Road transport & logistics innovations

Pathways to 2035

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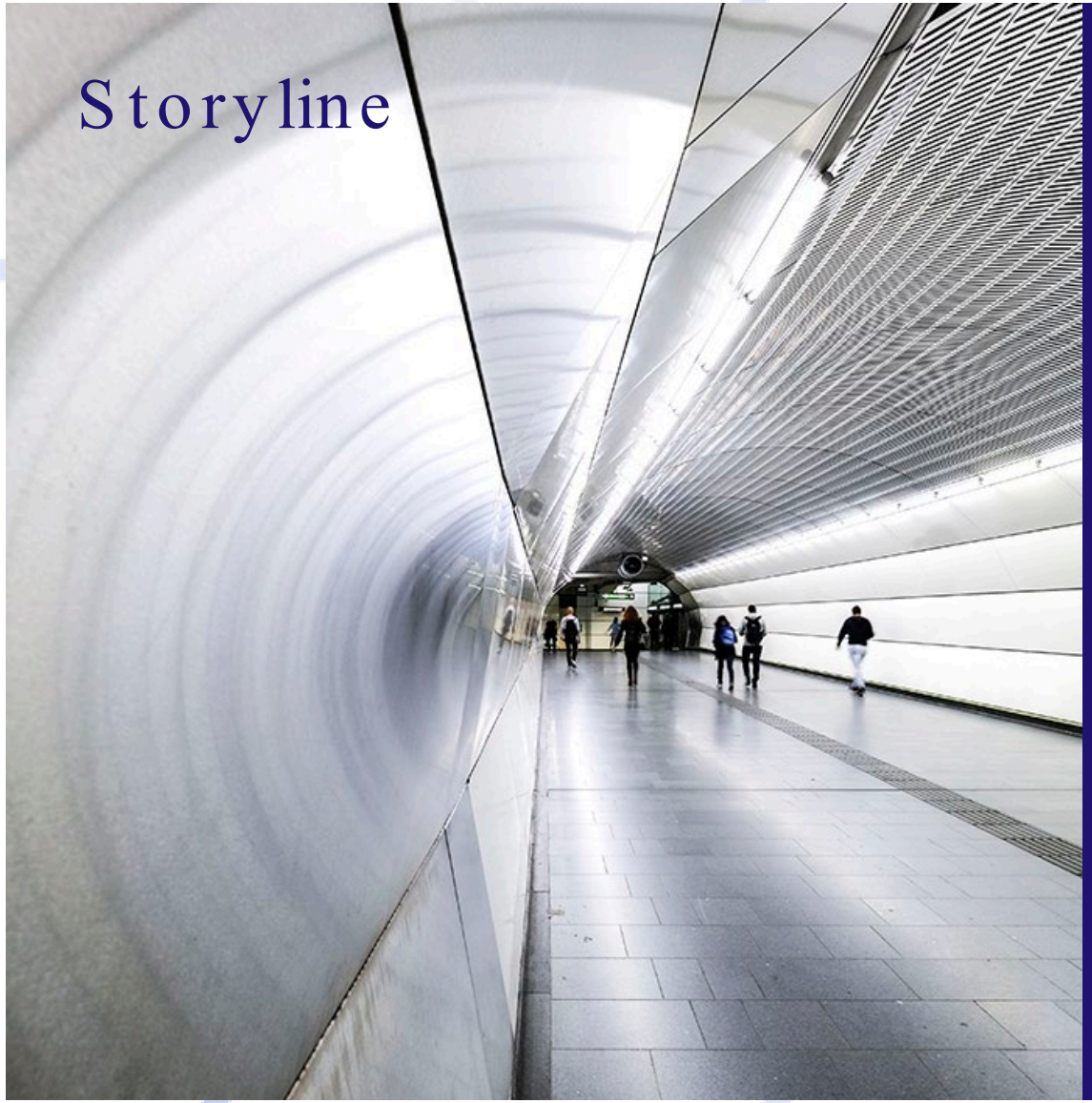
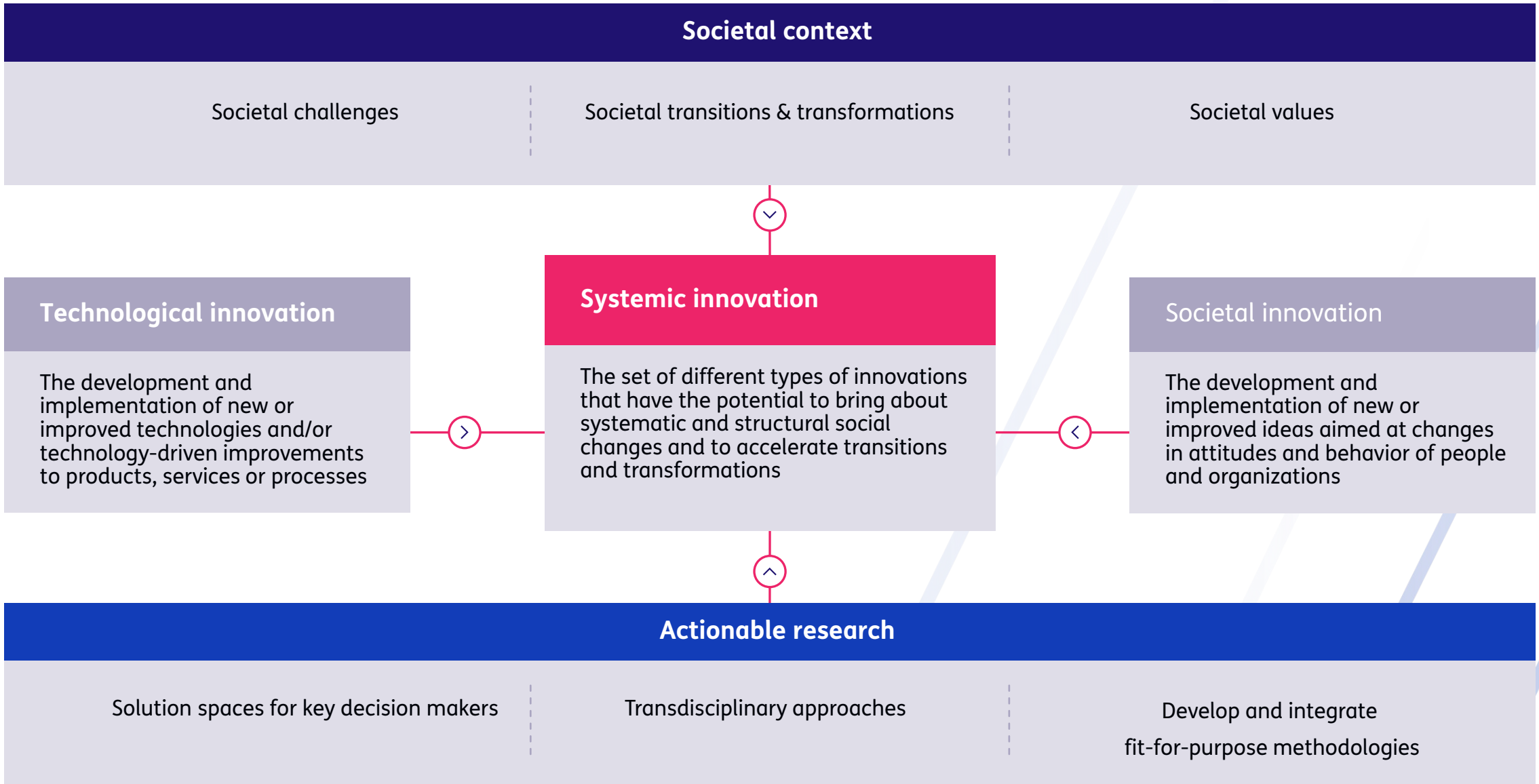
TNO Vector
Centre for Societal Innovation and Strategy

