

Competence Unit Training CU 34 – Process Selection

**Course: AM Cost Evaluation and management based on
process oriented approach (Part 1)**

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Outline

Introduction: Value chain and Performance

- What is Performance
- Key performance indicators

Process approach for performance assessment

- Recall of Process oriented approach
- Bizagi tool for process simulation and KPI evaluation
- Standard AM Processes

Particular KPI for AM process: Cost evaluation and monitoring

- Cost centers within AM process
- Generic process for cost estimation
- Learning AM cost estimation by examples
- Other Cost models in literature

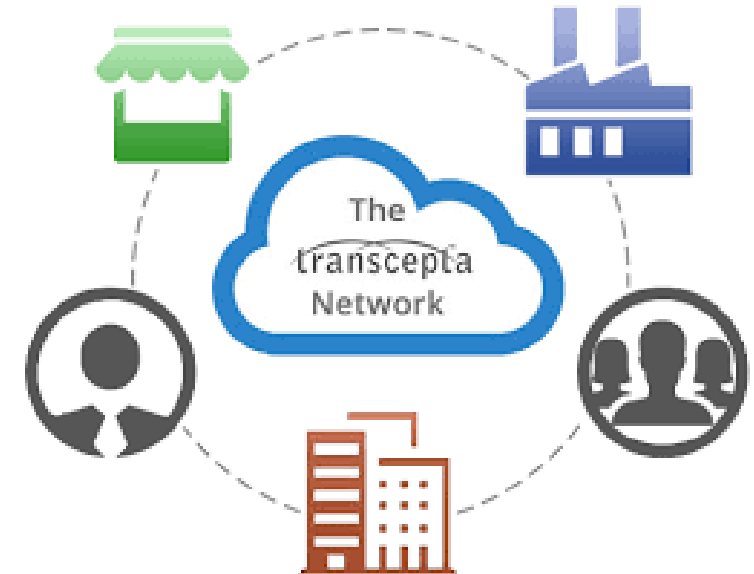
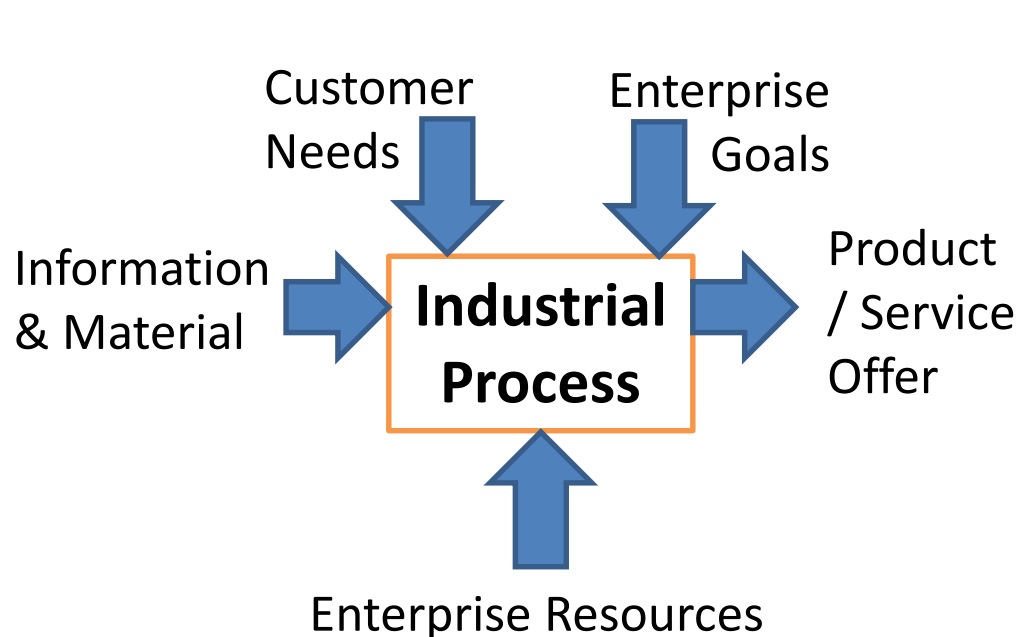
Case studies

- Advanced Case 1
- Homework: your particular case study

Introduction to Value chain and Performance

Enterprise as a System

Application of the principles of the systemic theory to organization

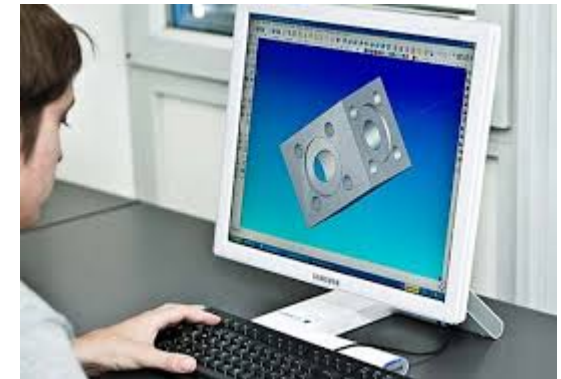


Enterprise as a system: Something (that we can identify) that do something (Process/activity) and have a structure. It evolves in time and in something (environment) for some reasons (Goal).

Value chain and industrial processes

How to reach the objective of the enterprise

- **Requirement Engineering**
 - Understand customer needs
 - Transform needs to formal specifications
- **Design**
 - Transform specification to product functions
 - Describe physical solution for each function (Module)
- **Process engineering**
 - Define manufacturing operations for each module
 - Identify necessary material and resources
- **Production planning**
 - Schedule operation and assign resources
 - Built the supplier network
 - Procure raw material
- **Manufacturing**
 - Send production orders
 - Realize operations



Requirement
Engineering

Design

Process
Engineering

Production
Planning

Manufacturing
& Assembly

Usage

Recycling

Value chain and industrial processes

Value Chain definition

A value chain is the full range of activities – including design, production, marketing and distribution – businesses conduct to bring a product or service from conception to delivery.

Porter's value chain classification

CORE PROCESSES

Primary level of core activities

Core Operations: the stage at which the raw materials are turned into the final product.

Second Level of core processes

Inbound logistics: receiving, storing and distributing of raw materials used in the production process.

Outbound logistics: the distribution of the final product to consumers.

Marketing and sales: advertising, promotions, sales-force organization, distribution channels, etc.

Service refers to the activities needed to maintain the product's performance.

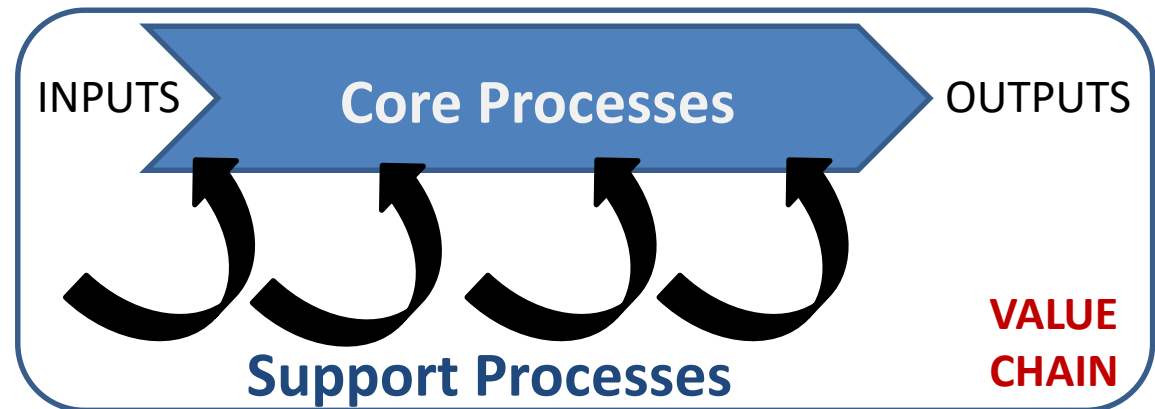
SUPPORT PROCESSES help the primary functions

Procurement is how the raw materials for the product are obtained.

Research and development for technology procurement

Human resource management to maintain the employees to help design, build and market the product.

Firm infrastructure planning, accounting, finance and quality-control mechanisms.

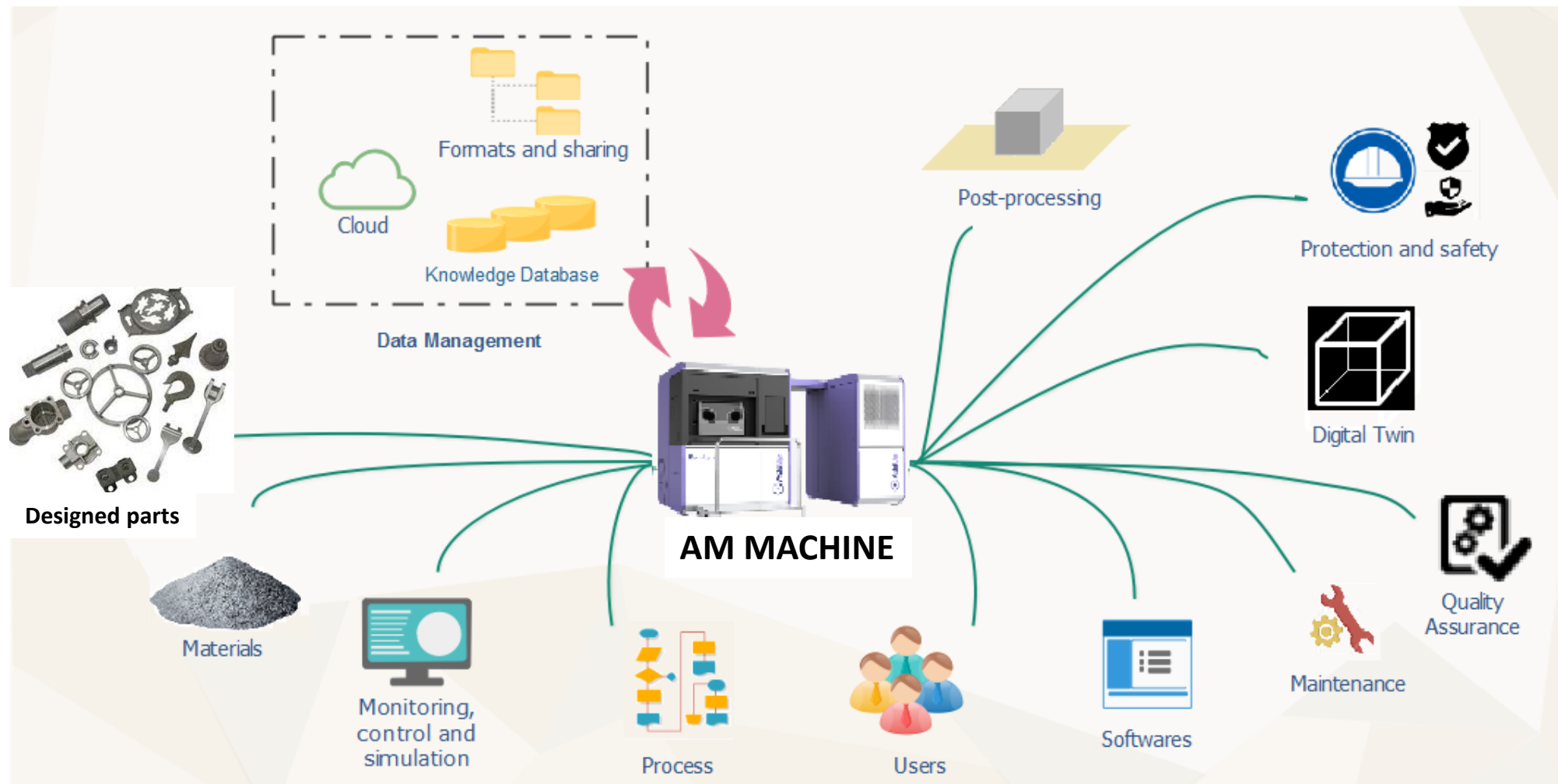


Interactional point of view

Heterogeneous entities
Lot of interactions

Internal environment Vs External environment

- Every interaction is done by one or a set of processes

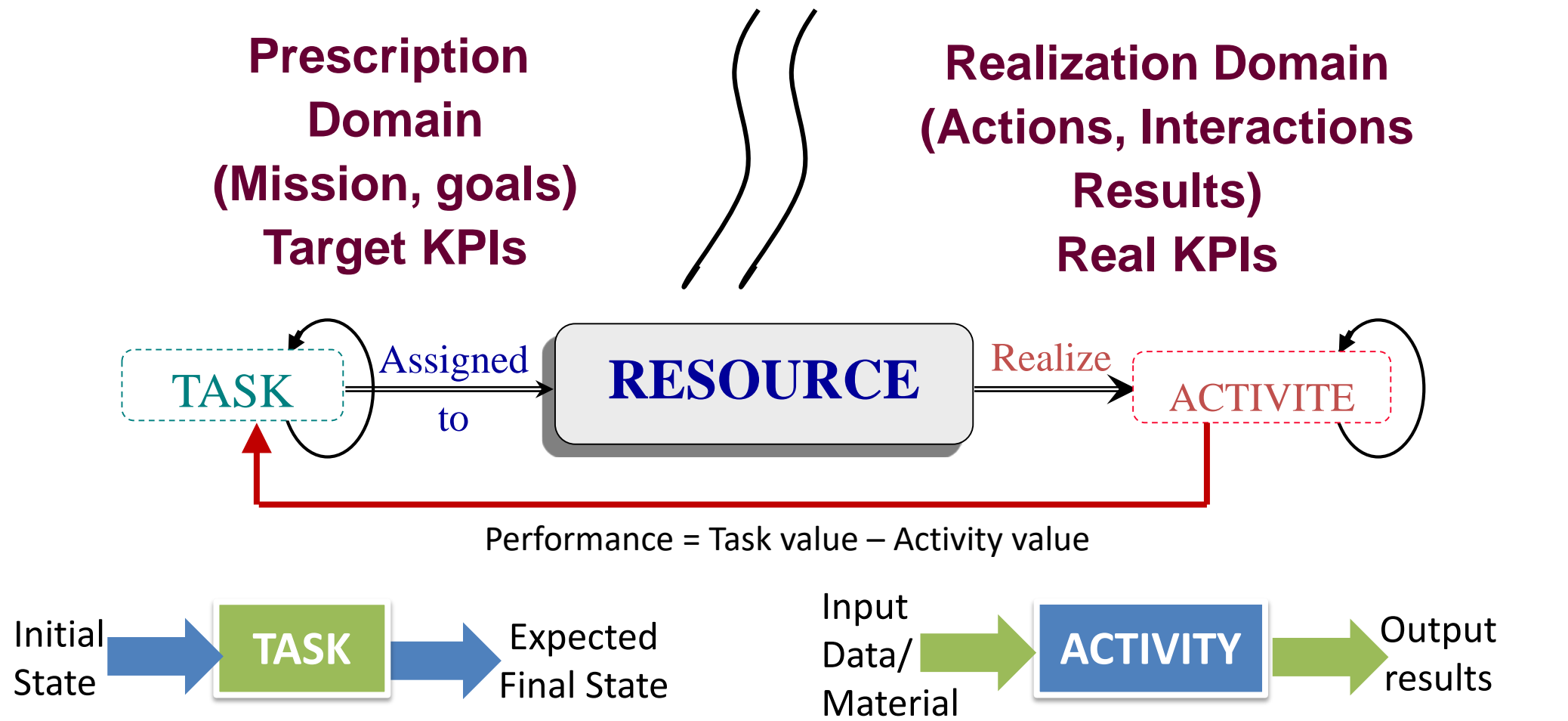


Operational point of view

Description of the work: Concept of task and activity

- Definition of Acacia

Reference: J. O. Hernandez : « Les systèmes de production automatisés : Une approche socio-technique »
Thèse de Doctorat, Université de Franche Comté 1995.



Key Performance

- **Company should provide a product with high performance:**

- High quality, low cost and short time of delivery
- But granting maximum of profit for the company

>>> KPIs ??

