Service Management – Forecasting Demand for Services

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Chair in Economics – Information and Service Systems (ISS)
Saarland University, Saarbrücken, Germany

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Thursdays, 8:00 – 10:00 a.m.
Room HS 024, B4 1

General Agenda

Chair in Information and Service Systems

Agenda Lecture 6

- **Overview Methods of Forecasting**
- Subjective Methods
  - Delphi Method
- Causal Models
  - Regression Analysis
- Time Series Models
  - N-Period Moving Average
  - Exponential Smoothing
    - Simple exponential smoothing
    - Trend adjustment
    - Seasonal adjustment

Problem:

A hairdresser in Saarbrücken with 3 employees never knows how many customers will come to his shop at what time and when to deploy his personnel. Sometimes, there are long queues and customers even leave the shop. At other times, there are no customers at all and the 3 employees are bored.

Solution: Forecasting

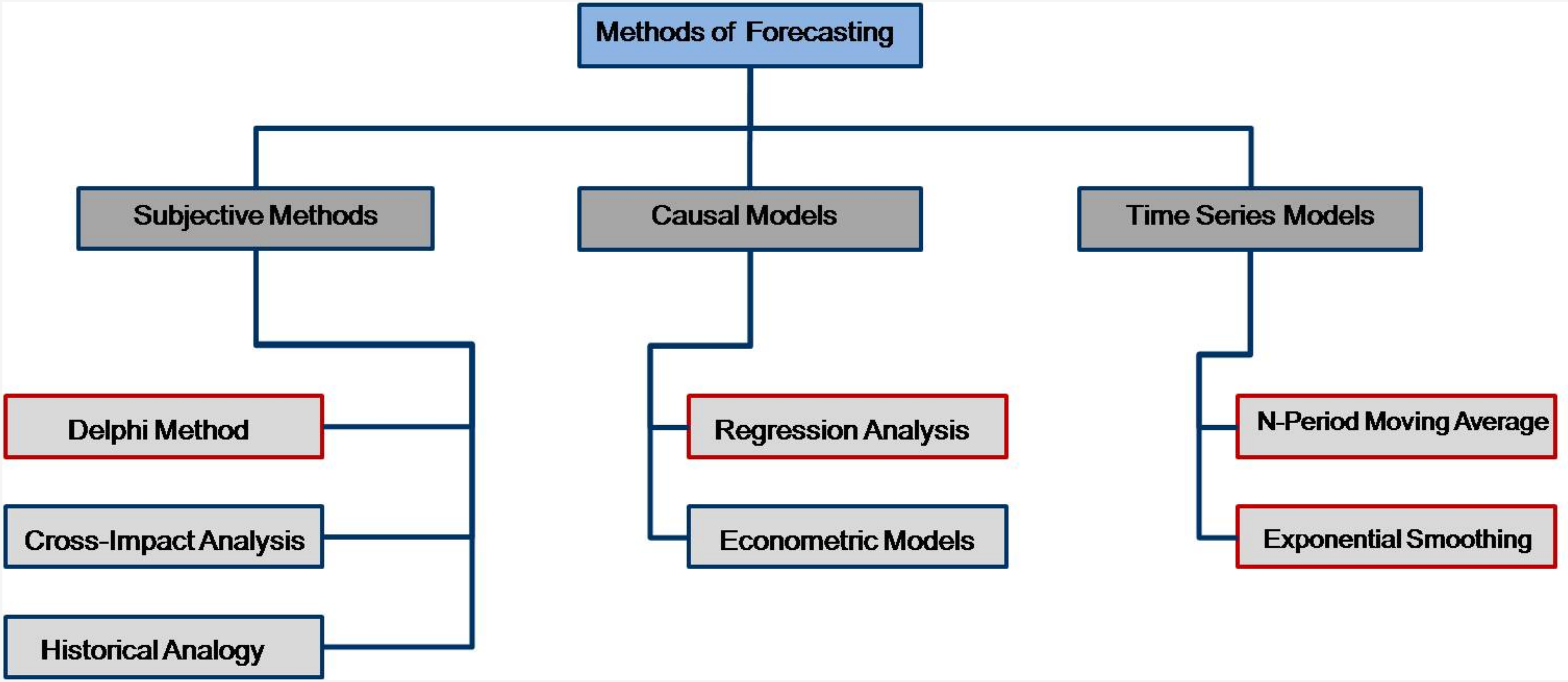
“Forecasting can be defined as the art of predicting the occurrence of events before they actually take place. “ (Archer, 1980)

Forecasting:

- Provides information about the uncertain future (e.g., regarding demand)
- Enables decision making and planning of activities and capacity
- Is done in advance before a certain event actually takes place.

