Linking Operations with Finance

What is supply chain management?

- Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace.

Source: https://www.investopedia.com/terms/s/scm.asp

- Trade-offs inherent in defining operations and supply chain strategy
  - Variety (more items can result in more sales)
  - Price (reduce manufacturing cost, purchase cost, and logistics cost)
  - Responsiveness (reduce working capital)
- Interdependency between Variety, Price, and Responsiveness.
- The triangle captures the idea that organisations deliver different types of ‘service’ to customers, which comes at a certain ‘cost’ and requires a certain amount of ‘inventory,’ or more generically, ‘cash’.

What is a good source to get information about a company's operations/finances/costs?

P&L Statement

Profit and Loss (2013)		
Sales revenue	£ 75,600	
Cost of goods sold (COGS)	£ –52,920	
Gross profit	*£ 22,680*	*30%*
Selling general and administrative (SG&A) Expenses	£ –15,120	
Earnings Before Interest, Taxes, Depreciation & Amortization (EBITDA)	*£ 7,560*	*10%*
Depreciation	£ –3,024	
Amortization	£ –	
Earnings Before Interest, Taxes (EBIT)	*£ 4,536*	*6%*
Taxes and interest	£ –2,646	
Net income / net profit	*£ 1,890*	*3%*
Earnings per share (eg 1,000 shares)	£ 1,89	

Cost that can be directly attributed to the sale, eg purchasing cost

Cost that can NOT be directly attributed to the sale, eg marketing costs

'Investments' in eg warehouses are depreciated, for instance over 20 years. This implies we account for 1/20th of the total cost each year. A depreciation is not a 'cash-out'. The actual cash has been spent when the warehouse was built!

Inventory write-offs are typically in amortization

Balance Sheet

Current assets can be converted into money in the short term. 'Current' refers to 'short-term'

Fixed assets are more difficult to convert into cash. They are 'long-term' assets.

Assets		Liabilities and owners' equity	
Current Assets		*Owners' equity*	
Cash	£ 6,600	Paid-in capital	£ 15,000
Accounts receivable	£ 6,200	Retained earnings	£ 800
Inventories	£ 5,000		
Total current assets	*£ 17,800*	*Total owners' equity*	*£ 15,800*
Fixed assets		*Liabilities*	
Property plant equipment	£ 20,000	*Current liabilities*	
		Accounts payable	£ 8,000
		Short-term bank loans	£ 4,000
		Long-term liabilities	
		Long-term bank loans	£ 10,000
Total fixed assets	*£ 20,000*	*Total liabilities*	*£ 22,000*
Total assets	£ 37,800		£ 37,800

Accounts receivable = turnover that has been invoiced to the customer, but has not yet been paid. eg partners that pay at 30 days or 60 days, consumers that buy on credit of 30 days...

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The owners' equity consists of the cash investments made in the company by the shareholders + any earnings that have not been paid as a dividend

