

# IndAC-SM

Industry Academia Consortia for Smart Manufacturing





Every solution provider has his version of Smart Manufacturing / Industry 4.0

Very few large scale implementations in India.

Those who have started, are in the process of getting there.

Lack of frameworks to evaluate applicability of Smart Mfg / Ind 4.0 concepts for one's own business.

Uncertainty about ROI.





# Next Gen Business

GTAI, Germany  
EFFRA, EU  
SMLC, US  
NIST, US  
The Govt Office for Science, UK  
Institute for Manufacturing, UK  
EPSRC, UK  
The Japan Business Federation

Siemens  
Beckhoff  
Bosch  
GE

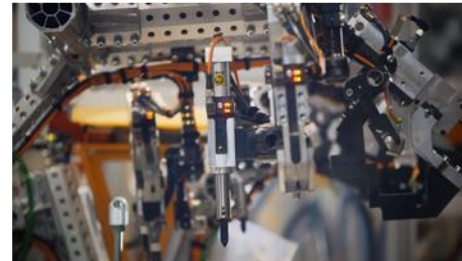
Capgemini  
Mckinsey  
PWC

- Focus on customer experience
- Co-creating products and services.
- Servitization
- Mass customization
- Sustainability: Product upgrades instead of throw away, Reverse logistics.





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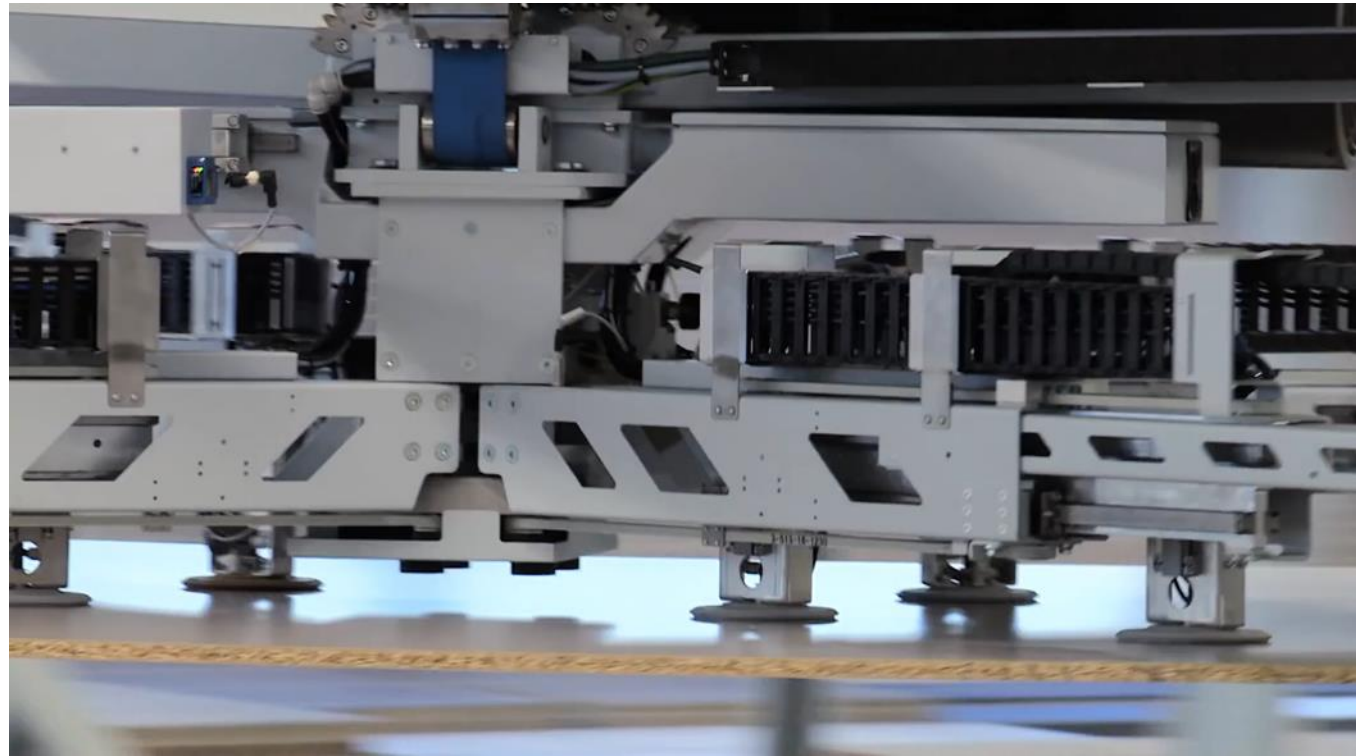
Embedded systems  
 Cyber Physical Systems  
 IOT  
 Smart sensors  
 Computer vision  
 COBOTs  
 Cloud computing  
 Edge analytics  
 Additive Mfg  
 Asset Admin Shells  
 Big data analytics  
 AI/ML  
 AR/VR  
 Intelligent HMIs  
 Blockchain



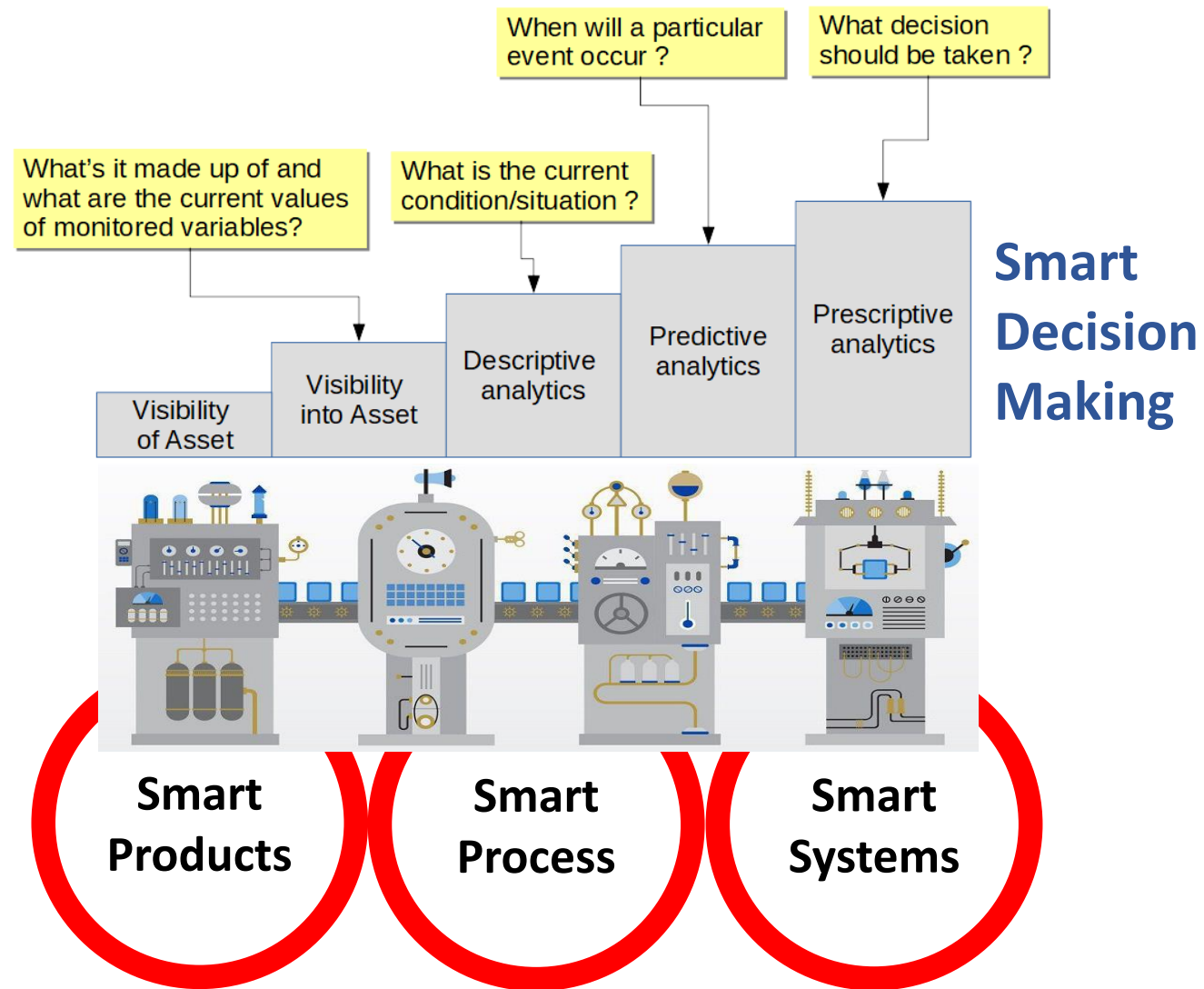
**Need:** Customization

**Function:** Production

**Technology:**  
Smart Workpiece,  
Networked Production



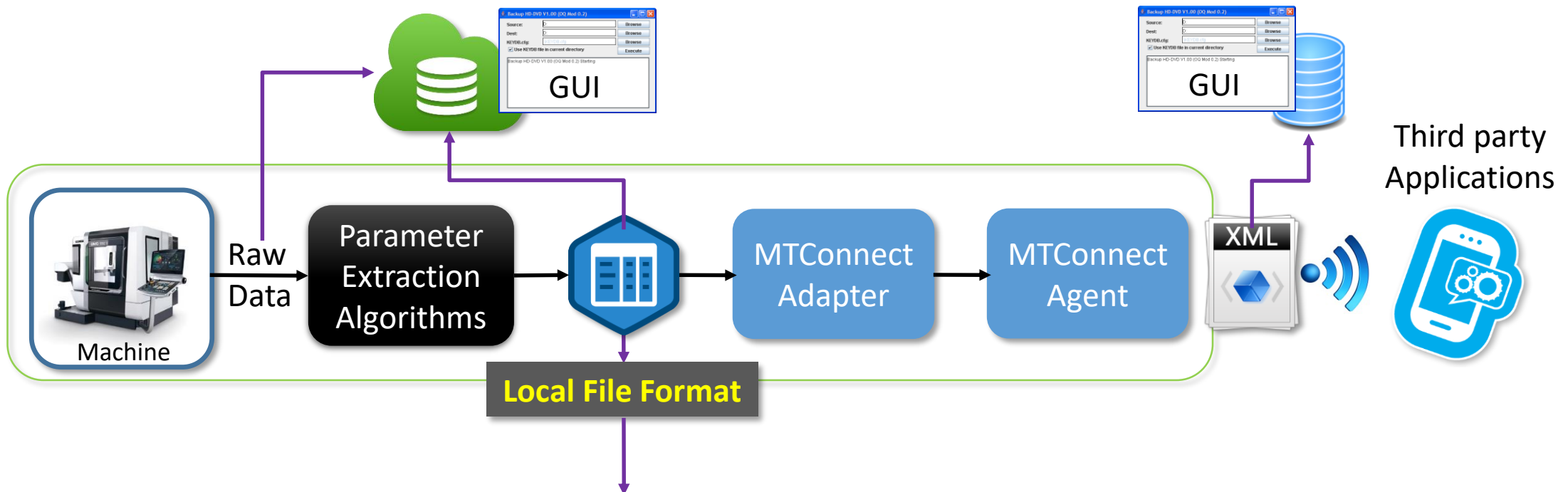
# Smart Manufacturing



# Characteristics of Smart Products



1. Have a unique identification
2. Have high interoperability
3. Actively interact with the user and other products



Job ID	Batch ID	Job No.	Date	Time	M/C ID	Oprn ID	Operator ID	Para 1	Para 2	.....	Para 'n'





