Julia for simulation using a planning model for helping SMEs in Decision Making

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Julia & Optimization days 2024

ADRIA Argumentation Décision Raisonnement Incertitude Apprentissage
Université Toulouse Capitole
iut Rodez Institut Universitaire de Technologie
IRIT Institut de Recherche en Informatique de Toulouse CNRS - INP - UT3 - UT1 - UT2J
Campus des Métiers et des Qualifications d'Excellence Industrie du futur Occitanie

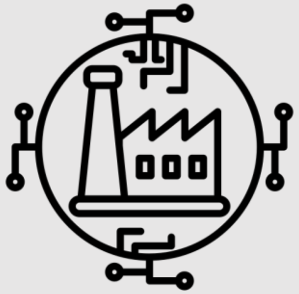
1. introduction
2. top-down decision process in traditional SMEs
3. group decision process
4. production planning model for simulation
5. production planning model
6. focus on an industrial problem
7. perspectives & conclusion

1. introduction

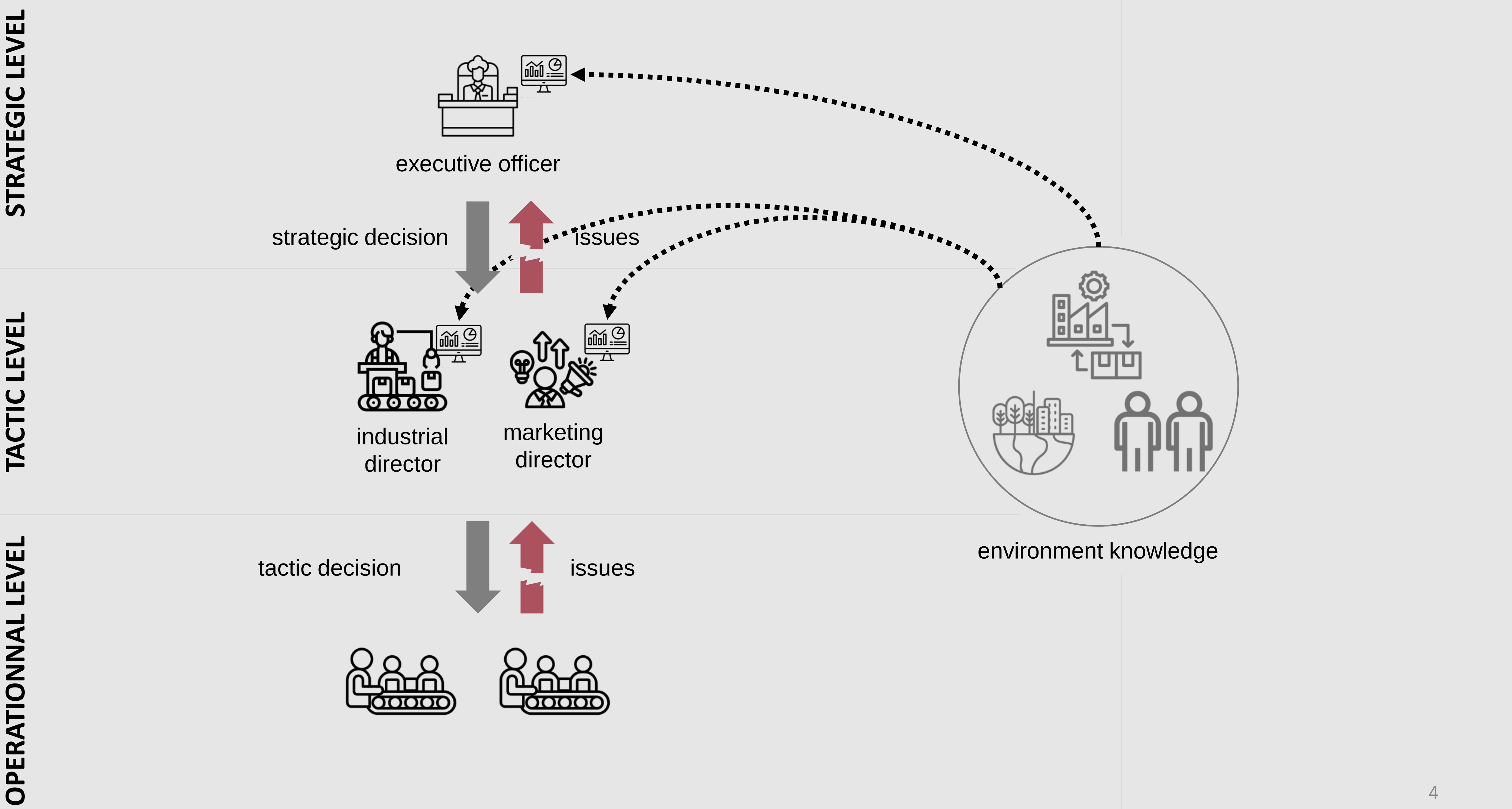
Small and
Medium
Enterprise

Volatile
Uncertain
Complex
Ambiguous

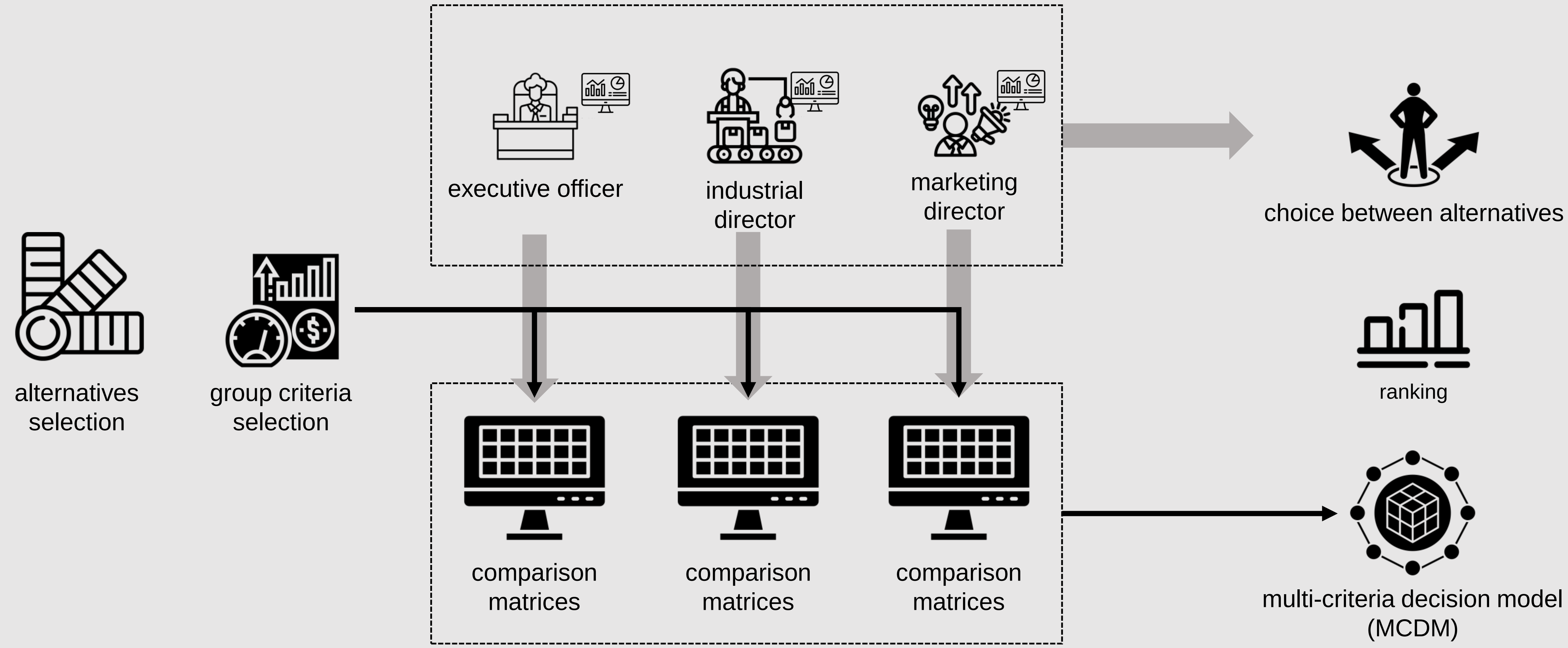
Industry 5.0
solutions



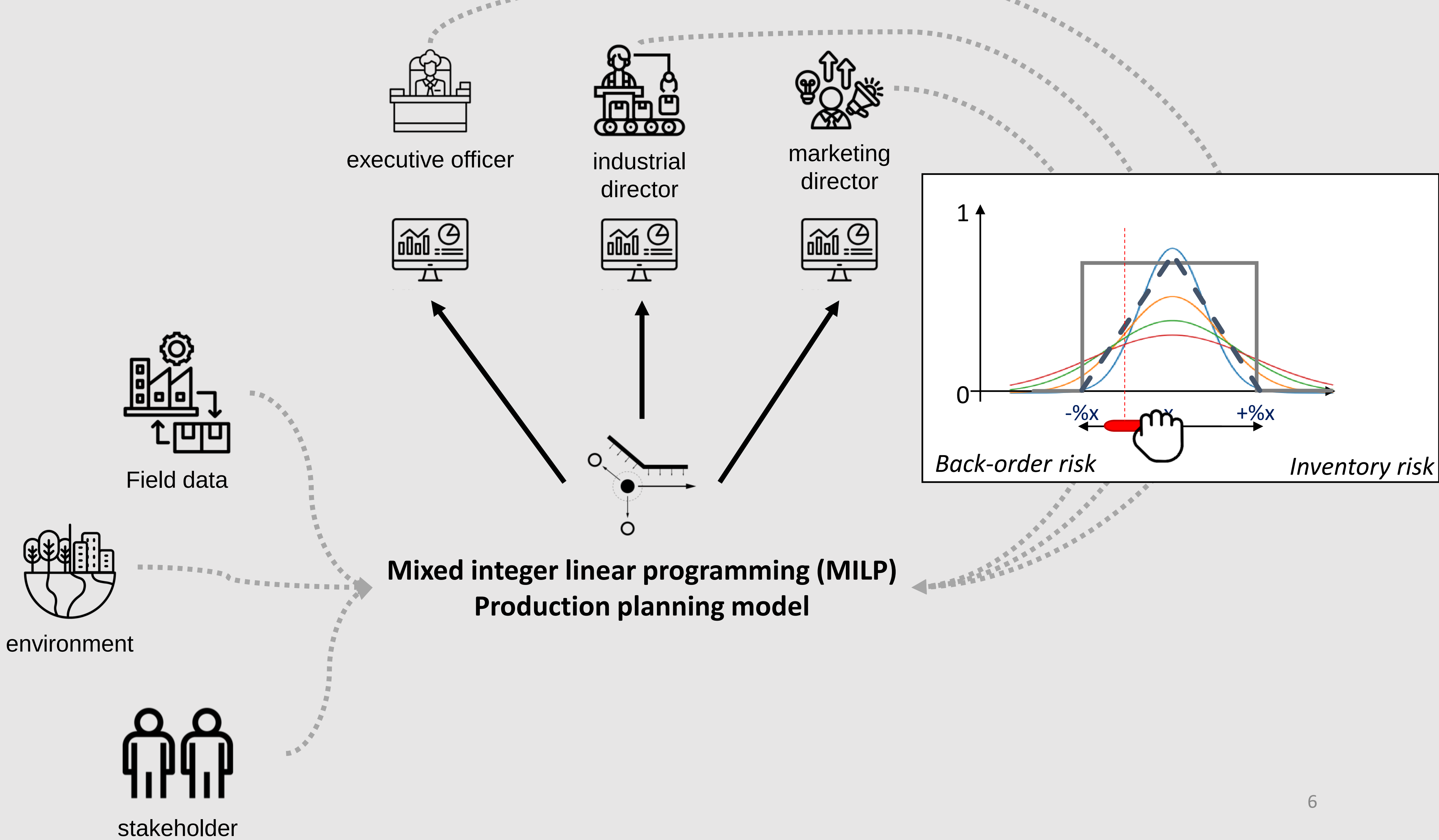
2. top-down decision process in traditional SMEs



3. group decision process



4. production planning model for simulation



5. production planning model

Mixed integer linear programming (MILP)
Production planning model

Optimization model

SIMULATION USE

Cbc (COIN-OR Branch and cut) solver

5. production planning model data

	Uncontrollable parameters
t	*indexes of period*
HP	*total number of periods*
i,j	*indexes of items*
ITEMS	*set of items*
$BOM_{i,j}$	*BOM links between any items,*

	Controllable parameters
$D_{i,t}$	*Demand of any end-items*
r	*indexes of resources*
R	*Sets of resources*
$ROU_{i,r}$	*Usage of resource for each items*
c_i	*unitary cost of a sourced items*
ic_i	*inventory cost*
bc_i	*backorder cost*
rc_r	*resources cost*
C_r	*Capacity of resources*

