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Business Analytics

SPARE PART OPTIMIZATION

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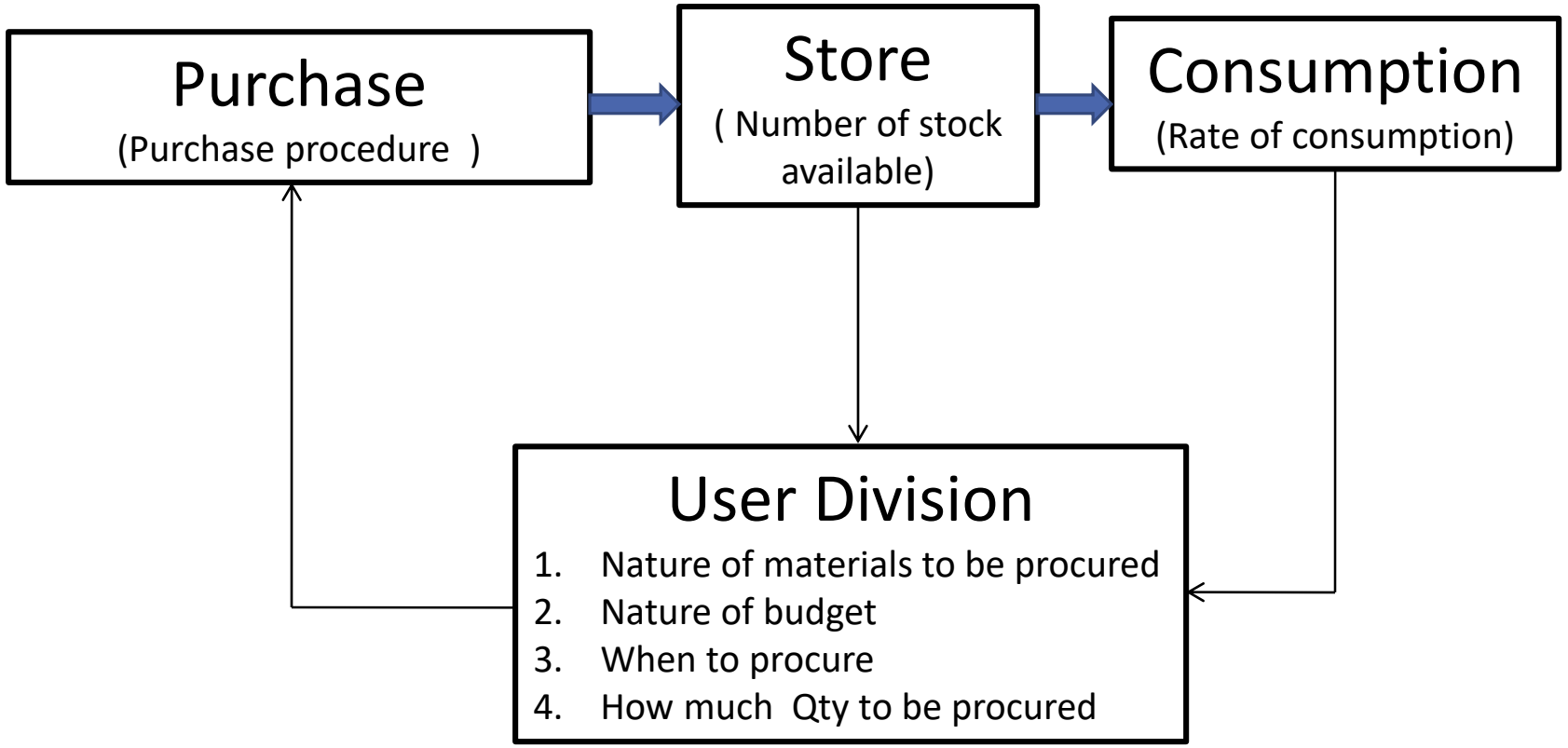
BASIC CONCEPT OF INVENTORY MANAGEMENT

Flow diagram for inventory management



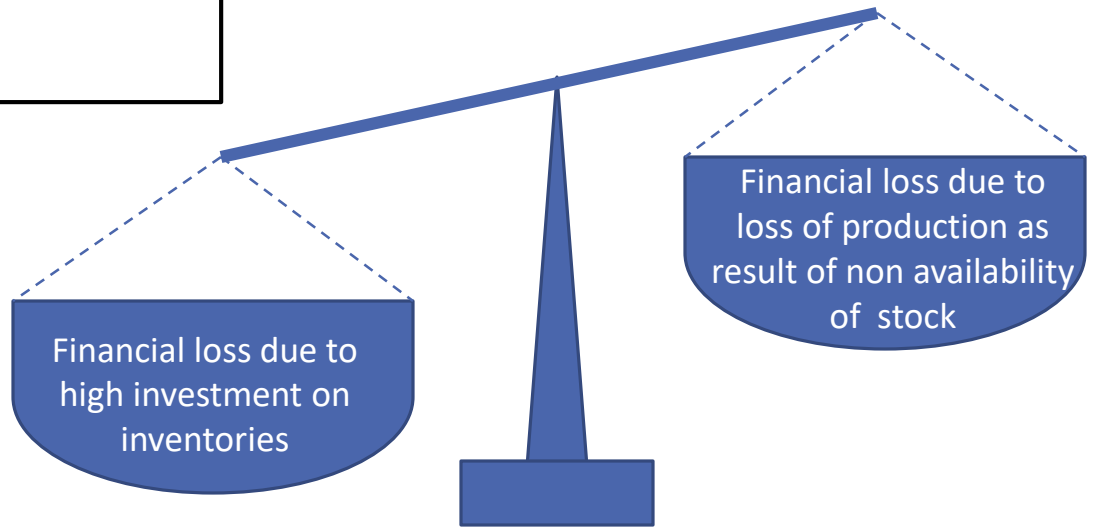
Impact of higher & Lower inventory

High Inventory Label

1. Locking of high working capital that leads to reduction of profit margin
2. Increases the storing cost
3. Chance of getting obsolete is high since the technology is improving at faster rate.
4. Loss of working capital due to damages / obsolesce / pilferages .
5. No risk of stock out

Low Inventory Label

1. Risk of loss of production due to non availability of required spare
2. High lead time can not ascertain the availability of spare at right time
3. Risk of stock out at any point of time .



Inventory management is a balancing act between financial loss due to high stock and loss of production due to non availability of stock

INVENTORY MEASURING PARAMETERS

$$\text{Inventory Turn over Ratio (ITR)} = \frac{\text{(Total consumption for the year)}}{\text{(Inventory available at the end of the year)}}$$

- ITR indicates the Inventory condition at any point of time
- The ratio is assigned between 1 and 10 depending upon the nature of Materials
- Ratio 1 implies number of inventory available is equal to the number of consumption per year.
- Ratio 10 implies number of inventory available is only 10% of the consumption per year.
- Higher ratio indicates better inventory management

Classification of materials

Type wise

1. **Rotatable spare** – Replaced, Reconditioned & Reused as a whole
2. **Insurance spare** – Standby materials for critical equipment
3. **Reconditioning spare** – Materials for reconditioning purpose.
4. **Consumables** - Materials required for operating & reconditioning
5. **Capital items** – Plant and equipments

Cost wise

1. **High value** – More than one lakh
2. **Low value** – Less than one Lakhs

Budget wise

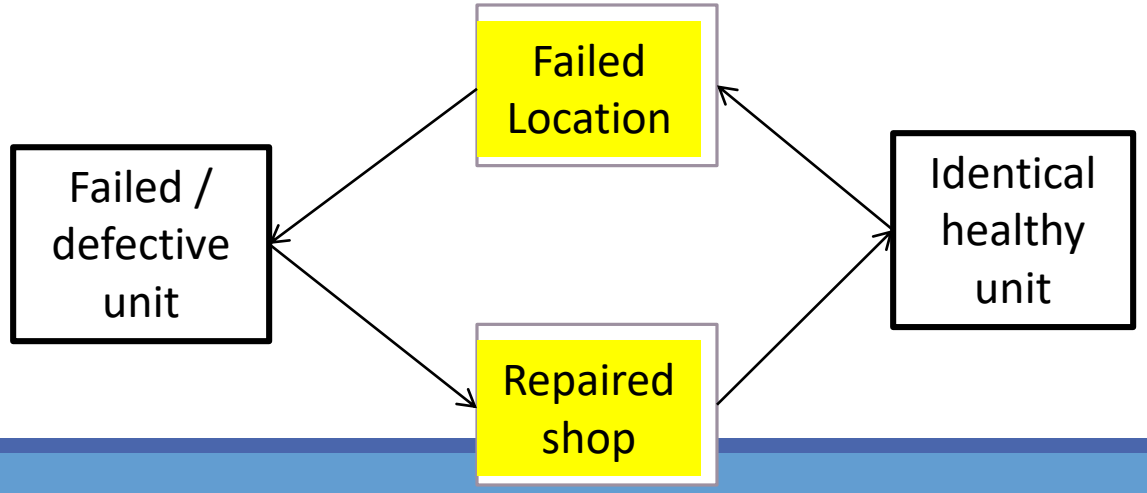
1. **Capital budget** – Plant & equipment : Having asset number, fixed life, Depreciation , Residual value, replaced after expiry of life
2. **Revenue budget** – Spares & consumables : No asset number, fixed life & depreciation , having scrap value, used for operating and reconditioning of equipments / system

Application wise

1. **Critical** – Without this materials production will be halted
2. **Important -** Without this materials production will not be halted but can not be ascertained
3. **Desirable -** Without this materials neither production will be halted or affected but it is required for the plant

1. Rotatable spare

- it is the identical units of the operating machineries
- Failed / defective operating units are replaced with this identical unit
- Released failed / defective units are repaired / reconditioned at shortest time and kept ready for replacement.
- As the spare is always in rotation – it is called rotational spare.
- Example : Electrical motor , pump, fan, blower compressor , gear box, transformer , switcher gear etc
- Normally this type of spare is maintained within 10% of total population.
- Initially it is supplied along with the package as mandatory spare.
- On expiry of life, it is disposed at scrap value and a new is procured through revenue budget.



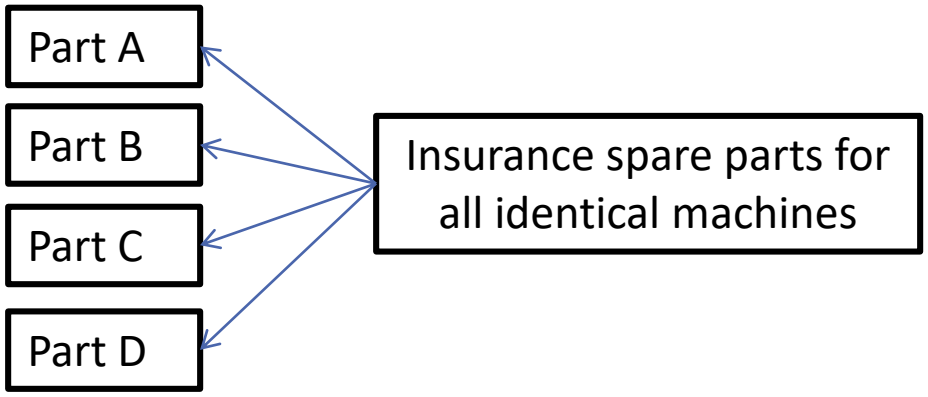
2. Insurance spare

- The insurance spare are those vital parts of a machine which have life nearly equal to that of a machine itself and are held as a stand by against any break down .
- These stand by units have a high reliability of performance and can be capitalised.
- It is supplied by the manufacturer along with the main equipment.
- Example : Generator Rotor, Turbine Rotor , Winding of Generator Transformer.
- It is some time referred as critical spare for 90% PLF

