Infrastructure Innovations

Meeting Environmental Challeng

Professor Spiro N. Pollalis

Director of the Zofnass Program for Sustainable Infrastructure

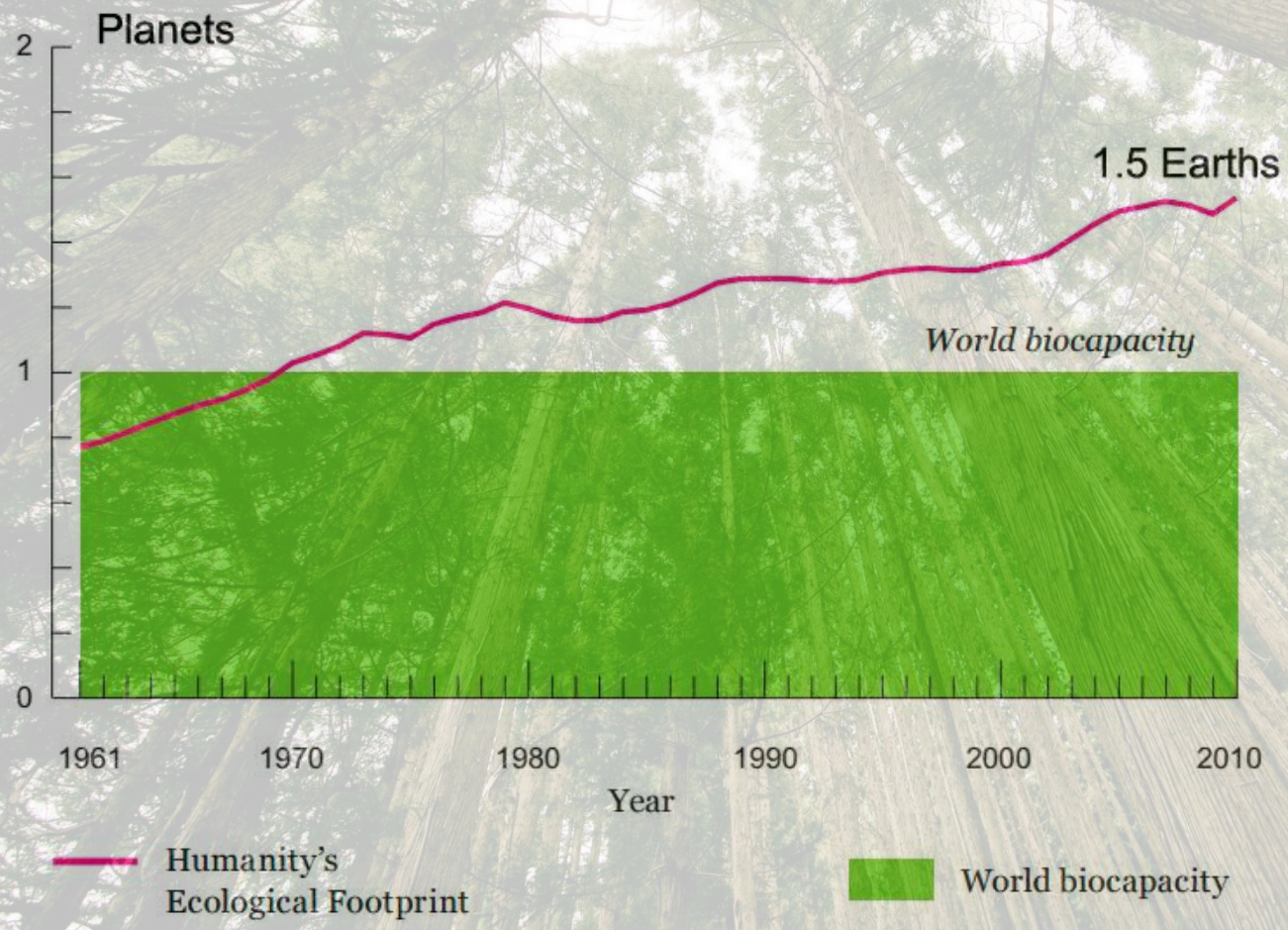
Graduate School of Design, Harvard University

ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE

Harvard University
Graduate School of Design

Environmental challenges

Major **environmental challenges**: (1) over-use and depletion of natural resources, (2) loss of biodiversity,(3) climate change and (4) impact on health.



1.5 Earths would be required to meet the demands humanity currently makes on nature. For more than 40 years, humanity's demand has exceeded the planet's biocapacity – the amount of biologically productive land and sea area that is available to regenerate these resources (Global Footprint Network, 2014).

Innovation is key to Infrastructure Investment

The world needs $94 trillion in infrastructure investment by 2040

(G20-backed Global Infrastructure Hub (https://www.reuters.com/article/us-global-infrastructure-report-idUSKBN1AA1A3)

Nearly 40% of the **$9 trillion** invested in infrastructure annually **is poorly spent because of** bottlenecks, **lack of innovation**, and market failures

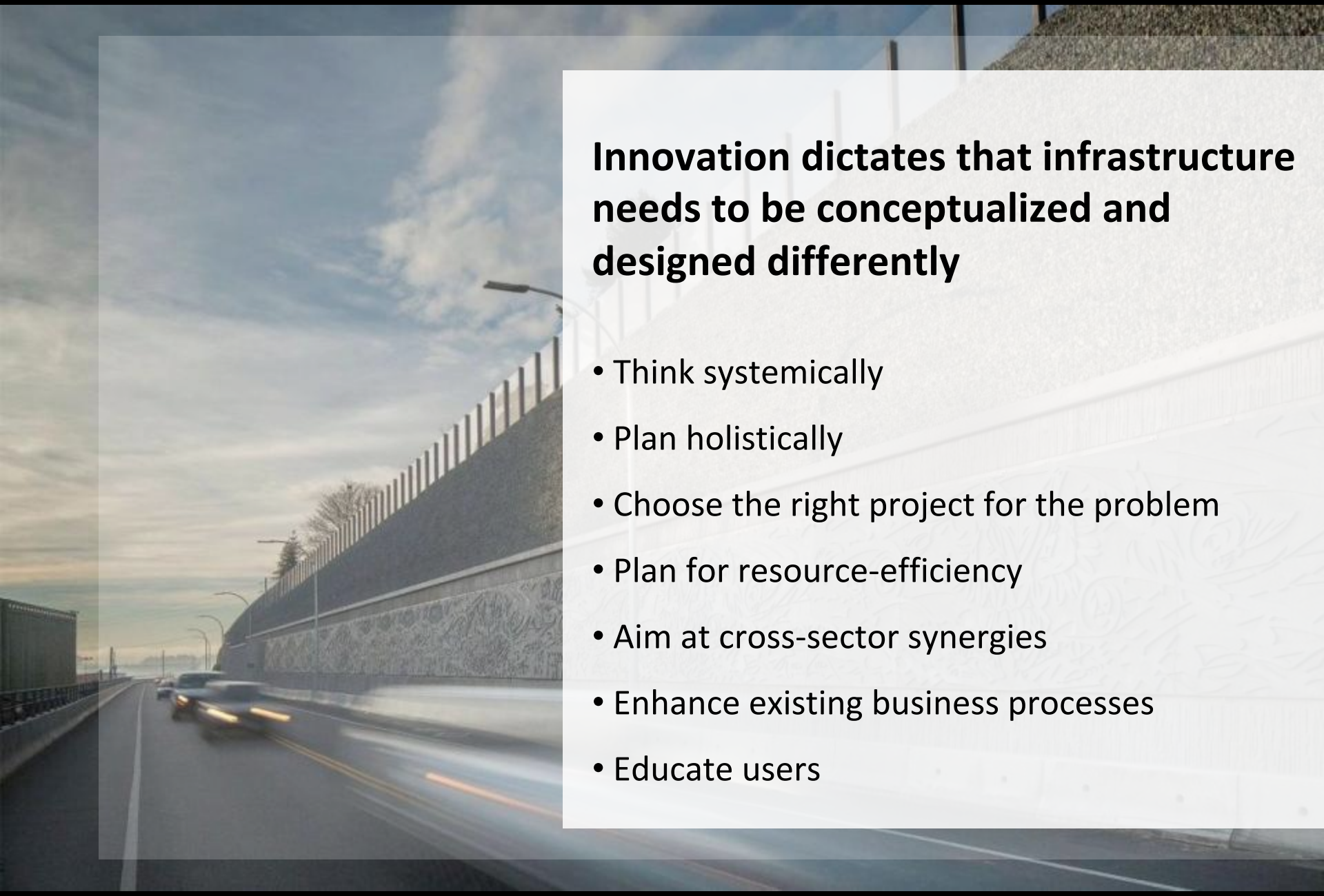
(https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/bold-ideas-to-transform-infrastructure)

Infrastructure and Innovation

According to the U.N.'s Sustainable Development Goals, **infrastructure and innovation are a single goal.**

Innovative solutions can be applied **in all phases of infrastructure development:** planning & financing, construction, operation & maintenance.

Innovation Transforms Planning Infrastructure



Innovation dictates that infrastructure needs to be conceptualized and designed differently

- Think systemically
- Plan holistically
- Choose the right project for the problem
- Plan for resource-efficiency
- Aim at cross-sector synergies
- Enhance existing business processes
- Educate users

Innovation Transforms Operating Infrastructure

When innovative infrastructure assets start operating they need:

- Smart monitoring
- Quick emergency response times
- Automation
- Connectivity between different components
- Data and cyber security

Infrastructure Innovations
Meeting Environmental Challenges

1. **Tools for Measuring Sustainability**
2. **Synergies for Self-Sufficient Cities**
3. **Disruptive Technologies Redefine Infrastructure**
4. **Digital Design and Simulation Tools**
5. **Enabling Innovation through Procurement**

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The Zofnass Program for Sustainable Infrastructure

A number of tools and methodologies have been developed worldwide for the best **implementation of sustainability principles** and **integrated and innovative planning**,

Buildings →

Multiple tools available e.g. LEED

Infrastructure →

Project scale

City scale

The Zofnass Program for Sustainable Infrastructure

ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE

Established in 2008 at the Harvard Graduate School of Design.

Develops **know-how, tools, and methodologies** for rating and planning sustainable infrastructure and cities.