(Archer, 1980)

Overview Methods of Forecasting



(Fitzsimmons & Fitzsimmons, 2011)

Overview Methods of Forecasting

Subjective methods:

- Delphi method: Expert opinions are collected in several rounds without a general discussion.
- Cross-impact analysis: Correlation between two events are analysed by a group of experts.
- Historical analogy: Performance of a new service is forecasted by using existing data of a similar service (e.g., life cycle performance)

Causal models:

- Regression analysis: Relationship between a dependent and an independent variable is calculated in one equation.
- Econometric models: Relationship between two variables is calculated in a system of equations.

Time series models:

- N-period moving average: Short-term forecasts when there is a pattern in the data (demand forecasting)
- Exponential smoothing: Short-term forecasts when there is a pattern in the data, trends and seasonality can be included, short-term (demand forecasting)

(Fitzsimmons & Fitzsimmons, 2011)

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Subjective Methods: Delphi Method

Subjective methods: Used at beginning of planning process, usually for long-term forecast period, high costs (Fitzsimmons & Fitzsimmons, 2011)

Delphi method:

Technique to achieve a group judgment for exploratory questions where detailed knowledge is not yet available. Group of experts receives a questionnaire in several rounds with opinion feedback after each round and answers them individually. After each round, they can revise their opinion. No direct discussion of the experts.

<u>Objectives</u>:

- Obtainment of an opinion consensus of a group of experts.
- Minimization of the biasing effects of dominant individuals and group pressure.

<u>Features of the method</u>:

- Opinions of experts are received by an anonymous, individually answered questionnaire.
- Systematic exercise of the procedure with several iterations and controlled feedback between the rounds.
- Group opinion is defined as an appropriate aggregate of individual opinions in the final round.

(Dalkey & Helmer, 1963; Dalkey, 1969)

Subjective Methods: Delphi Method

Example: U.S.-study (1953) regarding the number of A-bombs needed in case of a war against the Soviets

- Objective: Estimation of numerical quantity of bombs needed
- Tendency of different estimations to converge while experiment continues
- Difficulty: For each industry: Estimation needed of percentage that had to be destroyed and average number of bombs needed to do so.

Implementation:

- 7 experts (economists, physical-vulnerability specialist, systems analyst & electronics engineer)
- 5 questionnaires (Q) & 2 interviews (I)
  - **Q1:** Estimation of the minimum number of bombs needed & of further information required.
  - **I1:** Breakdown by industries regarding the number of bombs & explanation
  - **Q2:** Provision of further information, new estimation of number of bombs. Questions regarding additional factors of influence.
  - **Q3:** Revised estimation of number of bombs, information given on estimation of other experts. More facts provided.
  - **I3:** Detailed explanation of estimation.
  - **Q4:** Revised estimation of number of bombs under consideration of two other bombing schedules (consensus of all estimates so far: median of all responses)
  - **Q5:** Revision once more of own estimates(more info is given)

Median of the responses was taken as the consensus

(Dalkey & Helmer, 1963; Dalkey, 1969)

10 Minutes

- The hairdresser of Saarbrücken has collected the data regarding his clients for the past 2 months. He has listed the number of clients arriving per weekday and per time of day. He has also written down the turnover per haircut.

  He is interested in the expected number of clients for next Saturday. Furthermore, he would like to know if there is a relationship between the time of day and the turnover per haircut.

- Do you think that the Delphi method is suited for forecasts like this? Why/why not?

- Please write your answers down (papers will be collected).

