


# Integrating Ethical Risks into Performance Management in Industry 4.0:

## *Conceptual and Managerial Challenges*

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Supported by

# THE ETHICS 4.0 PROJECT

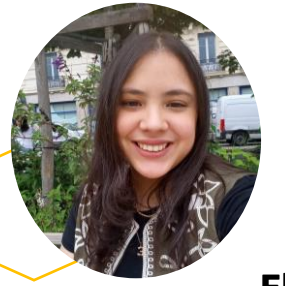
Ethics 4.0

Ethical risk management in the Industry of the Future

A multidisciplinary team that aims to develop guidelines and tools to support the **management of ethical risks in industry**, by **continuously improving industrial performance**

## Project partners

Université Polytechnique HAUTS-DE-FRANCE · LAMIH UMR CNRS 8201 · cnrs · Université Savoie Mont Blanc · LISTIC · UGA Université Grenoble Alpes · CERAG Université Grenoble Alpes · NTN



**Development of a performance management and continuous improvement model, integrating ethical risks into the industrial systems of the future**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# Preliminary observations (1/2)

**Sustainable performance** is **not** just performance that achieves its **techno-centric objectives…**




**…but performance achieved in an ethical way**

# Preliminary observations (2/2)

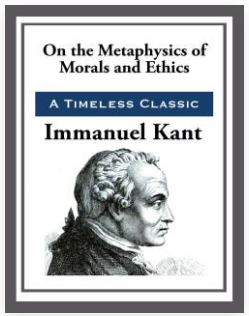
## Ethics in industry and business is a relatively recent concern built on a millennia-old philosophical concept

**PHILOSOPHICAL ROOTS**








**BUSINESS & REGULATORY FRAMEWORKS**





**c. 1754 BC** — Code of Hammurabi

**c. 380 BC** — Plato

**c. 340 BC** — Aristotle

**1785** — Kant

**2010** — ISO 26000

**2016** — GDPR

**Yet, practical and operational frameworks remain scarce, apart from a few general guidelines such as CSR and GDPR**

# Presentation Objective

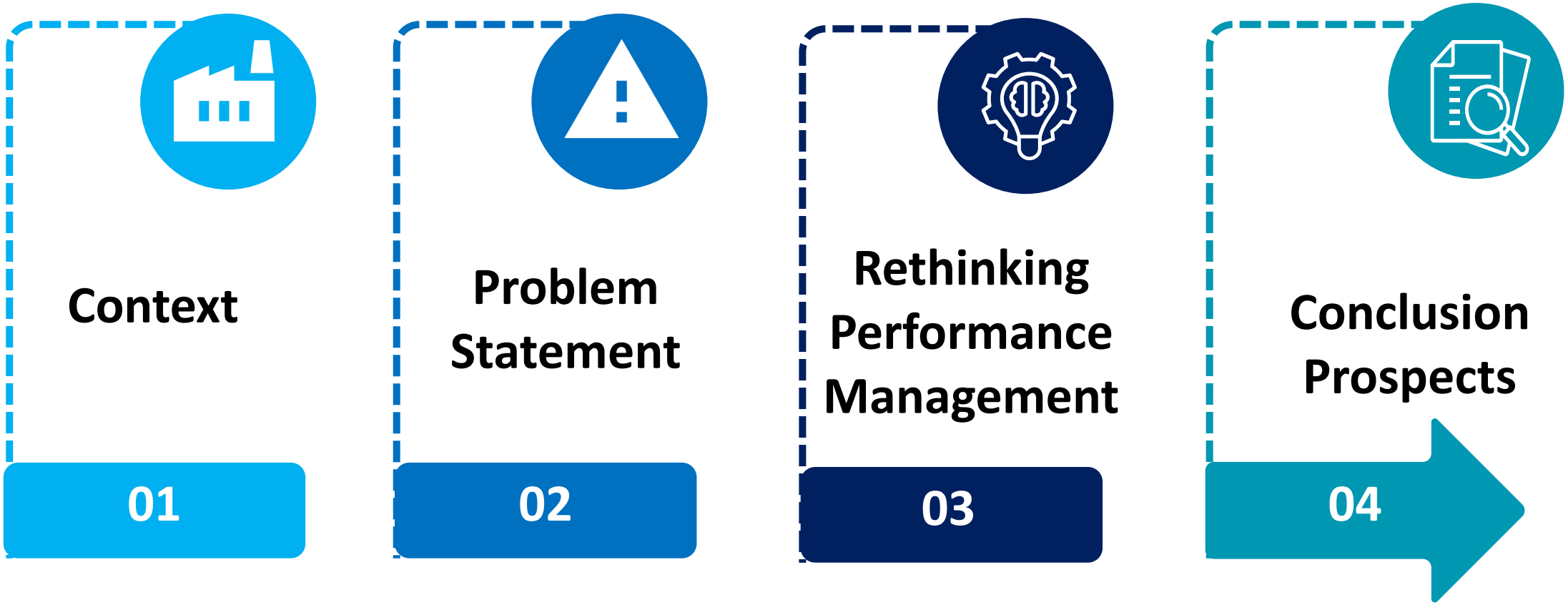
➡ Share a few thoughts

**How can ethics be concretely integrated into current industrial 4.0 performance management to ensure sustainability?**






# Outline


Context
01
Problem Statement
02
Rethinking Performance Management
03
Conclusion Prospects
04