Machine I	
Part A	Part C
Part B	Part D

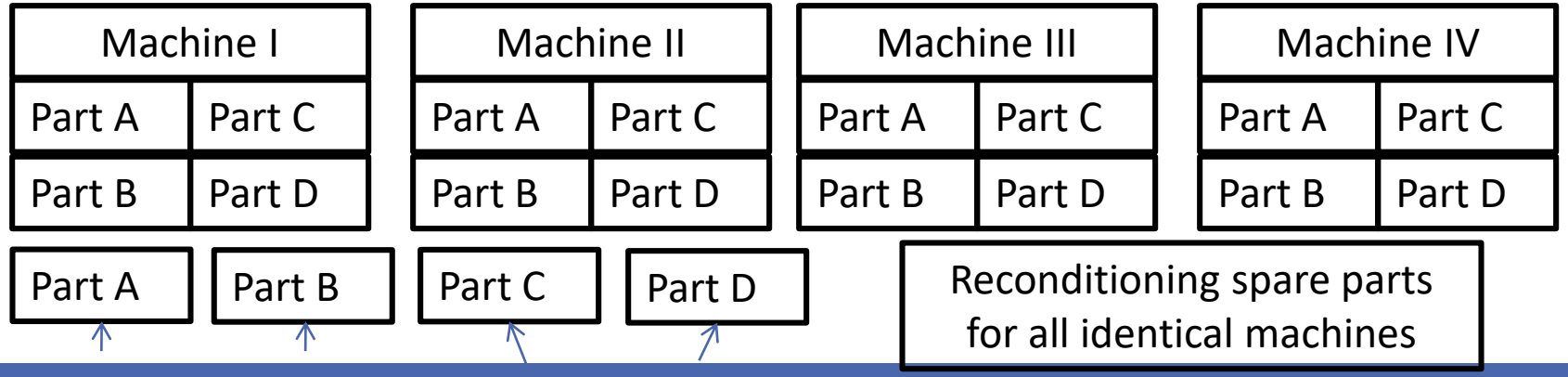
Machine II	
Part A	Part C
Part B	Part D

Machine III	
Part A	Part C
Part B	Part D



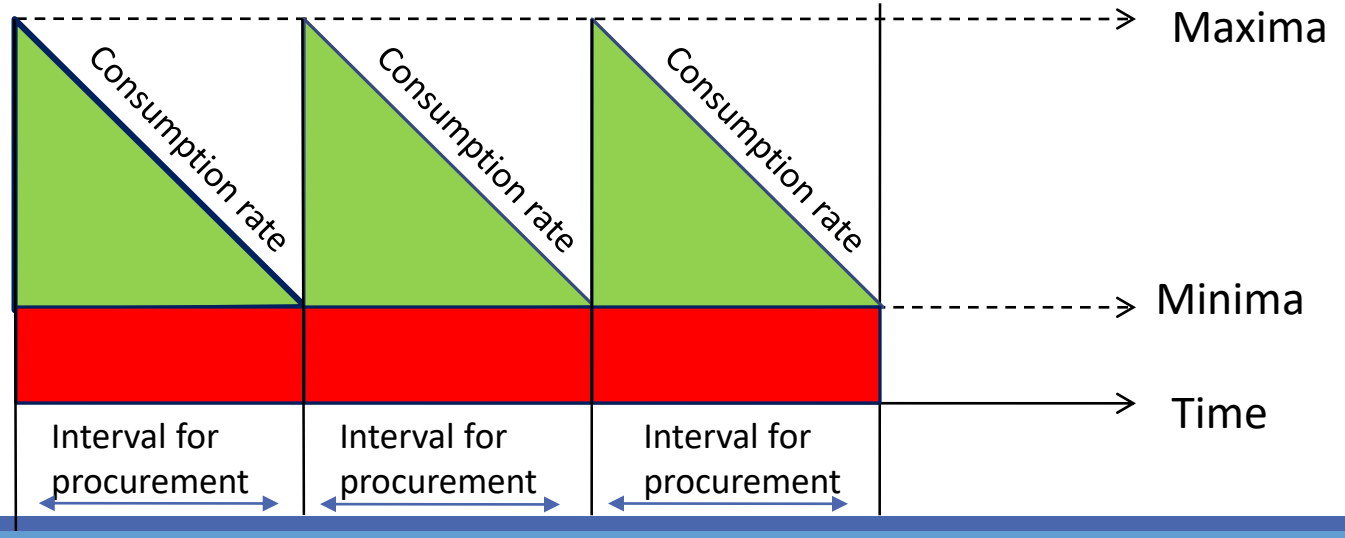
3. RECONDITIONING SPARE

- This are the spare parts of the operating machineries
- It is used for reconditioning / repair of various machine /equipments
- All these items comes under critical category because without these items machine & equipment can not be reconditioned / repaired
- These materials are procured under revenue budget
- Used materials are disposed at scrap value
- Example :Various identical component s of machine & equipments such as motor bearings, impellers of pump & fans, Pulley & hubs of gear box , light fittings (choke, tube, starter), transformer bushings, transformer oil etc.
- Number of stock should be sufficient enough to meet out the regular as well as emergency demand.
- Stocks are decided based on Consumption rate and Lead time for procurement
- Procurement is controlled through EOQ method



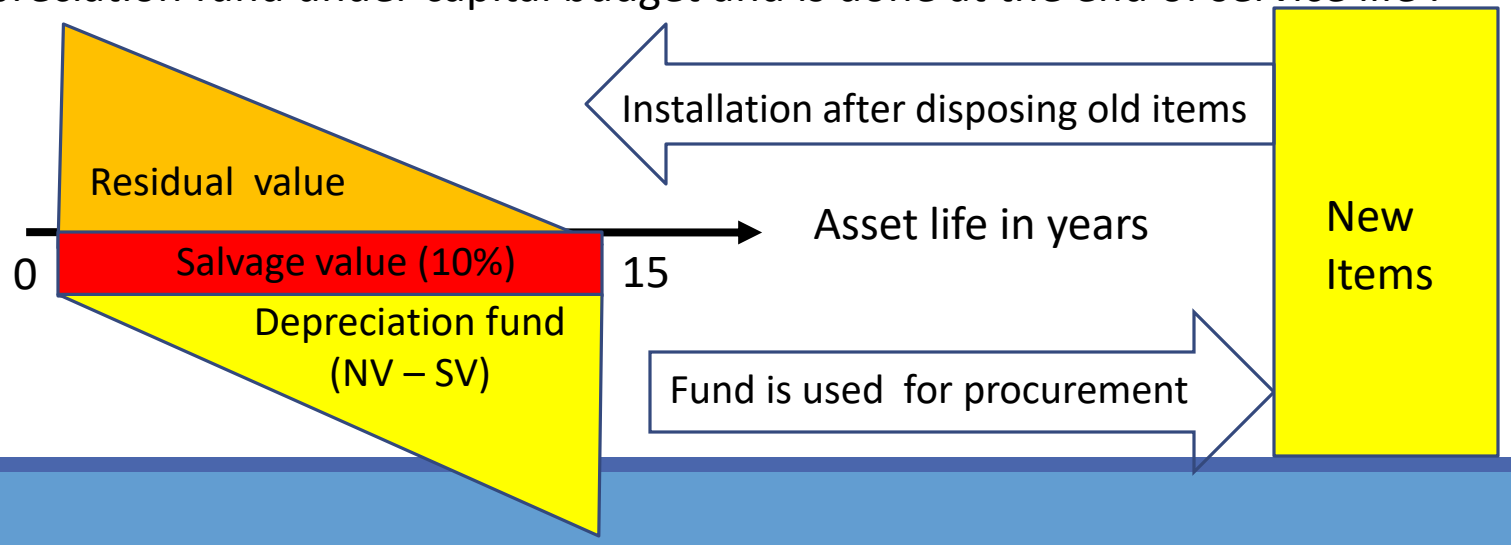
4. Consumables

- This materials are required for reconditioning / repair / operation of various machine /equipments .
- Example : Gaskets, Hardwires , Lubricants , fuse , contractor, chemical items, gas etc.
- All these items comes under important categories
- Consumption rate is very high
- Disposal is not assigned with these materials.
- Procurement through revenue budget at a fixed interval
- Stocks are decided based on Consumption rate and Lead time for procurement
- Procurement is controlled through Maxima- Minima basis

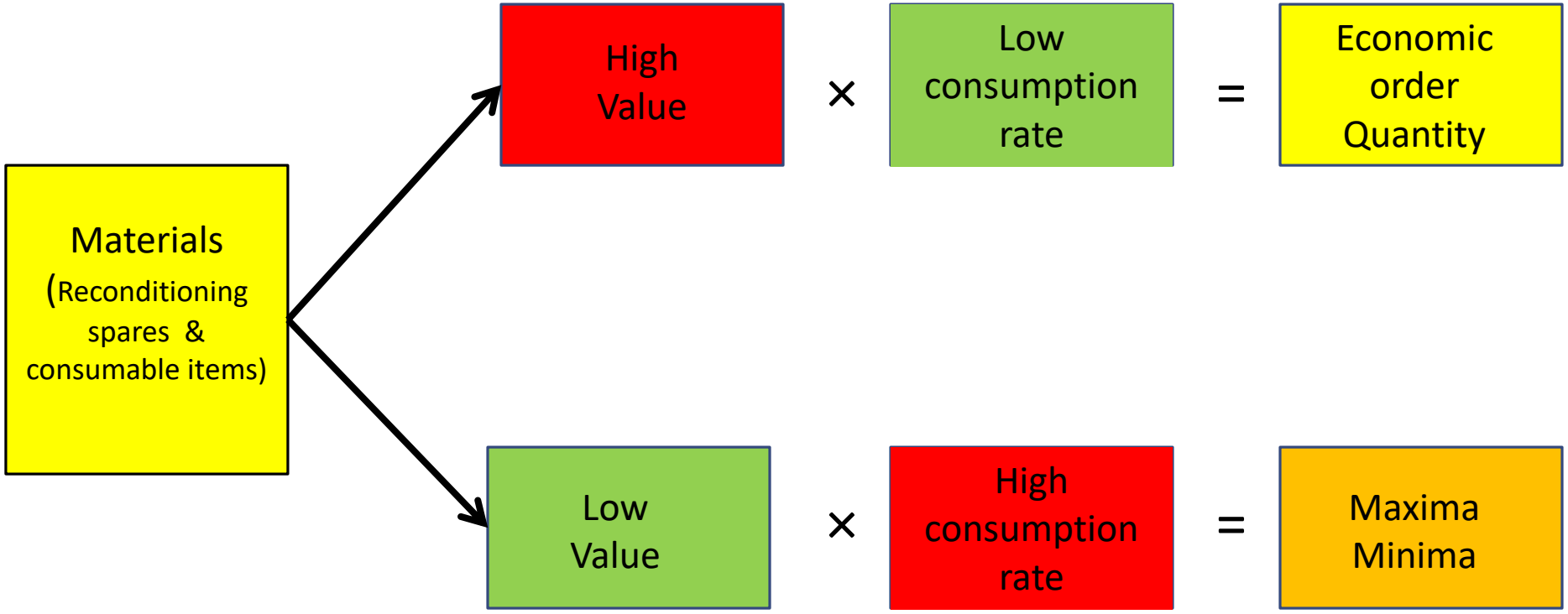


5. Capital items

- The Equipment , Machine, Tools & tackles, Instrument etc which are procured for setting up the plant and are directly or indirectly used for the production of the plant, are known as capital items.
- It comes under plant & equipment category and the investment is capitalized.
- All these items have asset number , fixed life and depreciation
- During service life depreciation amount is collected and kept aside for the procurement of new item at the end of life.
- At the end of life, it is disposed (survey reported) at residual (salvage) value.
- New item is procured from the depreciation fund against the disposal of the old items.
- Since procuring of new item is done from the depreciation fund it is considered as the reinvestment of the capital fund and therefore it can not be capitalized
- Procurement is through depreciation fund under capital budget and is done at the end of service life .



INVENTORY CONTROLLING METHODS



Economic order quantity (EOQ)

Economic Order Quantity (EOQ) =
(Average yearly Consumption X Lead Time [in years]) + Emergency Stock – Stock on hand

Transformer oil

1. Average yearly consumption = 80KL
2. Lead time for procurement = 1 year
3. Emergency stock = 80 KL
4. Stock in hand = 100 KL
5. EOQ = (80 x 1) + 80 -100 = 60 KL

16 mm^2 copper cable

1. Average yearly consumption = 1000 Mtr
2. Lead time for procurement = 1 year
3. Emergency stock = 100 Mtr
4. Stock in hand = 20 Mtr
5. EOQ = (1000 x 1) + 100 -20 = 1080 Mtr

Conveyor roller

1. Average yearly consumption = 300 Nos
2. Lead time for procurement = 1 year
3. Emergency stock = 50 Nos
4. Stock in hand = 10 Nos
5. EOQ = (300 x 1) + 50 -10 = 340 Nos

Roller Bearing (NU320)

1. Average yearly consumption = 20 Nos
2. Lead time for procurement = 1 year
3. Emergency stock = 6 Nos
4. Stock in hand = 10 Nos
5. EOQ = (20 x 1) + 6 -10 = 16 Nos

Maxima - Minima

1. Economic order quantity (EOQ)
[This is the quantity to be procured]
= (Minimum consumption X Maximum lead time)

2. Re order Level (ROL)
[At this level next order to be placed]
= (Max consumption X Maximum lead time)

3. Minimum order Level (MIOL)
[This is the quantity to be maintained at the store to prevent stock out condition]
= ROL - (Average consumption X Average lead time)

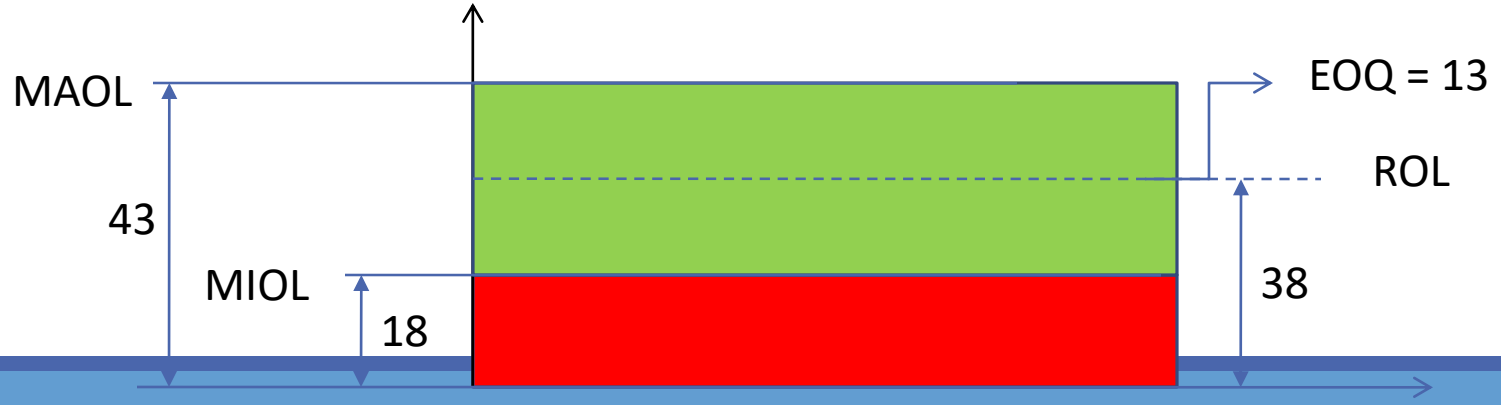
4. Maximum order Level (MAOL)
[This is the quantity above which stock is not allowed to exceed]
= ROL + EOQ - (Minimum consumption X Minimum lead time)

5. Avg inventory (MAOL)
[This is the quantity always available in the store]
= (MIOL + MAOL)/2

Maxima - Minima

	Max	Mini	Avg
Yearly consumption pattern (C)	75 Nos	25 Nos	50 Nos
Lead time for procurement (LT)	0.5 Yr	0.3 Yr	0.4 Yr

	Formula	Qty
EOQ	Mini(C) x Max (LT)	(25 x 0.5) = 13 Nos
ROL	Max (C) x Max (LT)	(75 x 0.5) = 38 Nos
MIOL	ROL – [Avg (C) x Avg (LT)]	(38 – 20) = 18 Nos
MAOL	ROL + EOQ – [Mini (C) X Mini (LT)]	(38+13 – 8) = 43 Nos
Avg Inventory	(MIOL +MAOL)/2	(18 +43)/2 = 31 Nos