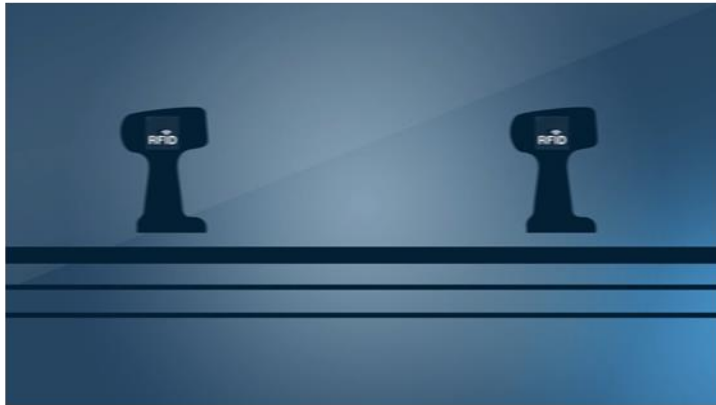
# Characteristics of Smart Products

1. Have a unique identification
2. Have high interoperability
3. Actively interact with the user and other products
4. Can store data about itself and learn
5. Deploy a language to display its features
6. Self assessment of health condition
7. Are capable of participating in or making decisions
8. Help in executing an action



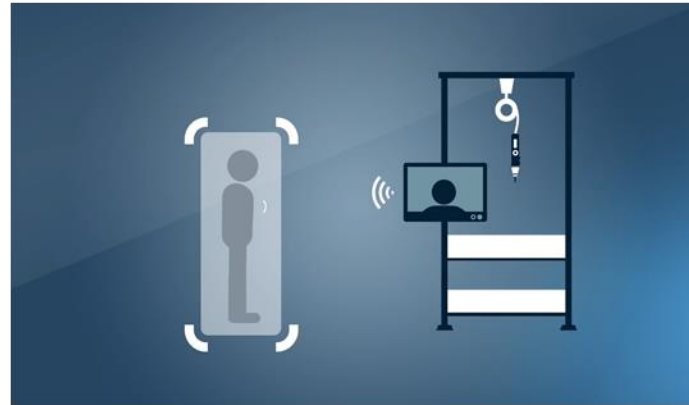
[Smart Shopfloor](#)

## Smart Products



Bosch

## Smart Workstations



Bosch

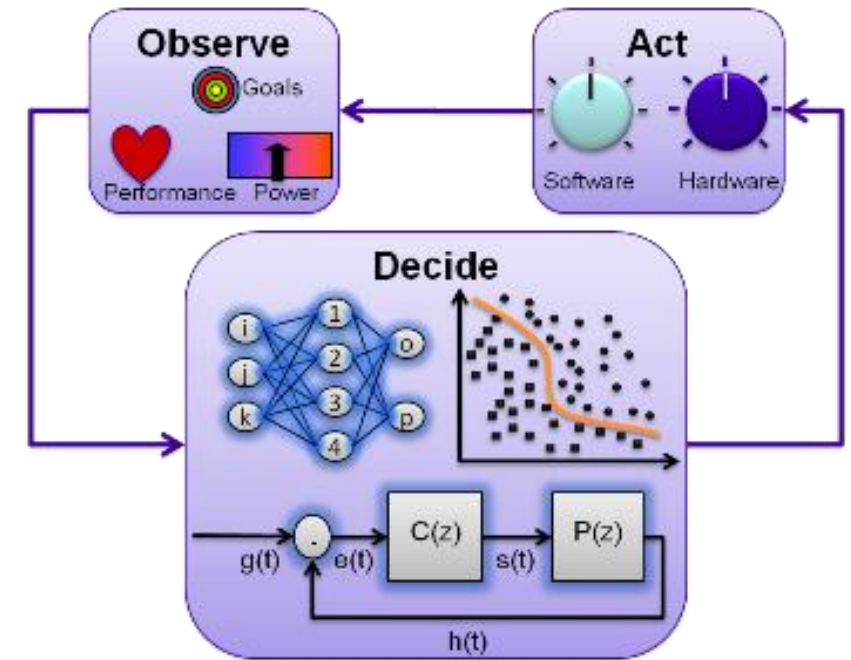
## Smart Workstations

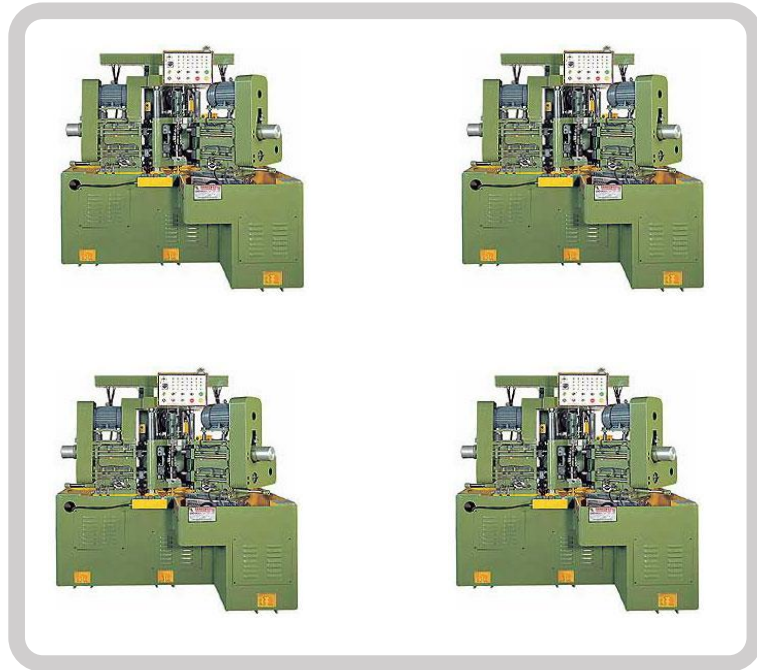


Bajaj Auto

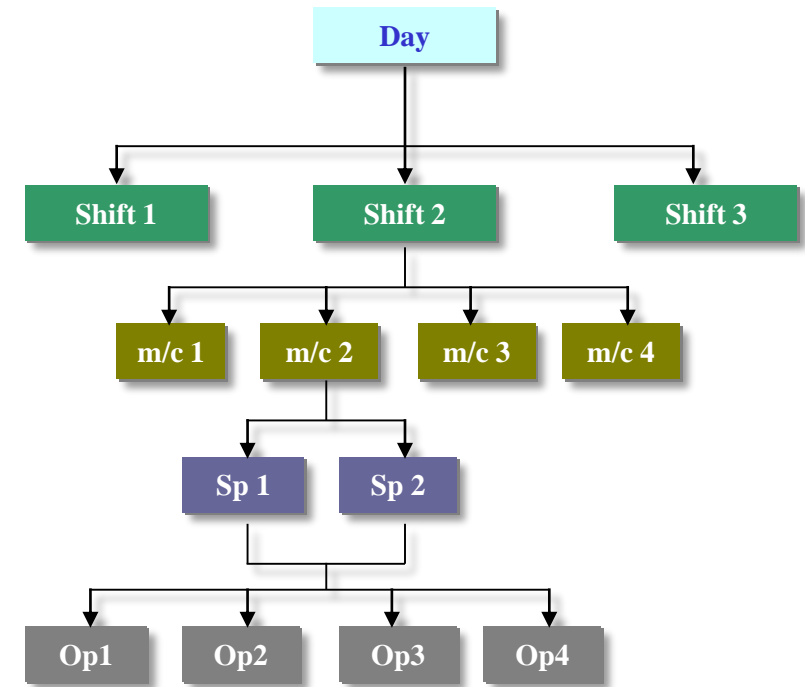
# Characteristics of Smart Processes

A self aware process that can observe its own execution and optimize its behavior around a user's or application's needs.





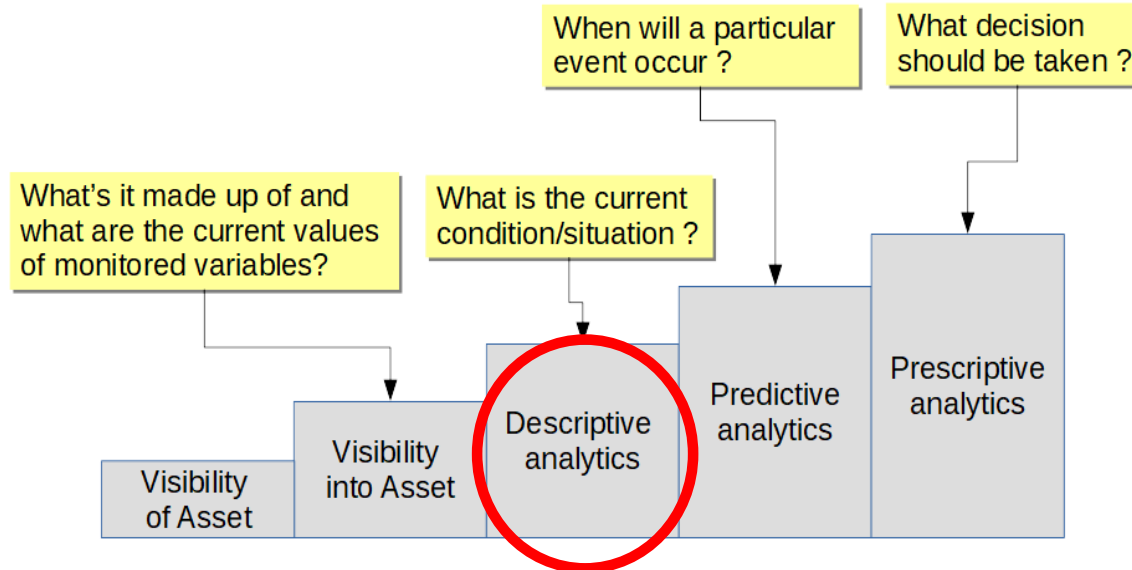
Shift to Shift  
 Machine to Machine,  
 Spindle to Spindle  
 Operator to Operator



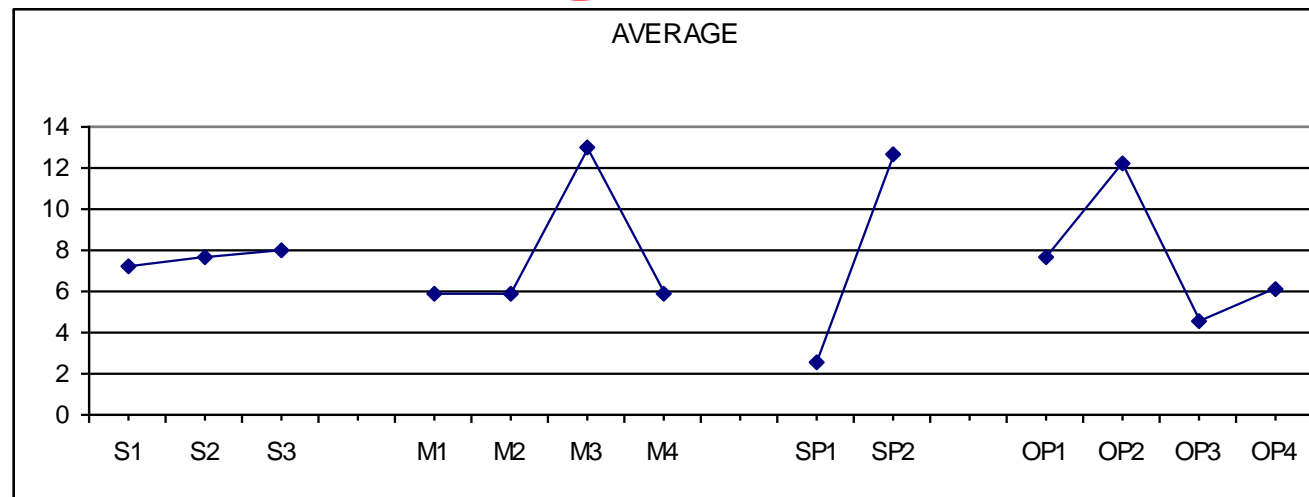


Day 1																							
Shift 1								Shift 2								Shift 3							
m/c 1		m/c 2		m/c 3		m/c 4		m/c 1		m/c 2		m/c 3		m/c 4		m/c 1		m/c 2		m/c 3		m/c 4	
SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2
OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4
OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3
OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2
OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1	OP2	OP2	OP3	OP3	OP4	OP4	OP1	OP1