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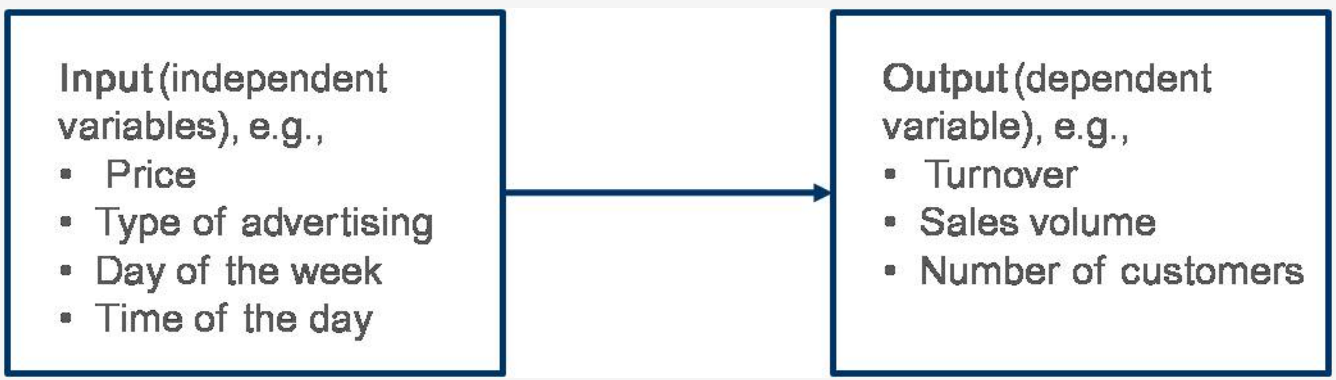
Causal Models: Regression Analysis

Causal relationship:
“If we have a relationship between ‘x’ and ‘y’; and if for any antecedent test factors the partial relationships between x and y do not disappear, then the original relationship should be called a causal one.” (Lazarsfeld, 1955)

Causal models: Identification of a relationship between several factors.

Here: Only linear relationships are being considered. How can they be measured?



Regression analysis: Relationship between one dependent variable (Y) and one or several independent variables (X_i): Describing of correlations in a quantitative way. A possible influence of variables X_i on variable Y can be identified to adopt service provision to demand.

- Dependent variable = Parameter which is supposed to be forecasted (Y)
- Independent variable(s) = Parameters which are supposed to influence the dependent variable (X_1, X_2, X_3, ...), also independent of each other
- Scale of measurement:
  - Metric for dependent variable (figure, e.g., price, turnover, sales, percentage of group)
  - Metric or nominal for independent variable(s) (figures, but also categories, e.g., type of advertising or service)
- Simple regression (univariate): One independent variable

$$Y = a_0 + a_1 X$$

- Multiple regression (multivariate): Several independent variables

$$Y = a_0 + a_1 X_1 + a_1 X_2 + \cdots + a_n X_n$$

a_0 = Constant (intersection point of regression line and Y-axis)

a_n = Regression coefficients (increase of regression line)

(Backhaus, 2006; Fitzsimmons & Fitzsimmons, 2011)

Example: Calculation of the number of children needing day care service within a certain census track

Variables:

Yi = Percentage of families from census track i in need of day care

X1i = Percentage of families in census track i with children under 5 years old

X2i = Percentage of families in census track i with a single female head of household

X3i = Percentage of families in census track i with both parents working

Regression model (calculated with e.g., SAS or SPSS):

$$Y = 0,58 * X_{1i} + 0,43 * X_{2i} + 0,85 * X_{3i}$$

(Fitzsimmons & Fitzsimmons, 2011)

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Time Series Models: N-Period Moving Average

Time Series Models: Used for short-term forecasts, observation values show a pattern

N-Period Moving Average:

- Forecasting of data on the basis of several data collections before
- E.g., forecasting of next Saturday's occupancy rate of a hotel on the basis of 3 previous Saturday's occupancy rates
- Average of previous data is taken: Eliminate accidental increases or decreases (changes each period)
  - t = period
  - MA_t = Moving average for period t
  - A_t = Observation in period t
  - N = Number of observations

$$MA_t = \frac{A_t + A_{t-1} + A_{t-2} + \cdots + A_{t-N+1}}{N}$$

  - E.g., Calculation of MA_4: Add the values of period 1-3 and divide by 3
    Calculation of MA_5: Add the values of period 2-4 and divide by 3
  - Average values are taken as forecasts for the next periods

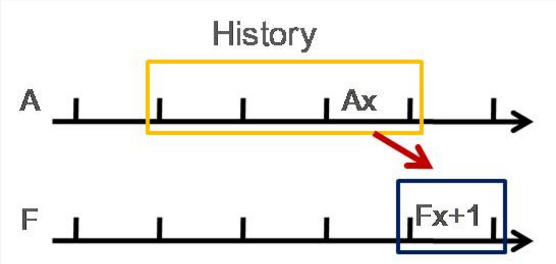
(Fitzsimmons & Fitzsimmons, 2011)

Example: Forecast for occupancy rate of a hotel on Saturdays for September 12

Saturday	Date	Period	Occupancy (A)	3-Period Moving Average	Forecast (F)
August	1	1	79		
August	8	2	84		
August	15	3	83	82	
August	22	4	81	83	82
August	29	5	98	87	83
September	5	6	100	93	87
September	12	7			93

Moving Average Period 3: $$MA_3 = \frac{83+84+79}{3} = 82$$

Moving Average Period 4: $$MA_4 = \frac{81+83+84}{3} = 83$$



Moving Averages are taken to forecast the occupancy rate for new period.

