ASSET MANAGEMENT

Unlocking lasting value

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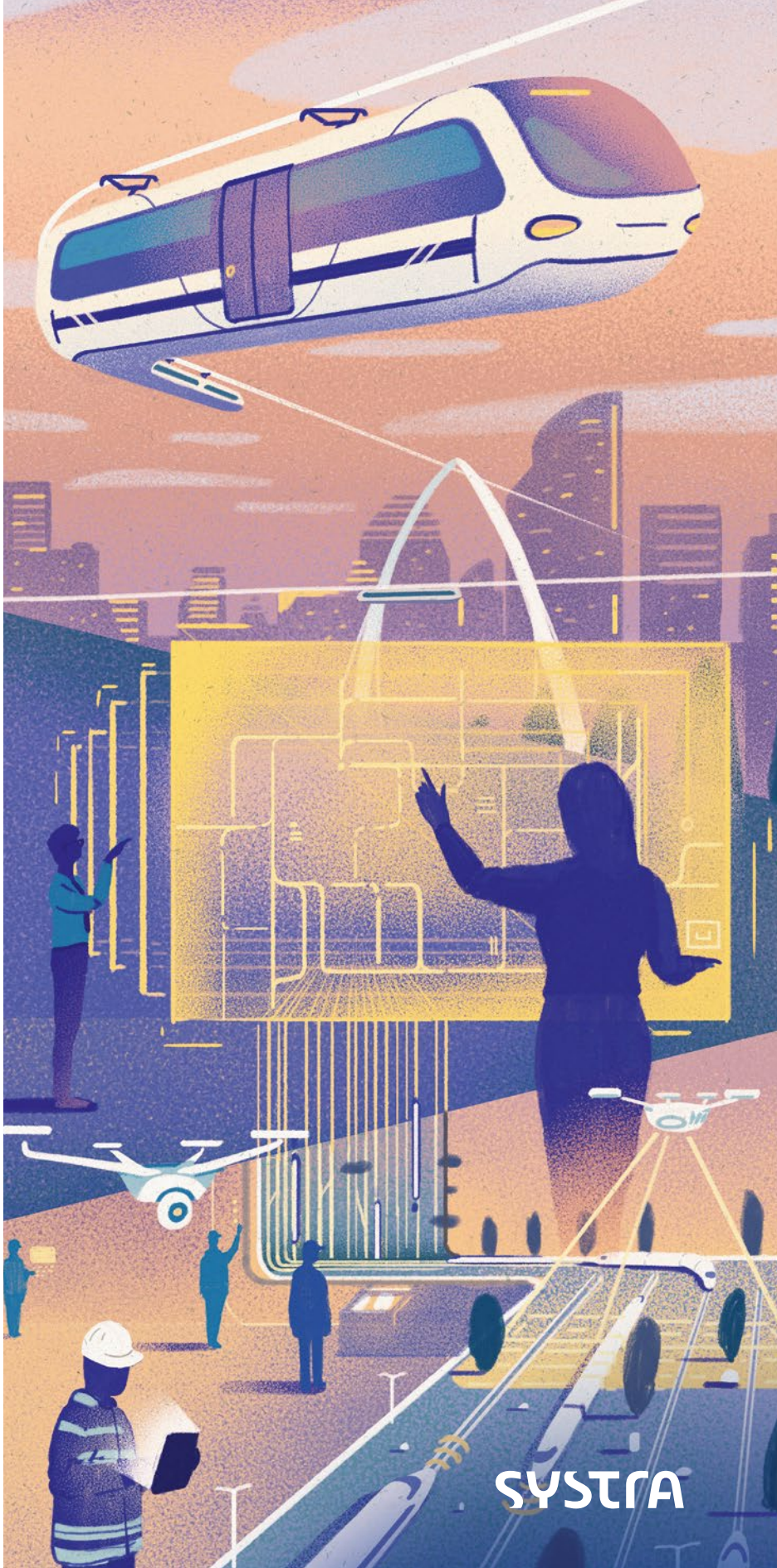


What if prediction were an exact science?

Nicolas Massart
Chief Technical & Innovation Officer at SYSTRA

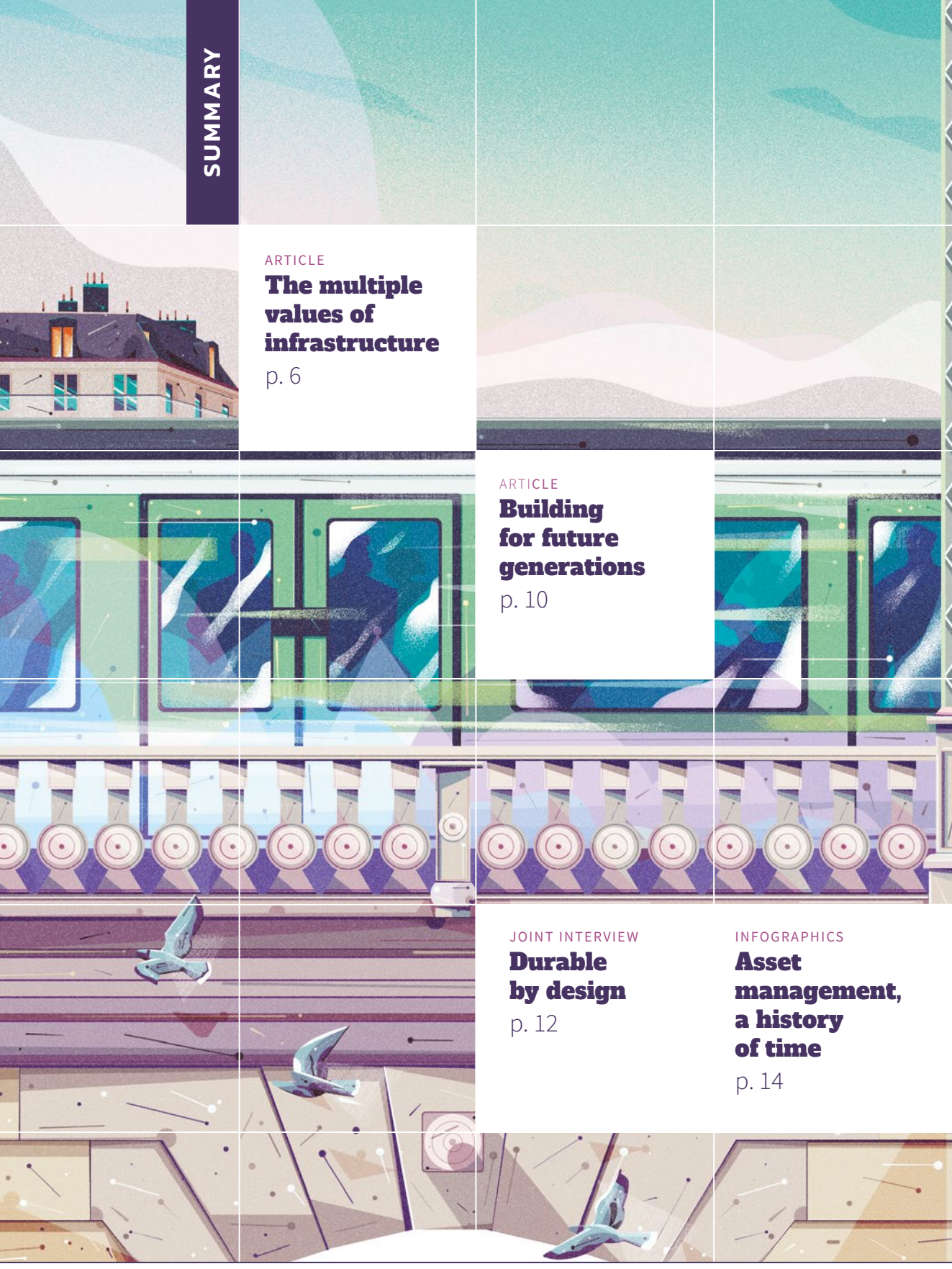
Although the term asset management is still fairly new, the concept of wealth management dates back far into antiquity. In the noughties, asset management became structured and codified by norms and standards in response to the new challenges of the global economy; its application is now being extended to more and more areas of our lives. We interviewed a number of ecosystem stakeholders with the intention of highlighting the diversity and scope of opportunities opened up by asset management, and those outcomes are now presented in this report.

