History and Theory of Revenue Management

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Agenda

1. Motivation

1. Single Resource Capacity Control

1. Customer Choice Behaviour

1. Motivation

Definition

Revenue Management
is a collection of methods, strategies and tactics that companies utilize to scientifically **manage demand** for their products.

It helps you to sell the...

- right **product**, at the
- right **time**, at the
- right **price**, to the
- right **customer**

Synonyms (with slightly different meanings):
yield management, pricing and revenue management, pricing and revenue optimization, revenue process optimization, demand management, demand chain management

Business Decisions

Revenue management helps with **structural** (segmentation), **price** building and **quantitative** decisions.

Key questions

- How can customers be segmented based on their willingness to pay?
- How to design products in order to prevent cannibalization between these segments?
- Which price to charge these segments?
- Should you charge different prices for different channels?
- Adjust the prices over time? (seasonal factors, historical data about demand, …)
- There is a bottleneck; sell to which segments and channels?
- How to handle complements (seats on two connecting airline flights) and substitutes (different car categories for rentals)?

And… how is this new?

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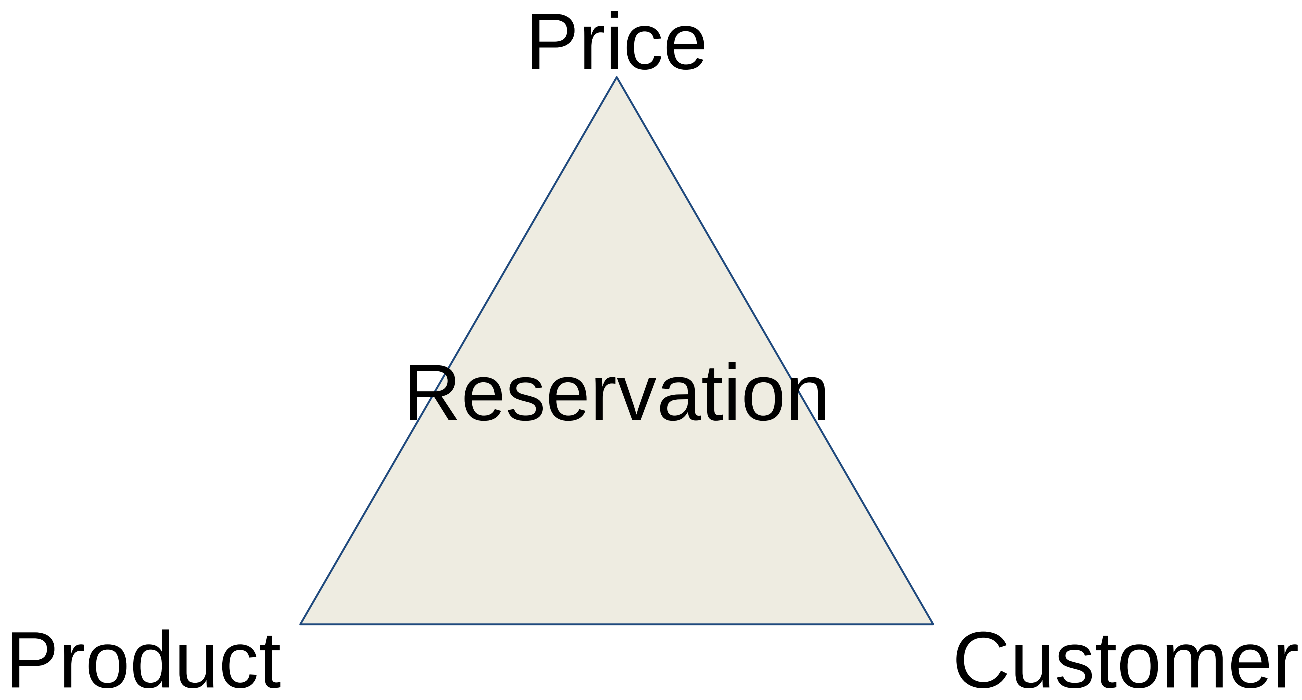
Every seller in history had to make those decisions!
So… what gives?

- Not the **WHAT** but the **HOW**
- A technologically complex, detailed and intensely operational approach
- Scientific advancements in economics, statistics and operational research
- Massive advancements in electronic data processing. Most of them younger than 20 years!
- Today: thousands of flights between hundred-thousands of source/destination pairs, each being booked at dozens of different prices… hundreds of days into the future.
- However: humans NOT obsolete! Good systems are based on synergy between technology and humans.