Storyline



- Societal context of innovation
- Objective of the analysis
- Road innovations and integration in logistics
- Trends and Future requirements
- Effects of road innovations
- Effects for logistics use cases
- Societal/political Resilience and Barriers
- How to use this approach?


Societal context
Societal challenges
Societal transitions & transformations
Societal values
Technological innovation
The development and implementation of new or improved technologies and/or technology-driven improvements to products, services or processes
Systemic innovation
The set of different types of innovations that have the potential to bring about systematic and structural social changes and to accelerate transitions and transformations
Societal innovation
The development and implementation of new or improved ideas aimed at changes in attitudes and behavior of people and organizations
Actionable research
Solution spaces for key decision makers
Transdisciplinary approaches
Develop and integrate fit-for-purpose methodologies

Creating a shared vision …

- Road innovations should be embedded in logistics (road remains a key mode…)
- Effects depend on logistics use cases
- Societal- and stakeholder targets & perceptions determine attractiveness
- Effects, targets & perceptions can change in the future
- Key decision makers should achieve a shared vision to enable effective actions

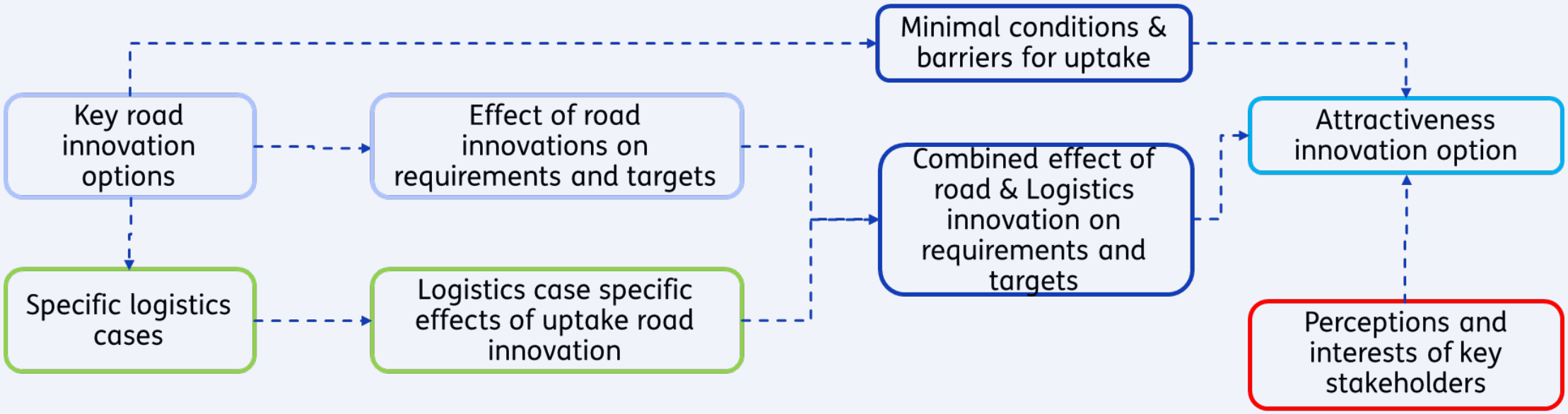
Create a collaborative quick scan approach (prototype) for short listing strategic options to accelerate and improve vision creation…

