SETTING THE STAGE FOR FUTURE MOBILITY

« Aller vite... mais avec des aspects techniques solides »

Prof. Dr.-Ing. Marc ANTONI
Rail System Director
INTERNATIONAL UNION OF RAILWAYS

« Aller vite...
mais avec des aspects techniques solides »

- Part 1 – Asset Management in general
- Part 2 – Modelling HSL Assets for Asset Management
- Part 3 – Safety & Security : Cyber issues

Part 1 – Asset Management in général

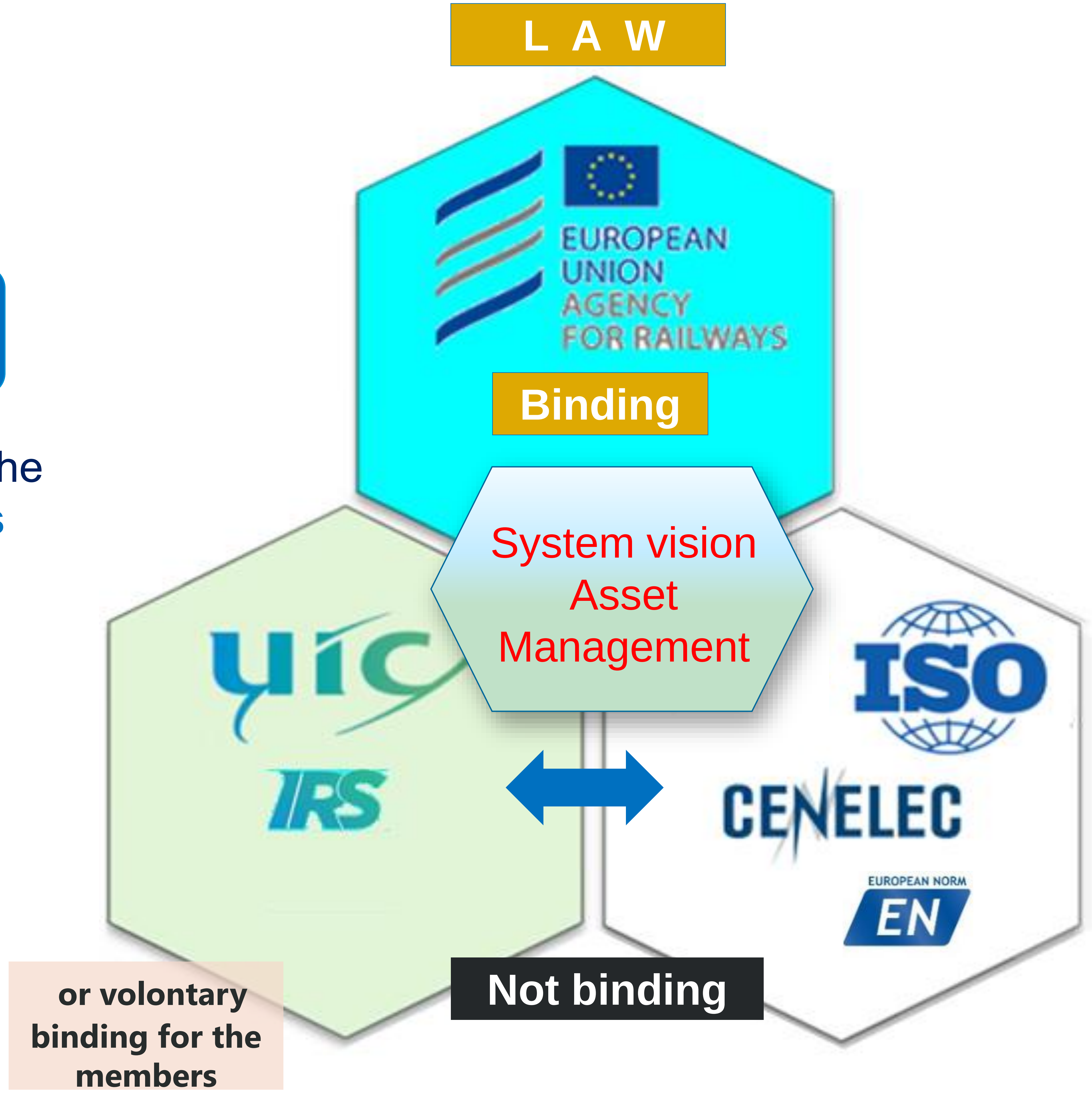
Standardisation: Complementarity within the EUAR-ESO-UIC trio

Regulation vs. Norms vs. Standards and requirements

Process-related standards

"Operator" responsible for the **system** and the **services**

- Operation
- Maintenance
- Integration
- High speed
- Freight
- Asset Management
- Safety/Security
- Organisation



Product-related standards

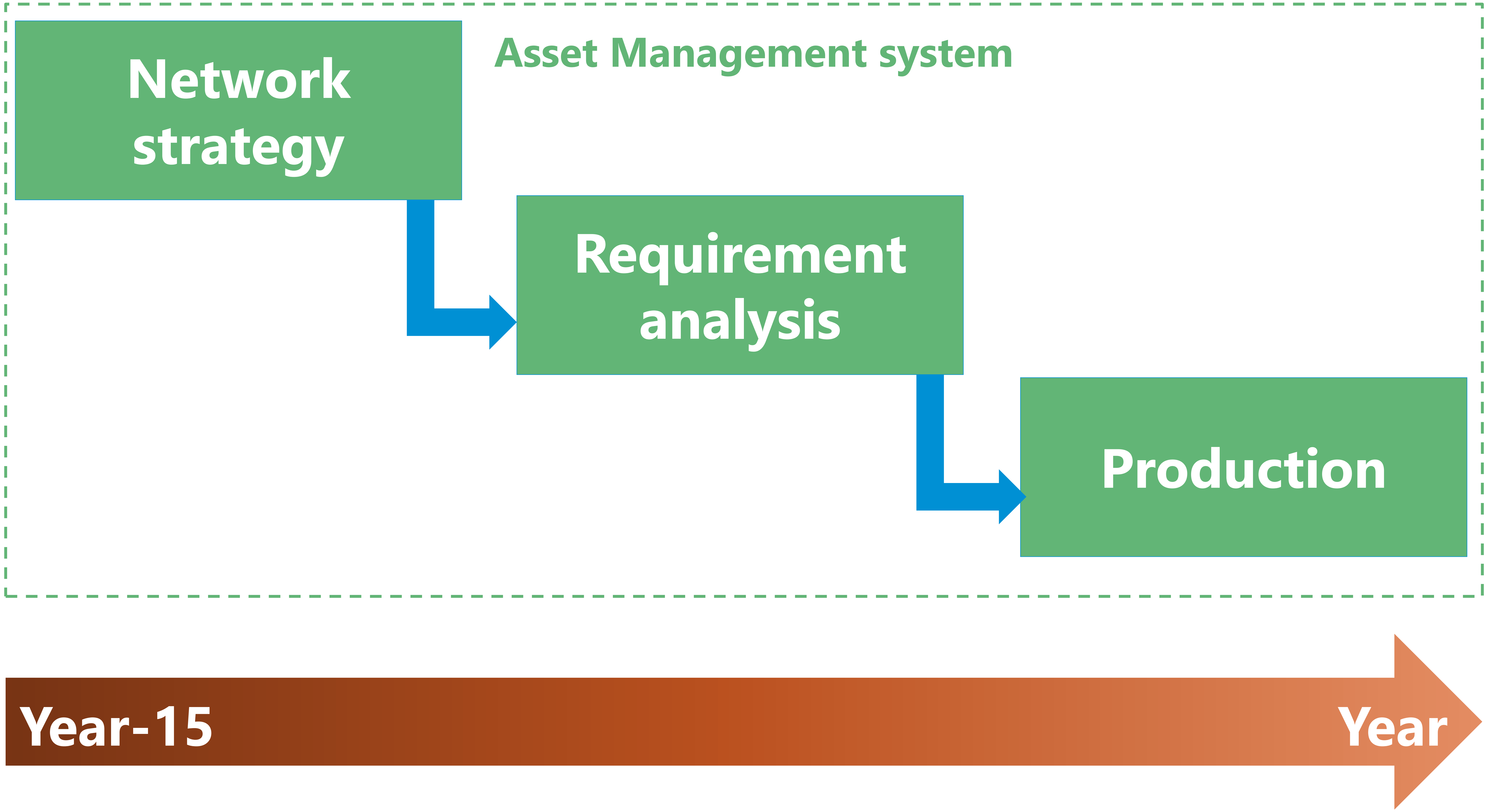
"Manufacturer" responsible for the **products**

- Products
- Sub-System
- Industrialisation

1 – Asset Management / Railways

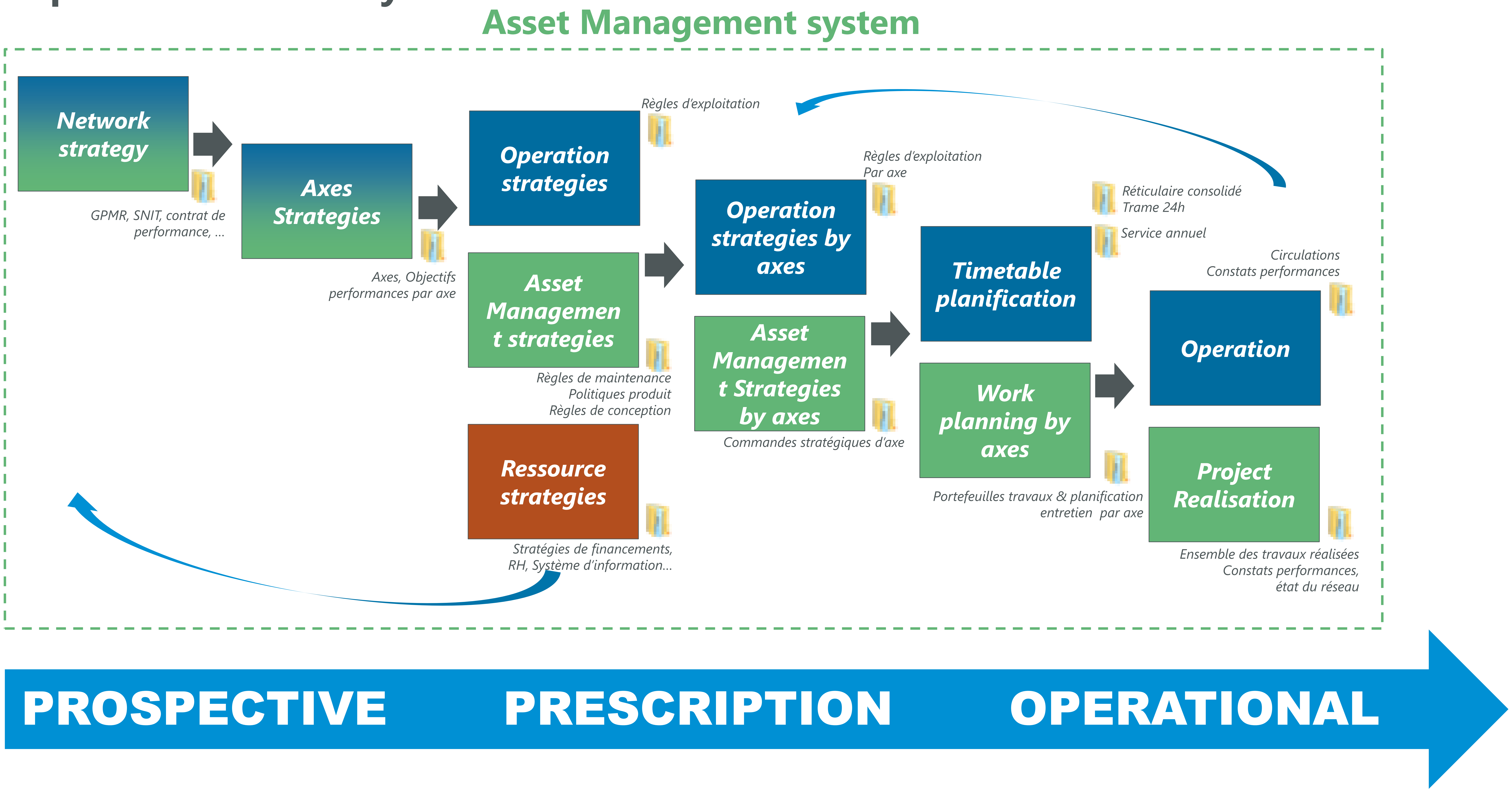
A perfect coherent system vision:

↗ performance requirement for assets definition, the conditions of use and the work to be carried out



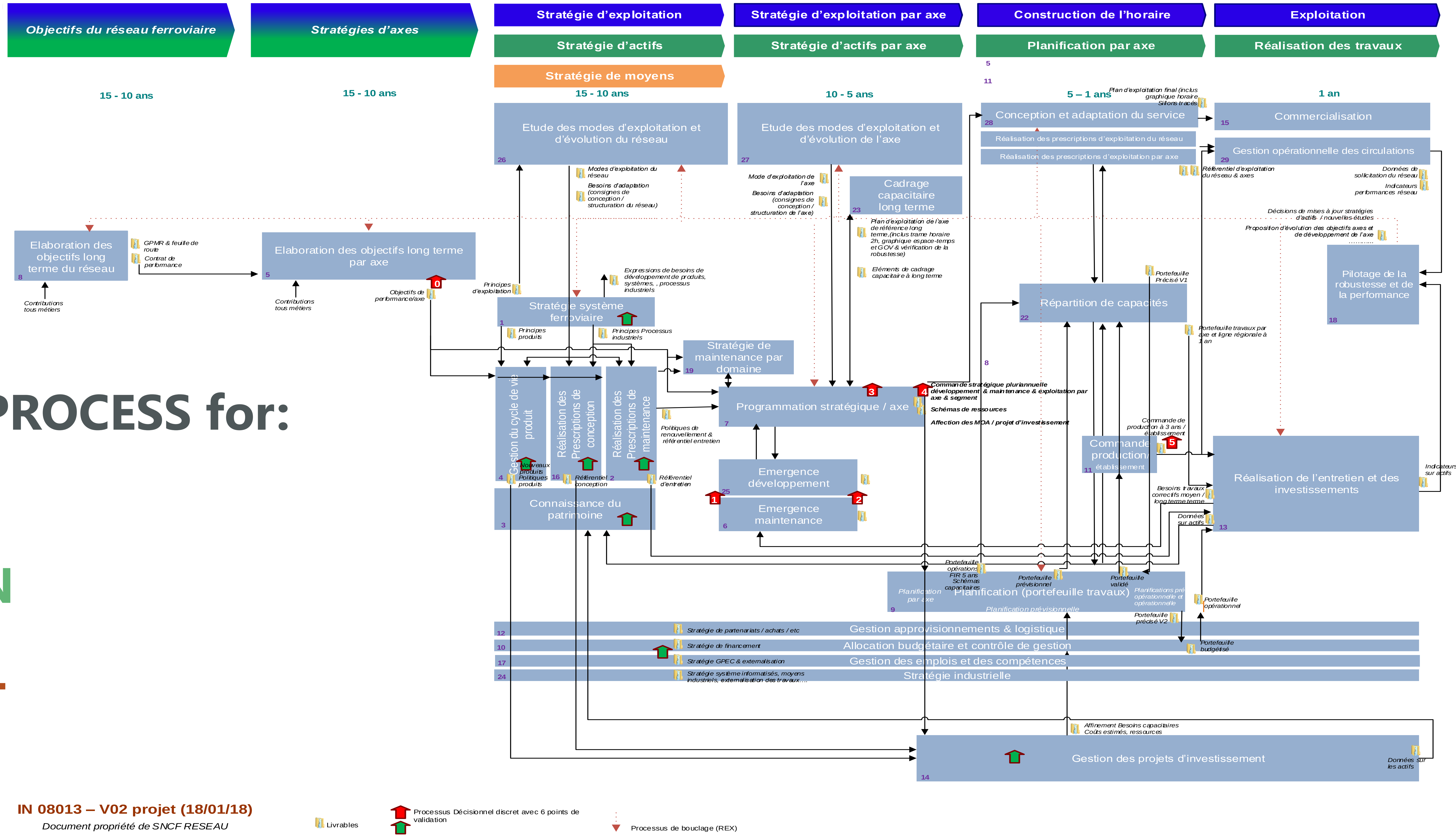
1 – Asset Management / Railways

A perfect coherent system vision:



1 – Asset Management / Railways

Macro-processus asset management



IN 08013 – V02 projet (18/01/18)

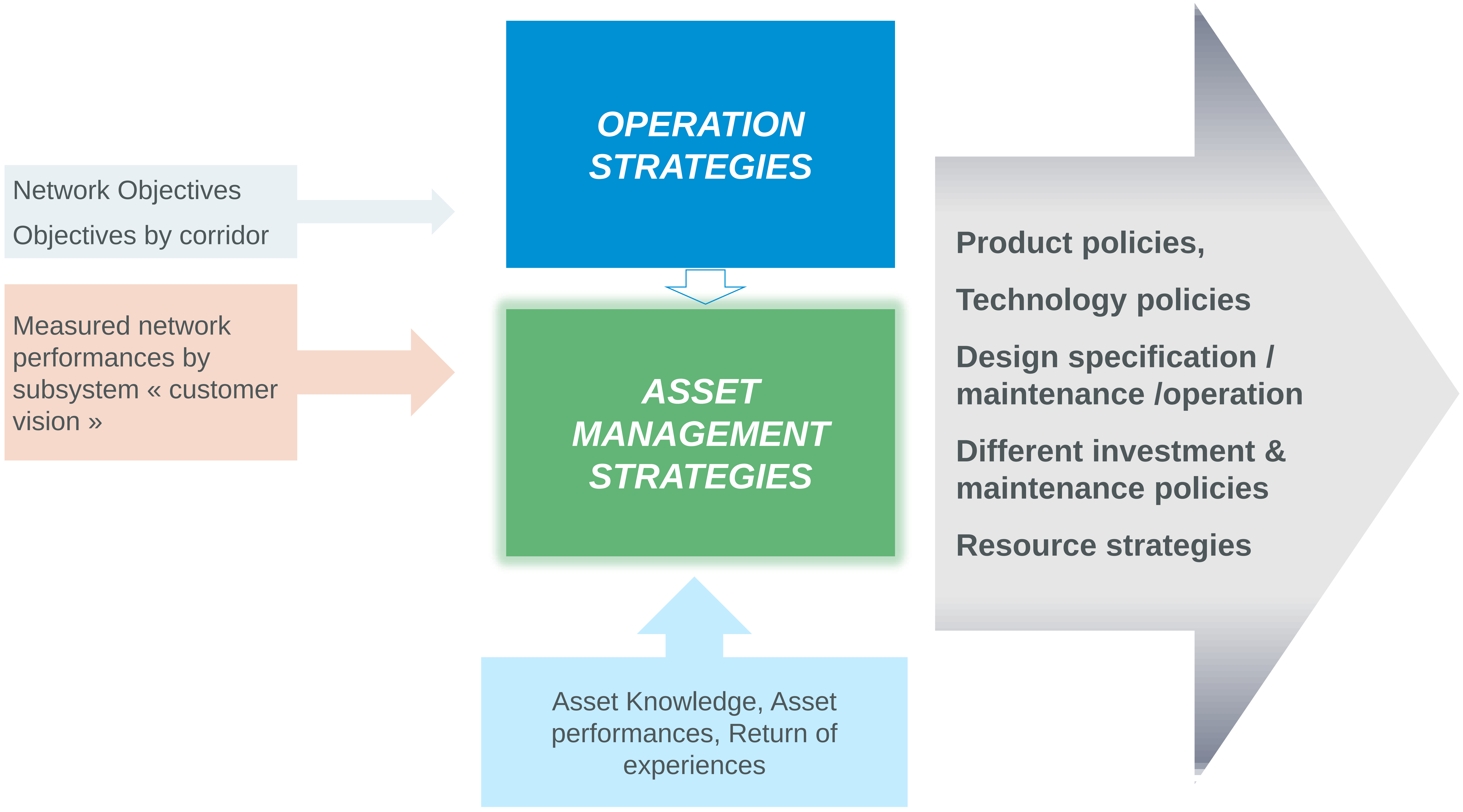
Document propriété de SNCF RESEAU

Target MACRO-PROCESS for:

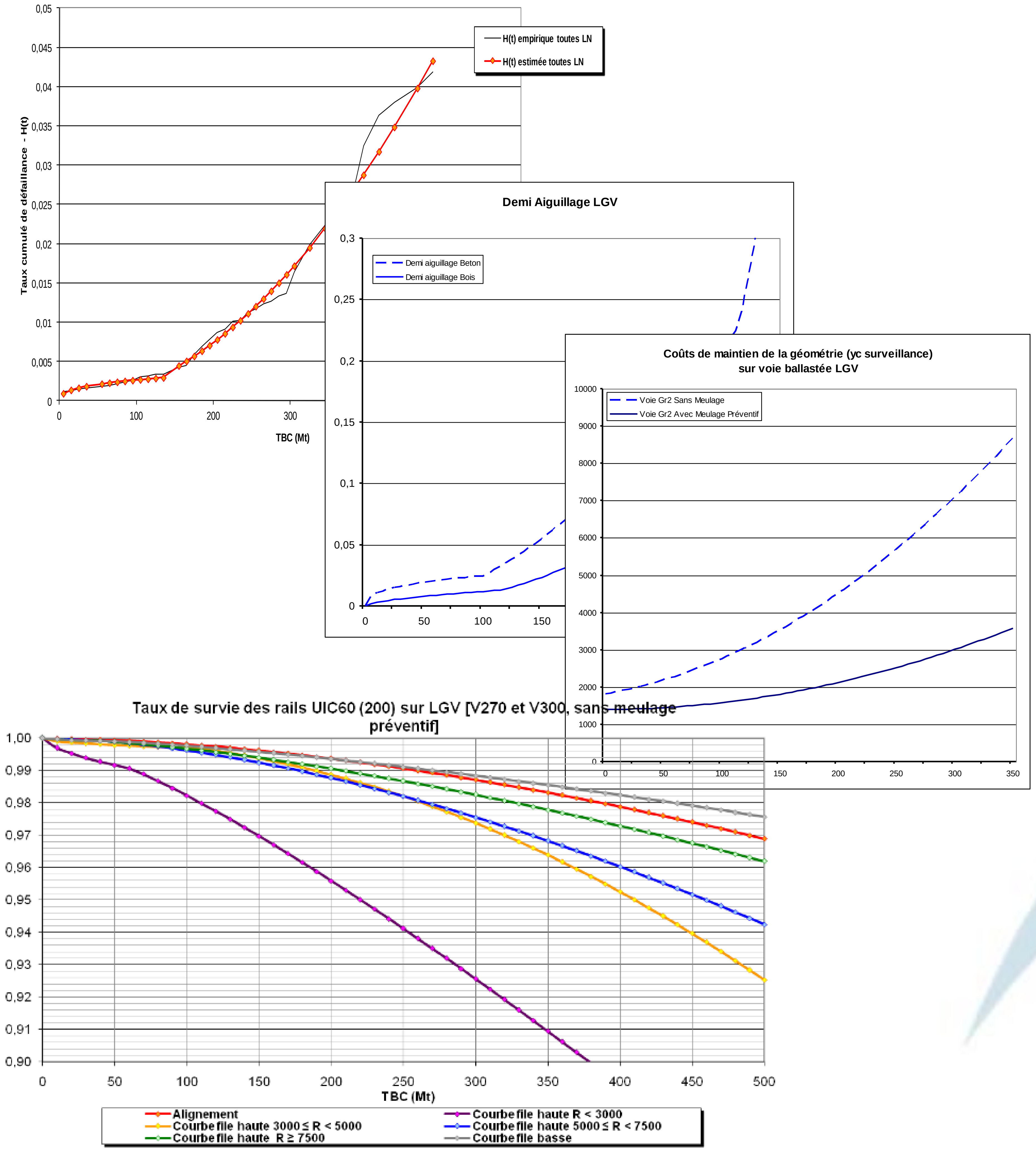
- ✓ PROSPECTIVE
- ✓ PRESCRIPTION
- ✓ OPERATIONAL