Motivation
Factors of a reservation



Motivation
Product

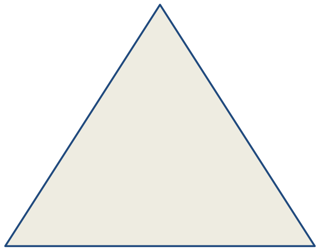
The product to be sold (here touristic services) is at the core of the reservation.

Which aspect guides the revenue?

- the hotel itself? (house with tradition?)
- the destination? (party town at the Riviera?)
- the experience? (become a monk for a week?)
- the rooms?
- the services? (24/7 massage service, Jet Ski?)

The product can be designed as soon as these main aspects are identified.

- New types of rooms?
- Additional price ranges?
- etc.



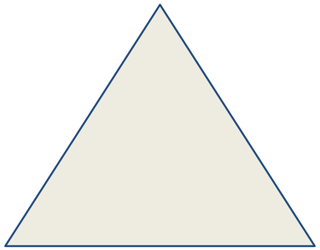
Motivation
Customer

Der Kunde ist der wichtigste Aspekt in der Preisgestaltung!
Jeder Kunde hat seine eigene Motivation:

- Verschiedene Motive
- Verschiedene Erwartungen
- Bereitschaft unterschiedliche Preise zu zahlen
- Interesse an verschiedenen Produkten

Um dieses Umfeld zu verstehen und zu handhaben muss der Markt segmentiert werden. Für jedes dieser Segmente muss folgendes angepasst werden:

- Interesse an verschiedenen Produktkategorien
- Preisgestaltung
- Reservierungsbestimmungen
- Marketing



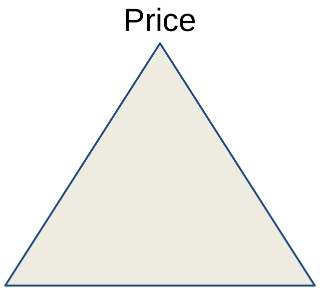
Customer

Motivation
Price

~~Obviously the price is the main control mechanism!~~ WRONG!

- price is determined according to **demand**
- prices aren't fixed, they **rise** and **fall**
- they're bound to **seasonal** flux
- there are **years** with lots of demand and years with little
- **channels** with hardly any demand
- local, regional and international **competition**

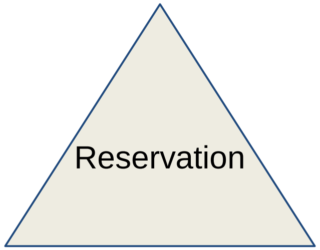
However there are techniques to influence the price/revenue.
One of the topics of this course.



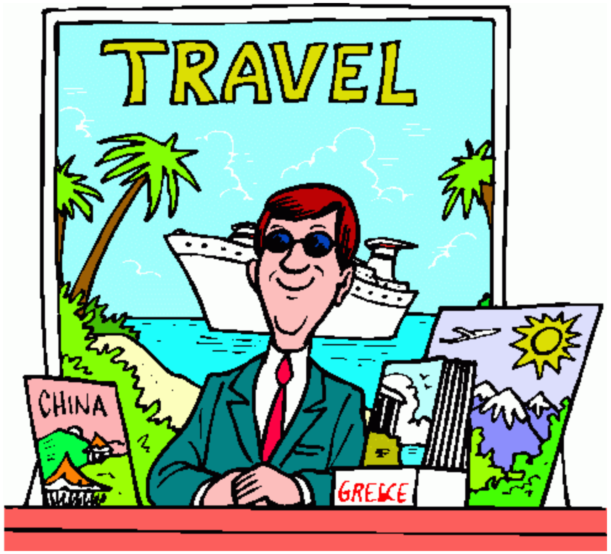
The moment of reservation itself is a key moment in revenue management that often doesn't get treated with the importance it deserves.

This moment is equally as important for the customer as it is for the hotel! Both parties need to work efficiently together.

Many techniques exist for both parties. For example forecasts based on historical data can be very valuable.



History
Then



History
Now

Booking.com

Expedia®

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„I’m willing to pay this price (or not)!”