Road transport & innovation assessed

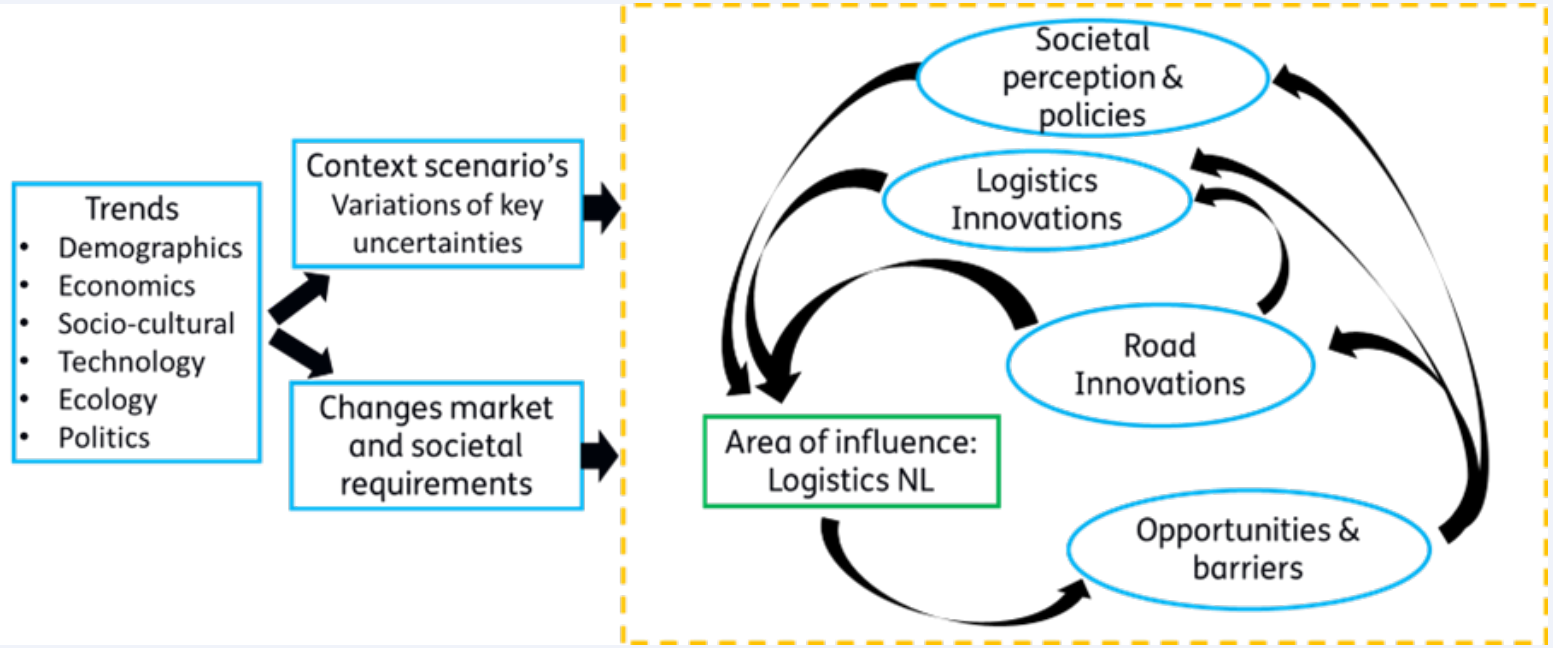
Automation technologies	
Automation Level	Sub-technologies considered
Partial Automation	• Lane centring • Hands-free lane changing • Adaptive cruise control
Conditional Automation	• Highway (supervised) automation; • Automated lane keeping system; • Platooning Support Function (PSF; L3 for following trucks); • Tele-operations.
High Automation	• Automated yard movers • Automated hub-to-hub operations for trucks (on public roads)

Propulsion technologies
Battery Electric Vehicles (BEVs)
Hydrogen Internal Combustion Engine (H2-ICE)
Hydrogen Fuel-Cell Electric Vehicles (FCEVs)
Biofuels
Synthetic Fuels

Which innovation is most attractive?



Influence of changing societal context in 2035



Key societal trends

1. Growing population especially in cities
2. Ageing and increase of dependency rate
3. Growing consumption (uncertain inflation level influenced by solutions for scarcity resources & labour)
4. Instability of geopolitics (could be high or low)
5. Economic dominance of Asia
6. Increasing resource scarcity
7. Scarcity on the labour market
8. Power of Big-tech companies
9. Widening inequalities
10. Societal divide & Inclusion
11. More need and focus on security
12. Pressure on government budgets
13. Decentralisation of government tasks
14. Accelerating technological change and hyperconnectivity
15. Changing nature of work
16. Lifelong education and learning
17. Climate change
18. Priority on climate change and environmental investments (depending on political climate)

Requirements for logistics - 2035

- Based on current practices, combined with the observed trends
- Different types of requirements:
  - market requirements should be overall positive in order to be commercially of interest
  - The overall contribution of the innovation to policy targets is important in case policy support is needed for the implementation of the innovation
  - societal aspects that are not explicitly addressed by policy (yet) but still play an important role for the acceptability and/or societal support

Requirements	
Market requirements	Competitive price
	Reliability of services (timing pick-up and delivery)
	Flexibility of service availability (ad-hoc booking and/or cancelation)
	Short lead time of service
	Ensure security of cargo (avoid damage and theft)
	Online presence, on-demand
	Real time information
Policy targets	Economic growth
	Ensure accessibility (reduce congestion)
	Reduction traffic injuries and fatalities
	Reduction of climate emissions
	Reduction emissions of pollutants and noise
Other societal requirements	Energy efficient operation
	Limit/reduce damage to infrastructure
	Efficient use of existing infrastructure
	Resilience to disruptions (f.i. energy outage)
	Data privacy
	Ensure cyber security
	Solve labour shortage
	Inclusive operation (including level playing field)
	Provide attractive working conditions:

Note: These are results of an internal Delphi exercise. To be repeated/validated with key stakeholders

Effects of technologies on requirements – ceteris paribus

Innovation	Effect on requirements (Rating + or – 0-5; +5 being very high positive)																				
	Market requirements							policy targets					Other societal requirements								
Technological Options	Competitive price	Reliability of services (timing pick-up and delivery)	Flexibility of service availability (ad-hoc booking and/or cancelation)	Short lead time of service	Ensure security of cargo (avoid damage and theft)	Online presence, on-demand	Real time information	Economic growth	Ensure accessibility (reduce congestion)	Reduction traffic injuries and fatalities	Reduction of climate emissions	Reduction emissions of pollutants and noise	Energy efficient operation	Limit/reduce damage to infrastructure	Efficient use of existing infrastructure	Resilience to disruptions (f.i. energy outage)	Data privacy	Ensure cyber security	Solve labour shortage	Inclusive operation (including level playing field)	Provide attractive working conditions:
Vehicle Automation > assuming logistics organisation unchanged																					
Driver assistance systems (L2)	0	0	0	0	2	0	0	0	0	2	0	1	0	1	0	0	0	0	0	0	0
Automated Lane Keeping System (ALKS, L3)	0	0	0	0	2	0	0	0	1	3	0	1	1	2	0	0	0	0	0	0	0
Tele-operation (L3)	3	0	0	0	-2	0	1	1,2	1	3	0	1	1	2	0	-5	-2	-3	2	-1	0
Platooning Autonomous Function (PAF)	3	0	-2	-2	-1	0	2	1,2	1	3	2	2	2	2	1	-5	-2	-2	2	-2	-1
Automated vehicle on confined environments (L4-5)	3	5	5	1	0	0	2	1,2	0	1	0	1	1	0	0	-5	-2	-1	2	0	0
Automated vehicle on public road (L4-5) - Short/Medium Haul	5	2	5	0	-2	0	2	2	2	3	0	1	3	2	2	-5	-2	-2	5	-3	0
Automated vehicle on public road (L4-5) - Long-Haul	5	2	5	3	-2	0	2	2	2	3	0	1	3	2	2	-5	-2	-2	5	-3	0
Zero-Emission Vehicles > assuming organisation unchanged																					
BEVs (Short and Medium Haul)	1	0	-4	0	0	0	0	0,4	0	0	5	5	5	0	0	-3	0	0	0	0	1
BEVs (Long-Haul)	3	0	-2	-1	0	0	0	1,2	0	0	5	5	5	0	0	-3	0	0	0	0	1
FCEVs Long Haul	-2	0	0	0	0	0	0	-0,8	0	0	5	5	2	0	0	0	0	0	0	0	1
H2-ICE Long Haul	-3	0	0	0	0	0	0	-1,2	0	0	4	3	0	0	0	0	0	0	0	0	0
Synthetic Fuels/ Bio-fuels long-haul	-3	0	0	0	0	0	0	-1,2	0	0	4	0	-1	0	0	0	0	0	0	0	0