Is based on the **unique collaboration of academic experts and industry specialists**

The Sustainability Industry Advisory Board:

AUTODESK, BARCLAYS, Bentley, CDM Smith, ch2m, Ecology and Environment, Golder Associates, HNTB, IDB Inter-American Development Bank, Kiewit, LA Metro, Louis Berger, Otak, The Nature Conservancy, NV5, POWER ENGINEERS, Stantec, TRC, WHI WREN HOUSE INFRASTRUCTURE

The Zofnass Program for Sustainable Infrastructure

Two tools have been developed by the Zofnass Program to translate the principles of **sustainability and resilience** into **day-to-day decision-making.**

ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE

Project scale ↓

2012

Envision®
Rating Tool

City scale ↓

2016

Zofnass Sustainable
Planning Guidelines

The Zofnass Program for Sustainable Infrastructure

Both tools are tailored to the **needs of the industry.** They provide:

- **Objectivity** in assessing sustainability
- **Common ground** for stakeholders' collaboration
- **Guidance** in the decision making process
- **Education** and **Innovative thinking**
- Improved **competiveness and recognition**

Zofnass Program Approach

The Zofnass approach focuses on:

5 categories of impact

- QUALITY OF LIFE
- RESOURCE ALLOCATION
- NATURAL WORLD
- CLIMATE & RISK
- LEADERSHIP

And 7 infrastructure systems

- Transportation
- Energy
- Landscape
- Solid Waste
- Water
- Information
- Food

The Envision® Rating System

ZOFNASS PROGRAM FOR SUSTAINABLE INFRASTRUCTURE
Graduate School of Design Harvard University

Focus after launching
RESEARCH & DISSEMINATION

INSTITUTE FOR SUSTAINABLE INFRASTRUCTURE
ISI

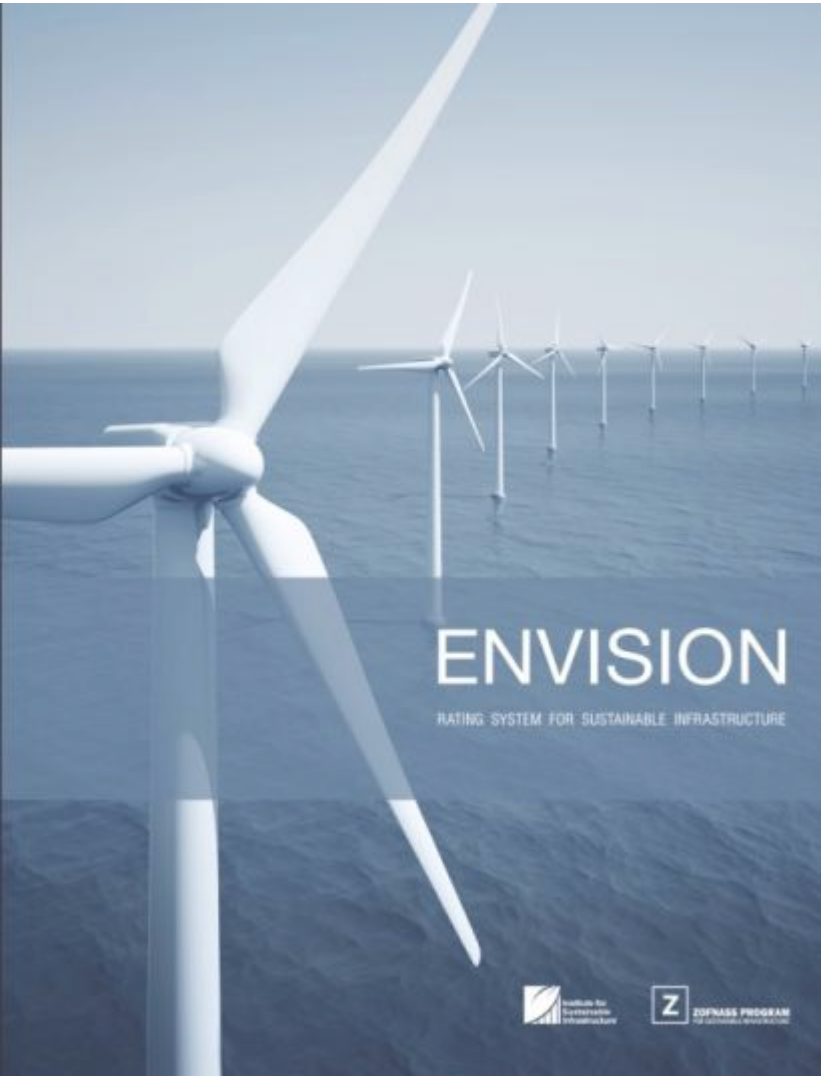
APWA ASCE ACEC

- American Public Works Association
- American Council of Engineering Companies
- American Society of Civil Engineers

The Envision Rating System

A TOOLKIT FOR SUSTAINABLE INFRASTRUCTURE PROJECTS

For Planning, Design and Construction phases



Envision® was developed by the **Zofnass Program at Harvard** and it was launched by ISI (Institute for Sustainable Development, Washington DC) in 2012.

It assesses the sustainability for civil infrastructure projects **regardless of type, size, complexity and location.**

Envision® fills a gap for a **holistic** rating system for sustainable infrastructure.

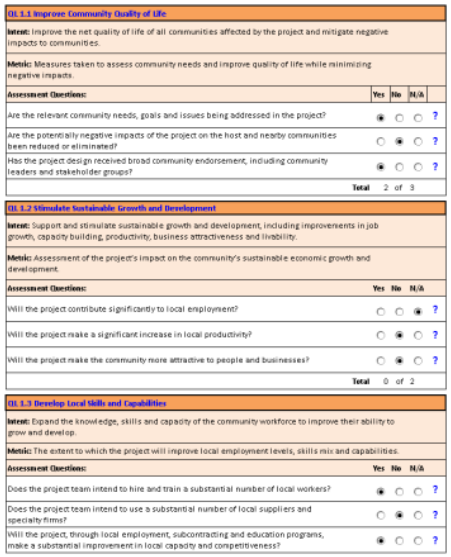
Envision® is **an overarching tool that covers all infrastructure projects,** unlike sector specific systems, (i.e., roads, ports).

The Envision Rating System

The **Envision® toolkit** includes:

Self Assessment Checklist

- Structured as a series of yes/no questions based on the Envision™ rating system criteria
- Serves to quickly compare project alternatives during first steps of planning.



QL 1.1 Improve Community Quality of Life

Intent: Improve the net quality of life of all communities affected by the project and mitigate negative impacts to communities.

Metric: Measures taken to assess community needs and improve quality of life while minimizing negative impacts.

Assessment Questions:	Yes	No	N/A	
Are the relevant community needs, goals and issues being addressed in the project?	◉	○	○	?
Are the potentially negative impacts of the project on the host and nearby communities been reduced or eliminated?	○	◉	○	?
Has the project design received broad community endorsement, including community leaders and stakeholder groups?	◉	○	○	?
Total	2 of 3			

QL 1.2 Stimulate Sustainable Growth and Development

Intent: Support and stimulate sustainable growth and development, including improvements in job growth, capacity building, productivity, business attractiveness and livability.

Metric: Assessment of the project's impact on the community's sustainable economic growth and development.

Assessment Questions:	Yes	No	N/A	
Will the project contribute significantly to local employment?	○	○	◉	?
Will the project make a significant increase in local productivity?	○	◉	○	?
Will the project make the community more attractive to people and businesses?	○	◉	○	?
Total	0 of 2			

QL 1.3 Develop Local Skills and Capabilities

Intent: Expand the knowledge, skills and capacity of the community workforce to improve their ability to grow and develop.

Metric: The extent to which the project will improve local employment levels, skills mix and capabilities.

Assessment Questions:	Yes	No	N/A	
Does the project team intend to hire and train a substantial number of local workers?	◉	○	○	?
Does the project team intend to use a substantial number of local suppliers and specialty firms?	○	◉	○	?
Will the project, through local employment, subcontracting and education programs, make a substantial improvement in local capacity and competitiveness?	◉	○	○	?

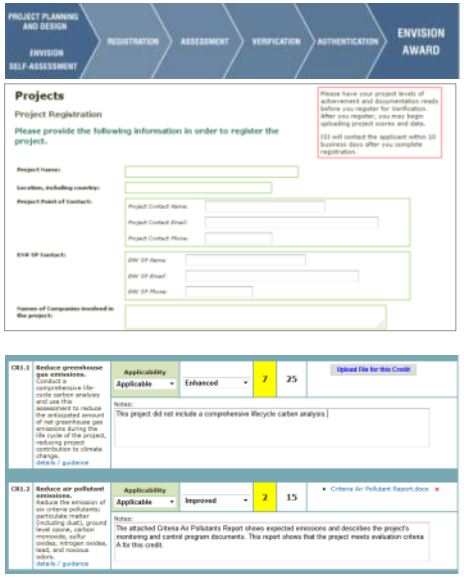
Envision® Rating Tool

- Assessment through a set of **60 credits** and the submission of required **documentation.**
- Different levels of achievement per credit are available.

QUALITY OF LIFE	PURPOSE	QL 1.1 Improve community quality of life	2	3	16	20	25
		QL 1.2 Stimulate sustainable growth and development	1	2	5	13	16
	WELLBEING	QL 1.3 Develop local skills and capabilities	1	2	5	12	15
		QL 2.1 Enhance public health and safety	2			10	
		QL 2.2 Minimize noise and vibration	1			5	11
		QL 2.3 Minimize light pollution	1	2	4	8	11
		QL 2.4 Improve community mobility and access	1	4	7	14	
		QL 2.5 Encourage alternative modes of transportation	1	3	6	12	15
		QL 2.6 Improve site accessibility, safety and wayfinding	1	3	6	12	15
		QL 3.1 Preserve historic and cultural resources	1		7	13	16
	COMMUNITY	QL 3.2 Preserve views and local character	1	3	6	11	14
		QL 3.3 Enhance public space	1	3	6	11	13
					Maximum QL Points:		181
LEADERSHIP	COLLABORATION	LD 1.1 Provide effective leadership and commitment	2	4	8	17	
		LD 1.2 Establish a sustainability management system	1	4	7	14	
		LD 1.3 Foster collaboration and teamwork	1	4	8	15	
		LD 1.4 Provide for stakeholder involvement	1	3	6	14	
	MANAGEMENT	LD 2.1 Pursue by-product synergy opportunities	1	3	6	12	16
		LD 2.2 Improve infrastructure integration	1	3	7	13	16
		LD 3.1 Plan for long-term monitoring and maintenance	1	3		10	
	PLANNING	LD 3.2 Address conflicting regulations and policies	1	3	4	8	
		LD 3.3 Extend useful life	1	3	6	12	
					Maximum LD Points:		121
RESOURCE ALLOCATION	MATERIALS	RA 1.1 Reduce net embodied energy	2	6	12	16	
		RA 1.2 Support sustainable procurement practices	2	3	6	8	
		RA 1.3 Use recycled materials	2	5	11	16	
		RA 1.4 Use regional materials	3	6	8	10	
		RA 1.5 Divert waste from landfills	1	3	6	11	
		RA 1.6 Reduce excavated materials taken off site	2	4	5	6	
		RA 1.7 Provide for deconstruction and recycling	1	4	8	12	
	ENERGY	RA 2.1 Reduce energy consumption	3	7	12	18	
		RA 2.2 Use renewable energy	4	8	13	15	20
		RA 2.3 Commission and monitor energy systems				11	
	WATER	RA 3.1 Protect fresh water availability	2	4	9	17	21
		RA 3.2 Reduce potable water consumption	1	3	13	17	21
		RA 3.3 Monitor water systems	1	3	6	11	
					Maximum RA Points:		167
NATURAL WORLD	SITING	NW 1.1 Preserve prime habitat			9	14	19
		NW 1.2 Protect wetlands and surface water	1	4	9	14	19
		NW 1.3 Preserve prime farmland			6	12	15
		NW 1.4 Avoid adverse geology		2	3	5	
	LAND & WATER	NW 1.5 Preserve floodplain functions	2	5	8	14	
		NW 1.6 Avoid unsuitable development on steep slopes	1		4	6	
		NW 1.7 Preserve greenfields	3	8	10	15	23
		NW 2.1 Manage stormwater		4	5	12	21
	BIODIVERSITY	NW 2.2 Reduce pesticide and fertilizer impacts	1	2	5	8	
		NW 2.3 Prevent surface and groundwater contamination	1	4	9	14	18
		NW 3.1 Preserve species biodiversity	2			13	16
		NW 3.2 Control invasive species			3	5	11
		NW 3.3 Restore disturbed soils				6	10
		NW 3.4 Maintain wetland and surface water functions	3	6	9	15	19
					Maximum NW Points:		253
CLIMATE & RISK	EMISSIONS	CR 1.1 Reduce greenhouse gas emissions	4	7	12	18	25
		CR 1.2 Reduce air pollutant emissions	2	6		12	15
		CR 2.1 Assess climate threat				15	
	RESILIENCE	CR 2.2 Avoid traps and vulnerabilities	2	6	12	16	20
		CR 2.3 Prepare for long-term adaptability				16	20
		CR 2.4 Prepare for short-term hazards	3		10	17	21
		CR 2.5 Manage heat islands effects	1	2	4	6	
					Maximum CR Points:		122
					Maximum TOTAL Points:		850

