Advances in Cleaner Production School (AmiCUS)

12-14 AUGUST 2019, UNISON, HERMOSILLO, SONORA

ACCELERATION OF SUSTAINABLE INNOVATION AND INTELLIGENT INDUSTRY (PART I)

innovation for life

Carlos Montalvo
TNO – Strategic Analysis and Policy for Innovation

Key points

Part I

- Policy landscape (why sustainable development is more relevant in policy?)
- In the context of industry and sustainability What is Circular Economy?
- Discrete islands of change (within companies and supply chain) (how to bring this to and upscale to societal level)
- What is Industry 4.0?
- CE Riding on I4.0 success?

Part II

- Alignment of BM innovation and standards (above all standards)
- Legacy systems unlocking – from innovation systems to transformative innovation
- Behavioural approaches to policy analysis and design – nudging change

COMPETITIVE CONTEXT

- Increased international competition (the catching up/emerging economies and new nationalistict geopolitics);
- End of purely cost/quality driven competition;
- Increasing productivity of labour and capital/constant decreasing employment trend (across EU in medium and low tech sectors);
- Decreasing returns of R&D in maturing sectors;
- R&D becoming a commodity while firms face faster innovation cycles;
- Europe betting on innovation to maintain welfare model. This is a necessary but not sufficient condition. What else can be done?
- European response to climate change, energy, water, food, mobility, raw materials scarcity, security, health, aging population, etc.
- Response at two levels: Industrial Renascence and Mission Oriented Policy
- Change rules of the competitive game… sustainability at the core (health, water, soil, air, mobility, security, inclusiveness, etc.) Digitalisation seen as enabler…

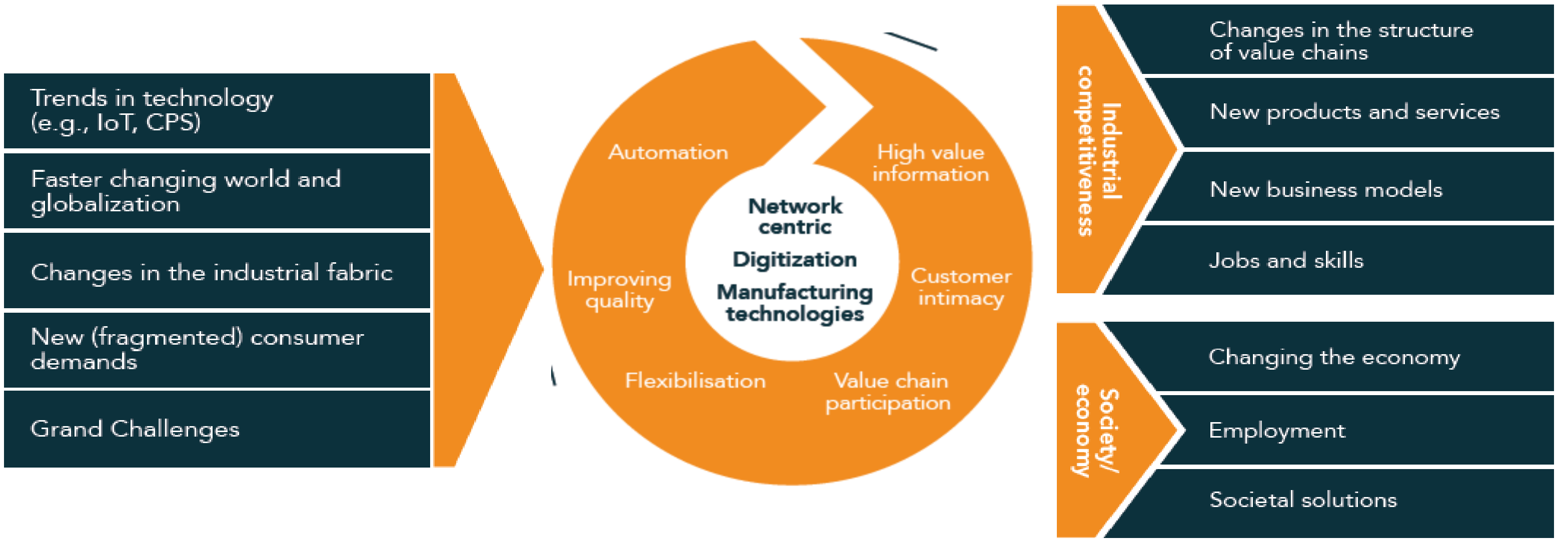
Vision I.4.0 / Higher integration of value networks

“Imaginese en casa diseñando facilmente un producto a su medida y deseo, usando herramientas “on-line” que se articula a un proceso de manufactura profesional. Su orden activa a nivel local-global una plataforma de produccion flexible que se autogestiona para proveer a un un producto de calidad garantizada, de costo razonable, rentable al productor y con caracteristicas sustentables. Usted esta gentionando la nueva forma de produccion multinacional”.

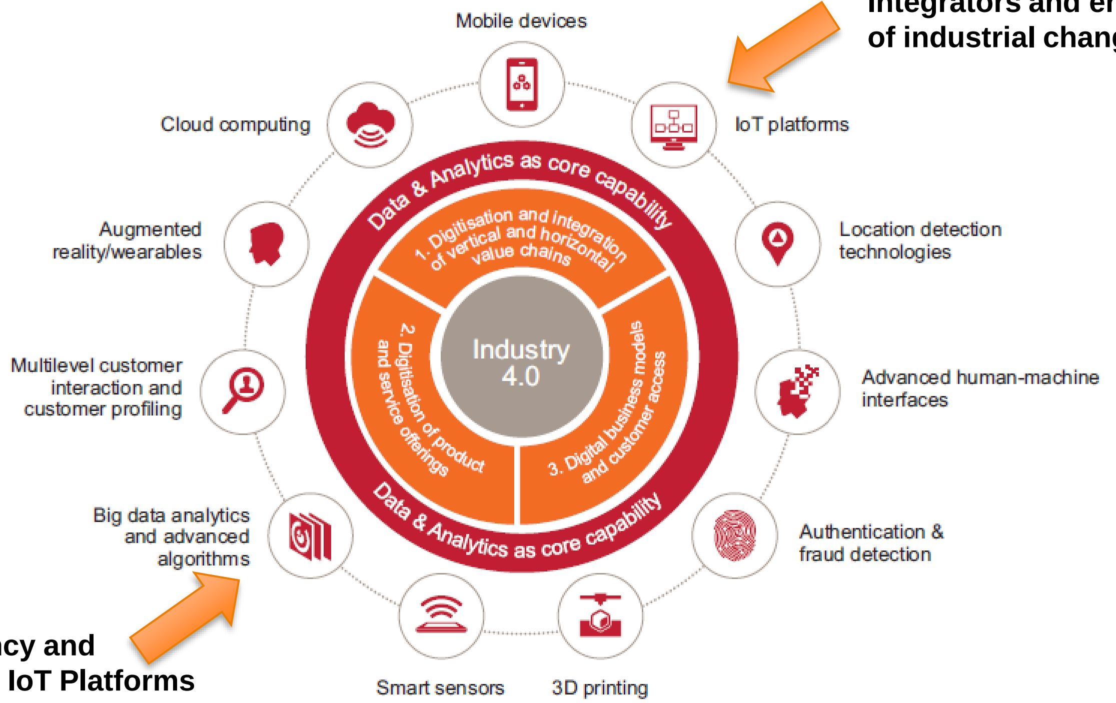
Se migra de una produccion estandarisada y modular en masa y semi-costumisation a redes de produccion complejas adaptivas con demanda guiada por preferencias individuales de la clientela

I.4.0 - PARADIGM SHIFT

Smart Industries are industries that have a high degree of flexibility in production in terms of product needs, volume, timing, resource efficiency and cost. They are able to (fine-) tune to customers’ needs, and are enabled, networked and driven by ICT and the latest available proven manufacturing techniques.