Multiple factors, sophisticated models, forecasting and estimation… all boils down to this simple truth

Key Performance Indicators

Important key performance indicators (KPIs) in hotel revenue management:

- **GOPPAR**
- **RevPOST**
- **RevPAR**
- **RevPOR**

They are used for specific targets based on:

- timing
- availability
- quantity
- marketplace demand

of a specific meeting space utilized by a group or **overlapping groups.**

Key Performance Indicators
"Revenue Per Available Room"

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$$\text{RevPAR} = \text{Average Daily Rate} * \text{Occupancy}\%$$

Comparison of hotels of different size.
Calculate market share and year-to-year performance.

A rising RevPAR indicates a rising occupancy rate and/or price.
Price fluctuations have a much higher influence on the RevPAR.

However! Only an overview, can't make statements about the real profitability of a hotel.
E.g. a RevPAR of €60.- can mean different things. Which hotel is working more profitable?

- Hotel A: 50% occupancy at €120.- ADR
- Hotel B: 100% occupancy at €60.- ADR

Ignores revenue from other sources, e.g. spa, seminar rooms, ...

Key Performance Indicators “Gross Operating Profit Per Available Room”

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$$\text{GOPPAR} = \frac{\text{G.O.P}}{\text{Available Rooms}} / \text{day}$$

$$\text{GOP} = \text{total revenue} - \text{total departmental and operating expenses}$$

Similar to RevPAR.

Better indicator for the actual performance of the hotel.
In addition to the revenue it takes also the departmental and operating expenses into account.

However, also does not take the overall revenue mix of the hotel into account.
Nevertheless it is good indicator to gauge the overall profitability and the worth of a hotel.

Key Performance Indicators “Revenue Per Occupied Room”

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$$\text{RevPOR} = \frac{\text{Total Room Revenue}}{\text{Total occupied rooms}}$$

$$\text{Total RevPOR incl. revenue from food \& beverages, amenities, etc.}$$

One of the most important parameters. It is used to gauge budget goals, forecasted demand and year-to-year performance.

Mostly used in addition or alternatively to RevPAR.
RevPAR can be calculated by multiplying RevPOR with the occupancy rate.
The “Total RevPOR” also takes extra services like room services, laundry, etc. into account.

RevPOR is independent of general and local economic fluctuations since it is independent of the occupancy rate.
It is used to gauge the overall potential of a hotel.

Key Performance Indicators
“Revenue Per Occupied Space Time”

RevPOST

...is a measure of the Revenue Efficiency of a Group or of a Hotel’s utilization of its Function Space

RevPOST may be used by Hotels, Meeting Planners, Revenue Managers, and financial analysts to compare the Revenue performance of different hotels in their markets.

2. Single Resource Capacity Control

Introduction

Single resource capacity control
We will now look at models for revenue management that are based on **single resources** and how to **optimally allocate** its **capacity** to **different classes** of demand.
That means: the same product is sold to different classes with different conditions. E.g. sale of hotel rooms for a given date at **different rate classes** or rebates.
In reality many RM problems show **network characteristics**. I.e. they consist of **bundles** of resources. However they are still mostly implemented using a collection of single resource models. Furthermore single resource models are the base for many heuristics.

Assumptions
distinct classes of same resource, (in the beginning) distinct and mutually exclusive market segments, units of capacity homogenous, consumer demands single unit of resource.

Key question
How to optimally allocate resource capacity to the various classes?

Control Types
Booking limits

Limit the **capacity** that will be sold in a specific **class**.
If the capacity for a specific class is used up it will be closed.
Either **partitioned** or **nested** classes.

Partitioning
Split capacity into buckets that can be exclusively sold in a specific class. Is a more valuable class sold out it will be closed regardless whether there is capacity left or not.

Nested
Hierarchical overlap between the classes. Higher valued classes can access the capacity of lower valued classes.

Usually nested strategies are used to prevent the situation where in which high value classes are closed although there is still capacity left.

Different point of view compared to booking limits. Not "how much capacity to **sell** up to", but "how much capacity to **protect**".
Again two versions, partitioned and nested.