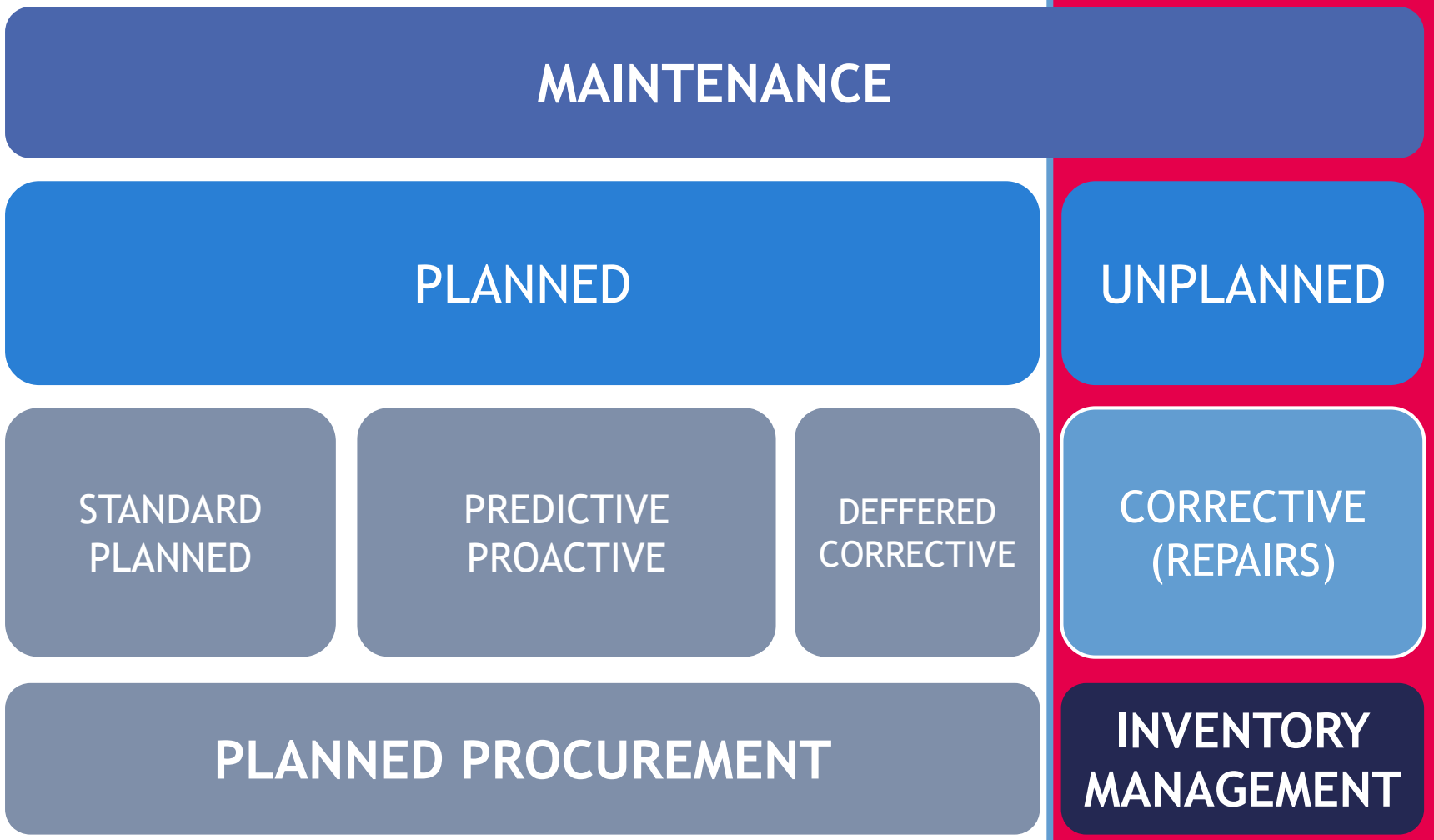
Effective Spare Parts Management: 8 Rules

Eight rules for efficient SPM

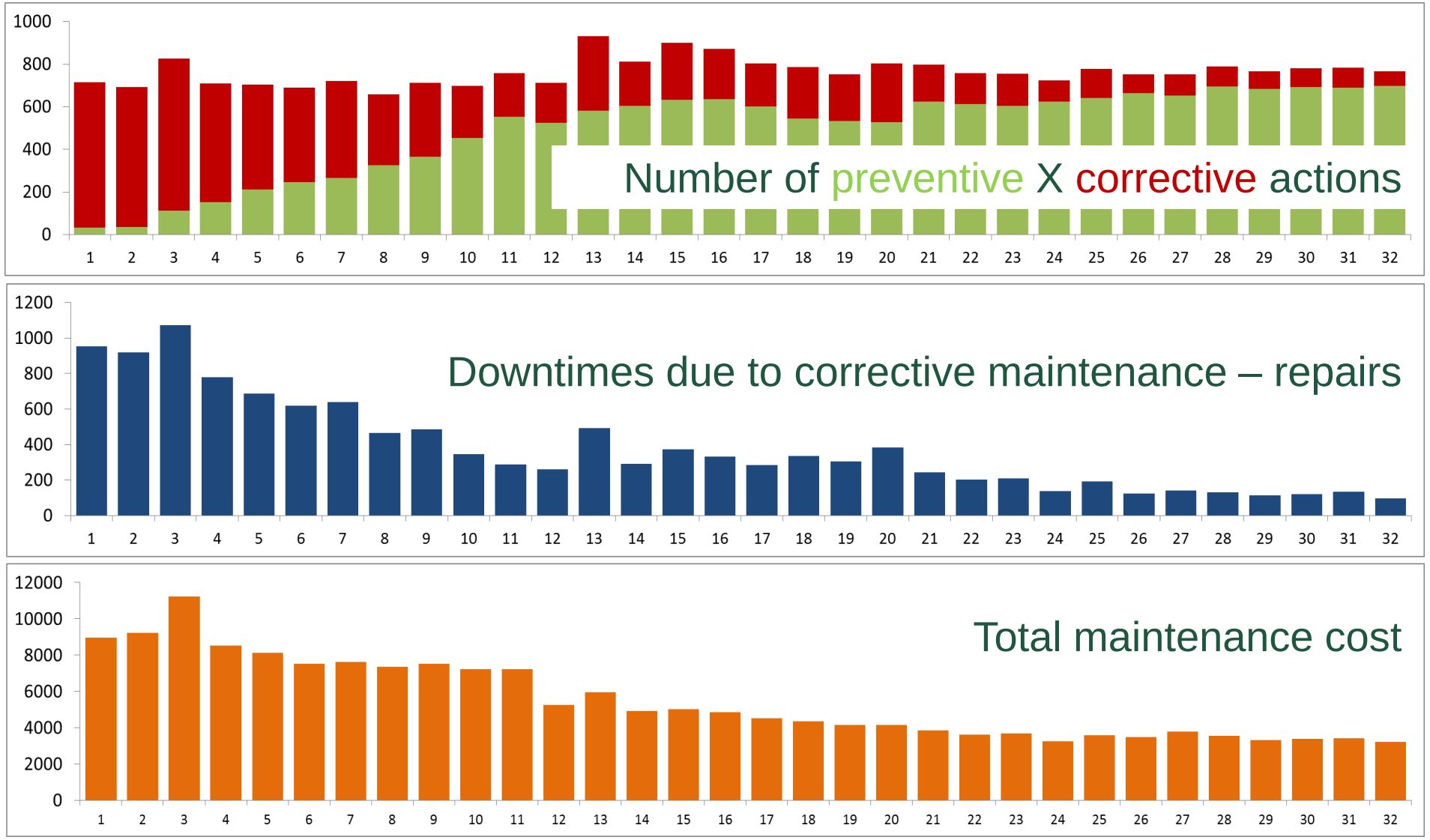
1) Go for preventive maintenance!
2) Eliminate process problems
3) Segment your spare parts portfolio
4) Evaluate spare parts criticality
5) Spare parts management starts with good forecasting
6) Use special methods for intermittent demand items
7) Consider the whole life cycle of your equipment
8) Implement a good information system for spare parts and maintenance inventory management

Go for preventive maintenance

Go for preventive maintenance!

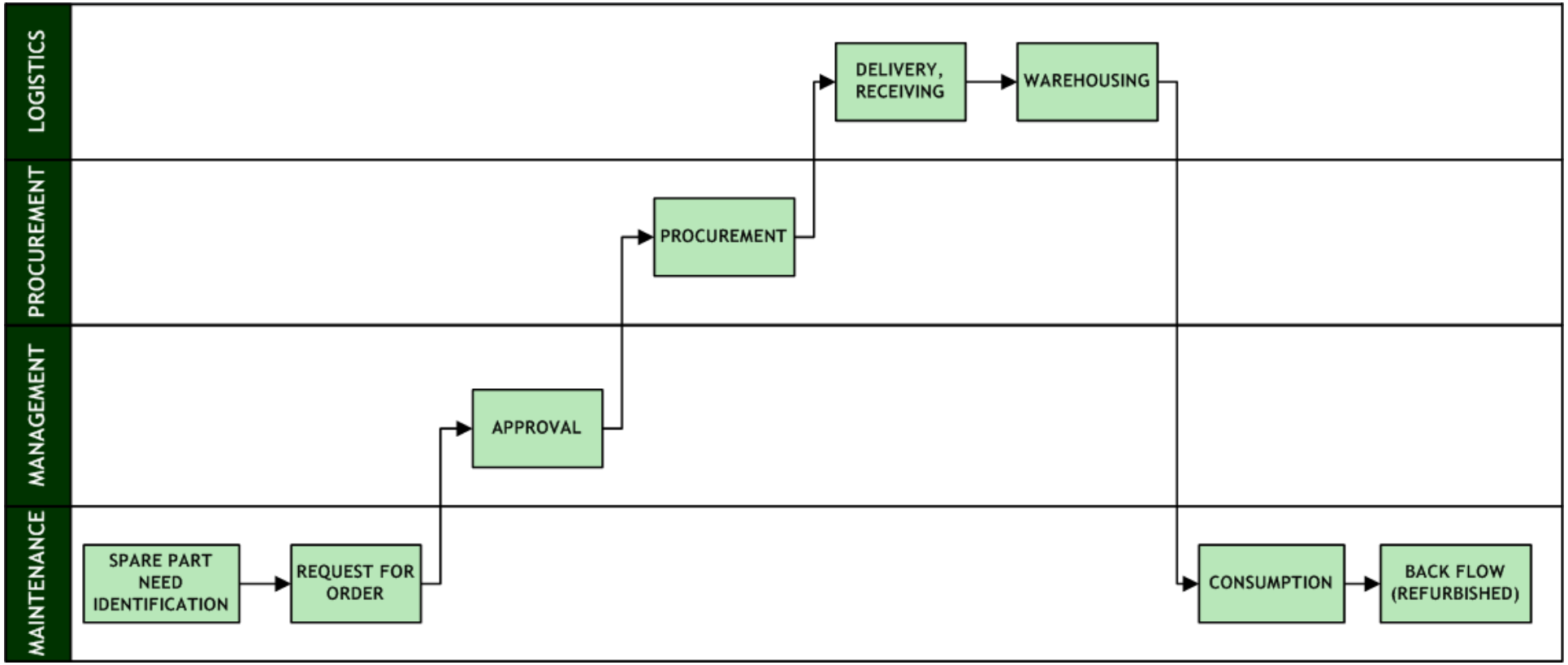


Prevention or correction?



Eliminate process problems

LIFE CYCLE OF A SP IN A COMPANY



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Eliminate process problems

SP NEED IDENTIFICATION	There is no direct **responsibility** of maintenance engineers/technicians **for "their" items and spare parts** levels.
REQUEST FOR ORDER	RFO created by someone else, not by the technician who had identified the need. The step of creating RFO may not be necessary in the process.
RFO APPROVAL	**How often are RFOs approved? Who approves?** Is RFO approved by means of IS workflow or by signing a paper copy? Alternatively, are both ways needed? After RFO is approved, the issued order must be approved again. **Too many approvers**, complicated approval procedure and hierarchy of responsibilities. Approving on high levels of management.

Eliminate process problems

PROCUREMENT	**Insufficient information available to procurement**, poor spare parts identification – the buyer hardly knows what should be bought, additional communication with maintenance technician is needed. **Missing or incomplete procurement specification in the IS**.
RECEPTION	Problems with missing (undelivered) documentation for the received material (certificates, declarations). Only “paper-based” archiving of spare parts documentation. Problems to find documentation when needed.
WAREHOUSING	Insufficient **identification of spare parts** in the warehouse. Problems with finding items stored in the warehouse. Inventory count discrepancies, physical stock different from information system data. Non-real value of stock in the information system. Existence of out-of-system stocks.