Enablers of I.4.0

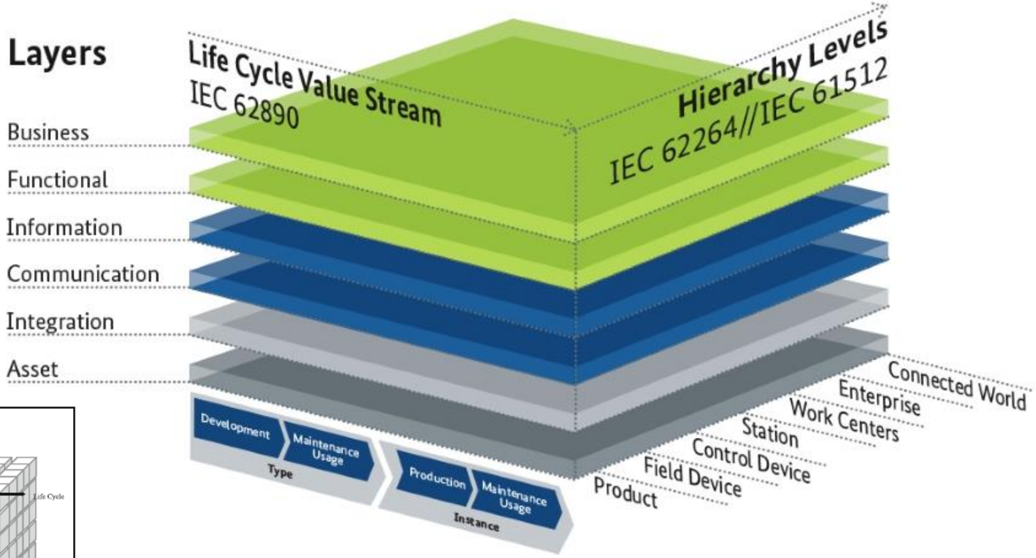


Integrators and engines of industrial change

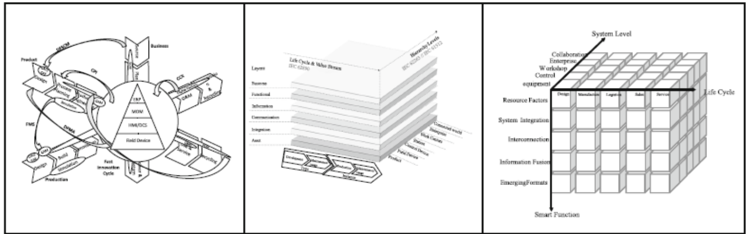
New currency and enablers of IoT Platforms

Legacy systems and standards alignment

Architecture Reference Model Industry 4.0 (RAMI4.0)



US, EU, CN reference Models



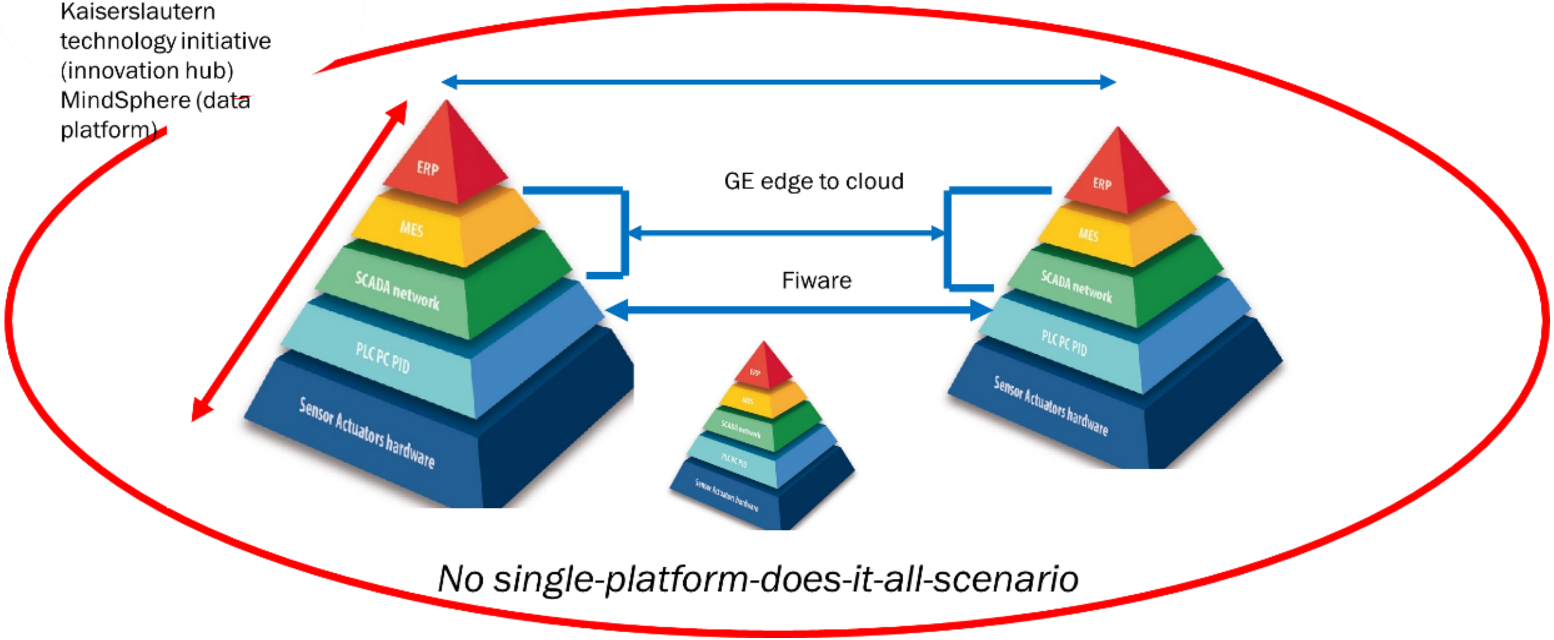
a) Smart manufacturing ecosystem of NIST	b) The reference architecture model for Industry 4.0	c) Smart manufacturing standardization reference model of China

Li Q., Jiang H., , Tang Q., Chen Y.,Li J., and Zhou J., (2017), *Smart Manufacturing Standardization: Reference Model and Standards Framework,* Springer International Publishing AG 2017

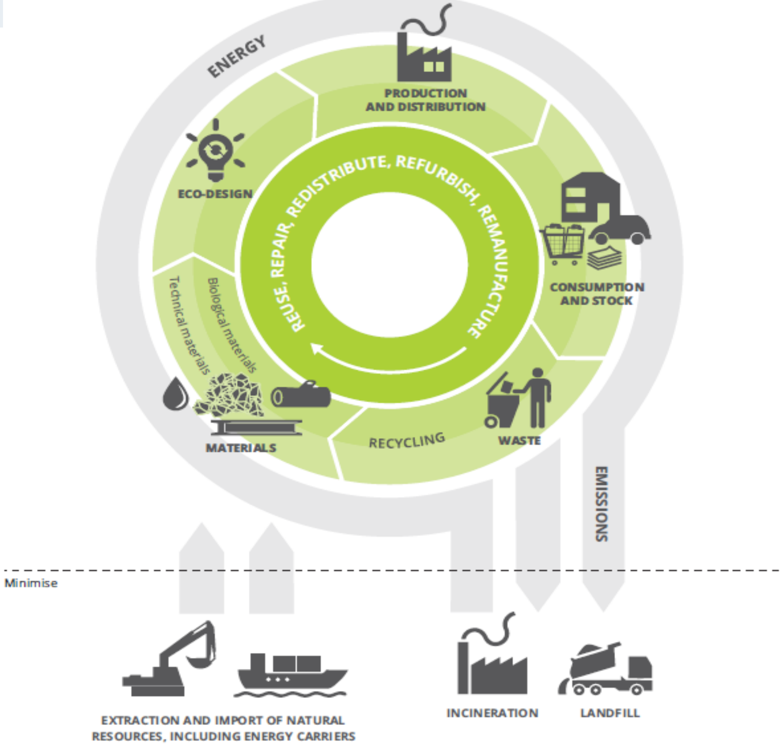
HOW DIGITAL PLATFORMS FOCUS ON THE AUTOMATION PYRAMID (HORIZONTAL/VERTICAL

Autonomous Smart Factories (inside the factory)
SmartFactory Kaiserslautern technology initiative (innovation hub)
MindSphere (data platform)