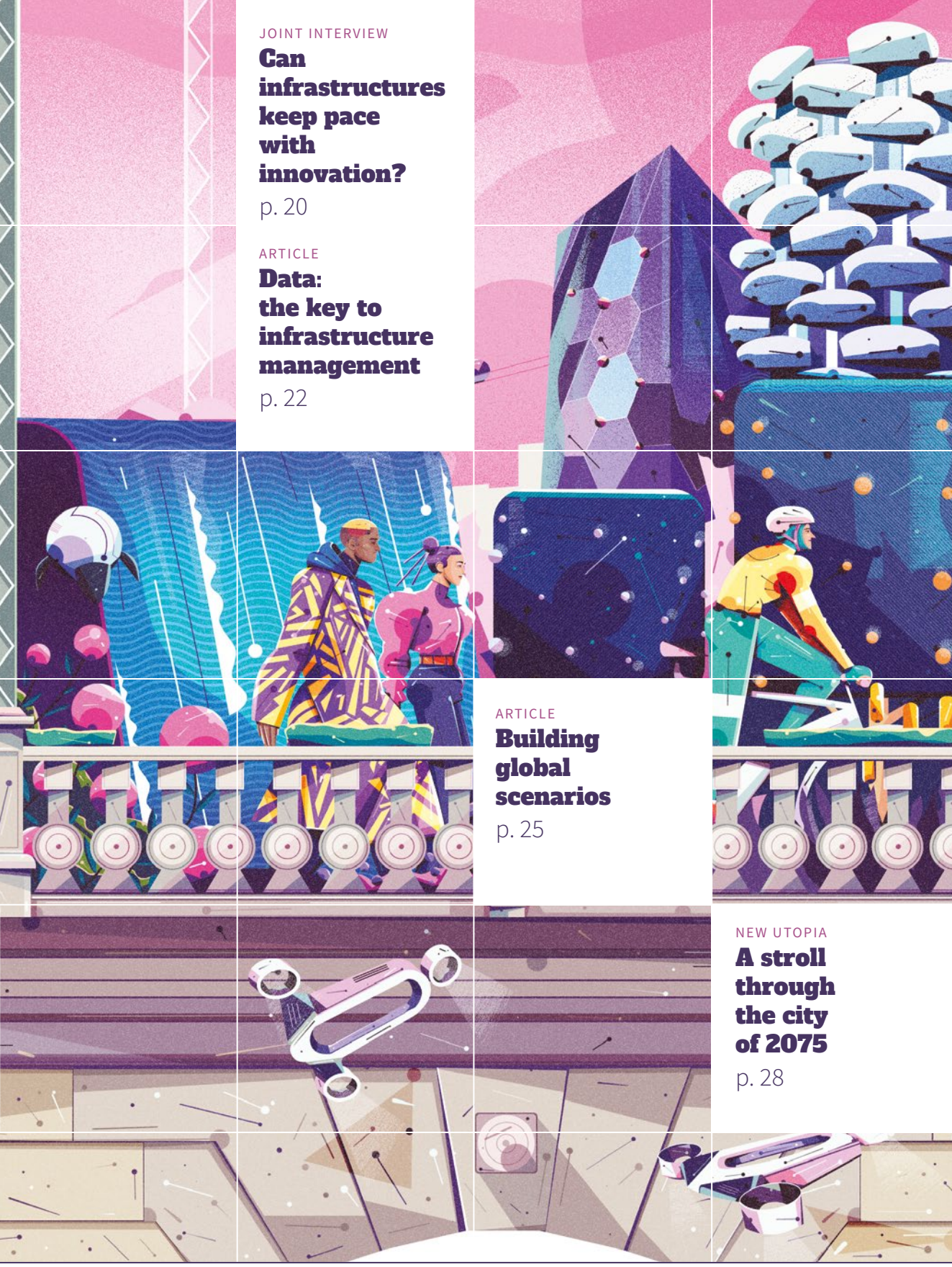
'Prevention is better than cure': this adage could perfectly well summarise the essential contribution made by asset management. It may well be an over-simplification, but it does reveal the paradigm shift now underway in many sectors, and particularly in mobility. As we respond to the crises that have come to define our times, be they health, environmental, economic or societal, we are continually asking and expecting more from our infrastructures and those who manage them. Performance is no longer just technical, operational or financial - it must also be sustainable. But what do we actually mean by sustainability? Is it purely about hitting carbon targets? Or is it broader than that? Is it about our ability to optimise infrastructure performance, now and in the future, at the same time as creating value, responding effectively to future changes and adapting to emerging challenges?

By its very essence, anticipation is not about invention, but about preparation. It is therefore a question not only of tools, but also of culture and organisation. Before we can 'manage' assets, we must first know what they are, understand them, and test them with a multitude of scenarios if we are to make informed decisions at the most appropriate time. Asset management is therefore much more than a method: it is a constant process of dialogue between different areas of expertise, data, time frames and priorities. Asset management brings together a diversity of stakeholders around essential issues, such as how do we ensure that today's infrastructures will always meet the needs of tomorrow?

We hope that these few pages will give you a clearer overview of this structurally essential topic, which is central to the major challenges to which engineering must now provide answers.

SUMMARY





The multiple values of infrastructure

WORDS
Renée Zachariou

ILLUSTRATION
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1- Hanif, N., Lombardo, C., Platz, D., Chan, C., Machano, J., Pozhidaev, D. et Balakrishnan, S., eds., *Managing Infrastructure Assets for Sustainable Development: A Handbook for Local and National Governments* (New York, United Nations, 2021).

"The objective is to maintain operational performance throughout the lifecycle, and to invest responsibly to improve the cost-performance-risk balance, thus increasing the value created."

What is the value of infrastructure? Is it always a financial value? In a sector where many actors collaborate, a plethora of definitions can be expected. Value is specific to all of them and is the starting point for every asset management approach.

DEFINING AND INCREASING FINANCIAL VALUE THROUGH ASSET MANAGEMENT

Asset management is the set of activities that enables the management of an organisation's assets to generate optimal value, while maintaining a balance between the level of performance, risks, and costs. With infrastructure, the assets are generally physical, but they can also be financial, which is where asset management comes from. In the world of transport, this includes buildings (stations, depots ...), networks (rail tracks, catenaries ...) and rolling stock (trains).

Value is assessed primarily on the basis of costs, which financial models evaluate simultaneously to reach an optimum between CAPEX and OPEX. CAPEX ('capital expenditure') corresponds to total investments, while OPEX ('operational expenditure') represents operating expenses. The objective is to maintain operational performance throughout the lifecycle, and to invest responsibly to improve the cost-performance-risk balance, thus increasing the value created.

The CAPEX-OPEX optimum defines the trade-offs for a given service value over the life of the asset. John Hardwick, executive director of asset management at the government agency Transport for New South Wales, Australia, favours this approach by emphasising a long-term vision. "For the government, it's the total cost that matters. And it's about the service you provide to users and the community."

BEYOND FINANCIAL VALUE: SERVING USERS

This touches on another value, namely service value. In a guide for public actors published in April 2021[1], the United Nations differentiates between the service value and the financial value of an asset. The former corresponds to "the level of service that one or more assets provide to users, owners, the community and citizens", while the latter refers to the cost of acquisition and operation.

The two definitions are complementary rather than competing, according to Thomas Paineau, senior investment director at Meridiam, an independent French investment company whose mission is to "develop, build and operate long-term sustainable infrastructure that improves people's quality of life". "Of course, we look at the financial dimension because we have to report to our investors. But that value is only going to be realised if the infrastructure contributes positively to the Sustainable Development Goals (SDGs, 17 goals defined by the UN since 2000)."

Not only do different definitions of value coexist, but value is not fixed in time. If we go back to traditional accounting methods, the value of an asset depreciates over time, with wear and tear. Nevertheless, a 100-year old bridge with full functionality has the same service value as a new bridge. It will, however, incur higher maintenance costs.

VALUING THE ENVIRONMENTAL IMPACT OF TODAY AND TOMORROW

"For us, there is no prior inferred trade-off between CAPEX and OPEX, because we monitor projects over twenty-five years, and on infrastructures that have

a lifespan of more than sixty years", says Thomas Paineau. Long-term thinking necessarily includes taking climate risk into account from the infrastructure design phase. Meridiam was involved in financing a tunnel under PortMiami, an area often hit by hurricanes. By adding an extra 1% to the construction price to install doors to seal the tunnel entrance in case of rising waters, tens of millions of dollars have been saved over the lifetime of the infrastructure.

AN INTEGRATED VIEW OF VALUE

Asset management is therefore not focused on the asset itself, but on the value that the asset can provide, in line with ISO 55001 (see p. 15). John Hardwick mentions the replacement of rail signalling systems in South-West Australia, where several options were available. One was to spend A$800 million to update the existing system, or new digital technology could be installed for an additional A$450 million. The technological innovation would reduce the amount of time operators spent on tracks (a safety issue) and increase the number of trains that could run on the line (a service issue). Taking everything into account via an asset management approach, the second option was chosen.

"It brings together information from several sources [...], enabling engineers and asset management teams to discuss options from the outset and to focus on long-term performance objectives."

The great strength of asset management is that it brings together information from several sources (financial services, maintenance managers, operational teams, and customer satisfaction surveys), enabling engineers and asset management teams to discuss options from the outset and to focus on long-term performance objectives.

THE HERITAGE VALUE OF TRANSPORT INFRASTRUCTURE

Transport infrastructure also has an asset value, and asset management is sometimes translated as 'heritage management'. According to the French dictionary *Larousse*, heritage is 'property inherited from one's forbears', meaning that asset management is a collective work over time, in order to build and grow one's network and heritage for the benefit of future generations.

With this in mind, Jean-Bruno Delrue, CEO of Mesea, the maintenance company for the Tours-Bordeaux South Europe Atlantic high-speed line (LGV SEA), says he is working closely with Lisea, the LGV SEA operator: "We have pooled financial and human resources in order to develop a joint approach that provides in-depth knowledge of the growth of our installations over time, in terms of the geometry of our tracks and the condition of our signalling equipment." Hervé Le Caignec, CEO of Lisea, adds that "to a large extent, Lisea relies on tools developed by Mesea (CMMS[2]) for asset inventory."

THE VALUE OF COLLABORATION

Having a holistic approach to every facet of infrastructure and to its values, which differ for each stakeholder, enables informed conversations with decision-makers and investors. Joubert Flores, former director of maintenance for the Rio de Janeiro metro (Brazil) and current vice-president of the International Union of Railways in Latin America, had to convince public authorities to invest in specific assets for the Rio de Janeiro metro. "After assessing the entire network, we identified fifty-one assets to be upgraded, eight of which had a high risk of failure. This allowed us to prioritise investments." While we focus here on the value of the infrastructure, its malfunctions also have a financial impact in the event of penalties set by the supervisory authority, and/or a drop in user revenue if the infrastructure is underperforming. There is also an economic impact, with an increase in OPEX if the assets fail badly, together with a reputational cost.