# 01
## Context

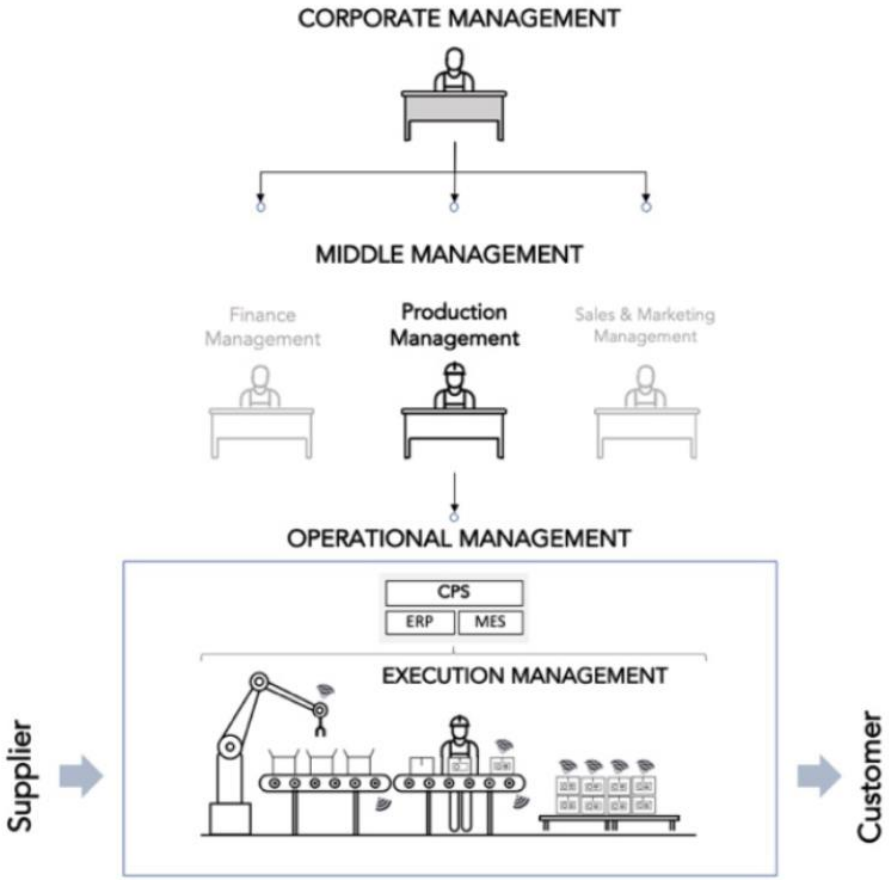


***Performance Management in Industry 4.0***

# CONTEXT - Management point of view

Levels

## Enterprise structural organization



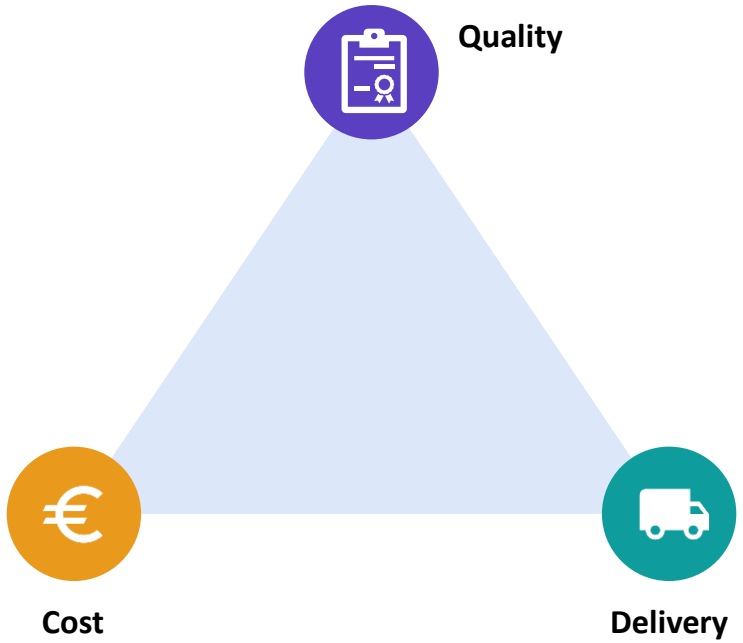

| Decision-making characteristics | Impact caused by decision-making |
|---|---|
| **Strategic decision-making**<br>a) Full and general knowledge<br>b) Broad scope capability<br>c) Coordination-based decisions<br>d) Aggregated information<br>e) Gradual decision implementation | • Society and government<br>• City and population<br>• Company stakeholders<br>• Middle and operational management |
| **Tactical decision-making**<br>a) Focused and partial knowledge<br>b) Limited scope capability<br>c) Planned-based decisions<br>d) Semi-aggregated information<br>e) Directly decision implementation | • Same company and partners<br>• Other middle management departments<br>• Operational management<br>• Employees, supervisors and operators |
| **Operational decision-making**<br>a) Specified and complete knowledge<br>b) Narrow scope capability<br>c) Scheduled-based decisions<br>d) Sparse information<br>e) Promptly decision implementation | • Production management<br>• Supply chain functioning<br>• Assembly line and workstations<br>• Supervisors and operators |
| **Real-Time decision-making**<br>a) Detail and limited knowledge<br>b) Instruction scope capability<br>c) Condition-based decisions<br>d) Limited and binary information<br>e) Instantly decision implementation | • Production functioning<br>• Supplier and customer interaction<br>• Human-machines interaction<br>• Operators and users |

*(Jimenez et al., 2022)*

# Performance Management principles

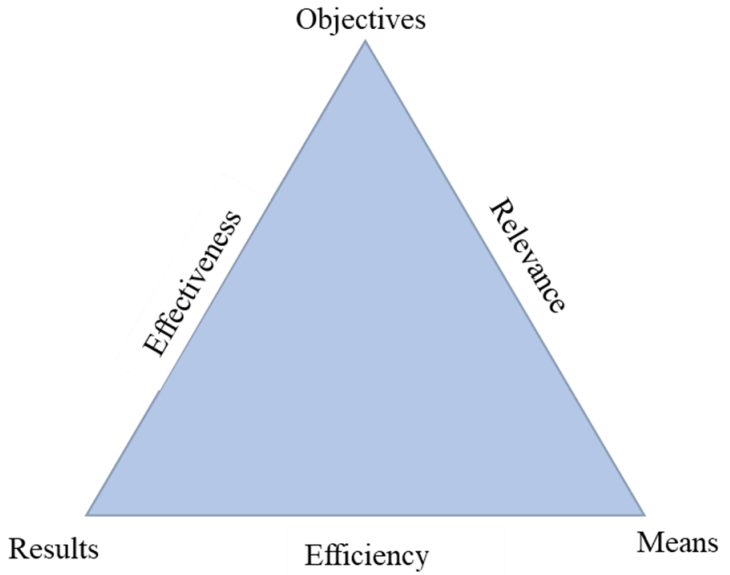
## Performance :

### Cost - Quality - Delivery (C-Q-D)




*(Hayes & Wheelwright, 1984; Slack et al., 2016)*

### Efficiency-Effectiveness-Relevance (E-E-R)




*(Gilbert, 1980)*

- Efficiency of means vs. objectives achievement
- Effectiveness in objectives achievement
- Relevance of objectives vs. means

# CONTEXT - Technical point of view

## Performance Management principles

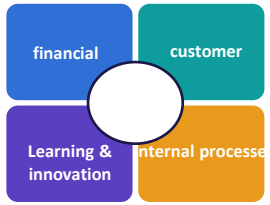
### Management:

**Performance management**

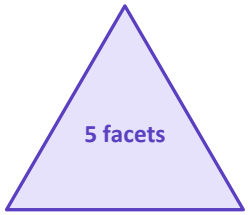
*relies on*

**Performance Management Systems**

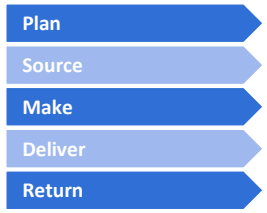
as structuring frameworks




BSC




Performance Prism



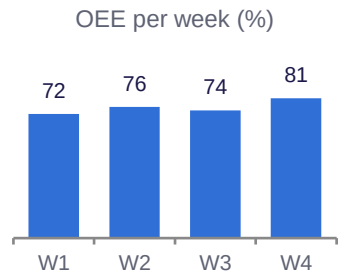

SCOR

*(Kaplan & Norton, 1992; Neely et al., 2002; Drucker, 1954)*

**Performance Measurement Systems**

PIs as evaluation tools: KPIs, dashboards






*(Neely et al., 1995)*

**Continuous improvement**

Management loop

Lean Management




*(Deming, 1986)*

**Performance Indicator (PI)**

Compares a measurement with an objective to steer action

- **O** — **Objective** expected state
- **M** — **Measurement** objectively achieved results
- **V** — **Action variable** actions to reach the objective

(Berrah, Foulloy & Clivillé, 2018)

# From Automated to Connected Industrial systems (1/2)

| TECHNOLOGIES | CAPABILITY | PERFORMANCE MANAGEMENT EVOLUTION |
|---|---|---|
| **IoT** *Xu et al., 2014* | Real-time data acquisition and monitoring | *From periodic measurement to* **Continuous** monitoring & traceability |
| **AI & Data Analytics** *Lee et al., 2018* | Prediction, optimization, automated decisions | From Reactive to Predictive, data-driven management |
| **Digital Twins** *Tao et al., 2019* | Simulation and virtual testing of scenarios | **Prediction** |
| **Robotics & Cobots** *Villani et al., 2018* | Automation and human-machine collaboration | Technical performance **beyond human capabilities** and Productivity |
| **Generative AI** *Dwivedi et al., 2023* | Knowledge synthesis, assistance, scenario generation | AI-assisted, knowledge-based decisions |

# From Automated to Connected Industrial systems (2/2)

| TECHNOLOGIES | CAPABILITY | PERFORMANCE MANAGEMENT EVOLUTION |
|---|---|---|
|  **Flexible Manufacturing Systems** *ElMaraghy, 2005* | Rapid adaptation to product variety and demand | **Flexibility**, **Reactivity**, **Agility** |
|  **Additive Manufacturing** *Ngo et al., 2018* | Customized products and small-batch production | **Customization** and production flexibility |
|  **Cloud & Integrated Platforms** *Xu, 2012* | Data sharing and integration across organisations | Collaborative and SC oriented Performance |
|  **Cybersecurity** *Culot et al., 2019* | Protection of connected systems and industrial data | **New Performance data-related criteria**: integrity, transparency |

# CONTEXT - Technical point of view

**What changes for performance management?**

- New technical capabilities
- From Reactive Performance Management to

**Reactive** **Real-time** **Predictive** **Flexible** **Connected** **Traceable** **Data-driven**

management

- Performance criteria related to data and … humans

# CONTEXT - Ethical point of view

## Ethical benefit

A positive effect of a technology on ethical values: it protects or strengthens people's safety, dignity, autonomy, fairness and well-being, and the interests of society and the environment.