- **Effectiveness**

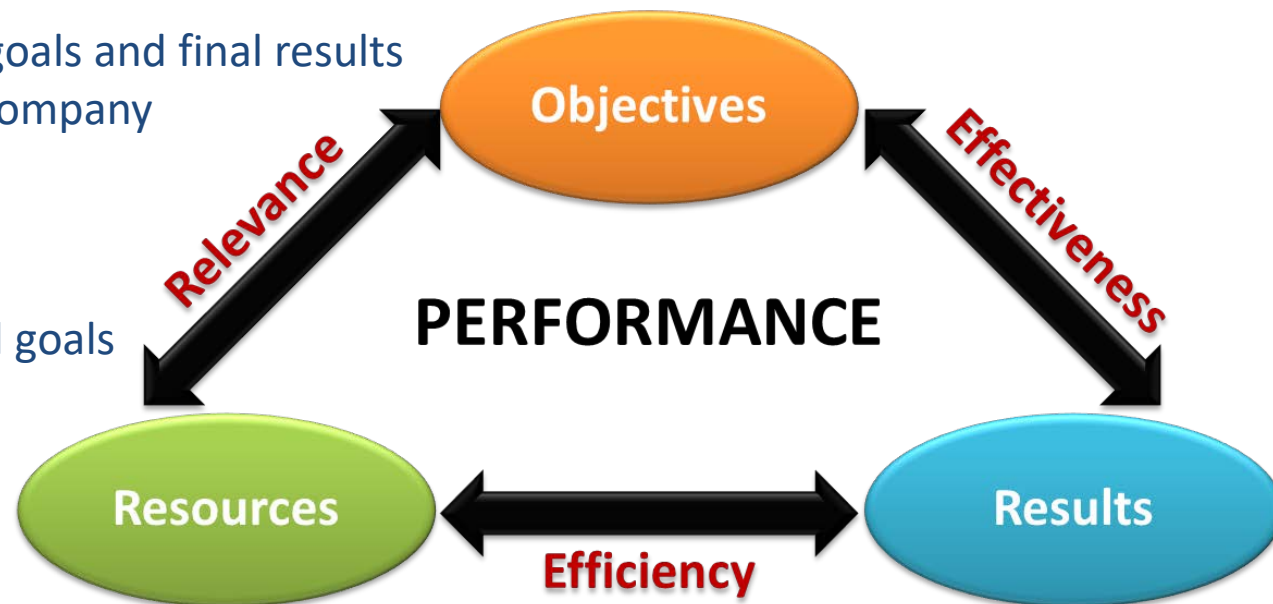
- Difference between expected goals and final results
- Inform on the capacity of the company to reach the goals

- **Relevance**

- Comparison between expected goals and engaged resources
- Inform on the capacity of the company to forecast and plan

- **Efficiency**

- Difference between resources and final results
- Inform on the capacity of the company to optimize its resources



Enterprise Performance Indicators

- **Economic**
 - Cost,
 - Profitability,
 - ...
- **Quality**
 - Product features,
 - Client satisfaction,
 - ...
- **Time**
 - Cycle time of process,
 - Delay on delivery,
 - ...
- **Sustainability**
 - Carbone footprint,
 - ...
- **Social**
 - Recruitment capacities
 - ...



Product Oriented Indicators

Process Oriented Indicators

Organization Oriented Indicators

Environment Oriented Indicators

Recall of Process Oriented Approach

Operational point of view

- **Definitions of task and activities**

- Activity is a set of tasks carried out in order to create a deliverable (project management), while Task should be thought of as a subset of an activity.
- The word task refers to 'work' or 'a piece of work to be done or undertaken'. The word activity refers to 'happening'. (ex, There are many activities going on in the club).
- Task is an activity that needs to be accomplished within a defined period of time or by a deadline to work towards work-related goals.

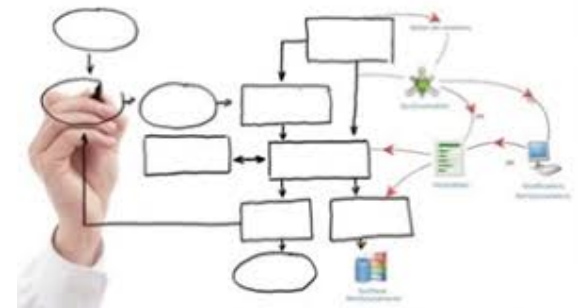
- **Concept of Process**

- Group of tasks/activities that are (semi-) organized in a consistent way, exchange inputs and outputs and contribute to the same generic goal. It calls to various resources to achieve a set of transformations on some objects from the same type.



- **Concept of Role**

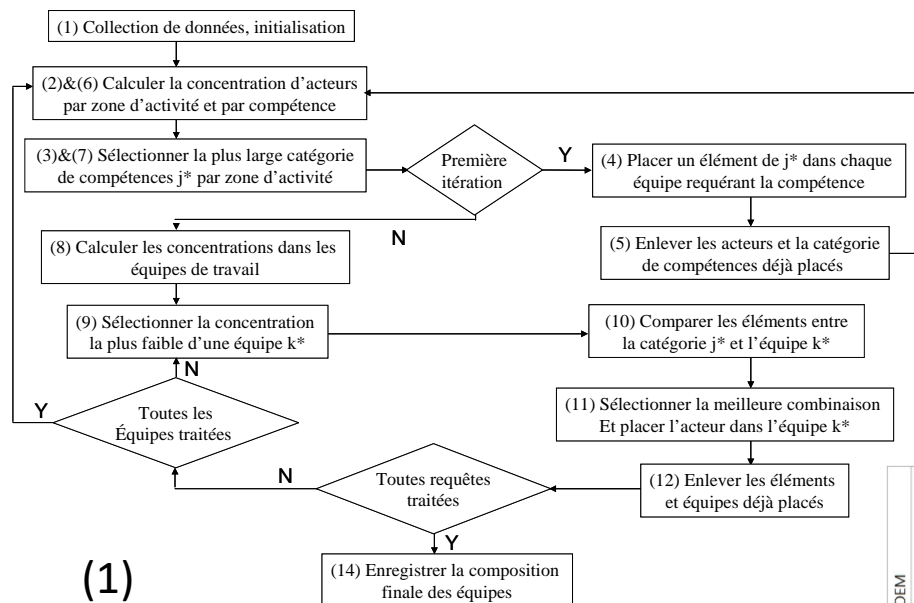
- How one resource contribute to an activity?
- Define set of missions and authorities
- In information systems : set of access rights to data (administrator, viewer, modifier, etc.)



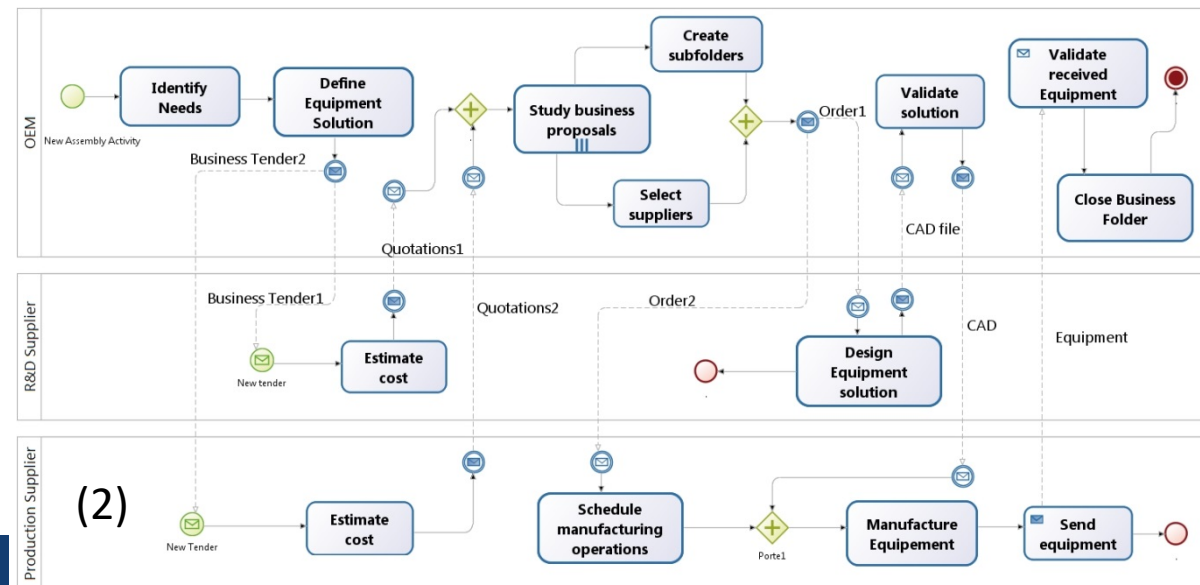
Operational point of view

• Example of processus

- (1) Workflow with set of actions to do without assignment
- (2) More information about the actors and exchanged flows



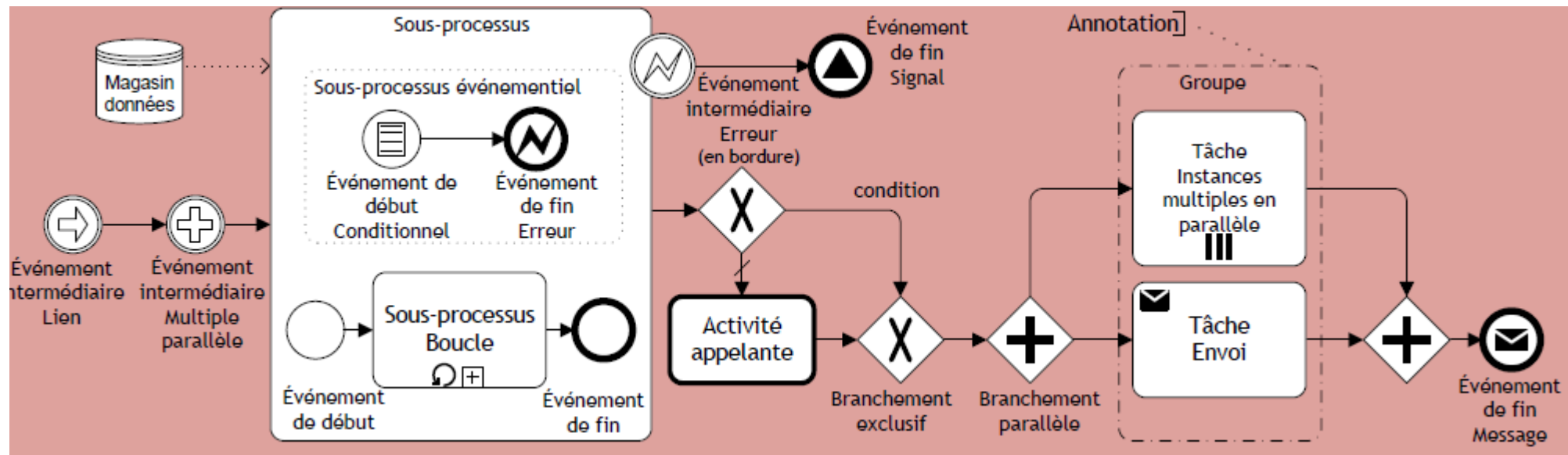
Need of formal process models



Process Modeling : BPMN

BPMN : Business Process Model Notation

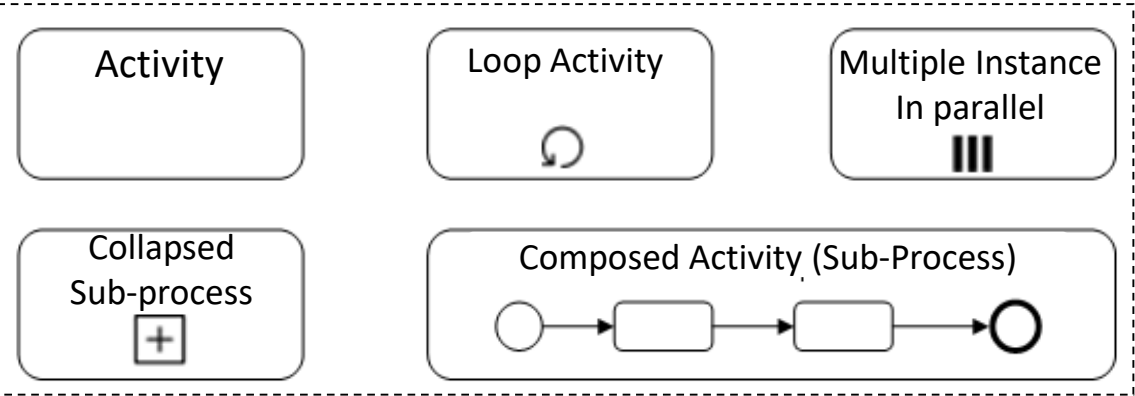
- >> As for UML, BPMN standard is created by OMG (Object Management Group, American Association). As a complementary process modelling language, it is:
- >> **to support Business Process oriented strategies**
- >> to capitalize and unify existing good practices identified in variety of process modelling languages
- >> Standard and rich formalism to cover large wide of operational situations



BPMN : Basic notations

The concept of activity

- >> Activity (or task): work unit, a job to be performed
- >> Colored with several notations



Main types of activities

- >> Loop; iterative activity > repeat an activity until one condition
- >> Multiple Instances of one activity, started in parallel or in sequence, applied to several objects (similar or not),
- >> Collapsed: Main activity is decomposed to sub-activities (Hierarchy relation of processes)

Activity Notations

- Sub-Process
- Loop
- Parallel Multiple instances
- Sequential Multiple instances
- AAd Hoc
- Compensation

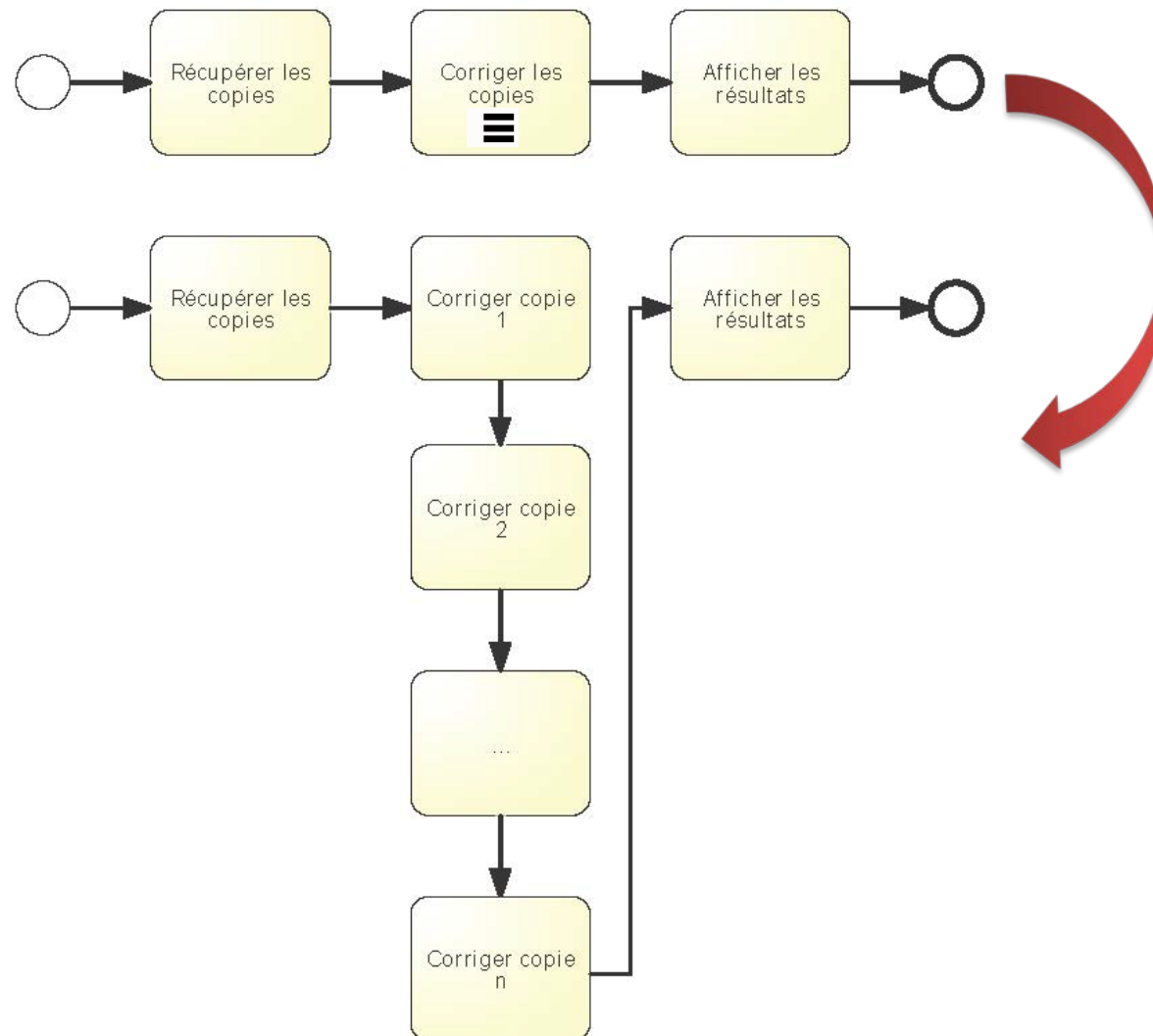
Types of activities

- Sending
- Reception
- User
- Manual
- Business rule
- Service (Automatic)
- Script