1 – Asset Management / Railways

ASSET MANAGEMENT STRATEGIES
INTEGRATION OF TECHNICAL NEEDS



1 – Asset Management / Railways
from digital to asset Management



Predictive maintenance goes through processing and cross-data. This is our number one challenge.
→ Part 2 for HSL

Corrective maintenan-ce

Preventative Maintenance
Based on calendar concepts or use units

Conditional Maintenance
Based on statements or measures revealing a degradation

Model-based predictive
Maintenance and advanced data analysis

1 – Asset Management / Railways

ASSET MANAGEMENT
INTEGRATION OF WORK NEEDS

Network Objectives

Objectives by axis

Measured network performances/ subsystem
« customer vision

Product policies, Technology policies

Design/maintenance/operating requirements

Differentiated Investment & Maintenance policies means strategies

OPERATION STRATEGIES

ASSET MANAGEMENT STRATEGIES

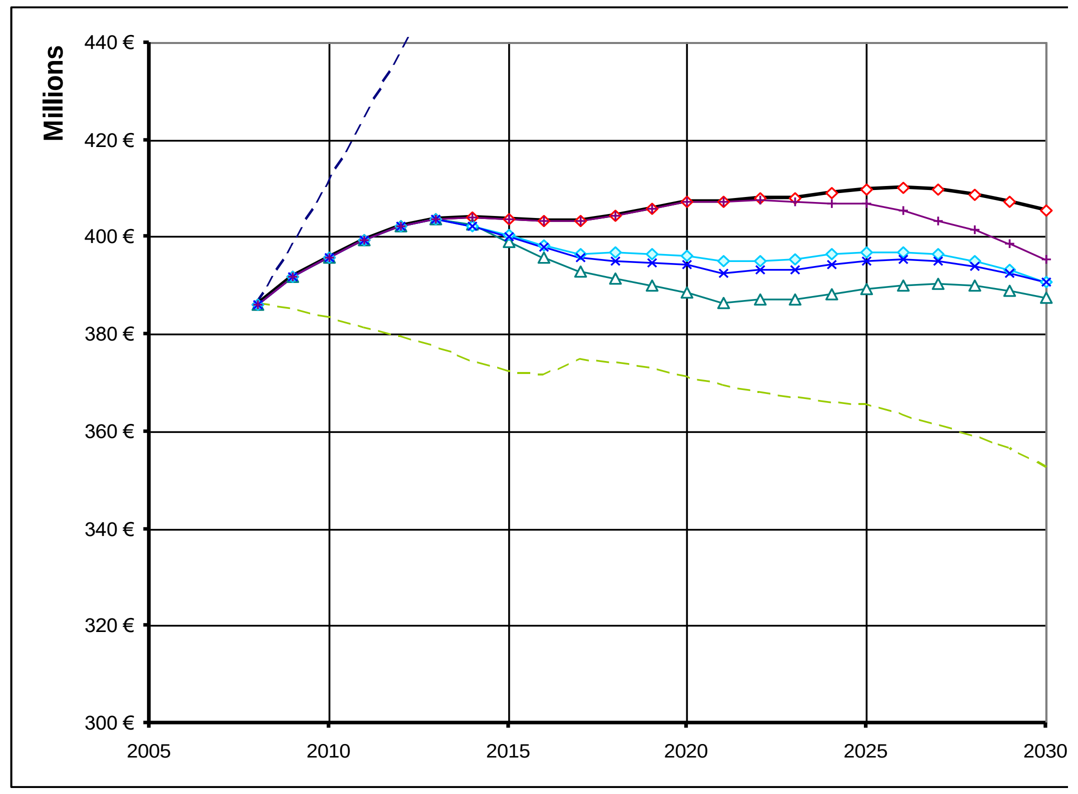
State of the patrimony of the axis/corridors
Emergences Asset Performances

Commands Strategic axis:
- Circulable capacity
- Object works framed to achieve
- Performance schedule to be achieved
- Resource plans

Refined means strategies

Estimation of the maintenance needs

Estimation of the maintenance needs and costs



2 – Asset Management /value-based approach

Contribution of a corridor or line to enhance the value of the network

The value of a line brought to the network can be expressed by different considerations:

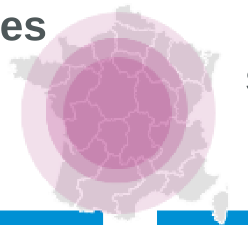
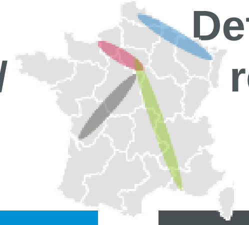
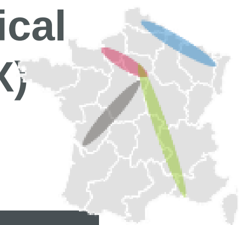
- **Commercial performance** (performance from the customer's point of view): passenger traffic, freight traffic, travel time, Traffic flow, regularity, Incident recovery time…
- **Strategic performance** (functions provided by the line): contribution to the resilience of the network (alternative route function), contribution to the economy of the territory, contribution to the interoperability of the network, etc.
- **Revenue**: tolls collected / train route

2 – Asset Management / value-based approach

Value structuration

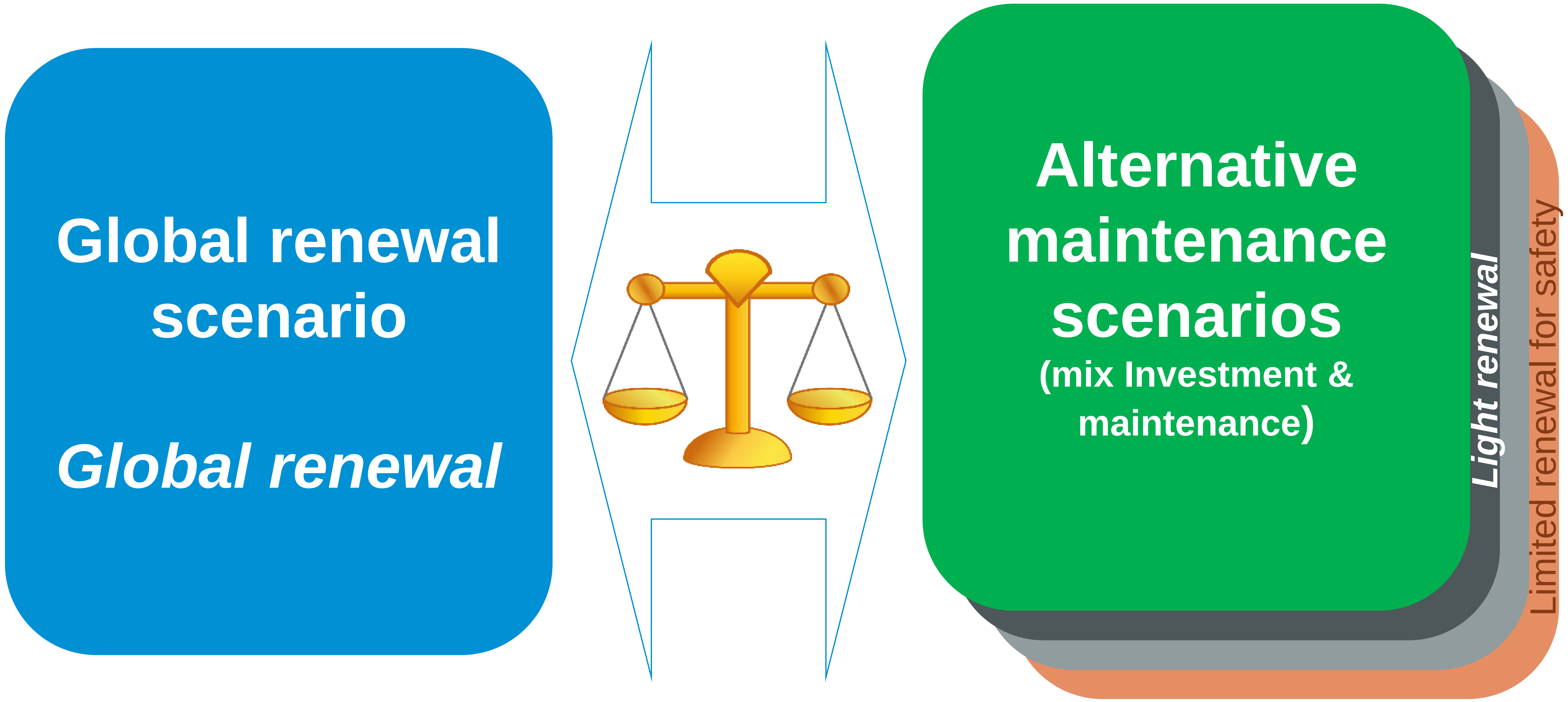
Network strategy	Axes strategy	Asset Strategies	
Decision on network piorities (performance contract)	10-year evaluation of sustainability / business / performance needs	Definition of possible technical responses (CAPEX / OPEX)	
National network rank 1*	Sustainable axes / Traffic increase or maintenance / Performance requirements / Important revenues	Renewals to ensure safety and increase performance requirements Modernizations New offers	**OPTIMAL MAINTENANCE**
National network rank 2*	Long-term axes / Traffic increase or maintenance / Performance requirement	(same as above)	**OPTIMAL MAINTENANCE**
National network rank 2*	Axes with uncertain traffic prospects or not guaranteeing certain economic criteria **	Adapted maintenance (renewal / maintenance mix) to ensure safety & security to control performance or performance decline Modernizations (subject to an economic model)	**ADAPTATED MAINTENANCE**
National network rank 2*	Axes with low traffic / low traffic & decreasing	(same as above)	**ADAPTATED MAINTENANCE**
Local lines*	Permanent lines / Increased traffic / Performance requirement	Adapted maintenance (renewal / maintenance mix) to ensure safety or renewals & developments if CPER financing	**LIMITED MAINTENANCE FOR SAFETY**
Local lines*	Long-term lines with stability or even reduction in traffic	Maintenance or adapted renewal submitted to CPER to ensure safety & reduced performance	**LIMITED MAINTENANCE FOR SAFETY**
Local lines*	Futureless lines	Maintenance adapted to ensure safety & lower performance ***	**LIMITED MAINTENANCE FOR SAFETY**

A-10

2 – Asset Management / value-based approach

Appropriate maintenance PRINCIPLES



***Global renewal**:* one-time renewal
Light renewal**:* smooth renewal and minimization of performance degradation related to the asset ***safety
***Safe renewal**:* smooth renewal of the line to protect against security risks

2 – Asset Management / value-based approach

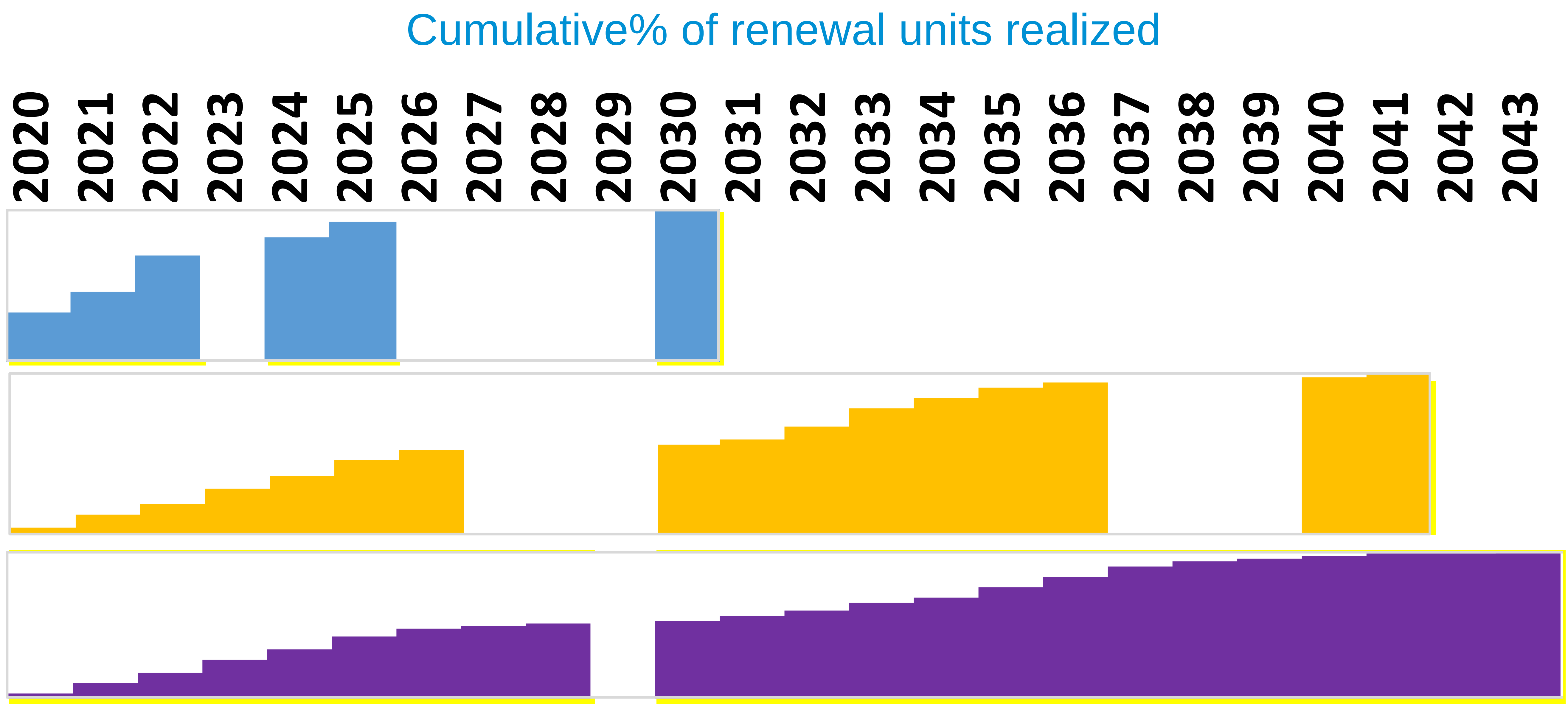
Appropriate maintenance
Example with different maintenance scenarios

SCENARIOS

Global regeneration (11 sites)

Lightened regeneration (43 yards, 49 maintenance operations)

Safety Regeneration (69 worksites, 75 maintenance operations)



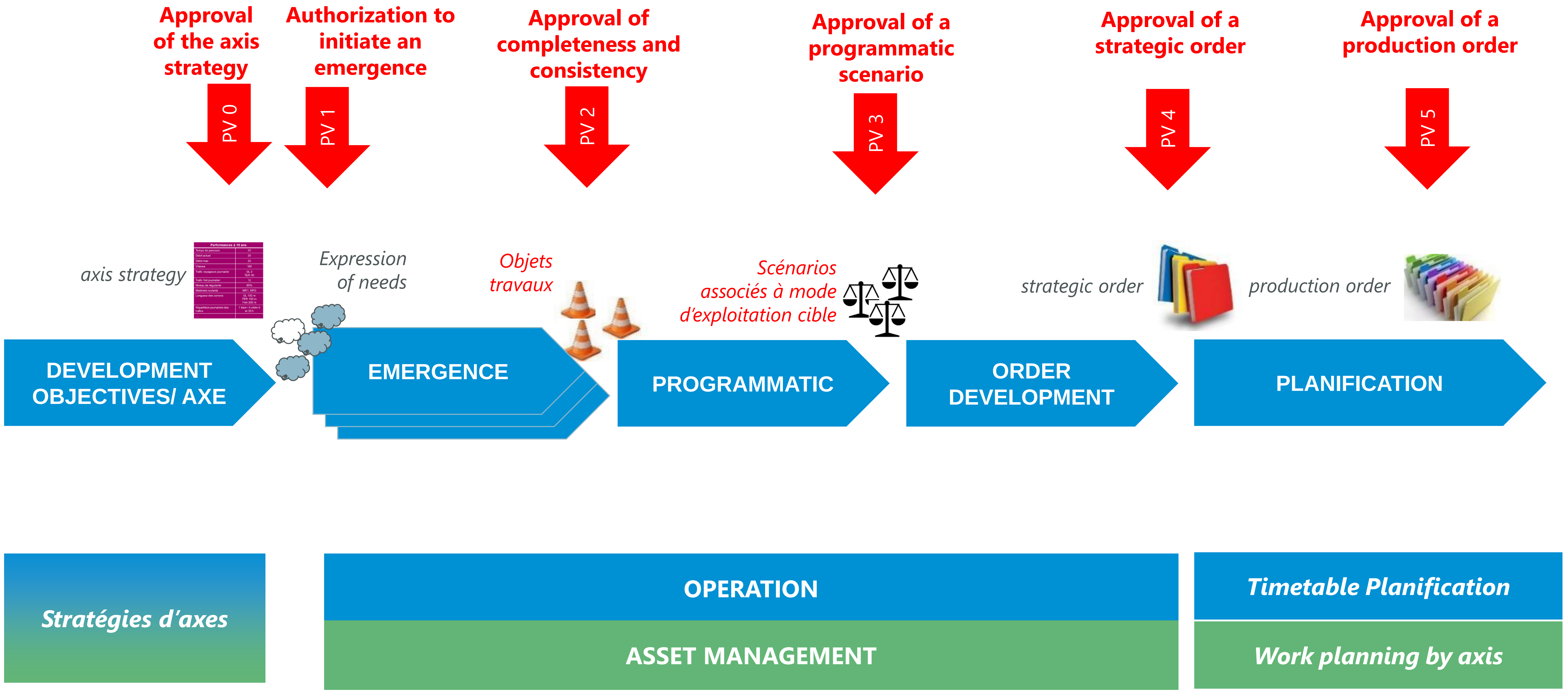
2 – Asset Management / value-based approach

Appropriate maintenance / EXAMPLE: SOCIO-ECONOMIC issues – Relation with global renewal - Focus on key balance statement

VAN actualisées à 4,5% en 2019 (M€)	Capacity Impact	CAPEX	OPEX	RU	IM	TOTAL
Variations	**De 0,2 à 1,9**	**+/- 10%**	**De 1 à 3**			
Reduced Regeneration **1**	**-16**	**+17**	**-19**	-	~	-
Reduced Regeneration **2**	**+18**	**+16**	**-19**	+	~	+
Reduced Regeneration **3**	**+2**	**-13**	**-19**	~	-	-
Reduced Regeneration **4**	**-12**	**+24**	**-19**	-	+	~
Safety Regeneration	**-21**	**+25**	**-24**	-	~	-

3 – Towards a governance within an axis vision

Decision-making process in a railway axis vision



Part 2 – Modeling HSL Assets for Asset Management

1 - Modelling for Infrastructure Management after conception engineering

Three steps (example for track) :

3 – Tools for LCC calculation at the national or route levels, including environmental effects, track possession and unavailability costs…

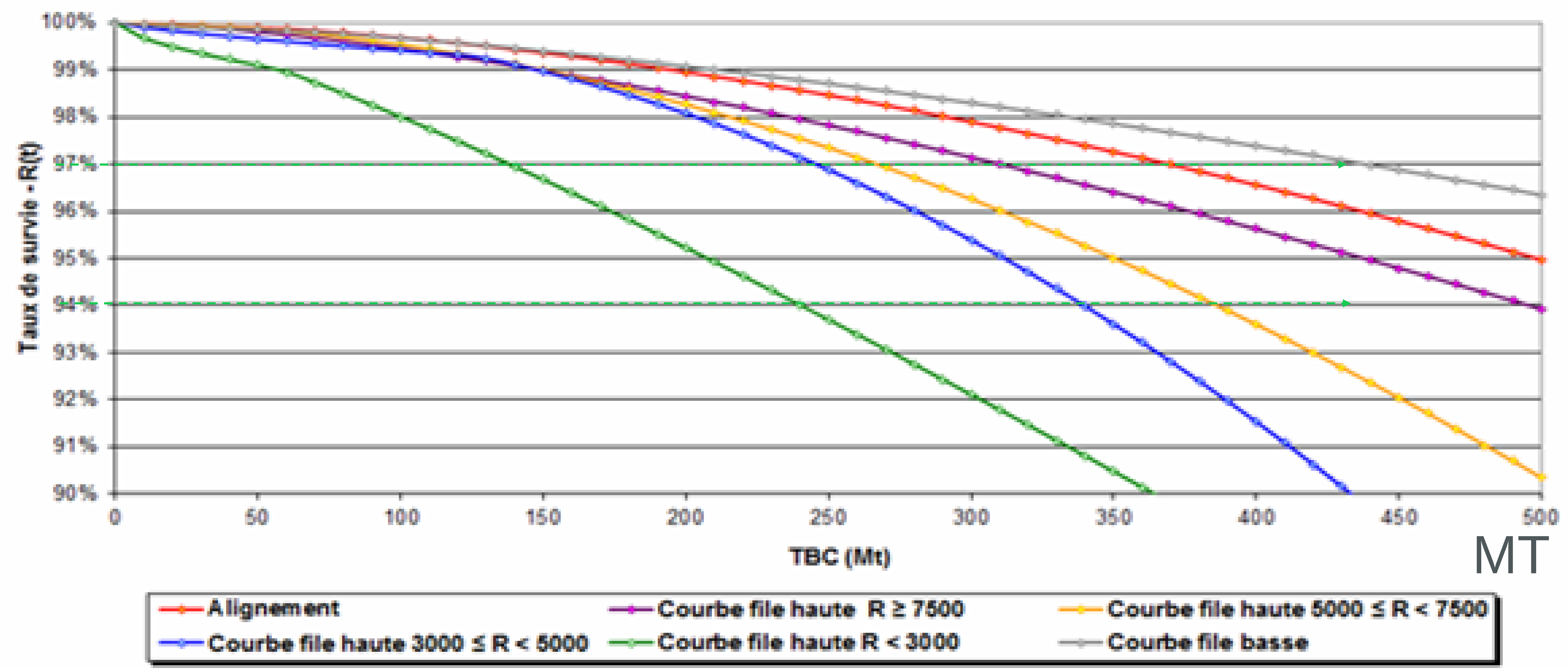
2 – Tools for the estimation of maintenance needs of the track (with different renewal strategies)