Day 1																							
Shift 1								Shift 2								Shift 3							
m/c 1		m/c 2		m/c 3		m/c 4		m/c 1		m/c 2		m/c 3		m/c 4		m/c 1		m/c 2		m/c 3		m/c 4	
SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2	SP1	SP2
0.4	10.5	0.6	16.8	4.6	10.6	0.3	8.4	0.8	10.9	1.3	17.4	4.8	10.9	0.6	8.7	1.2	11.3	1.9	18.1	5.0	11.1	1.0	9.0
0.3	8.4	0.4	10.5	12.2	28.3	0.2	6.3	0.6	8.7	0.8	10.9	12.8	28.9	0.5	6.5	1.0	9.0	1.2	11.3	13.4	29.6	0.7	6.8
0.2	6.3	0.3	8.4	7.6	17.7	0.6	16.8	0.5	6.5	0.6	8.7	8.0	18.1	1.3	17.4	0.7	6.8	1.0	9.0	8.4	18.5	1.9	18.1
0.6	16.8	0.2	6.3	6.1	14.2	0.4	10.5	1.3	17.4	0.5	6.5	6.4	14.5	0.8	10.9	1.9	18.1	0.7	6.8	6.7	14.8	1.2	11.3



Possible Causes	Possible Locations	Avg
S	1	7.25
	2	7.65
	3	8.05
M	1	5.85
	2	5.85
	3	13.05
	4	5.85
SP	1	2.6
	2	12.7
OP	1	7.65
	2	12.24
	3	4.59
	4	6.12



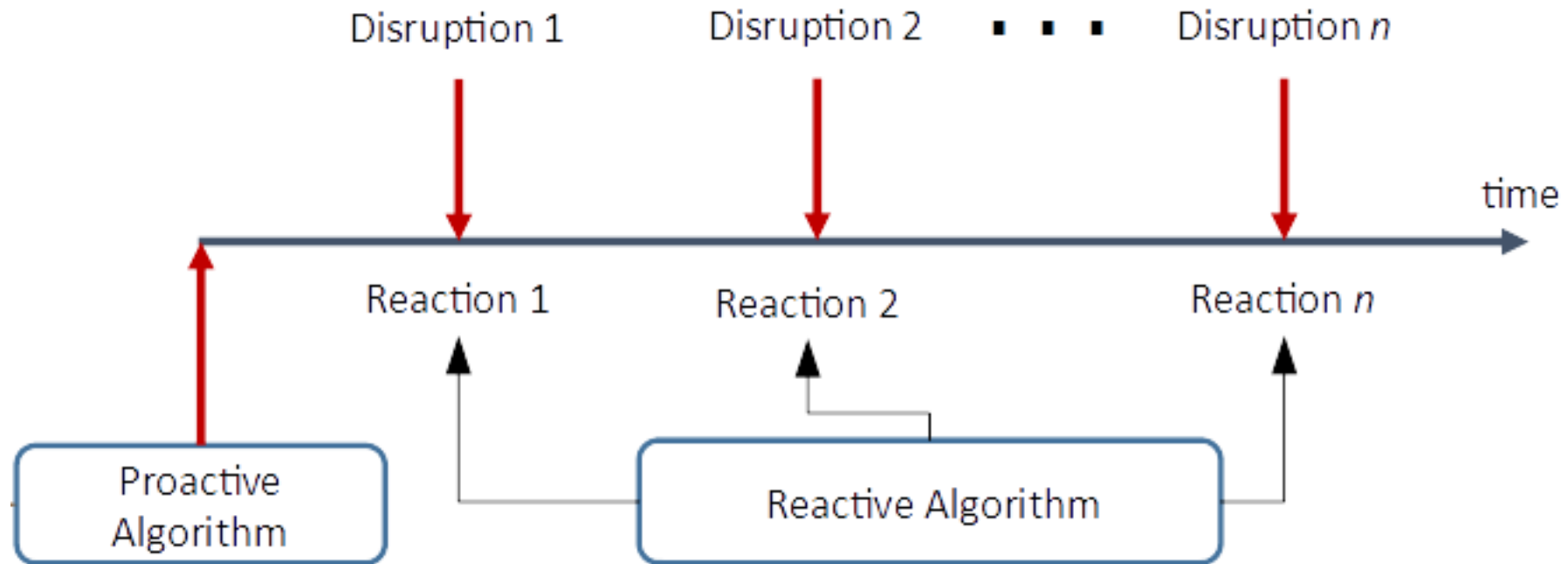
**Improvement Opportunity**

# Traceability:



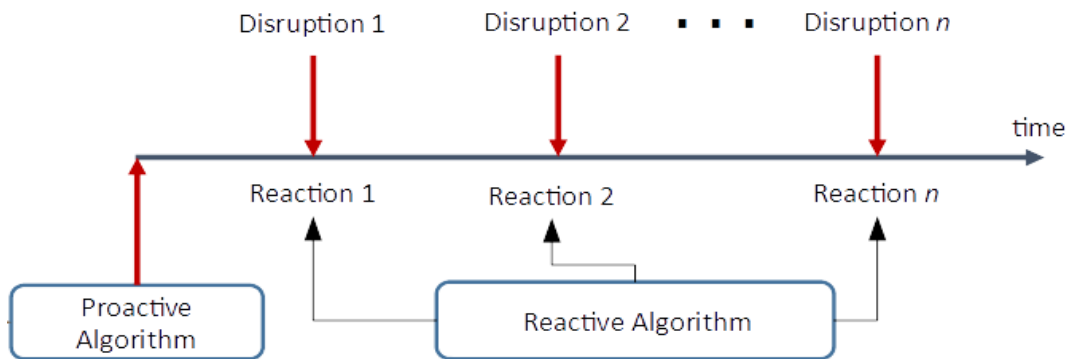
# Characteristics of Smart Systems

## Real Time Production Control





# Characteristics of Smart Systems



**Problem Set**

Please refer to the Problem pdf to know about the scheduling problems Problem

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**Format Set**

Please refer to the format pdf to know about the way you have to upload the excel sheet Format