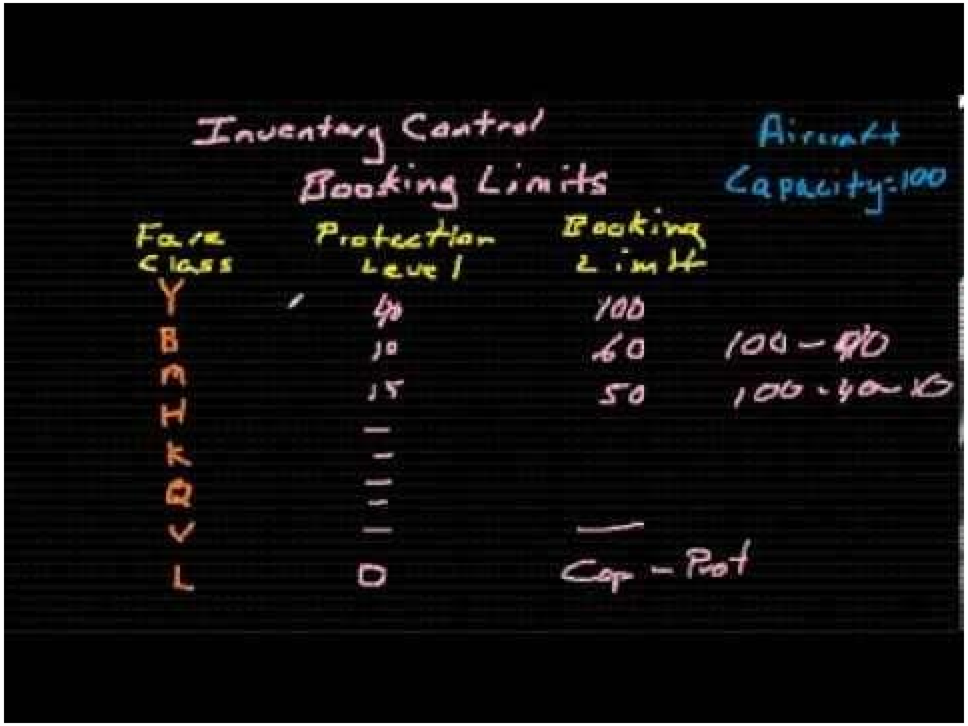
Partitioned
Identical to partitioned booking limits. Booking limit of 20 units is equivalent to protection of 20 units.

Nested
Again defined for sets of classes, ordered in a hierarchical manner. The protection level is defined as the amount of capacity to save for the respective classes and lower valued ones combined.

Connection between *y* and booking limit *b* for a class *j*:

$$b_j = Capacity - y_{j-1}, \quad j = 2, \ldots, n$$

Bookign Limit VS Protection Levels



https://www.youtube.com/watch?v=i7OgtWAdlsU

Control Types
Standard and Theft Nesting

Standard Nesting
Very simple. If demand is incoming, satisfy as long as the booking limit (or protection level) allows it (or no capacity is left).

Theft Nesting
In this variant satisfying a request not only lowers the capacity of the class but also steals capacity of the less valuable classes. This means the protection level for this class remains the same as long as units are available in lower classes.

Standard nesting has a forecasting aspect. Bookings in a class lower the probability of a future booking in it. **Theft** nesting on the other hand ignore this aspect, each booking is equally as likely.

Control Types
Bid Price

Revenue-based instead of class-based controls.
Accept/reject purchase based on a **threshold price** (depend on capacity and/or time)

Simpler, only one threshold price at a point in time instead of capacity numbers for each class.

BUT must be **updated after each sale**! A function depending on the capacity. Otherwise whole capacity potentially sold to any class succeeding current threshold. With update it can model the same segmentation policies as booking limits or protection levels.

If revenue information is available at time of purchase allows **fine grained** control of acceptance for individual purchases. Class based controls can only accept/reject whole class.

Displacement Cost

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While the mathematics of optimal capacity controls can become complex, the overriding logic is simple.

1. fulfill request if and only if **revenue is greater** than the **value** of the capacity **required**
2. the value of capacity should be measured by its (expected) **displacement cost** (aka **opportunity cost**), i.e. expected loss in future revenue from using the capacity now

Value Function

Measures the optimal expected revenue as a function (depends on method) of the remaining capacity. The displacement cost then is the **difference** between the value function at a capacity and the value function at a capacity - 1.

The logic is simply to compare revenues to displacement costs to make the accept or deny decision.