1 – Work of the deterioration and failure laws of each the track components

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

- **Failure laws of rails** :
  - lifespan of the rails on a ballasted HSL is about 400MT with 3% of cumulative defects, 700MT with 6%
  - the parameters of these laws are sensitive to track topology and aggressiveness of the rolling stock

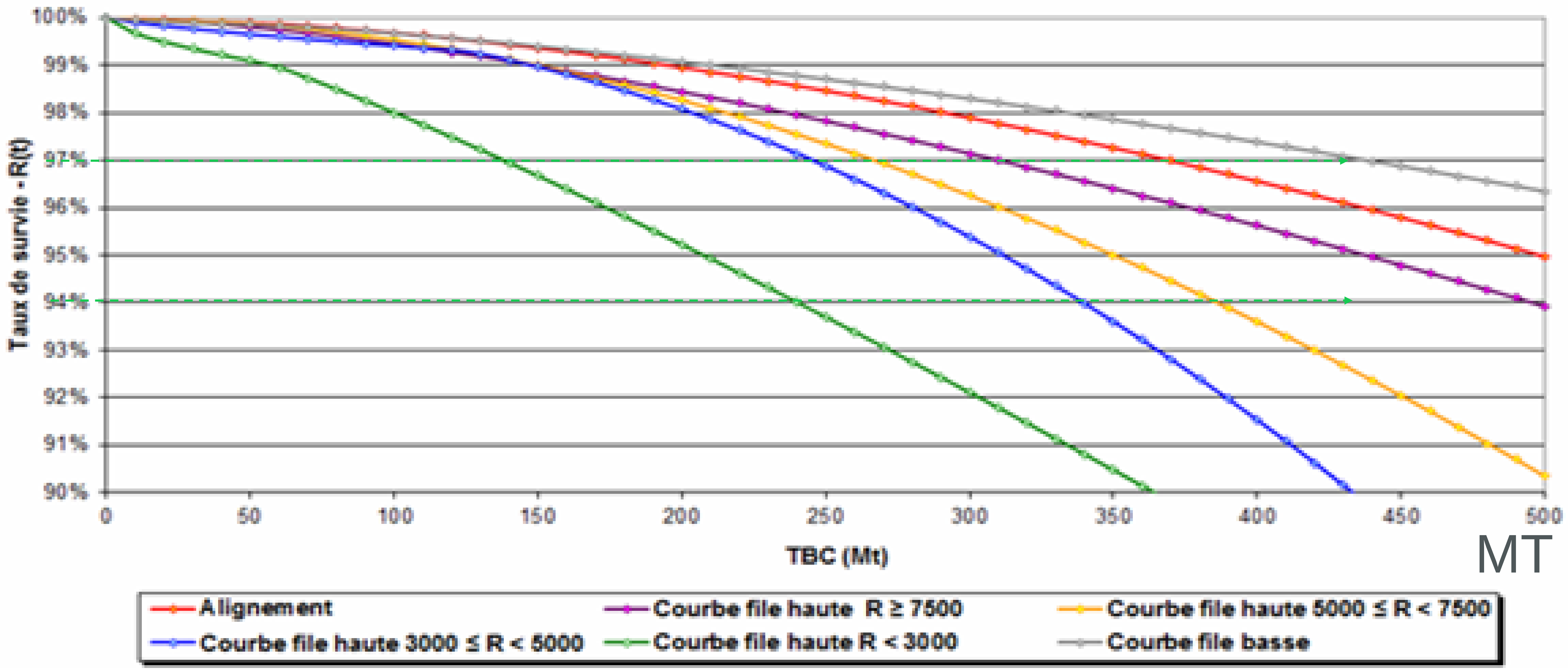


After 30 years of operations and 650MT with V300, more than ¾ of rails of LN1 are original. The last rails were replaced in 2018…

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

- **Failure laws of rails** :
  - lifespan of the rails on a ballasted HSL is about 400MT with 3% of cumulative defects, 700MT with 6%
  - the parameters of these laws are sensitive to track topology and aggressiveness of the rolling stock



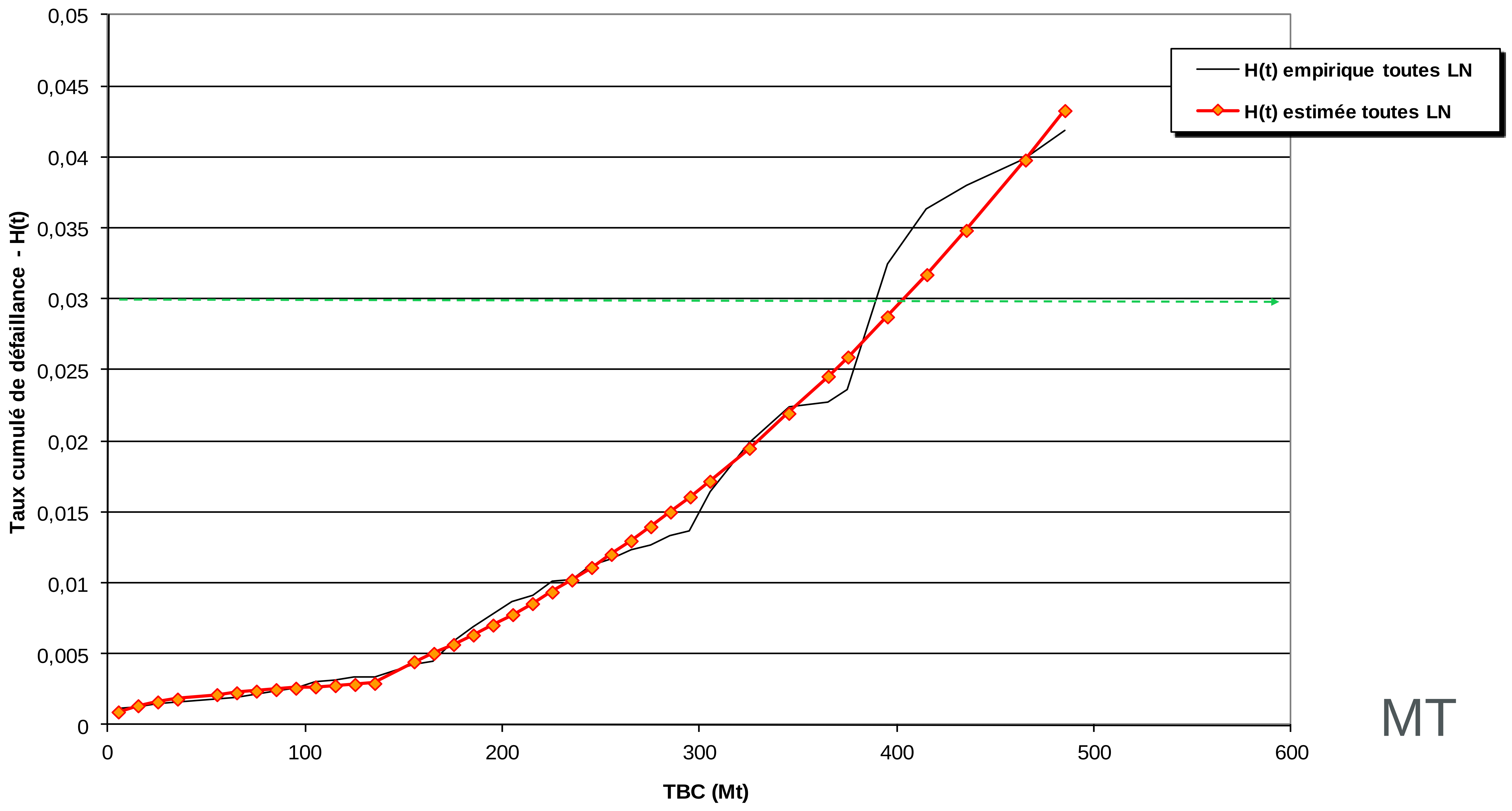
The failure rate can grow more quickly if the rolling stock has an important rate of “slippage” (20% for some materials)

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

- **Failure laws of aluminothermy welding**:

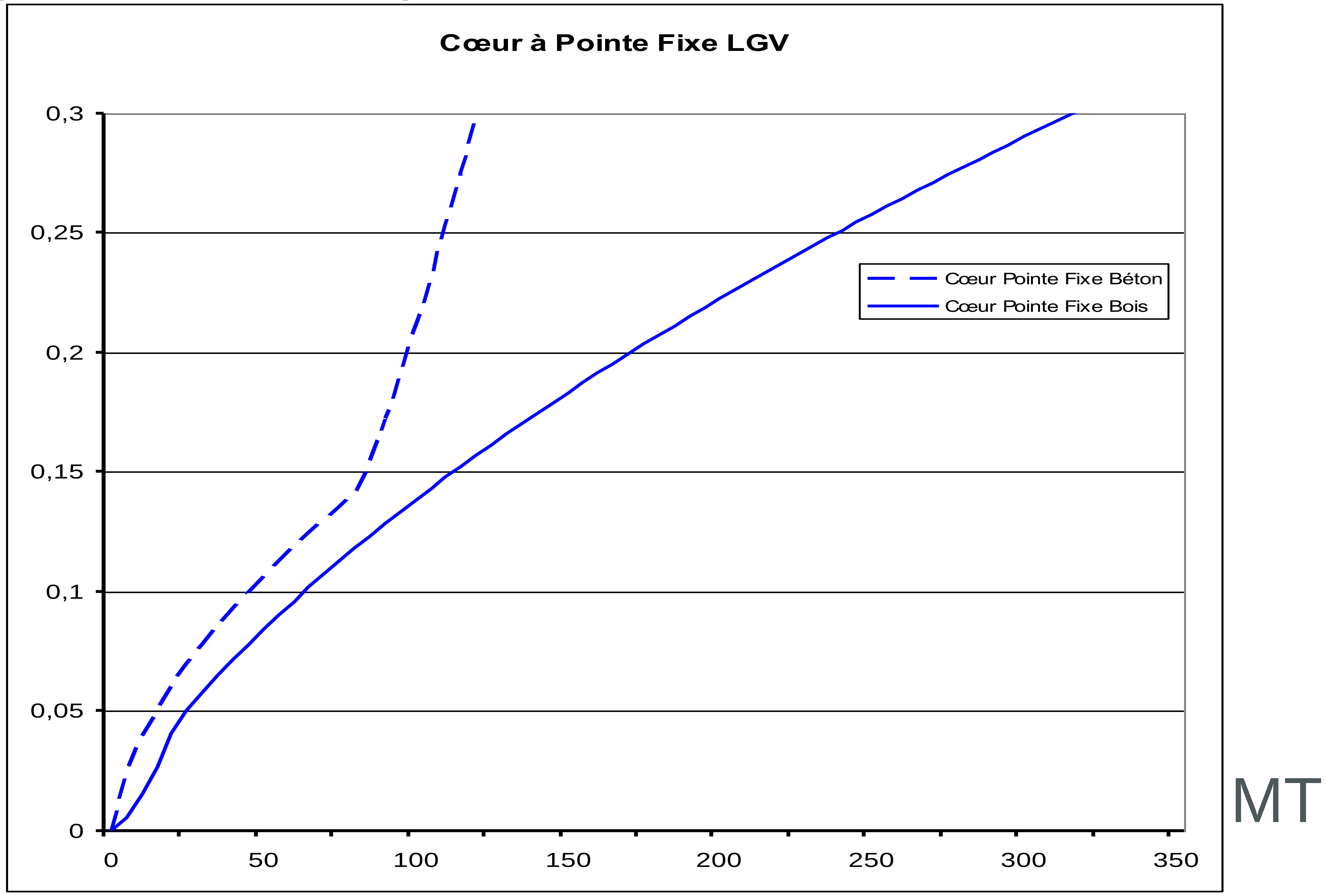
  - lifespan of a weld on ballasted HSL is about 400MT with 3% of cumulative defects [even without preventive grinding]



1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

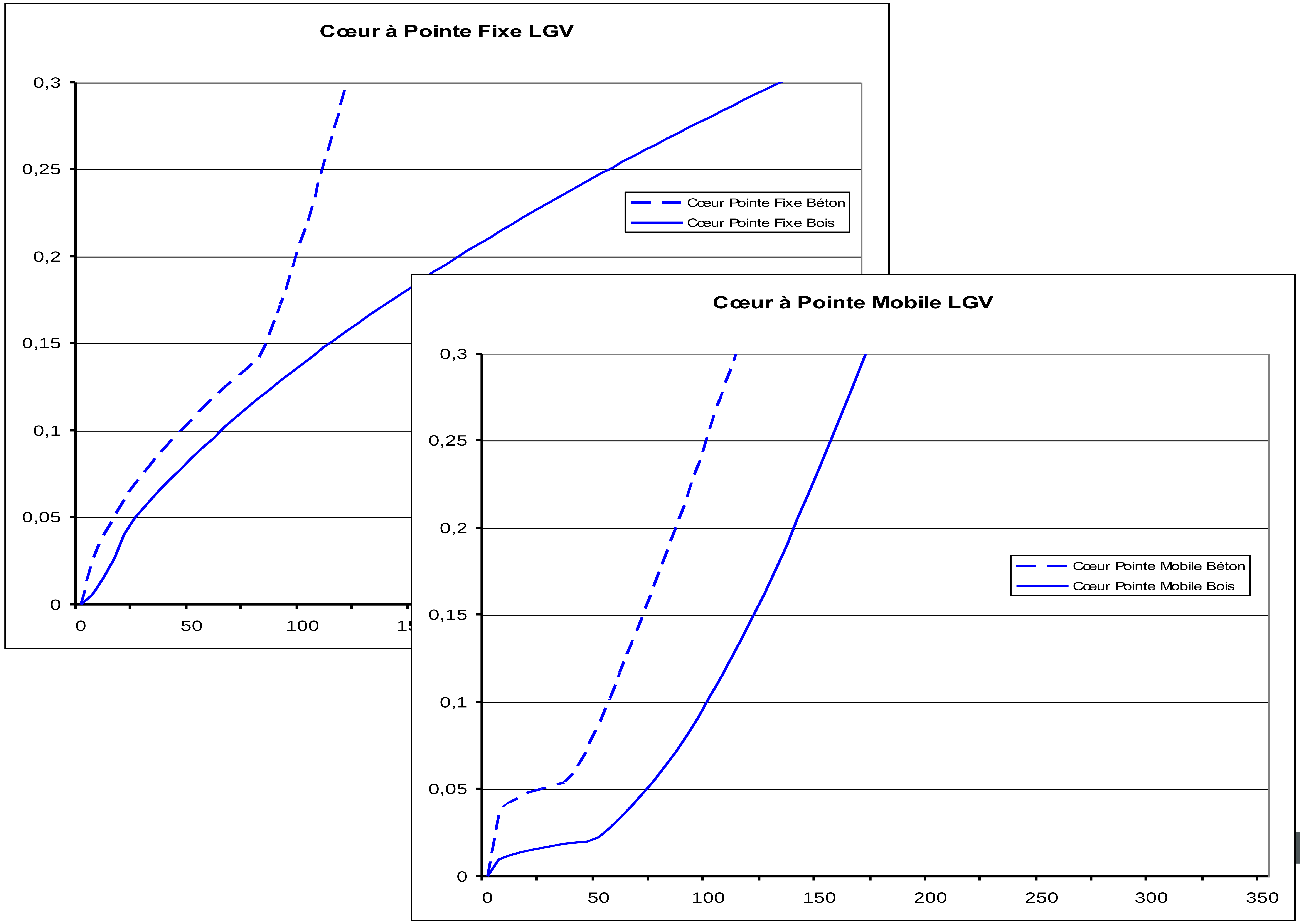
- **Failure laws of manganese or movable frogs**:
  - lifespan of these components is longer on wooden sleepers then on concrete ones
  - the parameters of these laws are sensitive to the aggressiveness of the rolling stock



1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

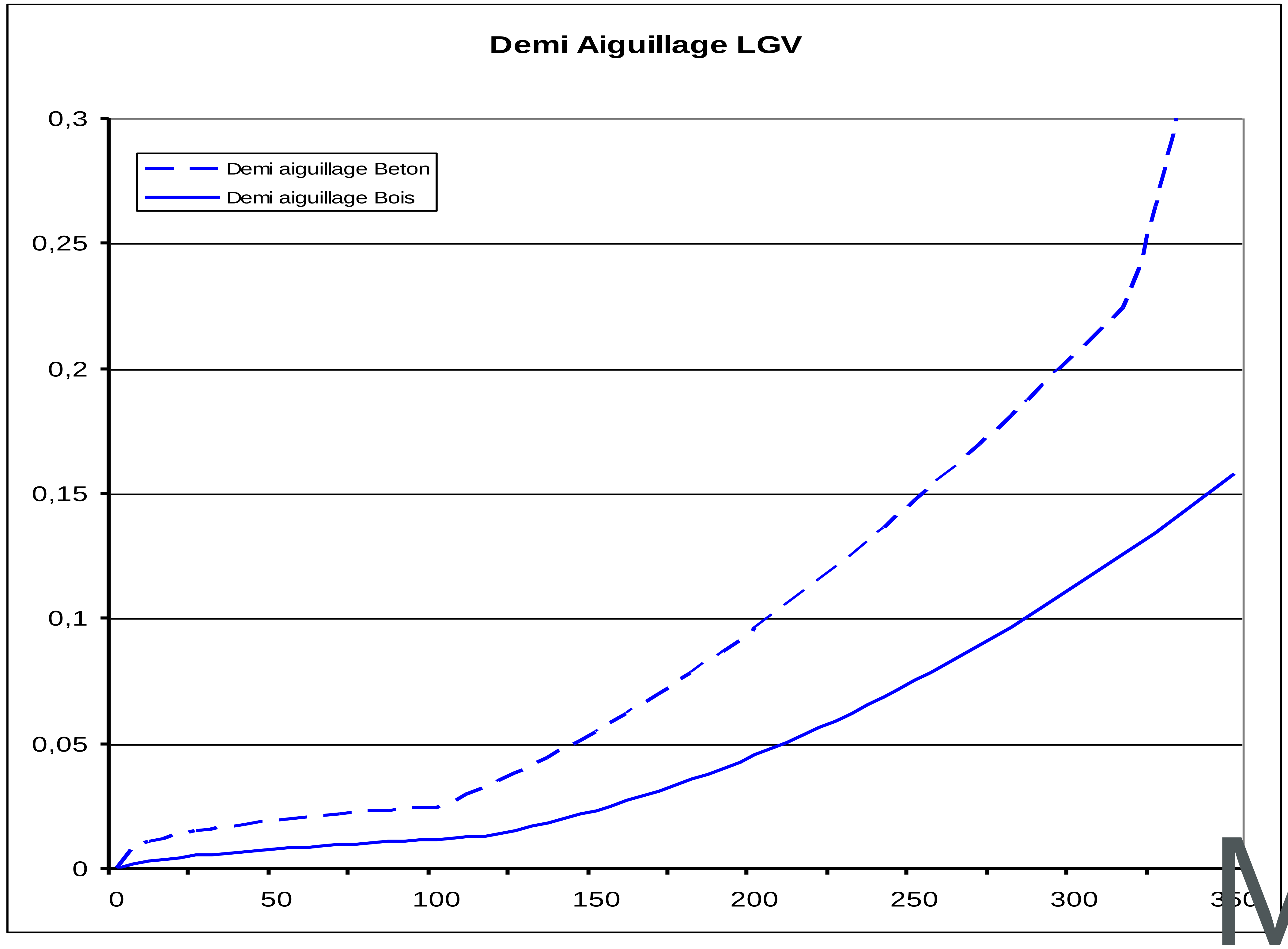
- **Failure laws of manganese or movable frogs**:
  - lifespan of these components is longer on wooden sleepers then on concrete ones
  - the parameters of these laws are sensitive to the aggressiveness of the rolling stock



1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

- **Failure laws of switch half switch set**:
  - lifespan of these components is longer on wood sleepers then on concrete ones
  - the parameters of these laws are sensitive to the aggressiveness of the rolling stock and the hardness of the track