Current liabilities are payable in the short term

Long-term liabilities are payable in the long term

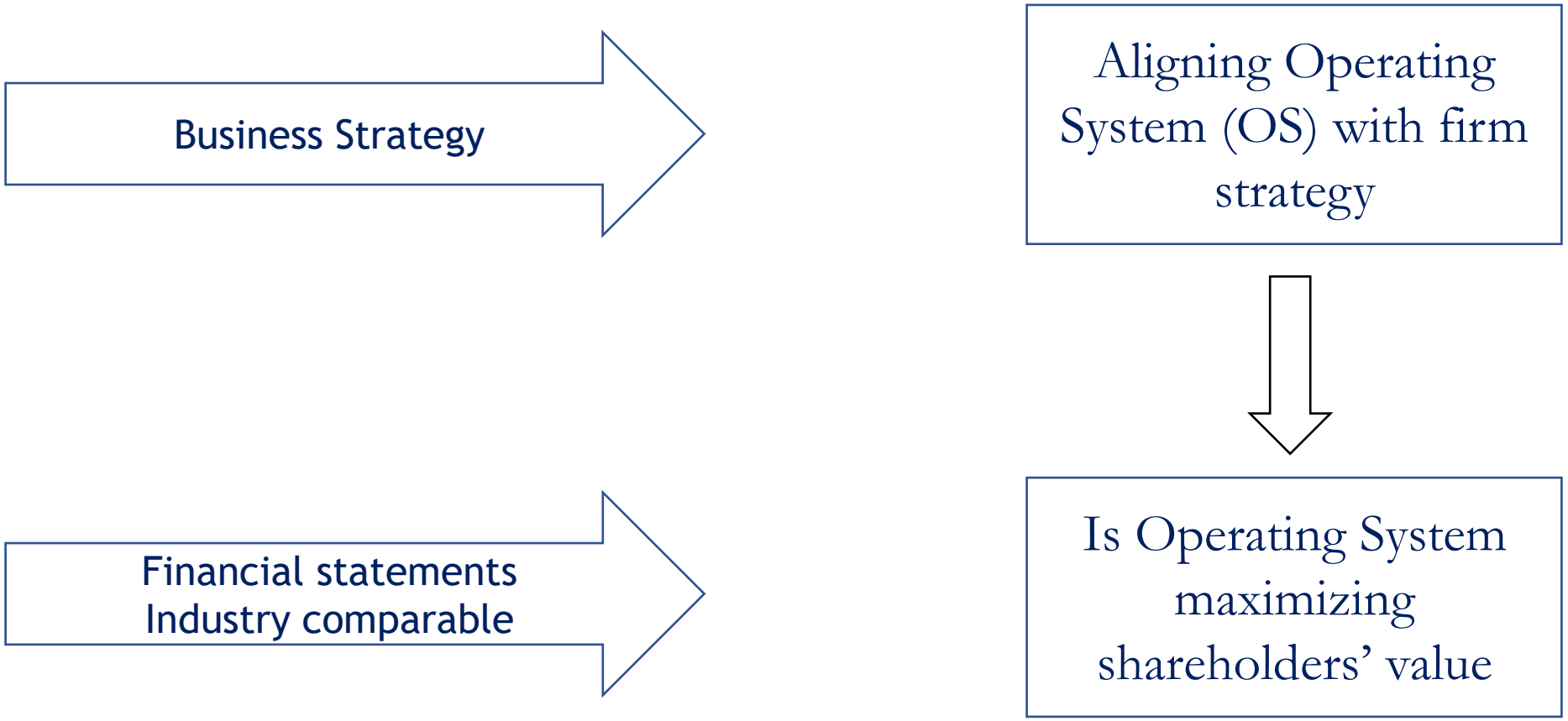
Accounts payable = costs that have been made and accounted for in the profit-and-loss ... but that still need to be paid, eg we pay our suppliers only after 30 days or 60 days

Creating and communicating value through operations

- Link operations to value creation
- Identify operational parameters that have greatest impact and value
- Prepare and communicate a detailed plan specifying what can be improved.

- If I am about to invest in, or acquire this firm, what exactly would I improve and how much value would this improvement create?

Operating system design roadmap



The goal of operations is to create value. Examining the operating system through this lens generates an unambiguous metric of its success and a path to ensure future improvements.

Value Metrics

Supply chain surplus

- The value created to end customers – total cost incurred by the supply chain
- Customer surplus + firm profits

- A good framework for measuring performance (value addition) is EVA **(Economic Value Added)**
  - The **value created** in **excess** of the **return required** by the firm's investors

- **Economic Value Added**
- Value added can be measured as **ROIC** (Return on Invested Capital), also referred to as Return on Capital Employed.
- The return required by investors is calculated as **WACC** (Weighted Average Cost of Capital).

$$EVA = (ROIC - WACC) * capital\ employed$$

ROIC (Return on Invested Capital) or Return on Capital Employed (ROCE)