BPMN : Basic notations

Multiple instance activity (sequential)

>> Correction of students' home works



BPMN diagram

4 types of arrows between activities and events



Untyped relation
Flow between 2
Activities from
The same process
(Same organization)



Conditional
Link between
2 activities



Default
Link between
2 activities

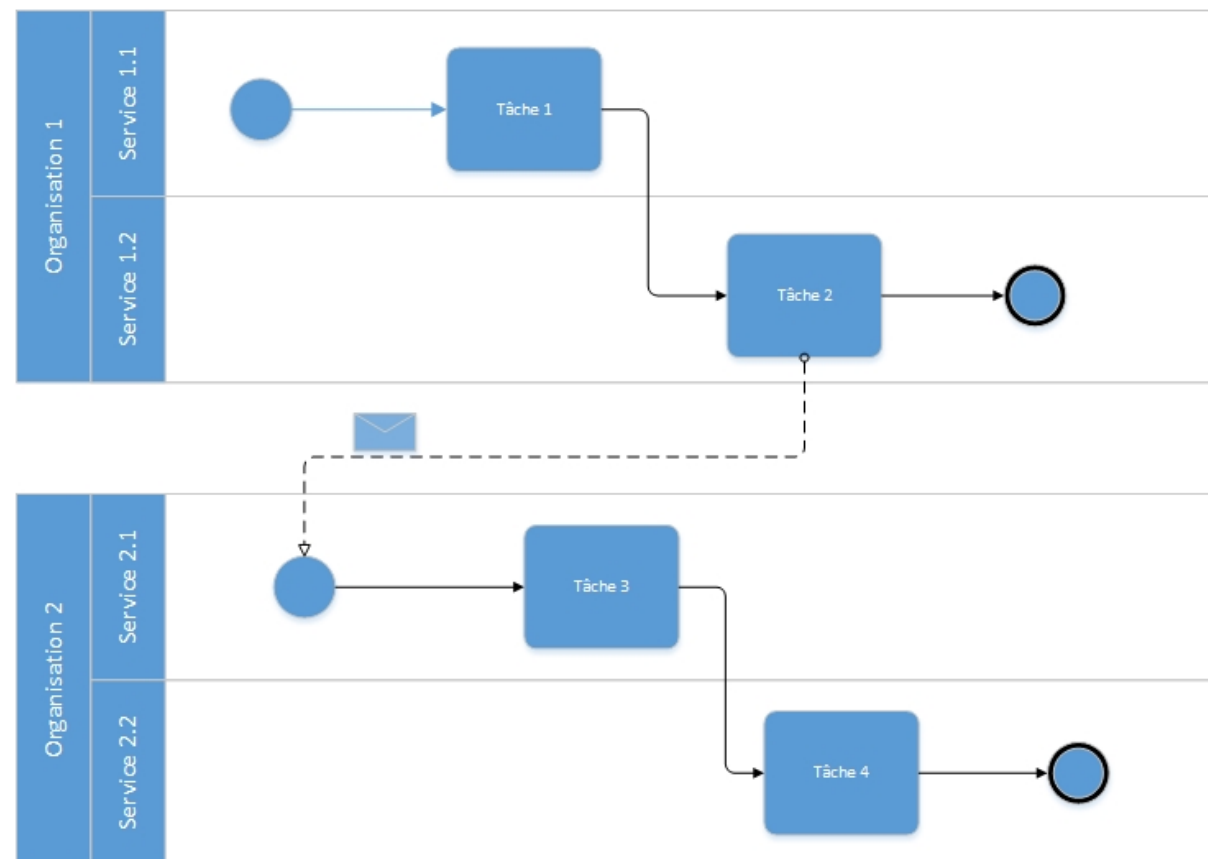


Message between
2 activities from
Different processes
(separate organizations)

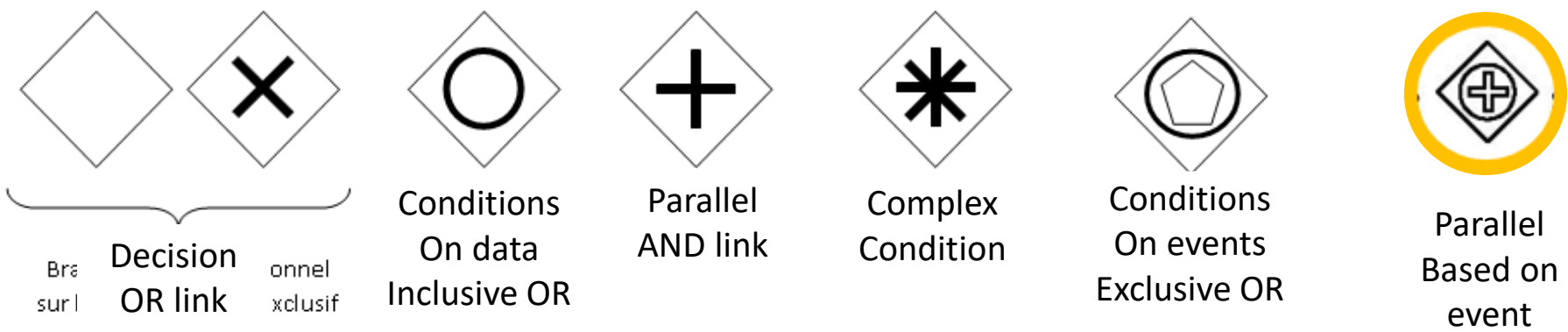
Swilanes (Pools and Lane)

Pool >> represent one organization or system and support one process accross roles or actors,

Lane >> represent one actor, role or responsability of activities in the organization or system, regarding the process of interest.



BPMN : Connection between activities

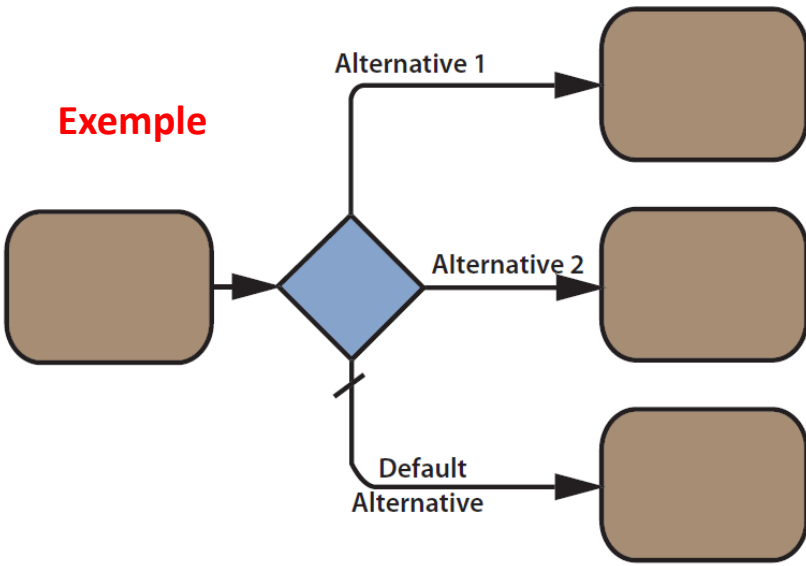
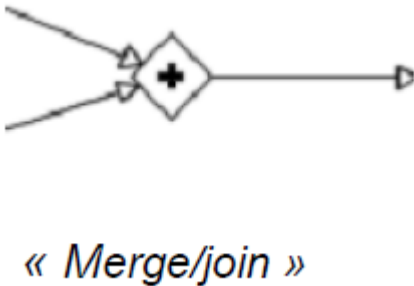
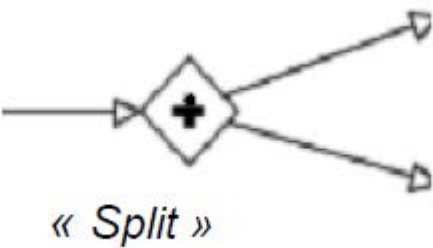


Inclusive: all conditions should be completed before creating the instance

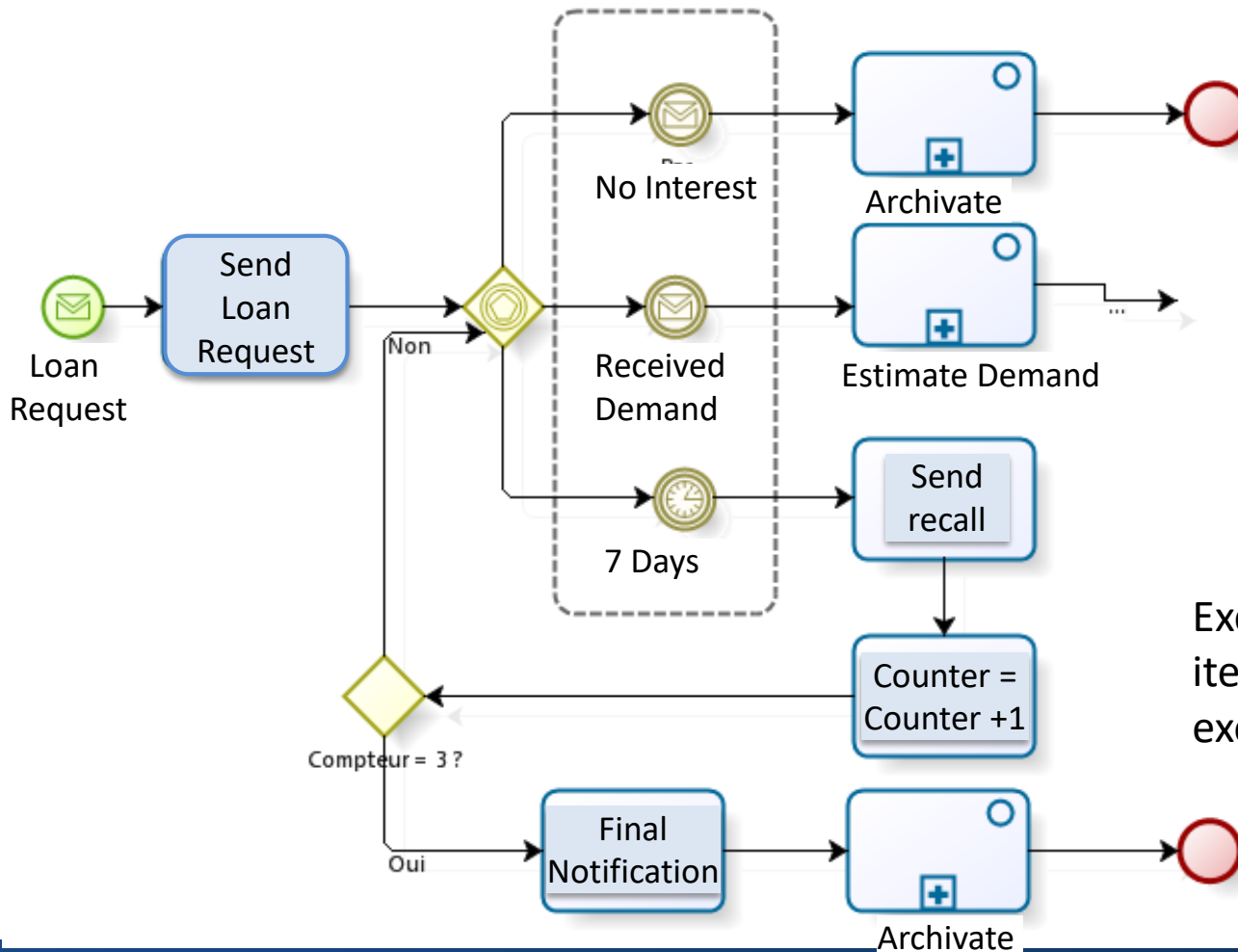
Exclusive: each new event create new instance of process

Parallel: all input flows are needed to have an output flow

Parallel based on event: the apparition of all events create new instance of proces



BPMN operators



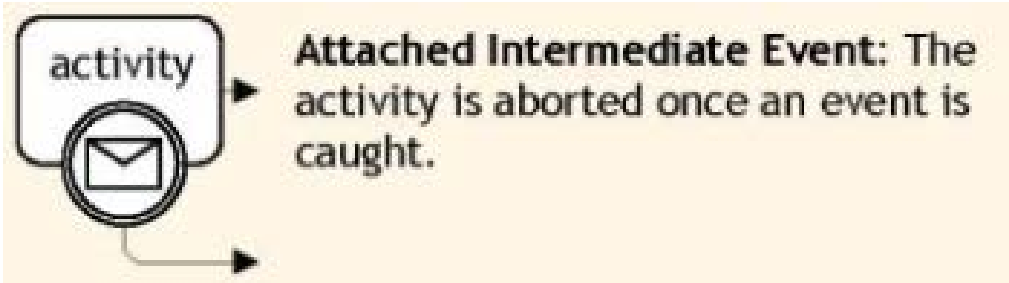
Inclusive Or: according to the choice, one, two or 3 paths (activities and flow) could be executed

Exclusive Or based on event the choosen itenary is those conected to the first executed event

BPMN Event notations

What is an EVENTS?