	Variables
$INV_{i,t} \geq 0$	*inventory of any items*
$BO_{i,t} \geq 0$	*backorder of any items*
$Tr_{i,t} \geq 0$	*Transfert or deliveries of any items*
$X_{i,t} \geq 0$	*supply of any resources, either internal or external*

5. production planning model

$$maximize \sum_{t=1}^{HP}\left[\sum_i pv_i Tr_{i,t} - \sum_i ic_i INV_{i,t} - \sum_i bc_i BO_{i,t} - \sum_i c_i X_{i,t}\right] \quad (1)$$

s.t.

$$INV_{i,t} - BO_{i,t} = INV_{i,t-1} - BO_{i,t-1} + X_{i,t} - \sum_{j \neq i} BOM_{j,i} * X_{j,t} - Tr_{i,t}, \forall i \in ITEMS, \forall j \in ITEMS, \forall t \in \{1:HP\} \quad (2)$$

$$\sum_i ROU_{i,r} * X_{i,t} \leq C_r, \forall t \in \{1:HP\}, \forall r \quad (3)$$

$$Tr_{i,t} + BO_{i,t} = D_{i,t} + BO_{i,t-1}, \forall i \in ITEMS, \forall t \in \{1:HP\} \quad (4)$$

$$Tr_{i,t}, BO_{i,t}, INV_{i,t}, X_{i,t} \geq 0, \forall i \in ITEMS, \forall t \in \{1:HP\} \quad (5)$$

6. focus on an industrial problem

SMEs strategic decision
(planning horizon of one year)

choice between two alternatives: deliveries **aggregated every 15 days** or **continuous deliveries**

3 decider : **Executive officer**, **Marketing director**, and **industrial director**

3 decision criteria	Executive officer	Industrial director	Marketing director
Inventory impact	Global cost	Inventory quantity	Back-order quantity
Corporate Social Responsibility (CSR) performance	CO2e/unit of added value	M3 lost by truck	CO2e/unit of added value
Client satisfaction	Delivery time	Delivery time	Delivery time

KPI for each deciders

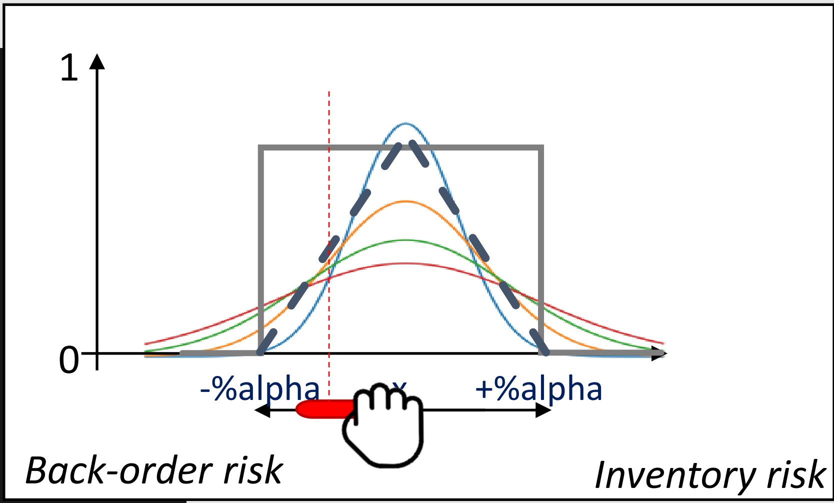
Demand recuperation for each items

```
demand = ReadData(raw".\DataUsine - V2\Dem-i_t.csv")
✓ 1.2s

Dict{Any, Any} with 8 entries:
  "creche"    => [0, 0, 5, 7, 0, 9, 9, 4, 10, 1  …  3, 6, 6, 5, 0, 7, 5, 10, 4,…
  "salon"     => [0, 2, 2, 2, 2, 3, 3, 3, 4, 4  …  2, 3, 2, 1, 2, 2, 1, 2, 1, 2]
  "sdj"       => [0, 5, 4, 3, 2, 1, 0, 0, 0, 0  …  1, 0, 2, 1, 4, 6, 4, 8, 6, 5]
  "chaise"    => [0, 0, 0, 0, 0, 0, 0, 0, 0, 0  …  0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
  "bois_brut" => [0, 0, 0, 0, 0, 0, 0, 0, 0, 0  …  0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
  "vis"       => [0, 0, 0, 0, 0, 0, 0, 0, 0, 0  …  0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
  "table"     => [0, 0, 0, 0, 0, 0, 0, 0, 0, 0  …  0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
  "meuble"    => [0, 0, 0, 0, 0, 0, 0, 0, 0, 0  …  0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
```