- A company's value is driven by its ability to generate cash flow from revenue growth and return on invested capital (ROIC) relative to its cost structure.
- It measures how efficiently a company uses the money it collects from investors and lenders.
- Companies that can increase ROIC or maintain a steady trajectory of increasing ROIC above the cost of capital will generate value.
- ROIC focuses solely on the company's operations.

$$ROIC = \frac{Net\ operating\ profit}{Capital\ Employed}$$

- It captures the two typical financial impacts of operational improvements: return (operating profits or income generated per period) and required invested capital (working capital tied up in inventory, fixed capital tied up in capacity)
- A high ROIC indicates that a larger chunk of profits can be invested back into the company to support further growth.
- The reinvested capital is employed can again be employed at a higher rate of return, which helps produce higher earnings per share.

- A company's ROIC can be disaggregated, so the root causes for key drivers in ROIC can be identified.
- E.g., ROIC can be broken down into profitability and efficiency of capital employed

$$ROIC = \frac{Net\ operating\ profit}{Sales} * \frac{Sales}{Capital\ employed} = Return\ on\ Sales * Capital\ Turns$$

- The Capital Turns ratio measures the efficiency of a company's use of its capital employed in generating sales revenue to the company.
- High inventory holdings require more capital investments and thus lower the capital turns and ROIC.