Help to identify particular situation that trigger or stop an activity



Specific event notations

EVENTS

Help to identify particular situation that trigger or stop an activity

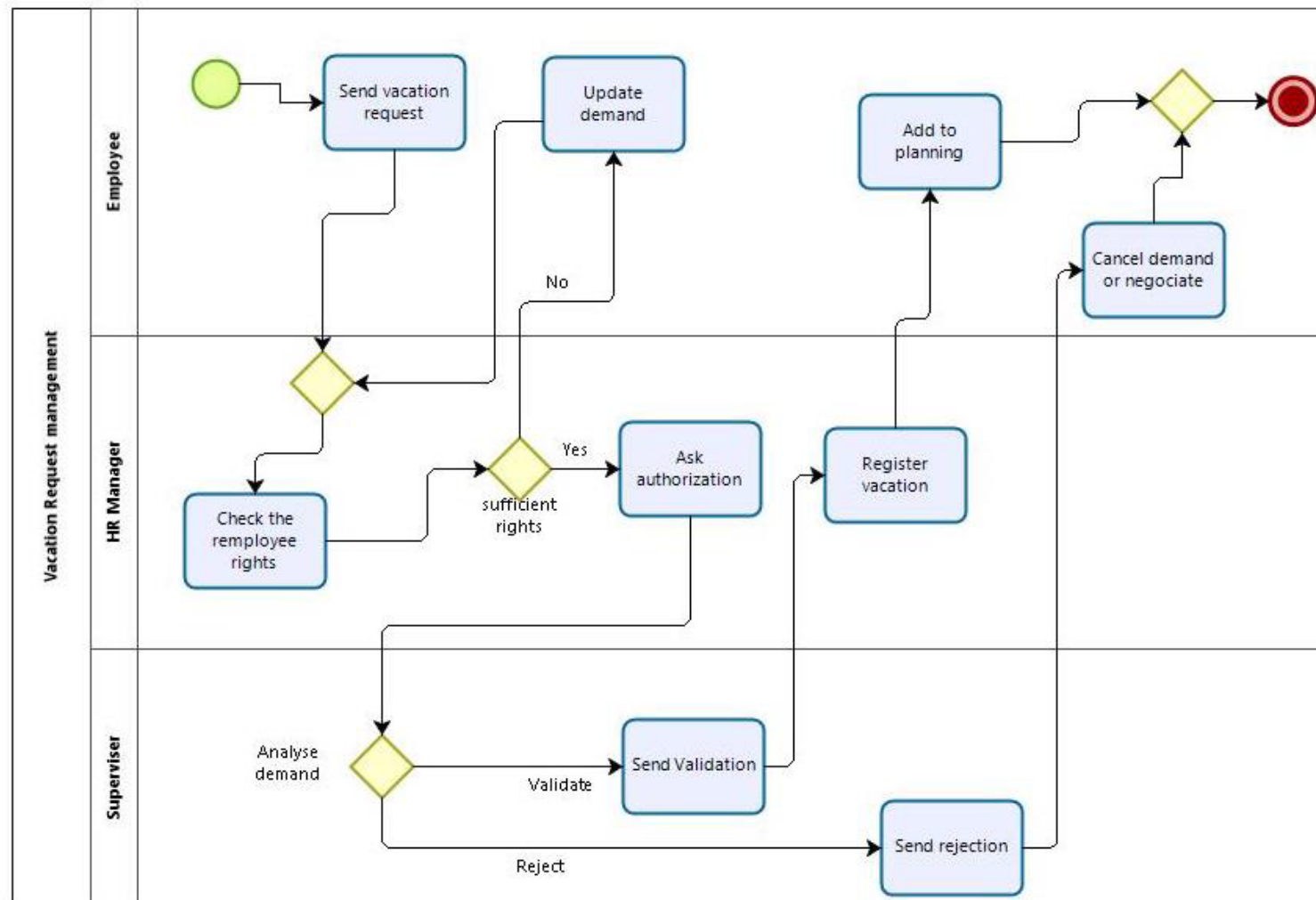
	Start			Intermediate			Sending	End
	Up-level process	Event based Sub process with interruption	Event based Sub process without interruption	Reception	Borderline with interruption	Borderline without interruption	Throwing	Closure
Plain: untyped events, when the process start or ends; state change of process								
Message: Receiving and sending								
Cyclic timer events: points in time spans or timeouts								
Climbing: evolving to superior responsibility level								
Conditional events: reacting to changed conditions or integrating business rules								
Link: Off-page connectors, Two corresponding links = sequence (connecting parts of processes)								
Error : Catching / throwing known errors in the planned process								
Annulation: réaction à l'annulation Cancel: reacting to a cancelled transaction or triggering cancellation								
Compensation: handling or triggering a compensation								
Signal: standard notifications across various processes, 1 signal can be caught multiple times								
Multiple: Catching or throwing one out of a set of events								
Multiple parallel: the reception of all events is done in parallel								
Terminate: triggering intermediate termination of a process								

Short example for understanding

Process of Vacation Request management

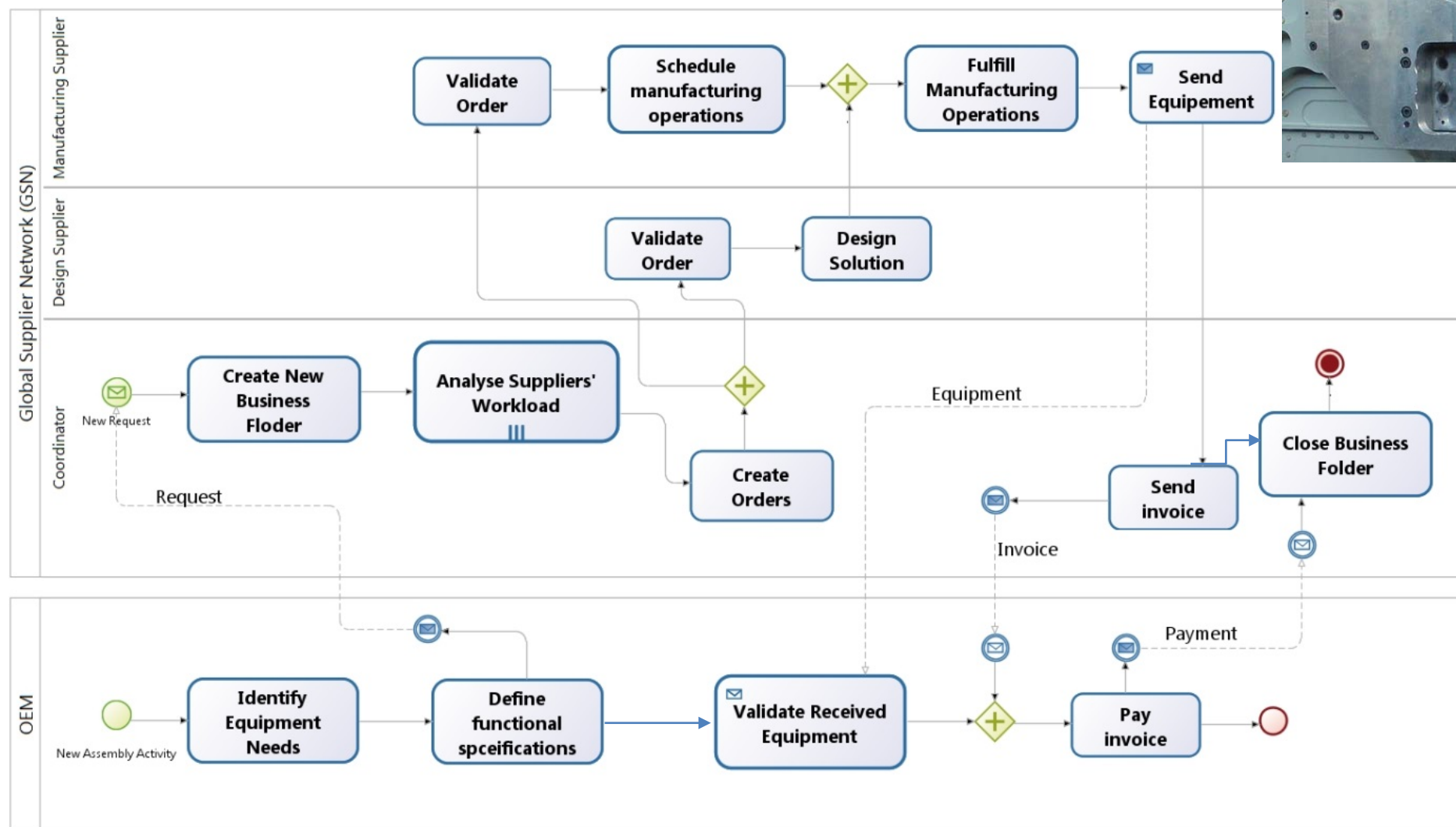
Information: application form; provisional service schedule

Actors: Employee, supervisor and Human Resource manager



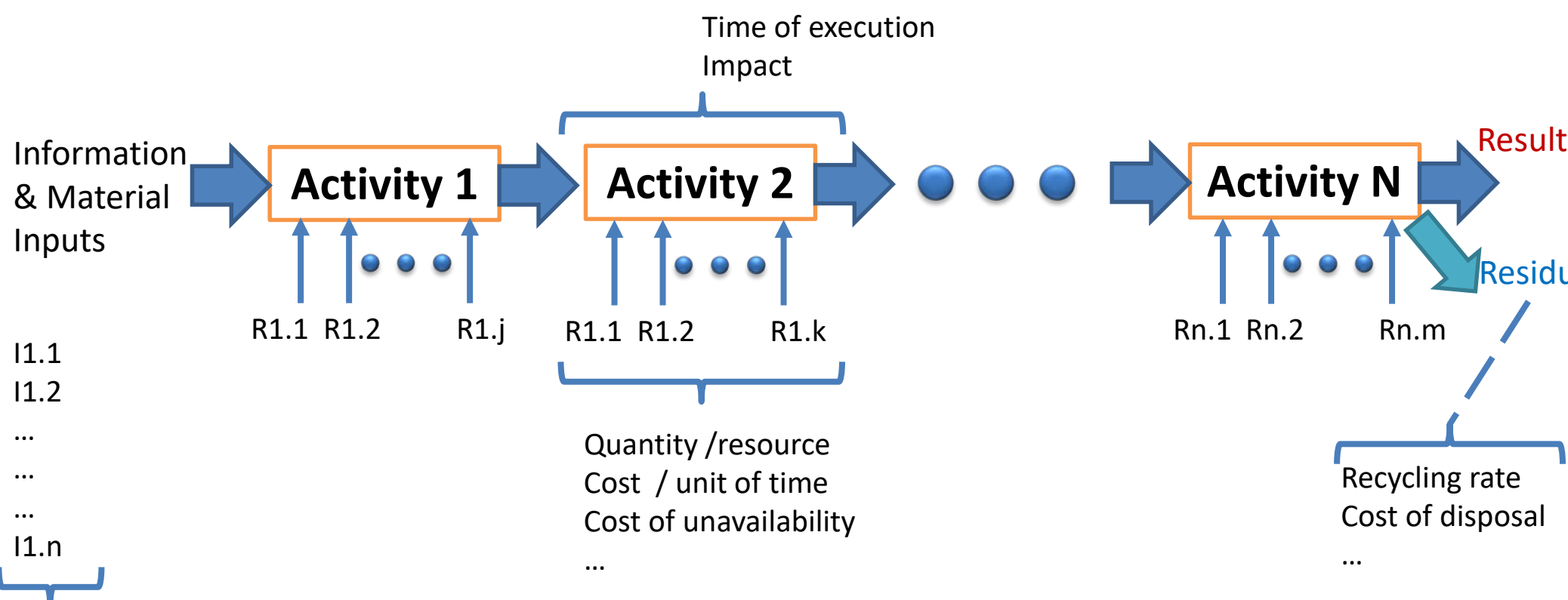
Second Example for understanding

Process of fixture tool realization in aeronautic industry



How to use process approach for costing

PRINCIPLE: Decompose Industrial Process to separate cost centers per activities



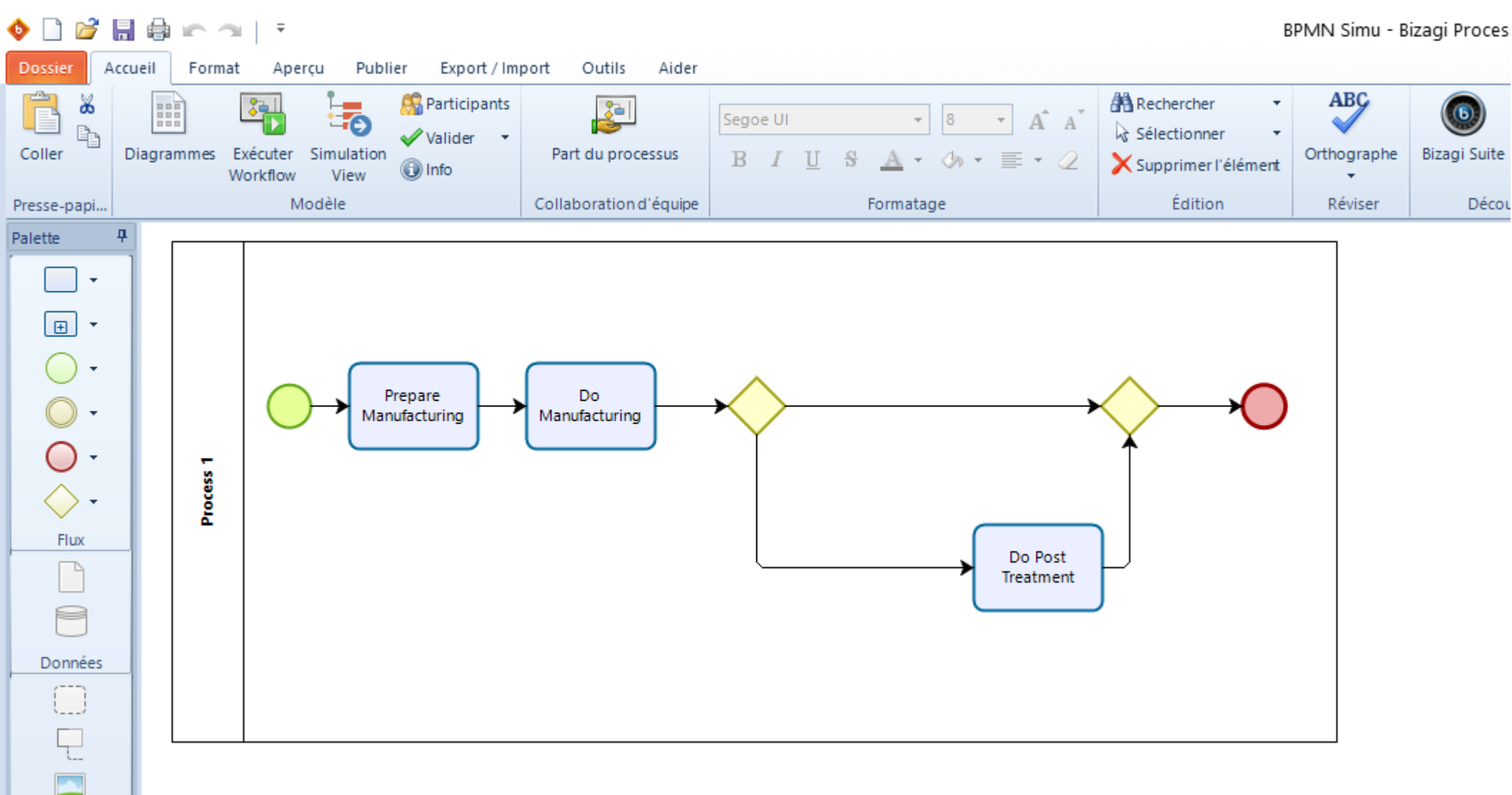
- I1.1
 - I1.2
 - ...
 - ...
 - ...
 - I1.n
- Quantity
- Cost of Provision
- Cost of treatment
- ...
- ...

Simplified model:

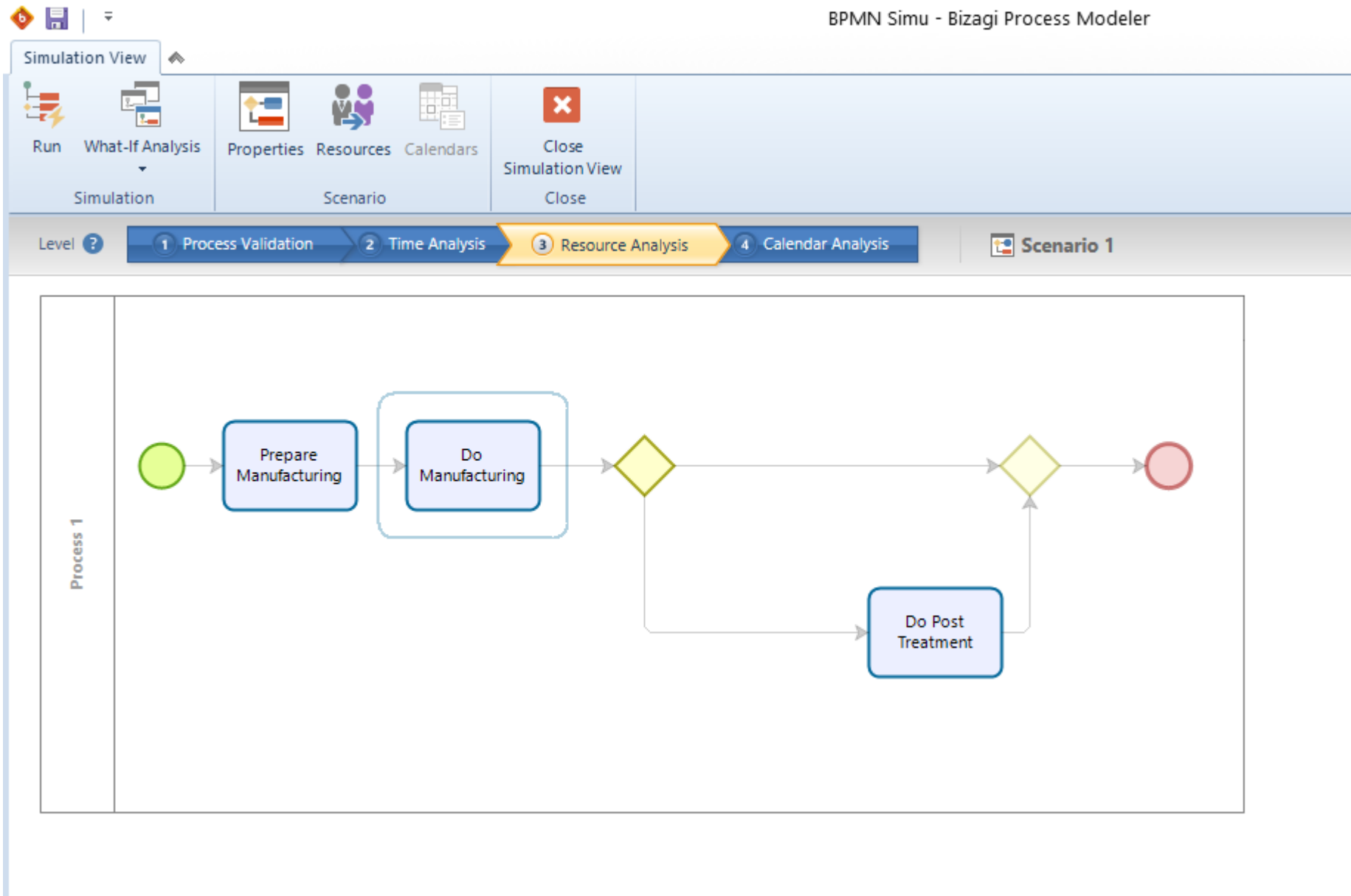
Cost to obtain result =

Cost of inputs + cost of activities + Cost of disposal +

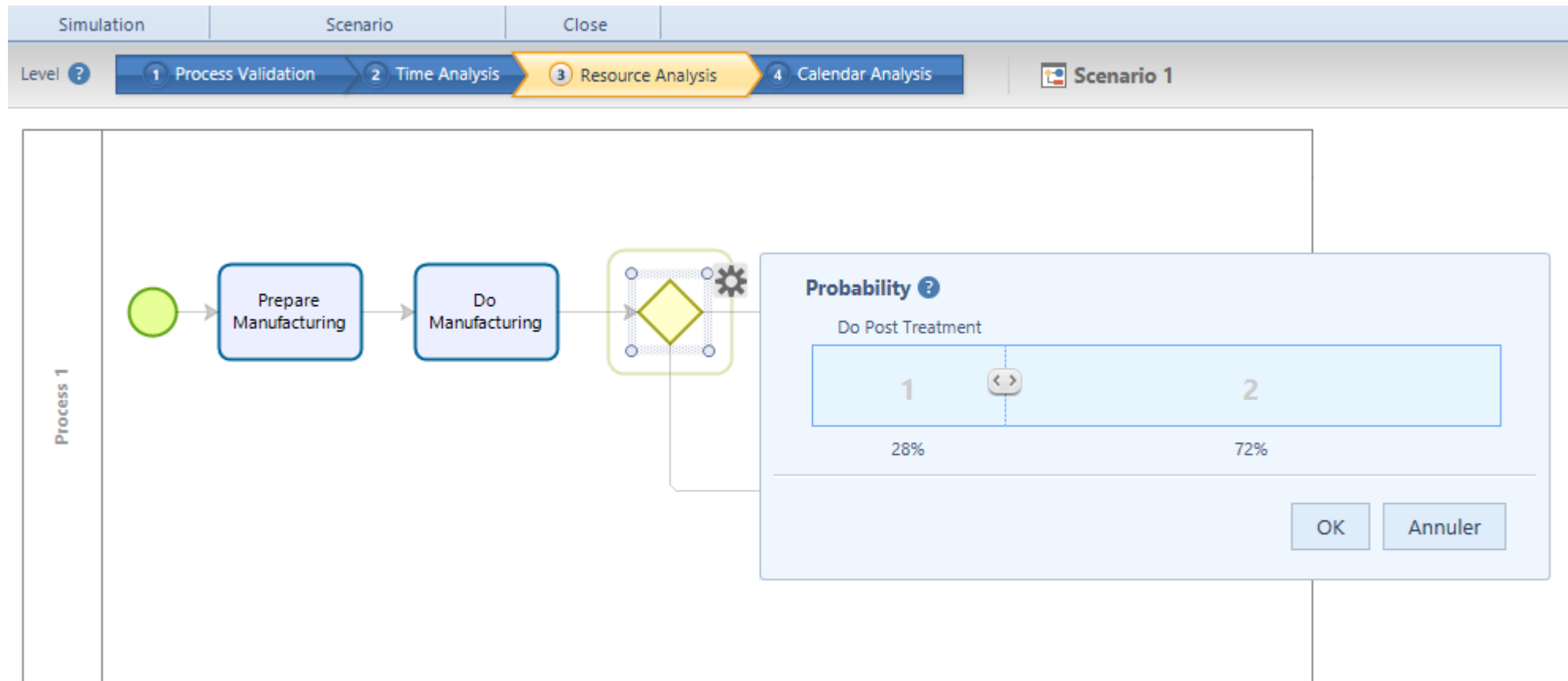
Example of process simulation with Bizagi : process creation



Example of process simulation with Bizagi



Example of process simulation with Bizagi: Gate configuration



Example of process simulation with Bizagi: Task configuration

Simulation Scenario Close

Level ? 1 Process Validation 2 Time Analysis 3 Resource Analysis 4 Calendar Analysis Scenario 1

Process 1

Prepare Manufacturing

Time

Wait time ?

0	0	0	0	
days	hrs	mins	secs	

Processing time ?

0	0	15	0	
days	hrs	mins	secs	

OK Cancel

Example of process simulation with Bizagi

Task Configuration

Simulation

Scenario

Simulation view

Level ?

1 Process Validation

2 Time Analysis

3 Resource Analysis

4 Calendar Analysis

Scenario 1

Process 1

Prepare Manufacturing

Mar

Parameter Type Selector

All

Constants

Continuous distributions

Discrete distributions

Duration

1,0

Floating

Numeric

ribution

most

tions in

symmetrical

It is useful

ations where

distributed

Truncated Normal Distribution

Triangular Distribution

OK

Cancel

Do Manufacturing

Time

Wait time ?

0

0

0

0

days

hrs

mins

secs

Processing time (mins) ?

Normal Distribution

Mean

12

Standard deviation

3

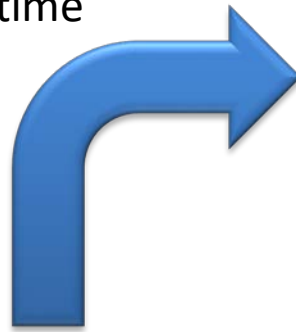
OK

Cancel

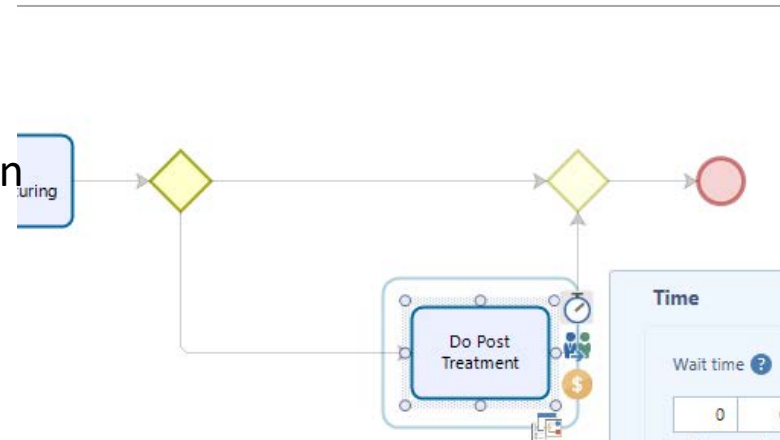
Example of process simulation with E

Task Configuration

Possibility to refine in resource section
Changing the wait time



3 Resource Analysis 4 Calendar Analysis Scenario 1



Time

Wait time ?

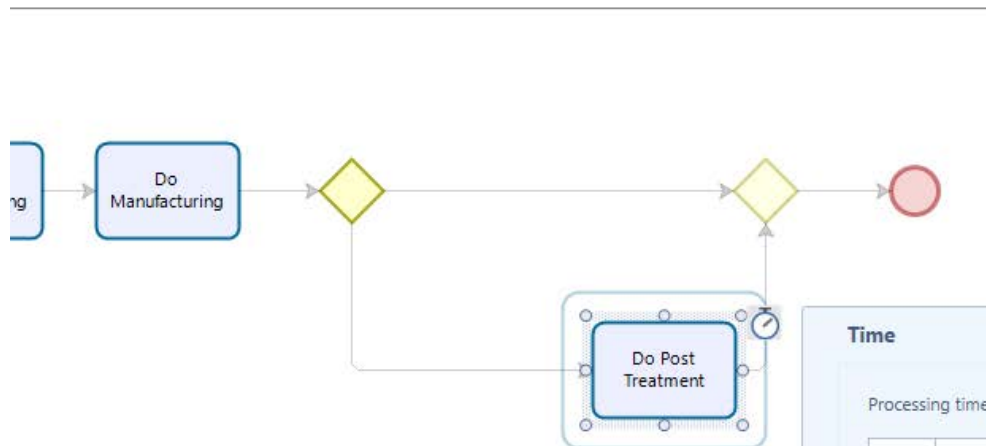
0	0	1	0	
days	hrs	mins	secs	

Processing time ?

0	0	5	0	
days	hrs	mins	secs	

OK Cancel

2 Time Analysis 3 Resource Analysis 4 Calendar Analysis Scenario 1



Time

Processing time ?

0	0	5	0	
days	hrs	mins	secs	

OK Cancel

Example of process simulation with Bizagi

Resource configuration

Properties

Resources

Calendars

Scenario

Close

Simulation View

Close

Process Validation

2 Time Analysis

3 Resource Analysis

4 Calendar Analysis

Scenario 1

Resources

AvailabilityCosts

Resources	Quantities
Machine AM 333	3
Operator	2
Equipment xxz	5

Resources

Resources

AvailabilityCosts

Resources	Fixed cost	Cost per hour
Machine AM 333	0.5	2
Operator	0.3	1.2
Equipment xxz	0	0.3

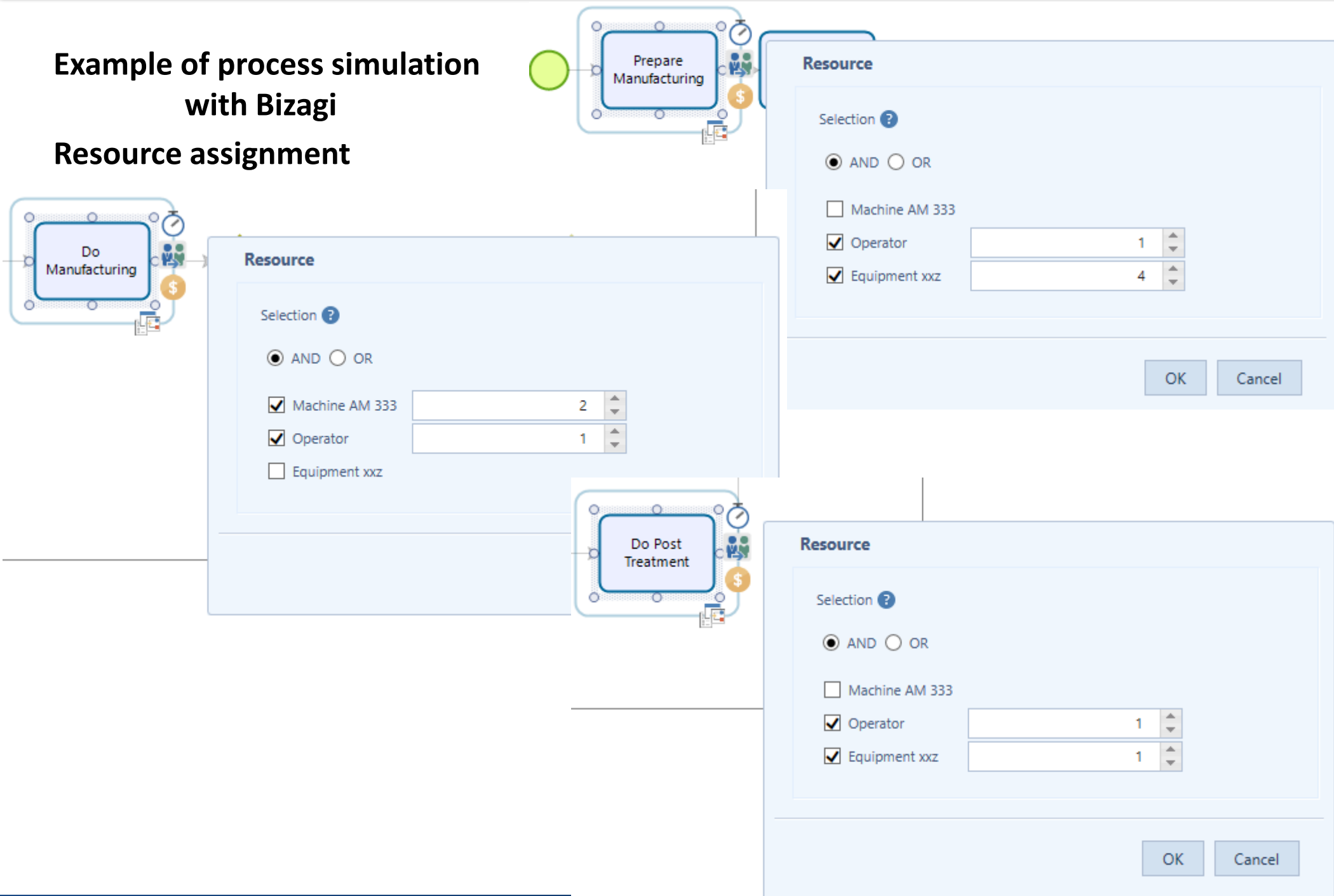
Resources

Ok

Prepare Manufacturing

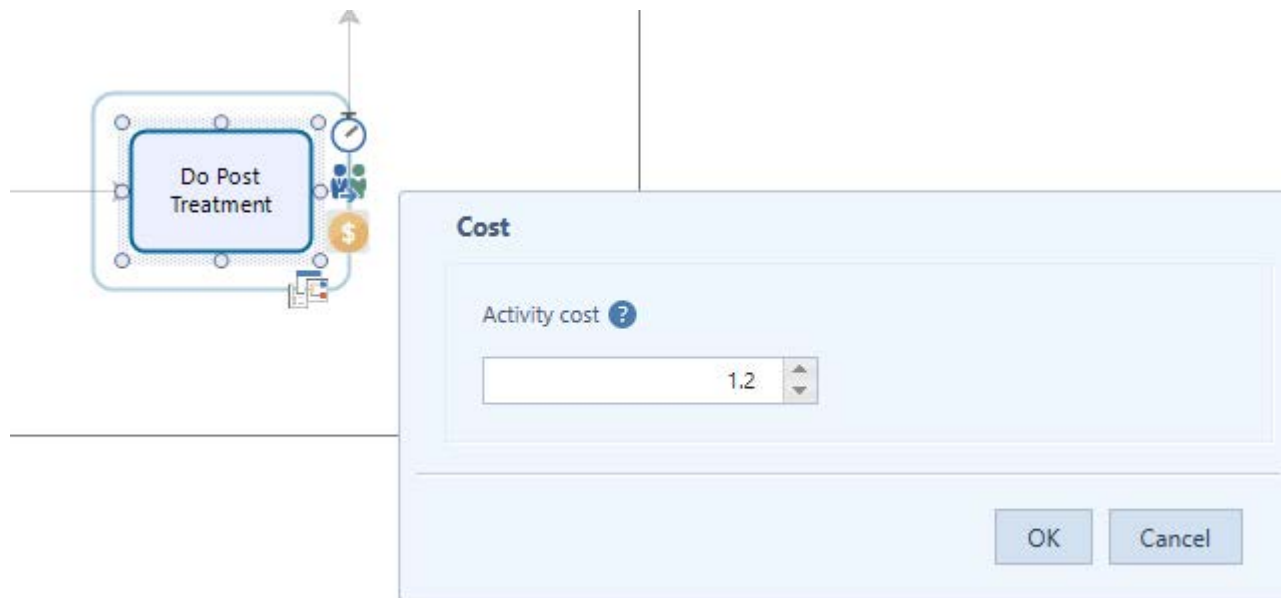
Example of process simulation with Bizagi