Adopting an effective asset management model is a bold and demanding challenge, which involves transforming the culture of stakeholders and changing the perspectives of several players.

2- CMMS: Computerized maintenance management system.

NUMTOTS: THE AFFECTIVE VALUE OF TRANSPORT INFRASTRUCTURES GOES VIRAL!

Numtots (New Urbanist Memes for Transit-Oriented Teens) are all about public transport and new urbanism, and share images online that often go viral, from reimagined subway maps to photomontages of life by public transport. Although their humour can sometimes be impenetrably obtuse, their attachment and commitment to public transport effectively express its affective value, which goes way beyond its value as merely a public service.

The full life cycle cost of a rolling stock is worth 2.5 to 3 times[1] its acquisition cost.

After installing a fault detection system on catenaries, one European operator reported cost savings of 8-10%[2] on maintenance activities.

1- SYSTRA Evaluation.
2- UITP (2019). *Digitalisation and Asset Maintenance.*

THE VALUE OF THE INFRASTRUCTURE ACCORDING TO

Hervé Le Caignec,
CEO of Lisea, LGV SEA operator (Sud Europe Atlantique high-speed line)
and Jean-Bruno Delrue,
CEO of Mesea,
Tours-Bordeaux LGV SEA maintenance company

JB.D. A transport infrastructure is first and foremost a public service, intended for individual users and companies. Its use value is therefore essential. On the other hand, it is inconceivable that the financial dimension be separated from it. A transport infrastructure is managed over a long period, and the optimisation of its overall cost starts at the design stage, which implies bringing the operator-maintainer on board at this stage, which is the spirit of the LGV SEA project. The maintenance effort and its impact on the structure must be optimised to guarantee its safety and performance, to postpone renewal operations for as long as possible.

H.LC. With the SEA high-speed line, the value of the infrastructure can be measured against multiple criteria. To meet the challenges of climate change, a modal shift to train transport between Paris and the main cities in Southwest France will be encouraged. The transfer of high-speed trains to a dedicated railway line also frees up a lot of capacity on the traditional lines, which is likely to encourage the development of regional express services (TER) or rail freight. Finally, the SEA high-speed line will serve the regional dynamics of the entire Atlantic coast and the greater Southwest. During the operating phase, we will also continue to monitor the impact of the project through an environmental observatory, and a socio-economic audit.

Building for future generations

The sustainable development objectives aim to extend the life of our infrastructures, but also to reflect on their use in the interest of future generations. When is it more beneficial to extend or transform their use?

Built in 1900, line 1 of the Paris metro carries 750,000 passengers daily from east to west. Although it has seen many changes in 120 years, including automation in 2013, it is a symbol of our ageing infrastructure. The age factor is not a given, says Fanny Lopez, historian of architecture and technology and lecturer at the Paris-Est School of Architecture. “A lot of infrastructures are close to one hundred-years-old. Obsolescence is an issue. In terms of the road and energy network, or nuclear and hydroelectric power stations, we tend to think that their enormous size is a byword for permanence, but they are weakening.” Roads, rail bridges, nuclear power plants and other infrastructures reveal potential or proven faults. They call for increased and targeted scrutiny, and better anticipation of failures in the shape of real asset management.

REUSE AND ANTICIPATE

With climate change, pressure on raw material resources and energy cost inflation, the sustainability of our infrastructure could become more central, not to say crucial in the future. The key components of concrete, sand and gravel (whose global demand amounts to 40 to 50 billion tonnes annually, according to the UN)[1], might run out in the future, while supply crises are already a fact of life in parts of the world.

Faced with these global challenges, the circular economy is gaining ground. Colas, a subsidiary of the Bouygues Group, recycles road construction materials, such as aggregates and ready-mix concrete, from its quarries and gravel pits, as such as aggregates and ready-mix concrete, as “control of key resources like aggregates and bitumen is essential for roadworks”[2]. Through subsidiary Eurovia, Vinci has developed “an innovative pavement renewal process with a very high recycling rate”, which “has increased the recycling rate of aggregates from pavement planing by 70% and has been reused locally in new road surface”[3].

Reusing hardware is not enough. We also need to anticipate changes in the way people live, so that we can begin adapting our infrastructures now to improve their resilience at a time when extreme climatic events seem to be increasingly commonplace. Proactive risk management includes predictive maintenance (using sensors and IoT connectivity), digital twins, and virtual and interactive replicas of infrastructures. In 2014, Singapore pioneered a detailed modelling of the city, including its entire road network, using 3D laser remote sensing technology (LiDAR). The centralised management of road infrastructures can detect faults such as potholes to reduce accidents, and achieve better planning of future developments, with detailed simula-

"Do we repair it and put it back into service, or could it be converted into a cycle and pedestrian path only?"

Greg Marsden Researcher at the University of Leeds, United Kingdom

WORDS
Sophie Kloetzli

ILLUSTRATION
Joe Waldron

1- Zhong, X., Deetman, S., Tukker, A. *et al.*, "Increasing material efficiencies of buildings to address the global sand crisis", *Nat. Sustain.* (2022).

2- "The materials", *Colas*, [online].

3- "How to optimise resources thanks to circular economy", *Vinci*, [online].

tions to improve traffic flow, and deal with potential road closures or new roundabouts.

RETHINKING USES

Greg Marsden, professor of transport governance at the Institute for Transport Studies at the University of Leeds, UK, is working on reduced mobility brought on by Covid-19. Despite the lifting of restrictions in early 2022, weekday road traffic in the UK is now only 91% of its pre-pandemic levels, due to the rise of homeworking, the effects of which are still unquantifiable. How does this affect the building of new infrastructures, as their use might change progressively or abruptly?

The changing use of infrastructures is now a real concern, and not just for the transport sector. Fanny Lopez, specialist in energy infrastructures, believes that "we have reached a tipping point, as electric and telecoms infrastructures, for instance, are undergoing major changes. Old telephone exchange systems have become obsolete in the age of digitalisation, and a number of thermal and nuclear power stations are scheduled to be shut down."

Demands for reversibility and mutability are increasing in other sectors, as seen in the Orlyval shuttle linking Orly airport to Antony in the southern suburbs of Paris. The Grand Paris Express, with the extension of line 14 to the south, will close the Orlyval line in 2024. But there are options available, with Orlyval turned into a new metro line as part of a project to build new stations between Orly and Antony. Other plans include converting it into a cycle track, or into a dedicated track for an autonomous shuttle service.

Greg Marsden sees replacement projects as valuable opportunities for rethinking the functions of structures. For example, these developments may, in some cases, go hand-in-hand with the increasing use of soft mobility or space calming options. "Sometimes, a road bridge has to be closed because it is faulty. Do we repair it and put it back into service, or could it be converted into a cycle and pedestrian path only?" This long-term change of infrastructure use is already happening as cities evolve. The High Line Park in Manhattan, New York, is a suspended urban park built in 2006 on a disused section of the old overhead railway tracks. In 2017, in Seoul, South Korea, an unused motorway was turned into massive, suspended gardens. In the age of ecological transition, sustainable, new, or reinvented infrastructures can adapt. They have been shown to be mutable and open to new uses.

Durable by design

WORDS Pascal Beria

Have the new imperatives of sustainability and adaptability for transport infrastructure changed the way new projects are conceived? How does asset management fit into this initial design phase? Have the professions changed the way they collaborate?

Denis Andlauer

Etienne Malouin

Etienne Malouin,
Director of Asset Management
at the Société de transport
de Montréal

Denis Andlauer,
Senior Director for Transportation
Strategies at CDPQ Infra, a
subsidiary of the Caisse de dépôt
et placement du Québec, Canada

What are the contributions of asset management and how does it contribute to long-term infrastructure?

Denis Andlauer An infrastructure project is based on a study of needs over five to six decades. Asset management seeks to anticipate from the beginning how infrastructure will be used over time, and how an asset-in-the-making can fit into a geographical and temporal space. In order to do this, we are collecting data from demographic statistics from over a twenty years' period. It's a short scale, so we are also relying on projections and users' wishes.

Etienne Malouin In Montreal, there is a great sensitivity to social acceptability. With new infrastructure, the asset manager obviously cannot simply draw a line on a map. Taking different uses into account is crucial to understanding the infrastructure's environment and its impact on surrounding communities.

How can we reconcile short-term budgetary constraints with the scalability of infrastructures in the longer term?

E.M. This is a complex question. When we design infrastructure, we always mean to integrate technical, normative or lifestyle changes, for ease of change. But how can we anticipate long-term innovations? It is a permanent compromise, driven by the market. We can plan the design of an infrastructure given the availability of materials over time. But even with a fifty-year forecast, we need to be able to bounce back in case some materials are no longer available.

D.A. Spending money at the onset without anticipating the future is natural. It's a struggle to get

CAPEX to agree to additional costs for potential long-term savings. Here is a good example: on the subway, the most worn-out assets are the stairs. There are two solutions: concrete or granite steps. But the price difference is substantial. As an operator, I know that concrete steps are brittle and need regular repair in the harsh Montreal winter. Choosing granite is more sustainable, but it has a significant financial impact. As part of the preliminary studies on the Réseau Express Métropolitain de l'Est Montréal, granite was chosen in the end, because we knew we were making long-term savings.

"But even with a fifty-year forecast, we need to be able to bounce back in case some materials are no longer available." **E.M.**

How do you integrate sustainability into your infrastructure projects?

D.A. We start from the basis that a transport network is structuring. If our project makes environmental sense for the community, it will generate adequate mobility throughout the territory, and articulate the right way to live there. We don't create infrastructures to just respond to what is already there, but to stimulate new urban dynamics in the city and innovative cross-border living areas. We are convinced that we are a catalyst for new urbanism, and this contribution allows us to create value for the community.