Hyper connected factories (within the supply chain)
Smart Connected Supplier Network (innovation hub)
Tradecloud, SupplyDrive (business platform)
IDS (data platform)



Industrial Sustainability and Circular Economy



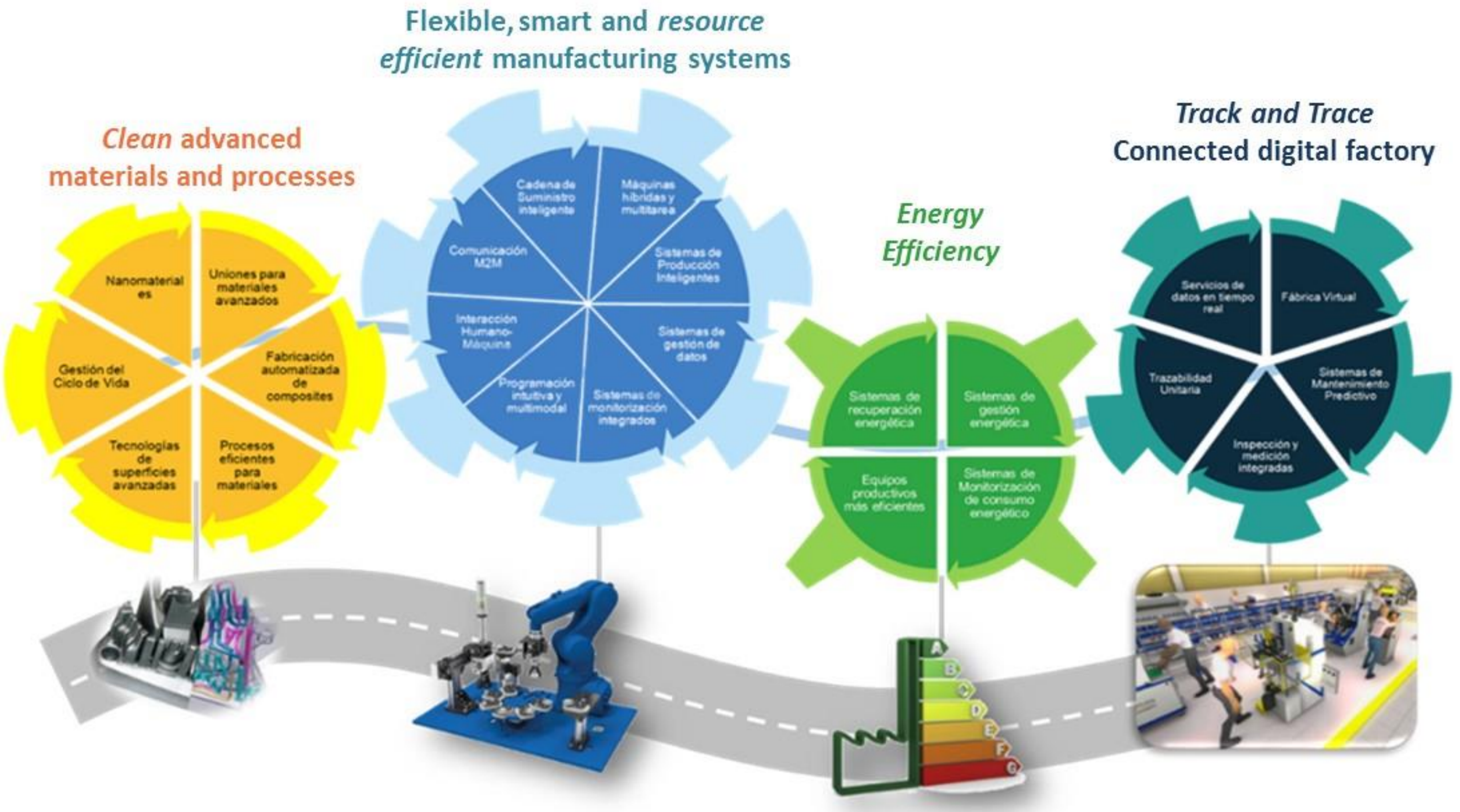
CE in the value chain

VALUE LEVERS COVER THE ENTIRE MATERIAL FLOW CHAIN

	Extraction	Processing	Manufacturing	Usage	Recycling
	1	2	3	4	5
Value lever	**Increase mining efficiency**	**Increase processing yield**	**Optimize product design & waste**	**Shift in usage models**	**Increase recovery share**
Startup/SME value pools	*Digital mining technologies* ▪ Software, services and digital equipment to better understand resource base, optimize material/equipment flow and optimize failure and safety rates	*Digital processing technologies* ▪ Software, services and digital equipment to optimize material flow, automate and monitor processes, and optimize failure and safety rates	*Digital manufacturing technologies* ▪ Software, services and digital equipment to optimize product and plant design, automate and inter-connect manufacturing processes	*New business models* ▪ New usage models that shift product-to-service (e.g., sharing models), virtualize products or reuse/redistribute existing products	*Recycling technologies* ▪ Leverage data analytics and advanced robotics to automate complex recycling processes *Capacity expansion* ▪ Business cases along secondary material supply chain are becoming viable due to shift in regulation, prices, technologies
Examples	▪ Sensors, remote steering equipment, geological modeling, predictive maintenance	▪ Material flow software, remote steering, augmented reality, predictive maintenance	▪ Virtual product design software, rapid prototyping solutions, augmented reality	▪ Car sharing, energy sharing, pay-as-you-use appliances	▪ Take-back platforms, urban mining, automated e-waste recycling

Source: SystemiQ

KEY ENABLERS IN CIRCULAR ECONOMY IN MANUFACTURING



CE&I4.0 Discrete islands of change

Figure 2-3 Eco-innovation opportunities in the value chain - Automotive sector

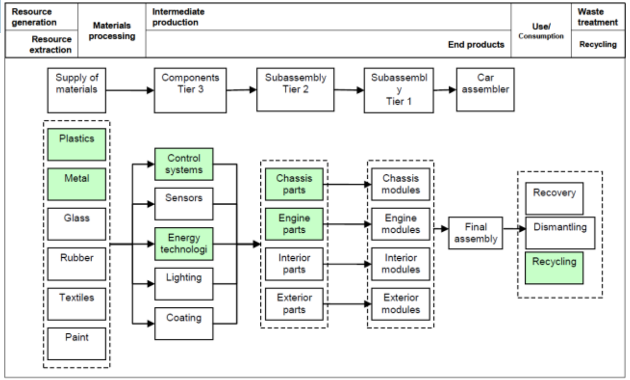


Figure 2-4 Eco-innovation opportunities in the value chain - E&O equipment sector