Resource assignment



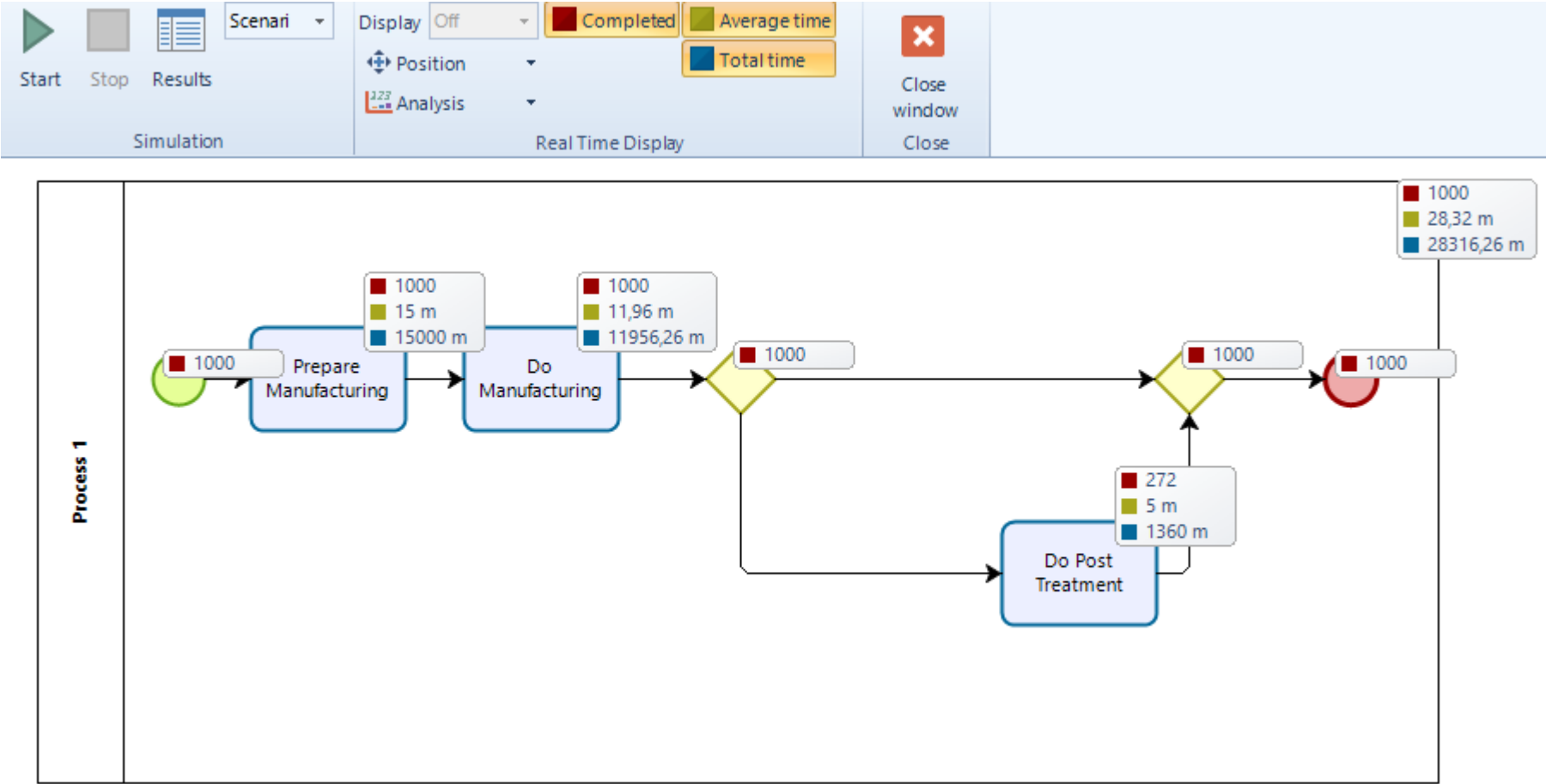
Example of process simulation with Bizagi

Possibility to refine activity cost



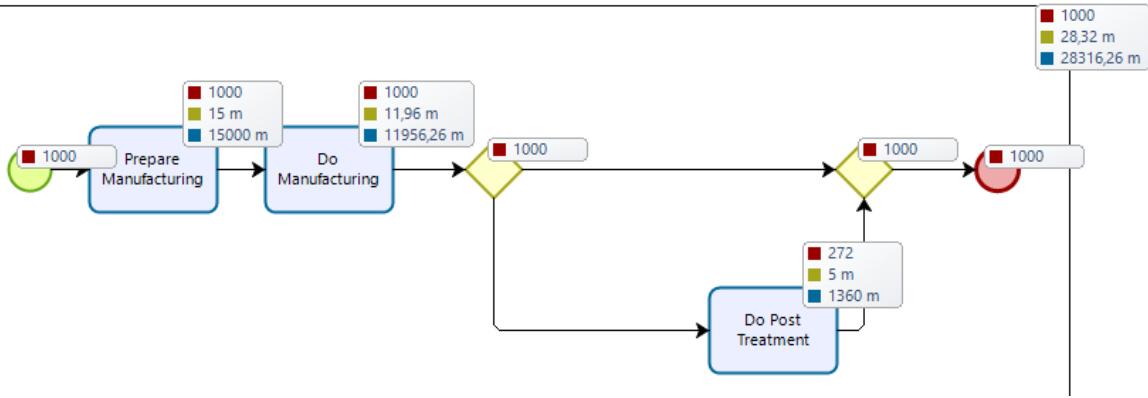
Example of process simulation with Bizagi

Time Analysis



Example of process simulation with Bizagi

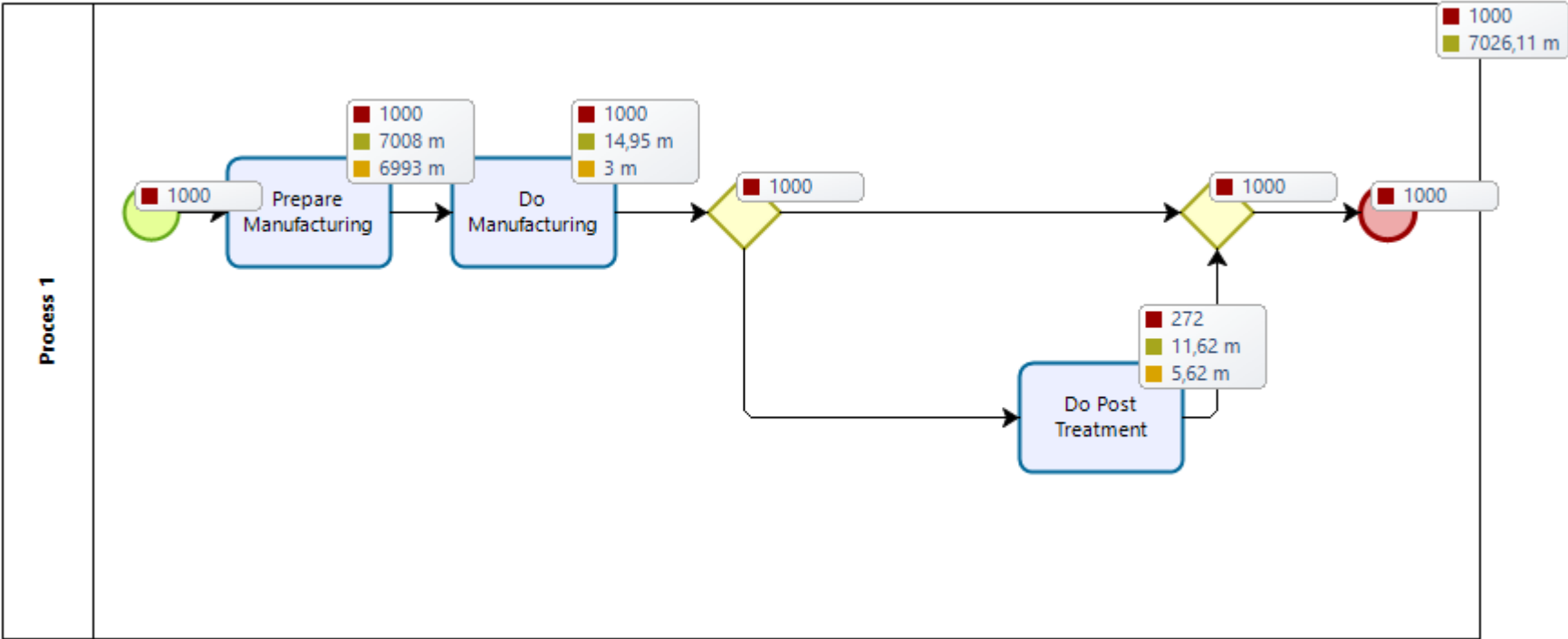
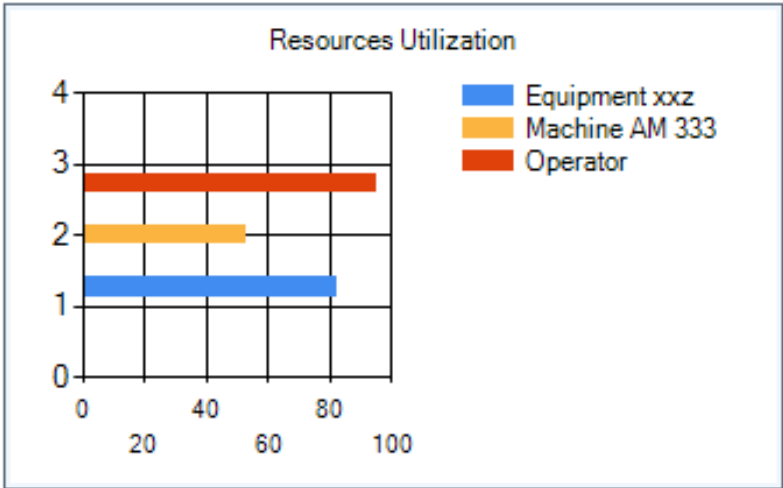
Time Analysis



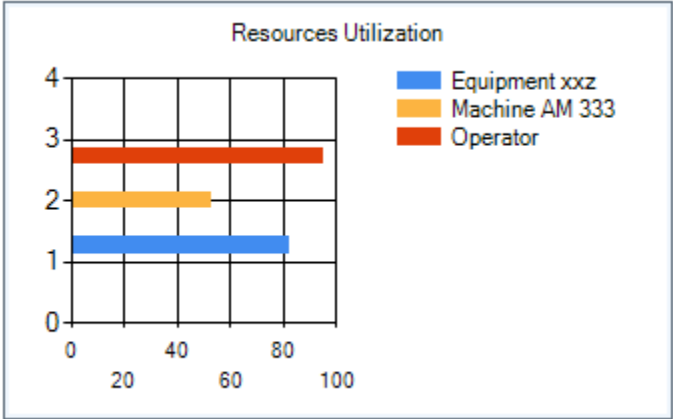
Scenario information	
Nom	Scenario 1
Time unit	Minutes
Durée	030,00:00:00

Name	Type	Instances completed	Instances started	Min. time	Max. time	Avg. time	Total time
Process 1	Process	1 000	1 000	16m 34s	41m 7s	28m 19s	19d 15h 56m 15s
NoneStart	Start event	1 000					
Prepare Manufacturing	Task	1 000	1 000	15m	15m	15m	10d 10h
Do Manufacturing	Task	1 000	1 000	1m 34s	21m 24s	11m 57s	8d 7h 16m 15s
Do Post Treatment	Task	272	272	5m	5m	5m	22h 40m
ExclusiveGateway	Gateway	1 000	1 000				
ExclusiveGateway	Gateway	1 000	1 000				
NoneEnd	End event	1 000					

Example of process simulation with Bizagi
Resource Exploitation



Example of process simulation with Bizagi
Resource Exploitation



Scenario information

Nom	Scenario 1
Time unit	Minutes
Durée	030,00:00:00

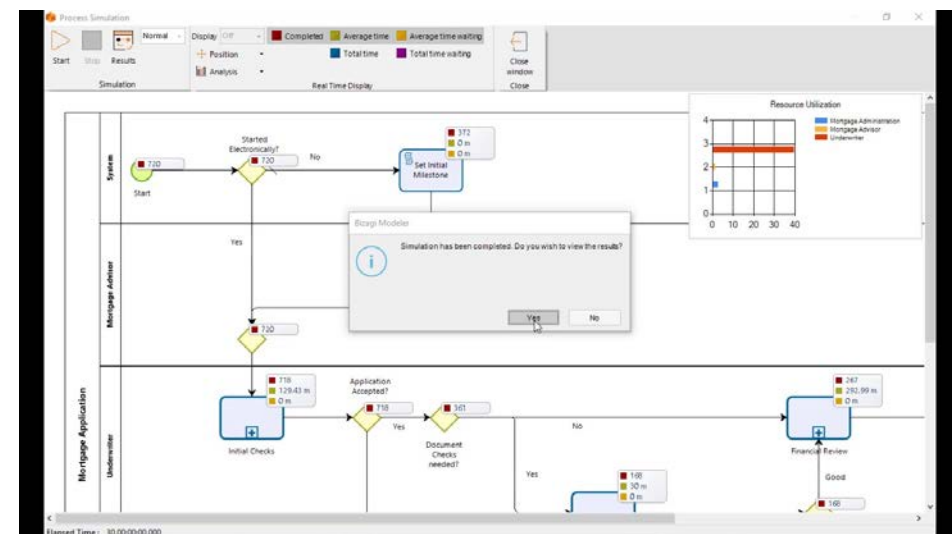
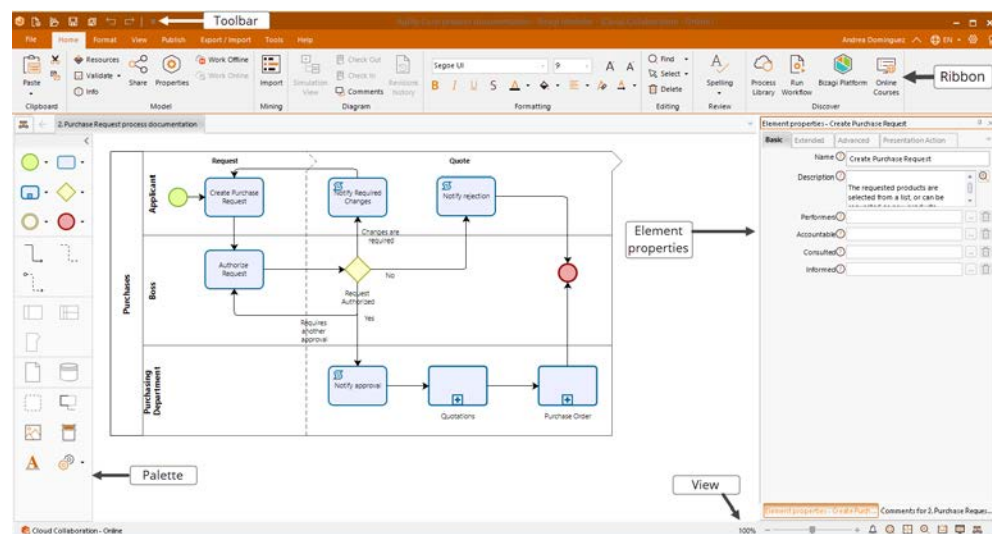
Resource	Utilization	Total fixed cost	Total unit cost	Total cost
Machine AM 333	53,11 %	500	47 825,04	48 325,04
Operator	95,24 %	681,6	34 305,91	34 987,51
Equipment xxz	82,13 %	0	18 489,6	18 489,6
Total		1 181,6	100 620,55	101 802,15