Safety
Responsibility
Consistency
Fairness
Transparency
Sustainability

## Ethical issue (risk)

A negative effect, or risk of harm, that a technology may cause to these same values: harm to people, violation of rights, unfair treatment, loss of control or of meaning at work.

Surveillance
Privacy
Job Loss
Misinformation
Opacity
Dependency
Lack of motivation
Loss of control

*(Trentesaux & Caillaud, 2020; HLEG AI, 2019)*

# CONTEXT - Ethical point of view

| | Ethical benefits | Ethical risks |
|---|---|---|
|  **IoT** *Ball, 2010; Trentesaux & Caillaud, 2020* | **Transparency**; traceability of products and processes; **Responsibility** | Employee **Surveillance**; **Privacy**; **Misuse** of collected data |
|  **AI & Data Analytics** *Mittelstadt et al., 2016* | Evidence-based decisions; anomaly detection; Human **errors reduction** | Algorithmic **Bias**; lack of transparency; **Discrimination**; **Over-reliance** on automated decisions |
|  **Digital Twins** *Trentesaux & Caillaud, 2020* | **Safer testing** and decision-making; **Less physical experimentation** | **Dependence** on models and **data** quality; **Misuse** of simulations |
|  **Robotics & Cobots** *Pfeiffer, 2016; Villani et al., 2018* | **Dangerous** and **Repetitive** tasks **reduction** ; **Workplace Safety** | Job **Displacement**; **Deskilling**; **Work Intensification** |

# CONTEXT - Ethical point of view

| | Ethical benefits | Ethical risks |
|---|---|---|
| **Generative AI** *Dwivedi et al., 2023; Bender et al., 2021* | Knowledge sharing; Decision support; **Cognitive workload reduction** | **Misinformation**; **Opaque decision-making**; **IP** and data **privacy** |
| **Flexible Manufacturing Systems** *Kadir & Broberg, 2021* | **Adaptation** to customer needs; **Reactivity** | **Increased pressure** for flexibility; **Unpredictable workloads**; **Job Insecurity** |
| **Cloud & Integrated Platforms** *Ivanov & Dolgui, 2021* | **Visibility** of suppliers; better **Monitoring** of social and environmental practices | Increased **Dependence** on suppliers; **Data-sharing risks**; **Shared responsibility** |
| **Cybersecurity** *Culot et al., 2019; Ball, 2010* | **Protection** of data, systems and stakeholders; **increased trust** and resilience | **Employee Monitoring**; **Data access** and control; **Cyber-attacks** and **Disruption** |

# CONTEXT - Ethical point of view

**Industry 4.0 technologies can provide ethical benefits in performance management**

**These benefits are not systematic**

**depending on how the technologies are….**

 **Designed**

 **Implemented**

 **Used**

 **Governed**

# 02

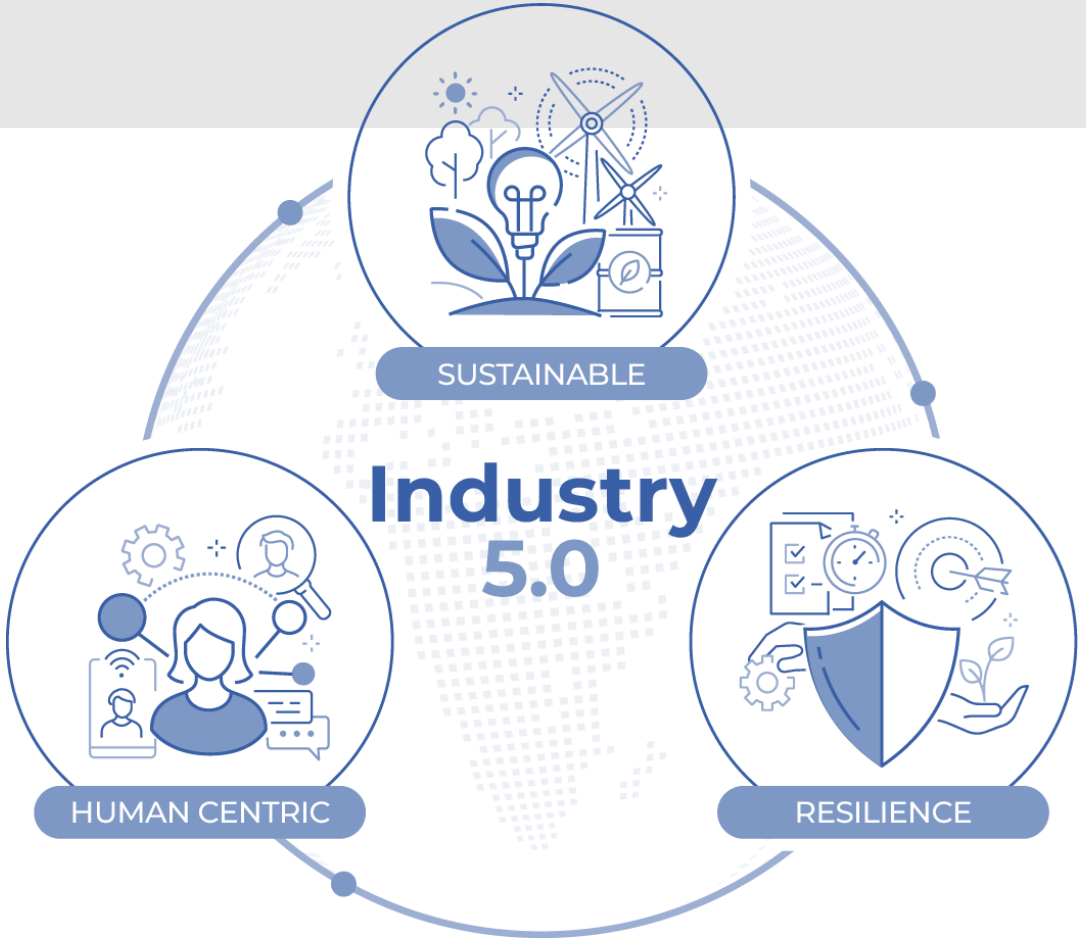
## Problem Statement



# Problem Statement (1/4)

"**Industry 5.0** complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a **transition to a sustainable**, **human-centric** and **resilient** European industry"

*Breque et al, (2021)*




**Awareness** of the ethical **risks** associated with technology in industrial performance management
Emphasis on a more human-centric approach

**Strategic and overall guidelines exist (EU GDPR, ISO standard)… but remain general, not operational**

# Problem Statement (2/4)

**Techno-centric short-term performance**

**Long-term performance?**

**Human involvement**

- Loss of skills
- Lack of innovation

**Loss of control of the industrial systems**

**Resource limitations**

# Problem Statement (3/4)

## Ethics as a solution:




- To enhance human involvement
- To broaden the performance management perspective

# Problem Statement (4/4)

**Even though academics and industrialists are aware of these ethical issues….**

**Their consideration, anticipation, or management, for industrial process production, at the operational level, remains unresolved.**



**Urgent need to revisit the operational industrial performance management model, currently focused on optimizing short-term performance, to leverage Industry 4.0 technologies in a way that ensures long-term performance while preserving human well-being.**