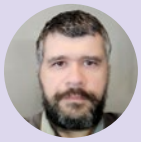
"We don't create infrastructures to just respond to what is already there, but to stimulate new urban dynamics in the city and innovative cross-border living areas." **D.A.**

In practice, how can we best anticipate the scalability of infrastructures?

D.A. Scalability is another matter. Let me give you an example. Our offices were built as closed spaces. We switched to open space, then to co-working. Offices have now become living places, so how can an asset be designed to last? With transport infrastructure, a lot of time is spent identifying users' needs and how to respond to them accordingly. This helps to reduce mistakes, but in the long run, we'll always have to deal with unforeseen events, and we must accept that.

L'asset management as seen by

Catherine Laplante,
Senior Transportation and Asset Management Economist, SYSTRA Canada



Paulo Nunes,
Manager, Maintenance Engineering & Asset Management Division, SYSTRA France

How do you define asset management and what do you expect from it?

Paulo Nunes Asset management covers a wide field, and our clients sometimes have their own take on it. Asset management means keeping cost-effective assets for as long as possible. Let's take the example of an older car that still serves its purpose, but with a slowing engine. Should I spend €2,000 on a new engine, when the car is probably worth that, or should I buy a new car?

Catherine Laplante For my team in Canada, the asset management approach comes into play even earlier. Our role is to support decision-makers as soon as the transport infrastructure is designed. What equipment will we choose and what will be the impact of this choice? We manage cost risks and assess the 'break-even point' of every investment. In economic jargon, break-even is the point at which revenue and total costs are the same, meaning that the business is making neither a profit nor a loss. The primary objective of asset management is to collect clear, reliable, and structured information to make the best decisions, whether for investment or for maintenance. This operating mode must be initiated by management and permeate the entire company. In other words, it means a genuine cultural change.

Time is a byword for future. How do we create models for future changes in needs or assets?

P.N. I want to challenge the idea that we can predict everything. I have a background in statistics, so I'm a big believer in modelling the future based on the past, but it's still a question of probabilities. In the short term, you can predict the future with great confidence, but the further into the future, the more difficult it becomes. Asset management is an iterative process. Even if we rely on known assets, we have to carry out inspections every two or three years to support our analyses.

Is climate change a factor in an asset management approach?

C.L. Of course it is. With a thirty-year plan for a rail network, one needs to take climate change into account, such as increasingly heavy rainfall, which could be damaging to the assets. One must assess the cost impact on the overall plan and consider a change of materials. Climate change is becoming an additional component in asset management.

P.N. A few years ago, the railway network in the Vallée de Chevreuse in Ile-de-France was flooded by heavy rains and the platform was washed away. You have to make improvements as you go and weigh up risk and opportunity to decide when is best to replace equipment.

Ghita Khettab,
Asset Management Group Leader
at SYSTRA

Tomorrow's infrastructures are essentially today's infrastructures too. Asset management provides the lever for extracting maximum value from them and making them last longer. Every asset management method is rooted in detailed knowledge of our assets, how they work, and what their life cycle looks like. Once we know that, the decision support strategy can be firmly based on tangible realities. So this involves us in acquiring and structuring all the relevant data. It's not about consuming data at all costs, but about finding the right combination of frequency and accuracy to provide input for the right use case.

Ignasi Oliver,
Head of Digitalisation and Metro
Innovation at TBM (Transports
Metropolitans de Barcelona)

Asset management is a dialogue. It is a common language, with data as its alphabet. It is crucial to collect the data, by making it intelligent, but also to understand it and redistribute it when relevant. You can have the best data sets in the world, but if no one understands what their purpose is, it has zero impact on the efficiency of asset management. Language is culture, of course. Asset management is about building a culture of innovation and interfaces from a data collection and processing system. This is the greatest organisational revolution of recent years. We are bringing together assets, businesses, players and users, and these interactions increase our ability to make decisions, and guide our choices in line with our strategic objectives.

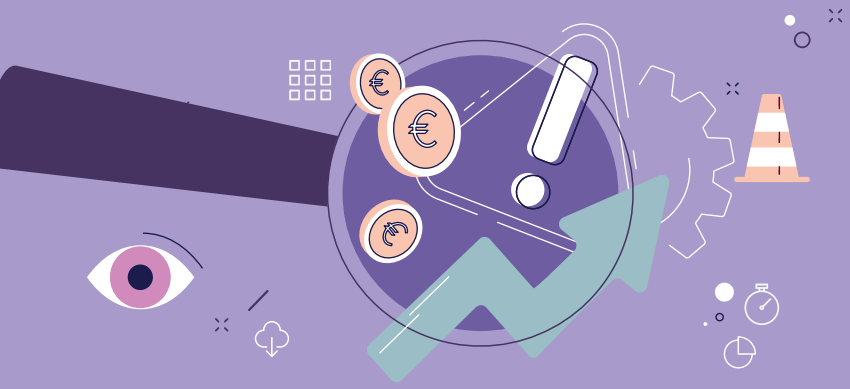
John Hardwick,
Executive Director - Asset
Management at Transport for
New South Wales, Australia

The value of any transport infrastructure lies in the service it delivers to users, and not in the assets themselves. We know that expectations will change over time, and we monitor changes closely to ensure that we can meet new expectations. The state of New South Wales believes that it's important to ensure that everyone in the community has the opportunity to travel easily and in comfort. For example, rail stations without lifts are unusable by some members of the community. To achieve our service targets, we make sure that everyone working on our network is on board with the concept of asset management: that means 30,000 full-time employees and 100,000 contract staff, from finance to human resources and infrastructure maintenance teams. Asset management gives us a better understanding of the transport network, and the opportunity to think in terms of its entire life cycle. It gives us an overview of the entire system, which helps us to prioritise investment, at the same time as controlling risks. Our ultimate goal is to run a transport system that supports economic growth and serves the public.

Marc-Olivier Maillefaud,
CEO at SYSTRA Brazil

Transport infrastructures have very long lifespans. They may undergo major changes like privatisation, changes of operator, re-nationalisation, major upgrading, division between multiple operators or multiple types of service. So asset management must be used as a central tool for facilitating these transitions and ensuring continuity of service quality.

Asset management in two concepts



Asset management:
Asset management is a formalised approach to managing an organisation's assets by making decisions on different timescales to generate optimal value.
Striking the right balance between the objectives of the different stakeholders is a major challenge, as the balance lies between cost management, risk management and performance management.
By mapping the assets that make up an infrastructure or a portfolio of activities, it is possible to manage the objectives accurately throughout their lifecycle.

Assets:
An asset is an element of potential or actual value to an organisation (see *The multiple values of infrastructure, p.6*). There are two main categories of assets in transport:
- physical assets such as the transport network (tracks, bridges, tunnels, catenaries, substations, sensors, software, IT solutions, etc.) and the fleet of rolling stock (buses, underground carriages, trams, trains, etc.);
- intangible assets such as skills, brands, customer relations, intellectual property, and data.

Equations

AM = performance + risk + cost
Asset management's aim is a managed performance, to guarantee the highest level of safety and availability of transport services.

AM = investment + maintenance
Asset management facilitates a two-pronged approach: initial investment and maintenance.

AM = Totex (Capex + Opex)
Asset management takes CAPEX and OPEX into account by managing Totex ('total expenditure') for optimal results, but never at the expense of either approach.

AM = Greenfield + Brownfield
Asset management applies to both greenfield and brownfield projects.
Greenfield investments integrate asset management from the onset: the players bring in their projects, with financial, environmental, technical, societal, and planning issues at stake.
Brownfield investments, on the other hand, look into cost optimisation and performance improvements: asset management then steps in to assess the opportunities.

A brief history of asset management

2,500 BCE
The Abusir papyri from northern Egypt were administrative documents recording equipment in two temples, priests' duties, and the list of daily offerings. Could this be the first asset register, the cornerstone of asset management?

1868
The Foreign and Colonial Government Trust, a long-term financial institution, was founded in London, and is seen today as the first asset management company.

1984
Australian researcher Penny Burns uses the term asset management in a transport document for the first time. Today, she chairs the Talking Infrastructure Association, which aims to improve transport decision-making and make it as 'future-proof' as possible.

2004
The British Standards Institute (BSI), in collaboration with the Institute of Asset Management (IAM), releases Public Available Specification 55 (PAS 55). Structured around the Plan-Do-Check-Act cycle of continual improvement, PAS 55 introduces the need for essential enablers, to ensure alignment in infrastructure management activities.

ISO 55001

2014
The ISO 55001 family was released to define long-term implementation. The Institut Français d'Asset Management Industriel (IFRAMI) in France and the Institute of Asset Management (IAM) in the United Kingdom were set up to enable the application of knowledge, training, and good practice in asset management.