(Fitzsimmons & Fitzsimmons, 2011)

Exponential smoothing: Used e.g., for demand forecasting, Based on N-period moving average

- Accidental increases or decreases in the average are “smoothed out” (extreme values weight less for forecasting of following periods): Advantage compared to other methods
- Old data is kept in calculation, but influence is reduced steadily
- “Defensive” forecasting method: Forecasting values often lower than actual values

Forecast error of the previous period is put back in next period

A_t = Actual observed value for current period t

S_t = Smoothed value for current period t

S_{t-1} = Smoothed value for previous period

$(A_t - S_{t-1})$ = Forecast error of previous period (Difference of actual and smoothed value of previous period)

α = Smoothing constant; between 0 and 1 (fraction of the forecast error that is added to smoothed value of previous period)

Smoothing value for current period [1]: $S_t = S_{t-1} + \alpha(A_t - S_{t-1})$

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Simple Exponential Smoothing

Calculating the smoothed value S_2 for period t_2

α = 0,5

$$S_2 = S_1 + \alpha(A_2 - S_1)$$

S_2 = 79,0 + 0,5 * (84 – 79,00) = 81,50

Saturday	Date	Period	Actual Occupancy	Smoothed Value	Forecast	Error
		t	A_t	S_t	F_t	$A_t - F_t$
August	1	1	79	79,00		
August	8	2	84	81,50	79	
August	15	3	83			
August	22	4	81			
August	29	5	98			
September	5	6	100			

(Fitzsimmons & Fitzsimmons, 2011)

Smoothed value of period t: Used as forecast for following period t+1

F_{t+1} = Forecast for following period t+1

$F_{t+1} = S_t$ ([2] Rounded to an integer)

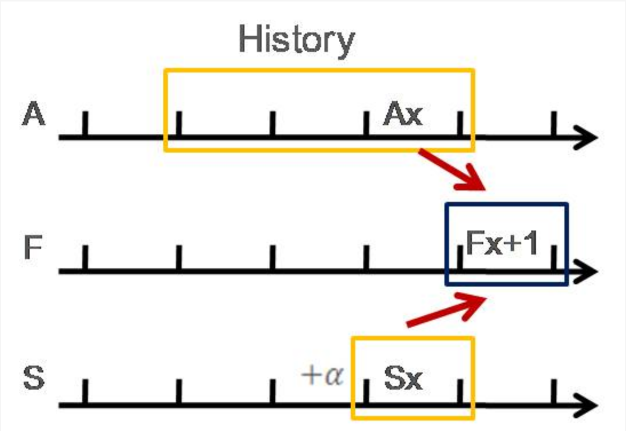
Example: Forecast of August 15 (F_3)

$F_3 = S_2 = 81{,}50$ Rounded to $F_3 = 82$

Rewriting of equation [3]:

$$S_t = \alpha(A_t) + (1-\alpha)S_{t-1}$$

A_t and S_{t-1} are weighted by α



(Fitzsimmons & Fitzsimmons, 2011)

Saturday	Date	Period	Actual Occupancy	Smoothed Value	Forecast	Error
		t	A_t	S_t	F_t	$A_t - F_t$
August	1	1	79	79,00		
August	8	2	84	81,50	79	5
August	15	3	83	82,25	82	1
August	22	4	81	81,63	82	-1
August	29	5	98	89,81	82	16
September	5	6	100	94,91	90	10

Correct forecasts only for some values.