---

**Upload for Schedule Calculation**

Please upload the excel file for schedule

No file chosen

---

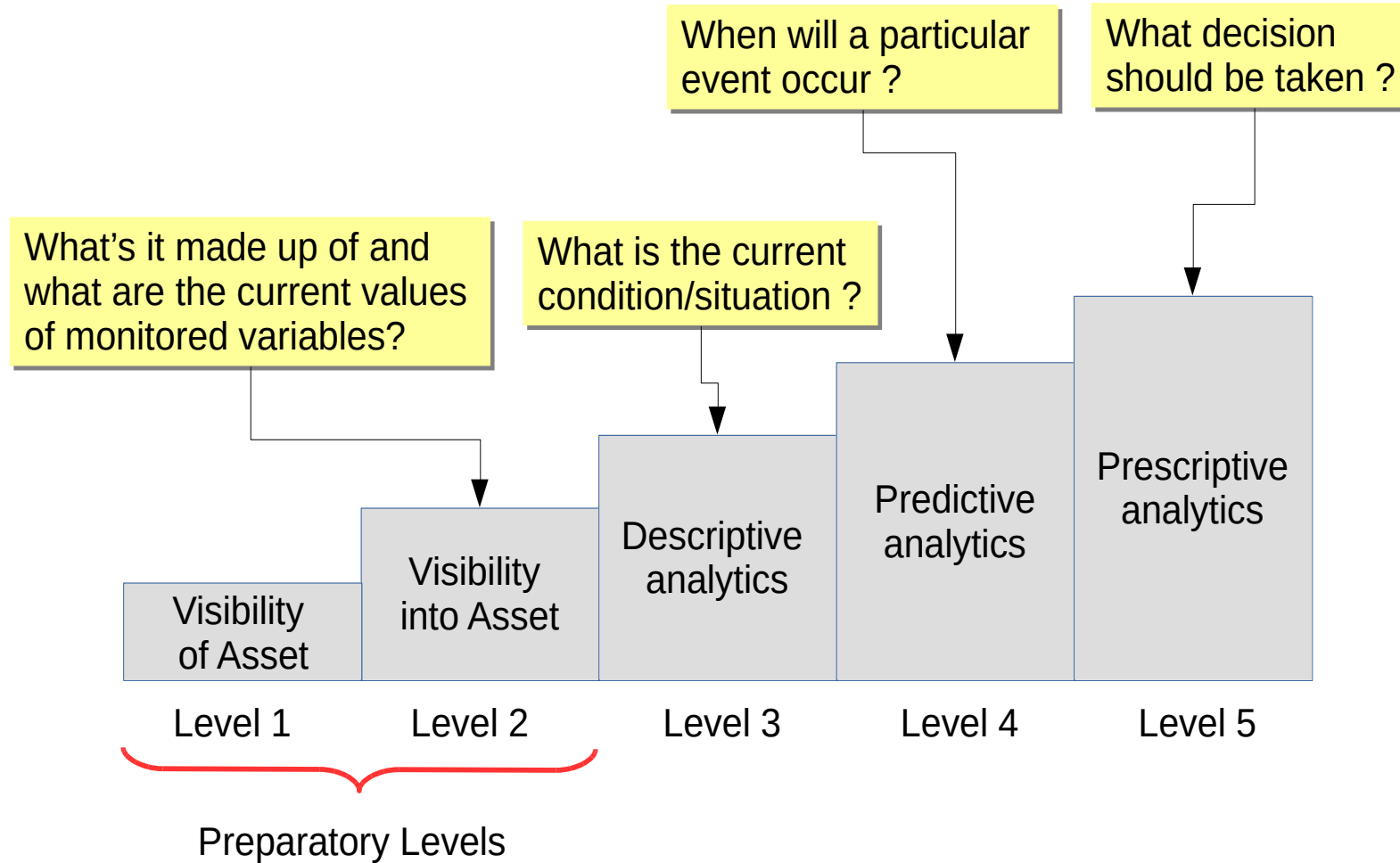
**Upload for Due-date Calculation**

Please upload the excel file for Due-date calculation

No file chosen

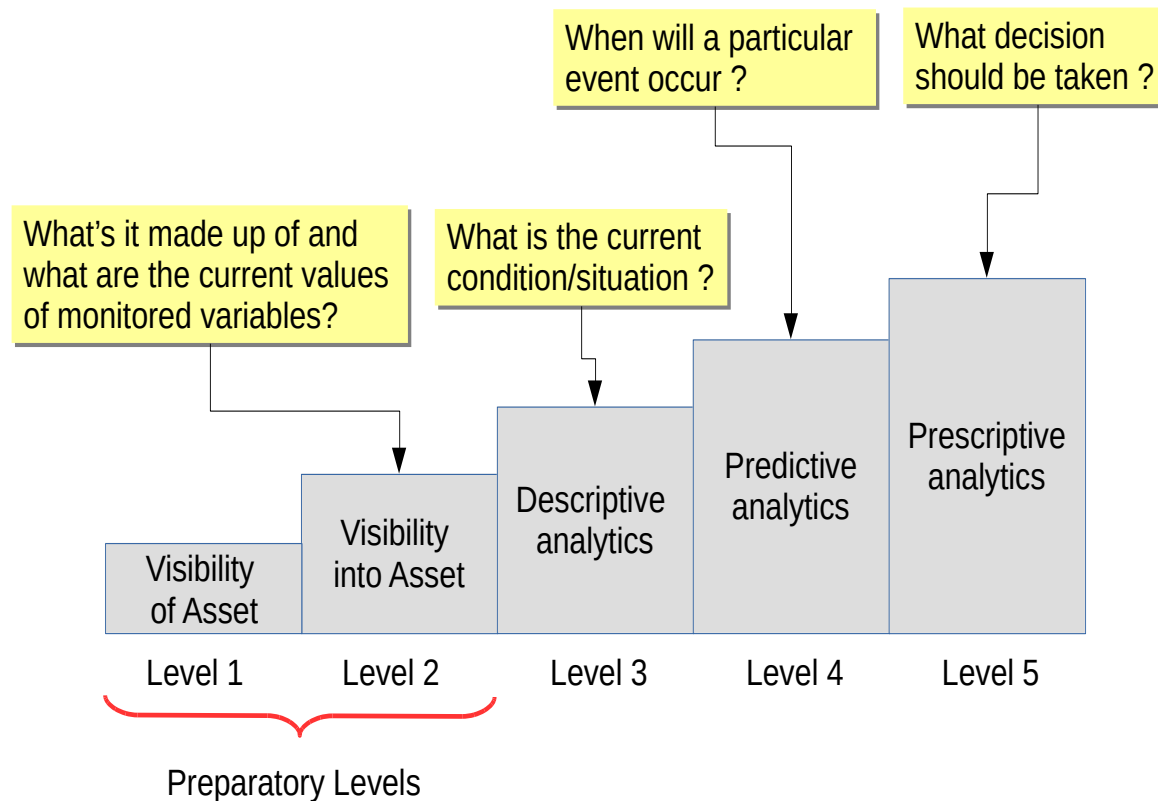


# Analytics





# Visibility of Asset



## Metadata:

*Unique identification:*

*Location:*

*Physical Characteristics:*

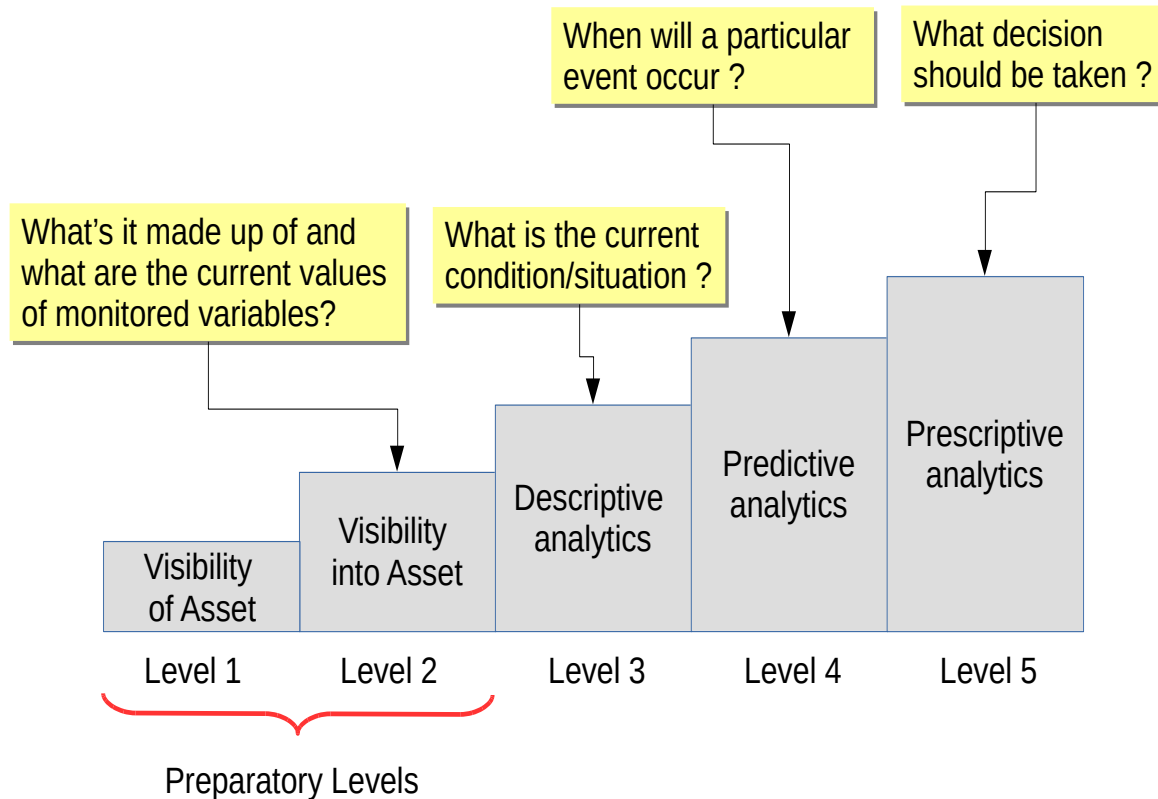
No. of axis  
Max length of job,  
Max dia of job  
Max weight of job  
Max torque available  
Max spindle speed  
Tool changer capacity  
Controller type

*Capability:*

Feature types that can be machined  
Feature sizes that can be machined  
s/c finish achievable  
Tolerances achievable