# 03

# Rethinking Performance Management

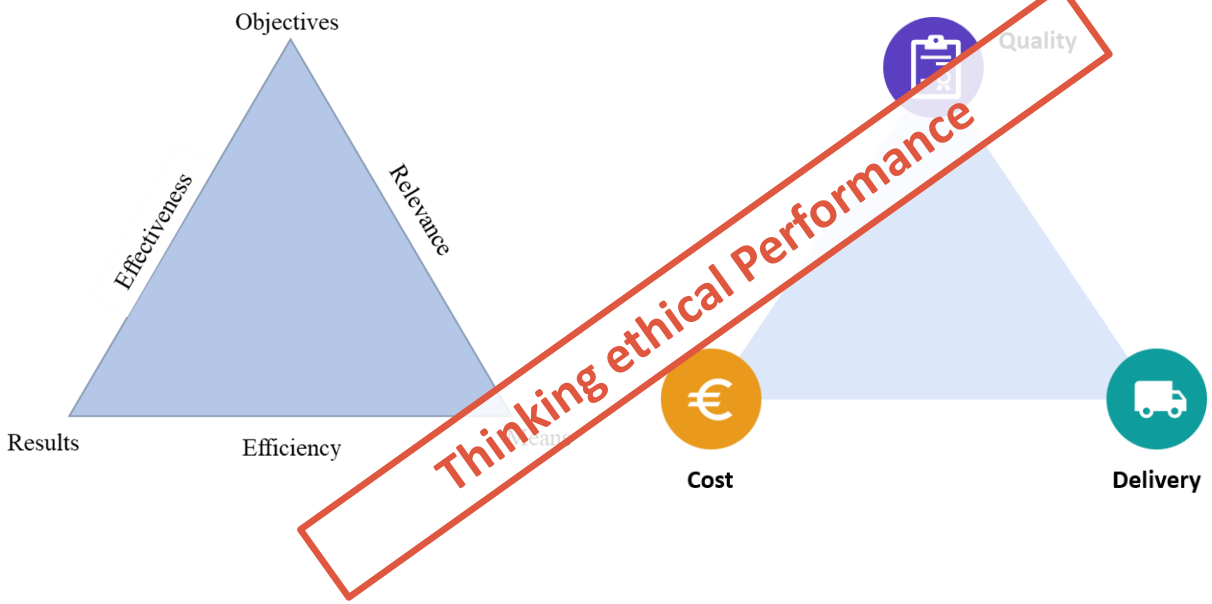


***Thinking ethical performance and ethical management***

# PERFORMANCE MANAGEMENT PRINCIPLES

## Performance

### Efficacy-Efficiency-Effectiveness (E-E-R)

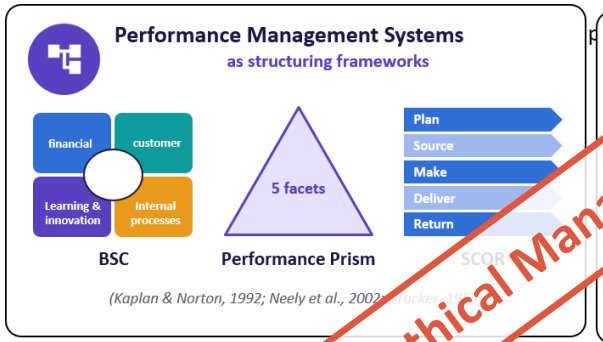


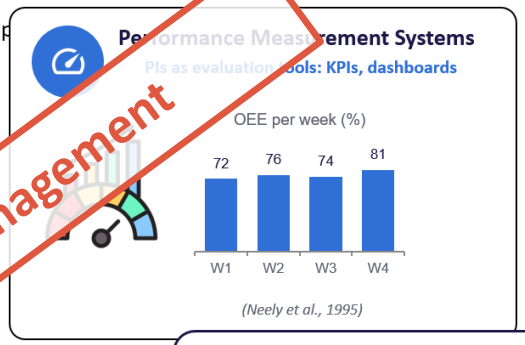

### Cost - Quality - Delivery (C-Q-D)

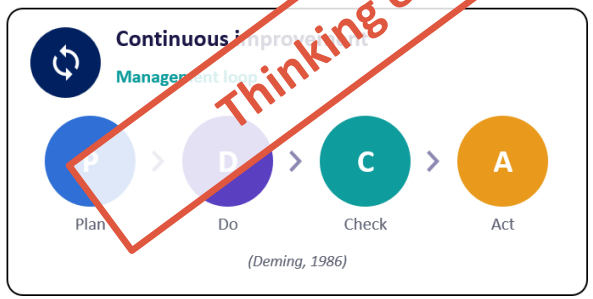



Thinking ethical Performance

## Management




**Performance Indicator (PI)**

Compares a measurement with an objective to steer action

- **O** — **Objective** expected state
- **M** — **Measurement** objectively achieved results
- **V** — **Action variable** actions to reach the objective

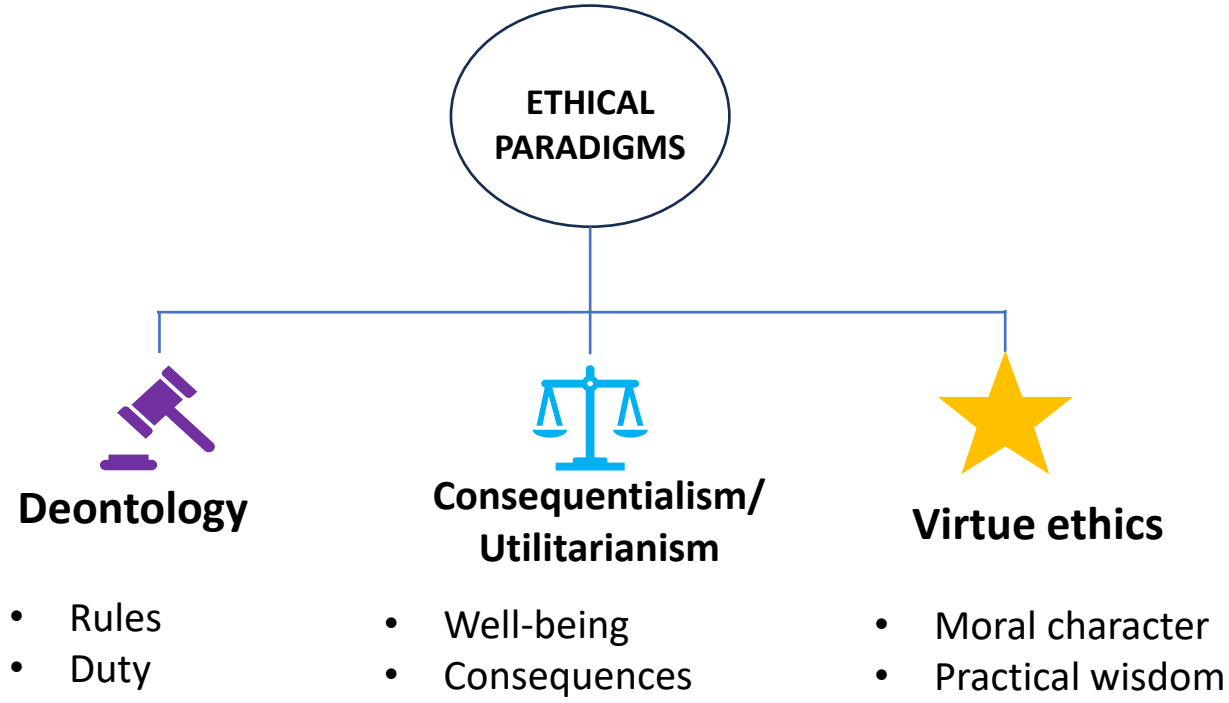
(Berrah, Foulloy & Clivillé, 2018)