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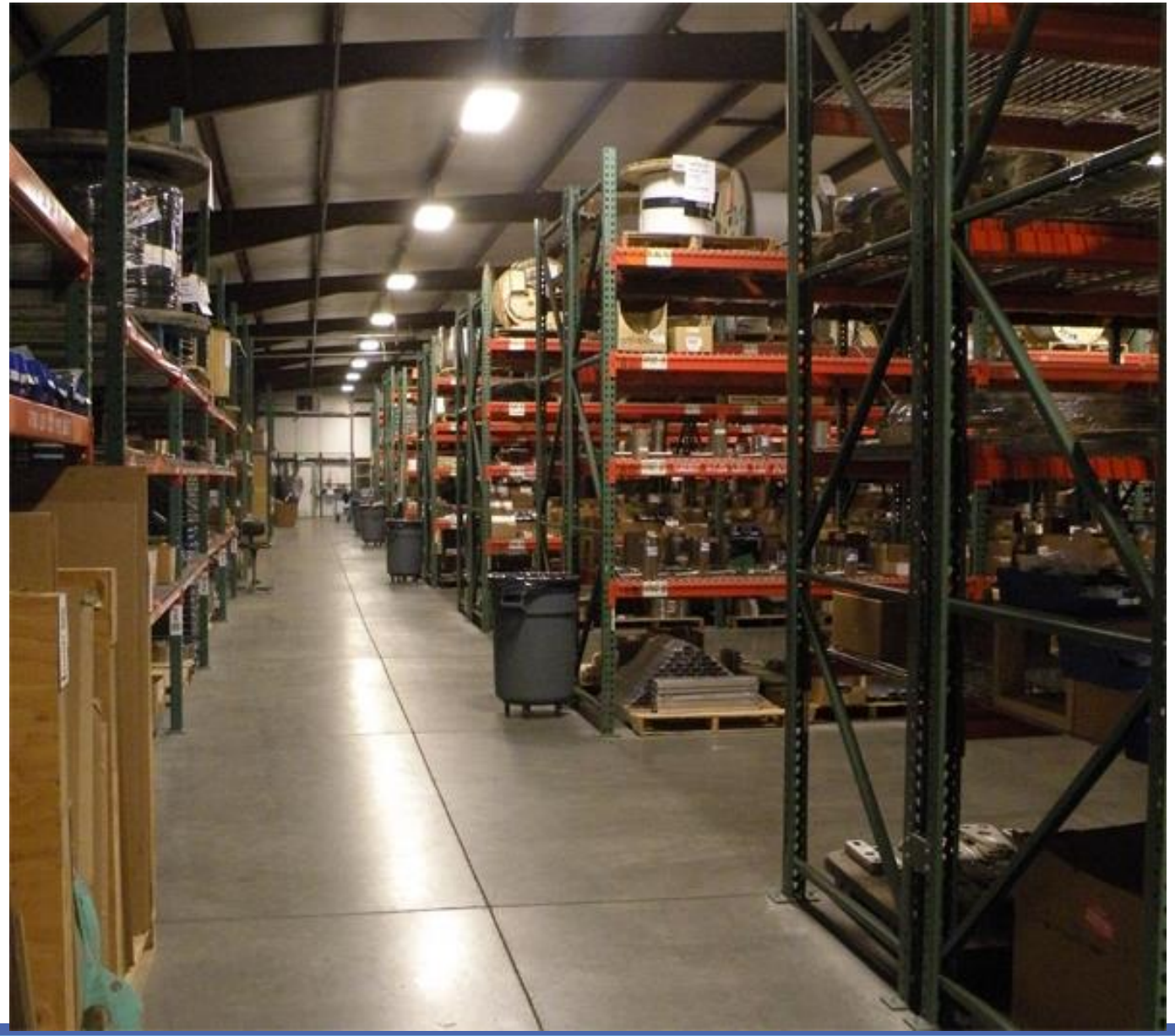

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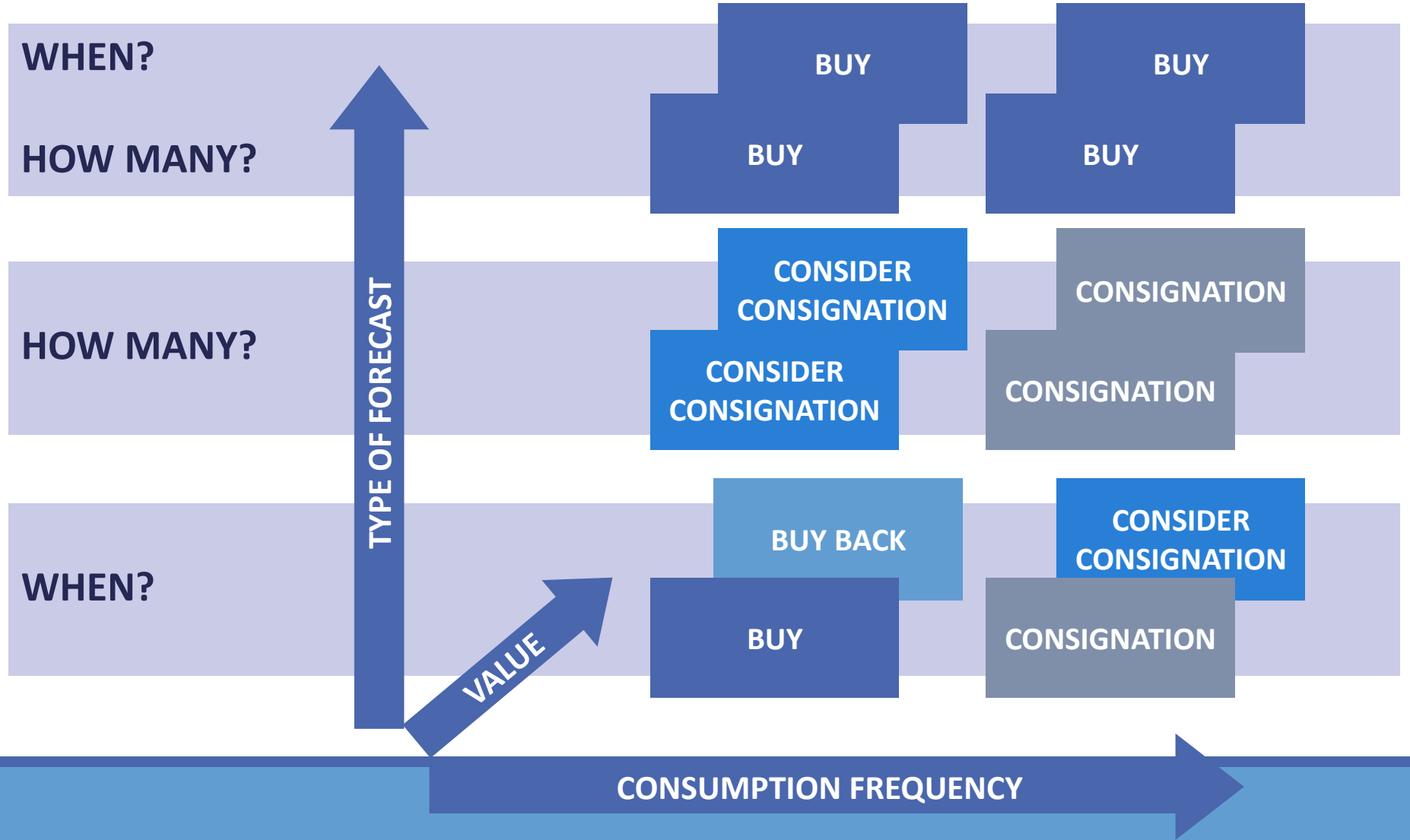
Eliminate process problems

CONSUMPTION	Slow spare part issues in case of sudden need. Issued spare parts are not consumed in fact. What happens then? Consumption of external material even in case the part is on stock.
WAREHOUSE RETURNS AND REFURBISHED SPARE PARTS	**Refurbished parts return to warehouse while new are bought.** Accounting price of refurbished items is much higher (or lower) than the non-realistic value of items on stock. Problematic or impossible returns of parts issued but not consumed. Insufficient control of parts dismantled from the maintained object (the information system has no information about these).