Engineering
(physical assets)

➔ Concrete action on the network

➔ Asset Management Plan (AMP)

➔ 0 to 5 years

Implementing the action plan

CONSULTING

Investment/maintenance outlines according to objectives and state of the network (performance/costs/risks) and constraints (budget/technical/human) human constraints

➔ Investment plan

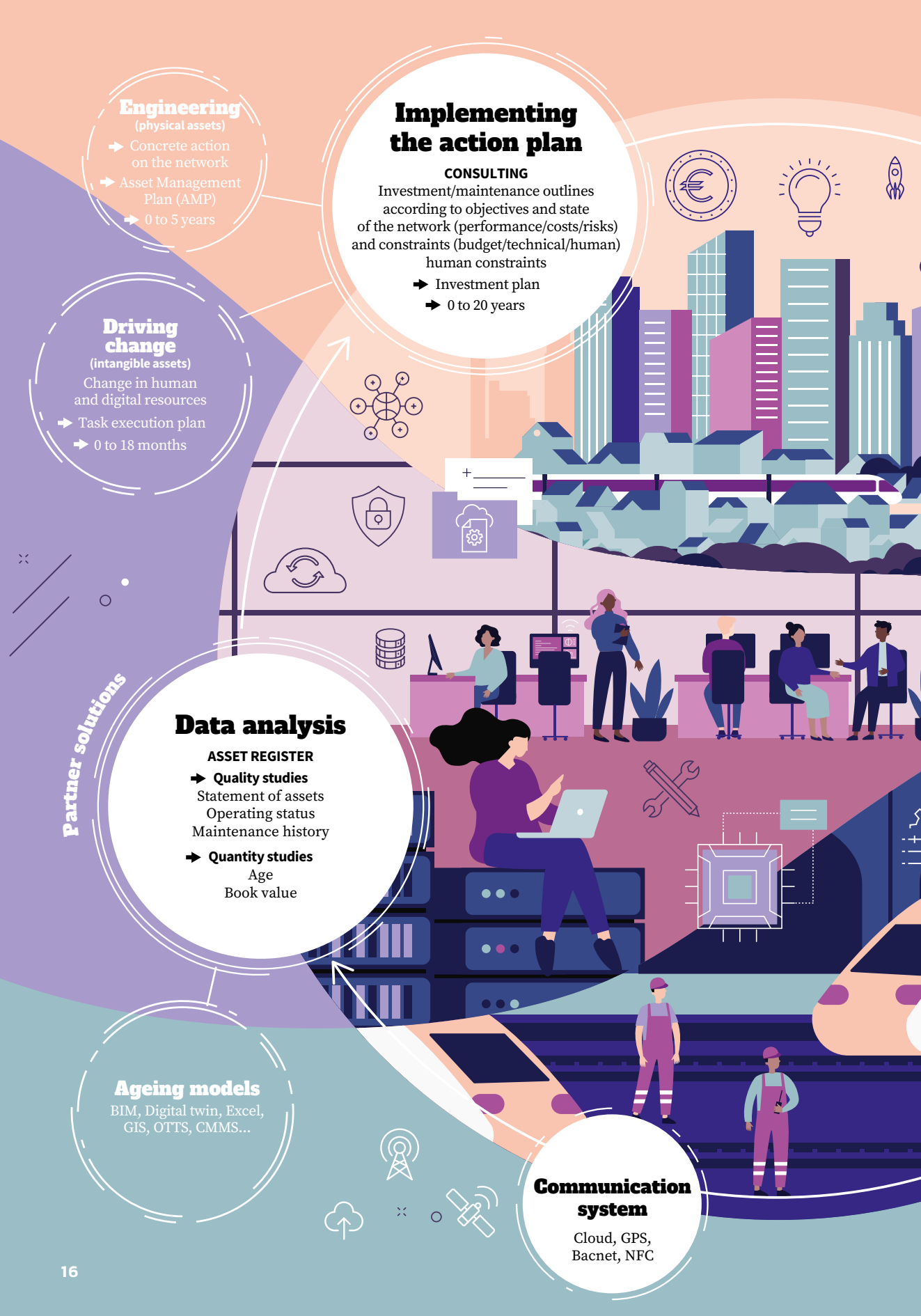
➔ 0 to 20 years

Driving change
(intangible assets)

Change in human and digital resources

➔ Task execution plan

➔ 0 to 18 months



Partner solutions

Data analysis

ASSET REGISTER

➔ **Quality studies**

Statement of assets
Operating status
Maintenance history

➔ **Quantity studies**

Age
Book value

Ageing models

BIM, Digital twin, Excel, GIS, OTTS, CMMS...

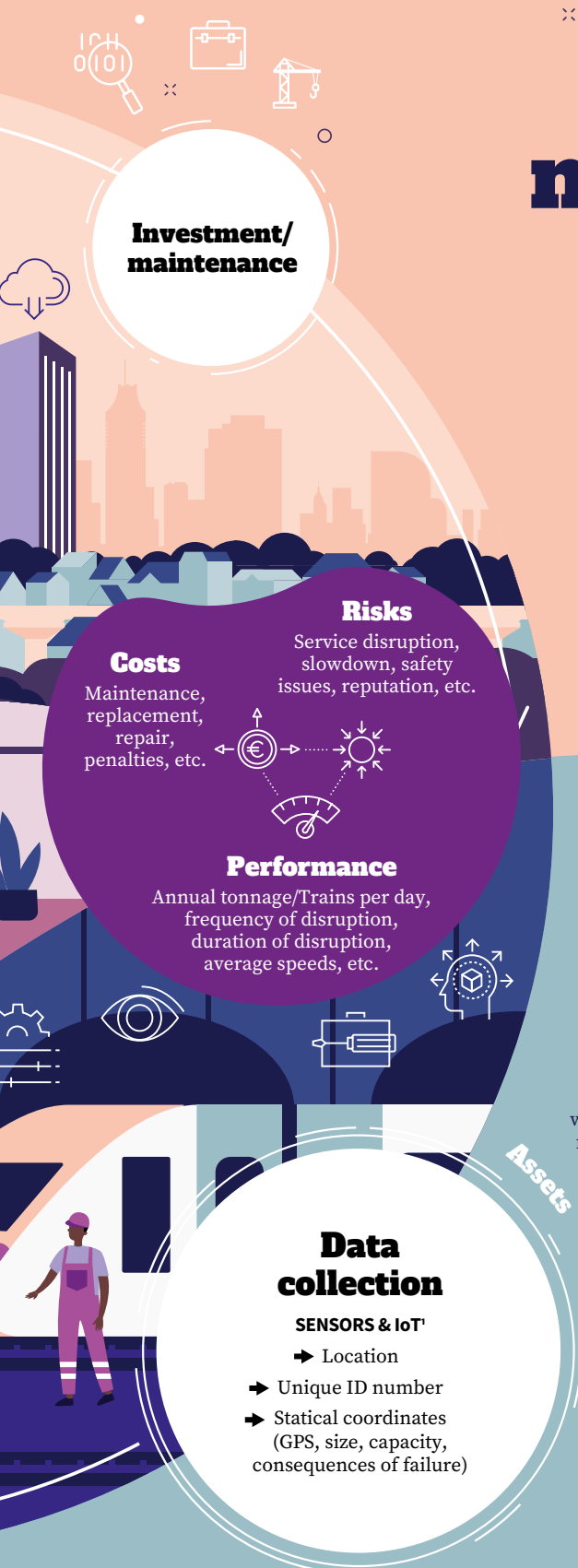
Communication system

Cloud, GPS, Bacnet, NFC

Asset management, a history of time

Whether projecting the life cycle from the design phase or extending the life of an automated system and railway tracks, the management of transport infrastructures is intimately linked to the notion of time. The aim of asset management is precisely to understand the different time frames of assets.

How does asset management fit in with the passing of time? How can it be defined? Let's look at the basics.



The lifecycle of asset management

For the asset management cycle to work, the first step is to know your assets and implement the appropriate measurement tools on the ground. The second step is to record all assets on a digital register, with their fixed and changing data. This will help structure the information pertaining to the state of the assets, which is a prerequisite for monitoring their evolution over time and for decision-making. To prepare for the replacement of obsolete assets, asset management teams will recommend investment and maintenance operations on the ground, a balancing exercise between inspection and asset maintenance activities. To ensure the long-term viability of assets, asset management practice needs to be shared by everyone involved in the lifecycle of transport infrastructure, such as infrastructure managers, operators, maintainers, investors, organising authorities and human resources.

1- Internet of Things, Internet des Objets

Asset management: what is it for?

Asset management is not only good to increase the value of infrastructures, it also enables to :

To understand the condition of the network

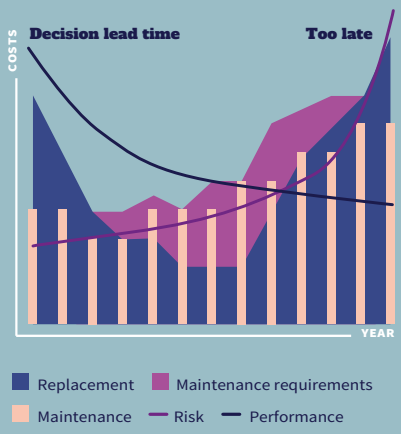
30 years

That's the average age of French rail network tracks and points, compared with just 15 years for its neighbour Germany. With a quarter of tracks already beyond their normal lifespan, the French network is ageing, with visible consequences on service quality and maintenance costs[1].

1- Report by Jean-Cyril Spinetta to the French Prime Minister on the future of rail transport, 15 February 2018.

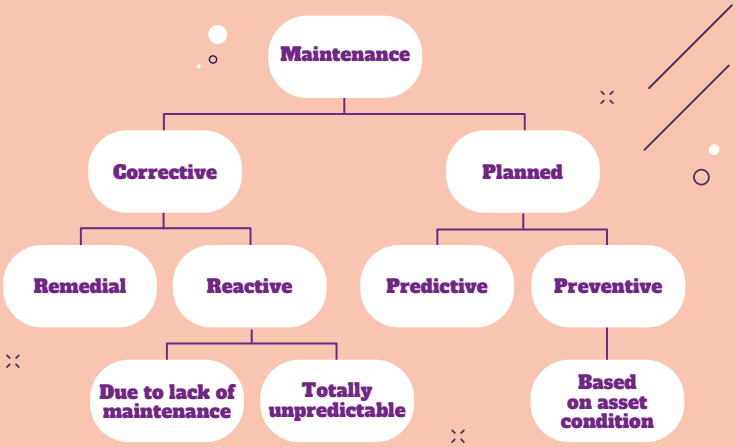
To act at the right time by modelling the lifecycle

To control and limit failures, asset management is crucial to build up an accurate analysis of the state of assets and to act at the right time.