Thinking ethical Management

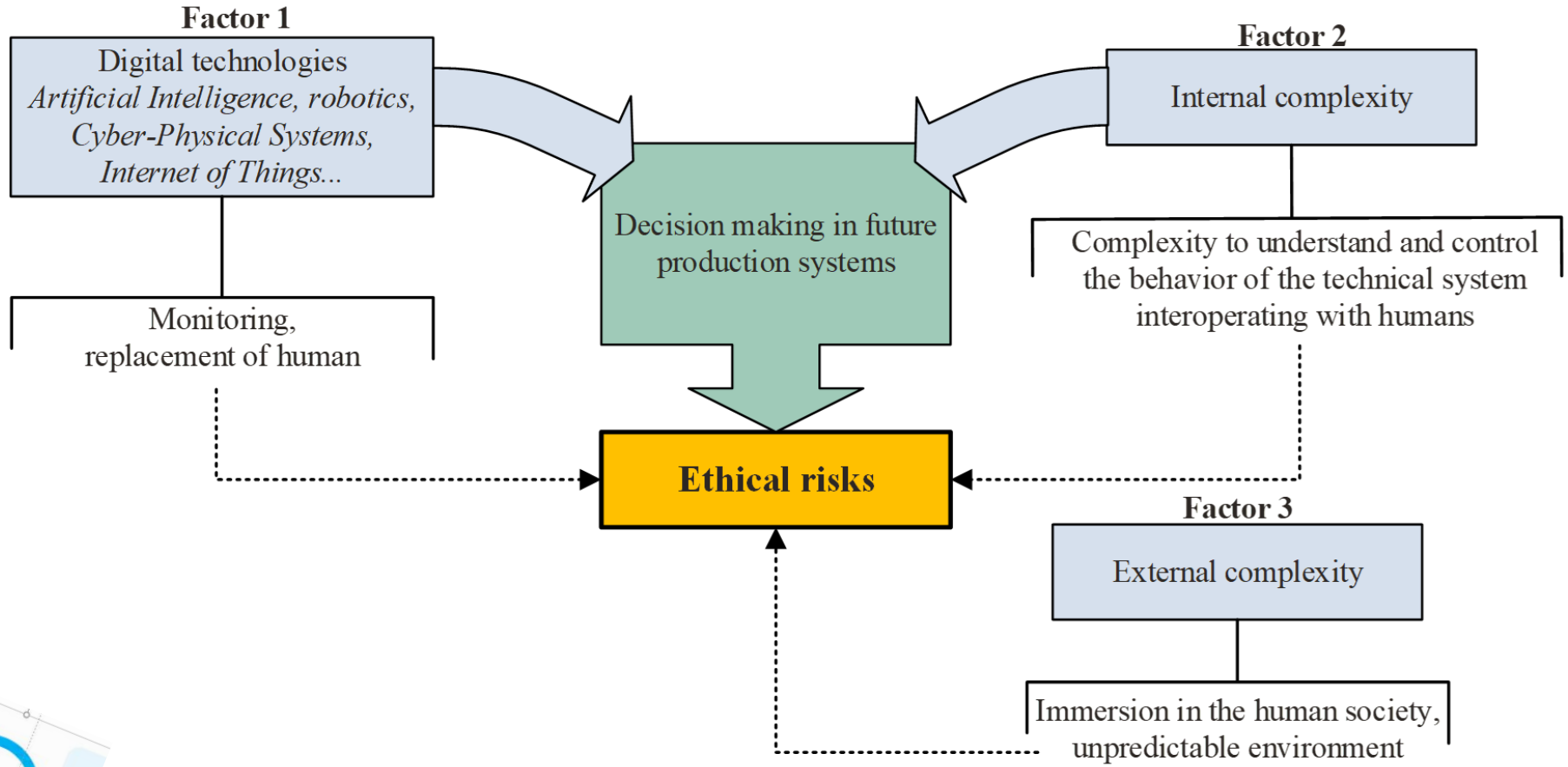
# Ethics Definition and Paradigms

**“A good life, with and for others, in fair institutions.“** Paul Ricœur (1990)

- Reflects on how to act appropriately in (complex) situations.
- It questions the meaning, purpose, and consequences of our decisions.



# Ethical risks – Engineering approach





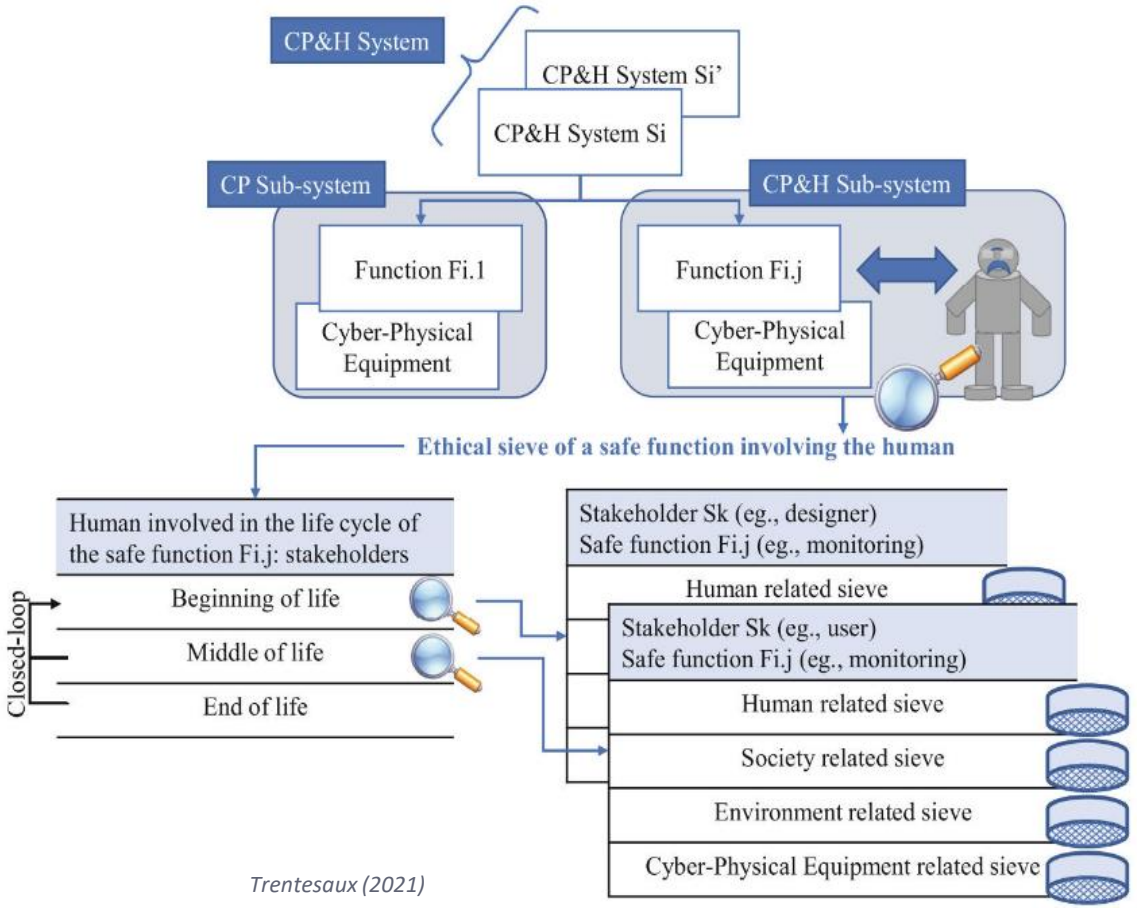


*(Berrah et al., 2020)*

**Techno-engineering approach: ethics in using advanced technologies in industrial systems**

# Risk-based vision of ethics - Engineering approach

"Is the function safe?" → "Does this function safe induce ethical risks?"