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Trend Adjustment

Trend: Average of change when comparing observed values of previous and actual periods over time

Trend value is added to smoothed value equation:

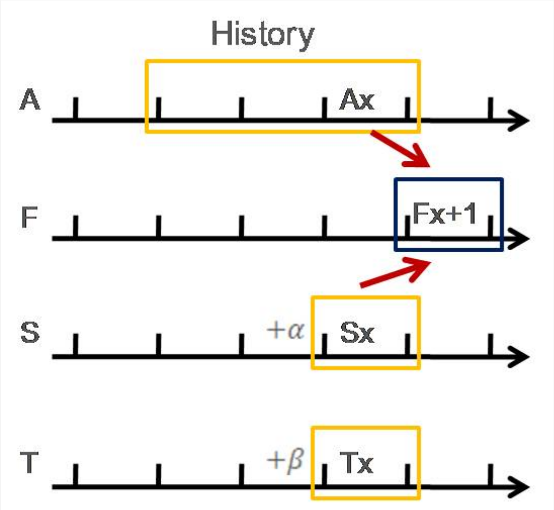
- T_{t-1} = Smoothed trend value of previous period
- T_t = Smoothed trend value of current period
- β = Smoothing constant (between 0 and 1): Can be the same as α or different

New equation of S_t including smoothed trend value [4]:

$$S_t = \alpha(A_t) + (1-\alpha)(S_{t-1} + T_{t-1})$$

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Trend Adjustment



Smoothed trend value of current period [5]:

$$T_t = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1}$$

F_{t+1} = Forecast for following period t+1

$F_{t+1} = S_t + T_t$ ([6] Rounded to an integer)

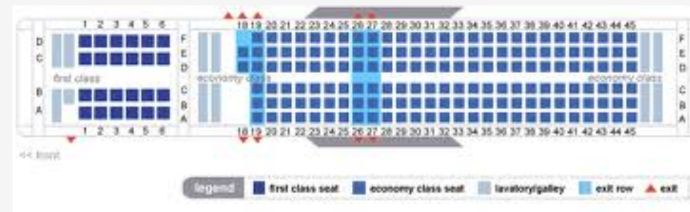
Relevance of smoothing constants (e.g. α, β ,):

- Fraction of forecast error is added to smoothed value in the next period
  - High value for constant: Higher weight of recent data (error)
  - Low value for constant: Lower weight of recent data (error)
- Usually between 0,1 and 0,5 in the industry
- Selection of constant: Difficult (trade-off between overreacting to random changes & overseeing a trend)

(Fitzsimmons & Fitzsimmons, 2011)

Example: A new airline wants to forecast the percentage number of seats sold (load factor) per week. The load factor increases nearly every week.

Task: Forecasting the load factor of week 3.



α = 0,5; β = 0,3

$F_2 = 31 + 0{,}00 = 31$ Using equation [6]

$S_2 = 0{,}5 * 40 + (1-0{,}5) * (31 + 0{,}00) = 35{,}5$ Using equation [4]

$T_2 = 0{,}3 * (35{,}50 - 31{,}00) + (1 - 0{,}3) * 0{,}00 = 1{,}35$ Using equation [5]

$F_3 = 35{,}5 + 1{,}35 = 36{,}85$ (Rounded to 37) Using equation [6]

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Trend Adjustment

Week	Actual Load Factor	Smoothed Value	Smoothed Trend	Forecast	Forecast Error
t	A_t	S_t	T_t	F_t	$\lvert A_t - F_t \rvert$
1	31	31,00	0,00		
2	40	35,50	1,35	31	9
3	43	39,93	2,27	37	6
4	52	47,10	3,74	42	10
5	49	49,92	3,47	51	2
6	64	58,69	5,06	53	11
7	58	60,88	4,20	64	6
8	68	66,54	4,63	65	3

Nearly correct forecast only for week 5 (for other weeks: Large differences between actual value and forecast).

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Seasonal Adjustment

Seasonality: Change in average actual values which returns every season (e.g., winter sports demand)

- Seasonal effects in exponential smoothing: Seasonality is removed from data, data is smoothed and finally seasonality is added again for the forecast
- Data for one full season is needed for forecast

L = Cycle, length of one season (e.g., 12 months)

I_t = Seasonality index (removes seasonality from data)

t-L = Data of the same month in the previous cycle (e.g., January 12 months ago)