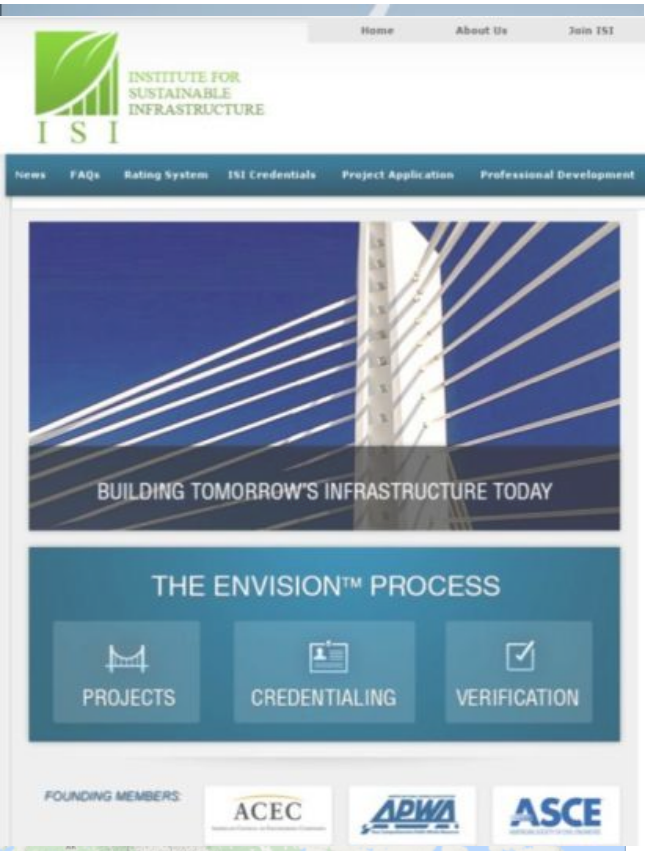
Project Evaluation & Verification

- Online register in the ISI platform for documentation upload
- Third-party verifier evaluation of the documentation
- **Bronze, Silver, Gold, and Platinum** awards based on the points collected by the project.



http://research.gsd.harvard.edu/zofnass/menu/envision/
https://www.sustainableinfrastructure.org

The Envision Rating System



In the six years since the launch of Envision:

- 6,000+ accredited ENV SPs
- 300+ projects using it for self-assessment
- 27 projects have gone through the verification process, more in the pipeline

Used by:

- City of Chicago
- New York City
- City of Los Angeles
- County of Los Angeles
- Inter-American Development Bank (awards program launched in 2013)

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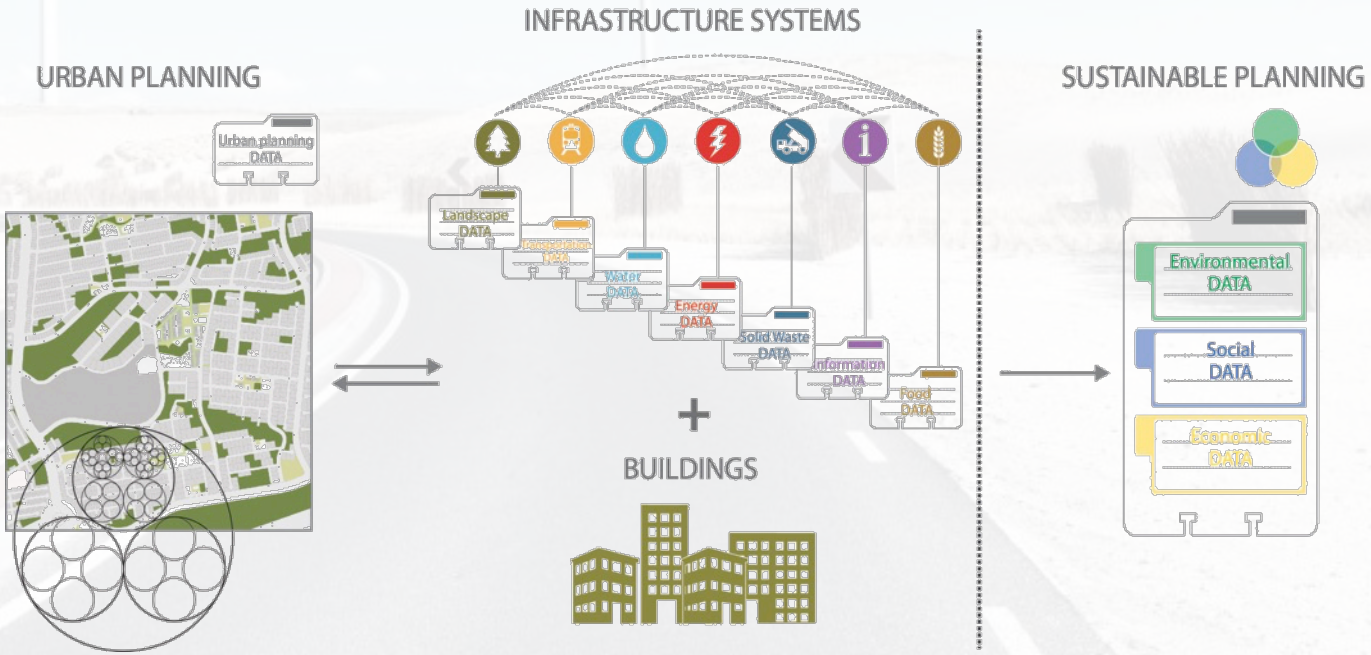
A city is a project

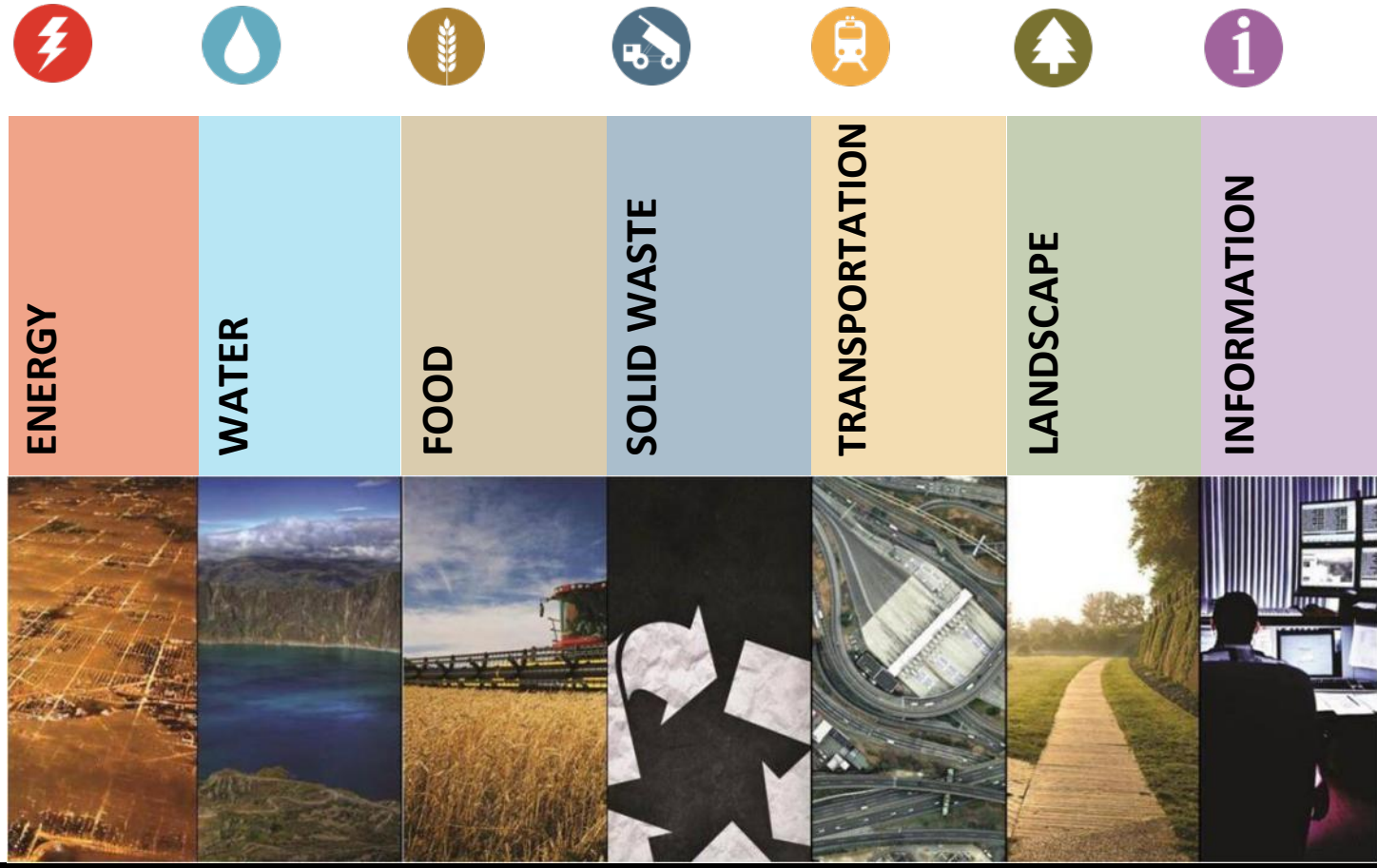
The Zofnass program considers **the city as a project**:

- Infrastructure development is inextricably linked to city scale planning.
- Infrastructure processes and entities constitute the infrastructure systems of the city



Infrastructure systems in synergy

Infrastructure systems are considered as **sub-systems of the city** that should function **in synergy**.



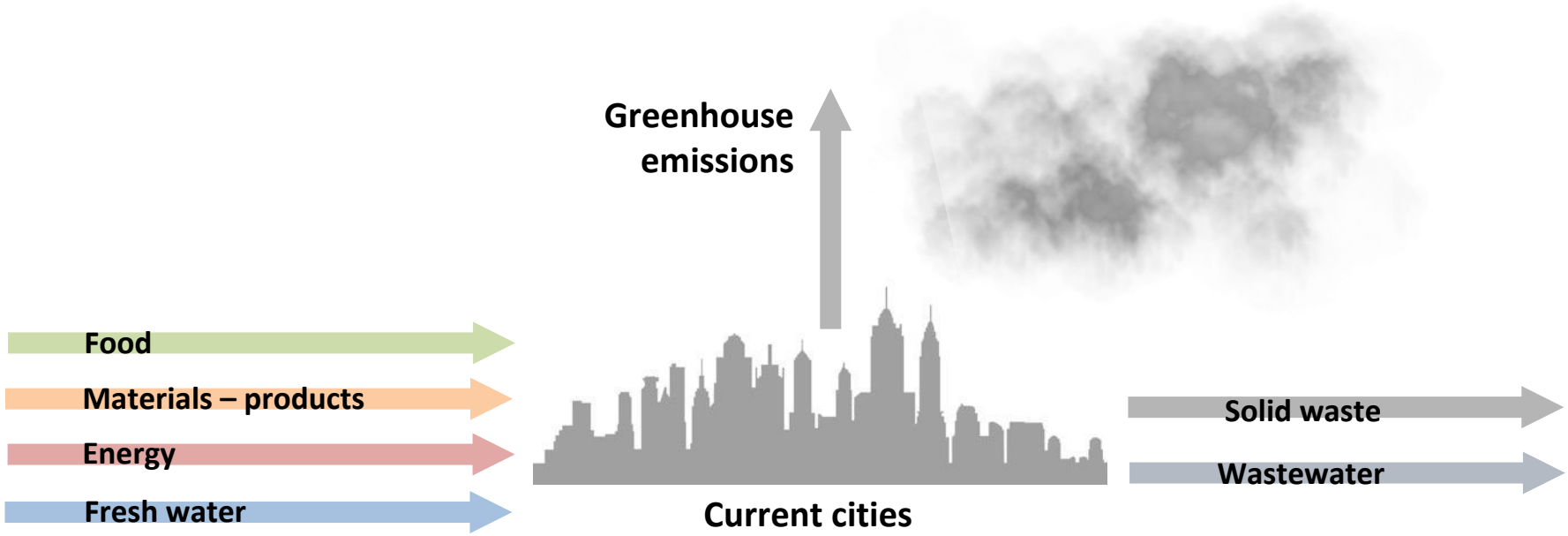
Infrastructure systems in synergy

Synergies refer to:

- Reducing the **initial demand** of other systems and the challenges for their operation
- Connecting **by-products** and feedstock needs
- Optimizing the **placement of entities**
- **Combining** entities
- **Mitigating** negative impacts of processes

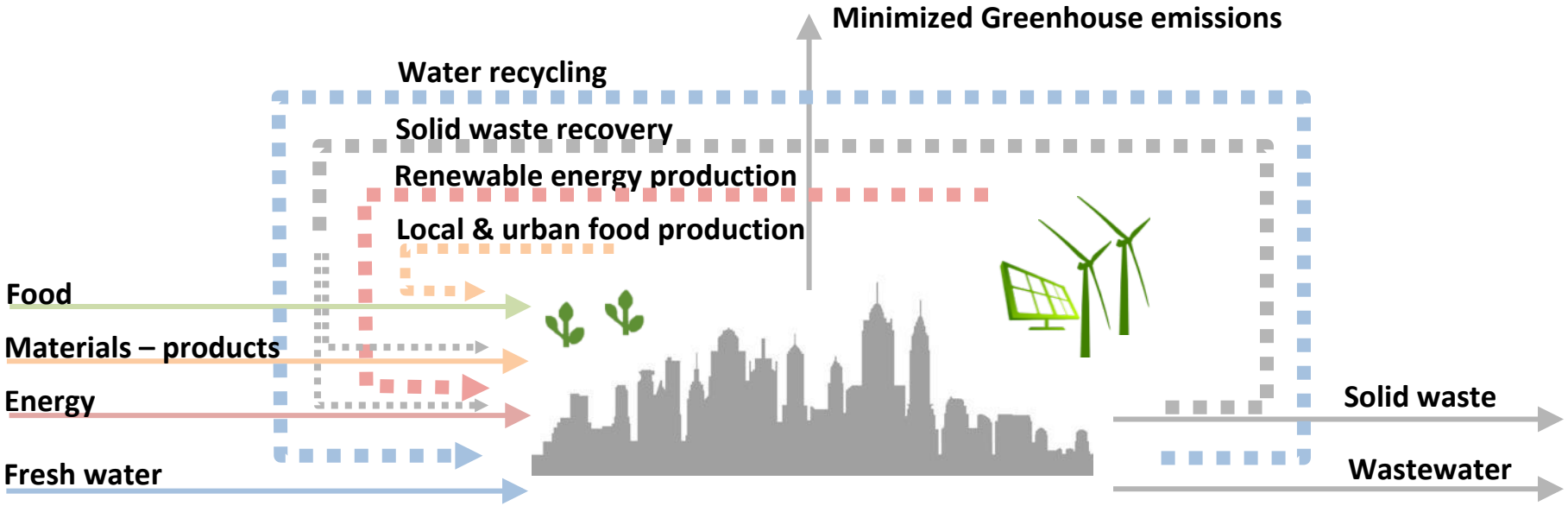
Current Cities

Current cities result in **increased resource consumption, emissions and waste production.**



A Sustainable City

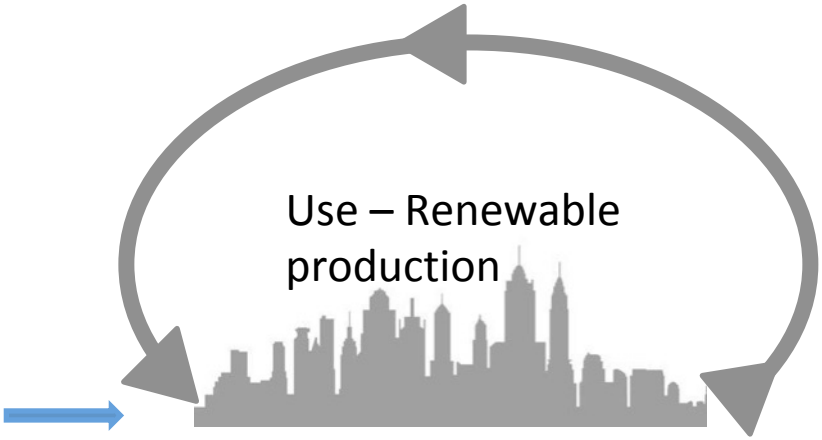
Sustainable city should be able to work as a ‘closed circuit’ recycling and reusing resources through **integrated infrastructure planning.**



A Sustainable City

The ‘closed circuit’ city model is the ultimate paradigm of the systemic, synergistic planning.

In its ideal form:



Produces all it needs for use, has no emissions and reuses its waste and by-products of processes as new resources.

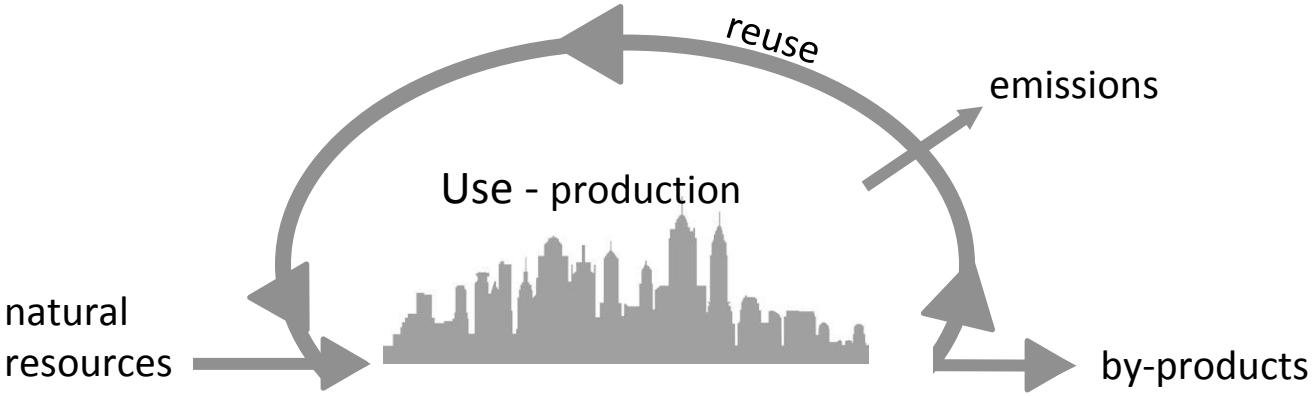
A zero-energy/ zero-emissions/ zero- waste city

Water is one resource that cannot be “produced” by the city, since it requires a supportive area, a catchment area. However, water conservation, wastewater recycling and rainwater harvesting can minimize water resource needs.

A Sustainable City

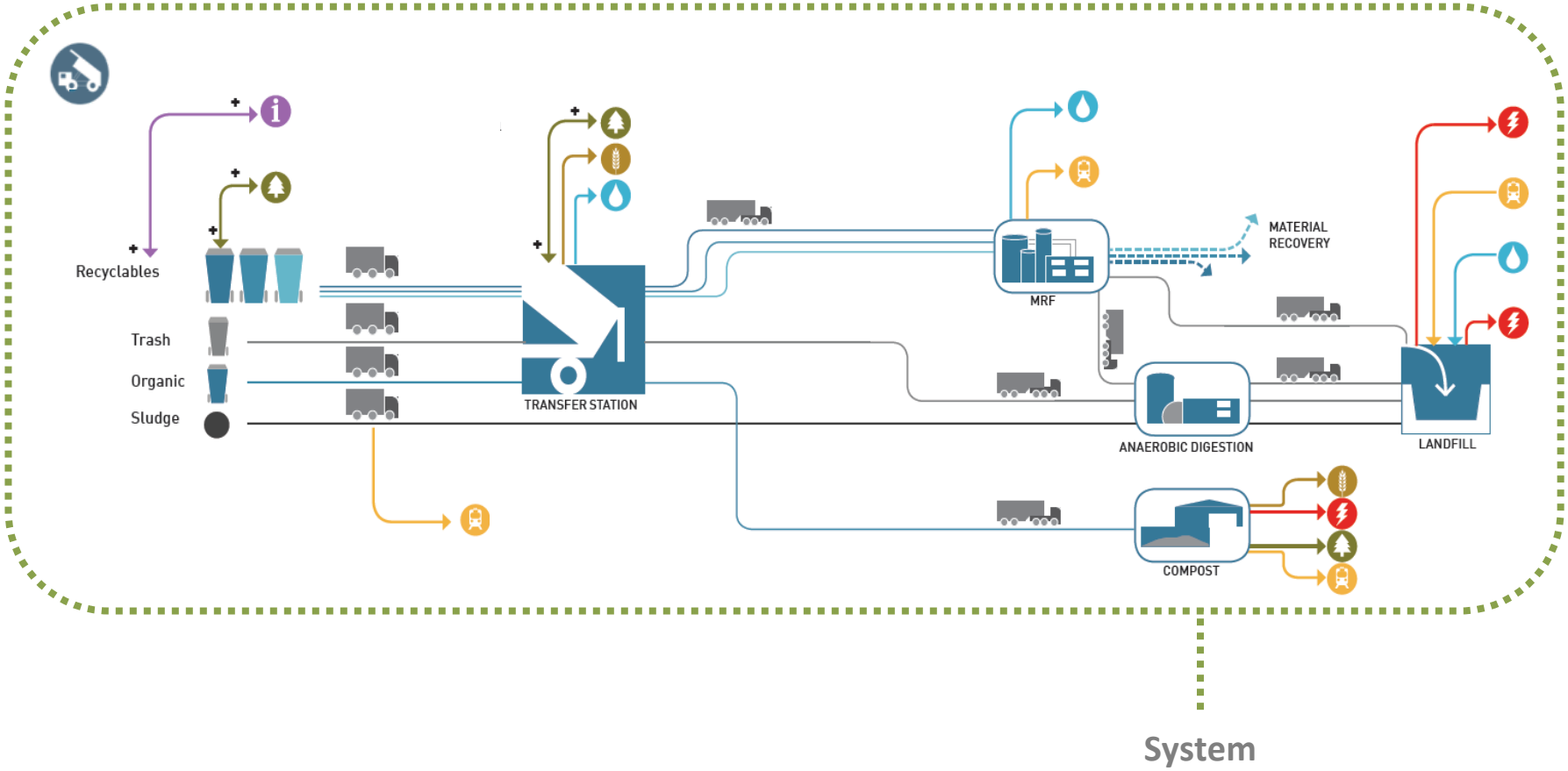
The 'closed circuit' city model could be summarized in the following strategies:

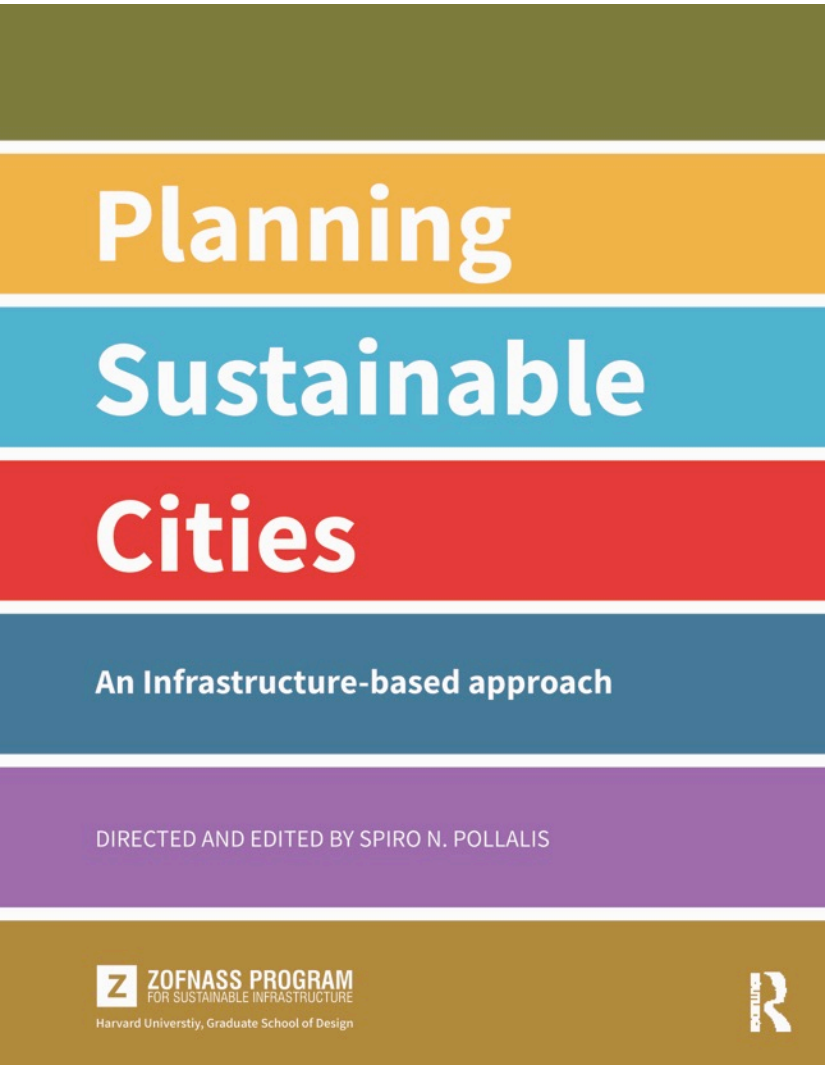
- Reduce import of resources
- **Produce** to cover reduced needs
- Minimize emissions
- **Re-use** by-products of processes



Reduced Consumption ▶ **Less resources needs** ▶ **Less production needs** ▶ **Less installed capacity for infrastructure** ▶ **Less emissions & By-products**

In DHA City Karachi (DCK), Pakistan, waste system planning identified opportunities in each part of the process for connecting by-products and feedstock needs reducing the initial demand of other systems.





Zofnass research at thecity scale:

- **fills a gap** between the professions of planners and engineers, both contributing to the fundamental process of planning and building infrastructure for cities.

- **responds to** the urgency of integrating these practices, with the objective to develop cities through **a unified and cross-disciplinary process.**

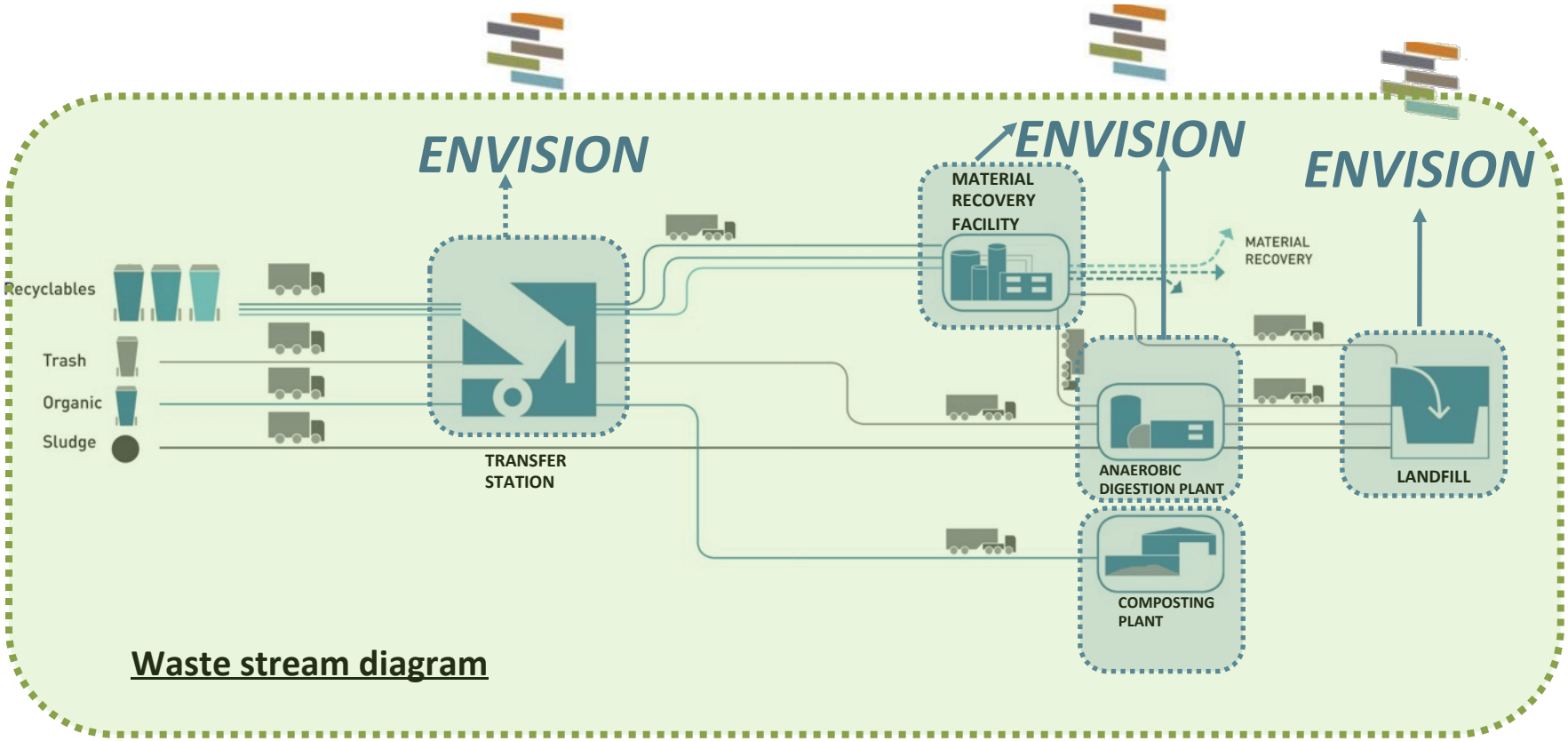
- **forms** the foundation of a **common collaborative platform**, among public authorities, planners, and engineers, enabling those who have traditionally functioned in silos to work together in infrastructure planning.

Zofnass Program - Sustainable Planning Guidelines

The Planning Guidelines:

- **do not prescribe specific actions** to reach the sustainability objectives.
- **determine the direction of planning** and they leave specific actions open-ended.
- facilitate the **development of customized actions** to each city's unique context, conditions, and priorities.
- **promote innovation**, allowing for the incorporation of new or improved technologies as they become available.

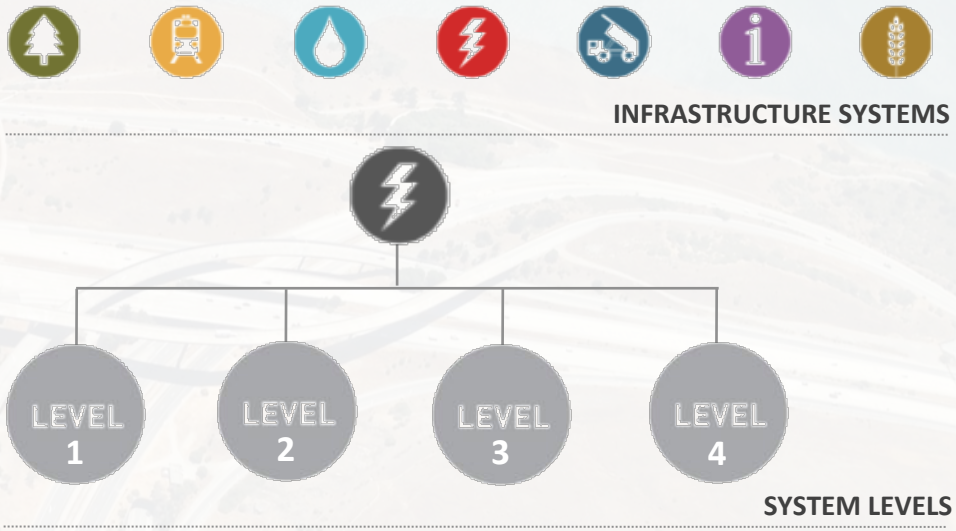
Infrastructure entities are **integrated components** of extended systems



Zofnass Sustainable
Planning Guidelines

Zofnass Program - Sustainable Planning Guidelines Structure

Each infrastructure is decoded in **four "system levels"**



System Levels

- Group processes and entities within the systems
- Organize a high level planning and decision making process

Zofnass Program - Sustainable Planning Guidelines Structure

- For each system level, a **set of objectives** is defined, indicating the general goals for planning decisions.
- Objectives are drawn from the **five focus areas** for sustainability used by the Zofnass Program.
- Planning **Guidelines** are then given as guidance for reaching each objective.

Strategies towards a sustainable Energy System:

SYSTEM PURPOSE: RELIABLE ACCESS TO ENERGY

ENERGY SAVING:
Avoid unnecessary energy consumption

SYSTEM EFFICIENCY:
Increase efficiency in generation, conversion, distribution, etc.

USE OF RENEWABLE ENERGY SOURCES:
Increase renewable energy use

MINIMIZATION OF FOSSIL FUELS IMPACT:
Minimize impact of conventional-fuel energy generation

Strategies towards a sustainable Transportation System:

SYSTEM PURPOSE: RELIABLE AND EQUAL ACCESSIBILITY

UNNECESSARY TRIP REDUCTION:
Reduce length and occurrence of passenger and freight trips

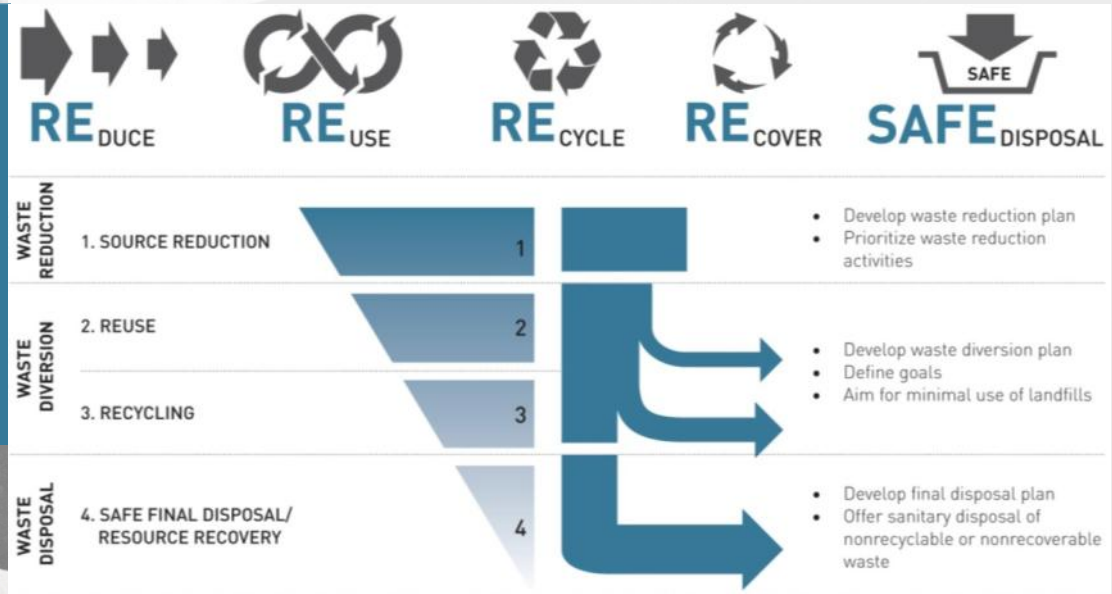
MODAL SHIFT:
Prioritize nonmotorized and low–energy–intensity modes