First step to take care of human behaviour

```
#-----#Delivery policies#-----#
Alt = [1,2]                                         #Number of alternatives
Cl = [2,1]                                          #Delivery cycle for each policies
tau = 0                                             #Period of the beginning of the plan
n = zeros(Int, maximum(Alt))
for i in 1:length(Alt)
    n[Alt[i]] = HP ÷ Cl[i]                          #Number of horizon splitting
end
DemandeSimu = Dict()
#-----#Human behavior facing uncertainty#-----#
alpha = 1.0
for (key, vecteur) in demand
    DemandeSimu[key] =  alpha .*demand[key]         #Delivery quantity altered by the decider if necessary
end
```



6. production planning model usage

Original forecasted demand

0	2	1		5	6	3	$FD_{\text{item 1}}$
4	5	1	...	2	1	4	$FD_{\text{item 2}}$
1	2	3		6	8	3	$FD_{\text{item 3}}$

Alt 1. Aggregated forecasted demand

0	2	0		6	0	9	$Dem_{\text{alt1,item 1}}$
0	9	0	...	3	0	5	$Dem_{\text{alt1,item 2}}$
0	3	0		9	0	11	$Dem_{\text{alt1,item 3}}$

Alt 2. Continuous forecasted demand

0	2	1		5	6	3	$Dem_{\text{alt2,item 1}}$
4	5	1	...	2	1	4	$Dem_{\text{alt2,item 2}}$
1	2	3		6	8	3	$Dem_{\text{alt2,item 3}}$

6. production planning model usage

Demand aggregation depending on the alternative for each items

$$\boldsymbol{Cl} = \{\boldsymbol{Cl1}, \boldsymbol{Cl2}, .., \boldsymbol{CLn}\}$$

Delivery cycle for each alternative in period of time

$$\boldsymbol{FD_{i,t}}, \forall \boldsymbol{i} \in \boldsymbol{ITEMS}, \forall \boldsymbol{t} \in \{\boldsymbol{1}: \boldsymbol{HP}\}$$

The forecasted demand is aggregated in function of each alternative:

$$\boldsymbol{n_{Alt}} = \frac{\boldsymbol{HP}}{\boldsymbol{CL_{Alt}}}, \forall \text{Alt} \in \{1;2\}$$

Number of aggregations in the planning horizon for each alternative

$$\boldsymbol{EC_{Alt,i,d_{Alt}*CL_{Alt}}} = \sum_{t=(d_{Alt}-1)*CL_{Alt}}^{t=d_{Alt}*CL_{Alt}} \boldsymbol{FD_t}, \forall \boldsymbol{d_{Alt}} \in \{\boldsymbol{1}; ..; \boldsymbol{n_{Alt}}\}$$

$EC_{Alt,i,t}$ *represent the delivery plan for each alternative, items and period*

For each alternative, a demand $D_{i,t}$ equal to the delivery plan for each alternative is extract and treated by the model:

$$\boldsymbol{D_{i,t}} = \boldsymbol{EC_{Alt,i,t}} \ \forall \boldsymbol{i} \in \boldsymbol{ITEMs}, \forall \boldsymbol{t} \in [\boldsymbol{1}: \boldsymbol{HP}]$$

6. production planning model usage

Bills of Materials

Row	Column1	creche	salon	sdj	chaise	table	meuble	vis	bois_brut
	String15	Int64	Int64	Int64	Int64	Int64	Int64	Int64	Int64
1	creche	0	0	0	8	2	1	0	0
2	salon	0	0	0	4	2	2	0	0
3	sdj	0	0	0	10	0	3	0	0
4	chaise	0	0	0	0	0	0	4	1
5	table	0	0	0	0	0	0	4	1
6	meuble	0	0	0	0	0	0	6	2
7	vis	0	0	0	0	0	0	0	0
8	bois_brut	0	0	0	0	0	0	0	0