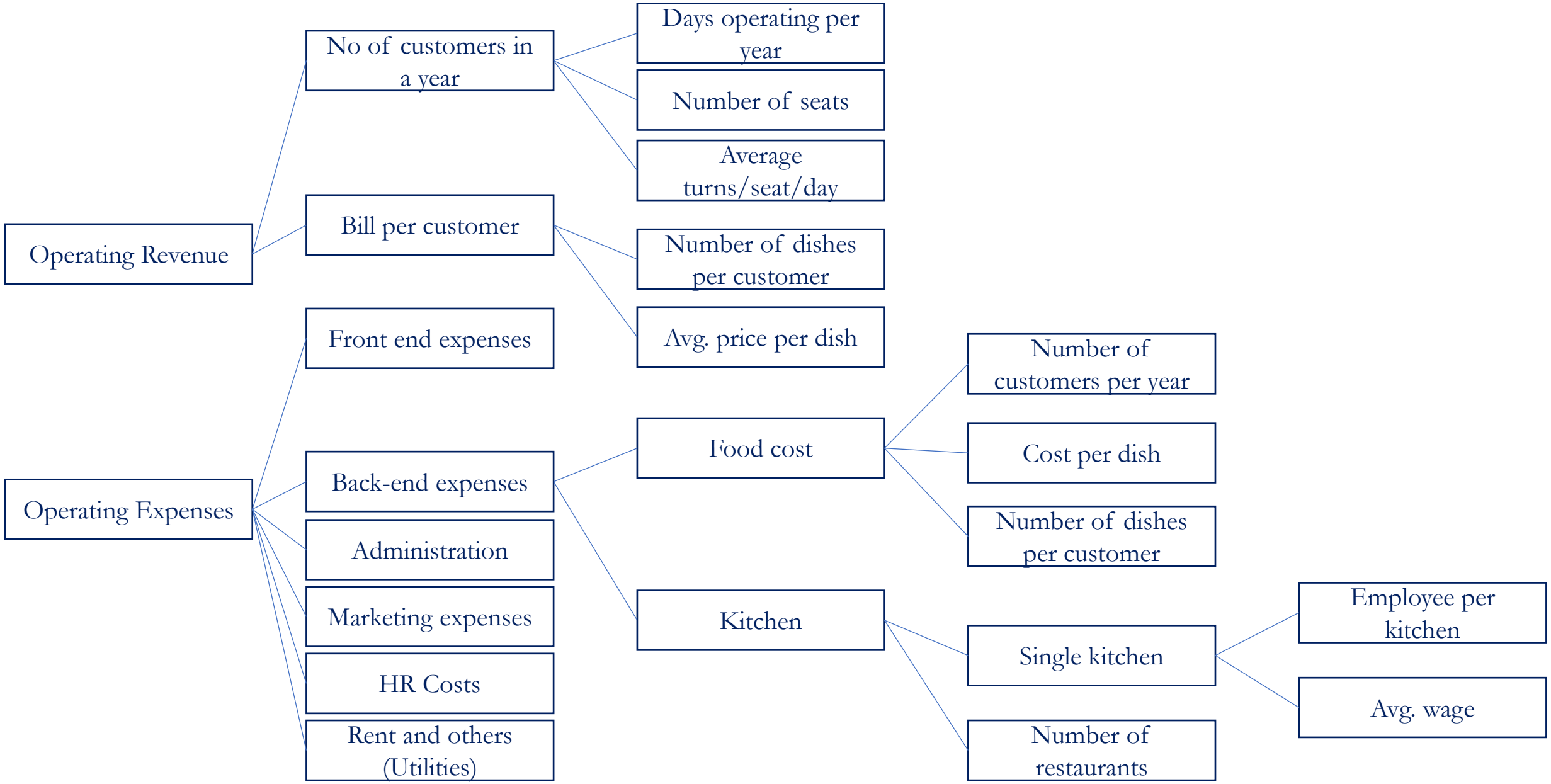
Performance Trees

- Performance trees disaggregate financial and operational performance.
- Trees can be used as a method of conducting sensitivity analysis and risk analysis
- There are a number of performance trees, such as the DuPont model, ROIC, and value trees that are used in the industry.
- By dis-aggregating measures, such as ROIC and value, performance trees are useful in determining how changes in operations affect ROIC, revenue growth and company value.

ROIC Tree

1. Start with the objective (ROIC) on one side
2. Decompose a variable into components
3. Decide which branches have an impact
    1. What are the main cost drivers
    2. What are the strategic levers
    3. Which inputs are most likely to change
4. Expand important branches
5. End with measures that can be tied to operations strategy

Example of a restaurant chain



Case Analysis – Kaffee Kostuum

How large should an order be, and how often should it be placed?

- Current practice: 1500 units to exploit scale economies
- Cycle inventory or stock = Q/2= 1500/2= 750
- *Cycle stock: Amount of inventory available to meet typical demand during a given period.*
- A reduction in batch size results in more frequent ordering and higher shipping costs (reducing the return on sales) but lower inventory holding and corresponding capital employed (increasing the capital turns).
- At the optimal order size, the yearly shipping costs are equal to the inventory holding costs; the reduction in inventory holding costs offsets the increased shipping costs of smaller order quantities.
- The EOQ determines the optimal order size.

$$Q^* = EOQ = \sqrt{\frac{2 * R * S}{H}}$$

- R is the demand rate (the usual proxy for this is the number of units sold in a year)
- S is the shipping or setup cost **per order** (independent of the number of units ordered)
- H is the **per unit** inventory holding cost

- Demand rate

$$Yearly\ throughput\ or\ demand\ rate = \frac{Revenues}{Sales\ price}$$

Revenues	€1,000,000
Sales Price	€325

3077

- **Shipping cost** = € 2,200

- **Holding cost:** It is the capital cost and insurance cost, which are 14% and 6%, respectively. The inventory holding costs are substantial.
  - Unit cost = 250, calculated as 325/1.3
  - Capital cost = 250*.14
  - Insurance cost=250*.06
  - Holding cost = (0.14+0.06)*250 = € 50

Revenues	€ 1,000,000.00
Sales Price	€ 325.00
Margin	30%
Unit Purchase/Production cost	€ 250.00
Yearly Capital cost	14%
Yearly Storage/Insurance cost	6%
Yearly Holding cost per unit	€ 50.00
Shipping/Setup cost per order	€ 2,200.00
Yearly Throughput/Demand rate	3077

As given in the case

Order quantity and frequency	
Order quantity	1500
Order frequency per year	2.05
Cycle Stock	750
Weeks of cycle stock	12.67
Yearly Purchasing costs	€ 769,250.00
Yearly Shipping/Setup costs	€ 4,512.93
Yearly inventory holding costs	€ 37,500.00
Yearly total costs	€ 811,262.93

$$Weeks\ of\ cycle\ stock = \frac{Cycle\ stock}{Yearly\ demand} \times 52$$

Yearly inventory holding costs are calculated using cycle stock.