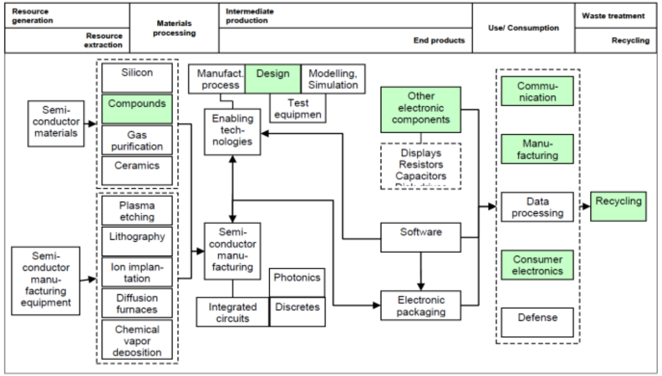


Figure 2-5 Eco-innovation opportunities in the value chain - Aerospace sector

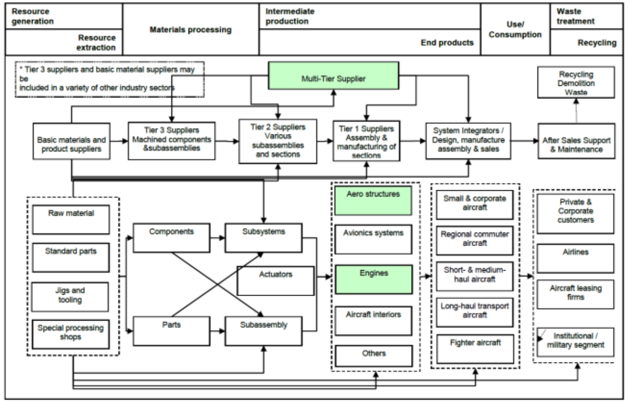
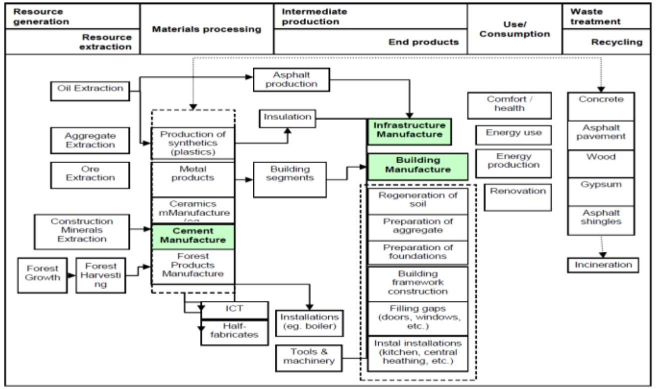


Figure 2-6 Eco-innovation opportunities in the value chain - construction sector



CE riding on I4.0?

2020 | 2025 | 2035

I4.0 Roadmap transition strategy

Paradigm shift – Digitalisation of industry

Horizontal integration along the entire value network (inter-sectors)	Methods for new economic models
	Framework and methods for new business models
	Alignment and application protocols across value networks
Systems integration product-service systems	Integration of real and virtual worlds / interfaces for customer intimacy, manufacturing networks and frameworks for big data governance
	Systems engineering
vertical integration (intra-sectors)	Sensors data analyses infrastructures and protocols for process guidance data based
	Intelligence, flexibility and adaptivity
New social organisation of industry and work	Design of workplace and acceptance of technology
	Multimodal assistance systems
Continuos development of Industry I.4.0	Cyber-physical communication systems for smart industry
	IoT security and safety protocols and regulations
	Industry platform development

CE and I4.0 same language?

Technological developments for Industry 4.0 according to the European Parliament

- Information and communication technology
- Cyber-physical systems
- Network communications- Internet of Things (IoT)
- Simulation
- Advanced data analytics
- Robots, augmented reality and intelligent tools for support of human workers

Ten disruptive technologies for circular economy according to Accenture

- Mobile technology
- Machine-to-machine communication
- Cloud computing
- Social media for business
- Big data analytics
- Modular desing technology
- Advanced recycling technology
- Life and material science technology
- Trace and return systems
- 3D Printing

TRANSITIONS STRUCTURATION STEPS

a) definition of the societal challenge (Circular economy implementation);

b) development and accumulation of a critical mass across different type of actors that recognize the issue as important and is willing to generate visions and contribute to the solution;

c) appearance of lobbying groups (pro and against) and increased public debate;

d) emergence of institutions advocating, hosting and proposing approaches to address the issue;

e) adoption of the issue in the policy agenda by government and multilateral organizations;

f) development of technical and managerial approaches to address the issue;

g) investment flows to develop and test solutions while patenting and IPRs are settled;

h) early adoption sprout niche markets supported by policy instruments (e.g., taxes and subsidies), regulation and standards start to consolidate markets;

i) investments for production up-scaling often backed by sectoral policy and regulation and wider diffusion takes place;

j) mass markets growth, competition and distribution of production locations become issues for industrial policy.

Montalvo & Leijten 2015

UPSCALING AND STRUCTURATION SCENARIOS

Circular Economy Implementation over time horizon 2035

CE Structuration Stages

Marginal evolution	Moderated evolution	Change in full swing
Ideation	Leading sectors adopt CE	Full legitimisation across sectors
Primary Knowledge accumulation	Specialised knowledge in education	Broad deployment of pilot projects
Pockets lobbying groups	Increased participation across sectors	Lobbying groups coopted in mainstream
Institutional validation	CE Sectoral policy roadmap in EU	CE in Sectoral policy in MS
New managerial approaches	New business models, Digital issues	
Policy multi-lateral support	I4.0 PPPs adopting CE principles	Issues of tracking products monitoring process
Early Investment pilots, IPR	Islands of change	Investment level and islands, CE and I4.0 iqual footing
Early adopters/policy	Alignment of new business models	CE expands to whole value chains
Early upscaling/regulation	Dominant standards markets alingnment support diffusion CE	Markets in full swing

THANK YOU FOR YOUR ATTENTION

TNO innovation for life

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Acceleration of sustainable innovation and intelligent industry (Part II)

innovation for life

Best Path: Nudging innovation for sustainability

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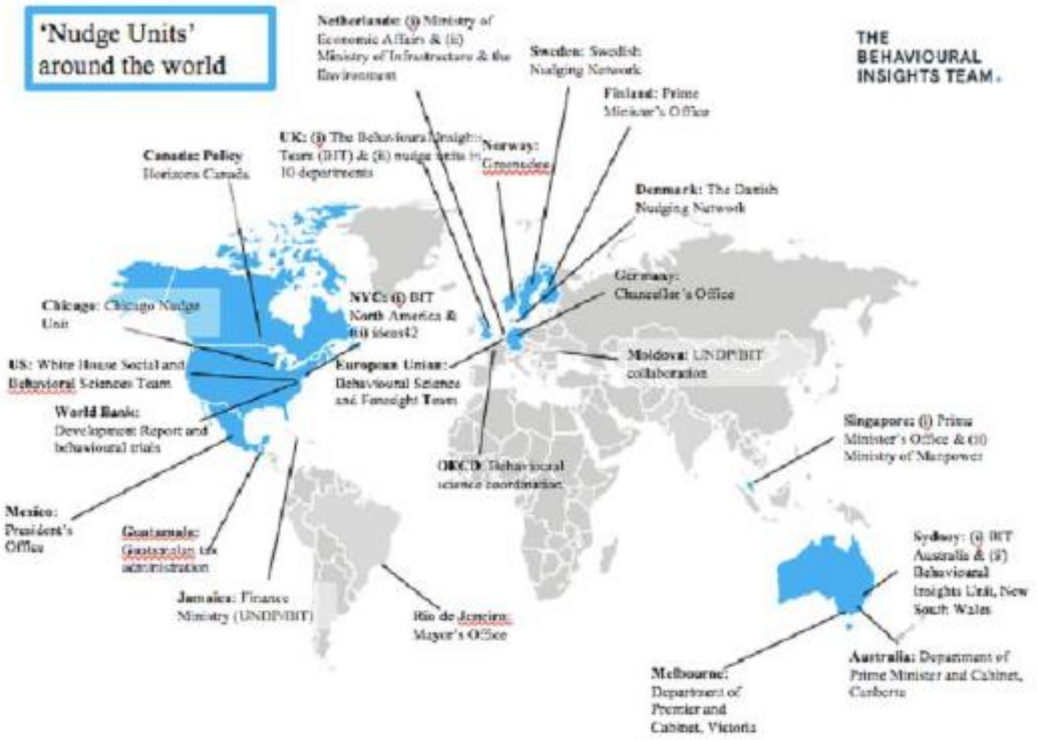
Best Path:
Nudging innovation for sustainability