Note: These are results of an internal Delphi exercise. To be repeated/validated with key stakeholders

Innovation packages

medium/long haul transport
Electrification (BEV)
Automation: package 1: L3; other packages L4/5

Innovation package 1: Limited automation

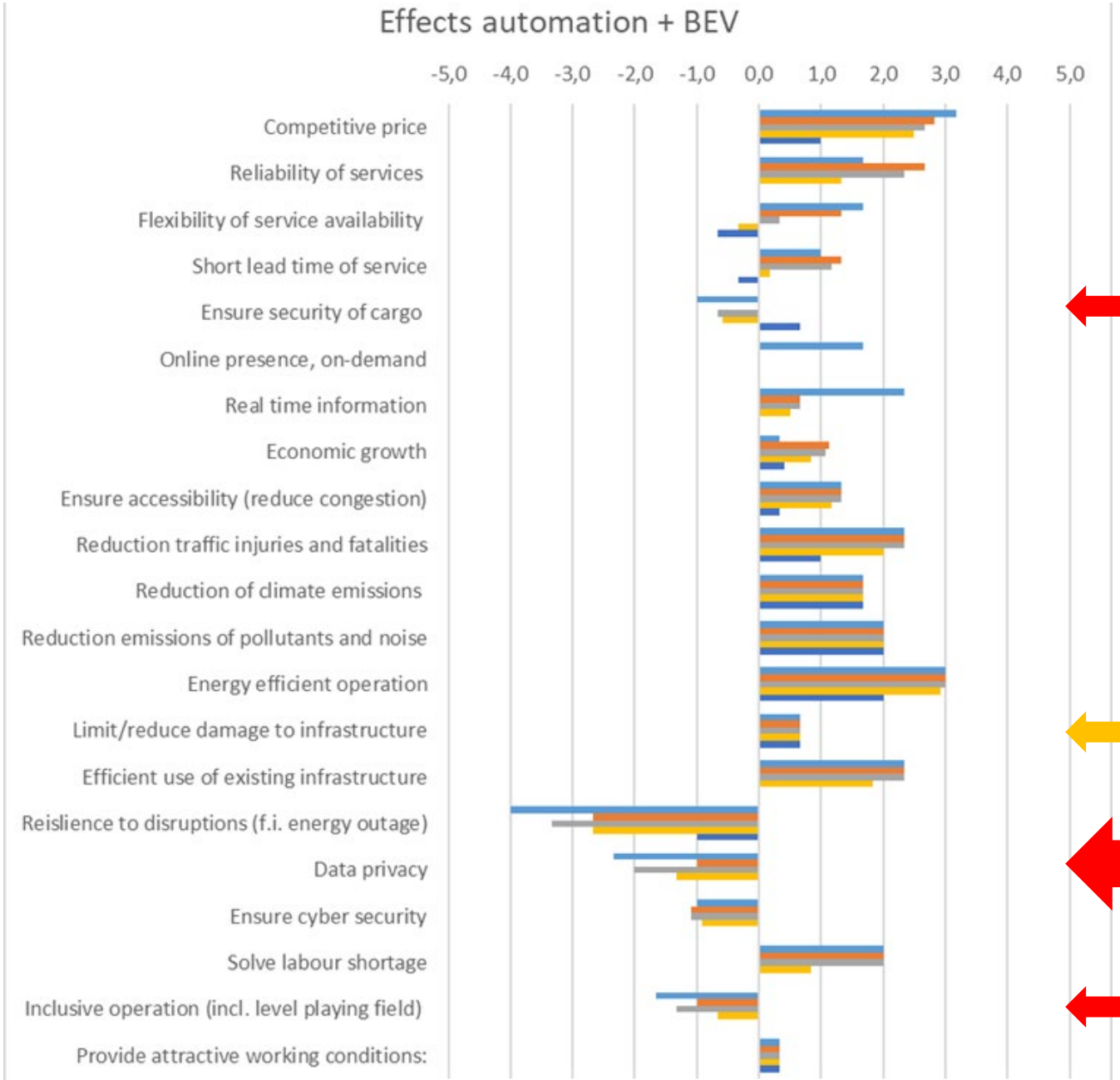
Innovation package 2: Automation on highways between hubs only allowed overnight