Routes between product and resources

Row	Column1	assemblage	production	supplier
	String15	Int64	Int64	Int64
1	creche	1	0	0
2	salon	1	0	0
3	sdj	1	0	0
4	chaise	0	1	0
5	table	0	1	0
6	meuble	0	1	0
7	vis	0	0	1
8	bois_brut	0	0	1

Resources capacity

Row	Ressource	capacity
	String15	Int64
1	assemblage	50
2	production	120
3	supplier	99999

Items sourcing cost

Row	ITEMS	cost
	String15	Int64
1	creche	2
2	salon	1
3	sdj	3
4	chaise	1
5	table	2
6	meuble	2
7	vis	3
8	bois_brut	2

Items backorder cost

Row	ITEMS	cost
	String15	Int64
1	creche	100
2	salon	100
3	sdj	100
4	chaise	0
5	table	0
6	meuble	0
7	vis	0
8	bois_brut	0

Items sale price

Row	ITEMS	saleprice
	String15	Int64
1	creche	1000
2	salon	1000
3	sdj	1000
4	chaise	0
5	table	0
6	meuble	0
7	vis	0
8	bois_brut	0

Items inventory cost

Row	ITEMS	cost
	String15	Int64
1	creche	5
2	salon	5
3	sdj	5
4	chaise	5
5	table	5
6	meuble	5
7	vis	5
8	bois_brut	5

6. production planning model

$$maximize \sum_{t=1}^{HP}\left[\sum_i pv_i Tr_{i,t} - \sum_i ic_i INV_{i,t} - \sum_i bc_i BO_{i,t} - \sum_i c_i X_{i,t}\right] \quad (1)$$

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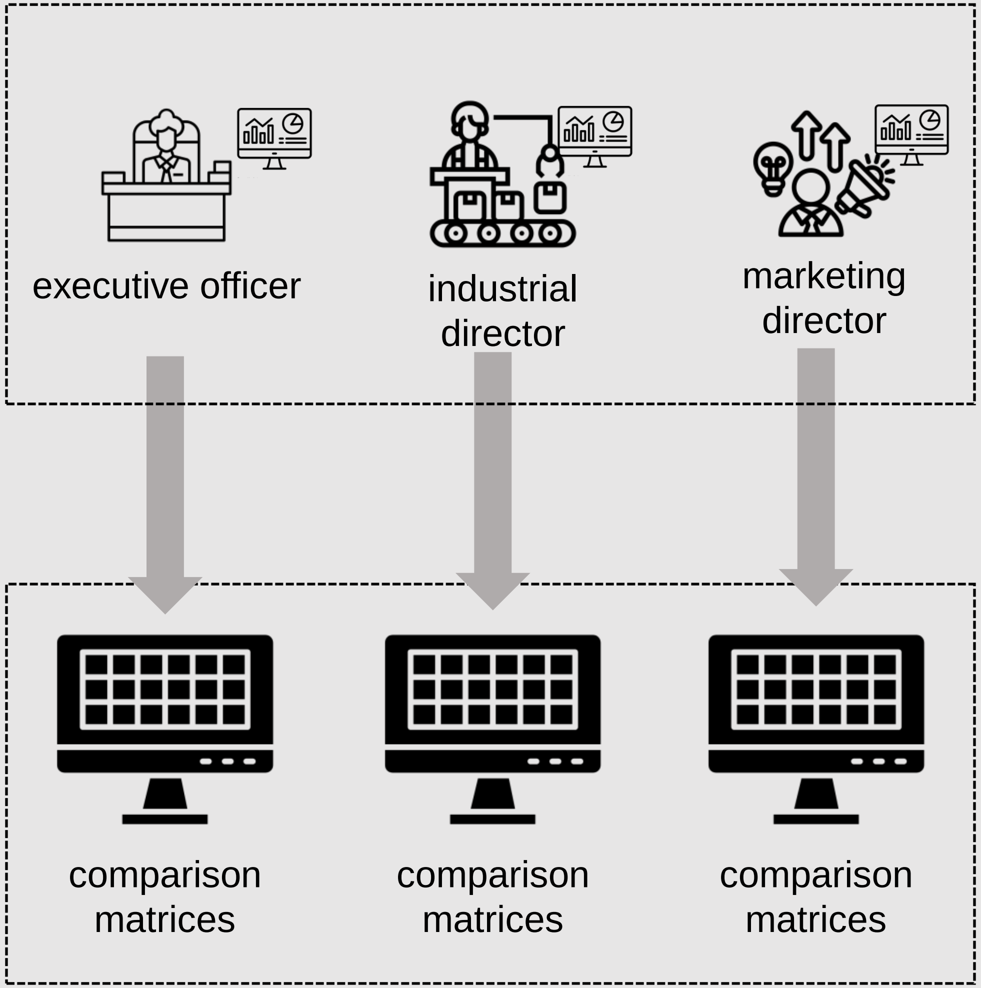
6. production planning model usage