If we employ EOQ

Order quantity and frequency	
Order quantity	520
Order frequency per year	5.91
Cycle Stock	260.18
Weeks of cycle stock	4.40
Yearly Purchasing costs	€ 769,250.00
Yearly Shipping/Setup costs	€ 13,009.04
Yearly inventory holding costs	€ 13,009.04
Yearly total costs	€ 795,268.07

Note: The yearly shipping costs are equal to the inventory holding costs

What is happening because of EOQ?

- The increased shipping costs of smaller order quantities are offset by the reduction in inventory holding costs.
- Although the opportunity costs of tied-up capital are not included in the income statement, a cycle stock reduction to Ic=520/2=260 units frees up (750-260) x €250 = €122,500 in working capital.

What is driving optimal order sizes and resulting cycle stock levels?

- **Shipping cost**:
- A higher cost per shipment will increase optimal order sizes and corresponding cycle stock levels.
- For instance, that means offshore replenishments or rails shipments requiring a large fixed cost per shipment lead to higher cycle stock and more capital tied up in inventory.
- **Inventory holding cost**:
- A higher unit holding cost, driven by the risk of obsolescence, for instance, will reduce optimal order sizes and corresponding cycle stock levels.

- **Demand rate**: Higher demand benefits from scale economies as the fixed cost per shipment can be distributed over a larger volume.
- According to the EOQ formula, an increase in the demand rate with factor n will increase the optimal order size and cycle stock with factor $\sqrt{n}$.
- It indicates that a decentralized policy with each store placing orders individually is not beneficial, as it involves lower scale economies and increases inventory levels.

$$Q^* = EOQ = \sqrt{\frac{2 * R * S}{H}}$$

When should an order be placed?

- An order should be placed well before inventory is depleted. In a multi-SKU (stock-keeping unit) setting, the optimal replenishment policy cannot be easily characterised.
- We opt for an ROP (re-order point) based on the individual inventory position, as it ensures a target service level is met.
- The means that as soon as the inventory position (=net stock + inventory on order) of one SKU drops below its reorder point, a batch order is placed for the whole chain and then allocated to the stores.

- Suppose the demand for a particular SKU is forecasted to be 5 units per week. If the forecast was 100% accurate, when should John order?

- Suppose the demand for a particular SKU is forecasted to be 5 units per week. If the forecast was 100% accurate, the order should be placed exactly L=16 weeks before depletion (supplier needs four months).
- In other words, when 5*16 = 80 units are left in inventory.
- But one cannot be sure about the demand.
- When the probability of over- or under-forecast is the same, we will run out of stock 50% of the time if we order at a reorder point (**ROP**) of 80 units.
- To reduce the stock-out probability, we should order sooner.

- If we increase the ROP from 80 to 85 and everything else remains the same, the average stock level just before the replenishment arrives is 85-80 = 5.
- However, the higher the deviations around the forecast, the higher the stock-out probability and vice versa.
- However, it is safe to assume a normal distribution of forecast errors (Central Limit Theorem).
- The central limit theorem states that if you have a population with mean μ and standard deviation σ and take sufficiently large random samples from the population with replacement, then the distribution of the sample means will be approximately normally distributed.