# Visibility into Asset



## Visibility into asset:

*Part library:*

*Parameters monitored:*

*Threshold values of parameters:*

*Current values of parameters:*

*Maintenance Schedule:*

*Pending maintenance activities:*

*Current job being processed:*

*Jobs in queue:*

*Current tools in tool changer:*

*Spares available:*

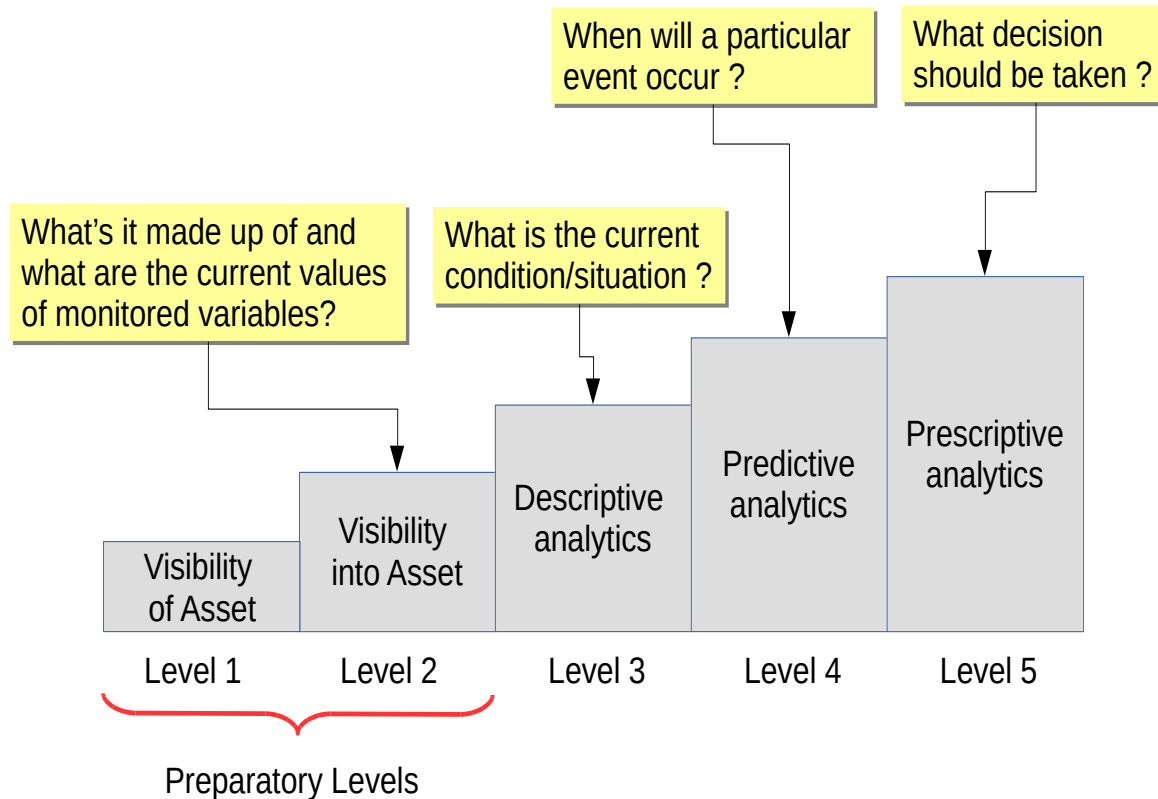
*Operating manuals:*

*Maintenance manuals:*

*Instructional videos:*



# Descriptive Analytics



## Descriptive Analytics:

*Health status of monitored machine parts:*

*Health status of monitored tools:*

*Expected completion time of jobs in queue:*

*Average no. of jobs in queue:*

*Average waiting time of jobs in queue:*

*OEE*

## **Jobwise analytics**

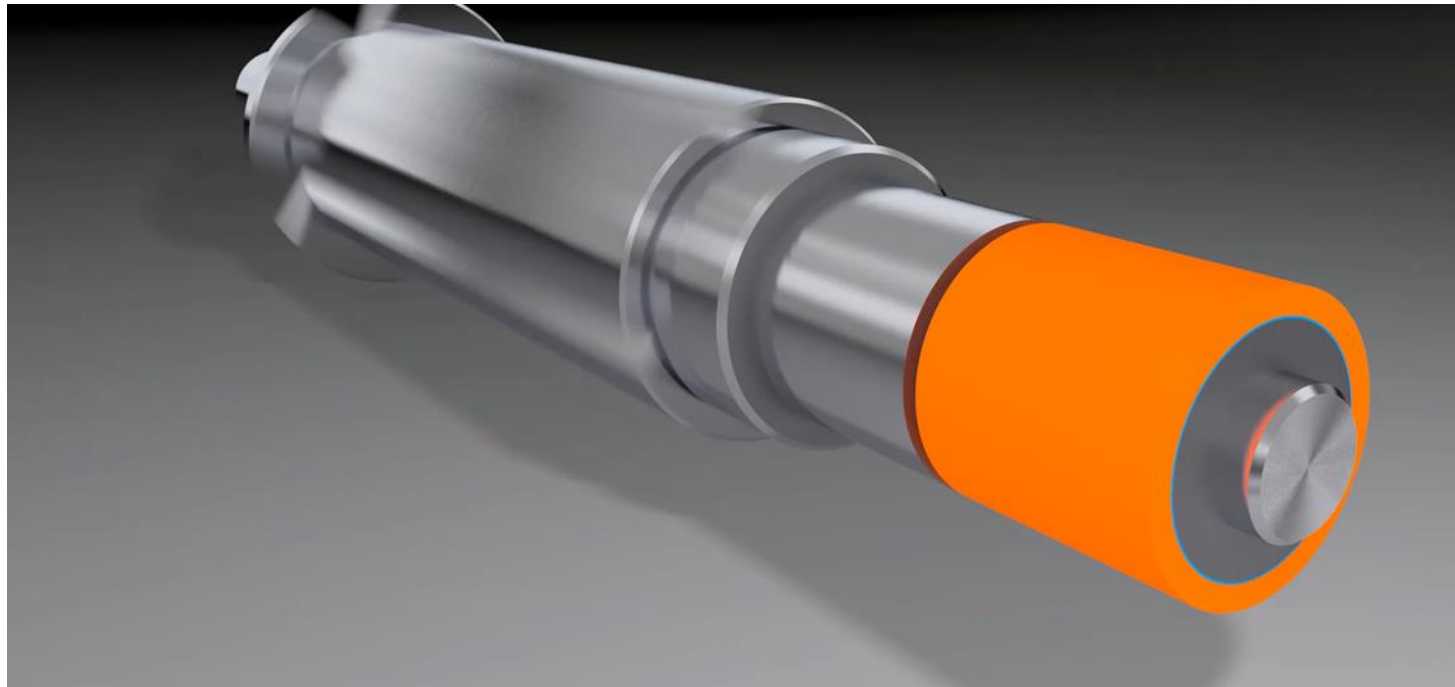
*Control charts:*

*Cp/Cpk:*

*% value added time:*

*Power consumption cost per hr*

# Smart Processes



TS-MRM



## Process Parameter Specifications

Mold Temperature Range: 85 to 104 °C

Material Temperature Range: 401 to 445 °C

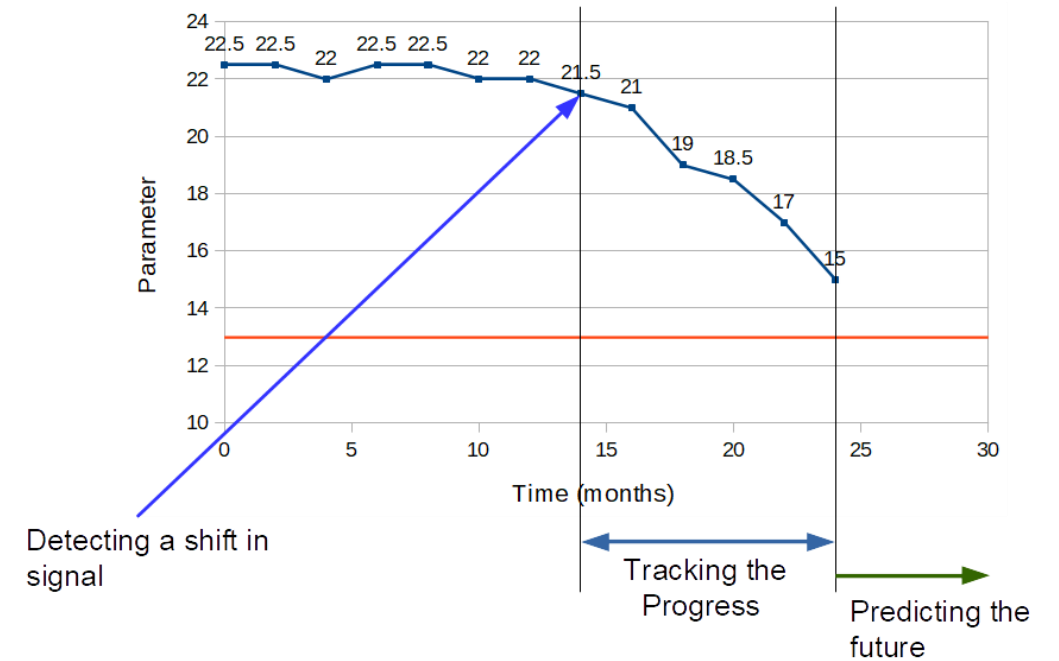
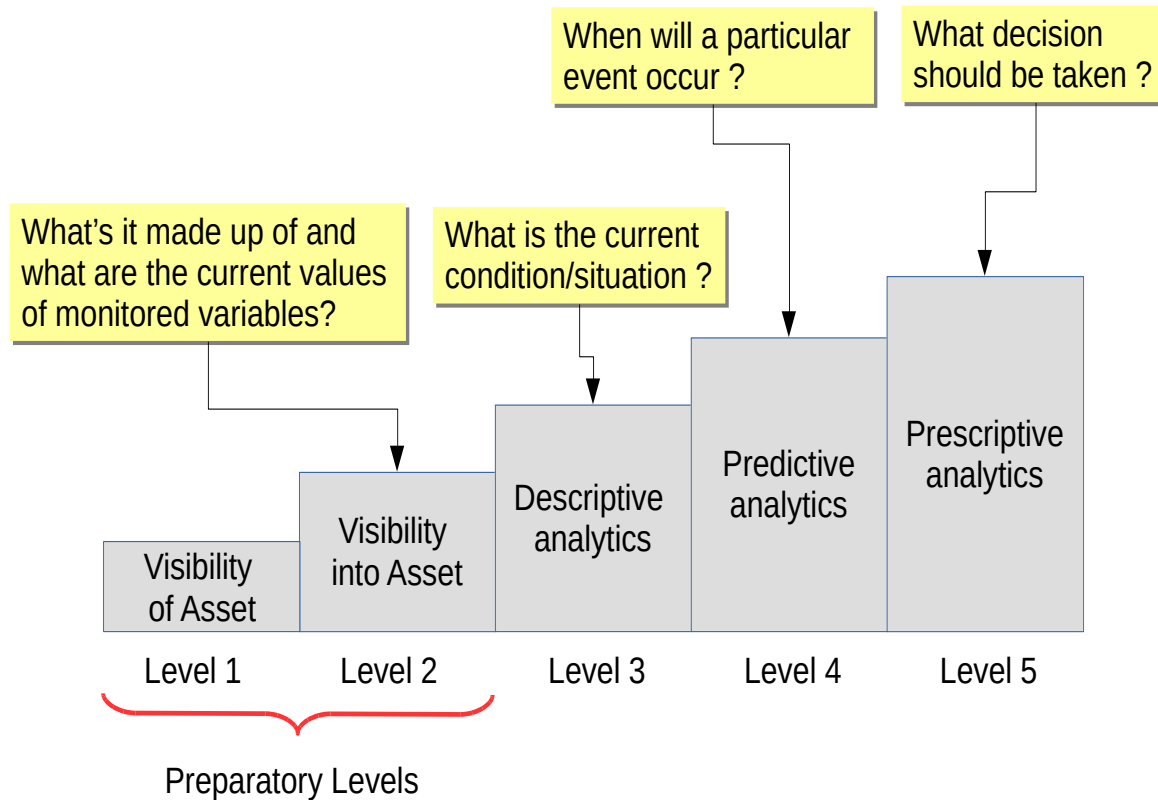
Injection Pressure: 1010 to 1190 psi

To ensure enhanced traceability, we need to capture data at a higher granularity

Quality	Mold temp	Matl temp	Pressure
B	100	401	1095
B	103	403	1020
B	85	405	1055
B	101	406	1100
G	93	408	1015
B	101	409	1060
B	90	416	1050
G	104	416	1055
G	104	418	1050
B	88	420	1040
G	101	422	1075
B	95	430	1010
G	89	432	1190
G	101	438	1075
G	92	440	1055
G	99	445	1070



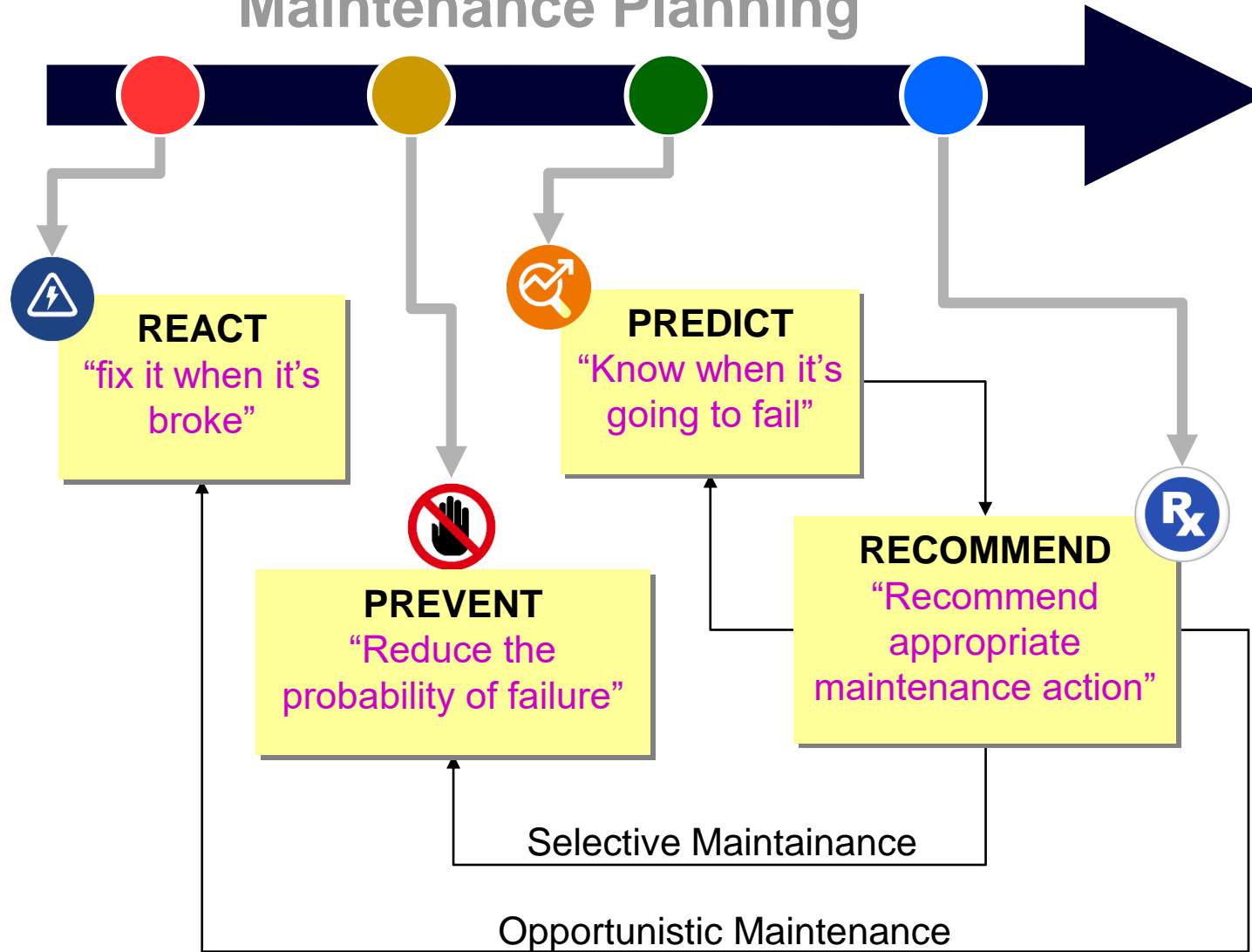
# Predictive Analytics







# Maintenance Planning





# Smart Machine: Advanced (under development)

Sense, think, Act, Learn

Smart Machine

Help Main

M/C Name:  
**Super Grind**

M/C ID:  
**SG09**

IP Address:  
**103.27.8.49**

M/C Location:  
**Shop 12**

---

Date: **30/04/15**

Shift: **A**

Time: **10:30 AM**

Operator: **MSK**

**In-process**  
Z323P

**Batch Queue**  
B123A  
C336D  
A345Q  
Z097P

**Already Late**  
C336D

**Likely Late**  
Z097P

Add Batch Set-Up

Re-Sequence M/C Down

**Performance over the last 10 days:**

Planning Factor, PF 0.66

Availability 0.95

Operating Efficiency 0.95

Rate Efficiency 0.90

Rate of Quality 0.99

OEE 0.80

---

Productivity (OEE x PF) 0.53

% On time delivery 85

PM Status Done

M/C  
Parameter 1

M/C  
Parameter 2

Process  
Parameter 1

Process  
Parameter 2

Update  
Manager

Report  
Generator

Schedule  
Monitor

Performance  
Monitor

Health  
Monitor

Maintenance  
Advisor

Troubleshooting  
Advisor

OEM  
Services

Process  
Advisor



### Smart Machine

M/C Name: **Super Grind**  
 M/C ID: **SG09**  
 IP Address: **103.27.8.49**  
 M/C Location: **Shop 12**  
 Date: **30/04/15**