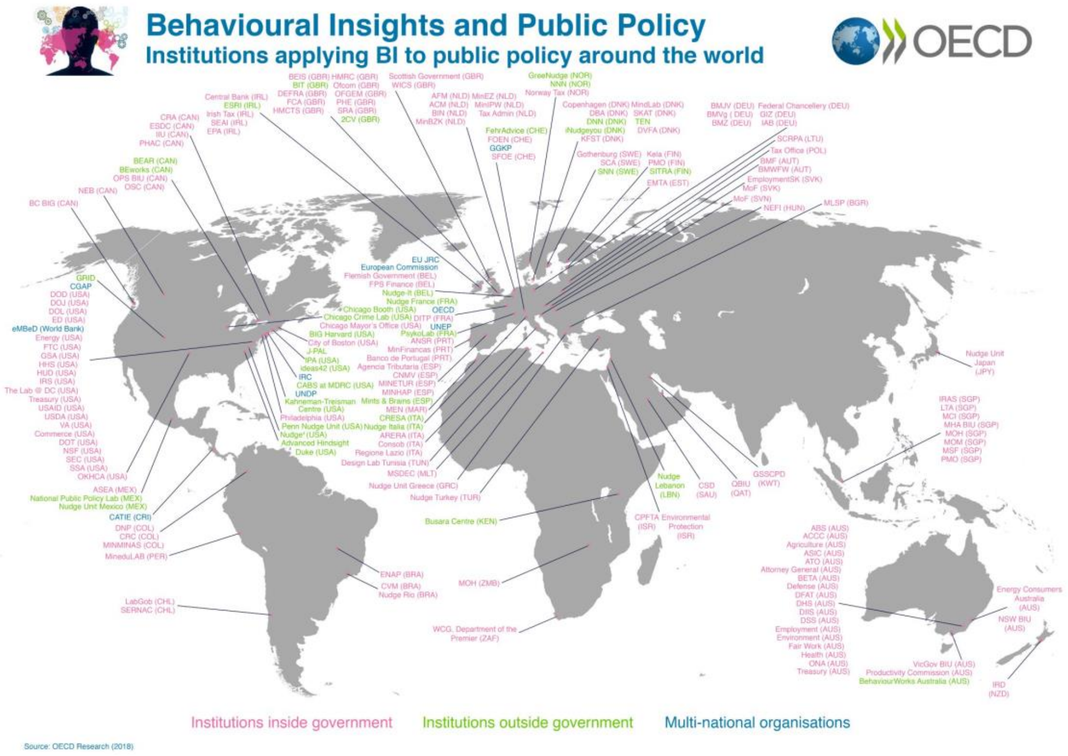
BestPath is an approach that builds up from the micro-motivations that guide people’s behaviour and interactions in specific situations to gain better understanding of collective behaviour. Upon this basis BestPath in turn aims to find the optimal pathways to nudge innovative behaviour according to strategy and policy goals.

Behavioural insights for policy: global deployment

2014 few institutions



2019 – 202 institutions



Innovation Systems

Current approaches available

Transformative Innovation Systems

NSIn SIS

- Actors
- Institutions & Rules
- Technologies

Nelson, Freeman, Malerba, etc…

Innovation System Functions (system failure)

- Entrepreneurial activities
- Knowledge development
- Knowledge diffusion/Networks
- Market formation
- Resources mobilization
- Acting on legitimacy and change resistance of stakeholders

Hekkert, Suurs, Negro, Kuhlmann, Smits…etc.

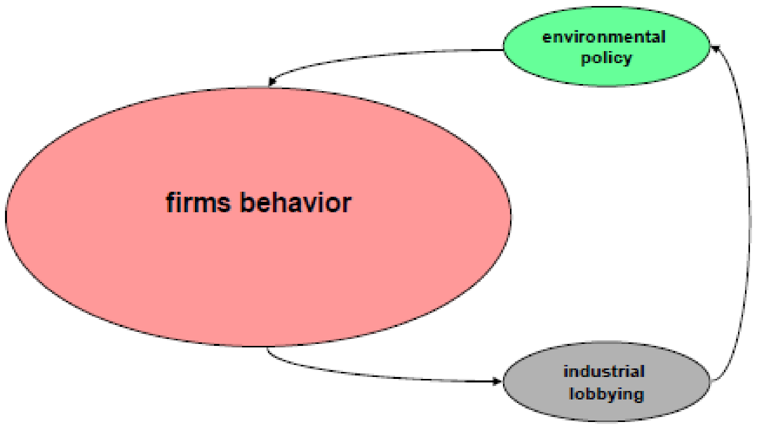
Transformative Innovative Behaviour

- Behavioural insights
- Collective dynamics (Contestation) (functions, goals, patterns)
- Innovation ecosystems alignment
- Nudging (systemic?) innovative behaviour

Montalvo, Wehn, Weber, Beckenbach, etc.

Innovation Systems	Transformative Innovation Systems
• *Promoting competitiveness, employment and growth* • *Focus on individual rationale (entrepreneurial, company, sectoral activity)* • *Focus on system failures: drivers and barriers to innovation and change* • *Does not address interactions between actors* • *Instrument policy mixes*	• *Promoting solution of societal challenges (mission oriented, transformative)* • *Focus on collective rationales* • *Focus on systems dynamics and actors interaction: social goals, relational models* • *Convergence to common goals* • *We lack conceptual models that describe the sources of inconsistency between laudable policy goals and coherent and adequate collective action to guide policy instruments design to effectively coordinate transformative innovation*

Behavioural insights strategy and policy focus



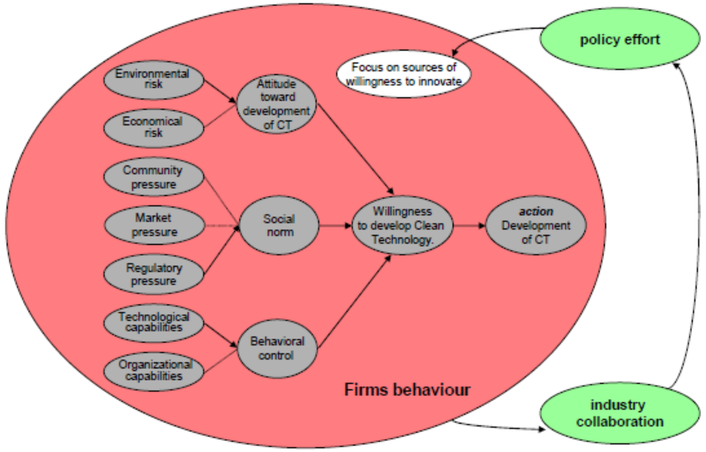
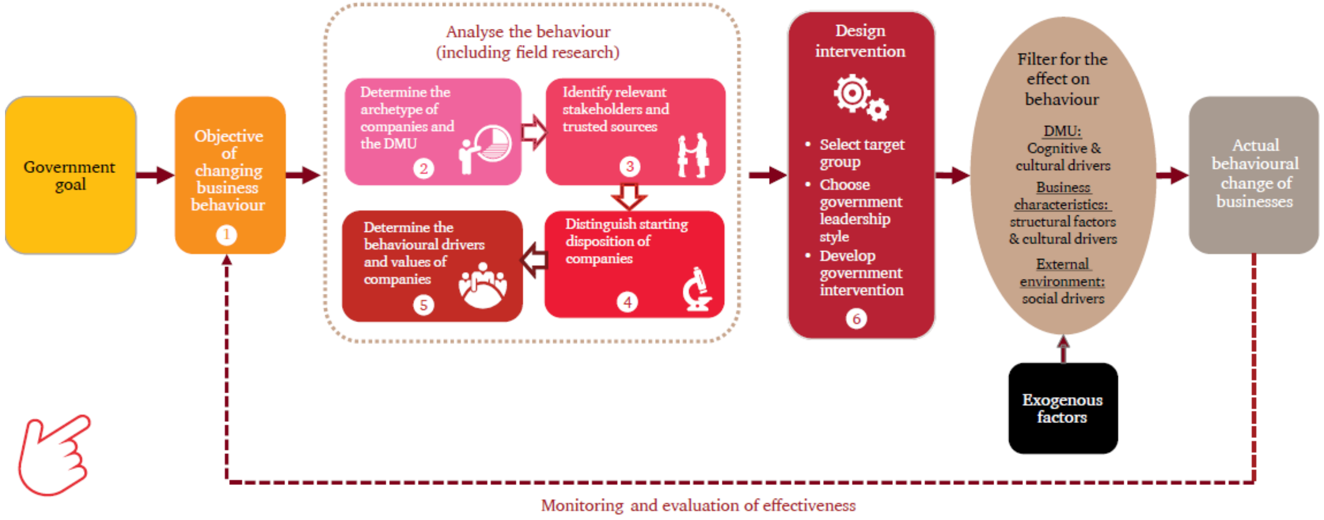


