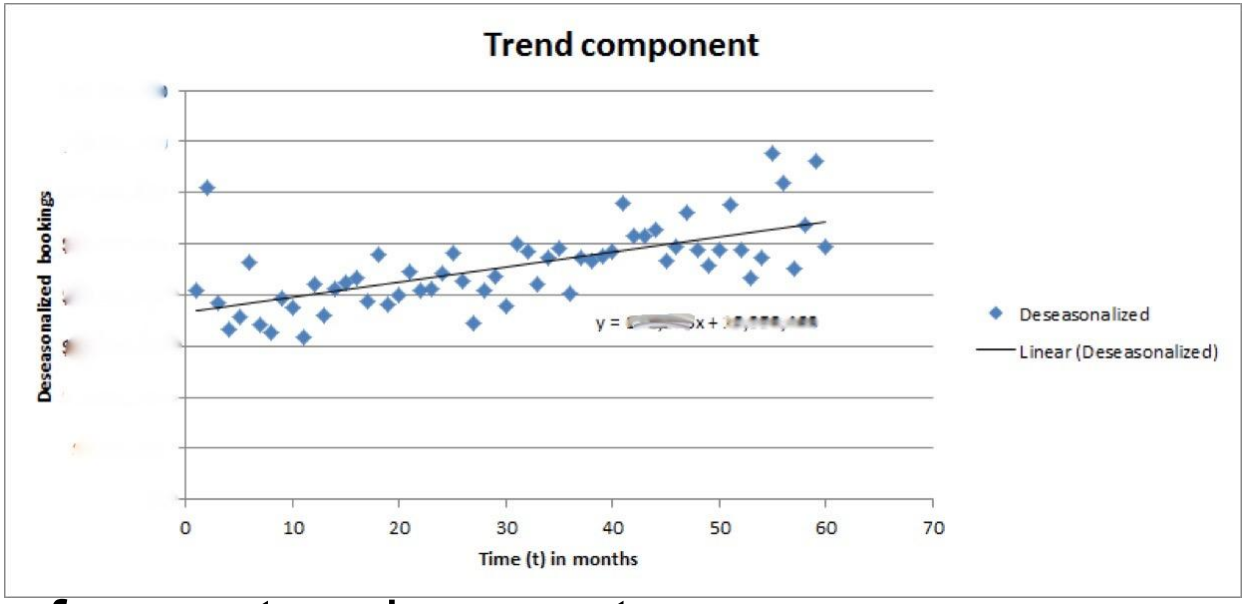
Time Series Model

Step 4: Trend & Forecast

› Compute trend of [Dt(y) vs. t(x)] with linear regression and use trend equation to calculate trend component



› Compute forecast and percent errors

$$F_t = \hat{y}_t s_t$$

Time Series Model

Step 5: Repeat whole process for other two time frames

› Choose training data (time frame of bookings)

› This is the data we are going to use to make the forecast

2011-2015 Bookings	2013-2015 Bookings	2014-2015 Bookings
• 60 data points	• 36 data points	• 24 data points

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Time Series Model

Step 6: Forecast Validation & Decision Making

› Example:

	Average percent error		
ATS	11-15	13-15	14-15
Feb	20.00%	13.00%	5.00%
Mar	9.25%	9.60%	12.00%
Apr	19.38%	2.74%	20.89%

› Choose best time frame model by each month to forecast

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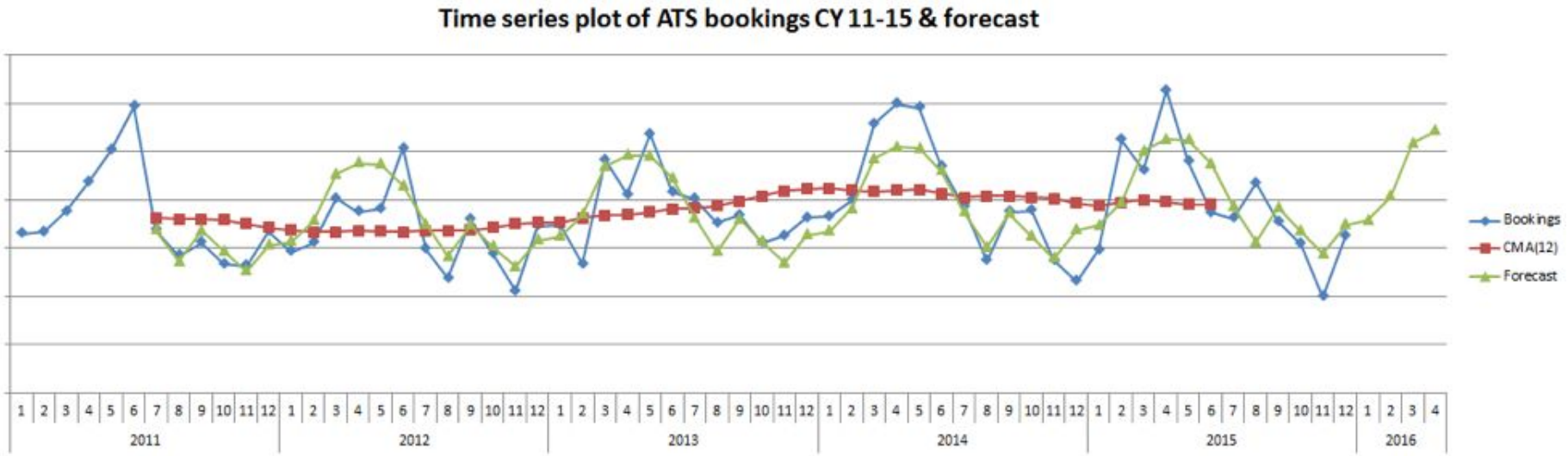
Time Series Model

Results

Example:



Time Series Model

Results

February	Daikin Error	UMN Error	Winning Model
Business Unit 1	-7.15%	-15.93%	Daikin
Business Unit 2	17.54%	-0.49%	UMN
Business Unit 3	-5.71%	-10.62%	Daikin

March	Daikin Error	UMN Error	Winning Model
Business Unit 1	-27.66%	-10.86%	UMN
Business Unit 2	-6.92%	-0.60%	UMN
Business Unit 3	-21.39%	-12.82%	UMN

Daikin's Average Abs. Error	14.39%
UMN Average Abs. Error	8.55%

~ 6%

ERROR

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Recommendations

- Time Series Model
  - Better outlier handling
  - Automate it
- Probability Model
  - Consider machine learning concepts
  - Optimize weighting factors
  - Obtain consistent data

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LESSON LEARNED

- Communication with sponsor
  - Weekly meetings, emails, progress reports
- Back up data
- Understanding data assumptions

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QUESTIONS?

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