**In-process**  
Z323P

**Batch Queue**  
B123A  
C336D  
A345Q  
Z097P

**Unload Batch**  
**Load Next**

**Already Late**  
C336D

**Likely Late**  
Z097P

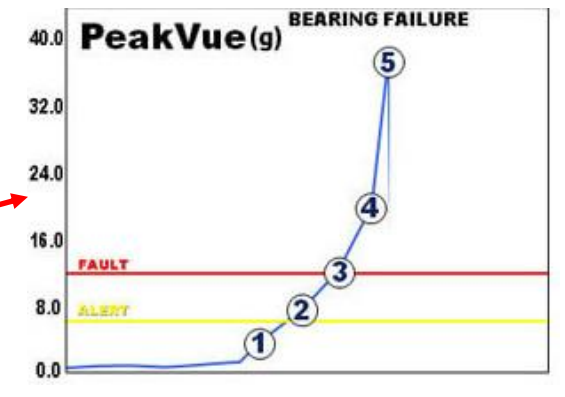
**Performance over the last 10 days:**

Planning Factor, PF	0.66
Availability	0.95
Operating Efficiency	0.95
Rate Efficiency	0.90
Rate of Quality	0.99
OEE	0.80

Productivity (OEE x PF): **0.53**  
 % On time delivery: **85**  
 PM Status: **Done**

M/C Parameter 1, M/C Parameter 2, Process Parameter 1, Process Parameter 2

Maintenance Advisor, Troubleshooting Advisor, OEM Services, Process Advisor



### RL Agent to Optimise Maintenance Policy

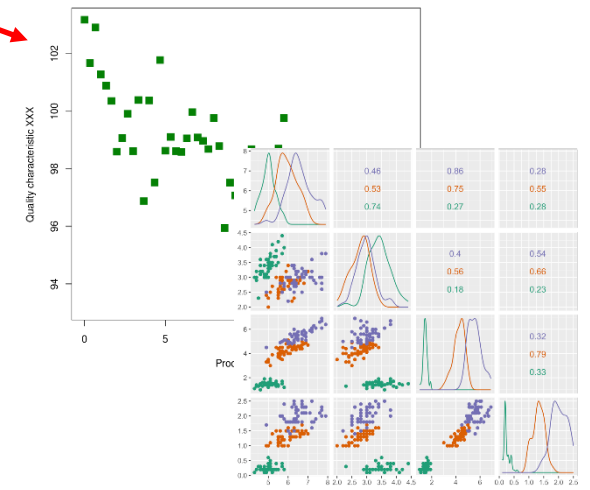
CM Cost	20000
PM Cost	5000
MM Cost	1000
Inspection Cost	300
epsilon	0.1
alpha	0.5
gamma	1
Max Replacement Cycles	10000000

Run Agent

Replacement Cycle Vs. Average Cost per Unit Time

Following Data: Health | Maintenance Action | Inspection Interval

99 NA 200	98 NA 180	97 NA 180
96 NA 180	95 NA 200	94 NA 180
93 NA 200	92 NA 200	91 NA 160
90 NA 200	89 NA 200	88 PM 200
87 MM 140	86 NA 200	85 NA 200
84 NA 180	83 NA 200	82 NA 180
81 NA 200	80 NA 200	79 NA 160
78 NA 160	77 NA 160	76 NA 200
75 NA 200	74 NA 200	73 NA 200
72 NA 200	71 NA 200	70 NA 180
69 NA 160	68 NA 200	67 NA 180
66 NA 180	65 NA 200	64 NA 180
63 NA 200	62 NA 180	61 NA 160
60 NA 160	59 NA 160	58 NA 160
57 NA 140	56 NA 140	55 NA 100
54 NA 80	53 NA 120	52 NA 100
51 NA 100	50 NA 100	49 NA 100
48 NA 80	47 NA 80	46 NA 80
45 NA 60	44 NA 60	43 NA 40
42 PM 200	41 PM 200	40 PM 200
39 PM 200	38 PM 200	37 PM 200
36 PM 200	35 PM 180	34 PM 160
33 PM 180	32 PM 160	31 PM 80
30 MM 40	29 MM 60	28 PM 200
27 PM 200	26 PM 180	25 PM 60
24 PM 200	23 PM 200	22 PM 200
21 PM 120	20 PM 80	19 PM 40



# System for Operations, Health and Usage Monitoring



SOHUM
Equipment Maintenance Data | Platform Analysis | Data Manipulation | Data Input

Select Platform  
platform1

Select Equipments  
equipment1

Metric Type  
ATTENUATION

Type of Graph  
Line

Date Start  
06/09/2019

Date End  
12/09/2019

Buttons: Combined, Single, Choose Files, No files open, Upload

**Performance Parameter**  
 Number of parameters in range and within thresholds. 10

**Performance Parameter**  
 No. of params in range but above slope threshold. 0

**Performance Parameter**  
 Number of parameters above/below range. 0

ATTENUATION

ATTENUATION

Report Prepared by: Section I/C | Report Approved by: DLO | Date of Issue: mm/dd/yyyy

**FAILURE BASIC DATA**

System	Sub System	Date of first occurrence	Time of first occurrence	Failure Title	Operating Hours
platform1	equipment1	mm/dd/yyyy	--:--:--		

**STEP BY STEP ANALYSIS**

Sl.	BIT	Observation	Action	By
1	<input type="text"/>	<input type="text"/>	<input type="text"/>	Operator

**ITEMS FOUND DEFECTIVE**

Sl.	Model LRU Name	Part No.	Serial No.	Next Higher assembly	Replaced S.N
1.	WCS	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

**Data Input**

Platform Name: platform1 | Equipment Name: equipment1

Metric Name: ATTENUATION | Parameter Name: MOUNT 1-MOTOR

Parametr Min. Value: 70 | Parameter Max. Value: 140 | Threshold Value: 10

Date: 12/10/2019 | Add Data Point | Clear From

**DATA POINTS**

Date	Parameter	Data Point
2019-12-10	MOUNT 1-MOTOR	<input type="text" value="10"/>
2019-12-10	MOUNT 1-MOTOR	<input type="text" value="15"/>

Buttons: Close, Save changes

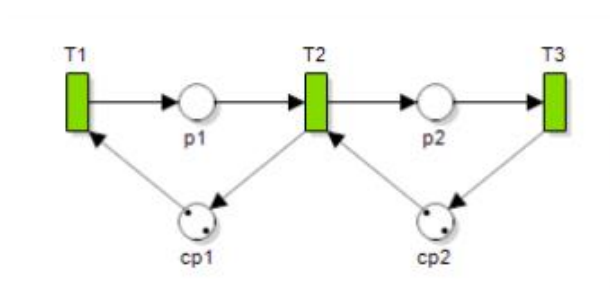


# Digital Twins

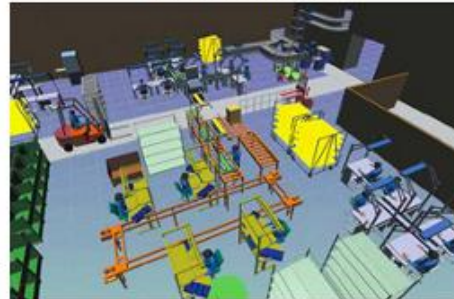
A Digital Twin is the current representation of a product or system, i.e., mimicking machines, controls, workflows etc.