- Assuming normally distributed forecast errors and a standard deviation of the error term of 2.5 per week for a particular suit, the standard deviation during the 16-week replenishment lead time is $2.5*\sqrt{16} = 10$.
- In simple terms, it means that the standard deviation of sample means, i.e., the standard deviation of error – which could be above or below the actual requirement can be, on average, 2.5 standard deviations away from the mean. CLT helps us to forecast it for the entire 16-week period, which is given by $2.5*\sqrt{16} = 10$

- The probability of demand not exceeding 85 units is then derived from the **Cycle Service Level** (an indicator of the probability of having enough stock to meet demand).
- CSL=norm.dist(85,80,10,True)=70%
  - The excel formula: *norm.dist* returns the normal distribution for the specified mean and standard deviation.
  - X=value for which you want to check, mean=arithmetic mean of the distribution, standard deviation of the distribution, True= if it is cumulative distribution function or false if cumulative mass function.
- Hence, there is a 30% probability of running out of stock prior to the replenishment.

- To reduce the stock-out probability to 5% (with 85 ROP, it is 30%), for instance, we must increase the ROP beyond 85. We can do this manually by iteration or directly by inverting the formula as below
- Let's use the formula norm.inv(.95,80,10). What do you get? What does your answer mean?
- What is the safety stock?
- Is = 96.6-80 = 16.5 units of safety stock.
- Days of Inventory (DOIs) = 16.5/5 = 3.3 weeks of safety stock.

- The higher the forecast accuracy, the lower the deviations of the forecast errors and the lower the safety stock requirements. This is formalized in the definition of safety stocks

$$I_s = z * \sigma * \sqrt{L}$$

- With z = norm.s.inv(CSL)
  - The excel formula: norm.s.inv returns the inverse of standard normal cumulative distribution (mean =0 and SD=1)
- σ is the standard deviation of the forecast error and is linked to the average absolute forecast error or mean absolute deviation by

$$\sigma = \sqrt{\pi/2} * MAD \approx 1.25 * MAD$$

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- A standard deviation of error terms of 2.5 per week thus corresponds to a mean absolute deviation of 2 per week.

- A frequently used measure of prediction accuracy is the mean average percentage error (MAPE). It measures the accuracy as a percentage of the forecast.

- Using MAPE, we obtain an expression of the safety stock in terms of its forecast, which is equivalent to the number of days of safety stock.

$$DOI_s = z * 1.25 * MAPE * \sqrt{L}$$

- In our example, an MAD=2 for an average demand of 5 corresponds to a MAPE = 2/5= 0.40, indicating a 60% forecast accuracy (*already given in case*).
- With a 60% forecast accuracy, we thus should keep 3.3 weeks of safety stock.
- Extending it to all SKUs, with a total average demand of 3077/52 = 59 units per week, we find that the total safety stock across all SKUs for a 95% CSL would be
  - **demand per week* safety stock = 59*3.3=195 units**.

What is deriving safety stock levels?

- Three factors drive the optimal order size :
  - **Service level**: A higher target service level requires a lower probability of a stockout. This is ensured by increasing the reorder point and safety stock levels. Note that as the target service level approaches 100%, safety stocks increase non-linearly.
  - **Forecast error**: Increasing the forecast accuracy reduces the need for safety stocks. This can be done through advanced forecasting techniques or by pooling demands across products or locations. The statistical pooling effect resulting from aggregation will reduce the deviations of the forecast errors because aggregate forecasts tend to be more accurate.

- **Replenishment lead time**
- The lead time reduction allows lower safety stocks. Using the safety stock formula, one readily obtains that a lead time reduction by factor n reduces safety stocks by $\sqrt{n}$.

Concluding remarks

- The link between inventory and finance: Inventory levels show up only partially in the income statement. A key cost of holding inventory consists of the opportunity costs of having cash tied up in the capital. Reduced working capital requirements are good for the company and its future growth.
- It is not possible to be efficient on three fronts: Variety (more items), Price (low cost) and high responsiveness (reduce working capital needs). To improve financial performance, one of these dimensions might have to be forfeited in favour of more focus.