	Executive officer	Industrial director	Marketing director
Inventory impact	**Global inventory cost** $\sum_t INV_{i,t} * ic_i + BO_{i,t} * bc$	**Inventory quantity** $\sum_t INV_{i,t}$	**Back-order quantity** $\sum_t BO_{i,t}$
Corporate Social Responsibility (CSR) performance	**CO2e/unit of added value** $\sum_t \sum_i (\frac{D_{i,t}}{CT}) * 772$	**M3 lost by truck** $\sum_t \sum_i \left(\frac{D_{i,t}}{CT}\right) * CT - D_{i,t}$	**CO2e/unit of added value** $\sum_t \sum_i \frac{D_{i,t}}{CT} * 772$
Client satisfaction	**Delivery time** $\overline{FD_{i,t} - D_{i,t}}, \forall i \in ITEMs, \forall t \in \{1: HP\}$	**Delivery time** $\overline{FD_{i,t} - D_{i,t}}, \forall i \in ITEMs, \forall t \in \{1: HP\}$	**Delivery time** $\overline{FD_{i,t} - D_{i,t}}, \forall i \in ITEMs, \forall t \in \{1: HP\}$

6. production planning model usage

	Executive officer	Industrial director	Marketing director
Inventory impact	**Global inventory cost** ALT.1 : 93 211 euros ALT.2 : 95 744 euros	**Inventory quantity** ALT.1 :514 end–items + 40 produced items ALT.2 :834 end–items + 603 produced items	**Back-order quantity** ALT.1 :309 end–items ALT.2 :21 end–items
Corporate Social Responsibility (CSR) performance	**CO2e/unit of added value** ALT.1 :172.6 CO2e/UVA ALT.2 :184.9 CO2e/UVA	**M3 lost by truck** ALT.1 :0,52 m3 ALT.2 :0,825 m3	**CO2e/unit of added value** ALT.1 :172.6 CO2e/UVA ALT.2 :184.9 CO2e/UVA
Client satisfaction	**Delivery time** ALT.1 :1,49 week ALT.2 : <1 week	**Delivery time** ALT.1 :1,49 week ALT.2 : <1 week	**Delivery time** ALT.1 :1,49 week ALT.2 : <1 week

6. production planning model usage



AHP METHOD PROCESS

1. Matrices aggregation

$$a_{i,j} = \frac{1}{n} * (a_{dec1} + \cdots + a_{decn}) \quad (6)$$

2. Matrices normalization

$$a_{i,j}^{norm} = \frac{a_{i,j}}{\sum_{i=1}^{n} a_{i,j}} \quad (7)$$

3. Computation of priority vector

$$w_i = \frac{1}{n} \sum_{j=1}^{n} a_{i,j}^{norm} \quad (8)$$

4. Consistency ratio

5. Ranking of alternatives

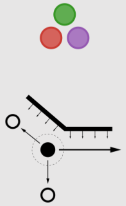
The analytic hierarchy process—what it is and how it is used – Saaty, 1987

AHP Method implemented in Julia result

```
Poids des critères : [0.3333333333333333, 0.3333333333333333, 0.3333333333333333]
Taux de cohérence pour le critère 1 : NaN
Taux de cohérence pour le critère 2 : NaN
Taux de cohérence pour le critère 3 : NaN

Classement final des alternatives :
Alternative : Alternative 2, Poids : 0.5020163109214799
Alternative : Alternative 1, Poids : 0.49798368907852

Matrices pour chaque critère :
Matrice  pour le critère 1:
[1.0 1.289231989389298; 0.7756555904835206 1.0]
Matrice  pour le critère 2:
[1.0 2.7144176165949063; 0.36840314986403866 1.0]
Matrice  pour le critère 3:
[1.0 0.25; 3.9999999999999996 1.0]

Matrices normalisées pour chaque critère :
Matrice normalisée pour le critère 1:
[0.5631722758396489 0.5631722758396489; 0.43682772416035104 0.43682772416035104]
Matrice normalisée pour le critère 2:
[0.7307787913959111 0.7307787913959111; 0.2692212086040889 0.2692212086040889]
Matrice normalisée pour le critère 3:
[0.2 0.2; 0.7999999999999999 0.8]

Vecteurs de priorités pour chaque critère :
Critère 1: [0.5631722758396489, 0.43682772416035104]
Critère 2: [0.7307787913959111, 0.2692212086040889]
Critère 3: [0.2, 0.8]
```