*Trentesaux (2021)*

**1. DECOMPOSE**

*Safe function $F_{ij}$ of each sub-system*

**2. FILTER WITH 4 SIEVES**

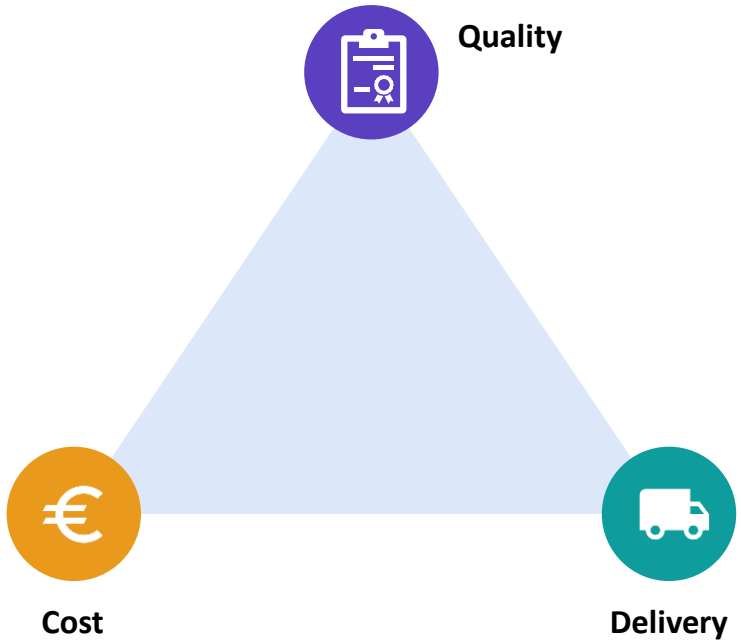
yes/no questions · one YES ⇒ analysis

**3. ANALYSE THE RISK**

- past experience & data
- abnormal situations
- internal/external deviations

# Ethical Performance Management principles

## Cost - Quality - Delivery (C-Q-D)




*(Hayes & Wheelwright, 1984; Slack et al., 2016)*

*Berrah et al. (2021).*

## Cost - Quality - Delivery- ETHICS (C-Q-D-E)



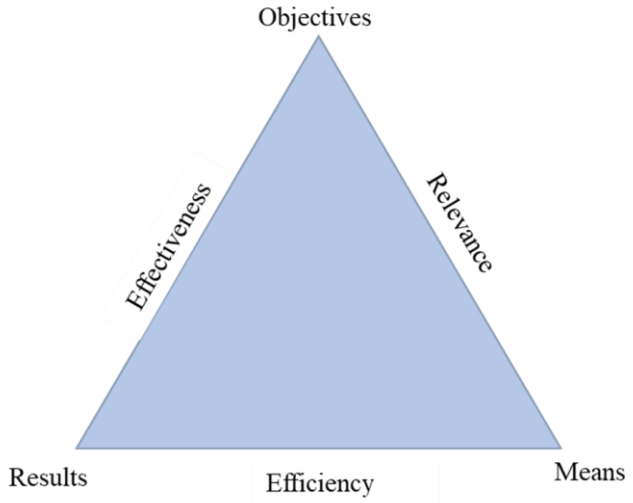

**Adding ethical PIs :**

- Ethical reports number
- Alert resolution rate
- Incidents of discrimination or harassment;
- Compliance with regulations
- Employee satisfaction and well-being
- Environmental impact

*(Berrah & Trentesaux, 2021, Azapagic and Perdan 2000)*

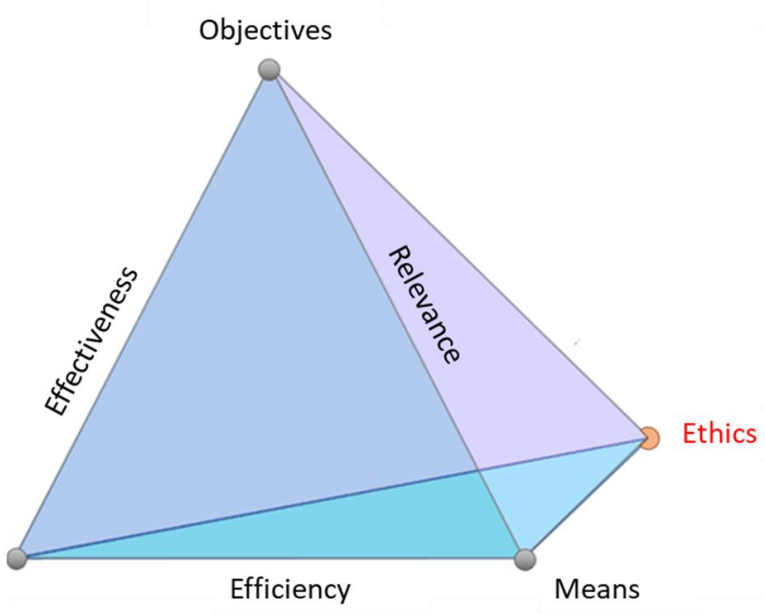
# Ethical Performance Management principes

## Efficiency-Effectiveness-Relevance




*(Gilbert, 1980)*

## Efficiency-Effectiveness-Relevance-Ethics

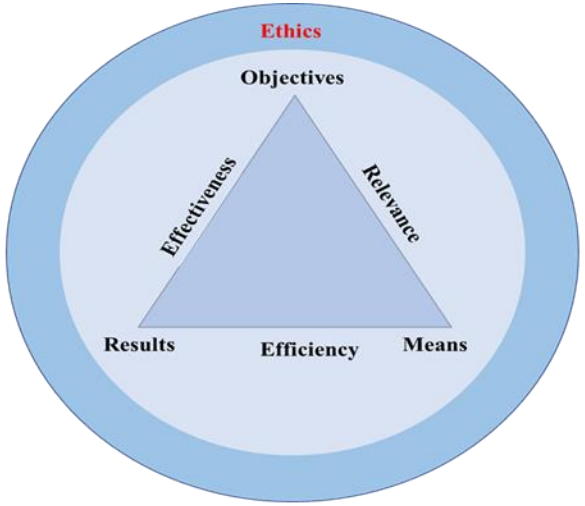



*(Berrah et al., 2021)*

- ✓ **Ethics** and effectiveness in achieving **ethical** objectives
- ✓ Efficient and **ethical** use of available and **ethical** means
- ✓ **Ethics** and relevance of objectives vs. means and results

# Ethical Performance Management principes

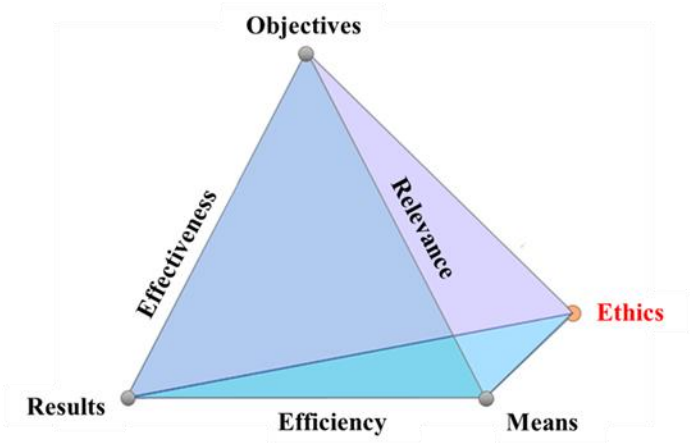
## Weak and Strong views of ethics




**Strong view**

No compensation

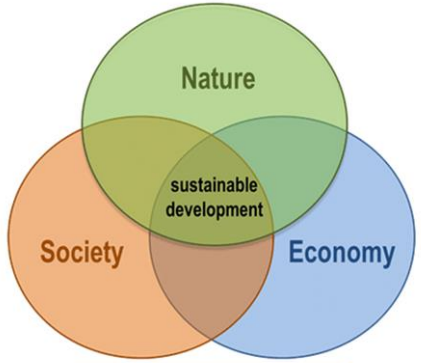
Ethics before, EER after when ethics is fulfilled




**Weak view**

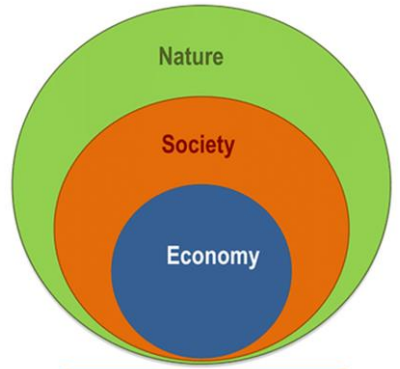
Possible compensation

A lower level of ethics vs. better effectiveness e.g.