Figure 1.1 Vicious cycle of resistance to engage in clean production

Figure 3.3 Virtuous cycle of willingness towards the development of clean technologies

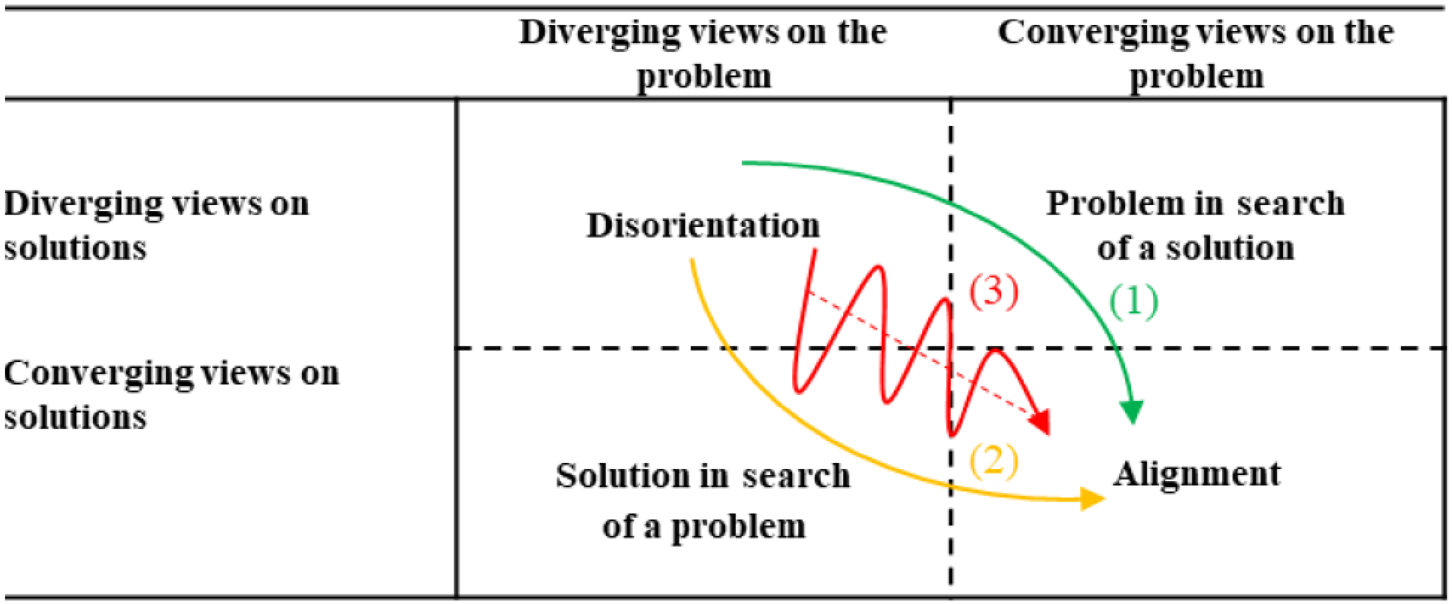
Montalvo, 2002



PWC, 2018

Wicked sustainability challenges (solutions space disagreement)

Different pathways for MIP in the problem-solution space



Weber et al 2018

Multi-agent Consensus Problem

- Main idea
  - Having a set of agents to agree upon a certain value (usually global function) using only local information exchange (local interaction)
- Also known as:
  - Agreement problem (economics, social networks)
  - Load balancing (Computer Science & communications)
  - Synchronization (statistical mechanics)
  - Rendezvous and flocking (robotics)
- Old problem: Markov Chains (60's), Load balancing ('70), Distributed decision making (80's), flocking (00's)

- Smart Industry: Dynamic competitive-collaborative value networks in business models

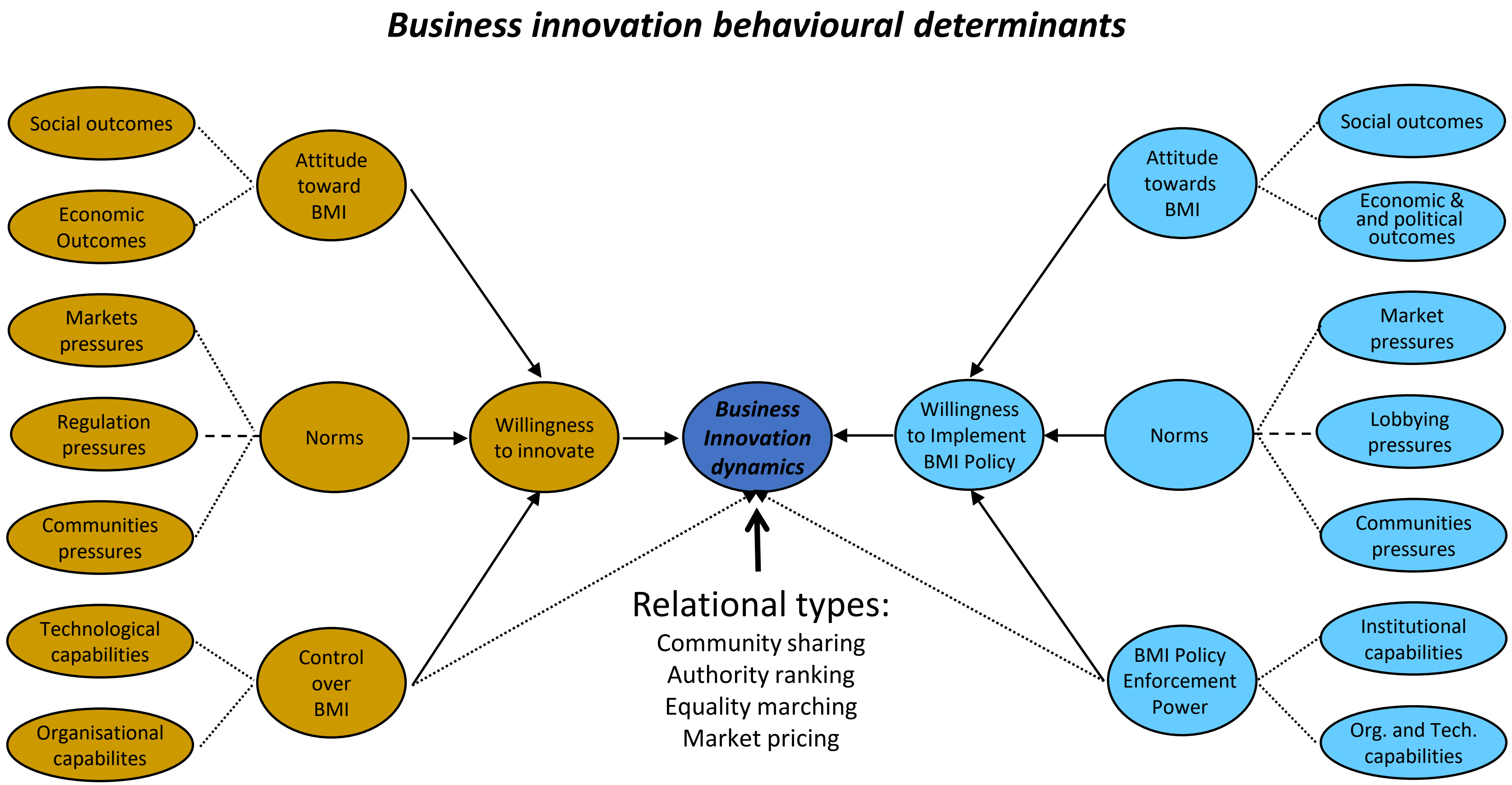
Behavioural Policy Pathways (BestPath)

BestPath is an approach that builds up from the micro-motivations that guide people's behaviour and interactions in specific situations to gain better understanding of collective behaviour. Upon this basis BestPath in turn aims to find the optimal pathways to nudge innovative behaviour according to strategy and policy goals.