A_t = Actual observed value for current period t

$\bar{A}$ = Average value for all periods in the cycle L

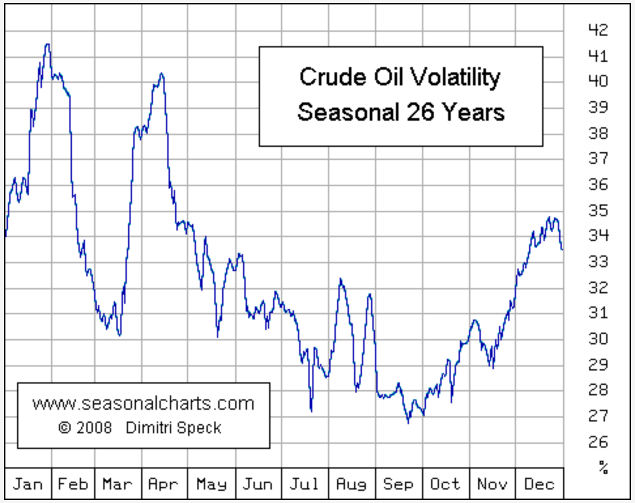
γ = Smoothing constant (can be between 0 and 1)

Calculation of the average value for all periods in L [7]:

$$\bar{A} = \frac{(A_1 + A_2 + \cdots + A_L)}{L}$$

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Seasonal Adjustment



Calculation of standard seasonality index [8]:

$$I_t = \frac{A_t}{\bar{A}}$$

Calculation of smoothed value [9]:

$$S_t = \alpha \frac{A_t}{I_{t-L}} + (1-\alpha) S_{t-1}$$

Calculation of forecast for following period (seasonalising the smoothed value) [10]:

$$F_{t+1} = S_t * I_{t-L+1}$$ (Rounded to an integer)

Calculation of the smoothed seasonality index [11]:

$$I_t = \gamma * \frac{A_t}{S_t} + (1-\gamma) * I_{t-L}$$

(Fitzsimmons & Fitzsimmons, 2011)

Time Series Models: Exponential Smoothing: Seasonal Adjustment

Example: Calculation of the number of people using a ferry to a Caribbean island (changes due to season), years 2009 and 2010.

α = 0,2; γ = 0,3

$\bar{A}$ = 1971,83 (2009)

S_{13} = 0,2 * 1,806/0,837 +(1 – 0,2) * 1,794,00 = 1866,74 Using equation [9]

F_{14} = 1866,74 * 0,662 = 1235,78 Using equation [10] (Rounded to 1236)

I_{13} = 0,3 * 1806/1866,74 + (1 – 0,3) * 0,867 = 0,876 Using equation [11]

(Fitzsimmons & Fitzsimmons, 2011)

Period	Week	Actual Passengers	Smoothed Value	Index	Forecast	Forecast Error
	t	A_t	S_t	I_t	F_t	
			2009			
January	1	1.651	(-)	0,837	(-)	
February	2	1.305	(-)	0,662	(-)	
March	3	1.617	(-)	0,820	(-)	
April	4	1.721	(-)	0,873	(-)	
May	5	2.015	(-)	1,022	(-)	
June	6	2.297	(-)	1,165	(-)	
July	7	2.606	(-)	1,322	(-)	
August	8	2.687	(-)	1,363	(-)	
September	9	2.292	(-)	1,162	(-)	
October	10	1.981	(-)	1,005	(-)	
November	11	1.696	(-)	0,860	(-)	
December	12	1.794	1.794	0,910	(-)	
			2010			
January	13	1.806	1.866,74	0,876	(-)	(-)
February	14	1.731	2.016,35	0,721	1,236	495
March	15	1.733	2.035,76	0,829	1,653	80
April	16	1.904	2.064,81	0,888	1,777	127
May	17	2.036	2.050,28	1,013	2,110	74
June	18	2.560	2.079,71	1,185	2,389	171
July	19	2.679	2.069,06	1,314	2,749	70
August	20	2.821	2.069,19	1,363	2,820	1
September	21	2.359	2.061,38	1,157	2,404	45
October	22	2.160	2.078,95	1,015	2,072	88
November	23	1.802	2.082,23	0,862	1,788	14
December	24	1.853	2.073,04	0,905	1,895	42

Outlook

1. Introduction
2. Service Strategy
3. New Service Development (NSD)
4. Service Quality
5. Supporting Facility
6. Forecasting Demand for Services
7. **Managing Capacity and Demand (Part A)**
8. Managing Capacity and Demand (Part B)
9. Managing Waiting Lines
10. Capacity Planning and Queuing Models
11. Services and Information Systems
12. ITIL Service Design
13. IT Service Infrastructures
14. Guest Lecture – Dr. Roehn, Deutsche Telekom
15. Summary and Outlook

Literature

Books:

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