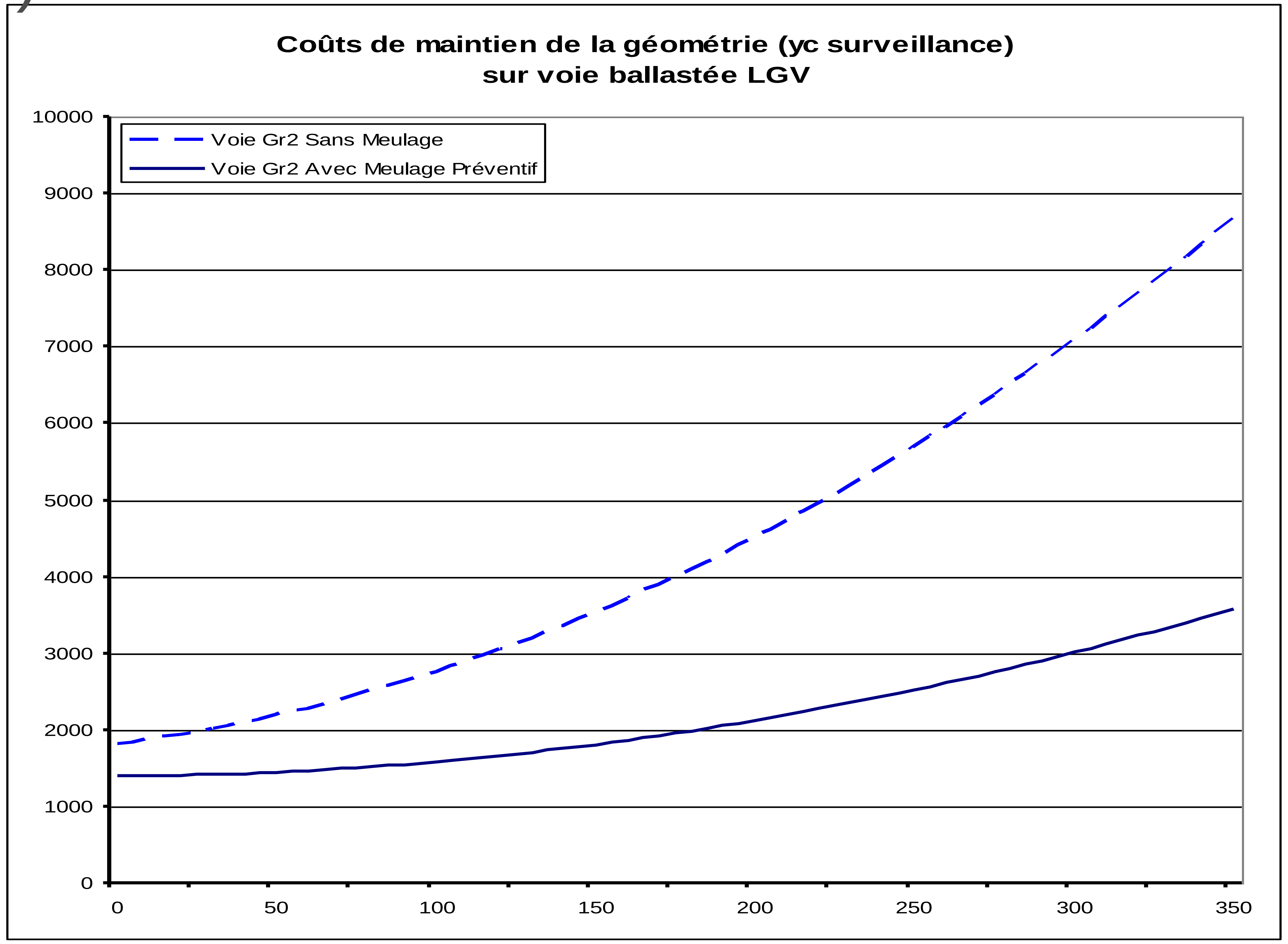


MT

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

- **Geometry degradation laws**:
  - lifespan of the ballast, without sand-gravel mix bitumen or PAD, is approximately 25 years on HSL (>300)
  - this lifespan will be much higher with sand-gravel mix bitumen and/or PAD
  - maintenance needs follow Cochet-Maumy laws



MT

The parameters of these laws depend on grinding, the type of **rolling stock**, etc.

$$\mathrm{Im}(N) = k \times 0{,}8 \times \delta \times \left(a + b \times \left(2^{\frac{N}{5}} - 1 \right) \right)$$

1 - Modelling for Infrastructure Management after conception engineering

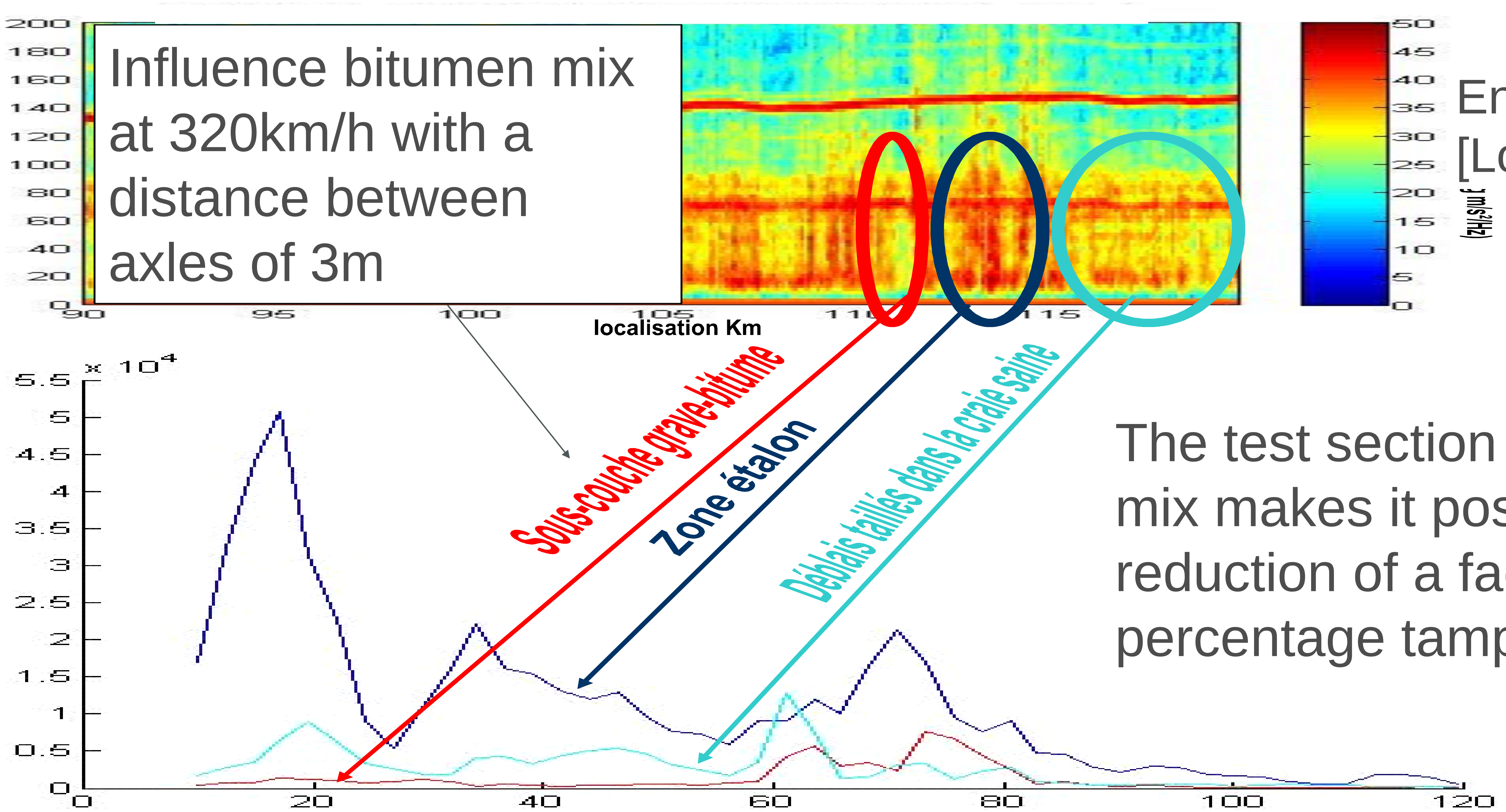
Step 1: Lifespan of the components (ballasted HSL)

The nature of the under layer has a significant influence on track lifespan and HSL geometry
⇒ specific Cochet-Maumy parameters

Frequencies [Hz]

Energy measured [Log (m/s²/Hz)]

Energy measured [m/s²/Hz]

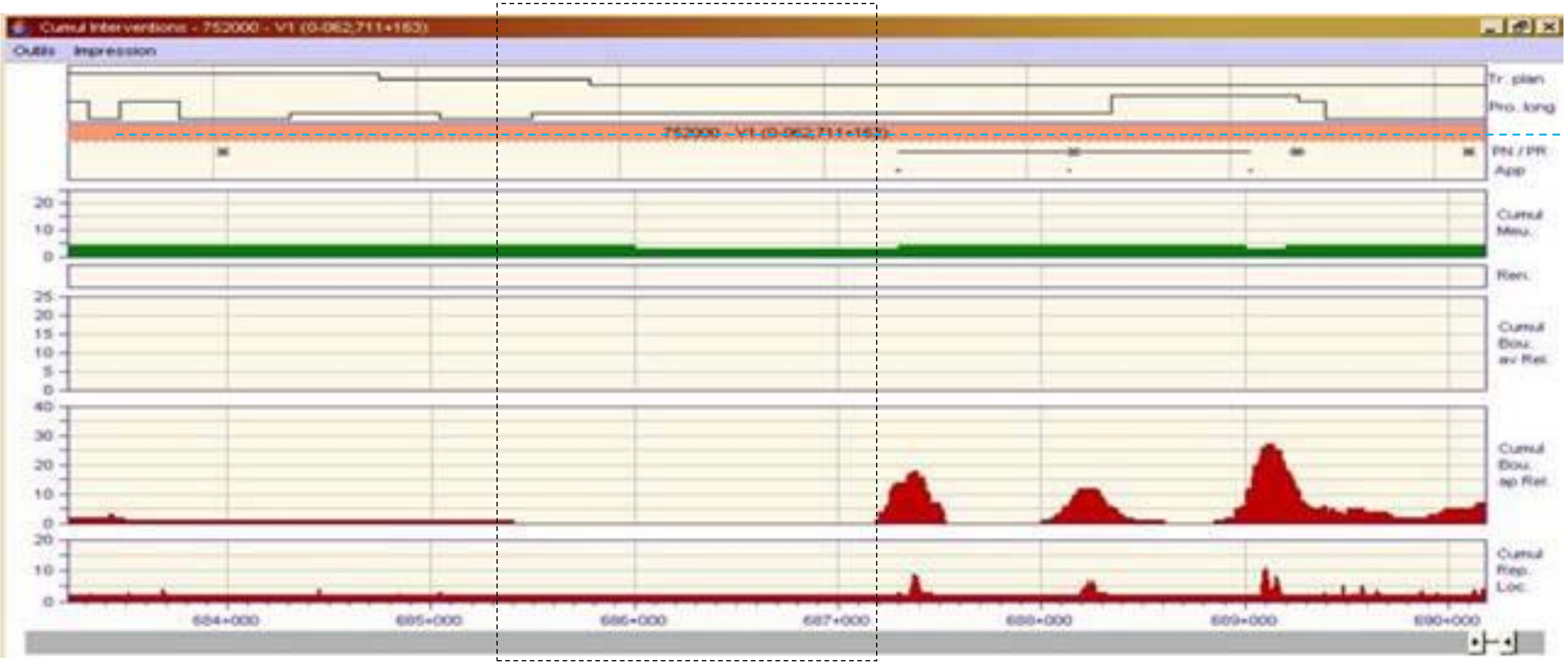


The test section test with Bituminous mix makes it possible to obtain a reduction of a factor 2 of the annual percentage tamp length

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

Some under sleeper PAD have an influence on track lifespan and HSL geometry ⇒ specific Cochet-Maumy parameters



Maintenance interventions

1 - Modelling for Infrastructure Management after conception engineering

Step 1: Lifespan of the components (ballasted HSL)

Some under sleeper PAD have an influence on track lifespan and HSL geometry ⇒ specific Cochet-Maumy parameters

Average of longitudinal levelling

1 - Modelling for Infrastructure Management after conception engineering

Step 2: Estimation of maintenance needs (ballasted HSL)

Tools for estimation of track maintenance needs (EBM) :

Principe / ballasted track:

1 – Cyclical or programmed operations:

Fixed charges determined by the standards for track surveillance, programmed maintenance, structure…

2 – Preventive conditioned maintenance:

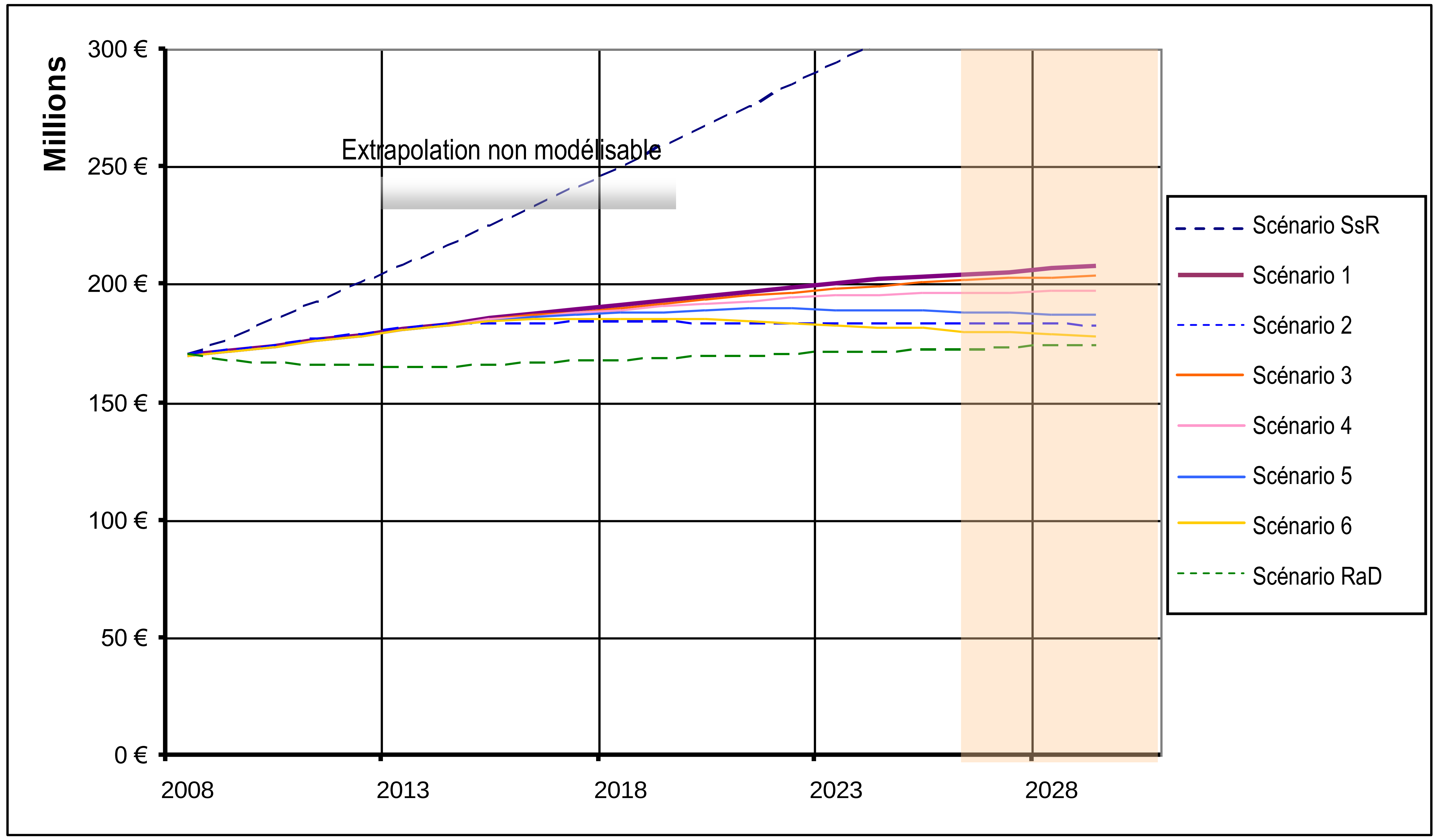
- Levelling maintenance charges: Interventions conditioned by the information coming from track surveillance. Probabilistic estimation of the intervention needs for a specific route, for a UIC group of routes…
- Asset replacement charges: Interventions conditioned by asset defect detection… Probabilistic estimation of the failure laws of each asset

1 - Modelling for Infrastructure Management after conception engineering

Step 2: Estimation of maintenance needs (ballasted HSL)

Example of estimation of maintenance needs for the French network

Switches & Crossing UIC 1 to 6

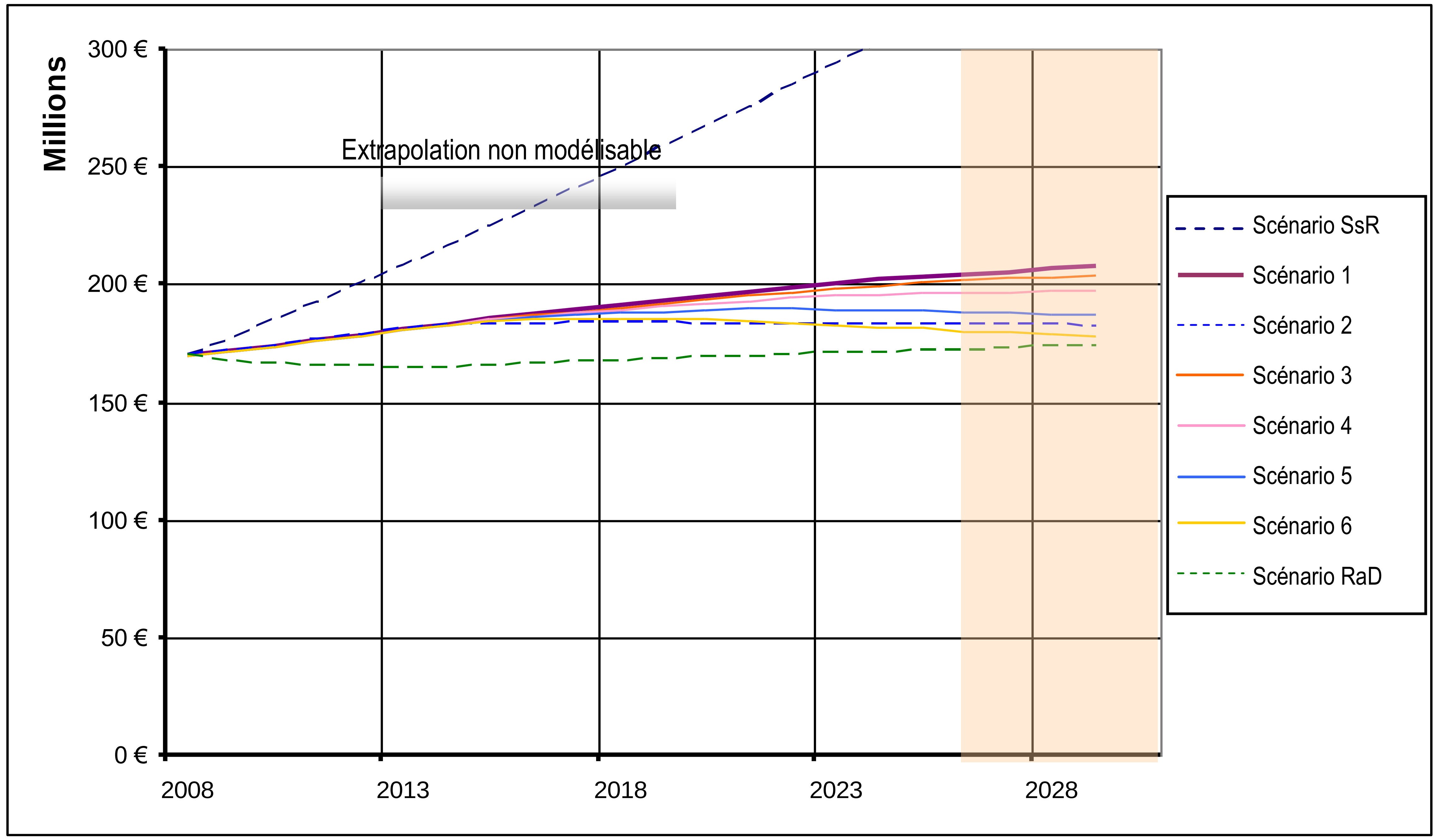


1 - Modelling for Infrastructure Management after conception engineering

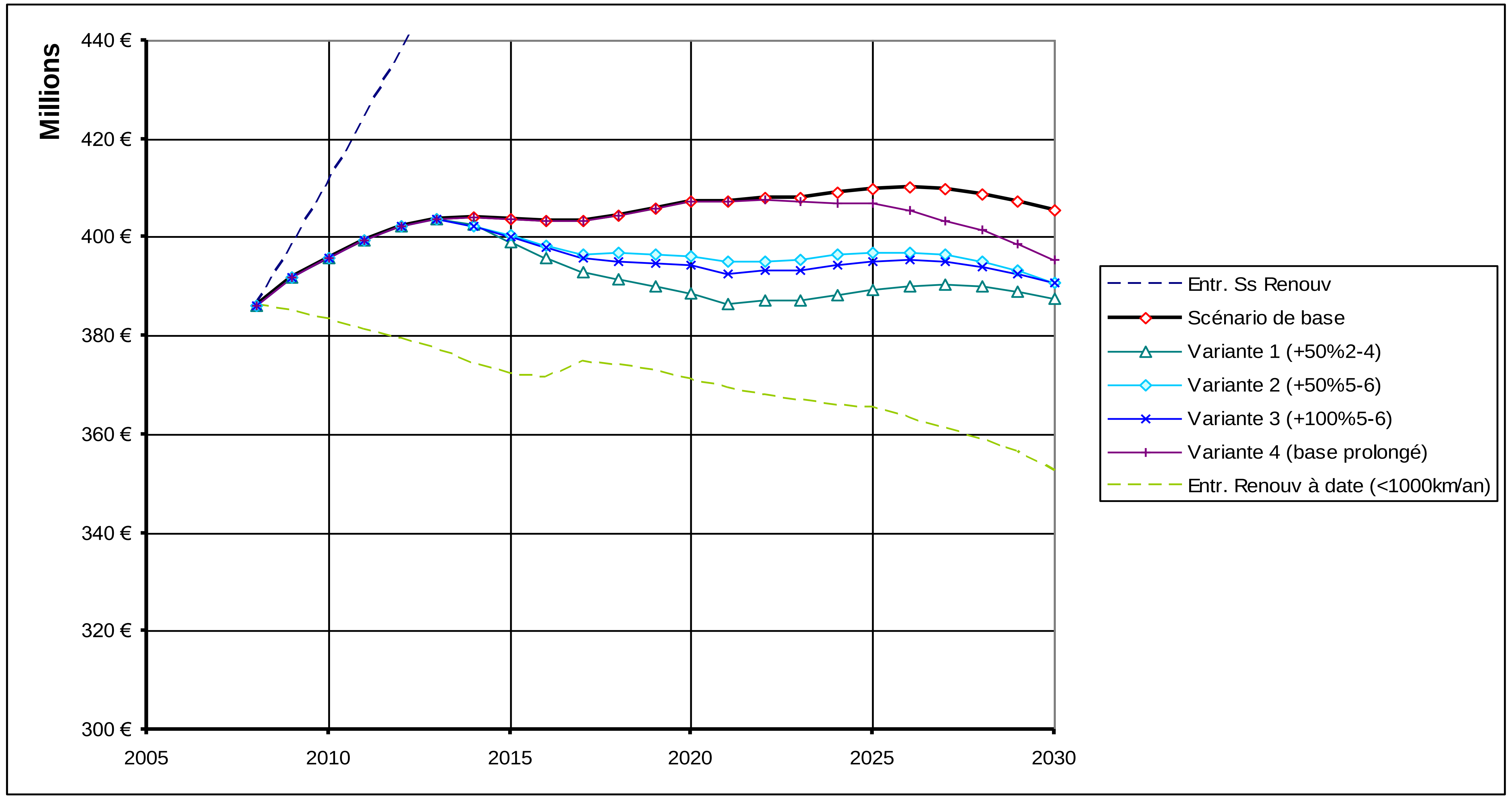
Step 2: Estimation of maintenance needs (ballasted HSL)