Bizagi Tool for performance assesment within Process oriented approach

https://www.youtube.com/watch?v=KgO8K6FFJdU&ab_channel=Bizagi

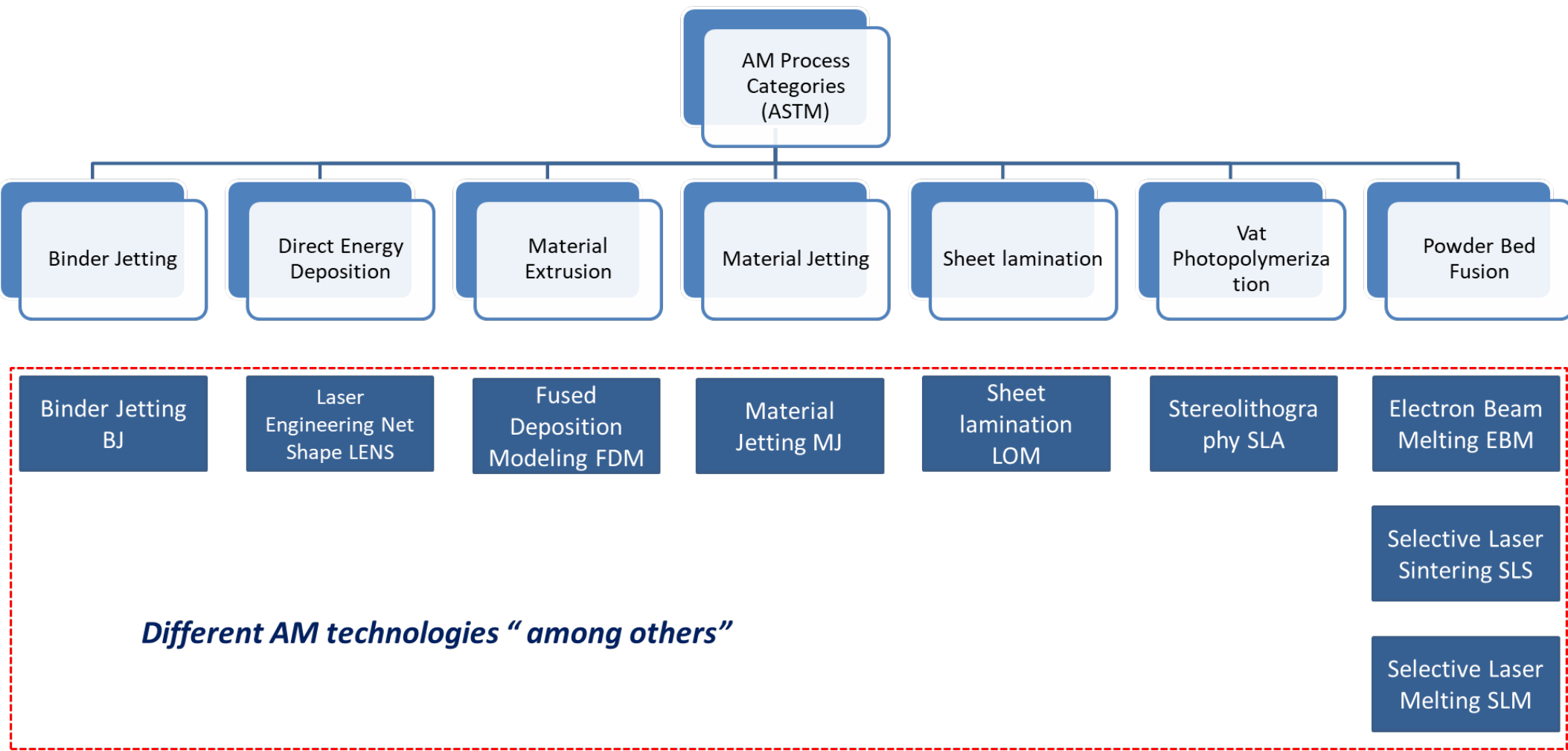
https://www.youtube.com/watch?v=eJAHrU_GvOk&ab_channel=Bizagi

https://www.youtube.com/watch?v=CeiEjGOT8HE&ab_channel=Bizagi



Standard AM Processes

Main AM Technologies (ISO/ASTM 52900 Standard)



Main AM Technologies

>> Every technology can be represented by a process

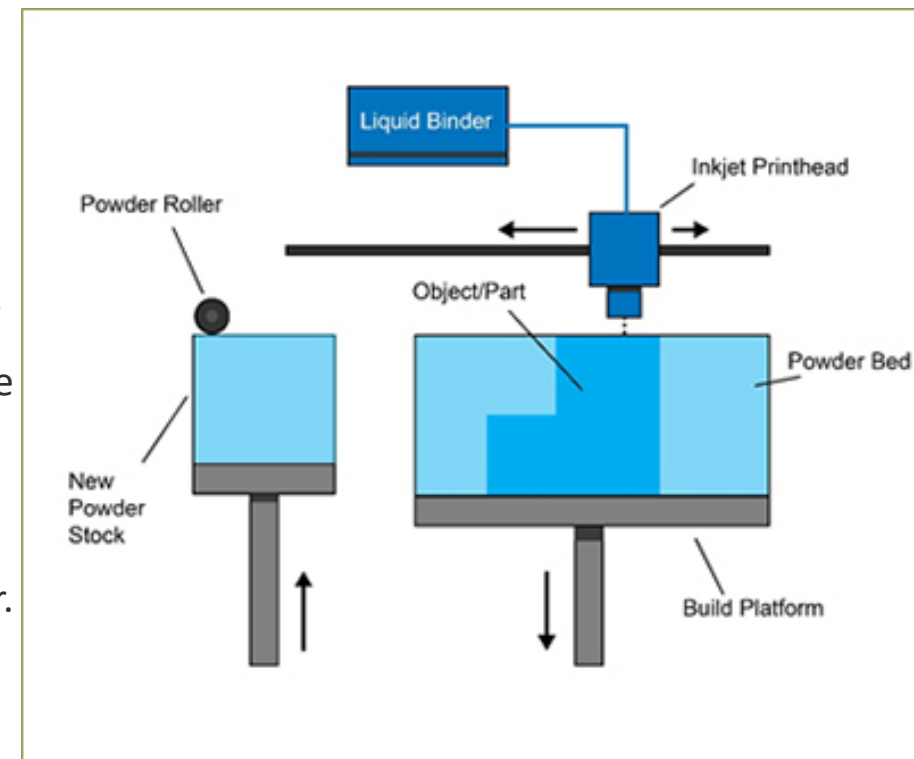
Material jetting,

Additive manufacturing process in which droplets of build material are selectively deposited.

Ex: PP (Polymer jetting)

Steps:

1. Powder material is spread over the build platform using a roller.
2. The print head deposits the binder adhesive on top of the powder where required.
3. The build platform is lowered by the model's layer thickness.
4. Another layer of powder is spread over the previous layer. The object is formed where the powder is bound to the liquid.
5. Unbound powder remains in position surrounding the object.
6. The process is repeated until the entire object has been made.



Main AM Technologies

>> Every technology can be represented by a process

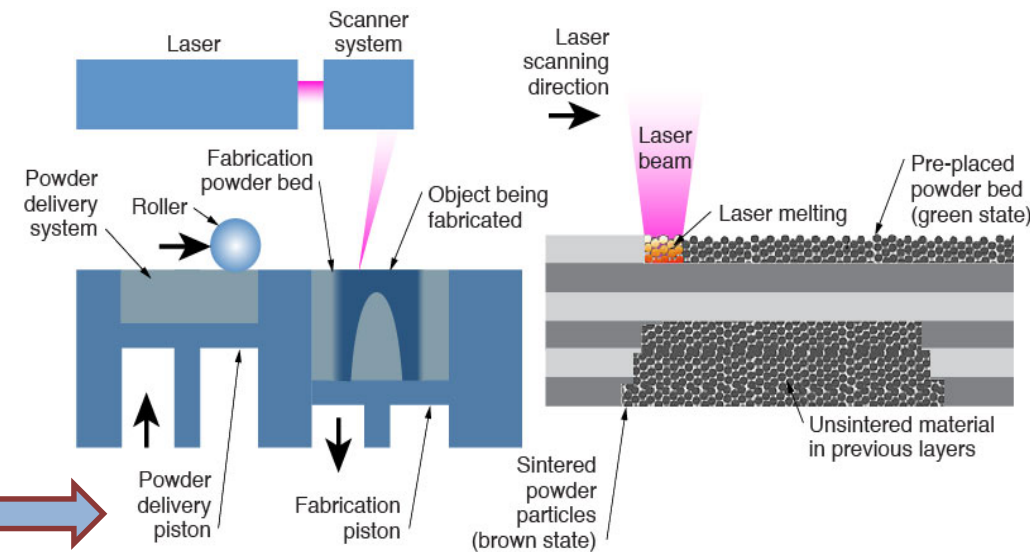
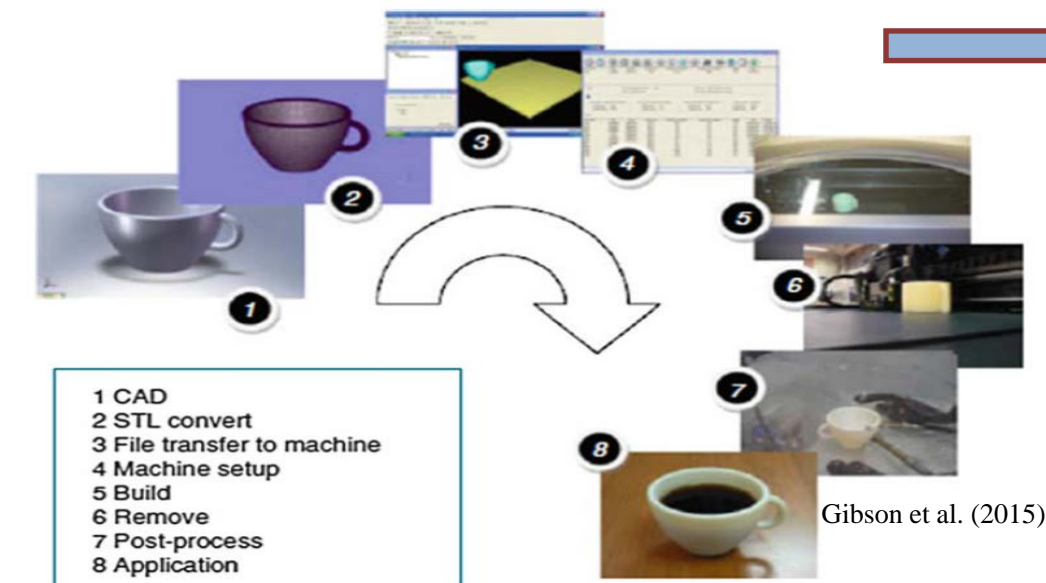
Powder bed fusion

Thermal **energy selectively fuses regions of a powder bed.**

Ex: SLS, SLM, DMLS, SMLM, EBM (Electron Beam)

ASTM (2012)

PBF Process



- A thin layer of powder is spread
- Energy source melts or sinters the powder
- The platform goes down
- The powder is spread for another layer
- The process repeated

Main AM Technologies

>> Every technology can be represented by a process

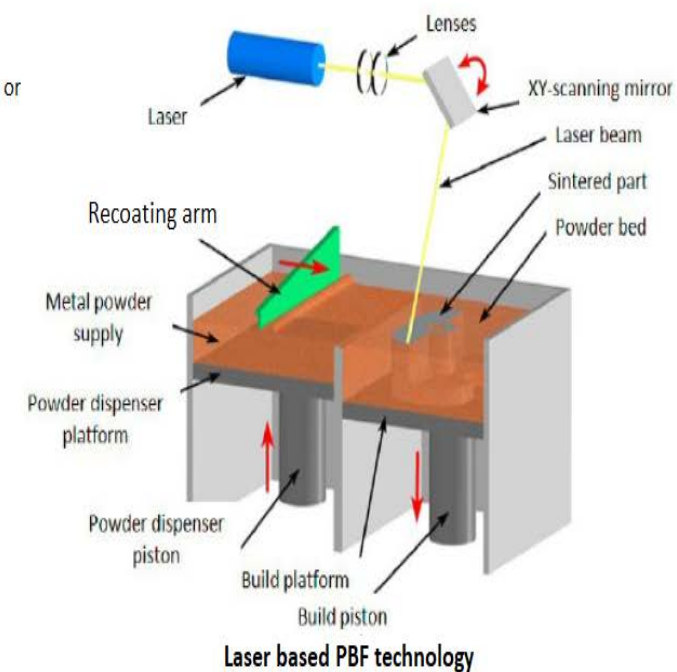
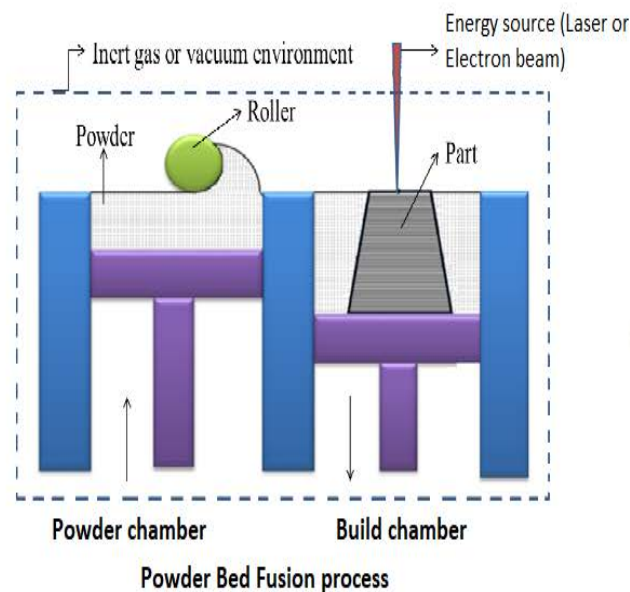
Powder bed fusion

AM process in which thermal energy selectively fuses regions of a powder bed.

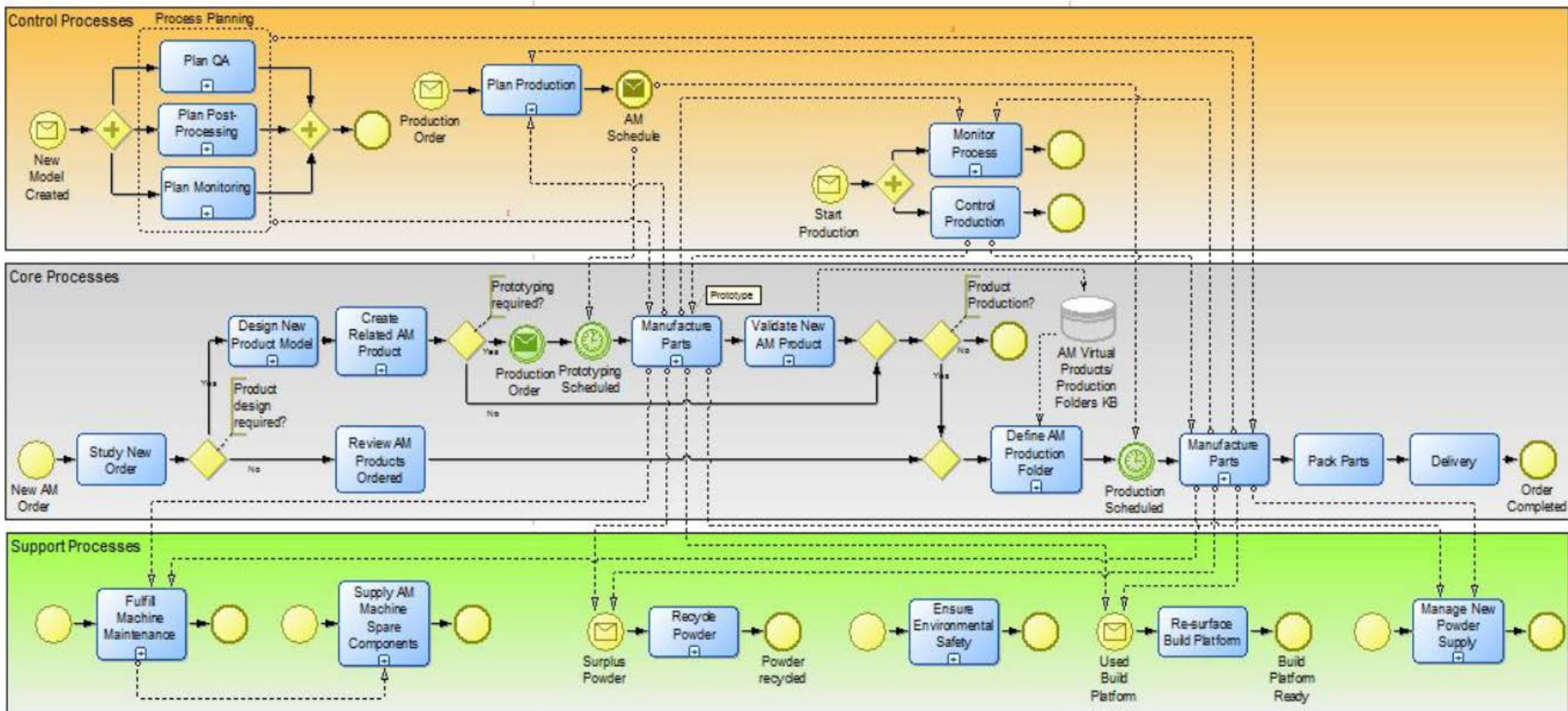
Ex: SLS, SLM, DMLS, SMLM, EBM

Steps:

1. A layer, typically 0.1mm thick of material is spread over the build platform.
2. A laser fuses the first layer or first cross section of the model.
3. A new layer of powder is spread across the previous layer using a roller.
4. Further layers or cross sections are fused and added.
5. The process repeats until the entire model is created. Loose, unfused powder is removed during post processing.