Innovation package 3: Automation on highways between hubs

Innovation package 4: End-to-end autonomous

Innovation package 5: Autonomous trucks as a service

Effects for logistics use cases



Effect including implementation of solution: smart lateral movement of trucks

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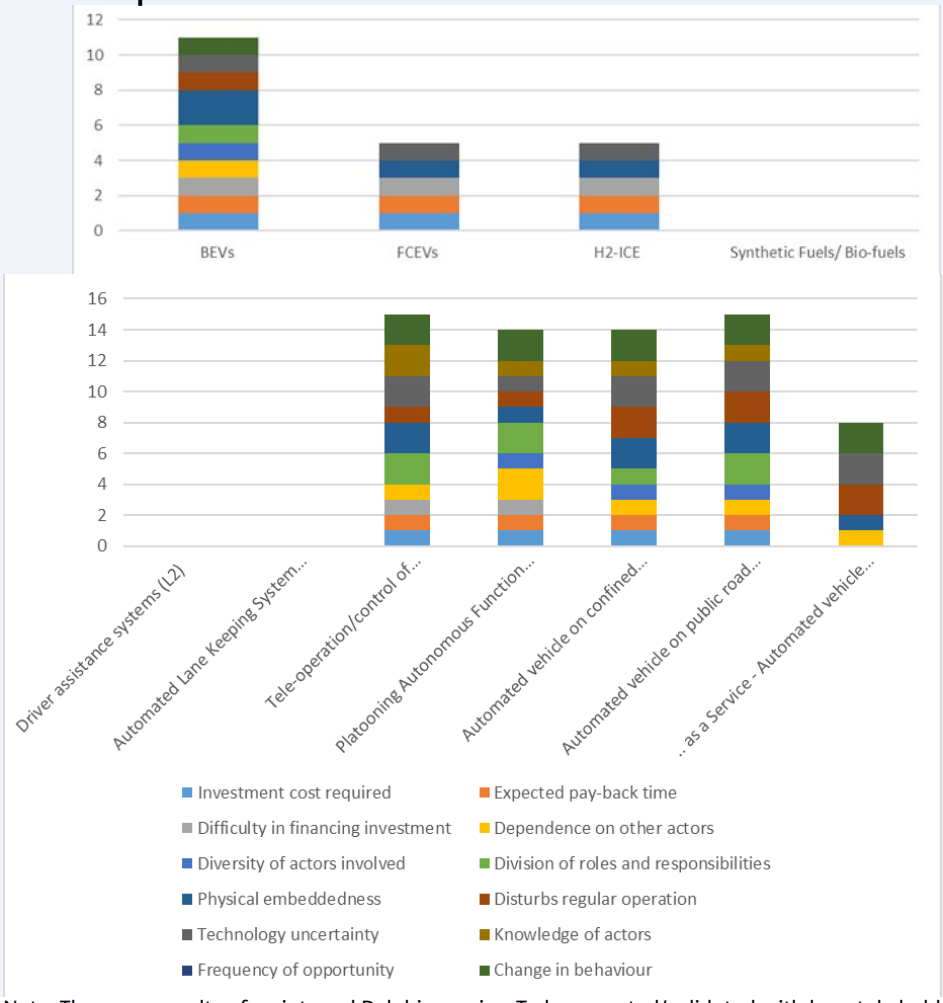
Barriers for uptake – Y-factor approach

Category	Factor	Value 0 No barrier	Value 1 Possible barrier	Value 2 Significant barrier	Definition	Specifics
Costs and financing	Investment cost required	Absent	Medium	Large	The degree to which the investment costs are significant in size for the investor	
	Expected pay-back time	<5 years	5–12 years	>12 years	The degree to which the expected pay-back time is significant	
	Difficulty in financing investment	Low	Medium	Large	The degree to which financing or attracting appropriate financial means is difficult	
Multi-actor complexity	Dependence on other actors	No	Little	Much	The degree to which the responsible actors depend on actions of other actors	cyber, legal
	Diversity of actors involved	Low	Medium	Large	The degree to which the actors involved have opposing interests, values, roles, skills and expectations, or face issues regarding public acceptance	
	Division of roles and responsibilities	Clear	Somewhat unclear	Unclear	The degree to which the roles and responsibilities are unclear	Liability
Physical interdependences	Physical embeddedness	No	Medium	High	The degree to which change is required in connected or related technical systems	
	Disturbs regular operation	No	Slightly	Strongly	The degree to which regular operation, in duration and intensity, is disrupted	
	Technology uncertainty	Fully proven	Small	Large	The degree to which technological reliability and performance are uncertain	technological progress
Behaviour	Knowledge of actors	High	Low	Lacking	The degree to which responsible actors possess the knowledge required	
	Frequency of opportunity	Often	Medium	Rarely	The frequency to which responsible actors have the opportunity to properly consider the abatement measure	
	Change in behaviour	No	Slight	Severe	The degree to which the actors involved need to change their behavioural patterns	

Road operators:



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The Y factor for Climate Change abatement – A method to rank options beyond abatement costs – E.J.L. Chappin, M.Soana, C.E.C Arensman TUDelft 2020

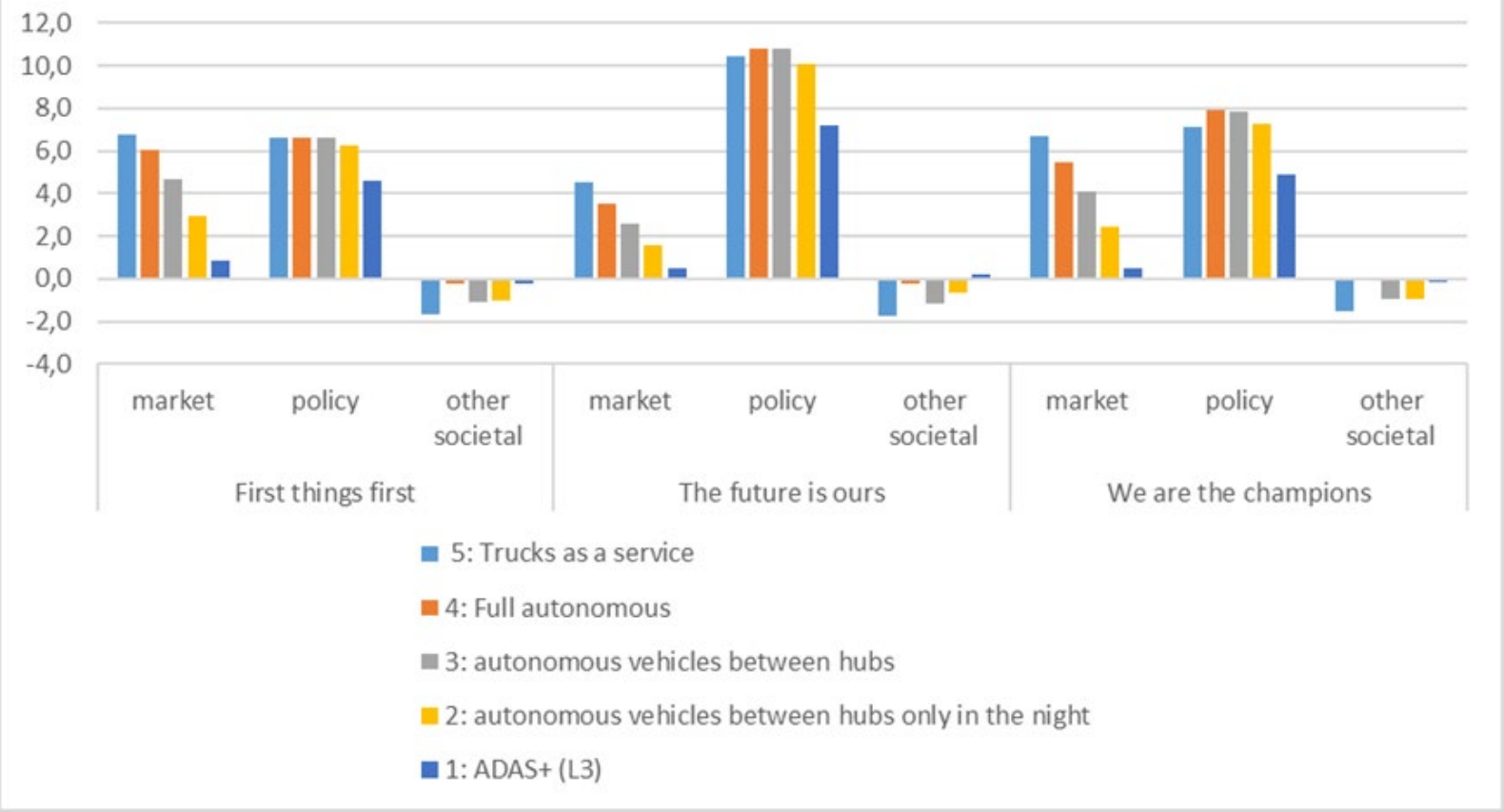
Requirements for logistics – 2035 (2)