Example of estimation of maintenance needs for the French network

Switches & Crossing UIC 1 to 6



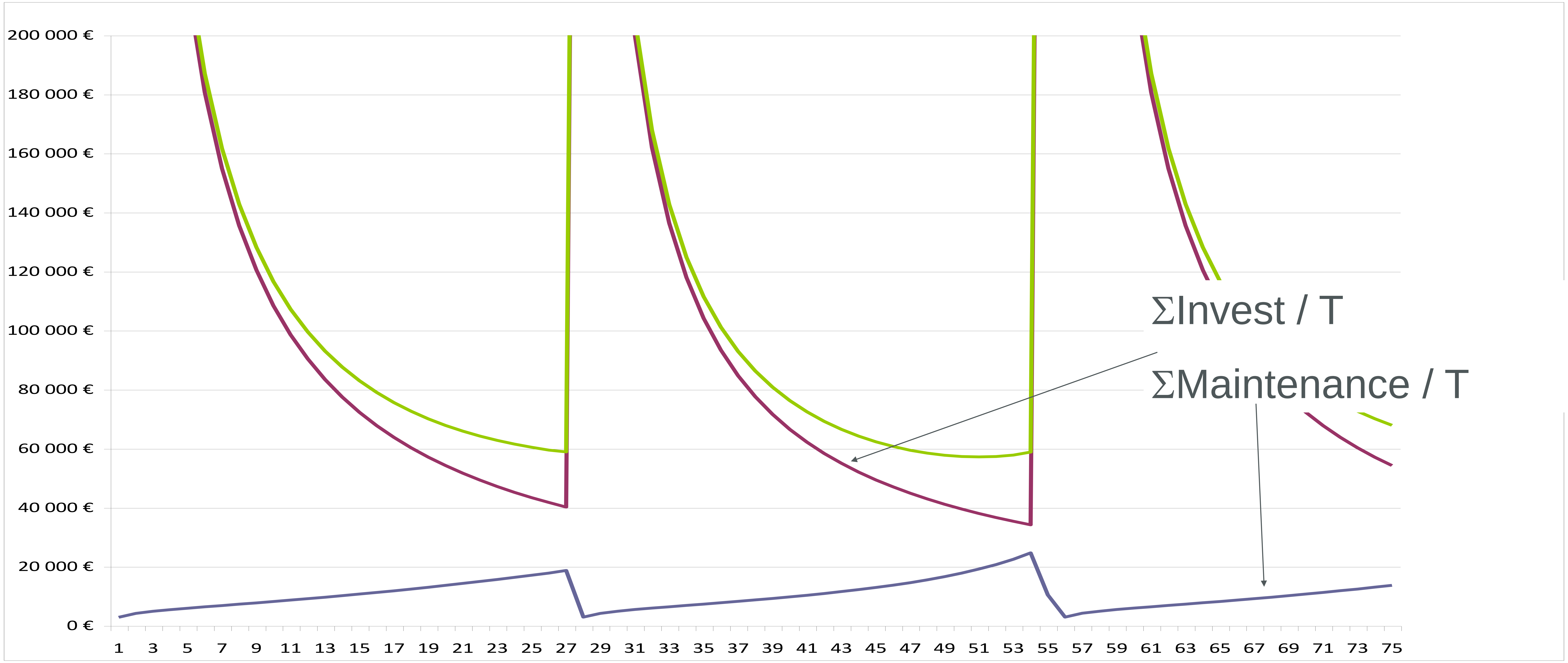
Normal Track UIC 1 to 6



1 - Modelling for Infrastructure Management after conception engineering

Step 3: LCC calculations (ballasted and unballasted HSL)

HSL ballasted track (UIC group3)

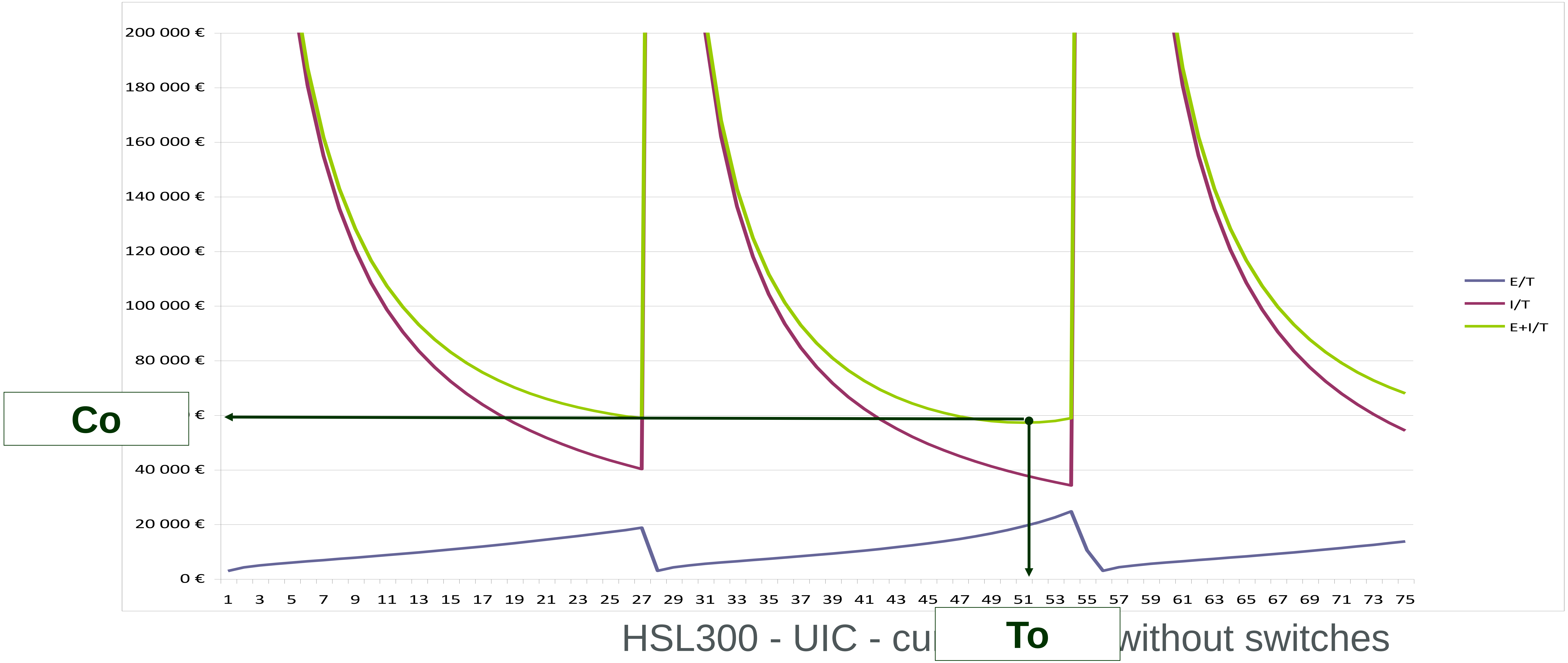


HSL300 - UIC - current track without switches

1 - Modelling for Infrastructure Management after conception engineering

Step 3: LCC calculations (ballasted and unballasted HSL)

HSL ballasted track (UIC group3)

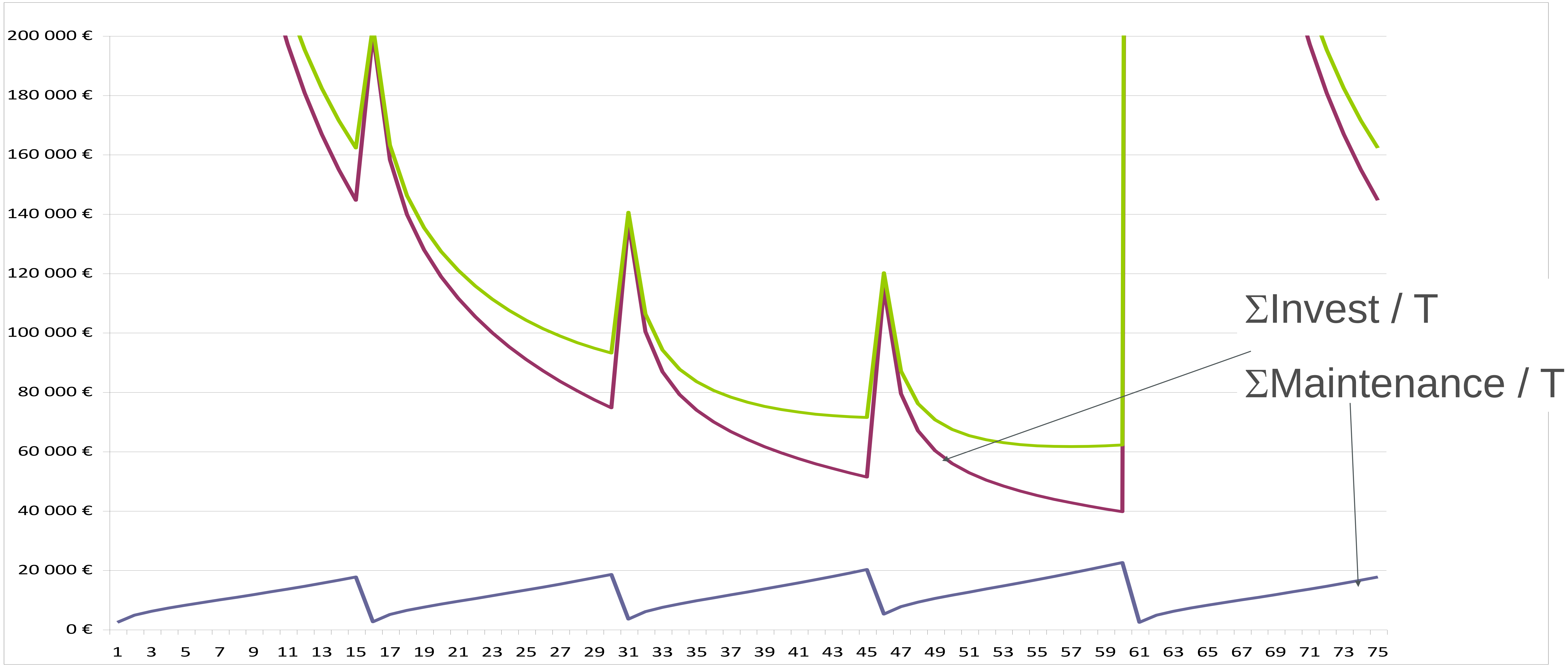


HSL300 - UIC - cu without switches

1 - Modelling for Infrastructure Management after conception engineering

Step 3: LCC calculations (ballasted and unballasted HSL)

Slab track

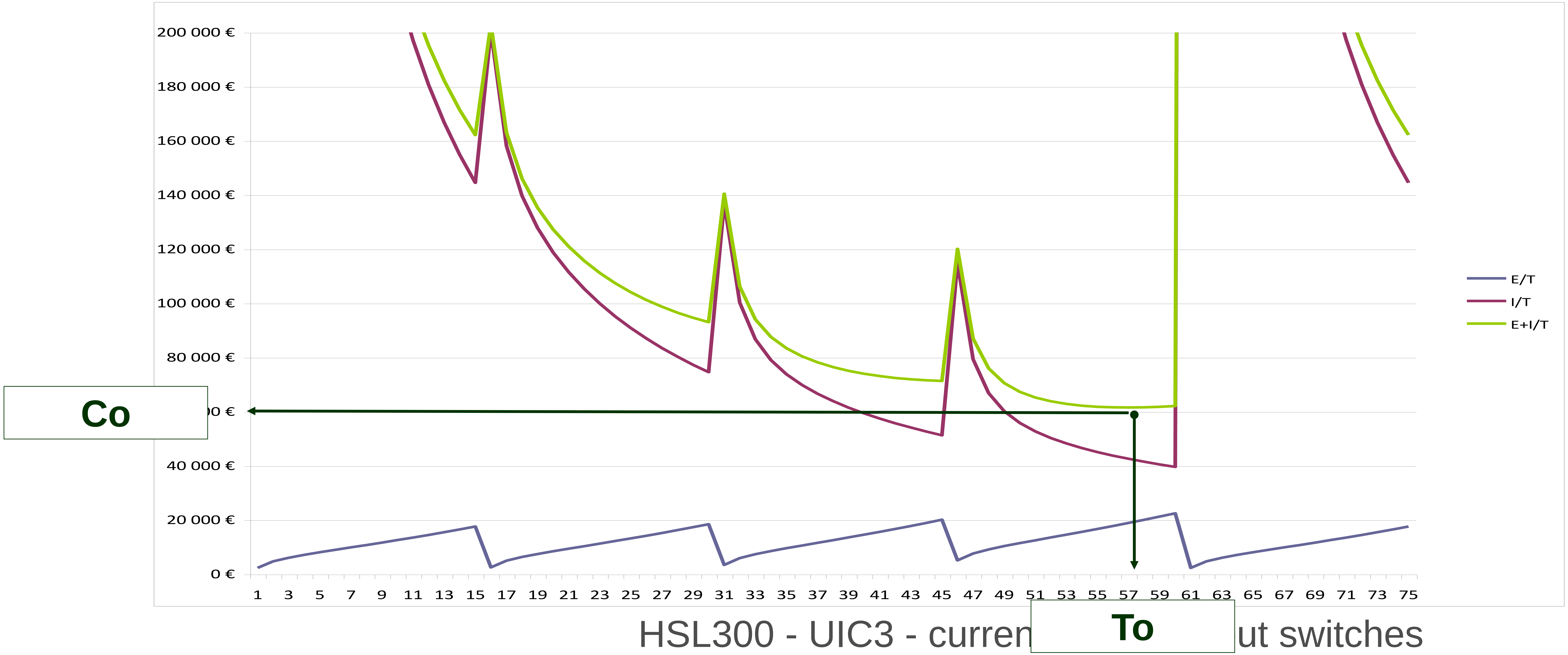


HSL300 - UIC3 - current track without switches

1 - Modelling for Infrastructure Management after conception engineering

Step 3: LCC calculations (ballasted and unballasted HSL)

Slab track



HSL300 - UIC3 - curren ut switches

2 - Modelling for Infrastructure Management before conception engineering

Thanks to its experience of component and sub-system behaviour, IMs can:

→ specify and optimise new components to facilitate maintenance, taking into account usage, environment, specific quality targets,…

→ optimise the dimension of spare parts and the corresponding maintenance organisation.

The following examples come from signalling:
- choice of failure laws,
- architecture choice for critical computerised system.

2 - Modelling for Infrastructure Management before conception engineering

Modeling methods: renewal density for successive replaced components

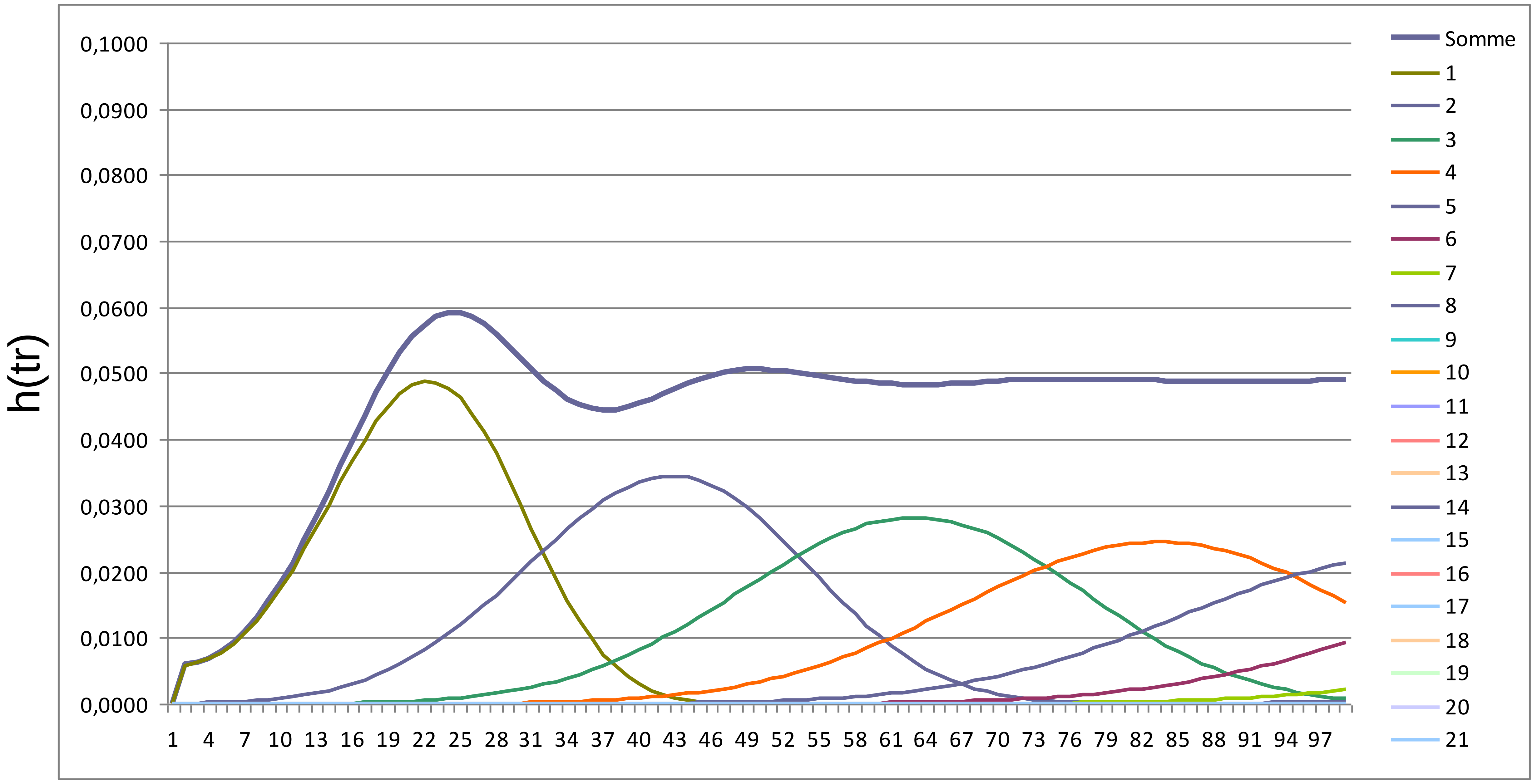
Without system ageing

- The renewal density gives the replacements due to failure at time *t* :

$$h(t) = \sum_{n=1}^{\infty} -[(1-F(t))']^{*n}$$

where * denotes the convolution.

- The integral of this function gives the number of expected replacements before time *t* .



Reduced time tr beta = 3,4

2 - Modelling for Infrastructure Management before conception engineering

Modeling methods: renewal density for successive replaced components

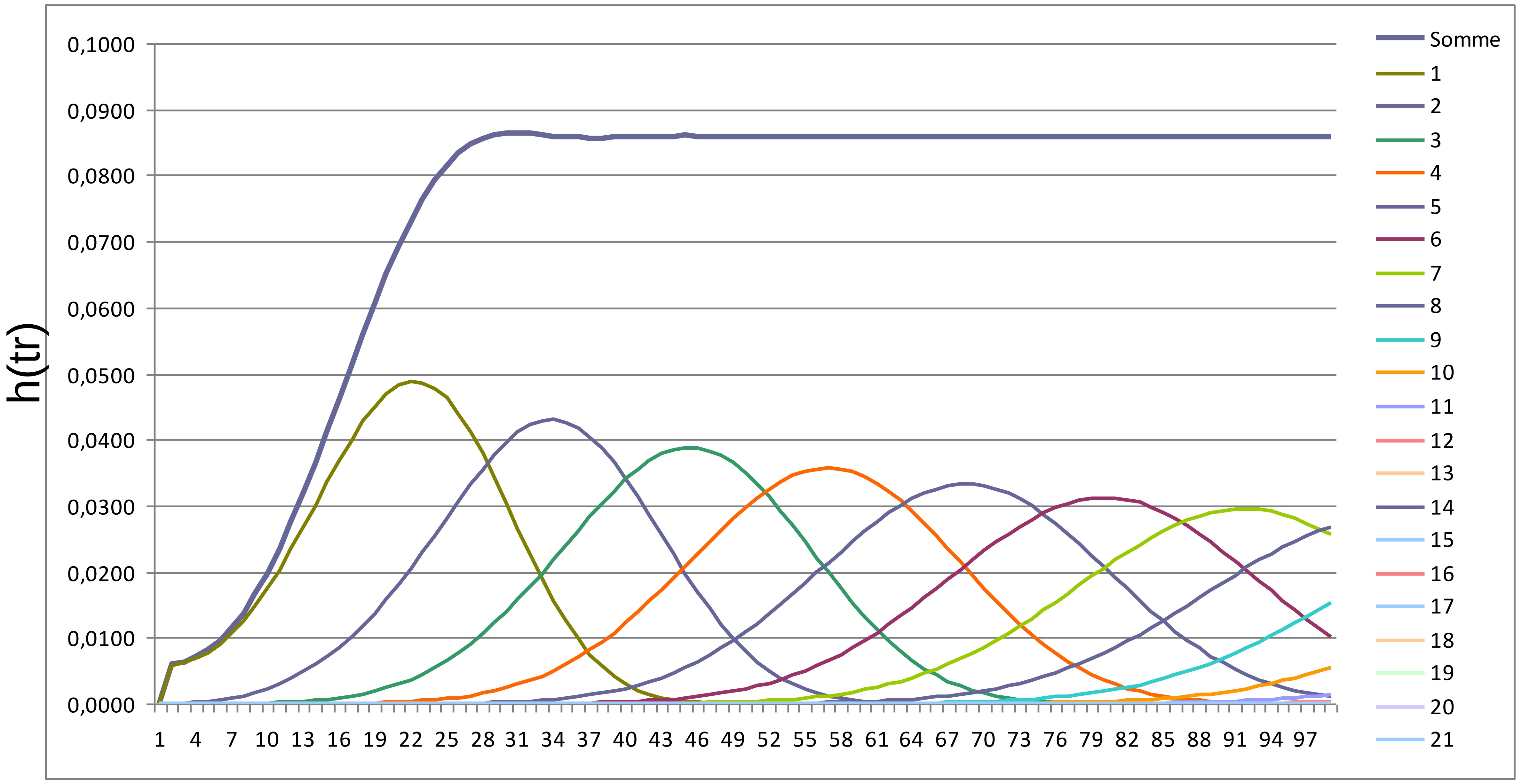
With system aging

- We can include the ageing of the system (or effects of repairs) by using a factor *K*

$$\eta_n = \eta_0 \cdot K$$

at the n^{th} replacement.