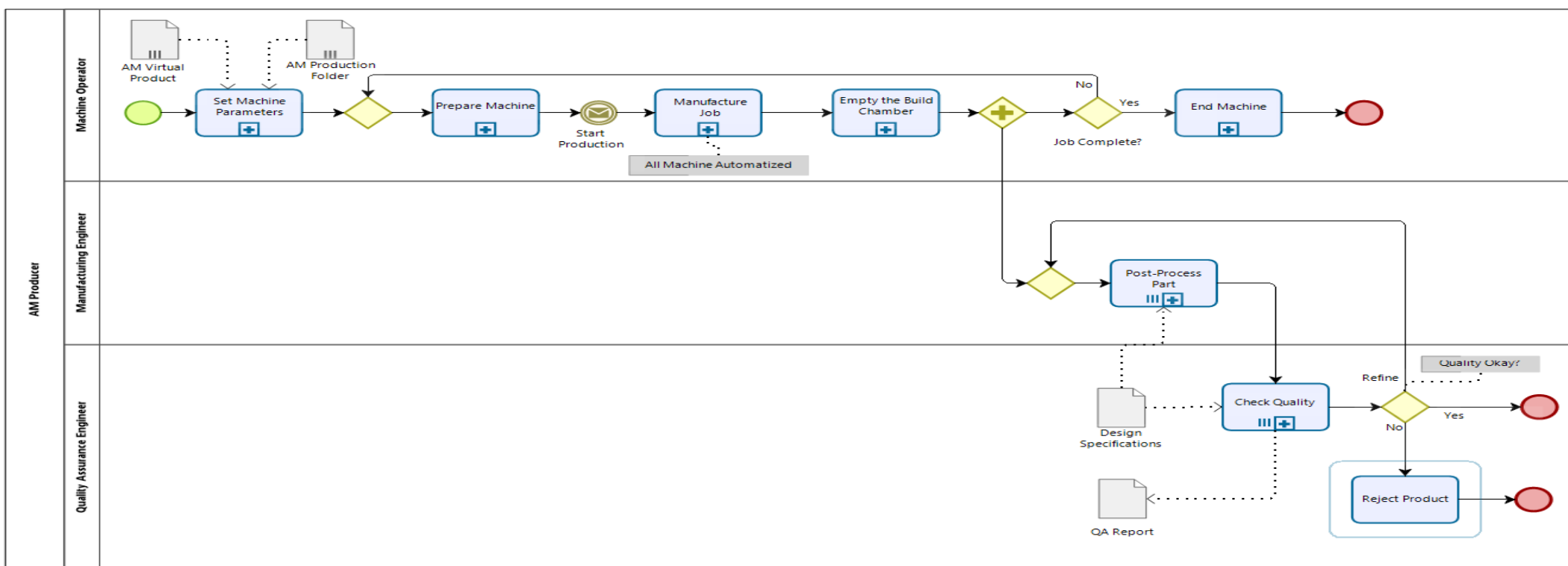


Main AM processes according to value chain model



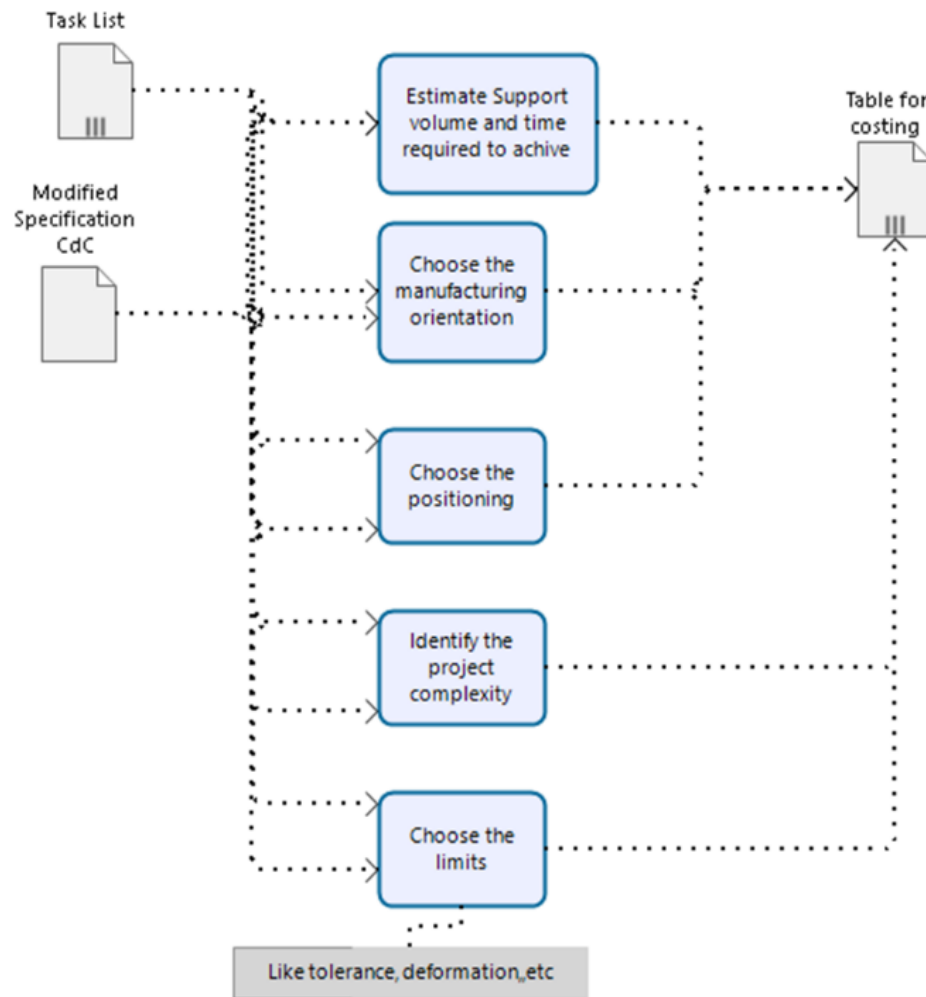
Main AM processes according to value chain model

Generic Process

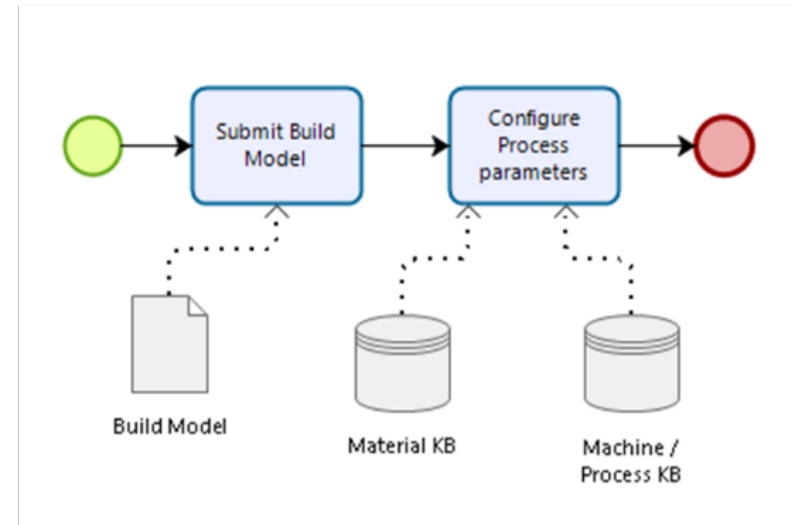


Main AM processes according to value chain model

Define general characteristics and set machine parameters

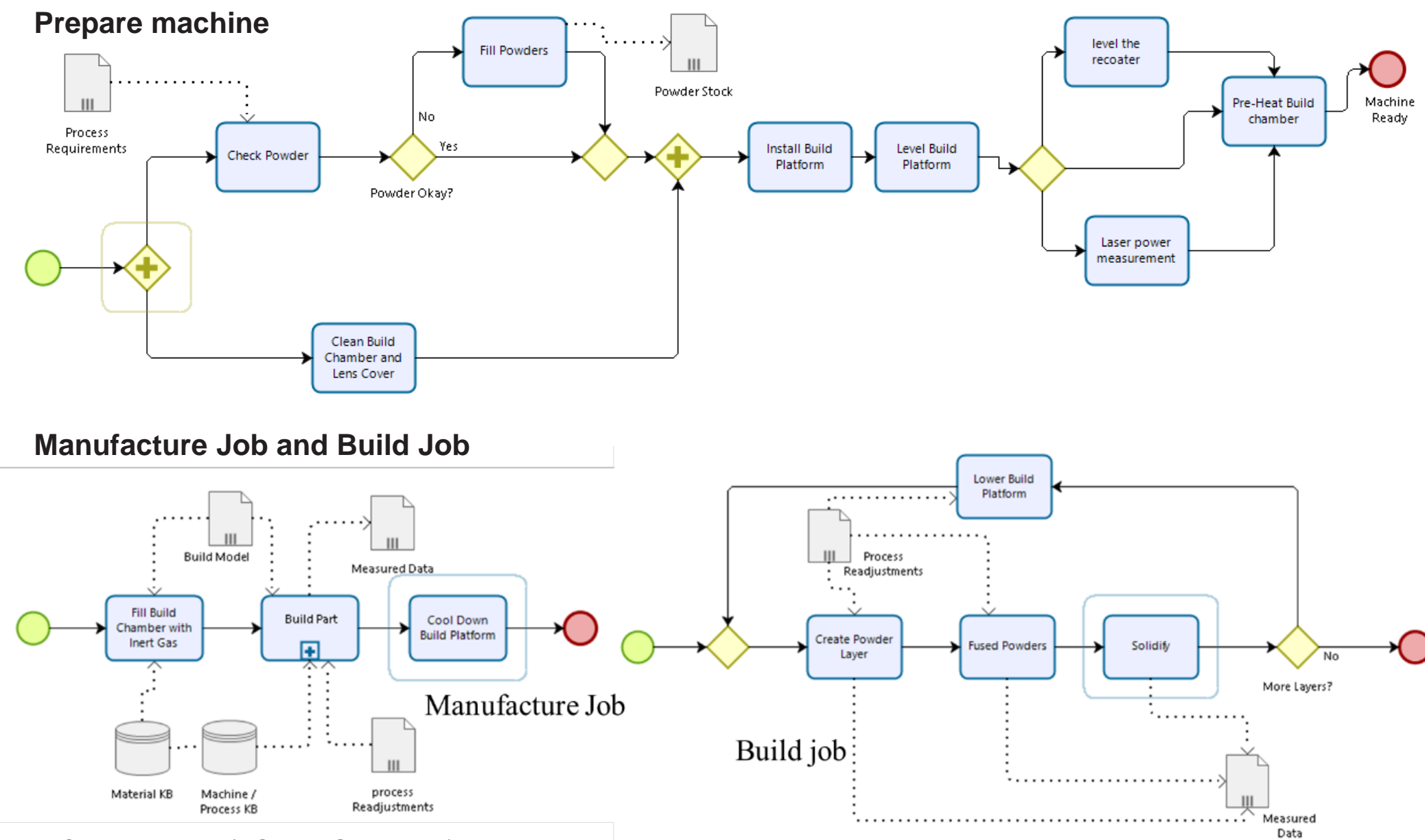


Define general characteristics



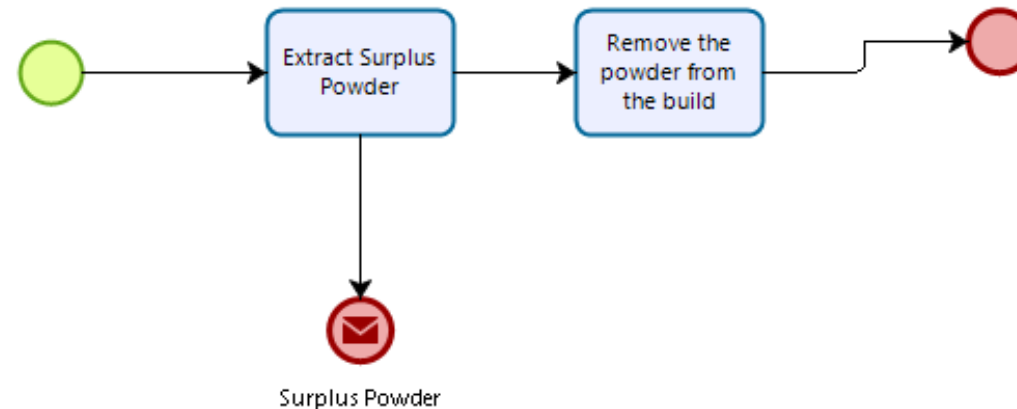
Set machine parameters activity

Main AM processes according to value chain model

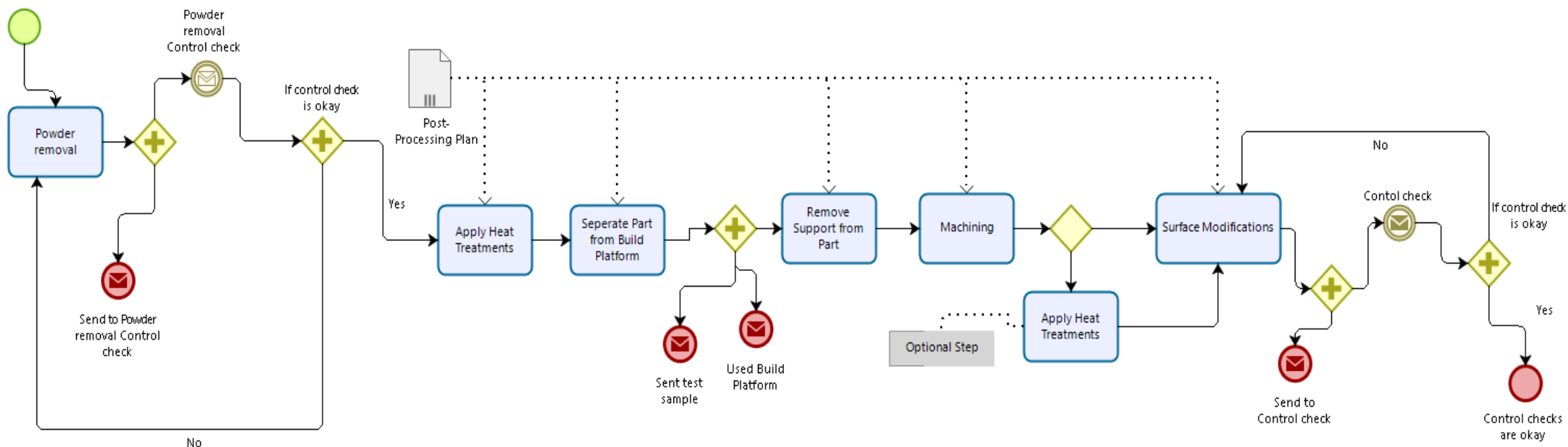


Main AM processes according to value chain model

Machine output treatment



Post Process treatment



Competence Unit Training CU 34 – Process Selection

**Course: AM Cost Evaluation and management based on
process oriented approach (Part 1)**

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