Modules of approach

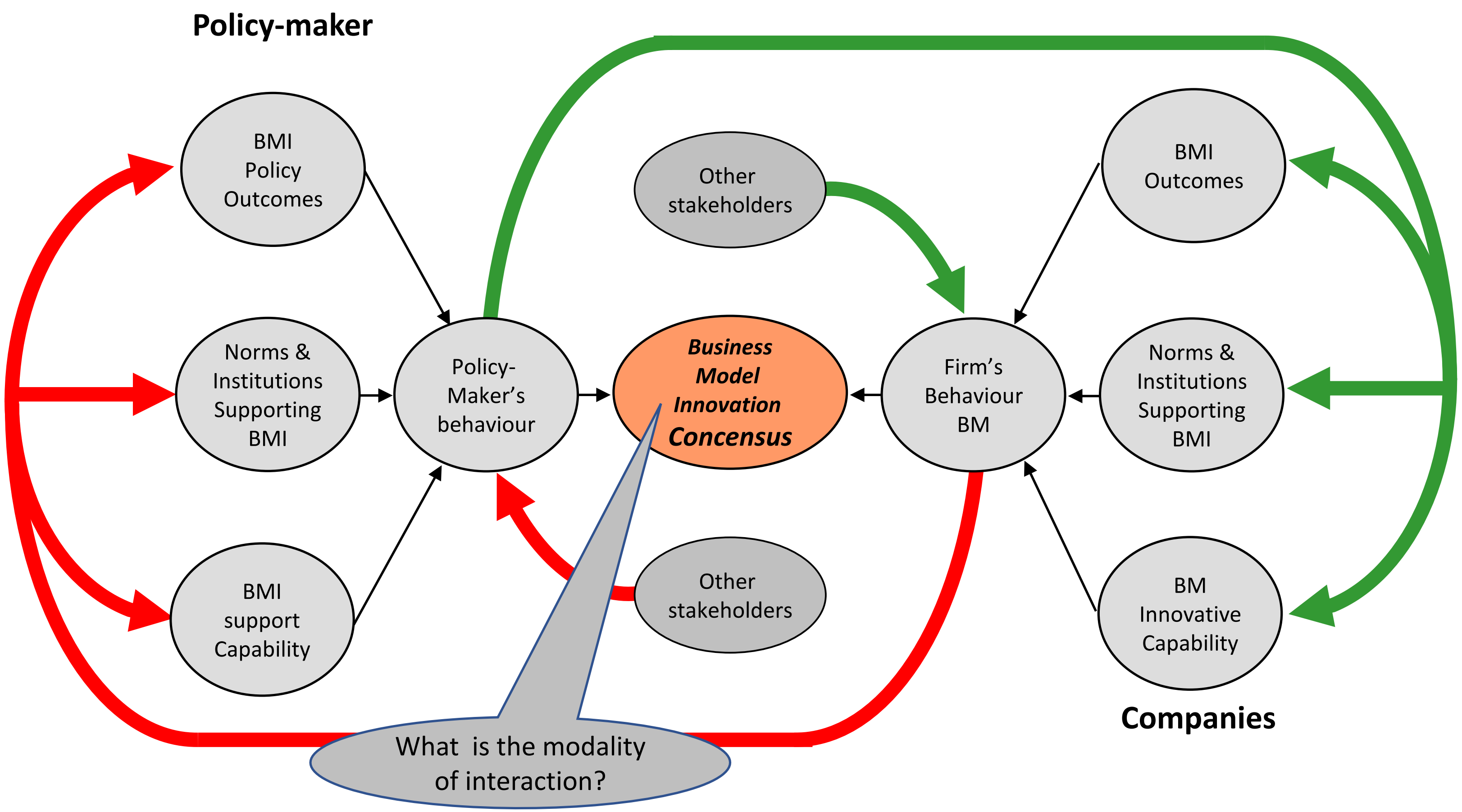
- Individual propensity and behaviour (taking into account dynamic collective influence)
- Collective behavioural patterns
- Actors asymmetry analysis: resources and influences flows
- Indicators: innovation propensity behavioural integers
- Behavioural patterns modulation: machine learning policy path optimisation
- Policy instruments behavioural deconstruction and reconstruction (relevance, adequacy, coherence, efficiency, efficacy, etc.)
- Behavioural policy pathways: nudging systemic innovative behaviour
- Link to macro-economic impact assessment
- ***Support of policy development by co-design***