SYSTEM EFFICIENCY: Improve functionality of infrastructure, users' behaviors, and efficiency of vehicles

MINIMIZATION OF FOSSIL FUEL USE:
Link transport fuel supply with renewable energy sources

Strategies towards a sustainable Solid Waste System:

SYSTEM PURPOSE: DIVERSION FROM LANDFILLS



Strategies towards a sustainable Water System:

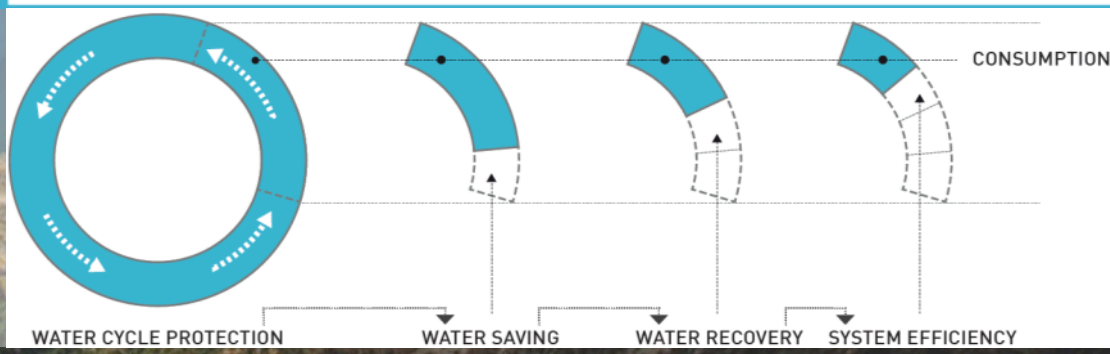
SYSTEM PURPOSE: RELIABLE ACCESS TO WATER

WATERSHED MANAGEMENT:
Preserve long-term renewability and quality of water resources

WATER SAVING:
Reduce water consumption

WATER RECOVERY:
Reuse water with fit-for-purpose treatment

SYSTEM EFFICIENCY:
Minimize leakages



Food Infrastructure

Strategies towards a sustainable Food System:

SYSTEM PURPOSE:
FOOD SECURITY

FOODSHED MANAGEMENT:
Secure city's food supply—support sustainable ways of production

FOOD WASTE REDUCTION:
Minimize food waste—divert food waste from landfills

FOOD LOSS REDUCTION:
Minimize food loss between production and consumption

LOCAL AND URBAN PRODUCTION:
Support local decentralized or urban production—minimize imports

Development following the Zofnass Approach

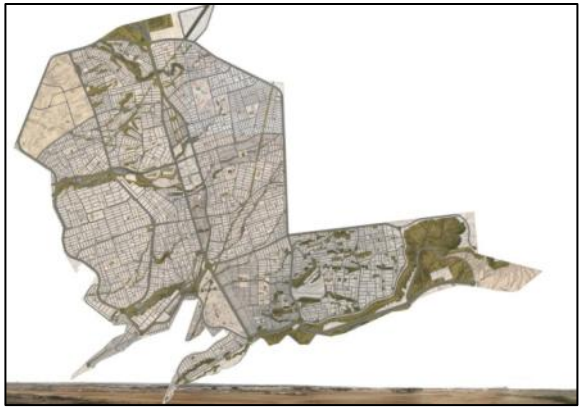
Two examples of different scales of the **application of the Zofnass Planning Guidelines**:

+

AN EXPANDING DEVELOPMENT

Development of the Hellinikon former airport of Athens, Greece. (6,000,000 m^2 ; 1,500 acres)

A NEW URBAN DEVELOPMENT



Master plan for new DHA City Karachi, Pakistan. (600,000 people; 47,000,000 m^2; 11,640 acres)

Development following the Zofnass Approach

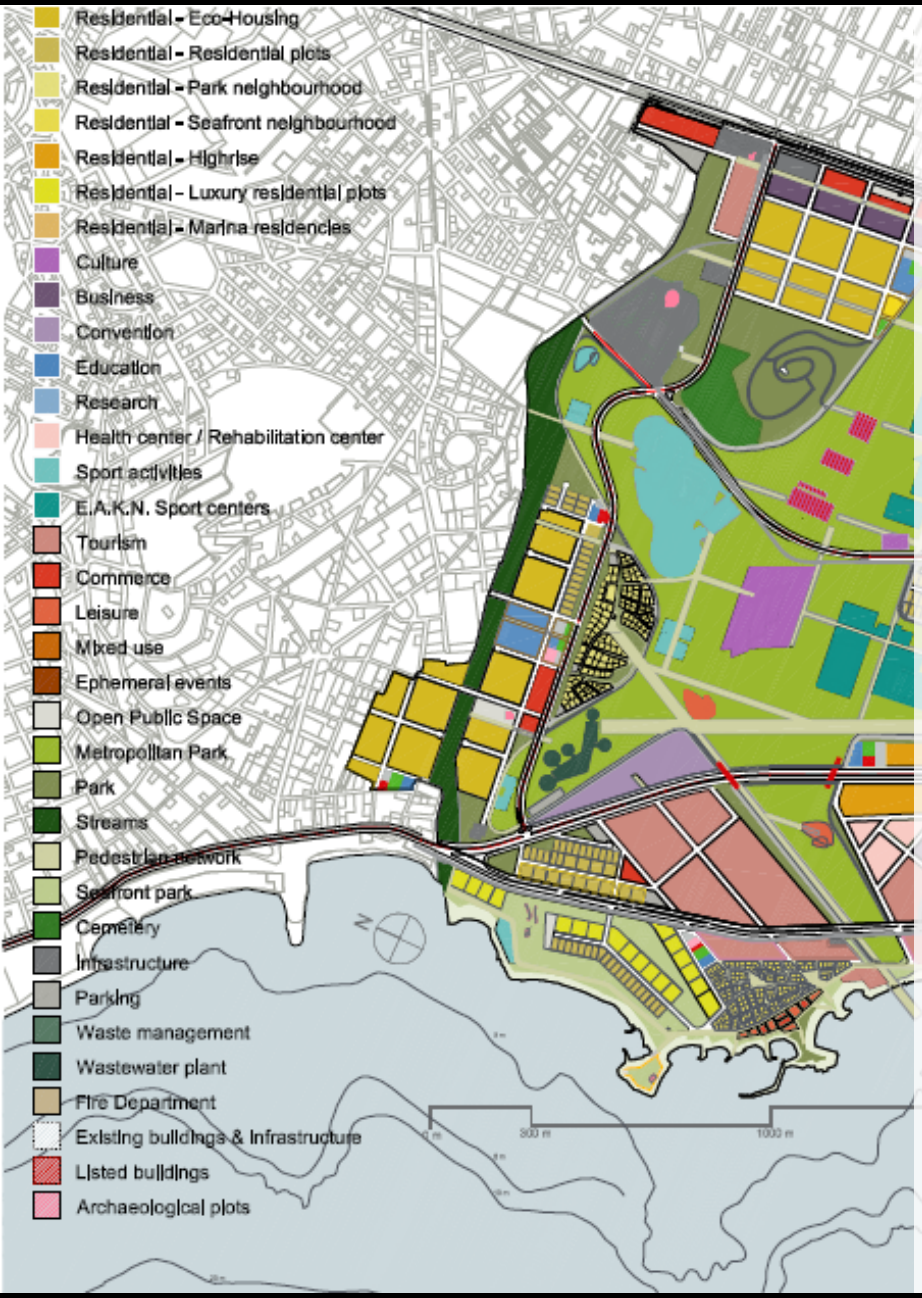
PROJECT:
Development of the Hellinikon former airport of Athens, Greece

DESIGN TEAM:
HELLINIKON AE
Prof. S.N.Pollalis as CEO & Chief Planner

Total area for development:
6,000,000 m² (approx. 1,500 acres)

AN EXPANDING DEVELOPMENT

Development following the Zofnass Approach



Planning followed the **holistic approach** of the Zofnass program.

Environmental protection

Green development

Social prosperity

Phases

Planning

Construction

Function

Planning Scales

Infrastructure

Blocks

Buildings

Soil

Water

Energy

Air

Health & Comfort

Awareness

Innovation

Certification

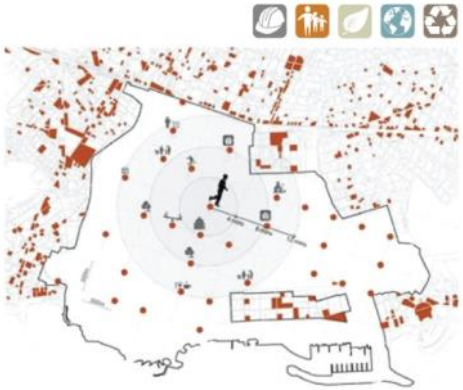
Planning strategies & related Zofnass categories:

1

A self-sufficient city integrated with its surrounding context

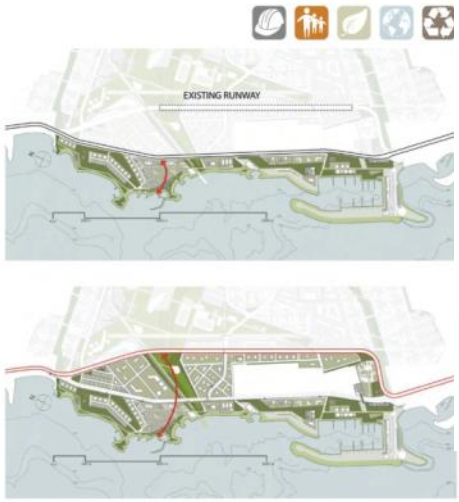
2

Minimization of car use & connectivity with adjacent municipalities



3

Existing avenue relocation & restoration of coastline's continuity



4

Creation of a metropolitan park and provision for an accessible waterfront

Planning strategies & related Zofnass categories:

5

Land use synergies

6

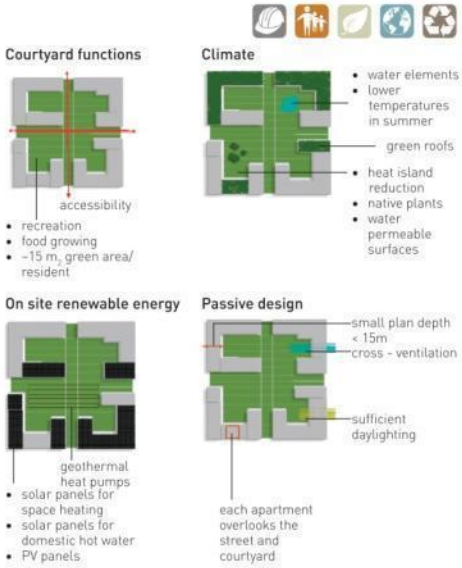
Sustainable infrastructures & renewable energy sources