- This translates the fact that even a new component has a reduced lifetime if it is introduced into an ageing system.



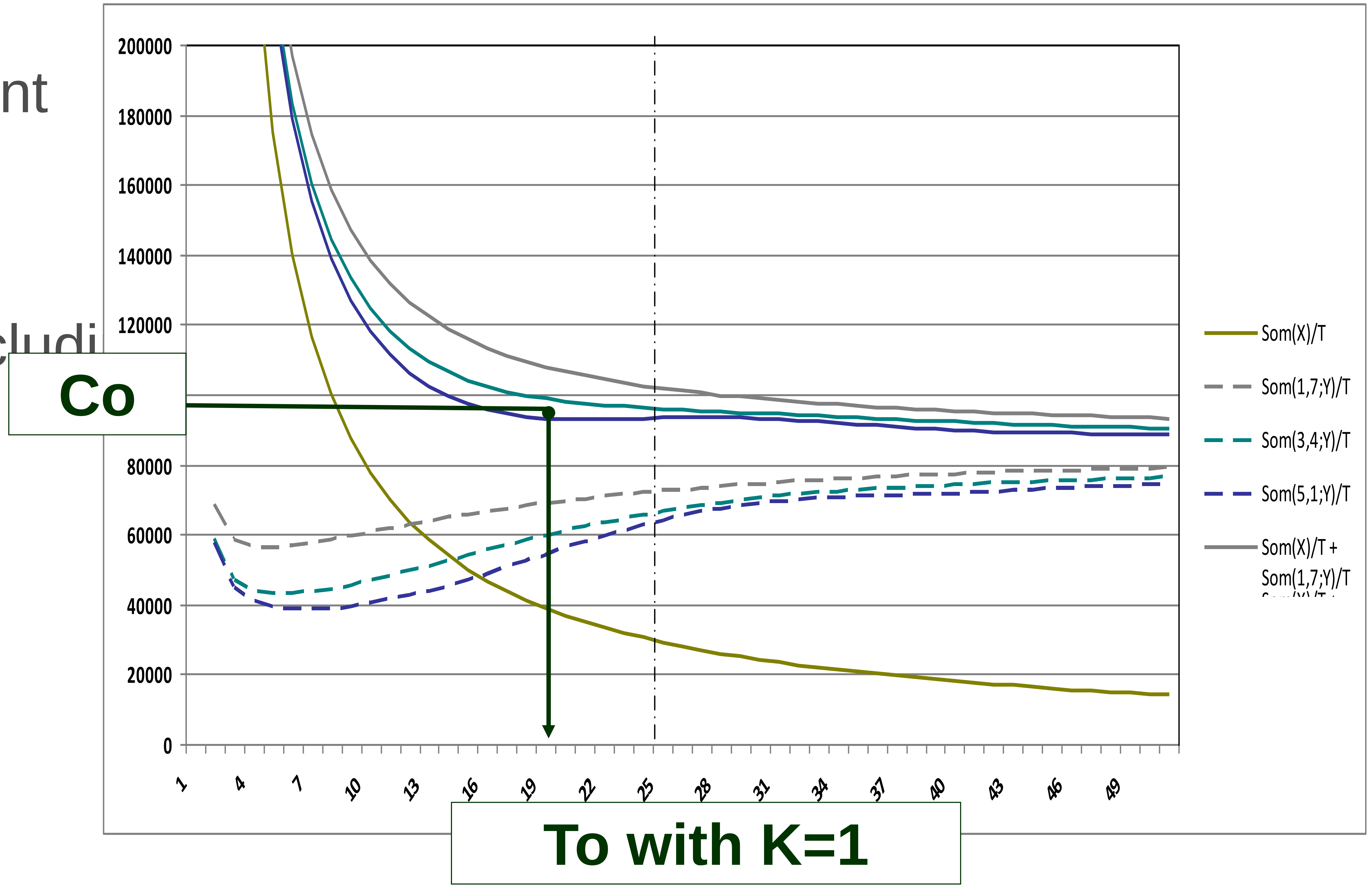
Reduced time tr

beta = 3,4
K = 0,75

2 - Modelling for Infrastructure Management before conception engineering

Modeling methods: renewal density for successive replaced components

- **Maintenance expenses: $Y(t) = c_i(t) + c_u \cdot n \cdot h(t)$**
  - c_i: current costs
  - c_u: replacement costs for one component
  - n: number of components
  - $h(t)$: renewal density
- Expected global maintenance expenses (includi
  renewal) per year:



$$C(T)/T = [X + \sum_{t=0}^{T-1} \int_{t}^{t+1} Y(t)]/T$$

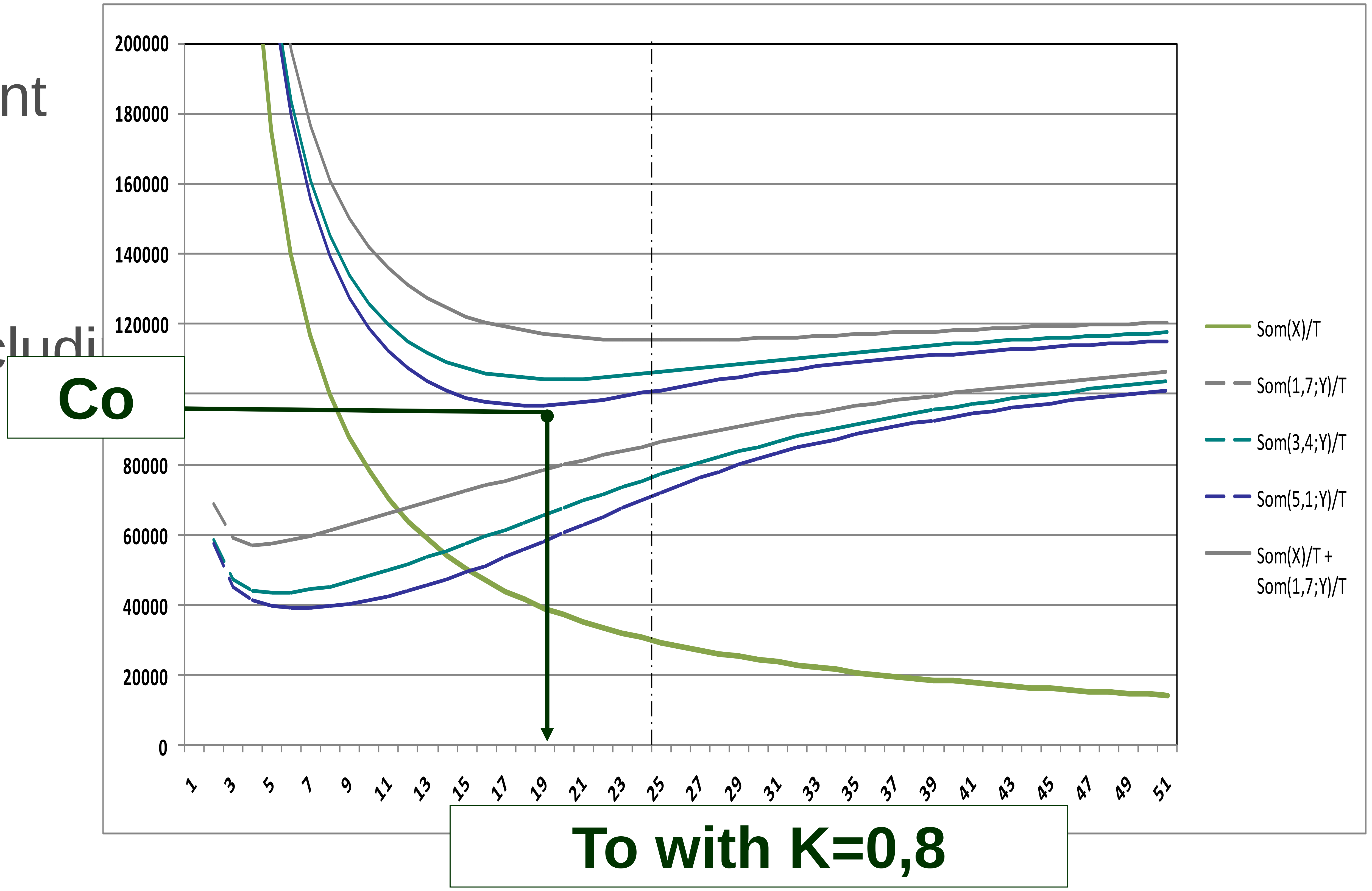
$E(T)$

With X: renewal costs

2 - Modelling for Infrastructure Management before conception engineering

Modeling methods: renewal density for successive replaced components

- **Maintenance expenses: $Y(t) = c_i(t) + c_u \cdot n \cdot h(t)$**
  - c_i: current costs
  - c_u: replacement costs for one component
  - n: number of components
  - $h(t)$: renewal density
- Expected global maintenance expenses (includi
  renewal) per year:



$$C(T)/T = [X + \sum_{t=0}^{T-1} \int_{t}^{t+1} Y(t)]/T$$

$E(T)$

With X: renewal costs

2 - Modelling for Infrastructure Management before conception engineering

Modeling methods: renewal density for successive replaced components

Design choices could have a huge impact on a maintenance strategy and on the chances of reaching the right quality level (availability, security, safety…) with the economic target value

The terms of the requirements have to be chosen taking into consideration the context of use and the economic and organizational targets… which are not known by suppliers

2 - Modelling for Infrastructure Management before conception engineering

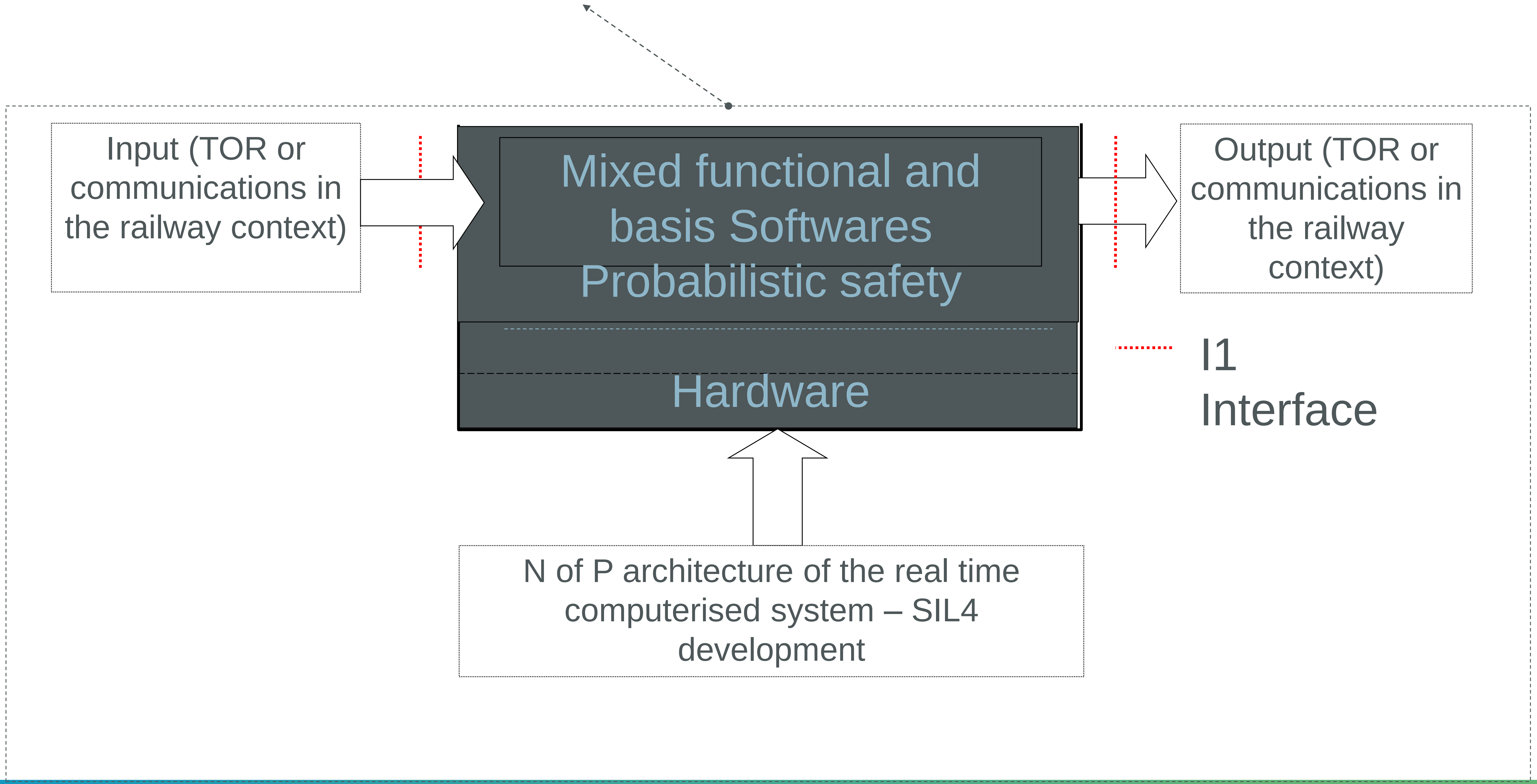
Architecture choice for a critical computerized system

Classical architecture

- Without independence between System and Functional SW

Proposed architecture

- With distinction between HW & System SW and the functional SW



2 - Modelling for Infrastructure Management before conception engineering

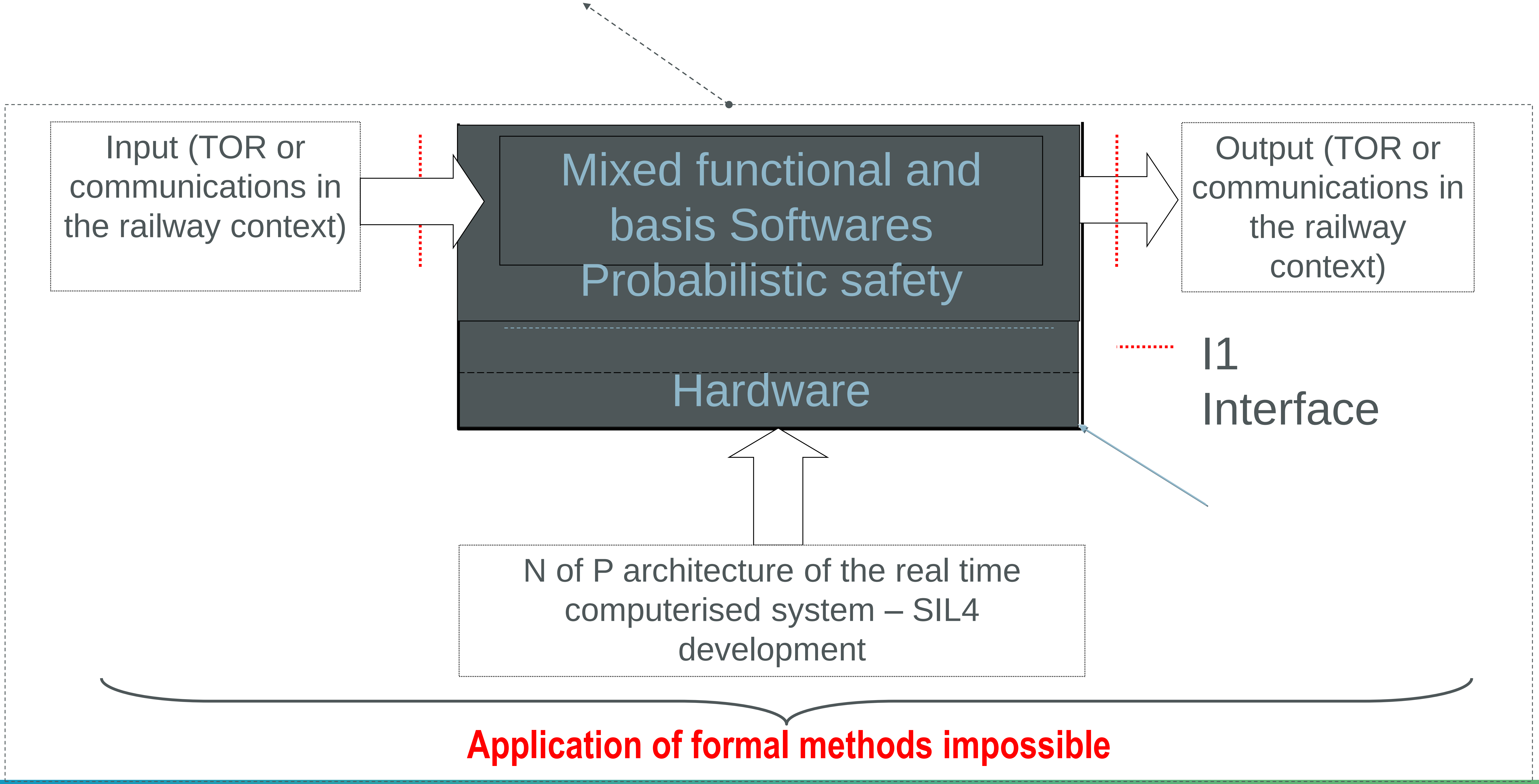
Architecture choice for a critical computerized system

Classical architecture

- Without independence between System and Functional SW

Proposed architecture

- With distinction between HW & System SW and the functional SW



2 - Modelling for Infrastructure Management before conception engineering

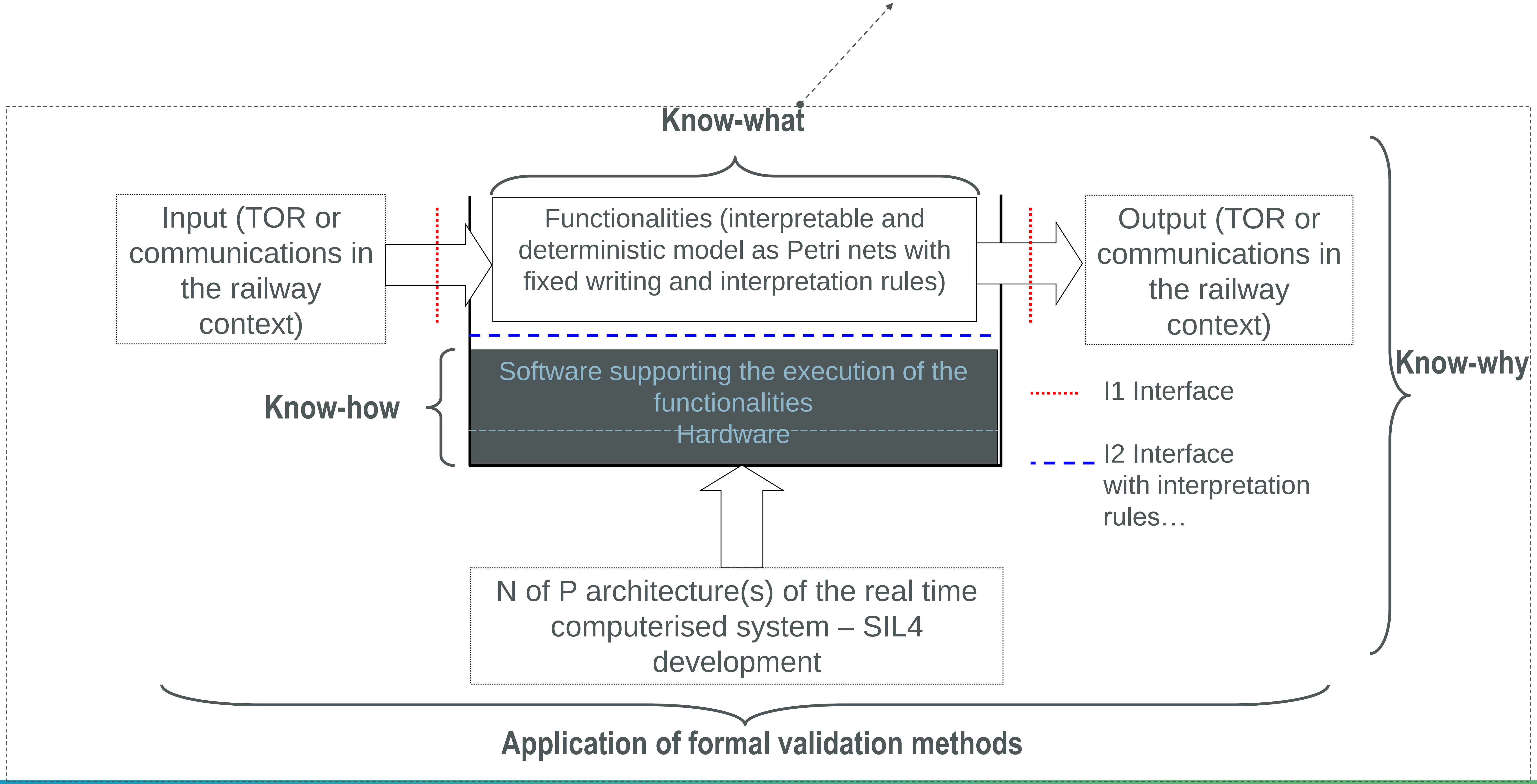
Architecture choice for a critical computerized system