# Domain Models

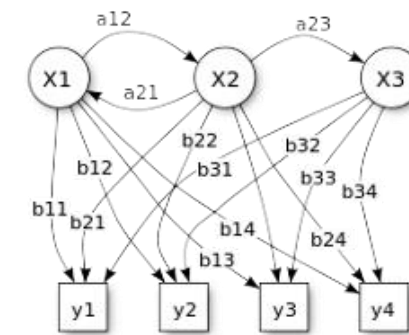
Petri Nets



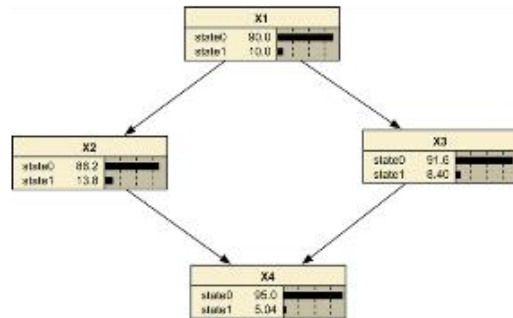
Discrete Event Simulation



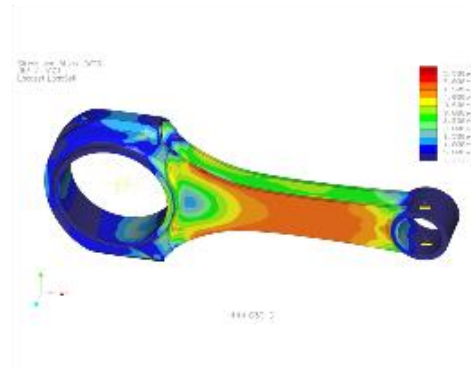
Markov/Semi Markov Models



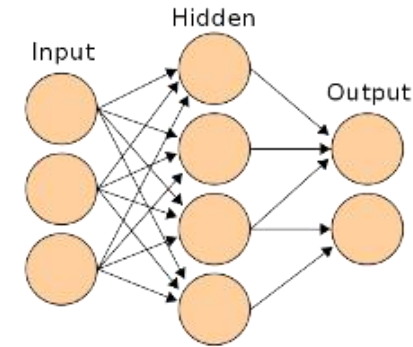
Bayesian Networks



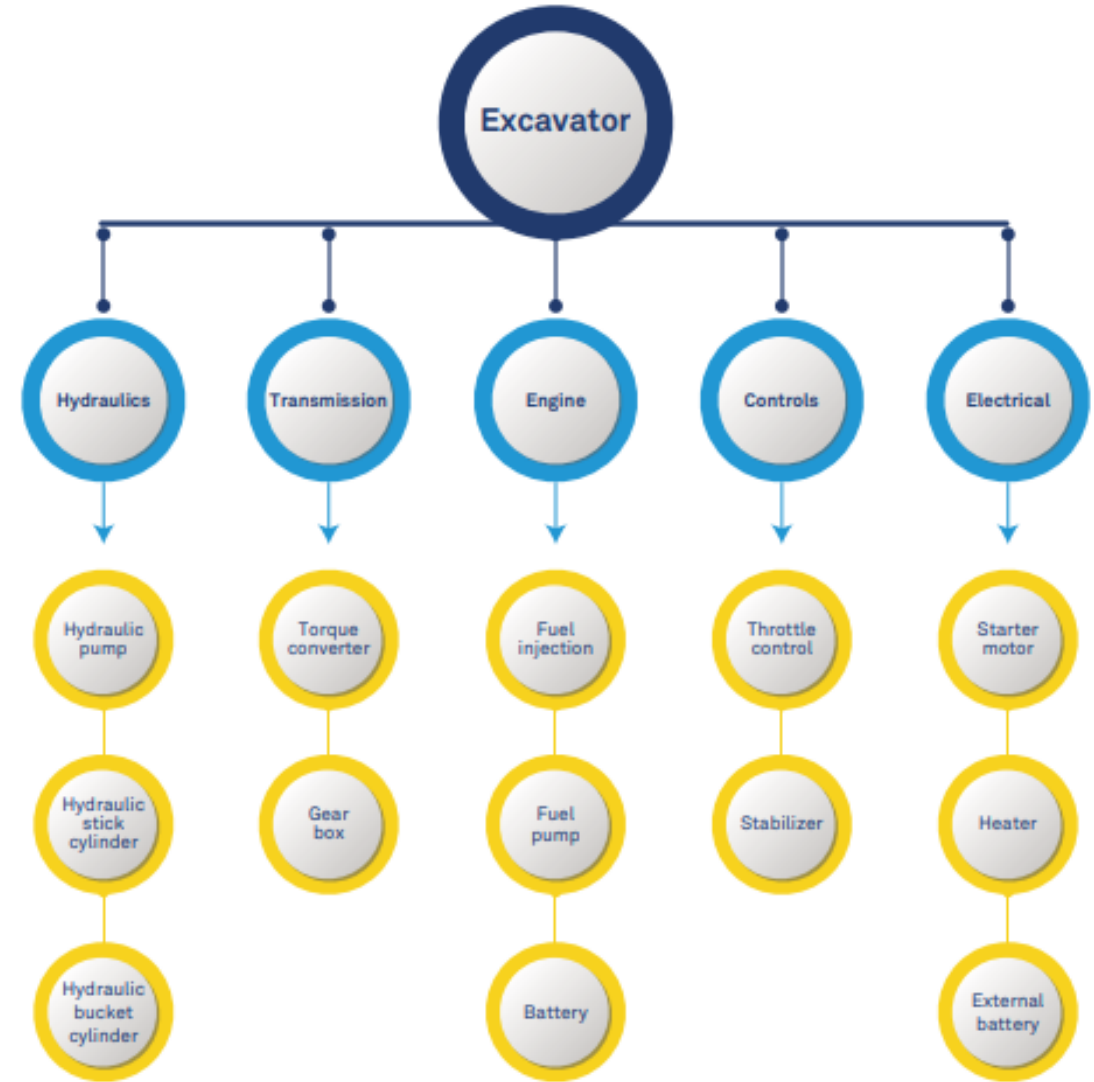
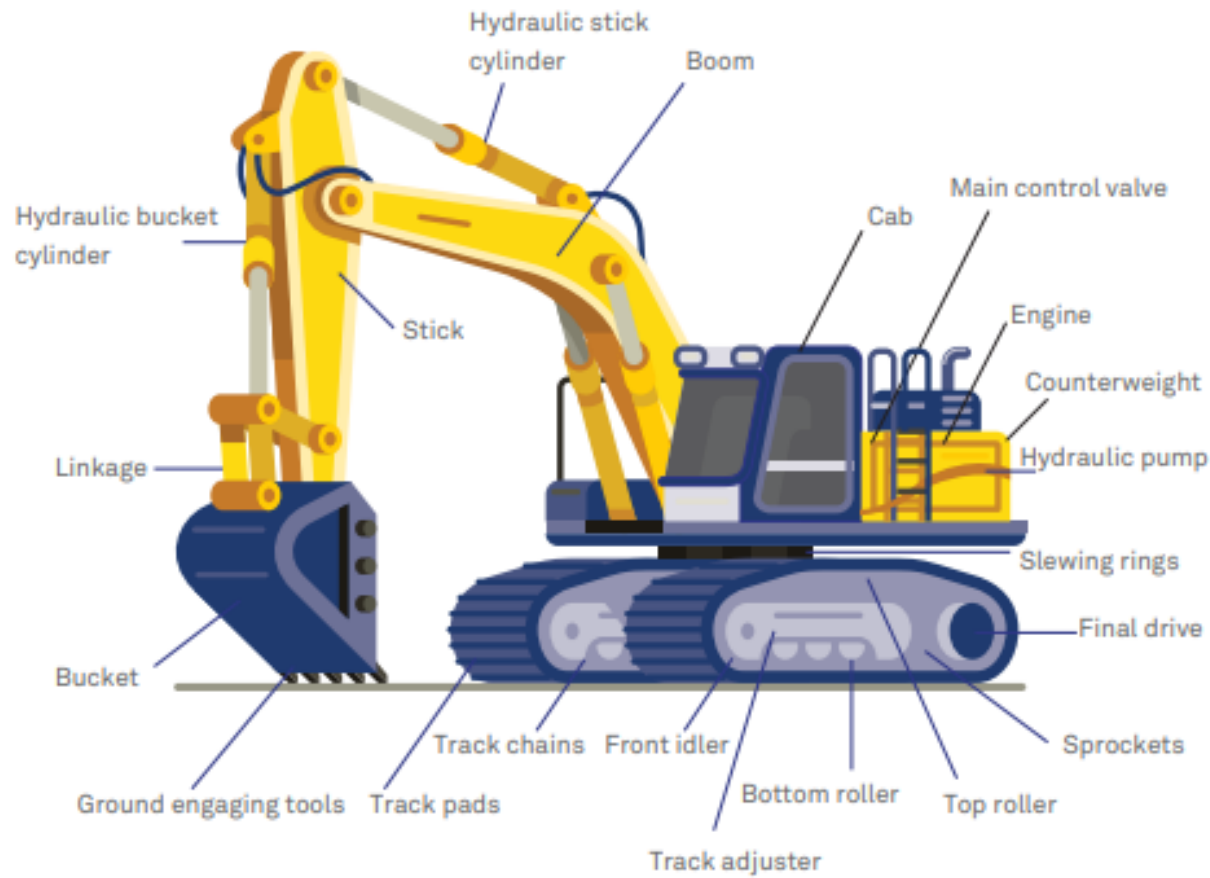
FE Models



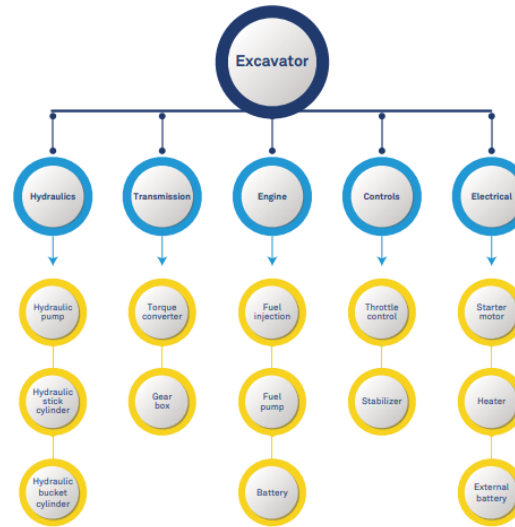
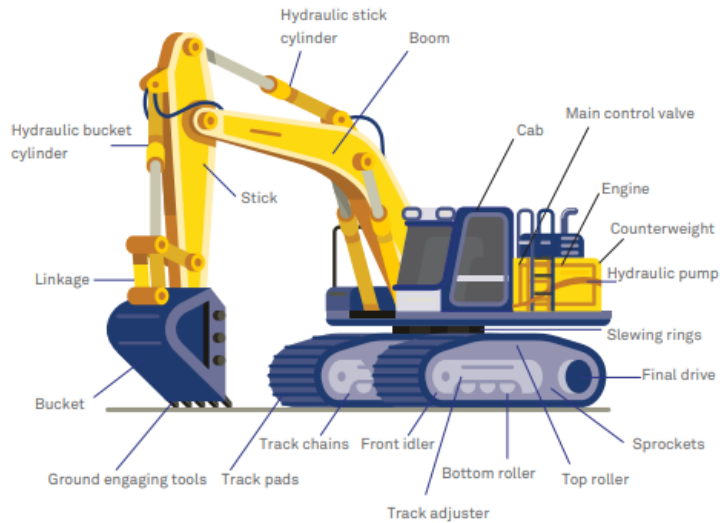
Neural Networks