7

Compact neighborhoods with local centers & connectivity with surroundings

8

"Eco-housing" the development's model urban blocks



Sustainable Infrastructure systems Planning

Use of renewable energy sources

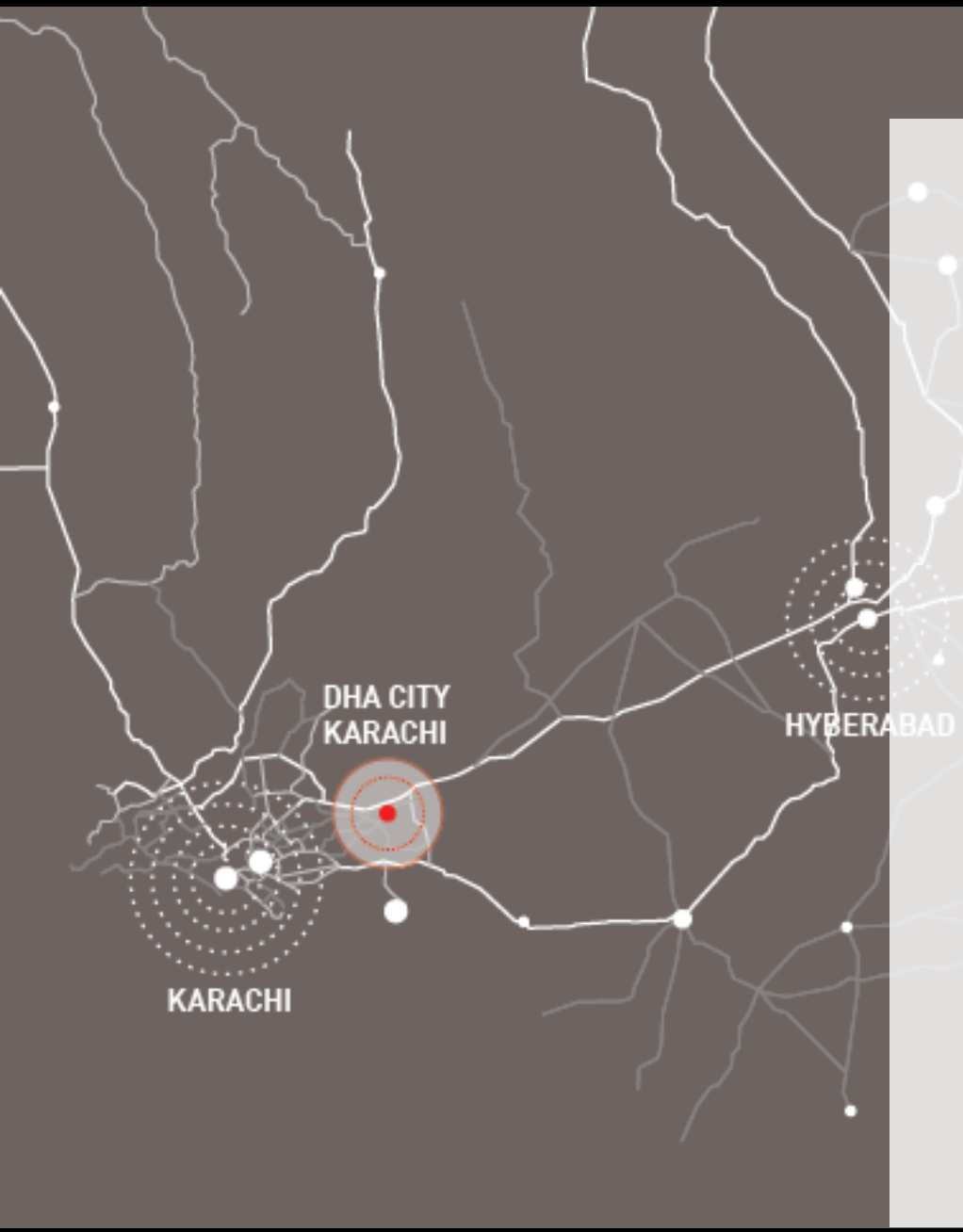
Water streams & soil management

Waste & Grey water management

Limitation of private vehicles & connection to the surroundings

Metropolitan Park & Accessible sea limit

Development according to the Zofnass Approach



PROJECT:

Master plan for the new DHA City Karachi (DCK), Karachi, Pakistan

PLANNING:

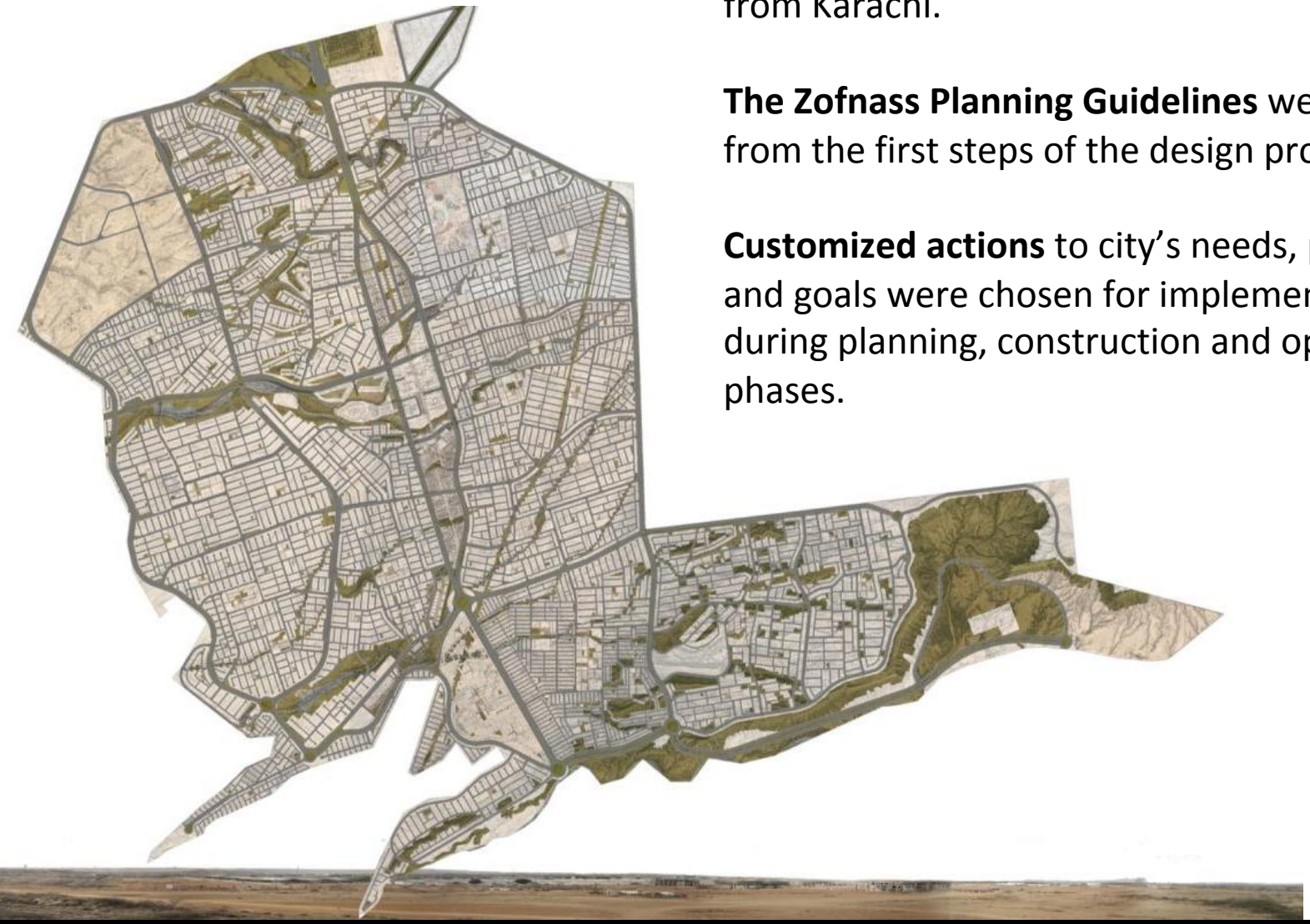
Prof. S.N.Pollalis chief planner of the partnership Osmani & Company (PVT.) LtD, RMJM, Doxiadis Associates

Total area:

47,000,000 m² (11,640 acres)

A NEW URBAN DEVELOPMENT

Development following the Zofnass Approach

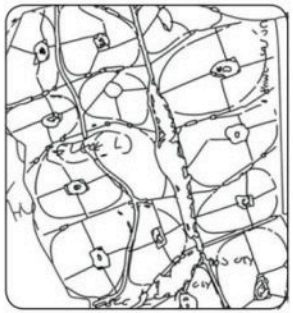


The **DHA City, Karachi in Pakistan** located 40 km from Karachi.

The Zofnass Planning Guidelines were used from the first steps of the design process.

Customized actions to city's needs, potentials and goals were chosen for implementation during planning, construction and operation phases.

Planning Principles



1 Cities within the city

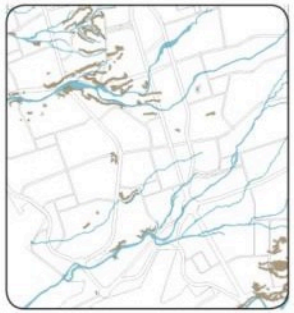
- A network of cities within a city
- Evolving Ekistics theory
- Dynamic, organic shapes adjusted to terrain

2 Self-sufficient

- A supra-regional downtown district
- Adoption of 'dynapolis' concept
- Self-reliance infrastructure

3 Mixed landuse

- Mixed use development
- Multiple community centers
- Walking distances



4 Adaptation to context

- Preservation of topography
- Avoidance of development on critical ridges
- Balance of cut & fill operations

5 Green corridors

- Preservation of existing streams for natural drainage and enhancement as green corridors
- Rainwater storage through two lakes with parallel recreational potential

6 Sustainable infrastructure

- Holistic integrated planning for infrastructure systems:
  - Transportation
  - Energy
  - Water
  - Solid waste
  - Landscape
  - Information

Sustainable Infrastructure systems Planning

TRANSPORTATION

An integrated public transport system combined with extensive networks of pedestrian and bicycle infrastructure are promoting green and non-motorized transportation.

WATER

100% of wastewater treated and recycled through a decentralize sewage system. A separate stormwater treatment system incorporating the natural landscape (nalahs), artificial lakes and green areas. Water conservation strategies and methods for economy in use of potable water

ENERGY

Use of renewable energy sources up to 30% both in public and private sectors. Measures for energy demand reduction.

WASTE

100% of waste produced in DHA City will be treated before final disposal Separate waste collection streams are organized through community centers proximities. High percentage of waste diverted from landfill.

LANDSCAPE

Landscape infrastructure in DHA City host ecological, productive, supporting and recreational activities that include rainwater/ stormwater management, air quality improvement, carbon sequestration, water infiltration, enhancement of local productivity, high quality recreation and accessibility to all residents.

INFORMATION

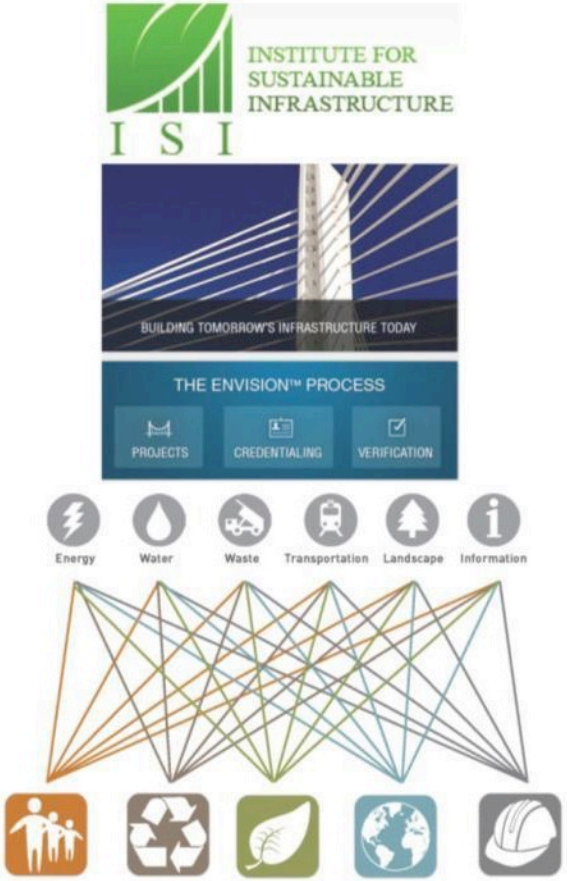
Information infrastructure in DHA city has a dual significance. Enhancing social and economic sustainability through state of the art information and communication networks and becoming a factor for optimizing sustainability performance in all other infrastructure categories, transforming DHA city to a smart city.