Classical architecture

- Without independence between System and Functional SW

Proposed architecture

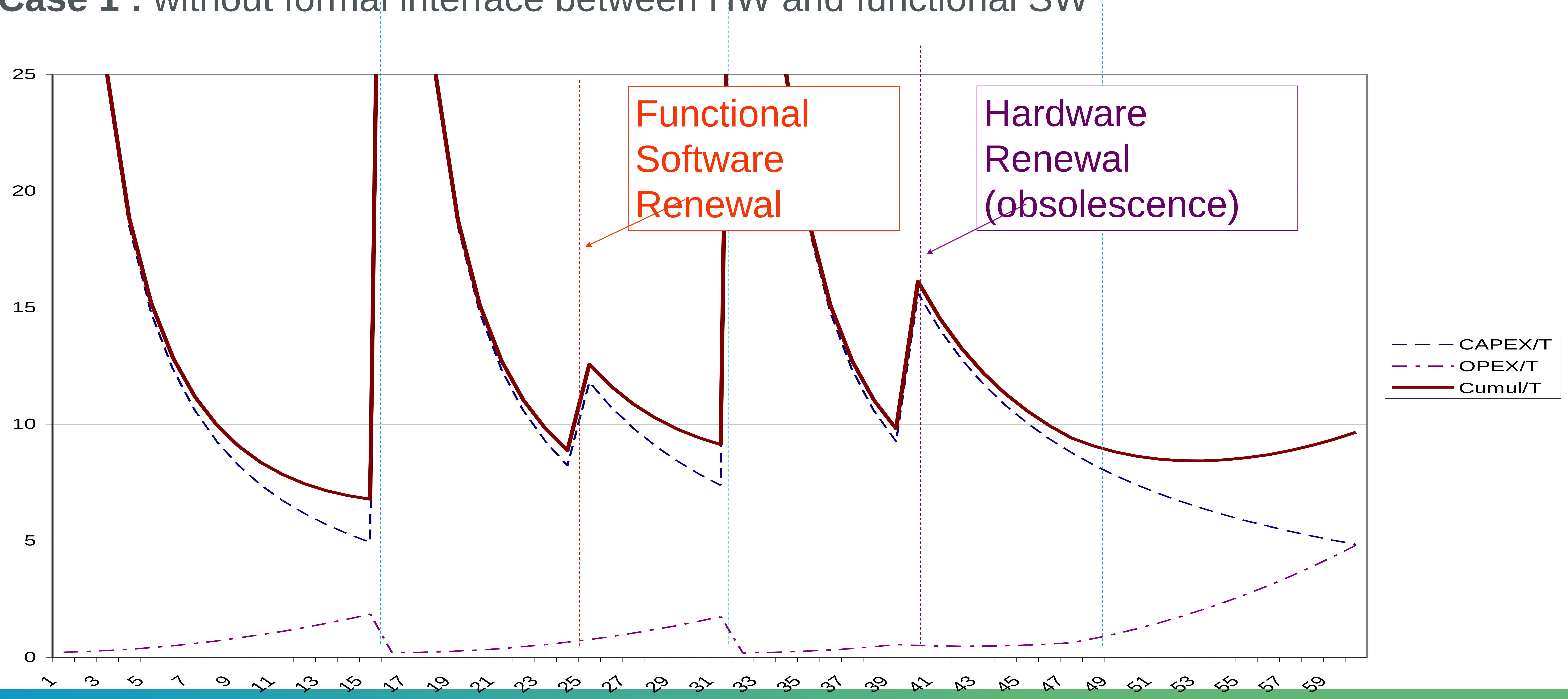
- With distinction between HW&System SW and the functional SW



2 - Modelling for Infrastructure Management before conception engineering

Step 3: LCC calculations (Critical IT system with and without formal interface between HW and functional SW)

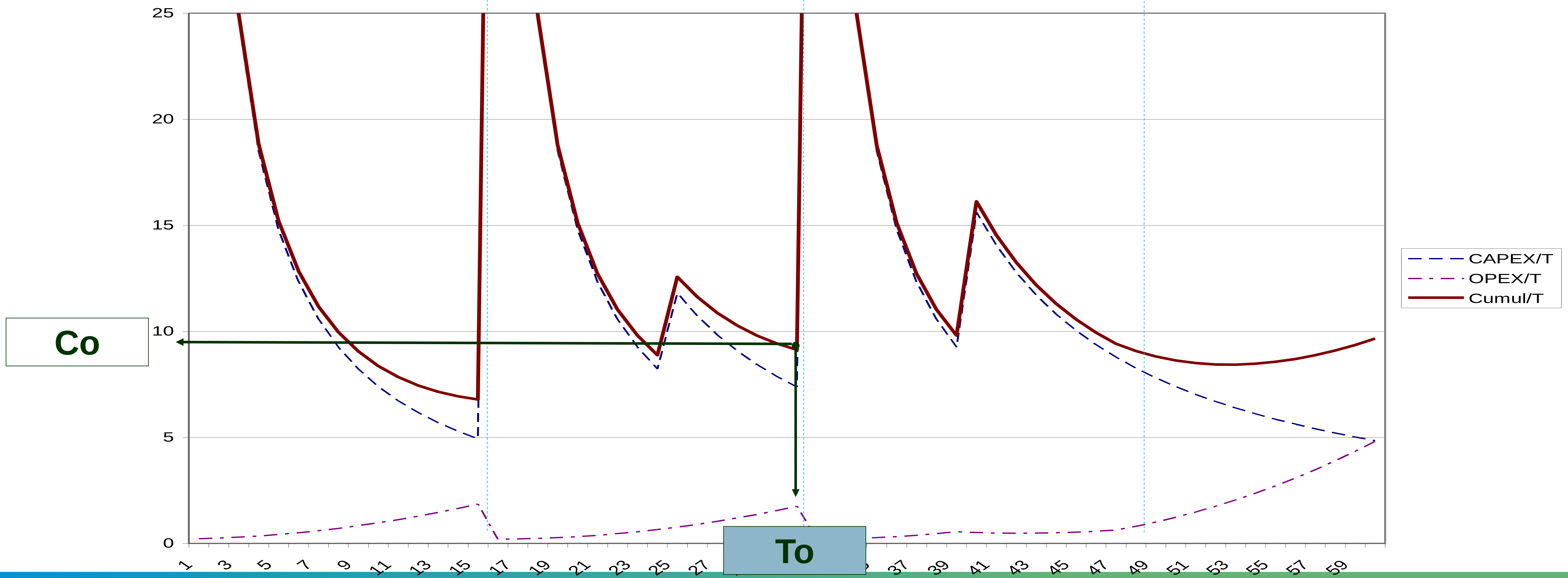
- **Case 1 :** without formal interface between HW and functional SW



2 - Modelling for Infrastructure Management before conception engineering

Step 3: LCC calculations (Critical IT system with and without formal interface between HW and functional SW)

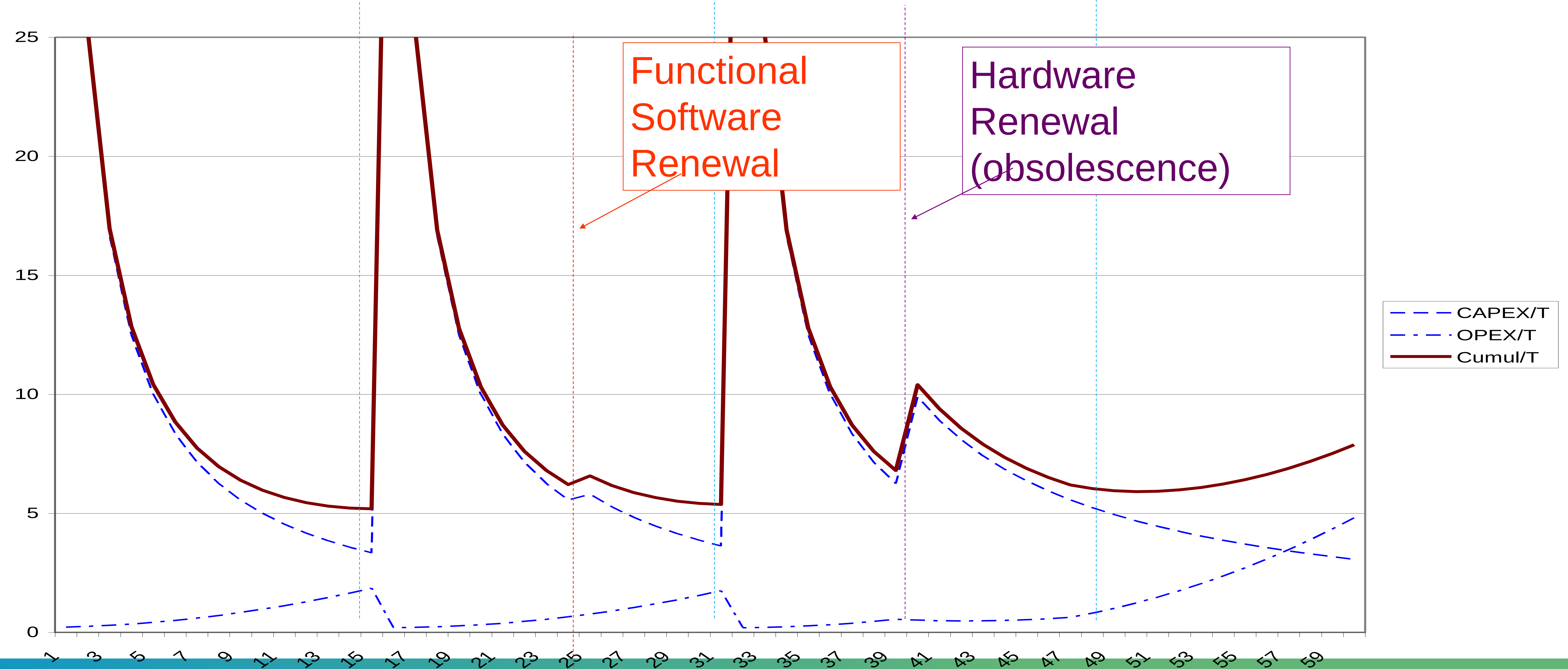
- **Case 1 :** without formal interface between HW and functional SW



2 - Modelling for Infrastructure Management before conception engineering

Step 3: LCC calculations (Critical IT system with and without formal interface between HW and functional SW)

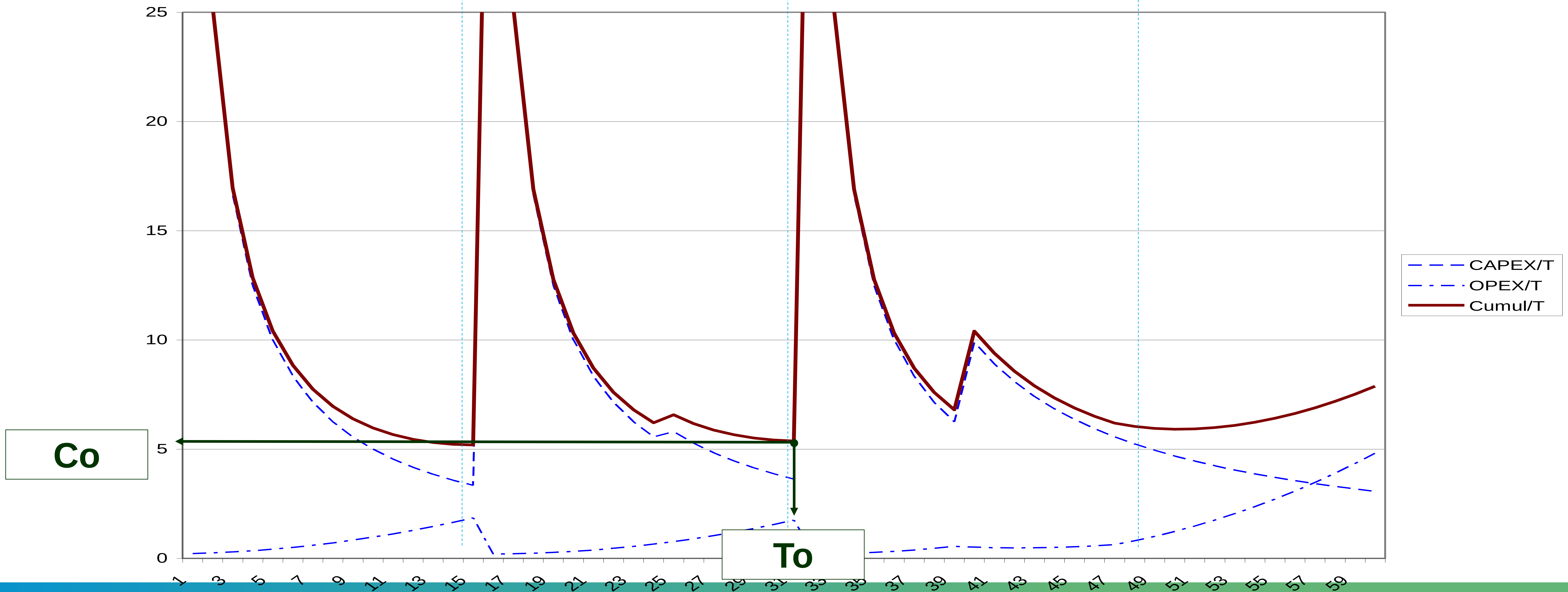
- **Case 2 :** with a formal interface between HW and functional SW



2 - Modelling for Infrastructure Management before conception engineering

Step 3: LCC calculations (Critical IT system with and without formal interface between HW and functional SW)

- **Case 2 :** with a formal interface between HW and functional SW



Part 3 – Safety & Security : Cyber issues

?

1 - Safety and cybersecurity issues

Safety and cybersecurity issues have become a concern for UIC in recent years (in the different functional “layers” of the rail system)

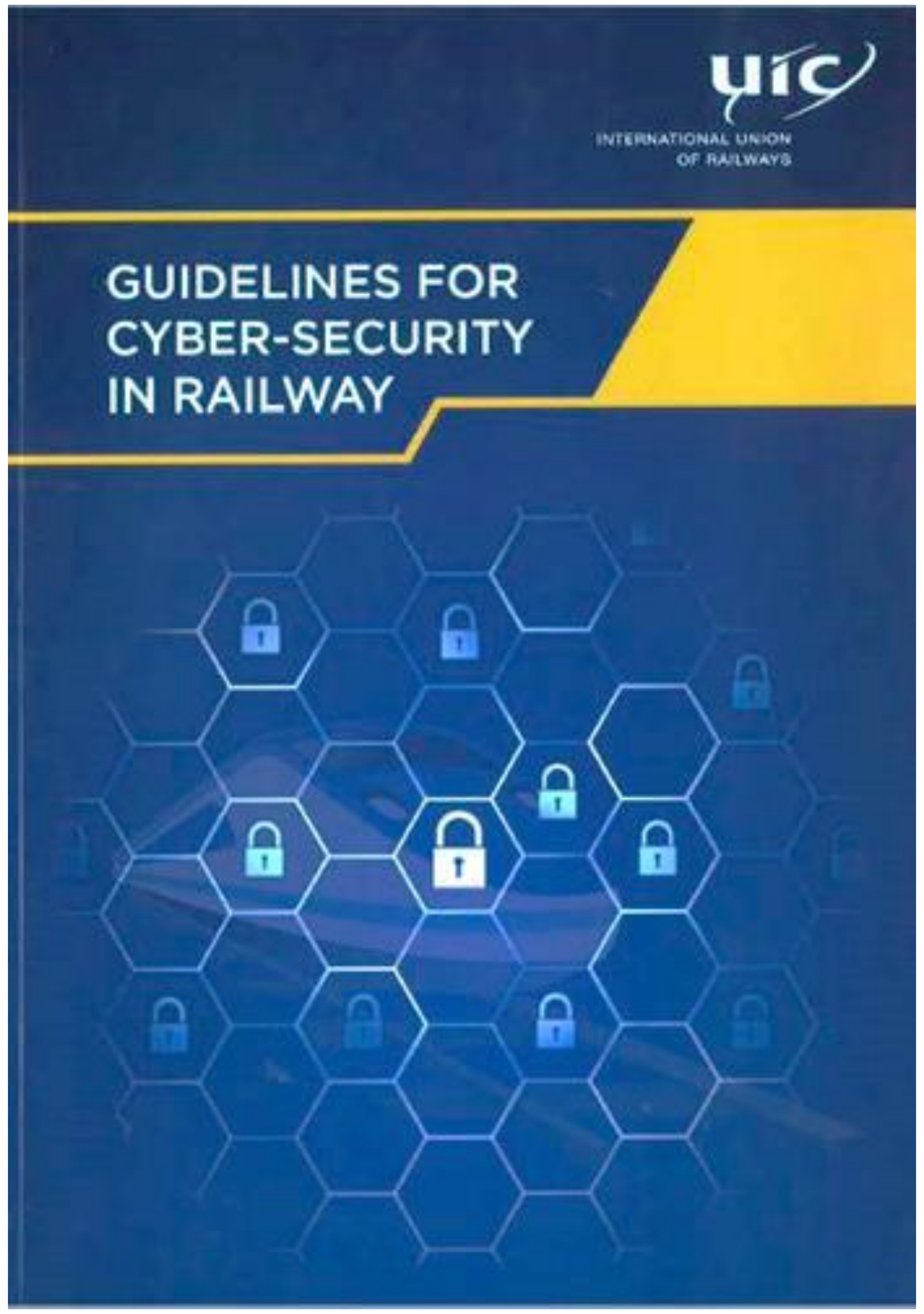
Different levels of fragility in rail services have been identified:

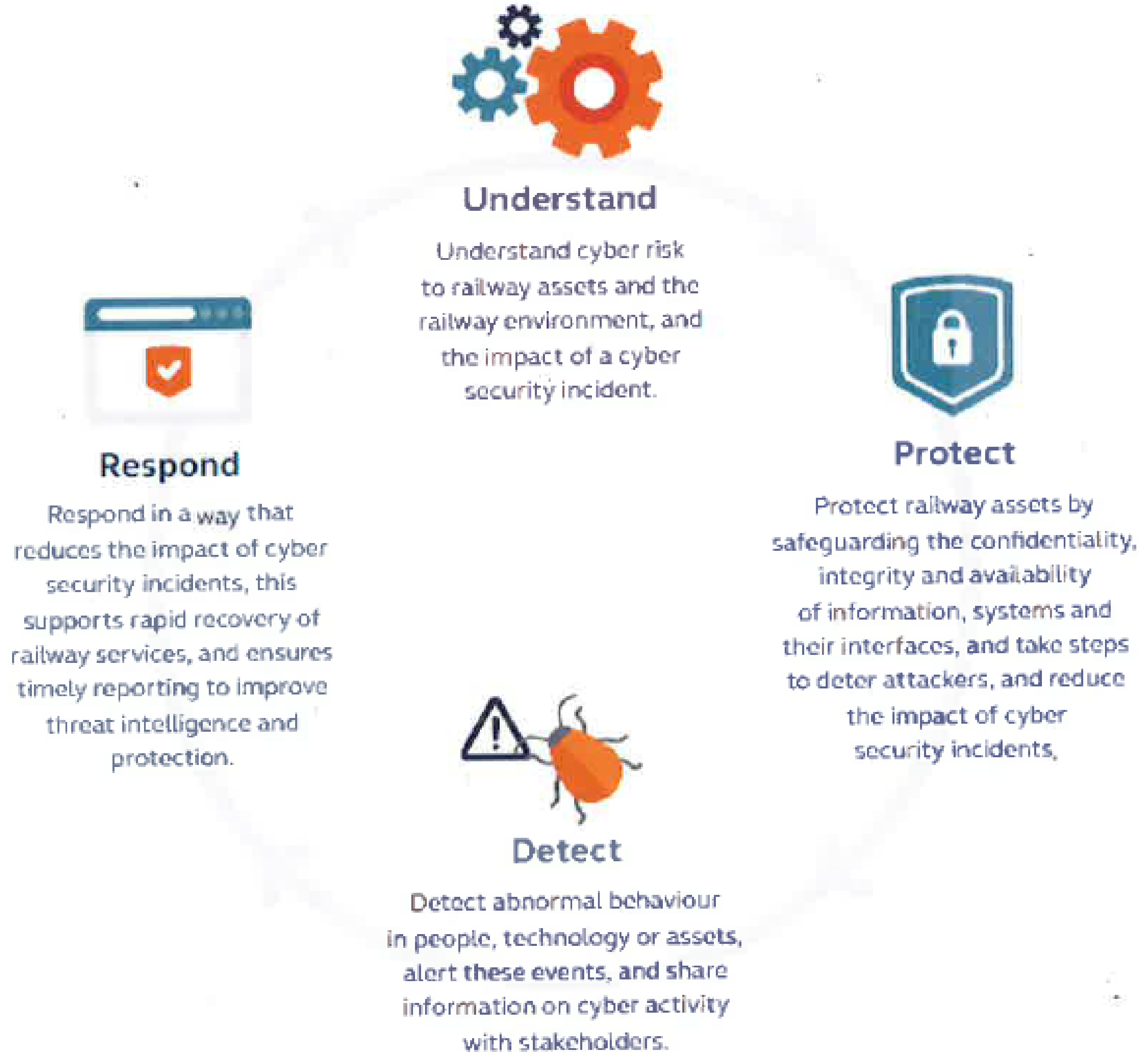
- Information systems in relation to the customer
- Traffic management information systems, contracts, customs information, rolling stock and infrastructure maintenance information
- Critical operating systems

= Business AND Systems

1 - Safety and cybersecurity issues

Following a pathfinder project called ARGUS, implemented in cooperation with the COLPOFER group (OSJD) and well-known industrial players such as Cyclus, Splunk, Airbus, APSYS and others, UIC has created its first Guidelines for Cyber-Security in Railways.