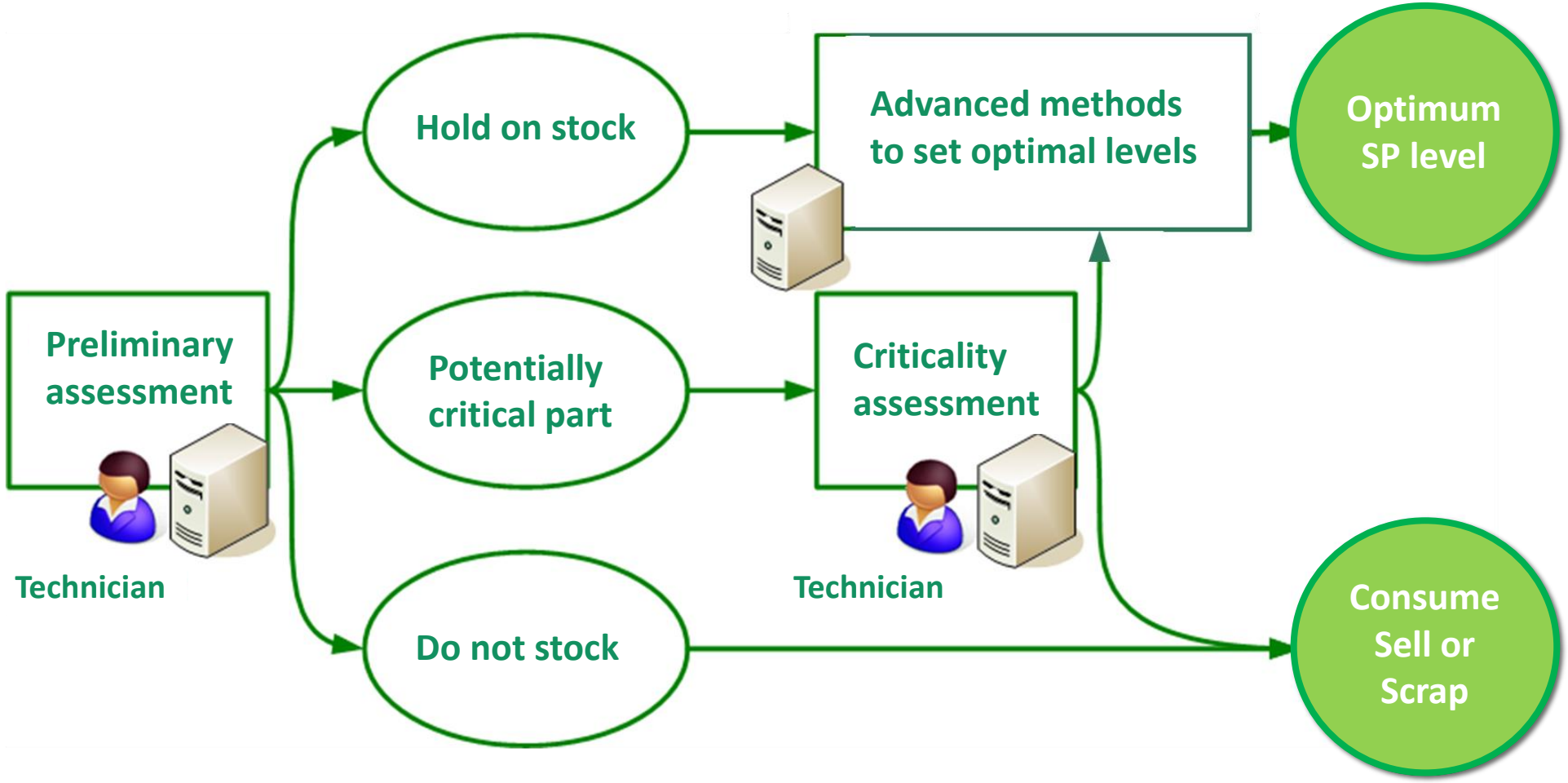
Segment your spare parts portfolio

Strategic segmentation of spare parts

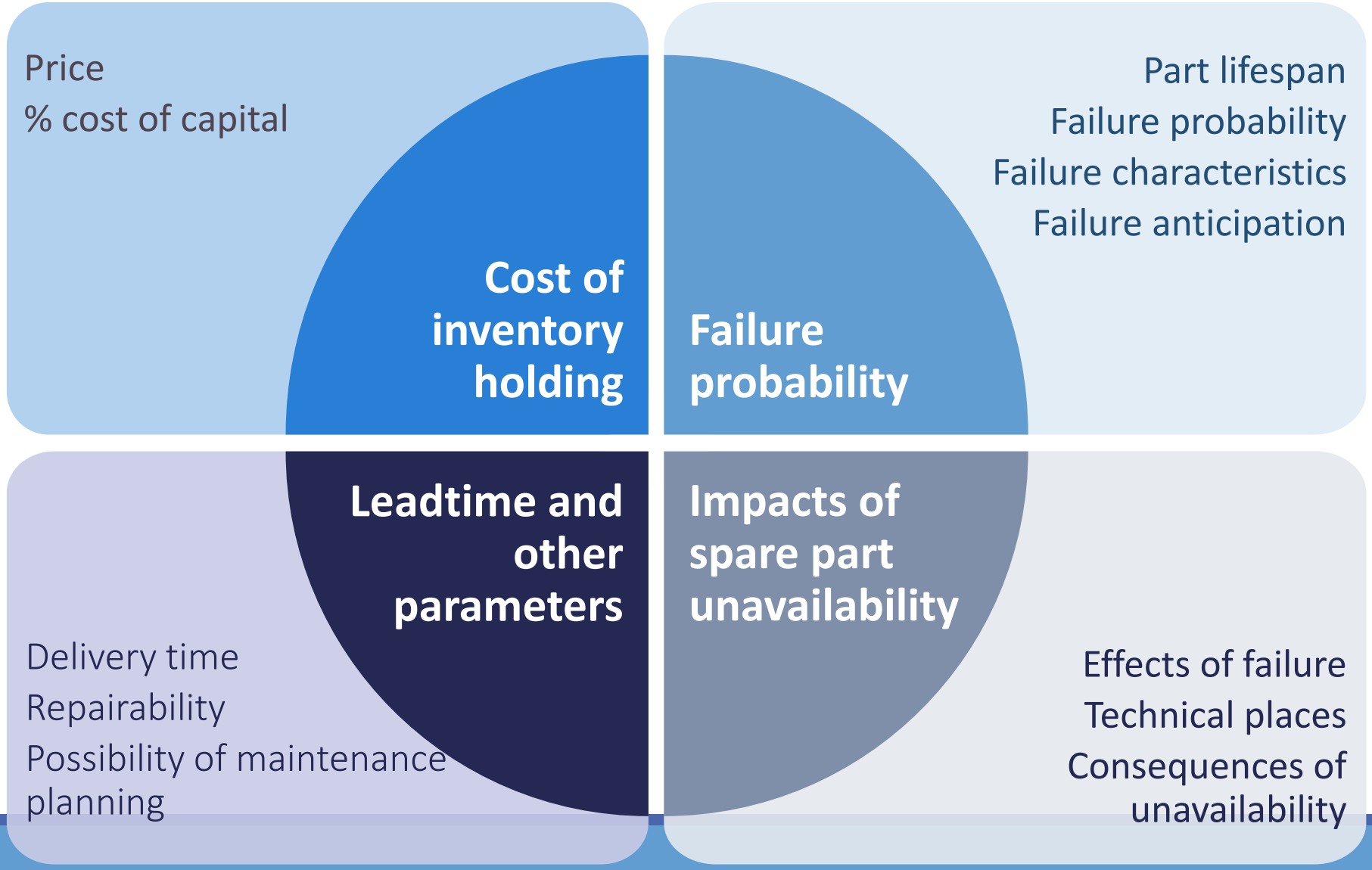


Evaluate spare parts criticality

Criticality assessment phases

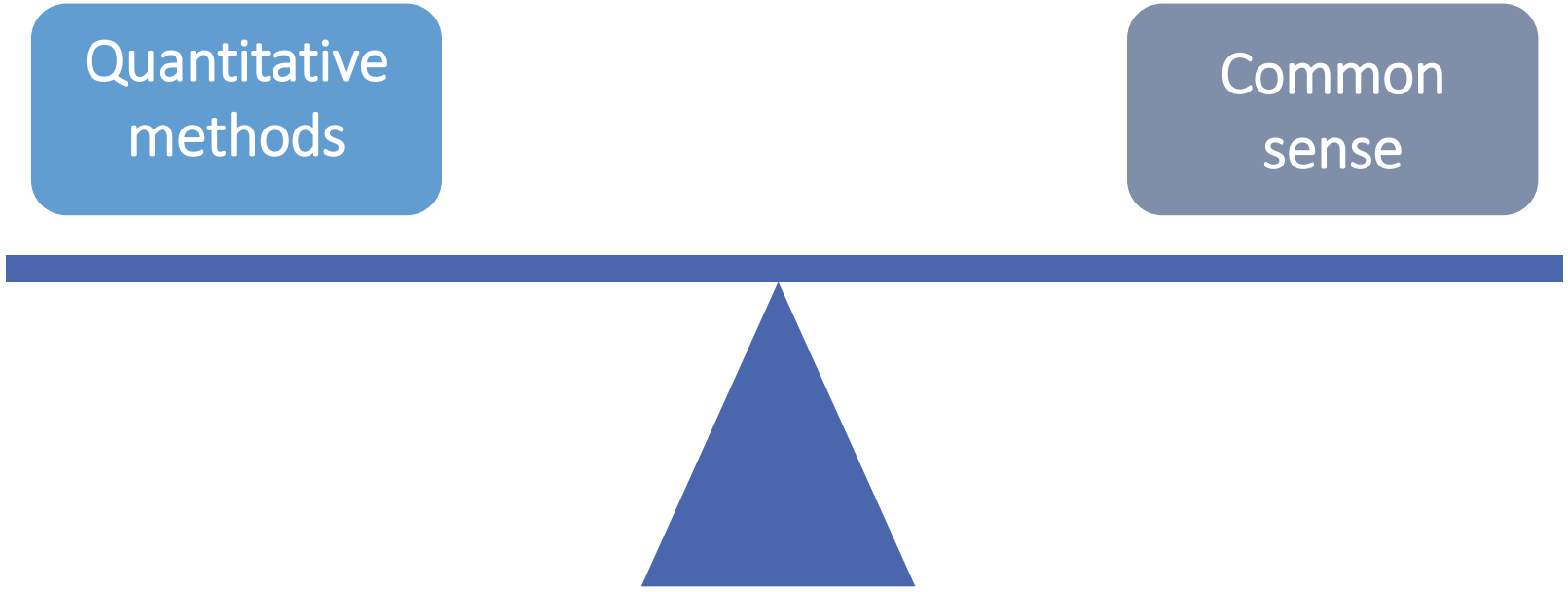


Evaluate spare parts criticality



Spare parts management starts with good forecasting

Quantitative methods x Common sense



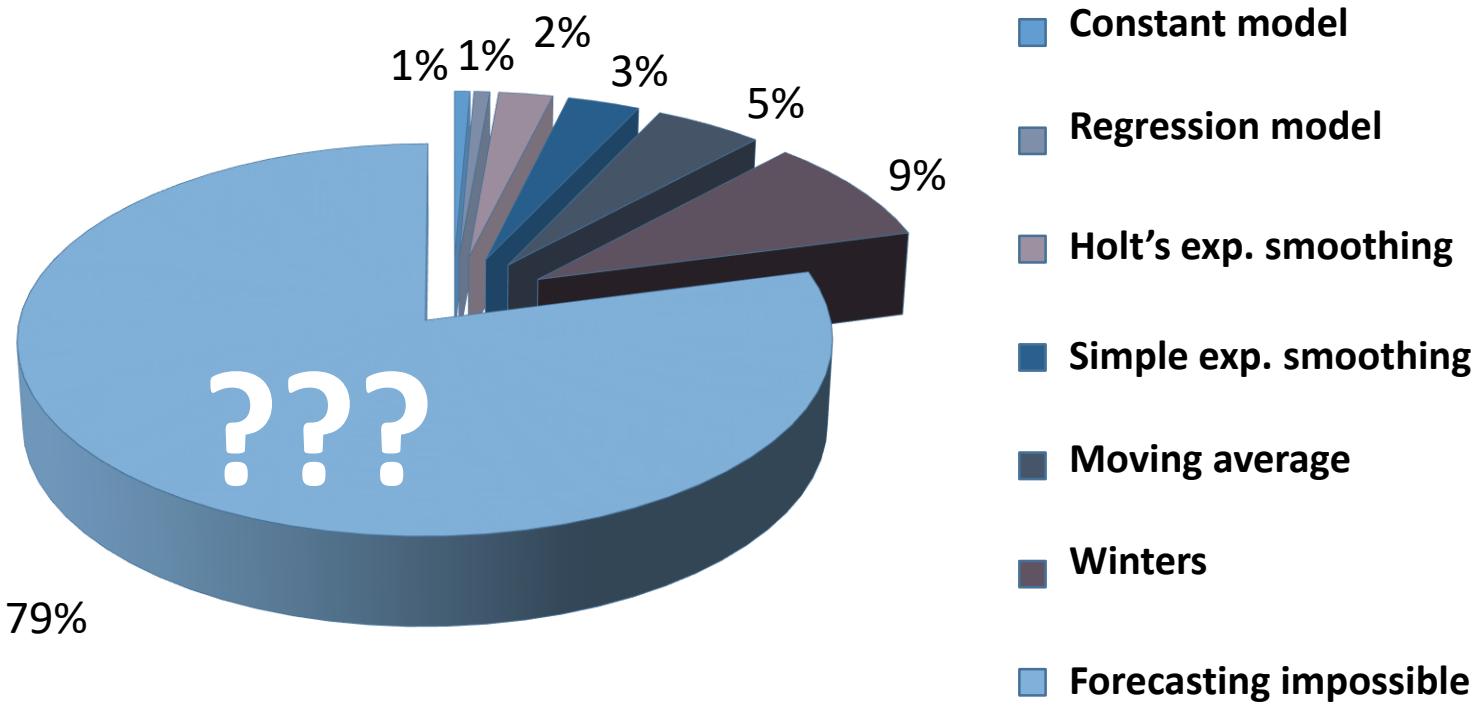
Quantitative methods x Common sense

Unexplained / Random	Minimize
Common sense	Make efficient
Quantitative methods	Maximize

Forecasting step-by-step

1. **Visualisation of time series**
   For better understanding of the time series
2. **Calculation of forecasts using all available methods**
3. **Calculation of accuracy**
   Absolute and relative errors, evaluation on testing season
4. **Selection of the best method**
   Best accuracy and reliability

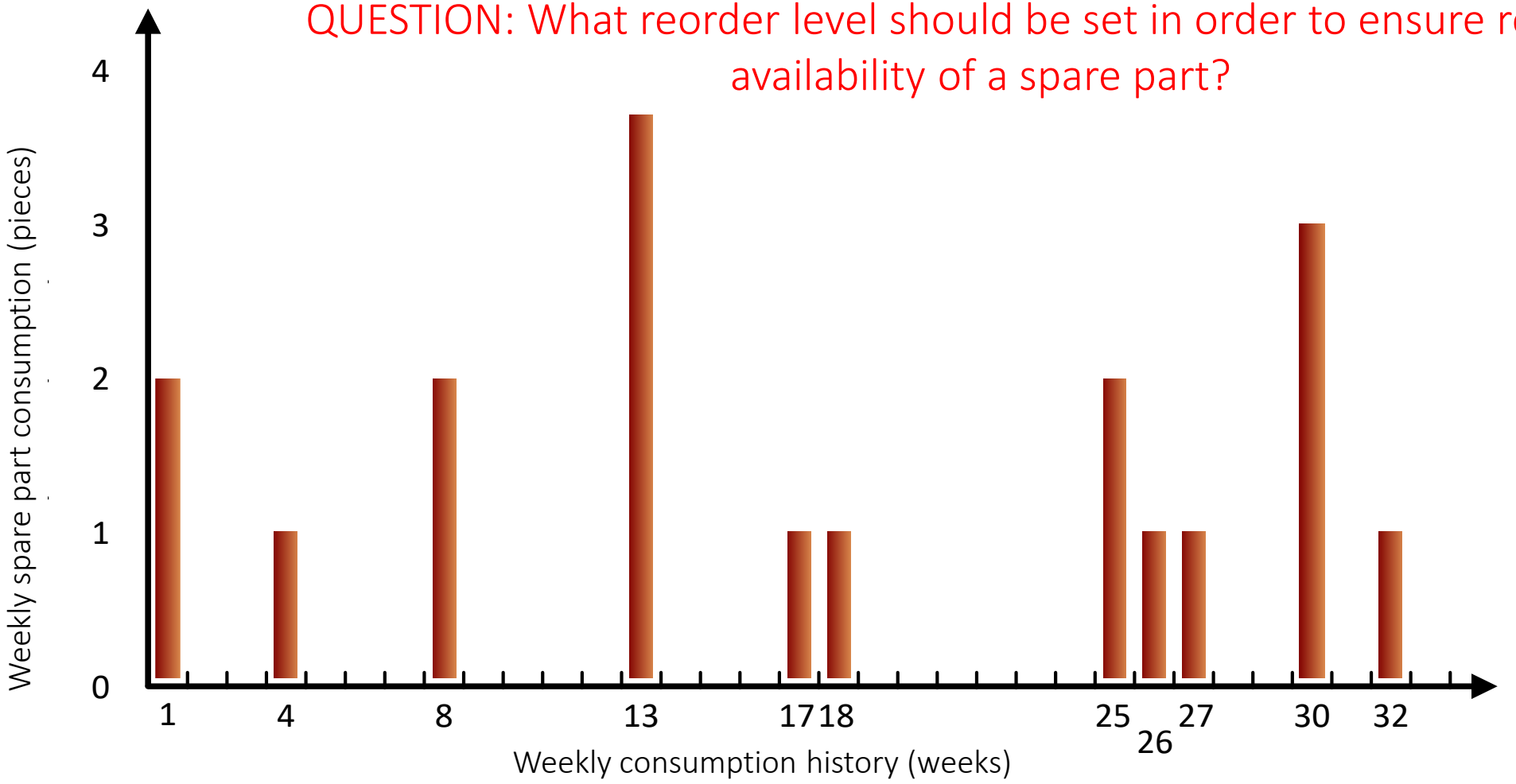
Which method is the best for spare parts?



Use special methods for intermittent demand items

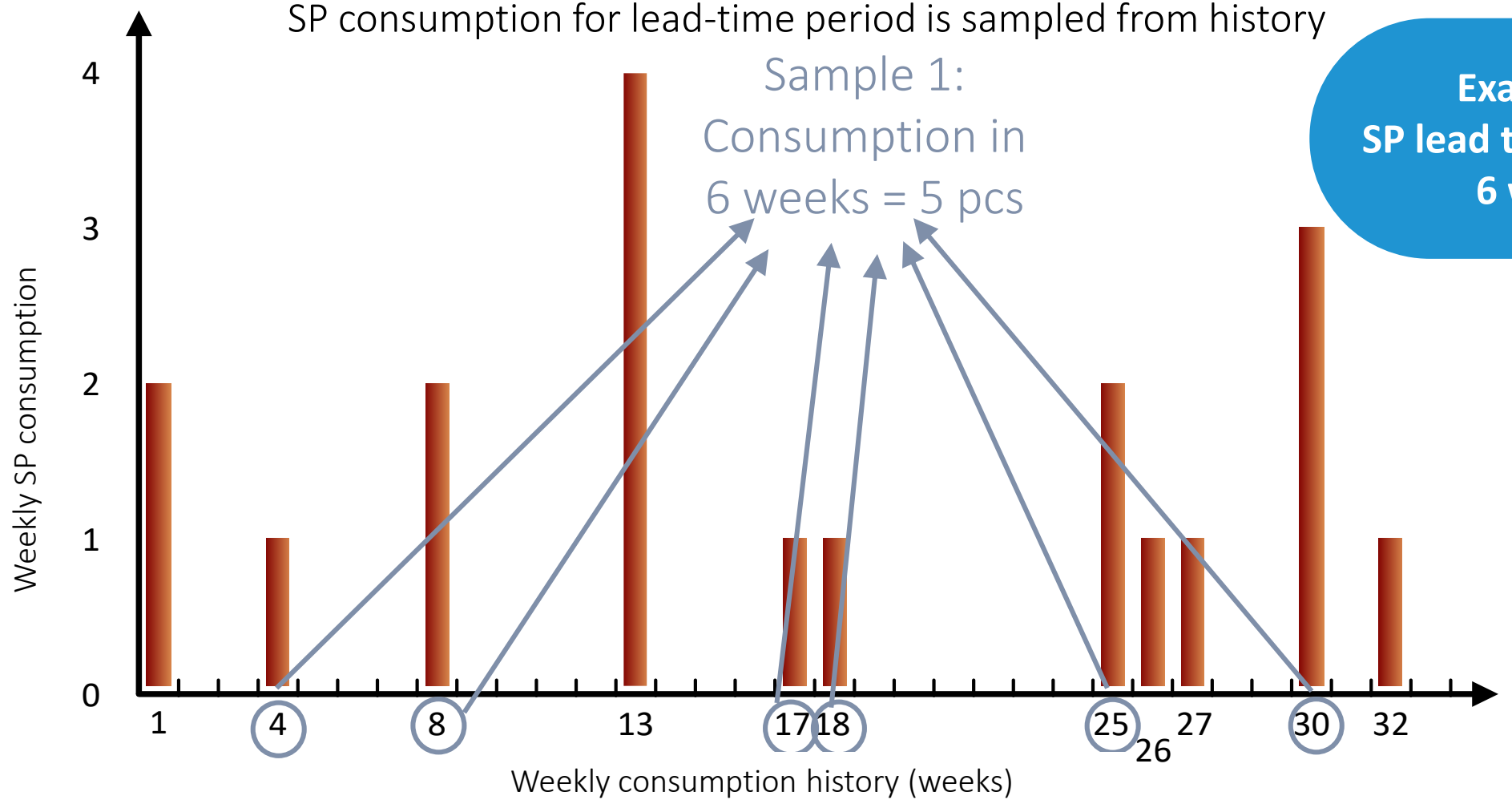
Spare parts – intermittent demand

QUESTION: What reorder level should be set in order to ensure required availability of a spare part?