- Relative importance of requirements can differ by scenario
- Weights and scores are determined by a Delphi approach with a small group of experts (with the actual stakeholders is preferred)

Requirements		Relevance (score 1-5) by scenario		
		First things first	The future is ours	We are the champions
Market requirements	Competitive price	5	3	5
	Reliability of services (timing pick-up and delivery)	4	3	4
	Flexibility of service availability (ad-hoc booking and/or cancelation)	4	2	4
	Short lead time of service	3	2	4
	Ensure security of cargo (avoid damage and theft)	4	4	4
	Online presence, on-demand	5	4	5
	Real time information	4	4	4
Policy targets	Economic growth	5	2	5
	Ensure accessibility (reduce congestion)	3	5	4
	Reduction traffic injuries and fatalities	3	5	2
	Reduction of climate emissions	3	5	3
	Reduction emissions of pollutants and noise	3	5	2
Other societal requirements	Energy efficient operation	3	5	5
	Limit/reduce damage to infrastructure	3	5	4
	Efficient use of existing infrastructure	4	5	4
	Resilience to disruptions (f.i. energy outage)	4	3	5
	Data privacy	4	5	4
	Ensure cyber security	4	4	4
	Solve labour shortage	5	2	5
	Inclusive operation (including level playing field)	4	5	2
	Provide attractive working conditions:	5	4	3

Note: These are results of an internal Delphi exercise. To be repeated/validated with key stakeholders

Check on "political" resilience



Note: These are results of an internal Delphi exercise. To be repeated/validated with key stakeholders

Conclusion: low risk due to political changes

How to integrate this approach in a broader process?

- Which transitions is targeted?
- Who are the key stakeholders?
- Agree on a collaborative approach create shared insights & define targets
- The presented approach provides guidance to this process and can trim down the options
  - Relevant technologies
  - Possible use cases
  - Relevant future trends to consider
  - Requirements and relative importance by stakeholder
  - Effects of innovations and integration in logistics; make assumptions made and scoring rules explicit
  - Define barriers for uptake and assess risks

- A resulting short list of options can be assessed in more detail. For instance first a more precise assessment of effects by semi-quantitative approaches (e.g. system dynamics) and only very small set of preferred options with larger and quantitative models (accepting its limitations).