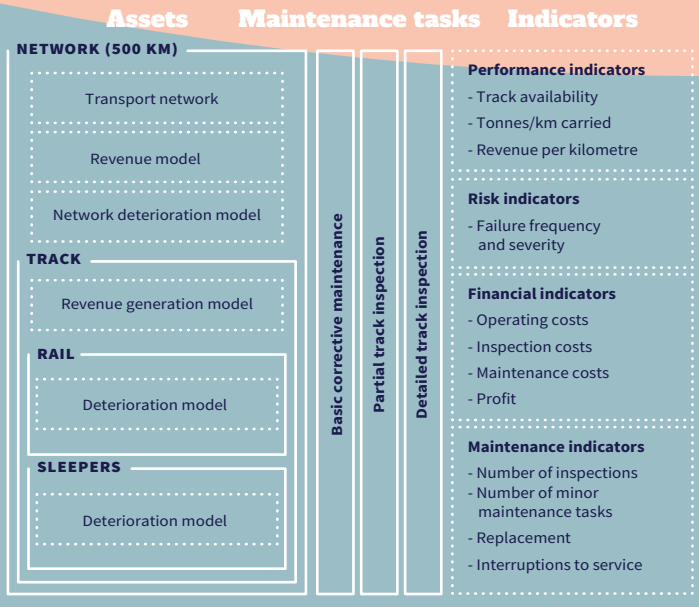
To increase security and availability on the network

After the collapse of the Morandi bridge in Genoa in 2018, of the Marginal Pinheiros bridge in Sao Paulo in 2018, and debris from the Larocque bridge in Southwest France blocking safe passage for 170 boats, it has become vital to reduce exposure to accidents, or early replacement of assets, by supervision and preventive intervention. This is a major issue, both for user safety and for the operational or financial value of assets. When the balance between performance, cost and risk is achieved, and the ability to anticipate the current and future needs of the organisation is mastered, the maturity of asset management has been tried and tested.



Efficiency gains on a rail network: an illustration

The indicators act to quantify the performance of day-to-day asset maintenance and the performance of short- and medium-term planning.



Can infrastructures keep pace with innovation?

WORDS
Guillaume Renouard

As the issues around how we manage the obsolescence of hi-tech objects gains momentum in our societies, what about transport infrastructures? How can they capture the opportunities created by technological innovation? How can they be upgraded, not only their engineered structures, but also their systems?

Christelle Chichignoud

Thomas Chauvière

Answers of two experts from SYSTRA, Christelle Chichignoud Group Sustainability Director and Thomas Chauvière, Group Innovation Director

Infrastructures are the permanent fixtures of our cities. They are there for the duration, whereas flows, uses and technologies are evolving all the time. How do we reconcile these two very different temporal realities?

Christelle Chichignoud I don't see these two concepts as contradictory. Building a transport infrastructure involves thinking about how it will evolve over time, and anticipating the uses and practices that will be grafted onto it in future years. An infrastructure may be a thing of technical beauty, but its primary purpose is to serve a region or community. Its essential qualities should be such that it remains viable for decades after its construction.

Thomas Chauvière I would add that while the physical infrastructure may appear fixed and unchangeable, that is not actually the case, since there are some transport system components that also evolve over time. Take the Paris metro for example. The first trains were largely constructed from timber before they gradually evolved into all-steel trains to limit the risk of fire. Some lines became automated in response to increasing demand, which in turn improved service flow - and therefore punctuality, while passenger information systems were improved to give users greater clarity. All these developments effectively strengthened the backbone of the infrastructure, enabling it to adapt and respond to public demand and changes in passenger usage patterns.

Managing how the infrastructure evolves over time also means thinking about its end of life. How is this issue of obsolescence being addressed in terms of infrastructure? Is there such a thing as an infrastructure obsolescence or repairability index?

T.C. I'm not sure that the concept of obsolescence actually applies here, since a transport infrastructure isn't the same as a yoghurt pot printed with an expiry date! The challenge of asset management is more about taking account of all the variables that will enable the necessary changes to be made to the infrastructure throughout its lifecycle. This involves not only the issues around ageing, but also standards compliance and more technical issues, such as software obsolescence and the industrial solutions used to manage and operate the infrastructure. Covering all these aspects demands a cross-functional overview to ensure the reliability of all the services provided by the infrastructure, and the ability to plan ahead as part of setting medium and long-term strategies with the ability to respond effectively to changes in use. Once again, it's all about making short-term considerations work with longer term objectives.

C.C. I also think that talking about obsolescence in the context of an infrastructure is missing the point. It reduces the complexity of the subject and issues that flow from it to a purely technical level. But the truth is that infrastructures are designed to service a given area or community by making travel easier and creating a dynamic mobility.

"I prefer to talk about durability rather than obsolescence."

Can technology be leveraged to achieve that sustainability? What are the most promising innovations from your perspective?

T.C. Naturally, new technologies are constantly being introduced and used to upgrade infrastructures. Take metro system automation, for example, where the latest digital technologies are enabling ageing infrastructures to deliver an effective response to the new challenges of urban transport. And then there's the example of how new technologies have been developed to address the challenge of detecting rail defects and problems with track geometry, both of which are the root cause of the railway infrastructure disaster scenarios we all fear. These solutions include exploiting the properties of optical fibres, and monitoring solutions that use spectral analysis or image recognition. Innovative methods like these are being integrated into new and existing infrastructures to identify specific maintenance needs, and in the more general sense to guarantee the desired levels of performance and safety.

Right now, the most important area of innovation is data management, as we learn to make more effective use of existing data and generate new data by exploiting the potential of the IoT : great allies for a predictive maintenance! So, we must be able to 'listen' to what our infrastructures are telling us, and use these data to model and simulate their behaviours and dynamics so that we can understand them better and contribute higher levels of value (in terms of maintenance costs, safety and network performance) at every stage in their lifecycle.

C.C. Technology is still primarily a resource for addressing sustainability and innovation issues effectively, and it is very important to achieve early-stage identification of the problems that infrastructure managers are seeking to solve. Once those needs are clearly defined, we can use any technology, provided its practicality, outcomes and benefits have been demonstrated. The key is then the way in which infrastructure operations and maintenance teams adopt these technologies and define their own use cases.

"The bottom line is that we are constantly adopting new technologies, which are improving our asset management skills and practices."

Data: the key to infrastructure management

WORDS Guillaume Renouard

ILLUSTRATION Dan Matutina

The ability to anticipate events is a key concept in asset management. That being so, data provides a fundamental resource for managing future developments.

80% of the CO_2 emissions generated by an asset are determined by the choices made at the infrastructure design phase. This figure makes it immediately apparent just how important it is that infrastructure projects are fully thought through at the earliest stage, especially when they involve engineered structures with the potential lifespan of a century or more, such as a metro system, bridge, or viaduct. Technical issues, the regulatory environment, infrastructure usage… Every component of the project must be reviewed in detail to maximise infrastructure viability over time.

Data is a vital resource in this process because it gives us the opportunity to model the entire life cycle of the asset concerned by building a virtual asset at the design stage, or even creating a digital twin of the infrastructure. The virtual asset can then be operated in the same way as the physical asset to be managed. The flow of data through all information systems contributes to making our transport infrastructures smarter, more efficient and, above all, less environmentally impactful.

A VIRTUAL ASSET THAT WORKS FOR THE BENEFIT OF THE PHYSICAL ASSET

"Today, techniques like Building Information Modelling (BIM) allow us to build the virtual asset before the physical asset, and data plays a fundamental role in that design process. The higher the quality and relevance of the data we use, the smarter the virtual asset will be, which in turn allows us to simulate and test its level of operating efficiency more accurately", summarises Éric Pruvost, head of Digital Engineering Services at SYSTRA.

This 'descriptive twin' - as Éric Pruvost calls it - is a structured 3D representation based on data specific to the asset, and is also referred to as a 'technical dataset'. It will then use data to track the infrastructure as it evolves through every stage of its lifecycle. This capitalisation data will in turn allow simulation tools, and therefore the design of new infrastructures, to be further refined. A virtuous circle fuelled by data.

Instead of navigating purely by visual observation, thanks to the 'hot data' uploaded from the physical asset (SCADA[1], IoT[2], etc.) we then acquire a richer level of knowledge of the asset to understand its performance (through data analysis and modelling) and ultimately to operate and maintain it efficiently on the basis of its predicted future evolution.

WHAT CHALLENGES DOES THIS POSE FOR LOCAL AUTHORITIES AND THE FLOW OF DATA?

Data management requires considerable expertise so that data can be collected reliably and systematically. Circulating, using, and managing such massive volumes of structured or unstructured data generated by a series of information sources that are not always interconnected, is very much a long-term commitment. The first challenge is therefore to select data on the basis of its reliability and relevance. "You have to think in terms of the customer's needs and the potential for value creation. Just because something

1- Control and data acquisition system . 2- Internet of Things.

can be done doesn't mean it should be done. So, for example: which data should we collect to limit the risk of a points failure or rail breakage? And how often do we need to collect it? Asking questions like these can help to avoid the need to store huge volumes of data at prohibitive energy costs to gain information that is ultimately useless. Relevant expertise is fundamental here in order to select the right data for solving the problems we face and for developing a service and digital solutions that deliver real value", continues Éric Pruvost.