7. perspectives

Take care of the human behavior facing uncertainty



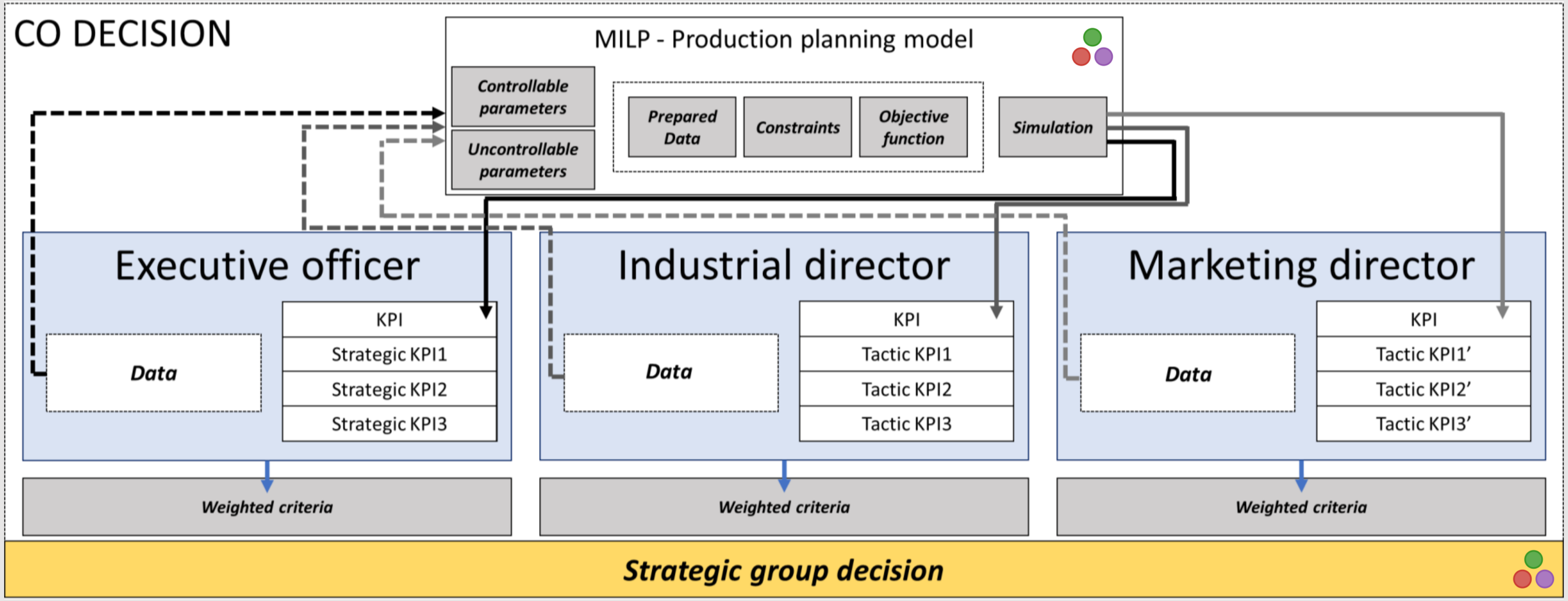
Improve our model and use it with a user interface tool

Implement different decision support systems

?

Solutions you use ?

7. conclusion



Julia for simulation using a planning model for helping SMEs in Decision Making

Thanks !

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- **GDNICDSST 2024 : Poster –** *"Preference Selection Dashboard for SMEs in Industry 5.0: Integrating Data from Varied Hierarchical Levels and Simulating Diverse Behaviors facing Uncertainty"*
- **EURO Journal on Decision Process 2024 : Article -** *"Adapting SMEs to the Challenges of Industry 4.0 and 5.0: a preference selection framework integrating Data from Varied Hierarchical Levels" (submitted)*

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