Models: Static Assumptions

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One of the first and **simplest** models. Makes following assumptions:

1. demand for the different classes arrives in **nonoverlapping intervals** in the order of increasing prices of the classes
2. demands for different classes are **independent random variables**
3. **perfect segmentation** between classes, i.e. demand for a given class, does not depend on the capacity controls (esp. availability of other classes)
4. no continuous time, i.e. **aggregate quantity** of demand arrives in a **single stage** and the decision is simply how much of this demand to accept
5. **no**, or **partially acceptable groups**
6. **risk neutrality**

Models: Static
2-Class Model

Oldest and **simplest** single-resource model for quantity based RM. Only uses **2 classes** with different prices.
Question: how much to accept for class 2 before only accepting class 1.
Similar to **“newsvendor problem”** and solved using simple **marginal analysis**. Should we accept request for class 2? Only as long as price 2 is bigger than price 1 adjusted for risk, i.e. probability that it will get sold.

$$\text{price}_2 \geq \text{price}_1 P(\text{demand}_1 \geq \text{remaining capacity})$$

This formula can be used directly as a **bid price control**

$$\pi(x) = \text{price}_1 P(\text{demand}_1 > x)$$

Or define an optimal **protection level** and **Littlewood’s Rule**

$$\text{price}_2 = \text{price}_1 P(\text{demand}_1 > \text{optimum})$$

$$\text{optimum} = \text{Distribution}^{-1}\left(1 - \frac{\text{price}_2}{\text{price}_1}\right)$$

Models: Static
n-Class Model I

Generalized version of the 2-class problem, now with **n classes**. Demand arrives in n stages, one for each class, with classes arriving in increasing order of their revenue values.

Dynamic Programming
A method for solving a **complex problem** by breaking it down into a collection of **simpler subproblems**, solving each of those subproblems just once, and storing their solutions.

Assumed sequence of events

1. realization of demand for class occurs and value observed
2. decide on quantity to accept. It must be less than remaining capacity. There is an optimum based on class, capacity and demand.
3. collect the revenue for this constellation and proceed to the next class.

Assumes demand is known beforehand for analytical convenience. In reality arrives over time. Model not dependent on it however.

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$$\mathrm{Value}_j(x) = \mathrm{price}_j * u + \mathrm{Value}_{j-1}(x-u)$$

In plain English
we observe demand, and try to come up with the **protection level** *u* that generates the **best value** for **this class** *j* while considering the value of **lower classes** *j-1* as well. *u* lies between 0 and either remaining demand or remaining capacity.

This is an **optimization problem**, we need to find the optimal parameters. Use smart software or create a table and look at the numbers.

Find the levels for the class *j* that brings that still has a bigger **marginal value** (delta value) according to the following formula. Booking limit and bid price can be calculated from this protection level

$$\text{protection level}_j = \max\left(x : \mathrm{price}_{j+1} < \Delta\mathrm{Value}_j(x)\right)$$

$$\Delta\mathrm{Value}_j(x) = \mathrm{Value}_j(x) - \mathrm{Value}_j(x-1)$$

Although optimal controls are pretty straight forward, not used widely. **In practice** several **heuristics** are used.

They are very **simple** to implement and run. Usually **good enough** and it's better to be "approximately right" than "precisely wrong".They predate optimal controls actually by more than a **decade**.

EMSR-a and **EMSR-b** (*expected marginal seat revenue*) based on the *n*-class, static, single resource model. Most popular heuristics.

Although EMSR-a is more publicized it's close cousin **EMSR-b** provides the **better results** and is **more popular** in practice.

EMSR-a is based on the idea of adding the protection levels produced by applying Littlewood's rule to successive pairs of classes.

Consider stage j + 1, in which demand of class j + 1 arrives with price p j+1. We are interested in computing how much capacity to reserve for the remaining classes, j, j − 1, . . . , 1; that is, the protection level, y j , for classes j and higher.
To do so, let us consider a single class k among the remaining classes j, j − 1, . . . , 1 and compare k and j + 1 in isolation. Considering only these two classes, we would use Littlewood's rule (2) and reserve capacity y k j+1 for class k, where

EMSR-a is certainly simple and has an intuitive appeal. For a short while it was even believed to be optimal, but this notion was quickly dispelled once the published work on optimal controls appeared.

Heuristics: EMSR-b

EMSR-b is again based on an **approximation** that reduces the problem at each stage to two classes, but in contrast to EMSR-a, the approximation is **based on aggregating demand rather than aggregating protection levels**.

Specifically, the demand from future classes is aggregated and treated as one class with a revenue equal to the weighted-average revenue.

In practice EMSR-b is more popular and generally seems to perform better than EMSR-a.

3. Customer Choice Behaviour

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Key assumption until now
Demand for each of the classes is completely **independent** of the **capacity controls** being applied by the seller.

Very unrealistic
Will customer rent **full price** room if **discounted** room is **available**?
Heuristic and exact methods to manage this exist.