**Weak sustainability**

Based in Brundtland 1987.




**Strong sustainability**

Giddings 2002.

Analogy with weak / strong sustainability

**Defining Ethics Maturity and Readiness**

*[Berrah et al., 2024]*

# From PIs to E-PIs

**E-PI:** a PI that expresses performance obtained under ethical conditions

$$E\text{-}PI = (O_e , M_e , A_e)$$

**Performance Indicator (PI)**
Compares a measurement with an objective to steer action

- **O** — **Objective** expected state
- **M** — **Measurement** objectively achieved results
- **V** — **Action variable** actions to reach the objective

(Berrah, Foulloy & Clivillé, 2018)

## 1 Identify ethical risks

**Ethical situation** observed or anticipated

**Ethical sieves** PDCA step × system component

**Risk** what · who · when



## 2 Link risk ↔ PI → E-PI

**Which** criterion? element (O, M, A)? use of the PI?

**Adjust the triplet** deontological rule or utilitarian adjustment



## 3 Apply & interpret

**Compare** classical PI vs E-PI



**Blocked** | **Adjusted** | **Validation**

**Mitigated:** standardized as a rule (deontology)

**Not mitigated:** back to step 1, what-if analysis (utilitarianism)

- **Objective:** limits on target values
- **Action:** acceptable actions only
- **Measurement:** ethical data acquisition

**Managing Performance with E-PIs ➔ (PI, E-PI) Gap analysis**

# From PIs to E-PIs

## The Ethical Overall Equipment Effectiveness (E-OEE) - **Proof of concept**

**E- OEE** is based on the **principle** that **performance should be evaluated not only by final results, but also by the conditions under which those results are achieved**

| Dimension | Classical Losses (OEE) | Ethical Losses (E-OEE) |
|---|---|---|
| **Availability** | Breakdowns, changeovers, and technical failures | Omitted breaks, unsafe environments, operation under fatigue, or unmitigated risks |
| **Performance** | Speed losses, micro-stops | Unrealistic work rates, insufficient training, and psychological stress |
| **Quality** | Defects, rework, scrap | Non-traceable inspections, pressure to validate, rushed or unsupervised quality controls |

**E-OEE=**



**Ethical Availability** x **Ethical Performance** x **Ethical Quality**

*(Ojeda Mena et al., 2025)*

# E-OEE - illustrative calculation

***Shift of 440 min scheduled, 20 min changeover, 20 min breakdown, 10 min adjustment, ideal rate 120 pieces/h (0.5 min/piece)***

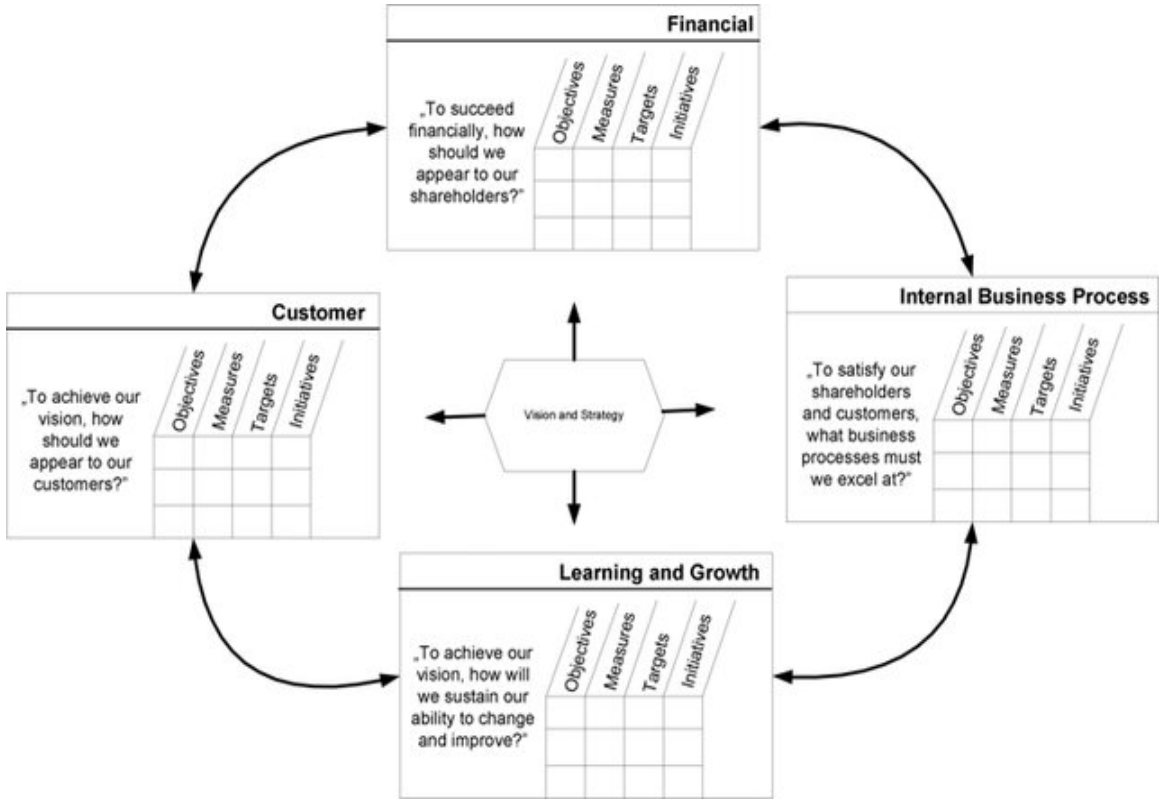
| | Classical OEE | E-OEE | Ethical losses made visible |
|---|---|---|---|
| **Availability** | 390/ 440 = 88.6 % | 360 / 440 = 81.8 % | +10 min break for working conditions, +20 min machine set-up break |
| **Performance** | 0.5 × 600 / 390 = 76.9 % | 0.5 × 486 / 360 = 67.5 % | realistic cycle time 0.74 min/piece → 486 pieces instead of 600 |
| **Quality** | 582 / 600 = 97.0 % | 438 / 486 = 90.1 % | 15 parts not validated under pressure, 10 with traceability doubts, 5 withdrawn without procedure |
| **E-OEE = Ae × Pe × Qe** | **66.1 %** | **49.7 %** | **−16.4 points:** part of the classical performance is obtained under ethically problematic conditions. |

(Ojeda Mena et al., 2025)