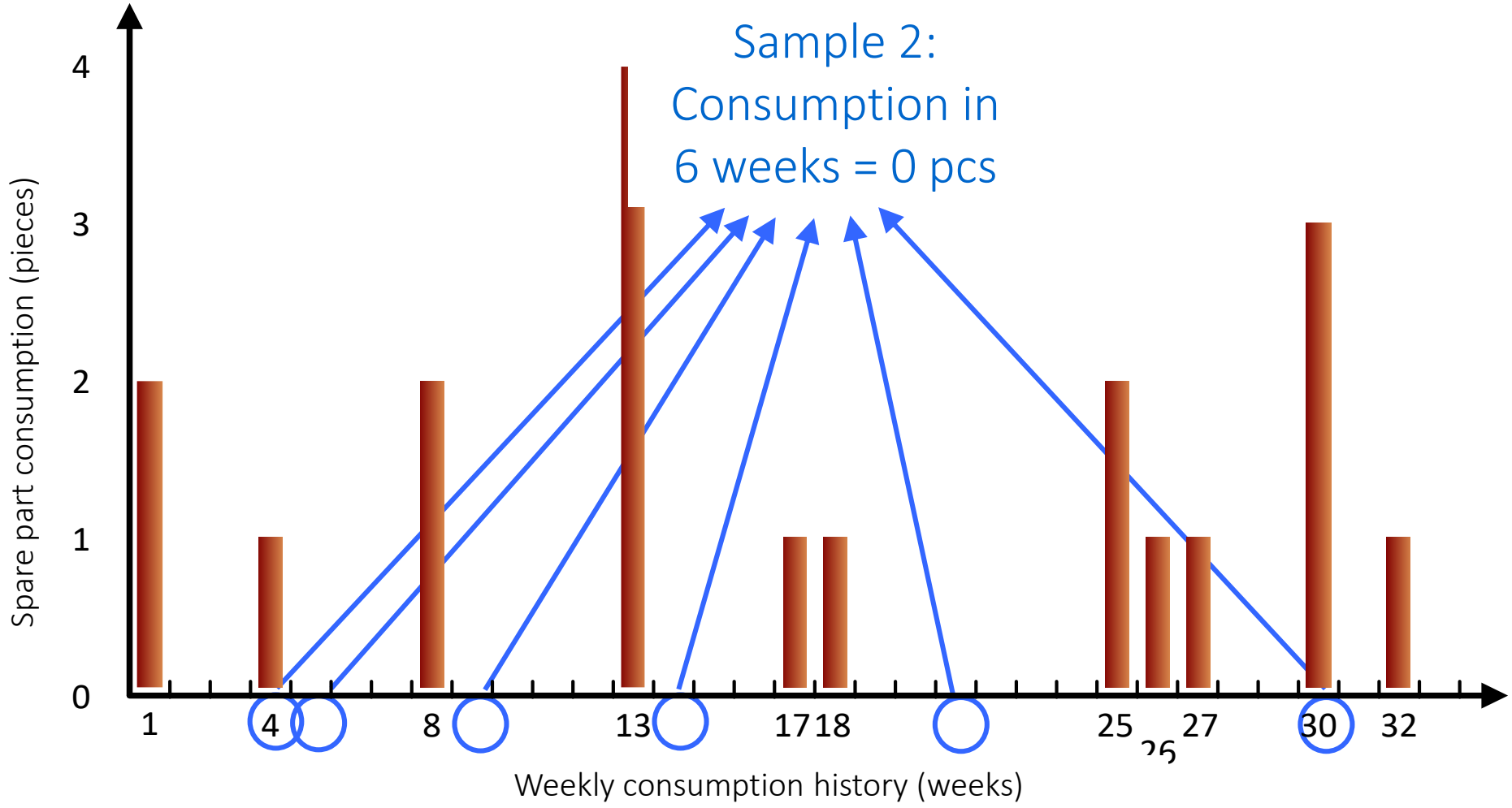


Bootstrapping

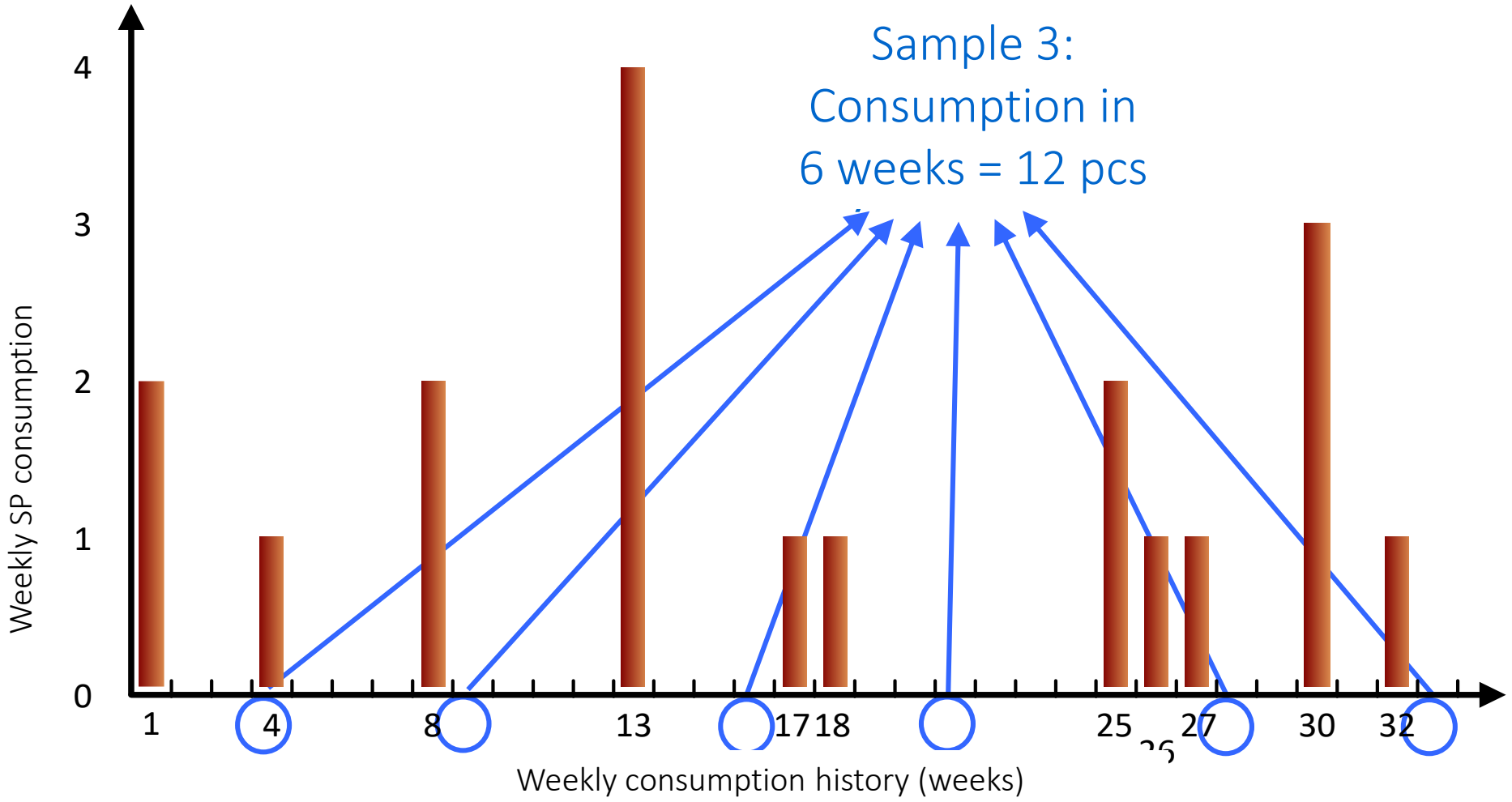
Bootstrapping = random sampling from history of consumptions.
SP consumption for lead-time period is sampled from history