Another point of focus is how the physical asset evolves throughout its lifecycle, because as fixed installations are upgraded, maintained, extended, and repaired, new data is generated. The virtual replica must naturally evolve in tandem if it is to continue to reflect the reality of the asset as it is operated and maintained. Open data exchange formats must be used to maintain continuity of data at all scales so that multiple stakeholders can collaborate in updating the technical dataset. This is the non-negotiable process that ensures that the virtual asset remains accessible over time and maintains a high-level of quality.

WHO OWNS AND MANAGES THE DATA?

In a world where data has a strategic level of importance, issues around its collection and governance inevitably arise: who is responsible for this data? Who processes it? Who owns it? "As engineers, we are involved in creating the data, and are also there to supervise construction of the physical asset based on, and developed out of, the digital asset. So, we remain responsible for the data until it is handed over to the customer", explains Éric Pruvost. In the operational phase, things become more complex and more open in a world where the absence of the technical dataset, or even a documentation database, remains the norm, and where the introduction of virtual assets and their associated value requires the definition of governance rules to boost asset performance.

"Just because something can be done doesn't mean it should be done."

Éric Pruvost Head of Digital Engineering Services at SYSTRA

"Open data exchange formats must be used to maintain continuity of data at all scales so that multiple stakeholders can collaborate in updating the technical dataset."

"Large-scale infrastructure managers like SNCF have their own engineering teams to ensure that this data is kept up to date, but the same is not necessarily true for a small local authority with responsibility for managing a single tramway line, for example. The local authority may prefer to outsource the management, operation, and maintenance of its infrastructure to a private operator, which could potentially result in operator dependency. Since it possesses the actual operational data, an incumbent operator will inevitably be in a strong position in any future tendering round. It is therefore essential that operators retain ownership of the information system that manages the technical dataset used for the operation process. At the heart of this change in governance lies the emergence of virtual assets, which will only increase in value, and which infrastructure owners must take ownership of."

A PRACTICAL EXAMPLE: THE SYSTRA CARBONTRACKER SOLUTION

Reducing CO_2 emissions is a major challenge, particularly for the transport industry, which is responsible for generating one-fifth of all global emissions. SYSTRA has responded to this challenge by developing its Carbontracker tool, which provides real-time measurement of the CO_2 impact of design decisions over the entire life cycle of the assets concerned, and can do so for an entire transport system infrastructure.

"The challenges we faced in developing Carbontracker revolve mainly around the relationship between data science and business expertise. We have also taken advantage of improved technology to achieve high levels of data interoperability, although there is still a lot of work to do before we can fully exploit the true value of project data. Our Carbontracker solution successfully addresses two key goals: using virtual asset data to introduce carbon management processes into the design phase of our projects, and offering project owners the resources needed to manage their carbon trajectory on the basis of quantified emission reduction ambitions", concludes Éric Pruvost.

THE DIGITAL TWIN: GRAIL OF ASSET MANAGEMENT

BIM makes it possible to model physical data in a virtual form, but the digital twin marks the next step forward. This concept uses an information system that processes interoperable asset data to link virtual assets with field-generated data (SCADA, IoT, etc.). It therefore offers the opportunity to develop a process, product or service using dynamic 3D visualisation. At this stage, the digital twin provides an enriched view of the asset and is already helping to optimise operations by producing more comprehensive analyses of incidents, for example.

By cross-referencing the field-generated data with base data from the technical dataset or from previous infrastructure projects, predictive maintenance becomes a very effective tool, based on artificial intelligence technologies or machine learning. More specifically, it can detect changes imperceptible to the human eye by, for example, detecting when the doors of a metro train start closing more slowly, which could indicate the risk of a future failure. It is then very easy to identify whether a simple technical adjustment will correct the problem, or whether a preventive repair is required to avoid a potential interruption to service. The result is a smart infrastructure that can continually monitor and analyse itself in order to prevent potential malfunctions, anticipate breakdowns, monitor wear and tear, and minimise incidents.

Building global scenarios

WORDS
Arnaud Pauchenne

Undertaking asset management primarily requires the adoption of a forward-looking approach, the ability to manage uncertainty, and, therefore, to plan for the future. It also requires the ability to envision the likely evolution of organisations, and the skills needed to build scenarios of the world we want to make a reality. This raises questions around the maturity of the stakeholders involved: are all of them ready to take action now to cope with future disruptive change?

ASSET MANAGEMENT: A CULTURAL SHIFT

From reaction to prediction, asset management has brought with it a series of profound changes in our approach to asset lifecycles, posing not only technical challenges, but more importantly cultural challenges in terms of stakeholder alignment. According to Ignasi Oliver, head of Metro Digitalisation & Innovation at TBM (Transports Metropolitans de Barcelona), "making good decisions relies on having the right information. Collecting data is the first step, but then you need to know how to use it and be prepared to make all the changes necessary. The technical building block may demonstrate the effectiveness of asset management, but it is the corporate culture around these questions that is the real trigger".

This analysis is shared by Katia Luce, solutions engineer at IBM Maximo (enterprise asset management software), who also sees a process of change underway not only in maintenance, but also at an organisational level in a much broader sense: "Asset management allows everyone to contribute to building a shared scenario for the future. We no longer have operations staff on one side and decision-makers on the other. Those who have already grasped this are proving to be the most successful: they bring all stakeholders together around the same scenario to align their culture, processes, and skills, and focus them on this single goal. It really is the fact of introducing a culture of asset management that makes the difference from the efficiency point of view. For those operators most convinced of this approach, asset management is a powerful lever for cross-functional transformation."

"Asset management allows everyone to contribute to building a shared scenario for the future. We no longer have operations sta on one side and decision-makers on the other." **Katia Luce** Solutions Engineer at IBM Maximo

SHARING INFORMATION FOR AN ENLIGHTENED FUTURE

In the space of just a few years, asset management has made it possible to break down the barriers between information silos and deliver information sharing on a scale that makes it a powerful lever for growth and support for decision-making. Ignasi Oliver can already see the benefits: “Digitalising the infrastructure, which asset management gives you the opportunity to do, is much more than simply another tool; it’s a radical step change in the way we think and act. We’ve got to know our infrastructures in a way that has improved everyone’s skills and, to a degree, readjusted the balance of power with manufacturers. Previously, they were the only ones with knowledge of the components they produced, but today, we have a much more interactive relationship in which they’re happy to accept our feedback. Collecting all this data has also enabled us to connect different areas of expertise together in ways that allow them to communicate freely with each other. This dynamic shift is powering innovation and enhancing the value of information gathered by the few for the benefit of the many.”

This mindset of openness and pooling of information helps organisations to overcome the initial limitations imposed by complex infrastructures that contain assets with widely differing levels of digitalisation. Katia Luce also sees the success of asset management as a direct result of wider awareness about its benefits: “The democratisation of these tools is clear to see. It’s no longer an option for operators, and although each infrastructure has its own modus operandi, asset management has become a way of working that technicians expect to see in all companies. They’re fully aware of the practical benefits they experience on a daily basis, from task optimisation to simpler management. asset management could simply not have developed as it has if it hadn’t been unanimously adopted by those who benefit from it most.”

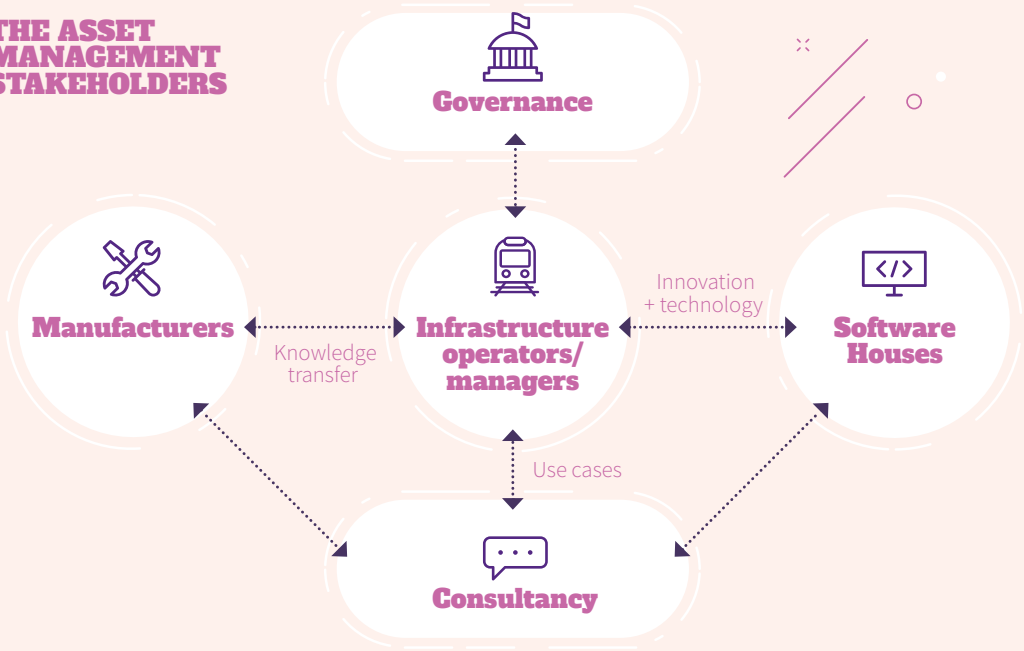
"This dynamic shift is powering innovation and enhancing the value of information gathered by the few for the benefit of the many."

Ignasi Oliver
Head of Metro Digitalisation & Innovation at TBM

COULD ASSET MANAGEMENT BE A TOOL FOR GOVERNANCE?