Thank you for your attention

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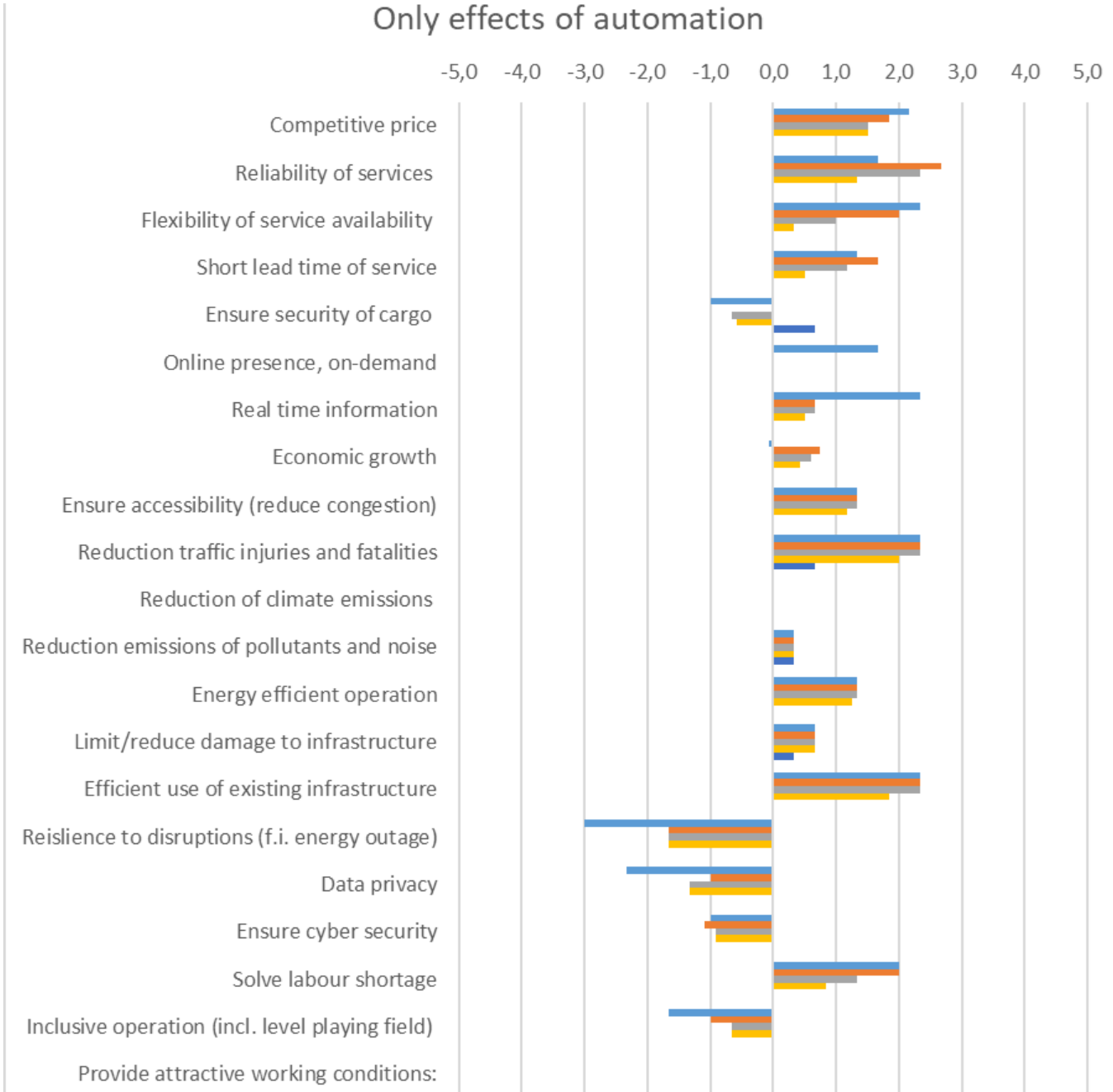
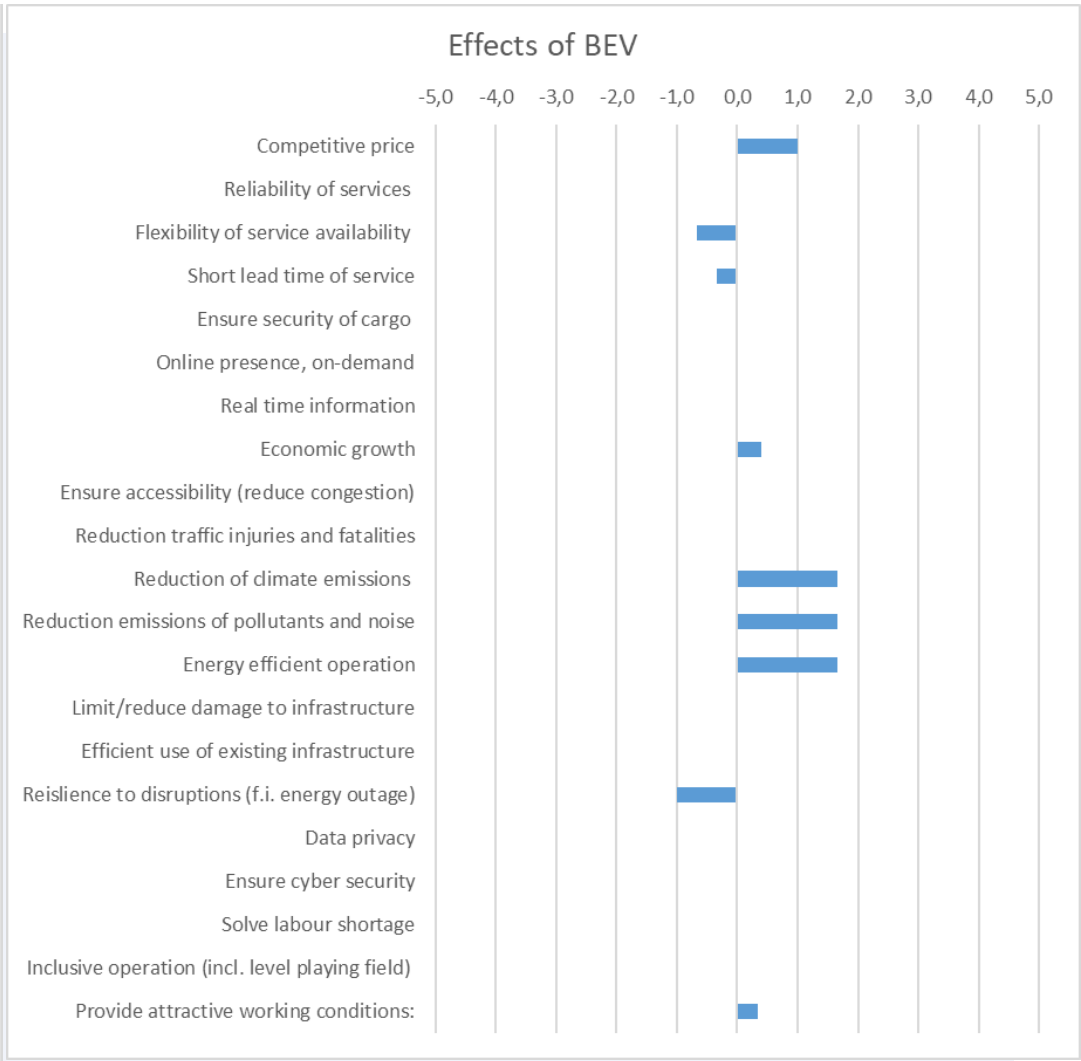
Uptake of road technologies by logistics – many options

Operational change	Implementation options
Battery Charging	• Charging facilities at home base • Roadside charging – no facilities on home base • Roadside charging long distance – resting time driver • Charging at logistical node (incl. hub) – (mostly) during handling • Roadside/at logistical node charging– additional lead time
Using driverless operation on highway	• No driverless operation • Yes, driver remains on board on the highway and performs alternative activities (mainly for short distance) • Driverless operation by transhipment at hub(s) – own account • Driverless operation by transhipment at hub(s) – other company
Transhipment for Hub-hub driverless highway services	• No transhipment at hub required (O + D directly at highway) • Transhipment at hub(s) – traditional • Transhipment at hub(s) – automated
Organisation of the last mile for Hub-hub driverless highway services	• Own account • Truck capacity from partner companies • Find partner company via an online B2B service platform • Last mile organised by the automated driving service for highways, i.e., no last mile organisation.
Automated driving and logistics services at night (combined with automated driving and hubs)	• Yes • Only automated driving at night • No changes to current operation
Cargo monitoring and security system - on board	• Yes, by driver • No, supervision on driverless truck • Yes, supervision on driverless truck by sensors, cameras, remote warning, and automated intervention organisation
Ownership models for trucks for driverless operation	• Truck operator buys truck • Automotive provides truck capacity as a Service or lease option • Automotive provides highway service for truck operators (in combination with online B2B service platform)
Customer (shipper) interaction with truck operator via online service platform	• Single company online application • Cooperating companies online application • Neutral LSP application • Automated driving service (on highways) online service

Effects for logistics use cases





Note: These are results of an internal Delphi exercise. To be repeated/validated with key stakeholders

3 scenarios of pathways to 2035

- **Scenario 'First things first…' - Instability and Crisis Management**: Political climate remains instable and several multi-directional changes between political streams will occur. Consequently, strategies that are initiated are soon adapted to another strategy. Problems that were there in 2024 linger on and are not structurally solved, evoking more crisis situations.