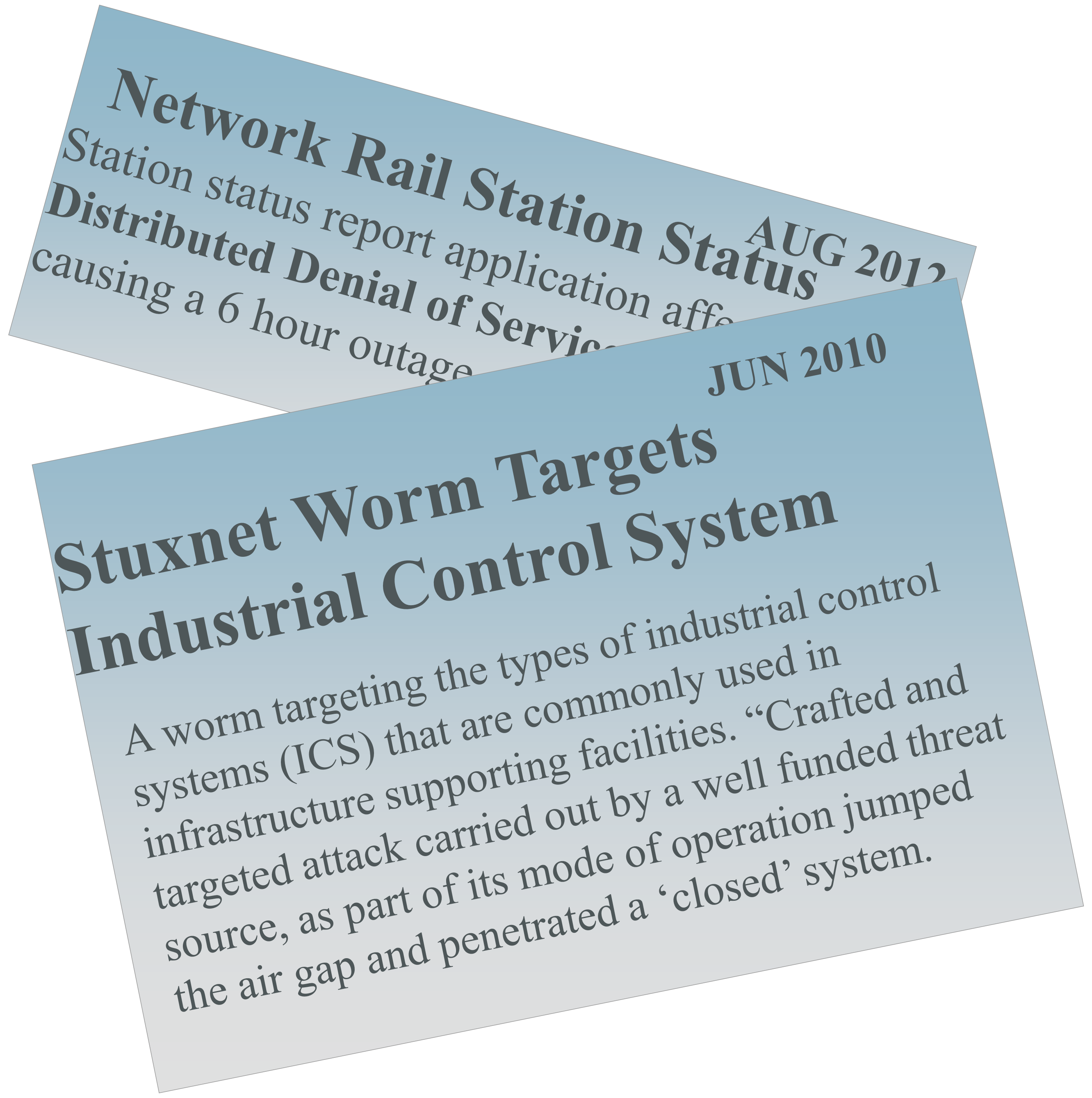
2 – Cyber risk: myth or reality?

We are currently in:
- A world engaged in digital warfare at economic and/or military level
- An interconnected and open digital world

<u>**This world represents a paradigm shift for the railways**</u>

- Railways are one of the priority targets of certain actors

- Today, railways use digital technologies and architectures that are particularly vulnerable to potential attack (internal or external)



2 – Cyber risk: myth or reality?

Railways have become stuck in a position of denial about the emergence and growth of risks related to cyber attacks, for many reasons:

1. Consequences of attacks vs. determinism of preventive costs
2. “Service provider” vs. “technical mastery of systems”
3. Transition from white box systems, or functional white box to black box vision
4. Not taking safety or cyber risks into account in security studies (application of CSM, obtaining AMEC...)

2 – Cyber risk: myth or reality?

From the Internet: possible takeover of station information systems, automatic vending machines (ransom requests to regain control)

Immobilisation of rolling stock in operation by unauthorised radio connection (links intended for remote maintenance, etc.)

A "man in the network" can cause a fire, field elements in unsafe conditions, change the functionality of certain signal boxes, etc.

Intrusion tests performed by IMs or RUs demonstrate the weaknesses in certain systems, existence of plausible attack scenarios, etc.

The list is not exhaustive, especially since some actors "map" the networks of friendly/hostile countries...

2 – Cyber risk: myth or reality?

Cyber risk is therefore a reality that can have a direct impact on rail traffic availability and safety.

We have experienced and will continue to experience a decline in the security levels of our critical infrastructure with the transition to digital. There are dangers that threaten us:

Three major dangers

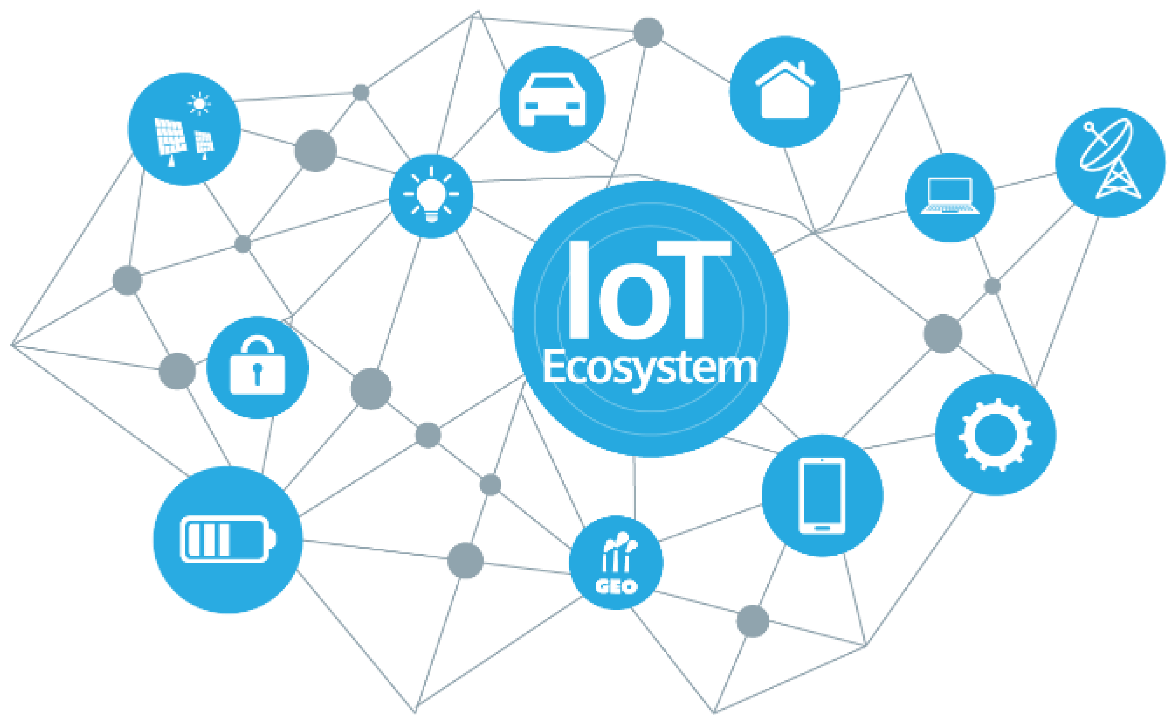
- Russia and former USSR: Hostile cyber attack/attack on behalf of industries or lobbies
- China: peaceful attacks on industrial knowledge and illegal information gathering
- Terrorist and/or extremist organisations

3 - Technological developments that threaten our systems

The evolution of technologies and modernism (technical and managerial) expose our systems to attack. Such developments include:

1. The emergence and uncontrolled spread of "railway clouds", cloud computing, IoTs, including for critical signalling systems

2. IoTs generally have only one common password to a series of products, registered in Hard internally, without the user being able to dynamically and frequently change it



3. Digital systems and networks (existing or future) that are poorly designed in terms of safety and security cannot subsequently be secured in practice

3 - Technological developments that threaten our systems

4. Modern systems are highly centralised, which makes them vulnerable to an attack

5. Modern systems are not developed with the use of functional modelling or formal methods and use cost, hardware, OS and "general public" protocols

6. The consequences of a targeted attack are far greater than those that could possibly be expected for attacks on older systems

4 - Taking cyber threats into account in system design rules and related security studies

1. Identification of security strategy levels
2. Real independence of networks with different levels of cybersecurity and business consequences
3. Gateways between networks with protocol breach
4. Functional white box modelling of systems and their means of communication
5. Systems development with the use of formal methods
6. Useful resilience through independent and non-digital technological means
7. Deployment of all radio communications in the railway sector > FRMCS

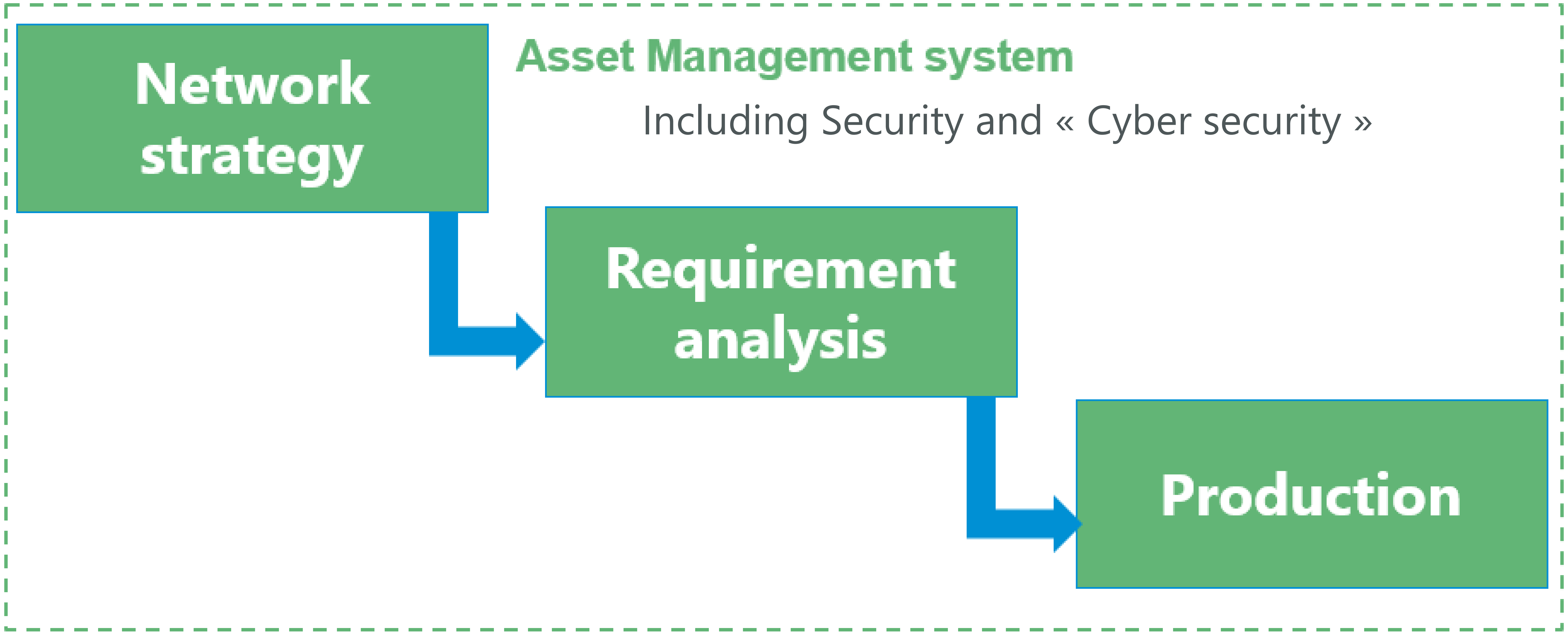
4 - Taking cyber threats into account in system design rules and related security studies

For safety demonstrations (application of Common Safety Methods):

- **Formalise** choices in security files in terms of acceptability of cyber consequences, types of network subset where certain systems can be deployed, etc.
- **Identify** the physical protective measures that must be associated with them (demonstration assumptions)
- **Identify** the rules of design, implementation, system integration that must be implemented (demonstration assumptions)
- **Consider, in addition to ER related to human and organisational factors or aspects of technical failure, ER possibly related to external attacks by malicious third parties**
- >Requires implementation of three types of measures (depending on the identified need):
  - Peripheral defence,
  - Defence in depth,
  - Endogenous defence (for SIL4 systems) and identify means of continuous verification of proper implementation and operation
- **Identify** (the nature of) the intrusion tests that will have to be performed regularly and on which railway subassembly (assumption of the demonstration)

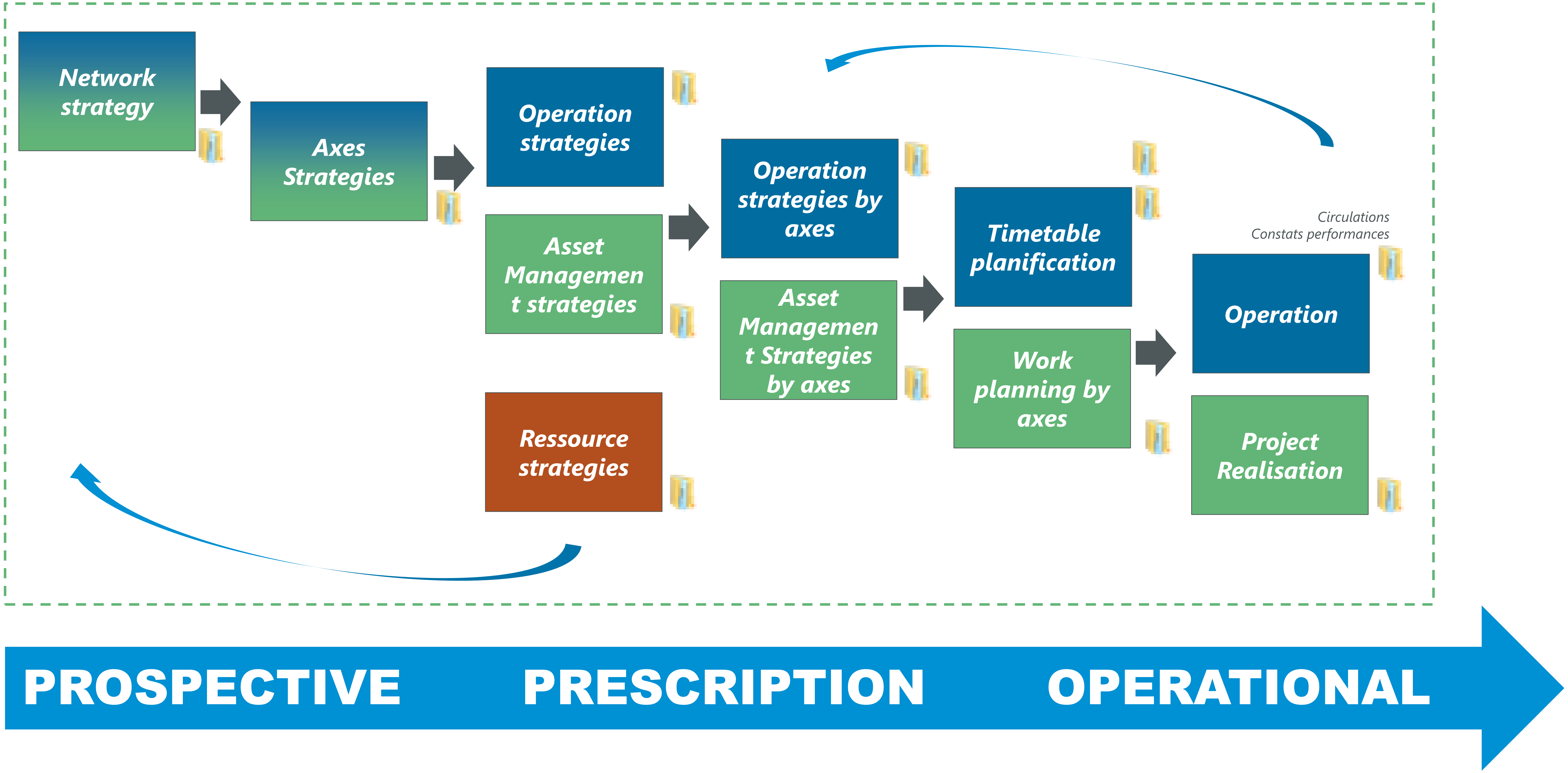
5 - Taking cyber risks into account in IMs' and RUs' asset management processes

The railways (RUs and IMs) are responsible for traffic safety; they must define and are responsible for the SMS (Safety Management System - more appropriately called "SSMS" (Safety and Security Management System))

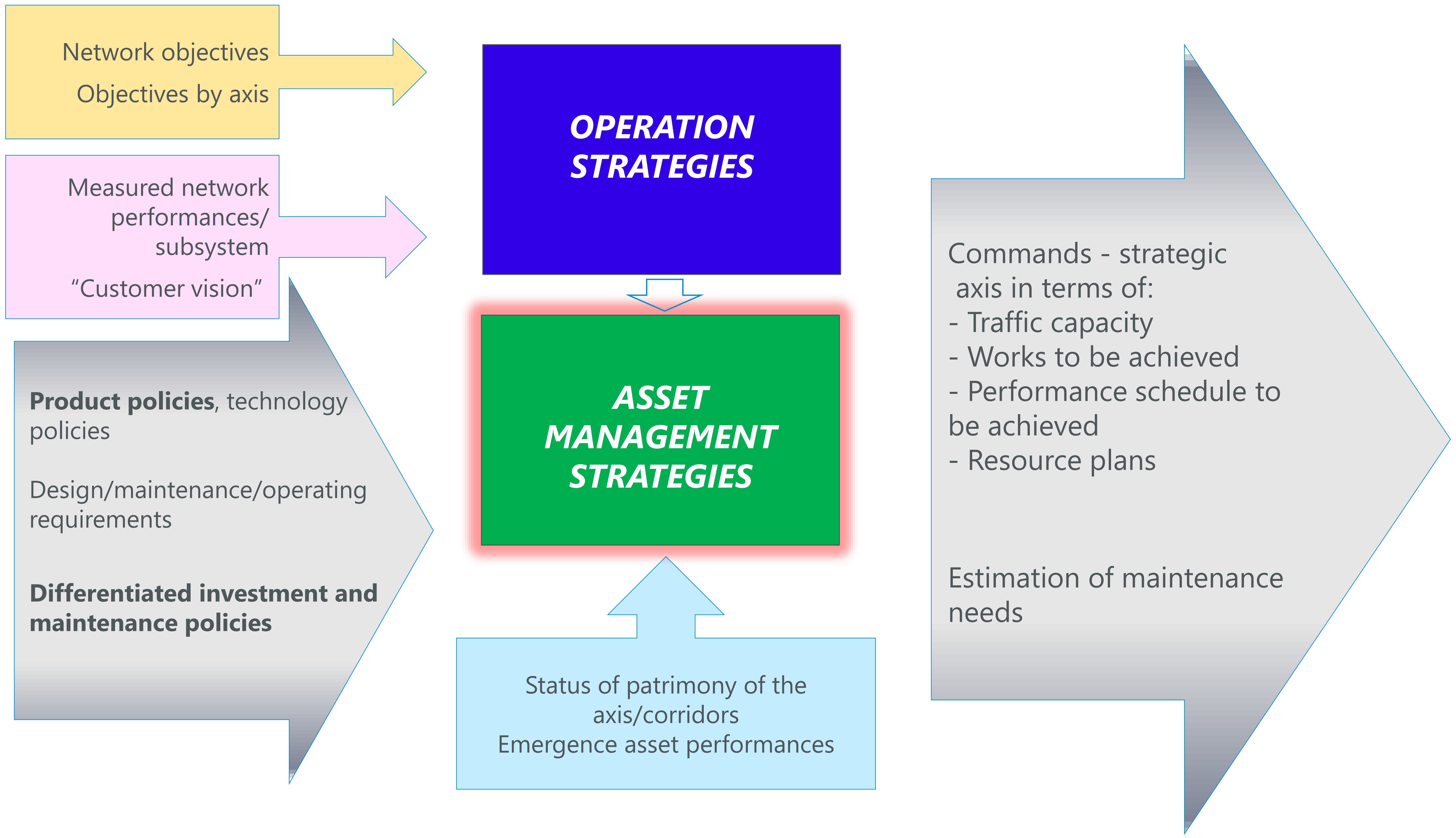


5 - Taking cyber risks into account in IMs' and RUs' asset management processes

A perfect coherent system vision → including Security and Cyber security:



5 - Taking cyber risks into account in IMs' and RUs' asset management processes



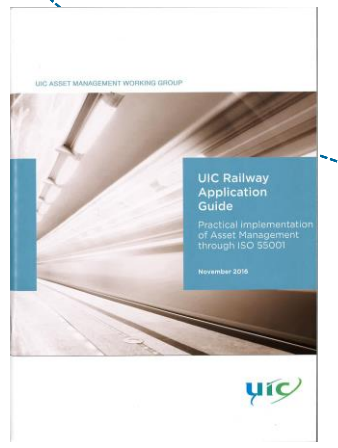
6 - UIC's work in this area will intensify in 2019

Publication of new IRSs

Sustainable development

Specialised cyber exchange platform: - telecoms and/or specialist manufacturers - standardisation bodies - railways

Development of the FRMCS system (in collaboration with 3GPP, ETSI, suppliers...)



UIC Railway Application Guide - Asset Management through ISO 55001

Projects: APRA and OSJD

6 - UIC's work in this area will intensify in 2019

- **2018 exploratory group conclusion: need for a practical approach**

- **Development of three axes:**
  - Definition of priorities: critical systems/safety
  - Participation in existing ad hoc telecoms work groups (ETSI, 3GPP, GSMA, etc.)
  - Cooperation with a group of specialised industrial companies already active in providing sound solutions to other industries (airborne, energy, etc.)

- **Registration in ad hoc telecoms work groups (H1)**

- **Identification/enrollment of 1st group of industrial companies (H1)**

- **Initial vision for possible technical solutions (end 2019)**

Complementary to other initiatives (processes, normative rules, etc.)

Stay in touch with UIC!

www.uic.org

#UICrail

Prof. Dr. Marc Antoni
Rail System Director
UIC Rail System Department

antoni@uic.org

Thank you for your kind attention!