The **safety stock** (also called minimum or resource inventory) helps to protect the ongoing operation of a company against demand, supply and inventory uncertainties.

- It depends on the **procurement time** (replenishment time) and the **average daily consumption**.
- The own safety stock also depends on the safety stock of the supplier (see below).

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery time depends on safety stock</td>
<td>Safety stock depends on replenishment time</td>
</tr>
</tbody>
</table>

Delivery time = replenishment time

Source: Tempelmeier
The safety stock covers 3 uncertainties:

- **Uncertainty in demand** (identified demand does not comply with daily demand)
- **Uncertainty in delivery** (target delivery time does not comply with actual delivery time)
- **Uncertainty in inventory** (book inventory balance and inventory do not match)
Inventory planning

**Outward stock movement distribution**
- Only consideration of normal distribution
- High effort for the schedulers to determine the type of distribution

**Data base**
- Data only available on a monthly basis
- Article specific replenishment time is not considered

**Causes for safety stocks**

**Forecasting quality**
- No differentiated application of appropriate forecasting methods
- Regularity/Unsteadiness of demands

**Cost transparency**
- Choice of high degrees of readiness for delivery
- Out-of-stock cost only assumed

Diagrams for: causes for safety stocks, forecasting quality, cost transparency.
Inventory planning

Time series of outward stock movements

outward stock movement distribution

Time series of forecasting errors

Distribution of forecasting errors

Quelle: RWTH Aachen
Inventory planning

Methods for the calculation of safety stock

- Calculation of safety stock by means of replenishment time
  - General practical formula
  - Coverage of additional consumption and delays in delivery by safety stock
  - Coverage of the average consumption during replenishment time

- Calculation of safety stock by means of service degree
  - Calculation of safety stock from service degree and standard deviation
Inventory planning

General practical formula

☐ Safety stock is to be **1/3 of the consumption** during normal replenishment time

☐ SB = 1/3 * consumption

Coverage of additional consumption und delays in delivery by safety stock

☐ In safety stock are considered both additional consumption and delays in delivery

☐ SB = replenishment time * additional consumption + delays in delivery * (average + additional consumption)

Coverage of the average consumption during replenishment time

☐ Safety stock covers the average consumption during replenishment time

☐ SB = Replenishment time * average consumption/day
The determination of the safety stock is closely connected to the knowledge of replenishment time, thus, the period the quantity of goods need from the point of time of order release until the arrival at the warehouse.

To the replenishment time belongs the duration of:

- administrative in-house proceeding
- order acceptance and processing at the supplier
- transport
- control of goods received
- quality control and storing
The FIRpress GmbH is a medium-sized mechanical and plant engineerer. Main products are hydraulic presses. The company has about 5000 employees inland and abroad. The FIRpress GmbH is a so called manufacturer of products with variants and a global company. The storage locations structure is distributed all over Europe. Some parts are also delivered from Asia.
Inventory planning

The reorder level in the subassembly „Hydraulic hoses“ of the FIRpress GmbH is 5000 hoses. Last year’s measurings gave an average consumption of 300 hoses per day. Currently there is an additional consumption of about 150 hoses per day. The replenishment time is 12 days. Because of the high demand for the manufacturer one has to face a delay in deliveries of 3 days.

Calculate the safety stock according to the three calculation methods used in practice by means of the replenishment time!

i) General practical formula:
   
   1/3 of the consumption during the normal replenishment time:
   
   \[ \frac{1}{3} \times 3600 = 1200 \text{ hoses} \]

ii) Coverage of additional consumption und delays in delivery by safety stock:

   Replenishment time * additional consumption + delay in delivery *(average + additional consumption)
   
   \[ 12 \text{ days} \times 150 \text{ hoses/day} + 3 \text{ days} \times 450 \text{ hoses/day} = 3150 \text{ hoses} \]

iii) Coverage of the average consumption during the replenishment time:

   Replenishment time * average consumption/day
   
   \[ 12 \text{ days} \times 300 \text{ hoses/day} = 3600 \text{ hoses} \]
The *statistical safety* \( s \) indicates the probability for the fulfillment of the given service degree with a given distribution of article inventories.

\[
S = 1 - \alpha
\]

is within a *confidence range*.

\[
\alpha = 1 - S
\]

the so called *probability of error* \( \alpha \) indicates the probability that the true parameter value is outside the confidence range.
The x-coordinates \( u_1 \) and \( u_2 \) are called **quantile** of the normal distribution. Provided with an index \( \gamma \) (with \( \gamma = \alpha \), \( \gamma = 1 - \alpha \), \( \gamma = 1 - \alpha/2 \)) and the indication of the algebraic sign the kennzeichnen die **quantiles** \( u_\gamma \) mark a quantifiable part of the area under the probability curve.

Statistical safety (service degree) 95%:
\[
s = 95\% \quad \alpha = 1 - s = 0,05
\]

Reading example:

With a probability of error \( \alpha = 0,05 \) is for:

\[
\gamma = 1 - \alpha = 0,95 \quad \Rightarrow \quad u_\gamma = u_{1-\alpha} = 1,645
\]
\[
\gamma = \alpha = 0,05 \quad \Rightarrow \quad u_\gamma = u_\alpha = -u_{1-\alpha} = -1,645
\]
\[
\gamma = 1 - \frac{\alpha}{2} = 0,975 \quad \Rightarrow \quad u_\gamma = u_{1-\frac{\alpha}{2}} = 1,960
\]

For a **symmetric** interval (normal distribution!):

\[
\gamma = 1 - \frac{\alpha}{2} = 0,975 \quad \Rightarrow \quad u_\gamma = 1,96 \text{ (aus Tabelle!)}
\]

\[
u_\gamma = 1,96 \approx 2,0 \quad (95,4\% \text{ stat. safety}).
\]
**Zielsetzungen**

- Minimale Lagerhaltungskosten
- Maximale Lieferbereitschaft

„Summe der Fehlmengenkosten und die Lagerhaltungskosten minimieren“

Servicegrad = \(\frac{\text{Anzahl sofort befriedigter Nachfragen}}{\text{Gesamtnanzahl der Nachfragen}} \times 100\%\)

Quelle: RWTH Aachen
The service department of the *FIRpress GmbH* gets on average 360 orders for hydraulic hoses per year. The management allows a maximum of 7 shortfalls per year.

- The standard deviation of the orders was identified to be $\sigma = 37$ pieces.
- Calculate the safety stock under consideration of the service degree!
- Is the *order frequency respectively order quantity* important for the determination of the safety stock?
The service degree adds up to: \((360-7)/360 = 0.9806 \approx 98.0\%\)

Probability of error: \(\alpha = 1 - 0.98 = 0.02\)

With the aid of the table of the standard deviation the error calculation yields:

\[
\gamma = 1 - \frac{0.02}{2} = 0.99 \quad \Rightarrow \quad u_\gamma = u_{1-\alpha} = 2.35
\]

From this results a safety stock \(SB\) of:

\[
SB = k \cdot \sigma = 2.35 \cdot 37 = 86.95
\]

The safety stock depends on the order frequency respectively order quantity. A large order quantity protects the very more against shortfalls before lapse of ordering time than a small one. Hence, one only needs a lower safety stock for one material when it is procured in larger lots because the occurrence of shortfall events is then more rarely.