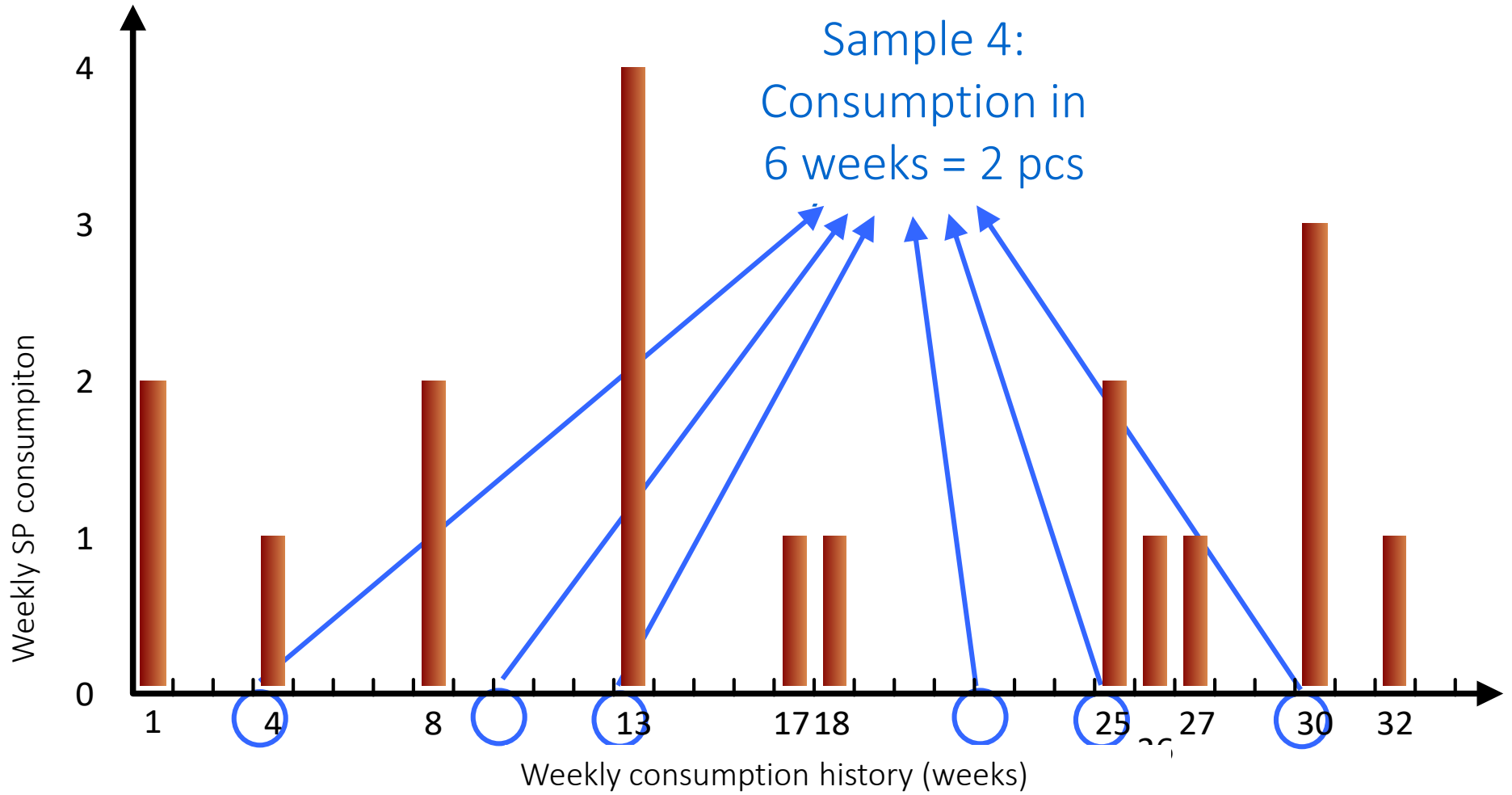
Bootstrapping



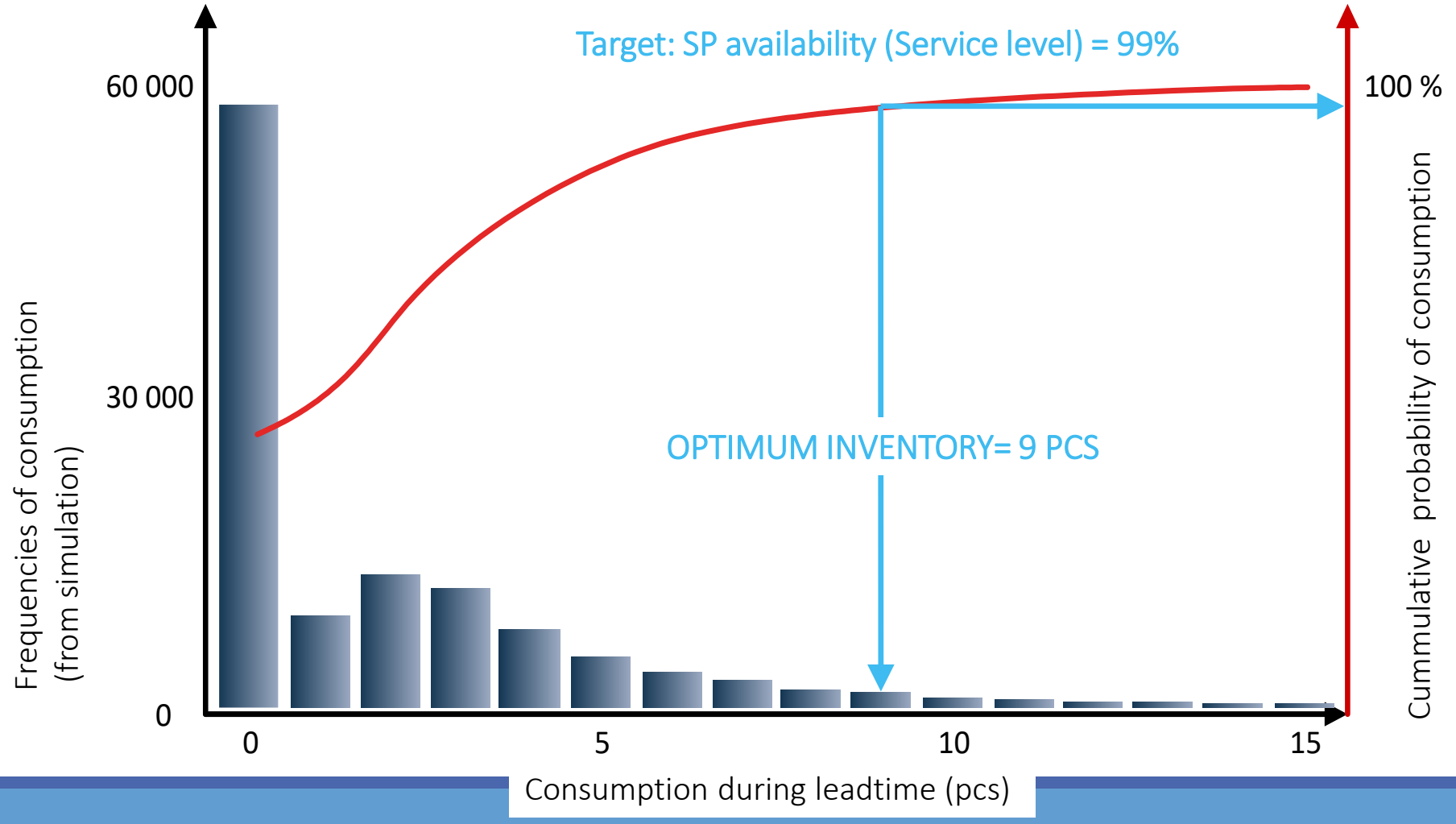
Bootstrapping



Bootstrapping



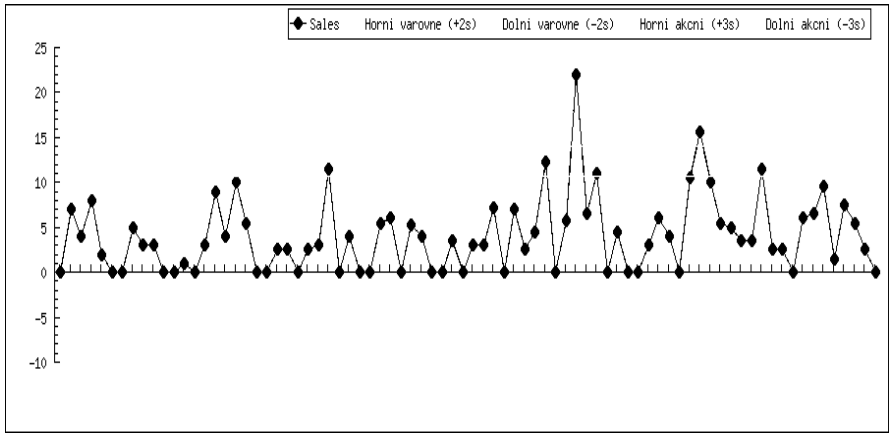
Example of 100 000 simulations of SP consumption

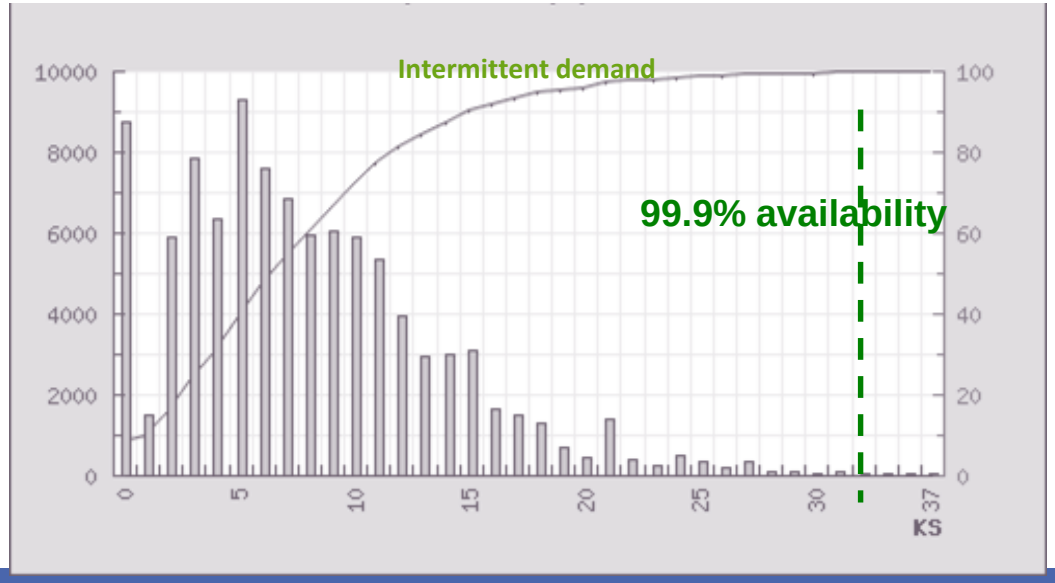


Bootstrapping application – a case study

Original inventory: **17 000 EUR**
(49 pcs)

Spare part lead-time: **32 days**





Recommended inventory

29 pcs

10 000 EUR

Savings

7 000 EUR

planning wizard 2.o

Detail | Objednávky | ABC Analýza | Trend | Struktura | Reporty

Cesta: Schäfer a Sýkora > Náhradní díly > 590 - Centrální sklad Rumburk > Tuzemské díly > Těsnění,Kalina > Těsnění,Kalina > 3517-0001

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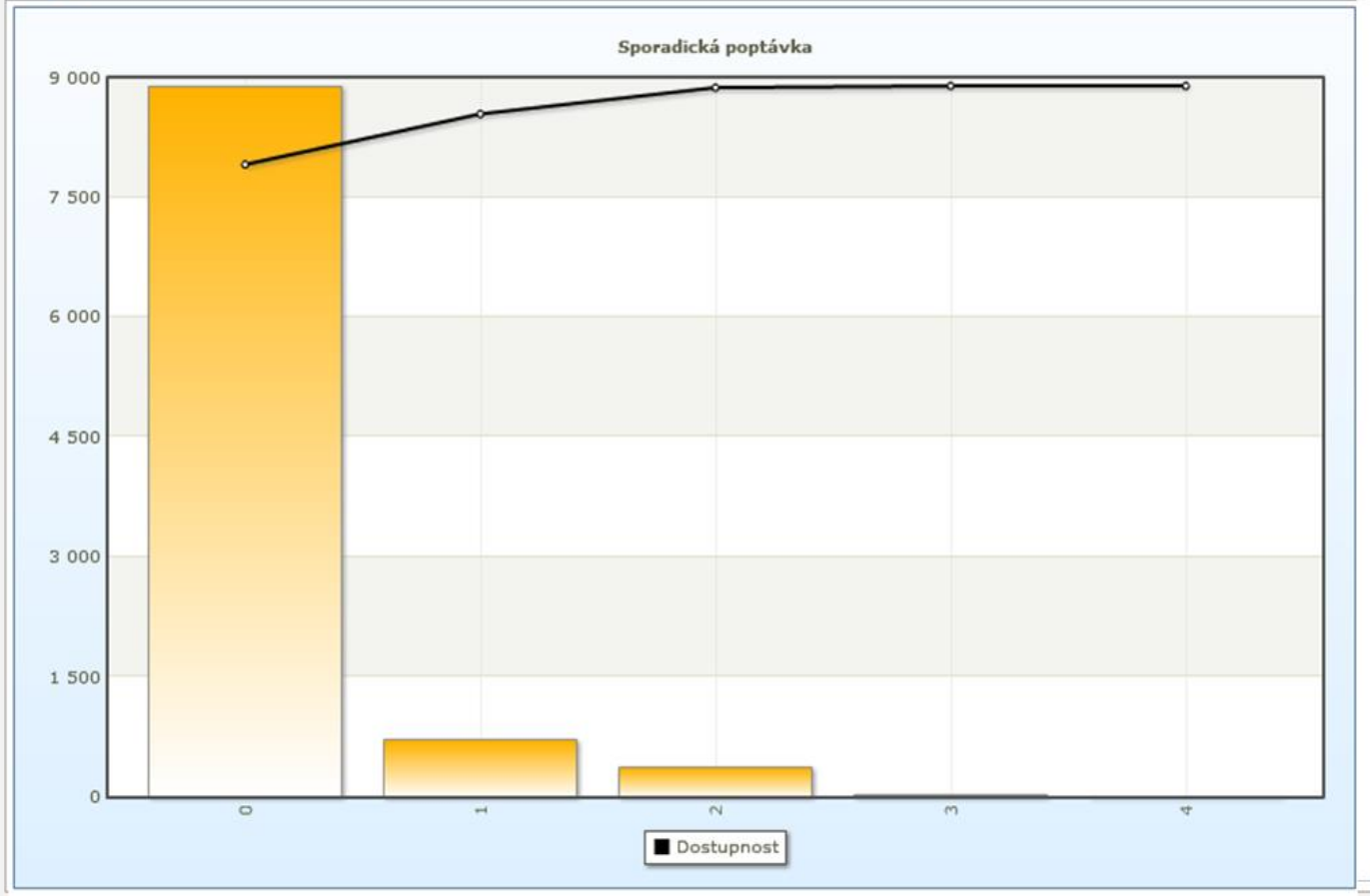
Schäfer a Sýkora

- Náhradní díly
- Osvětlovací technika
- Konsignace

Disponibilní zásoba	MIN. zásoba	ABC	Service level	PC	OBJ	Blokace
0.00 Kč (0 KS)	859.76 Kč (2 KS)	A (A)	100,0% (99.1%)	524.58 Kč	0.00 Kč (0 KS)	0 (mj)
				SC 429.88 Kč	Na cestě 0.00 Kč (0 KS)	

Logistické ukazatele | Detail | Forecast | Očistění forecastu | Očistění prodejů | Očistění leadtime

Sporadická poptávka



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Life cycle thinking:
Consider the whole life cycle of your assets

Life cycle thinking:
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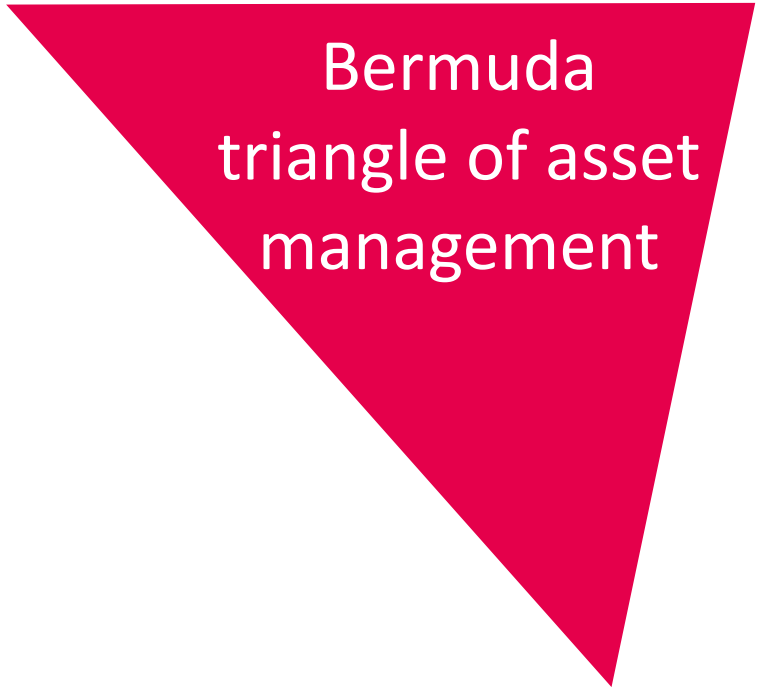
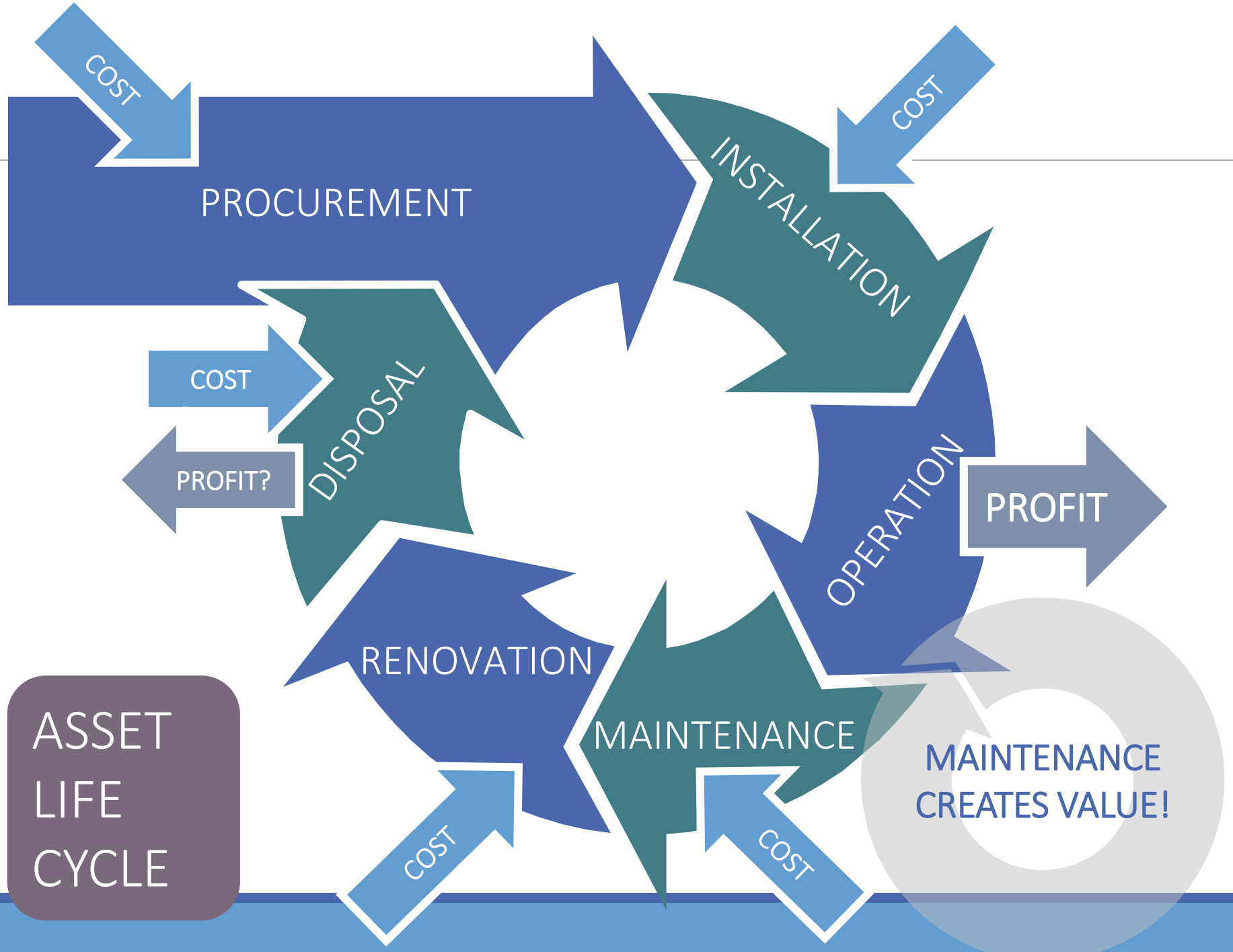
Life cycle thinking:

Consider the whole life cycle of your assets




COST
PROCUREMENT
COST
INSTALLATION
COST
DISPOSAL
PROFIT?
OPERATION
PROFIT
RENOVATION
MAINTENANCE
ASSET
LIFE
CYCLE
COST
COST
MAINTENANCE
CREATES VALUE!

Asset life cycle (Kari Komonen, EFNMS EAMC)

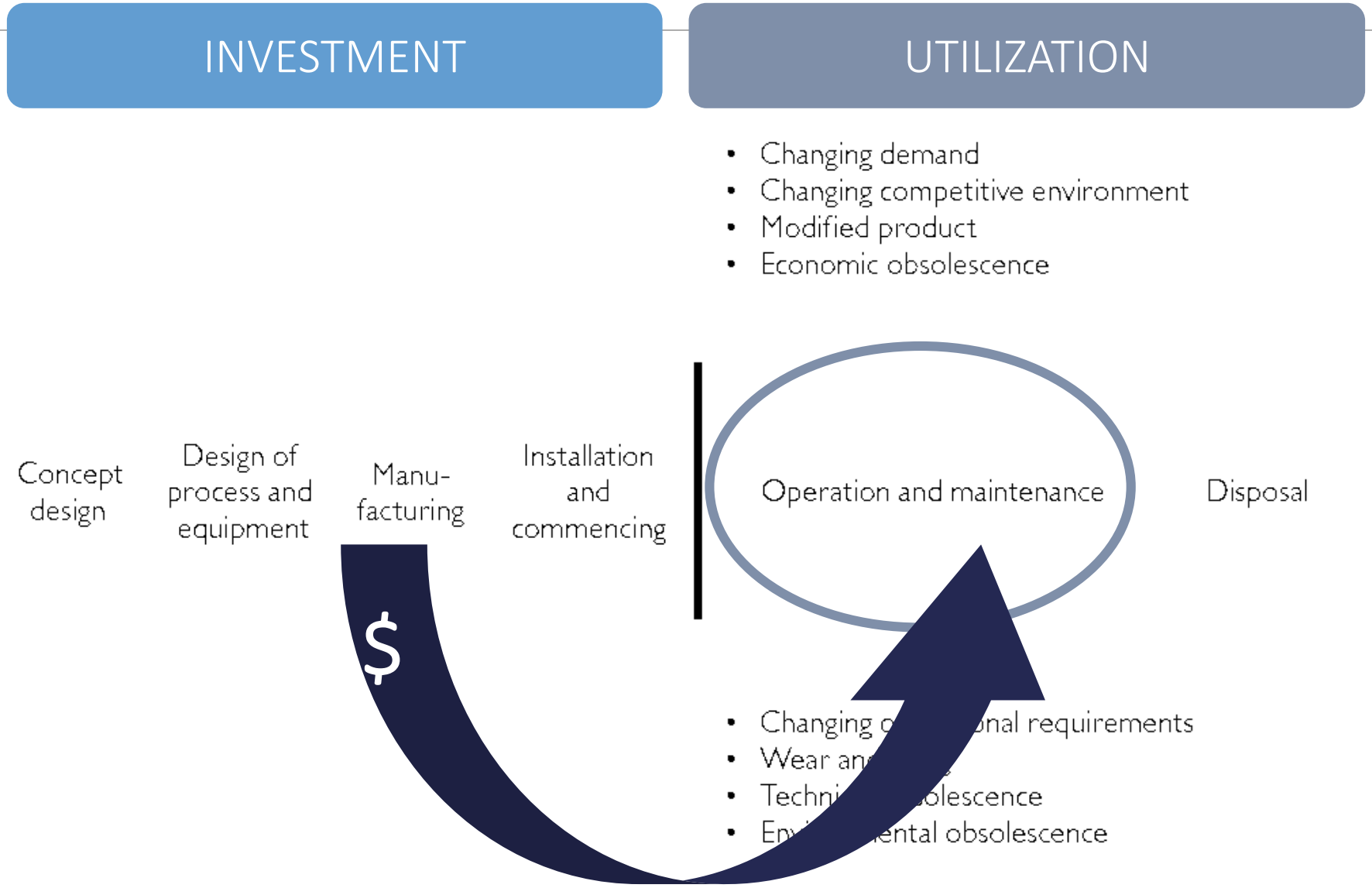
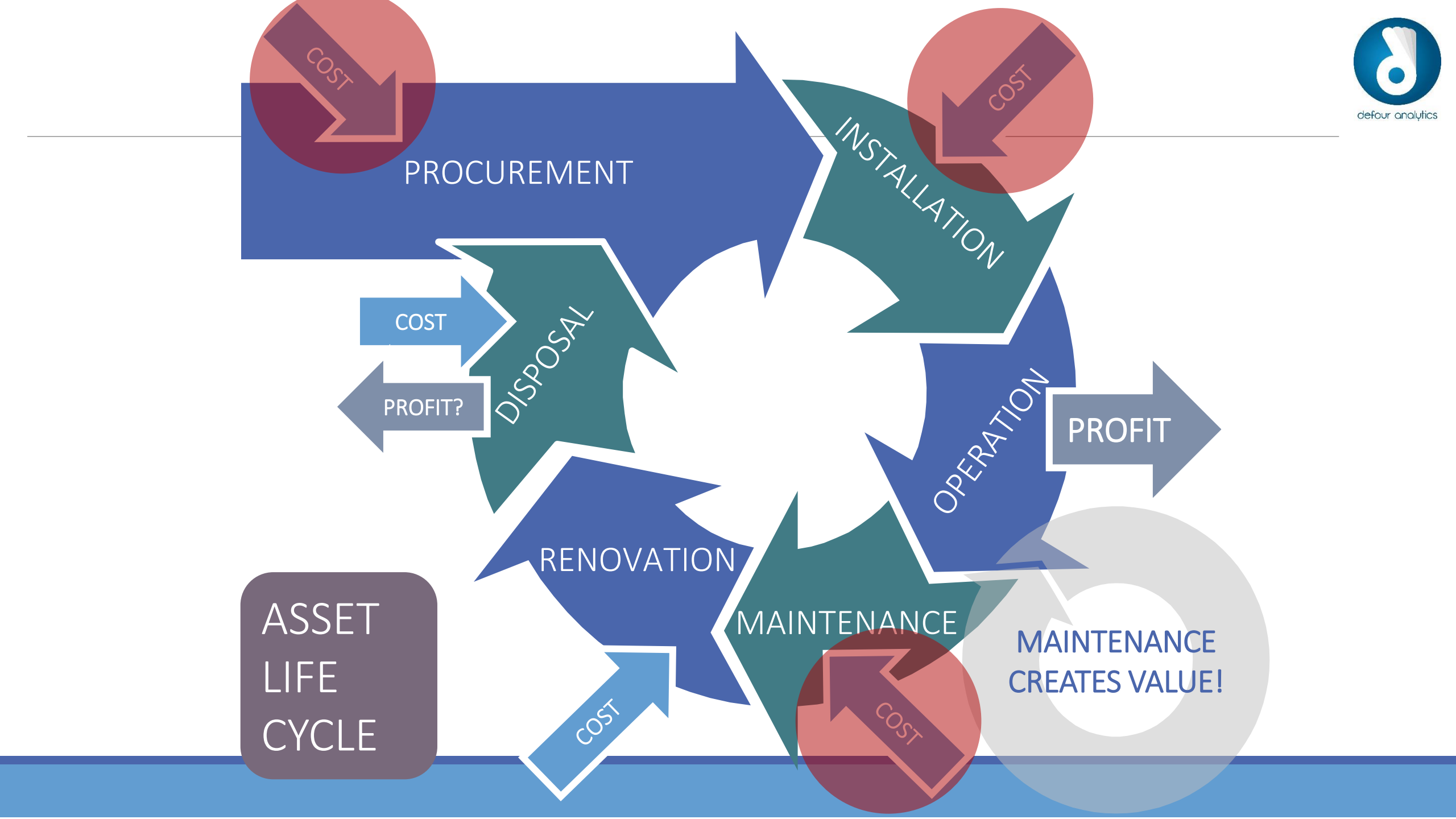


FIGURE 1. *Two guiding factors of asset management (Komonen 2009).*


COST
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RENOVATION
MAINTENANCE
COST
COST
ASSET
LIFE
CYCLE
MAINTENANCE
CREATES VALUE!

Efficient spare parts management
Conclusions

Efficient spare parts management – 8 rules

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- Preventive maintenance
- Processes without problems
- Segment your SP portfolio
- Assess the criticality
- Good forecasting
- Special methods for intermittent demand items
- Asset life cycle
- Good information system

Good information system for spare parts management

Unexplained / Random	Forecast accuracy and reliability	Minimize!
Common sense	Input of technicians and procurement Criticality analysis	Make efficient!
Quantitative methods	Forecasting Inventory levels Ordering	Maximize!

- Spare parts management involves balancing the timely availability of spares and minimizing capital blocked in overall inventory. Poor spare parts management directly leads to poor asset availability and plant reliability. Organizations, faced with the complexity of spare parts optimization, must have better control over MRO inventory.
- Comprehensive data analysis develops greater understanding and visibility of all aspects of spare parts management. The insight obtained by in-depth data analysis can help organizations build and execute better strategies.

Challenges in spare parts management:

- Ensuring timely spares availability to ensure greater asset availability
- Getting timely alerts on stock-outs of critical spares
- Identifying exceptions, outliers and issues for better inventory control
- Monitoring inventory turns, spillage and carrying costs
- Understanding blocked capital and inventory carrying cost
- Making informed financial planning and budgeting decisions
- Optimizing overall MRO inventory

How data analysis helps in spare parts optimization?

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- Identification and management of slow moving, non moving and obsolete items
- Understand physical placement options for items to increase store room efficiency
- Monitoring of spare part availability for upcoming PM's
- Understand consumption patterns and capital investment by performing ABC Analysis
- Critically rank and categorize items based on various procurement constraints and options
- Manage inspections, cycle counts and expiry
- Set min, max levels
- Determine economic order quantity (EOQ)
- Define stocking policies for capital and rotating assets or subassemblies
- Provide supporting analysis for building comprehensive strategies, executing strategic action plans and monitoring outcomes for timely adjustments
- Optimize inventory by balancing financial and reliability variables

Business Benefits

- Increase productivity
- Reduce compliance risks
- Lower maintenance cost
- Gain visibility across the enterprise with well defined performance metrics
- Reduce unplanned downtime, increase reliability of critical equipments
- Spare parts optimization
- Determine root causes of non-conformities
- Increased ROA

IT Benefits

- Reusable DW data models, ETL, metrics, scorecards, reports, KPI’s and OLAP
- Bridge gap between end user's perceived needs and actual business requirements
- Awareness of data analysis capabilities
- Improved data quality
- Ability to integrate other data sources outside of EAM for more comprehensive reporting
- Better leveraging of transaction data and IT infrastructure
- Time to focus on other projects

Our methodology and analysis techniques

- Determine Stock out Risk/Probability for critical assets spares using Weibull analysis
- Identify bottlenecks in the spares supply chain process by applying six-sigma analysis.
- Understand procurement efficiency by tracking KPIs for each PR
- Optimize stock holding with FSN and ABC Analysis.
- Forecast erratic spares demand by using Croston/ARIMA method.
- Identify slow moving and non moving items.
- Determine spare parts cost for budgeting purposes based on the Croston's Method.
- Find optimum spare parts inventory level.
- Understand demand patterns by classification based on Smooth. Irregular, Slow-moving. Mildly Erratic, Highly Erratic etc

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Case study description (as heat exchanger)

Problem statement

Stepwise description

R script

graphs

Concluding statements

Design Thinking

Ask the participants what kind of problems related to their industry can be solved using this concept.

Question & Answers

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THANK YOU