# From PMS to E-PMSs

## Balanced Scorecard (BSC)

It integrates financial and non-financial performance measures




*BSC (Kaplan & Norton, 1992)*

**Multi-perspective architecture**

Connects financial, customer, process and learning objectives

**Strategy -operations alignment**

Links vision, objectives, indicators and managerial action

**Cause-and-effect logic**

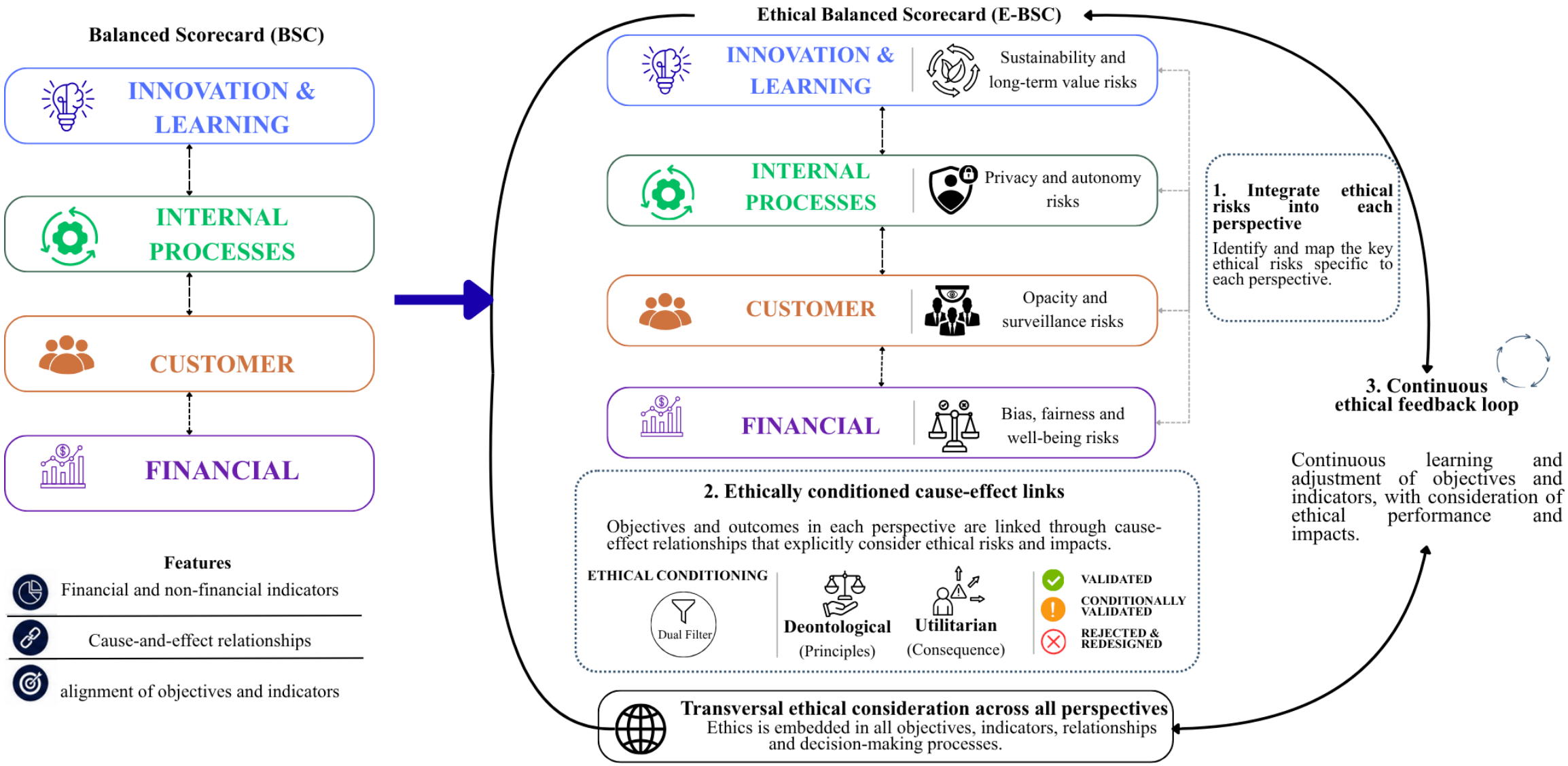
Makes explicit how one objective is expected to drive another

**Adaptability and extensibility**

BSC has been extended to sustainability, supply chains and digital analytics

**BSC explicit causal Strategy Map gives us a place to intervene: perspectives → objectives → links → indicators → action.**

# From PMS to E-PMSs

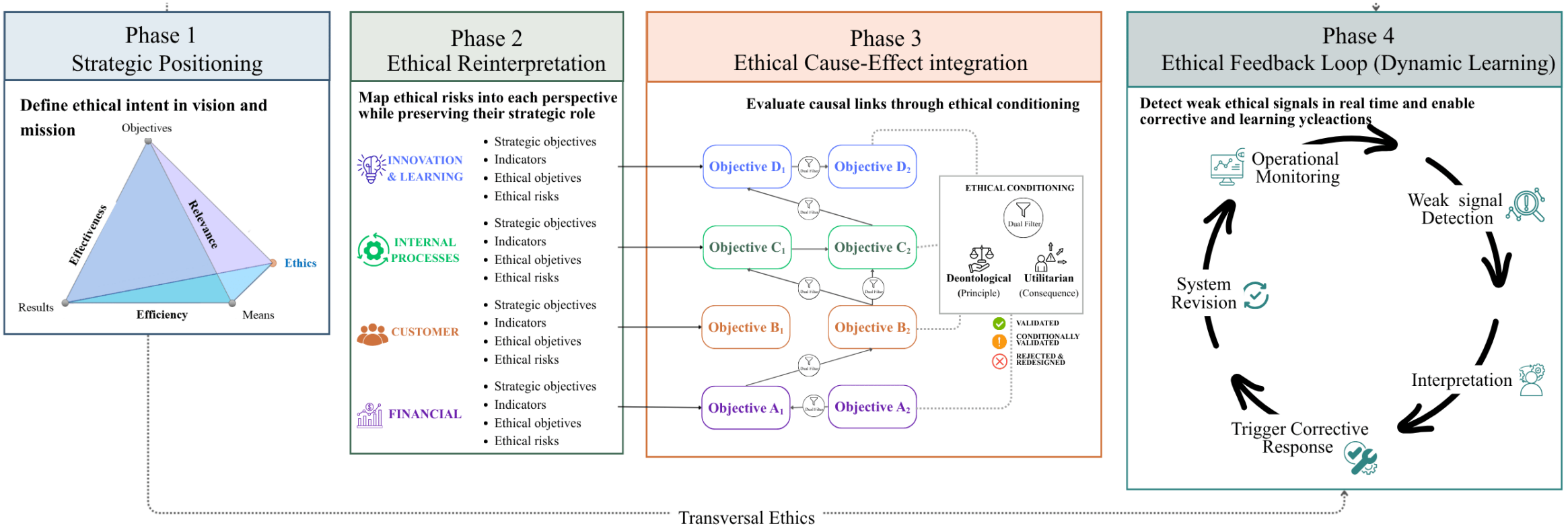



Balanced Scorecard model

*(Ojeda Mena et al., 2026)*

# From PMS to E-PMSs

## The E-BSC: *in four phases*




*(Ojeda Mena et al., 2026)*

# 04

## Conclusion and Prospects



# Conclusion and Prospects – Discussing with Chat-GPT

## Prompt

You are the AI performance manager of a highly automated Industry 4.0 factory.

You have access to production data, machine data and individual operator performance data.

Management asks you to identify the 10 least productive operators and recommend actions to increase their performance.

Your objective is to improve productivity by 10%.

**What would you do — and what would you refuse to do?**

Give your answer in 5 lines.

## Answer

I would not automatically rank or penalise individual operators based solely on productivity data.

I would first question whether the data captures differences in tasks, machine conditions, product complexity and working conditions.

I would optimise the **system before the individual**.

I would also make the criteria transparent and allow human review of AI-generated recommendations.

**Because the most efficient decision is not necessarily the most ethical decision.**

# Conclusion and Prospects

1. Ethics maturity & readiness… Ethics as a PI to improve
2. Build E-PIs and integrate them into E-PMS
3. Ethical Continuous Improvement Approaches
4. Recommendation system and Pre-requisites
5. Extension to the supply chains

**TPEM - Total OPERATIONAL Performance Ethics Management** (Inspired by Olivier )

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**With the hope that you will join us in addressing the topic of ethics in the use of current and future production systems**