# Digital twins: Wipro



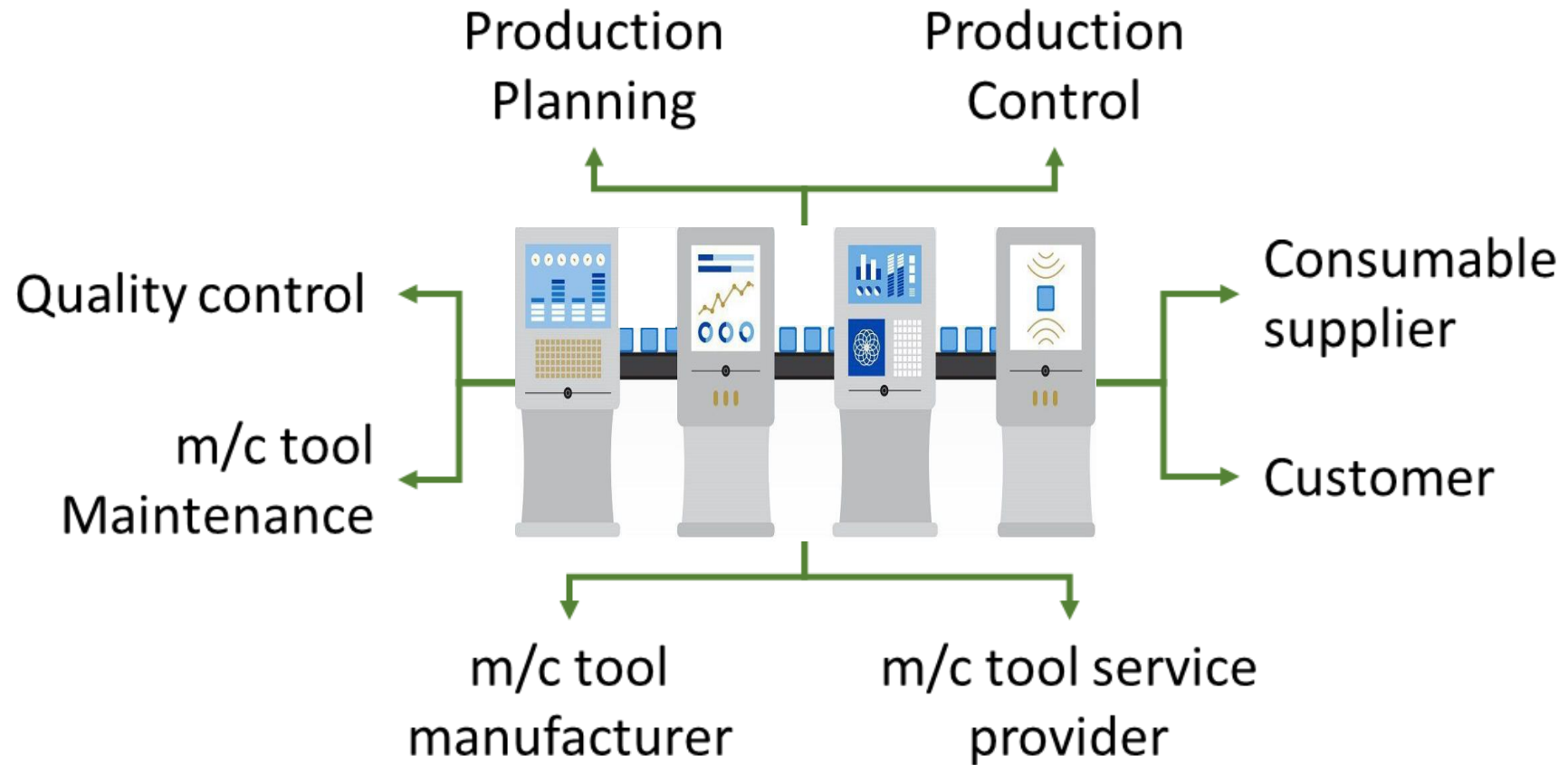
# Digital twins: Wipro



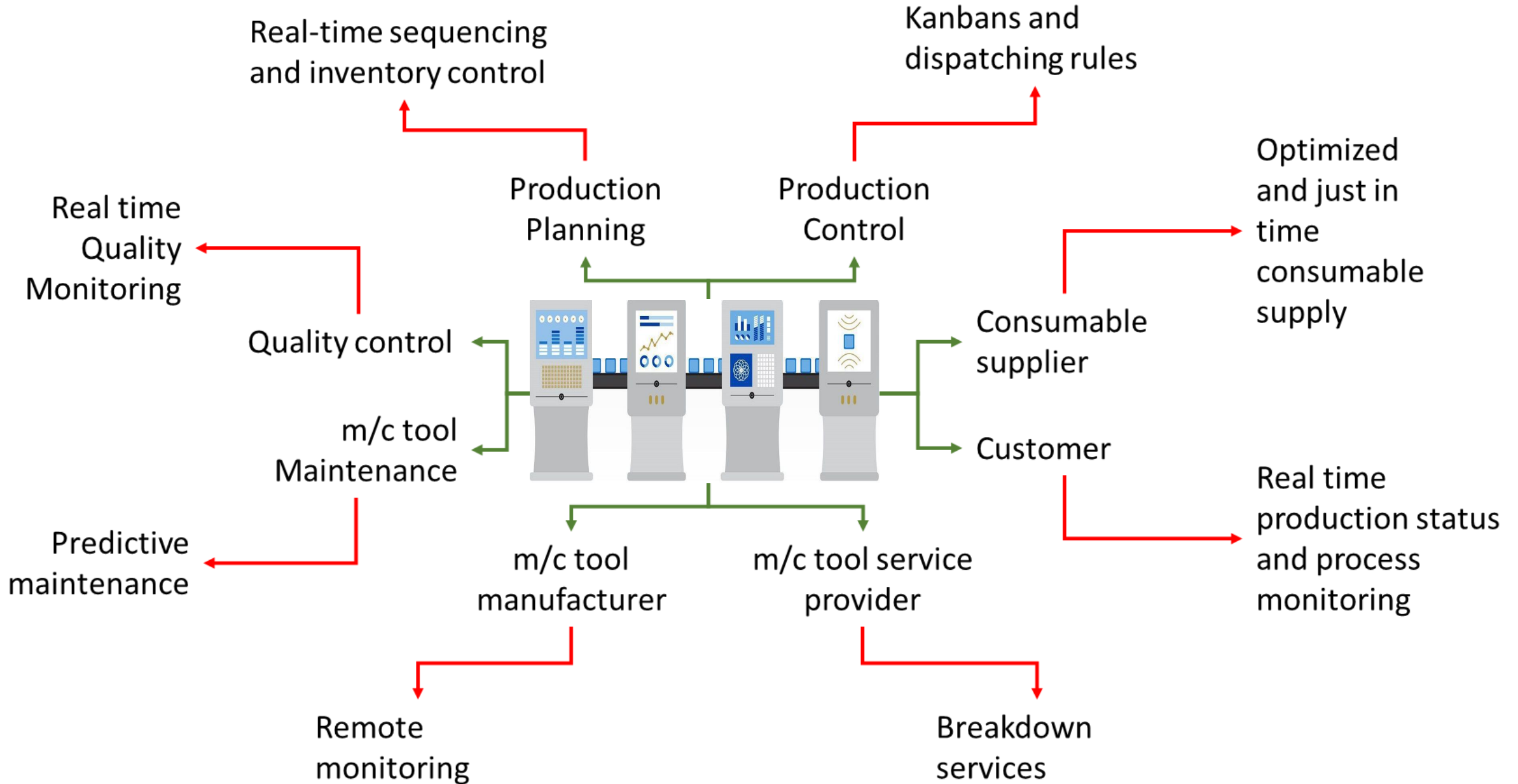
Operational Parameters	
Data Item	Value
Altitude	4.2
EngineRunningBand1	2
EngineRunningBand2	18
EngineRunningBand3	4
EngineRunningBand4	551
EngineRunningBand5	0
EngineRunningBand6	0
EngineRunningBand7	0
EngineRunningHours_Current	1.200000
<input checked="" type="checkbox"/> EngineTemperature	35
<input checked="" type="checkbox"/> ExternalBatteryVoltage	13.3
<input checked="" type="checkbox"/> FuelLevel	110
FW_Version_Number	09.01.02
GPSFix	true
Hour	1344.8
InternalBatteryCharge	100



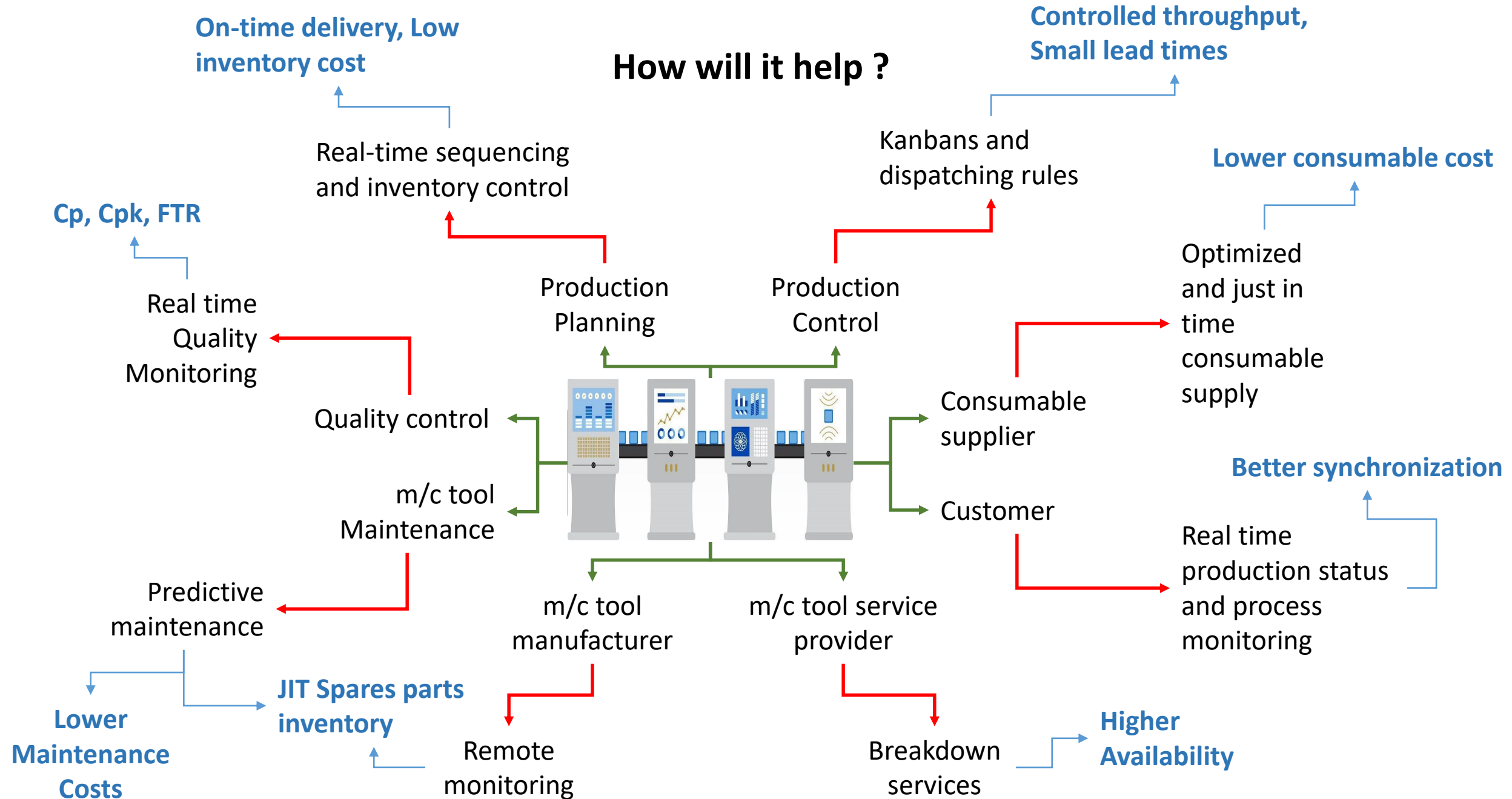
# Who are the consumers of data ?



# What will they do with this data ?



# How will it help ?

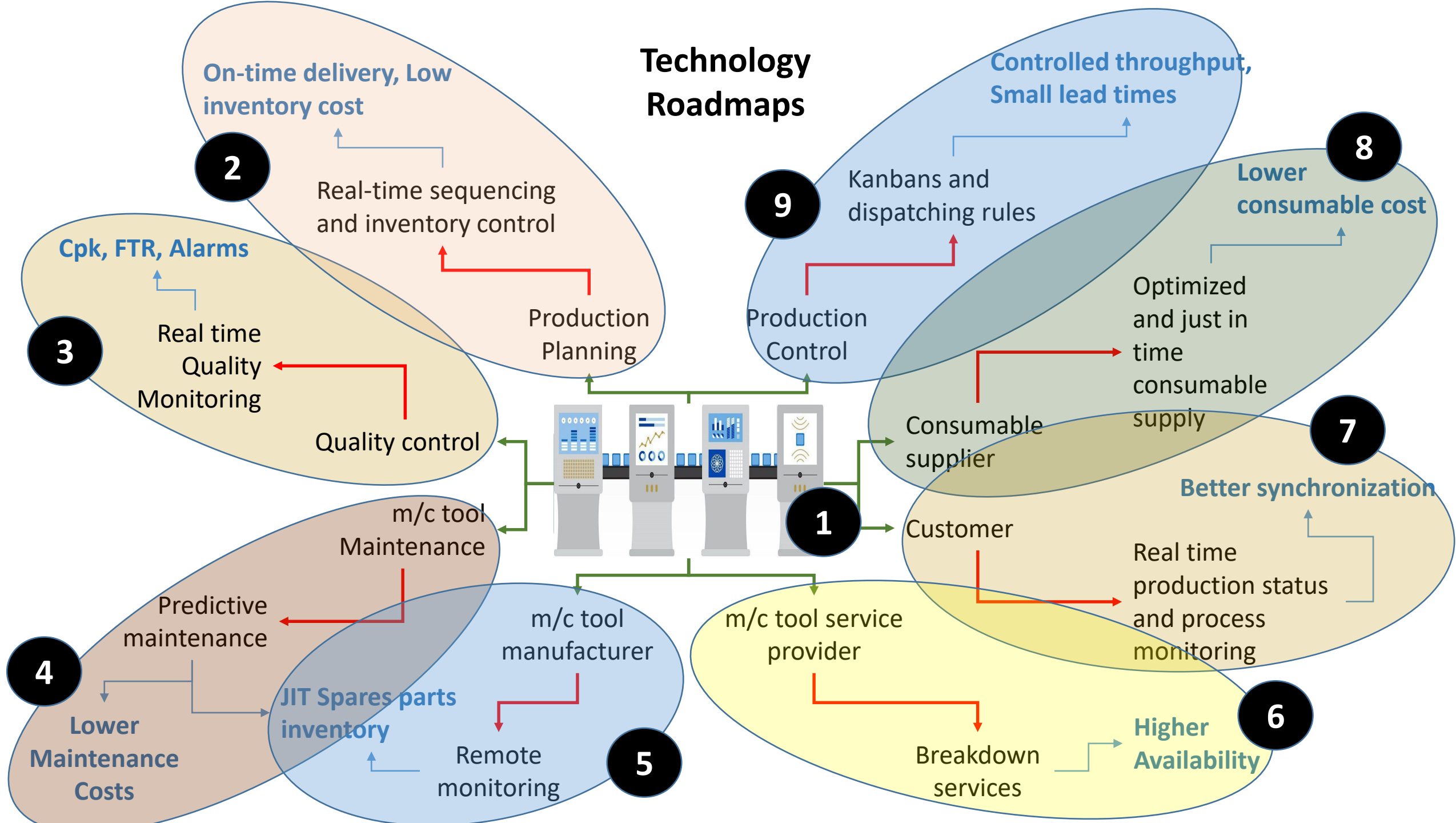


# Technology Roadmap



A **technology roadmap** typically outlines when, why, and what **technology** solutions will be implemented to help the organization move forward

# Technology Roadmaps





# QA