Some Terminology
Buy-up… customer buys higher fare when discount is closed
Diversion… customer takes another flight

These factors are important and should be included in the models!

Models
Buy-Up Factors I

Up until now we expected customer not to buy anything if his **class** of choice is **closed**. However, realistically there is a chance she will **buy up** to the **higher class**.

There are different approaches, however in current applications of the model, they are often simply made-up, reasonable-sounding numbers. A good rough-cut approach for incorporating choice behavior.

Easiest model is based on Littlewood and works for two classes (only). It introduces a probability q that a customer of class 2 buys up to class 1.

$$\text{price}_2 - \text{price}_1 * P(\text{demand}_1 \geq remaining) \geq q\text{price}_1(1 - P(\text{demand}_1 > remaining))$$

This model is more eager to close class 2. This makes intuitive sense because there is a chance that the customer will buy up.

More classes?
No more binary choice but **multinomial**. Littlewood not possible but EMSR-a and EMSR-b approximate multi class. Can be extended.

Modified EMSR-b

$$p_{j+1} = (1 - q_{j+1})\bar{p}_j P(S_j > y_j) + q_{j+1}\hat{p}_{j+1}$$

where q is the **probability** that a customer of a class **buys up** to one of the higher valued classes. $\hat{p} > p$ is an **estimate of the average revenue** received given that a customer buys up to one of the higher valued classes (e.g. $\hat{p}_{j+1} = p_j$ if customers are assumed to buy up to the next-highest price class).

Net result of this change is to **increase the protection level** and close down class $j + 1$ **earlier** than one would do under normal EMSR-b.

Grain of salt… it's an ad-hoc adjustment to an already **heuristic approach**!

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Modeling with general discrete-choice model, a more **theoretically sound** approach to incorporating choice behavior **than heuristics**.

provides insight into how choice behavior affects the optimal availability controls.

Time is discrete
In each period there is at most one arrival. The probability of arrival is denoted by λ assumed to be same for each period.
$N = \{1, . . . , n\}$ denote the entire set of classes
In each period t, the seller chooses a subset $S_t \subseteq N$ of classes to offer.
When the set of classes S_t is offered in period t, the probability that a customer chooses class $j \in S_t$ is denoted $P_j(S_t)$. $P_0(S_t)$ denotes the no- purchase probability.

History and Theory of Revenue Management

Hands on Exercises

Exercise 1

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Status Quo: Revenue management in your business

Form groups of up to four people and discuss the mentioned points. Write down your names and answers in a document (txt, doc, Google Doc …) and send it to elias.kaerle@sti2.at by the end of today. Subject: Status Quo. Prepare a short presentation (no slides, just orally) of your thought and present it after the preparation phase.

1) Identify your business:
   a) What: what do you (want to) sell?
   b) To whom: (potential) customers, target group(s)?
   c) Price(s) and Classes?
   d) Times: Is there a temporal change in your sales strategy? Daily, Weekly, Monthly, Saesonally, Annually?

2) Do you practice Revenue Management?
   a) Yes! What and how?
   b) No! Where do you see potential?

3) What can you apply from the just learned?
   a) Make a RM plan
   b) Estimate the change in revenue after applying 3.a

Exercise 2

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Questionnaire

Form groups of up to four people and discuss the mentioned questions. Write down your names and answers in a document (txt, doc, Google Doc …) and send it to elias.kaerle@sti2.at by the end of today. Subject: Questionnaire.

1. In what areas does RM make sense?
2. Besides rooms, to what else can you apply RM in hotels?
3. How do you know if you are selling at prices that are too low?
4. How do you know if you are selling at prices that are too high?
5. How to act during high demand?
6. How to act during low demand?

Preliminaries

You will use Excel to solve the following example.
(LibreOffice, or Google Sheets works fine as well)

The can be found on the course website (KPIs.xls)

Please build groups of three or four

Each group will solve the problem and can volunteer to present their results.

Volunteering will positively influence your grade!

Exercise 3: Basic Measures
GOPPAR, RevPOST, RevPAR, RevPor, ...

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This exercise is about calculating basic measures and KPIs for your hotel.

You'll find some toy data for an example hotel, namely its supply, demand, revenue and operational cost.

1. Open the provided “KPIs” excel file
2. Fill in the missing measures for the toy hotel
3. (optional calculate average monthly change)
4. Create a diagram for your data

Volunteer group will present their findings to the rest of the group. How did your hotel perform?