Having revolutionised maintenance, contributed to demolishing silos and building interfaces between areas of expertise, the ultimate stage of maturity for

THE ASSET MANAGEMENT STAKEHOLDERS



asset management is to welcome new stakeholders to the table; stakeholders whose focus is on achieving the environmental goals and targets set out in corporate strategies. "From the IBM perspective, it's clear that the future of asset management includes sustainable maintenance", says Katia Luce. "So, what of all this collected data? Well, we can start thinking about environmentally friendly maintenance by optimising travel, monitoring the right indicators and linking them to energy and natural resource consumption. As reporting requirements around these issues become tighter, it's clear that it will soon be necessary to measure and analyse every component of entire transport networks."

"Asset management can become a lever for achieving a large number of strategic goals and targets", she continues. "It's no longer an issue of sensors or platforms, but one of vision and governance, which everyone can get on board with, in their own way. For some companies, governance is highly integrated, and the points of contact we deal with are at a senior strategic level. For others, it remains an operational tool, so with those companies, we interact with points of contact in specific areas of expertise. The result is a multi-speed reality ranging from those who have made the management of asset-generated data a real lever for transformational change, and those who see its benefits only in terms of maintenance optimisation."

Asset management: supporting operator strategy, but also key to other non-financial considerations. "Asset management is a lever for innovation in all areas", argues Ignasi Oliver. "Asset management is no longer of interest only to maintenance managers and CIOs (Chief Information Officers). It can also be used as a tool for customer experience, social and environmental responsibility, human resources policy, etc. We must give ourselves permission to continually experiment with its possibilities, because the solutions that will enable us to achieve the sustainability ambitions set by our companies have yet to be invented. We're constantly testing, and recently launched an experiment that uses the IoT to monitor rail temperatures. We don't yet know what this new mass of data will allow us to develop, but we're certainly learning more about our network every day. Better knowledge means better management, and that knowledge then feeds into every area of expertise we have."

3 QUESTIONS FOR...

Marta Miralpeix, Business Development Manager at Smart Motors, an asset management digital solution developed out of a university research project conducted in 2006 around the Barcelona metro system

How has the asset management sector evolved from your perspective?

When we first started talking about using data generated by rail assets to create value for rail operators, people looked at us as if we'd just landed from another planet. There wasn't really a department for operators to talk to: IS saw it as a maintenance issue, maintenance suppliers saw it as an IS issue, and manufacturers didn't see it as an issue at all. But as a result of awareness-raising information campaigns demonstrating the practical benefits and implications, operators have gradually begun to structure themselves around these solutions.

What do you think was the reason for this new awareness and acceptance?

A change in the type of points of contact we deal with, I think. Around the second half of the 2010s, we started to see more people who embraced an innovation culture arrive in more cross-functional roles, and these people tended to work on a project basis. Nevertheless, although the commitment to innovation has become widespread, in many cases the barrier of experimentation and POC (Proof of Concept) still has to be overcome. In most cases, our point of contact is convinced of the benefits of asset digitalisation, but has an uphill battle to convince all the areas of expertise involved.

So, it's more an issue of culture really?

Absolutely. That's clear to see from the fact that these solutions are now included in contract tendering invitations, where they're accompanied by requests for soft skills and change support training programmes. There's now a real awareness on the part of operators, coupled with a willingness to rethink their business organisations around these approaches. Although the same technology-based tools are available to everyone, the possibilities they open up differ very significantly, depending on the governance choices made by operators and their level of asset management maturity. The question is therefore not so much 'what can be done' as 'what do we want to do with it?'.

WORDS
Guillaume Renouard

ILLUSTRATION
Joe Waldron

A stroll through the city of 2075

What will cities look like when infrastructure management and maintenance tasks are carried out smoothly and seamlessly in real time? Cities where transport systems constantly repair and optimise themselves? Those are the questions we set out to answer in this story, which takes us behind the scenes in the fictional city of Aloepolis.

26 April 2075. As the sun rises over Aloepolis, Sarah is about to leave her apartment. Like most of the buildings in our city, hers is covered with self-healing bio-facades that consume CO_2 and absorb heat. Both of these are important assets, given the critical rise in global temperatures since the beginning of the century.

But there's no need to go down to street level to start your journey: Sarah takes one of the many bridge-like links that connect buildings together and act as arterial routes suspended in mid-air. These bridges have some lanes for pedestrians and other lanes for all kinds of ultra-light vehicles. Sarah prefers the soft transport option and collects one of the shared electric bikes operated by the city authority from one of the terminals at the top of her building. She sets off immediately into a constant stream of bikes, scooters, and electric windsurfers (powered by a combination of wind and an electric propulsion system).

Despite the fact that it's still early morning, the temperature is already rising, but Sarah isn't bothered by it, because every bridge is flanked by rows of trees to provide soothing shade. In 2075, nature has reclaimed the upper hand in Aloepolis, as it has in most cities, and is now combined with ingenious innovations... the bridge Sarah is on is clad in photovoltaic cells, for example. The electricity it generates is fed into the city's power grid to supply energy to homes. And this is just one example of many energy optimisation solutions. Others include the use of bioluminescent algae instead of electricity to light shops.

Sarah enjoys the landscape as she cycles. That's because she doesn't need to worry about any technical or traffic problems. As it does every morning, the Fluimob personalised mobility app makes real-time preventive checks on the wear level of the bike's brakes, traffic intensity and those lanes open to traffic, which vary depending on how busy the city is at any given time. Adapting to Sarah's mood (happy and contemplative at this time of day) and the time she has available (she's in no hurry today), Fluimob sends her on a slight diversion to the Amaryllis bridge, which runs along the hills on the eastern edge of the city and has breathtaking views of the sea.

When she needs to travel longer distances, Fluimob offers her the option of descending to street level and taking a seat in an autonomous vehicle. The streets of Aloepolis would seem very alien to anyone who lived here at the turn of the century! No more traffic lights at junctions, no more collisions, no more traffic jams: now fully integrated into the city authority's transport system, all vehicles are connected to the Aloepolis central cloud, which uses advanced algorithms and meticulous calculation to drive real-time planning and fleet optimisation for maximum traffic fluidity and minimum energy consumption.

The concrete and asphalt have disappeared. All traffic routes are now surfaced entirely using natural materials that absorb heat, are partially permeable, and collect run-off water. At night, more space is allocated to merchandises roads, while during the day, the majority is reallocated to soft mobility in the public outdoor spaces dotted all over the city... and the pavements actually get wider! It's all part of a seamless and continual process of adaptation to make Aloepolis a more pleasant, friendly, and self-sufficient place to live. As well as autonomous vehicles and soft mobility options, the citizens

of Aloepolis also get around their city by riding an underground metro, that has been running for more than a hundred years now, but that has been modernized with an excellent overground system, along with a central cloud platform connexion, which manages countless connected data sources.

Metro passengers also have the opportunity to help maintain the system as well as travel on it by joining a city-sponsored rewards programme. To ride the system free of charge, all they have to do is wear a pair of connected glasses or contact lenses on every journey. These automatically provide useful maintenance data (metro door opening times, water ingress in underground spaces, defective escalators, etc.).

Other sensors are invisible to users, and every transport option in the city is fitted with tiny sensors that transmit real-time data to the central cloud. Installed in the headquarters of ACT (Aloepolis City Transport - a public institution working closely with the city authority), this virtual coordination brain is essentially a large room full of servers that receives data, processes it and issues alerts. The highly experienced maintenance team is on duty 24/7/365. The maintenance technicians of 2075 travel much less frequently than their predecessors. These days, they use augmented reality goggles and gloves to work remotely on ensuring that the infrastructure runs smoothly at all times without even leaving their workstation.

So, with every breath, the human/machine combination transforms the city, adapting it to its new environment. Sensors installed in the metro stations continuously transmit changes in temperature, enabling the server to control the ventilation systems and increase or decrease air flow rates as required. These sensors also act as synapses informing the central cloud of any signs of equipment ageing, so that individual items of hardware can be repaired before they have the chance to fail. The transport network evolves to ensure the continuous smooth and seamless flow of traffic.

The building Sarah is visiting is, like all the buildings in Aloepolis, a multi-purpose facility with housing, co-working spaces, gyms, garages and even schools. Inspired by termite mounds in the natural world, its outer walls are clad in ETFE (ethylene tetrafluoroethylene) membranes that optimise insulation by behaving like a lung, rising when it gets too hot and closing when the thermometer drops too low. The roof is shaped like a lotus flower to collect rainwater and maximise the diffusion of daylight.

Sarah joins her colleagues on the 18th floor. Her colleague Émilie, who lives in the building across the street, travelled to work using a system that looks like a hybrid between a zip wire and a cable car to connect the nearby buildings, while Marc has just stepped out of his safety suit (he's one of the few thrill-seeking residents who choose to travel by glider!).

The three of them are working on a unique exhibition project: a museum of the world as it used to be, which will reconstruct the city and its infrastructure to show the way they worked half a century ago. In other words, a transport system stripped of its cutting-edge control, maintenance, and communication systems, with a cabinet of curiosities showcasing the tools used back in the day by maintenance operators and infrastructure managers.

Sarah has already drawn together some ideas, which she's about to present to her colleagues: a cupboard crammed with thick paper files, maintenance inspection vehicles (which once did the job now done by drones, and the connected smart glasses and contact lenses worn by passengers), spare parts storage facilities (now anachronistic, thanks to better asset management), and workwear, safety shoes and long-obsolete hand tools once used to do the work now carried out by autonomous robots. There's no shortage of ideas, and Sarah is in no doubt that visitors will emerge from this journey through time rather disoriented.

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