- **Scenario 'The future is ours….' - Collectivism and Sustainability**: The focus is put on a more equal distribution of welfare at first, as such in particular serving the lower income groups. Many extreme weather conditions will occur, which make it clear for the majority that we have to act urgently to reduce climate change. Instability in the world and the growing resource scarcity strengthen collectivism in society and also create the drive for making smarter use of what we have. Consequently, after next elections the key focus on the 'people' remains and is extended with 'planet'.

- **Scenario 'We are the champions…' - Liberalism and Economic Growth**: The unstable and hardening global political climate combined with the heavy competition to get access to essential natural resources, causes a fear to end up on the losing side of global market economy. Liberalism is considered the one and only way forward, with as goal to ensure that the Netherlands remains relevant in the global economy and politically of interest for the leading countries. The red carpet is laid out for innovations and industry supporting this.

Note: These last two scenarios are largely inspired by the scenarios developed and recently updated by PBL (PBL, 6 juli 2023)

Overview challenges – based on prototype/draft

Key barriers for uptake BEV:

- Battery charging infrastructure:
  - Home base operators
  - Hubs/terminals
  - Resting/parking places
- Electricity network capacity
- Resilience measures (energy outage)

Technological needs - automotive:

- Security of cargo – to be mitigated by monitoring systems
- Reduce damage to infrastructure – mitigated by smart lateral movements of trucks to use a larger surface of the lane.
- Cyber security measures

Key barriers for uptake automation:

- Infrastructural needs - Hubs at highways
- Liability
- Adaptation legislation
- Cyber security measures
- Resilience measures (truck operation, supply chain, …)

Overview challenges – based on prototype/draft

Technological needs - automotive:

- Security of cargo – to be mitigated by monitoring systems
- Reduce damage to infrastructure – mitigated by smart lateral movements of trucks to use a larger surface of the lane.
- Cyber security measures

Societal Risks requiring (external) mitigation measures:

- Supply chain Resilience
- Data privacy
- Cyber security
- Inclusive operation

(Other) policy topics:

- Adaptation of relevant regulation (including allowing driverless operation)
- Liability issues
- Level playing field issues of corridor approach
- Supply chain resilience

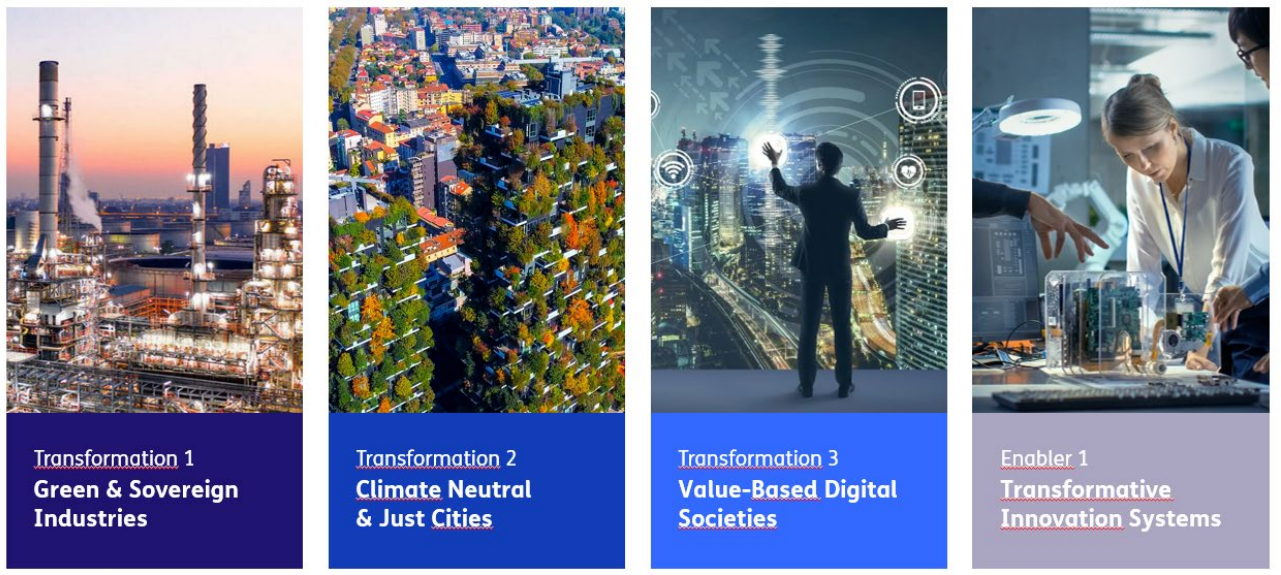
Further research

- This approach ….. should be regarded as a **prototype**.
- The framework developed has proven **effective for this assessment with limited availability of data** for the broad range of relevant variables. ….relatively easy to implement (in a collaborative approach) …. **cost effective**. …conclusions … are similar to conclusions of studies following a more elaborative approach. … no conflicting … identified…..
- In ERP Wiser Policy making a **system dynamics** approach is applied which is **more costly** to implement but **more precise**. It could be considered to use the approach developed in this KIP for an initial broad exploration of options, and then **as a next step** use a system dynamics approach **for the most interesting options**.
- The **assessment of barriers** of uptake is now done at high level. A **more in-depth** assessment is **recommended** ….
- The assessment of the effects of the truck technologies and logistical adaptations is done by **a Delphi method** and the scoring is there for **sensitive for interpretation and inconsistency**. **Specific guidelines** for how **to determine** the **scores** for requirements will be an improvement.
- In this project the information is gathered with a Delphi approach with the small set of team members. In the text it is indicated which **results should be reassessed with a larger group or experts/stakeholders**.

TNO Vector - mission

Translate social and technological developments into perspectives for action to increase future prosperity*

- Properly guiding transitions with proven methods (systems and scenarios)
- Accelerating socio-economic embeddedness of innovation
- From a view of metatrends and the international technological playing field



(*note: prosperity beyond GDP)