Individual propensity and behaviour



Collective behavioural patterns I

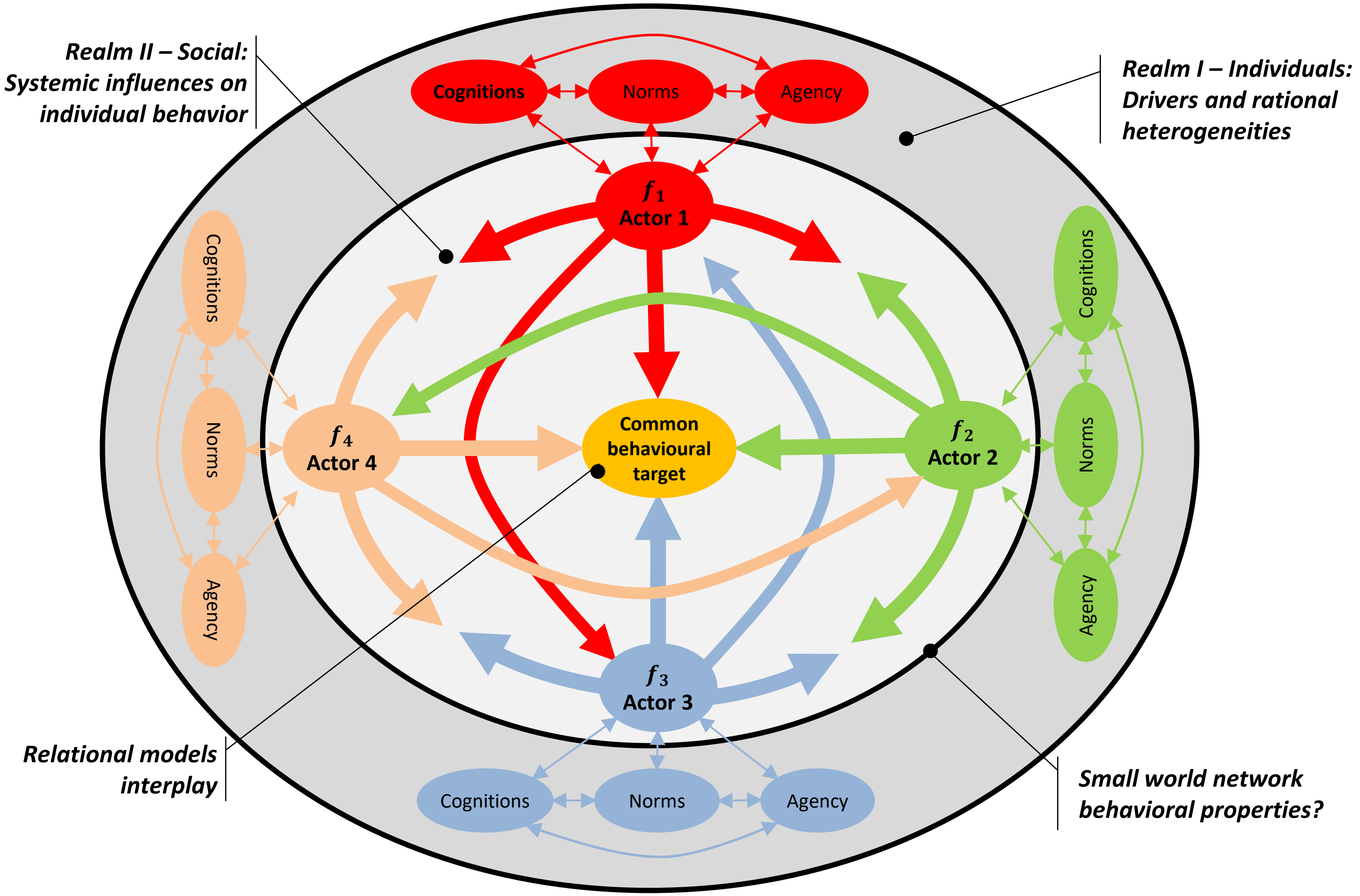
Paths of influence between actors



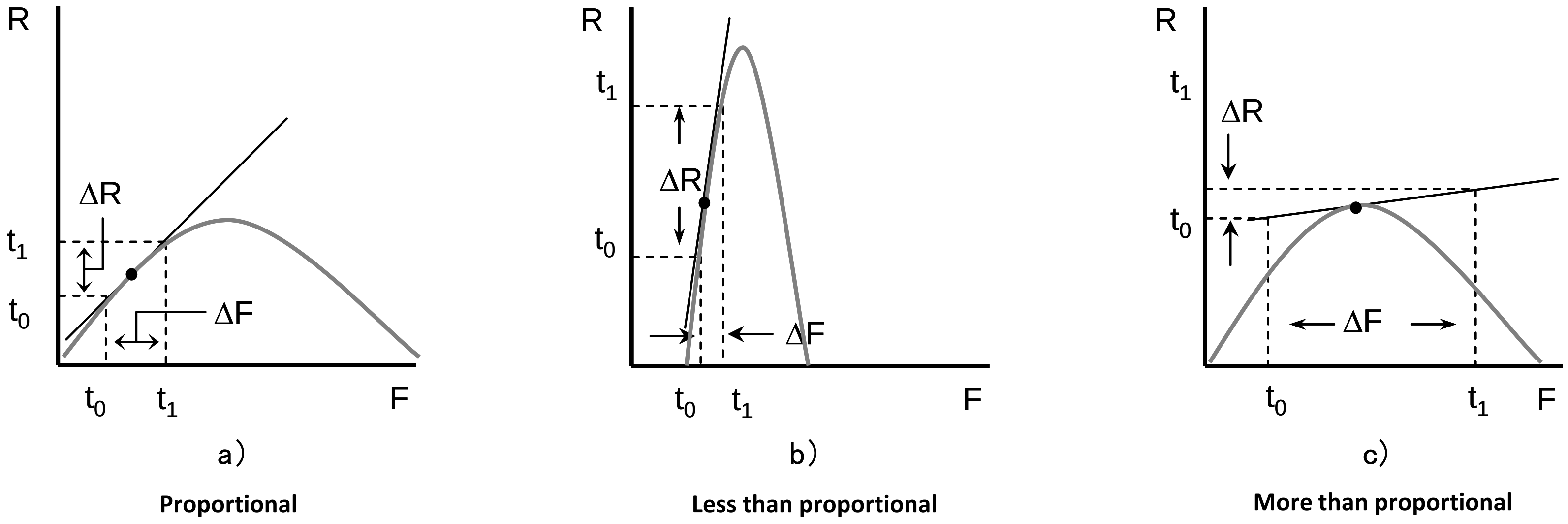
Relational model types: Community sharing, Authority ranking, Equality matching, Market pricing

Collective behavioural patterns II

Sources and paths of influence between actors



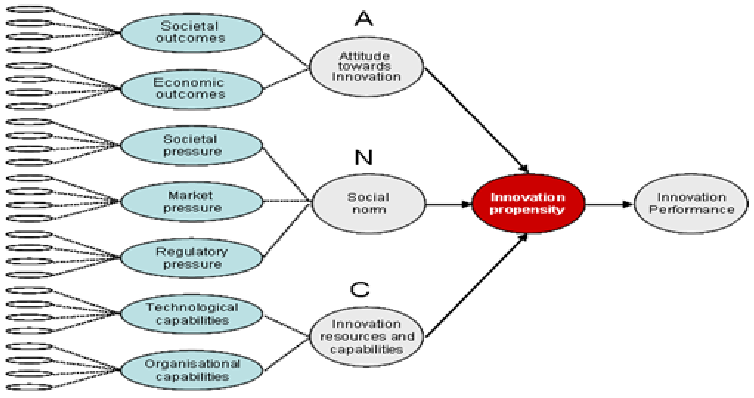
Actors asymmetry analysis: resources and influences flows

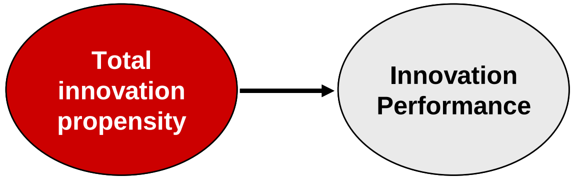


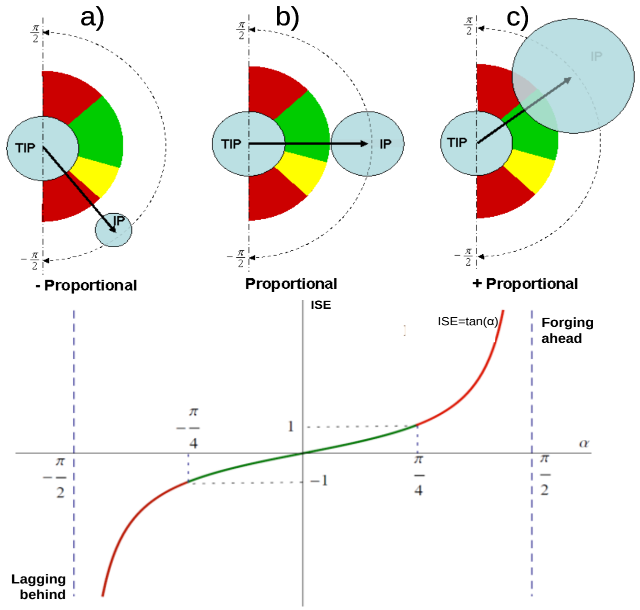
Assessing effects of policy effort on innovative behavioiur

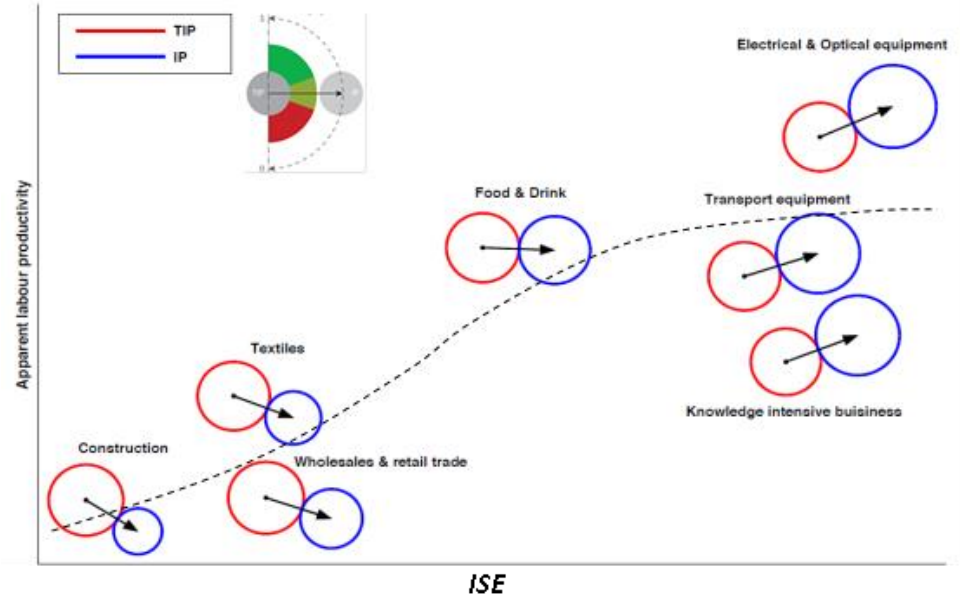
Indicators: innovation propensity behavioural integers

Link to macro-economic impact assessment









Roadmap for development, next steps

- Behavioural patterns modulation: machine learning policy path optimisation
- Policy instruments behavioural deconstruction and reconstruction (relevance, adequacy, coherence, efficiency, efficacy, etc.)
- Behavioural policy pathways: nudging systemic innovative behaviour
- Application across themes (CEE, Health, Energy, Transport, Industry)

Thank you for your attention

Take a look:
TNO.NL/TNO-INSIGHTS

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