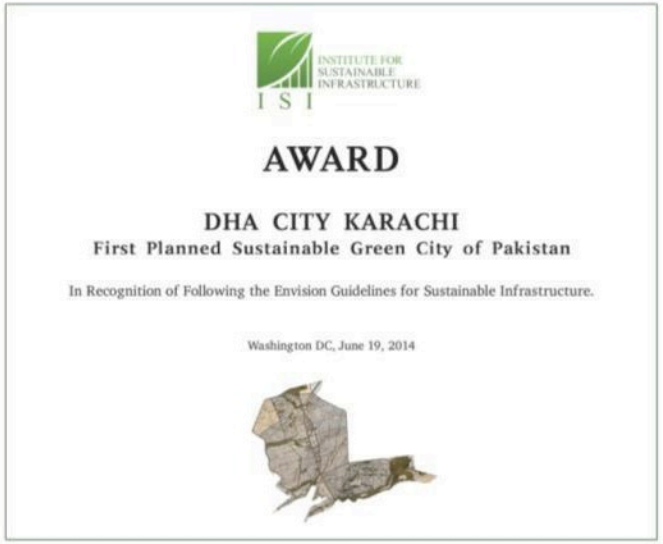
SUSTAINABILITY GOALS

- ☑ Reduce energy consumption by 15%
- ☑ Reduce emissions by 25% by 2020
- ☑ Renewable energy sources to 30%
- ☑ Recycle solid waste by 14%
- ☑ Energy recovery by 23%
- ☑ Compost recovery by 22%
- ☑ Waste diverted from landfill to 51%

Sustainable Performance Certification

DHA City Karachi was awarded by the international organization Insitute of Sustainable Infrastructure (ISI) as the 'First Planned Sustainable Green City of Pakistan'





INSTITUTE FOR SUSTAINABLE INFRASTRUCTURE
I S I

AWARD

DHA CITY KARACHI
First Planned Sustainable Green City of Pakistan

In Recognition of Following the Envision Guidelines for Sustainable Infrastructure.

Washington DC, June 19, 2014

INSTITUTE FOR SUSTAINABLE INFRASTRUCTURE
I S I

CERTIFICATE OF ACCOMPLISHMENT

Awarded to
DHA CITY KARACHI

It is certified that the Master Plan of DHA City Karachi, First Planned Sustainable Green City of Pakistan, has ensured Infrastructure Sustainability following the Envision Guidelines.

Washington DC, June 19, 2014

Bill Bertera
Executive Director

Infrastructure Innovations
Meeting Environmental Challenges

1. Tools for Measuring Sustainability
2. Synergies for Self-Sufficient Cities
3. Disruptive Technologies Redefine Infrastructure
4. Digital Design and Simulation Tools
5. Enabling Innovation through Procurement

Technology Adoption

The Engineering & Construction industry has an impact on the economy, the environment and the society serving almost all industries.

Compared to many other industries, it has traditionally been **slow at technological development.**

Technology Adoption

The World Economic Forum (WEF) attributed the E&C industry's **slow adoption of technological innovation** to a number of internal and external challenges such as:

"The persistent fragmentation of the industry, inadequate collaboration with suppliers and contractors, the difficulties in recruiting a talented workforce, and insufficient knowledge transfer from project to project."

"Shaping the future of construction Report"
May 2016. WEF & The Boston Consulting Group.

Technology Adoption

The risks and challenges of infrastructure transformation collide immediately with the traditional construction sector, as **most engineers look into history as a "model".**

The historical dataset does not represent what we will need in the next years.

We should **look at history by getting out of the box** and foster a culture of innovation in the infrastructure sector.

Advanced Technologies and Infrastructure Innovation

Today, **advanced technologies** can lead to **more integration and** different **-out of the box- ways of looking at infrastructure development.**

The “internet of things”, automation, cloud technology, robotics, 3D printing, advanced materials, mobile internet and renewable energy are some of the emerging technologies that can boost infrastructure innovation.

Advanced Technologies and Infrastructure Innovation

They can change both **new and existing infrastructure** by:

- improving the project delivery & the life-cycle performance of infrastructure projects
- increasing environmentally friendly and sustainable approaches
- offering risk-mitigating and immediate response solutions

Smart Cities Concept

Smart Cities focus on Information and Communication Technologies to help develop, deploy and promote urban sustainability.

Consequently, smart cities can be the **linchpin of innovation** integrating advanced technologies and infrastructure.

Autonomous and Connected Vehicles, Smart energy grids, Energy storage and Intelligent infrastructure networks are only some of the emerging smart solutions.

Smart Cities and Transportation Infrastructure

The **Transportation sector** has a profound and varied impact on individuals, communities and the environment .

Smart **Cities incorporate and expand** connected transportation data, technologies and applications **in a fully integrated manner** with other infrastructure systems (such as energy).

Automated and Connected Vehicles

Automated and Connected Vehicles (CAVs) are among the most researched and innovative automotive communication technologies starting to be deployed.

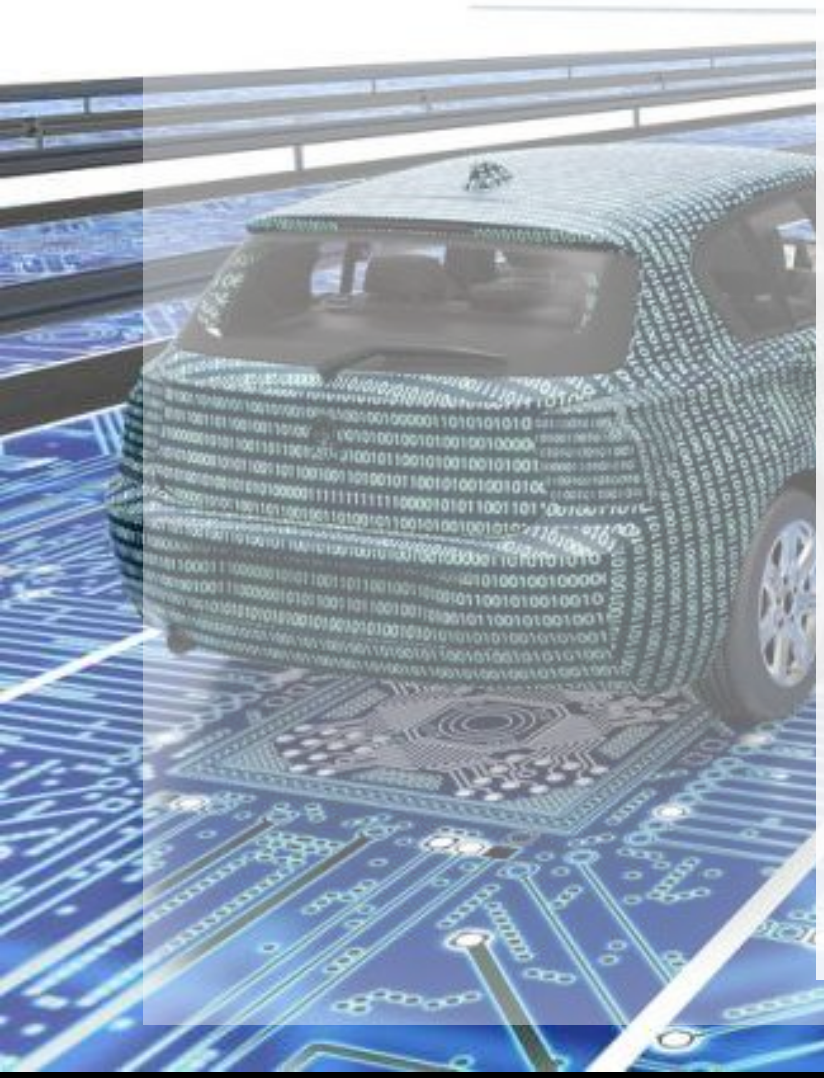
CAVs will collect data (road condition, outside temperatures and speed) which, together with connected road infrastructure, **will change how cities and highway authorities manage transport systems.**

Automated and Connected Vehicles

The potential for CAVs to bring transformative change **is huge.**
In order to gain the benefits of this innovation, CAVs:

- must be **fully integrated into the transportation network,** both receiving and sending information
- require **sensible regulatory regimes**

Automated and Connected Vehicles



Main benefits include:

- Reduction in road fatalities and injuries
- Mobility for the young, elderly, and impaired
- Reduction of congestion and travel time by increasing the capacity of the infrastructure
- Reduction of noise, air pollution and GHG emissions

Automated and Connected Vehicles

CAVs form **a part of a wider transformation** in urban mobility.

Shared mobility, automation, electrification and digital connectivity play a central role to the deployment ad successful delivery of CAVs.

Currently this technology is being tested while local governments prepae the ground for their circulation in the roads.

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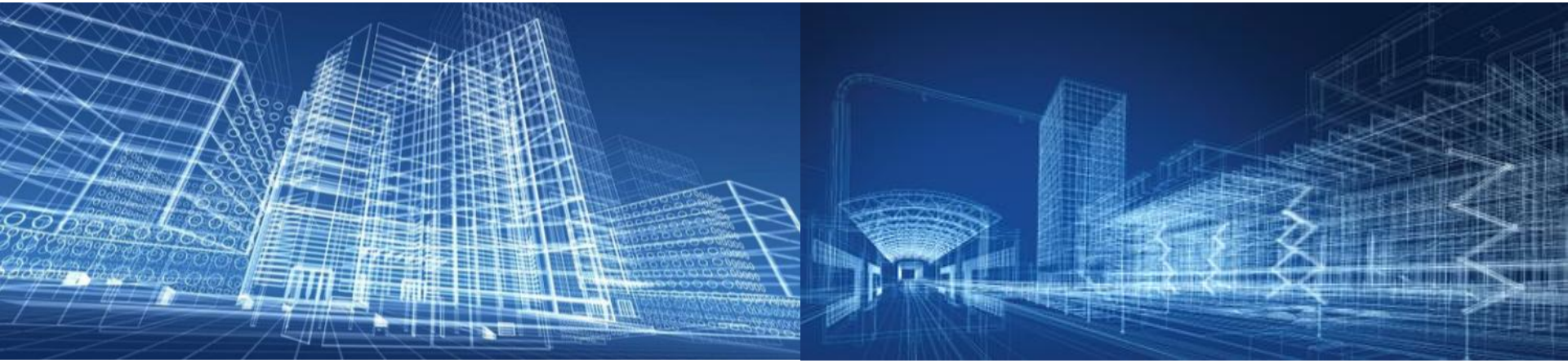
Digital Innovation

Advances in digital technology give the opportunity to improve sustainability and better monitor the environmental performance of infrastructure projects

Simulation provides New Opportunities

Using Building Information Modeling technologies to create a 'digital twin' model of the infrastructure project can:

- Improve project management and streamline the construction process
- Encourage interdisciplinary cooperation at an early stage – sustainability solutions should get incorporated early in the process
- Accurately simulate project's environmental performance during operation
- Provide better management, monitoring and maintenance of the project during operation



Big Data

Infrastructure digital models should be interconnected and take advantage of the extensive databases produced by smart cities applications in order to make even more accurate projections and predict future usage and performance.

Accurate Predictions – Resilience

Creating an accurate digital model of an infrastructure project becomes essential to the actual construction of the project

Simulation and big data usage can improve performance but also predict traps and vulnerabilities

Aviation and Aerospace Pioneers

Aviation and aerospace industries were the first to exploit the benefits of digital simulation tools already from the early 90s

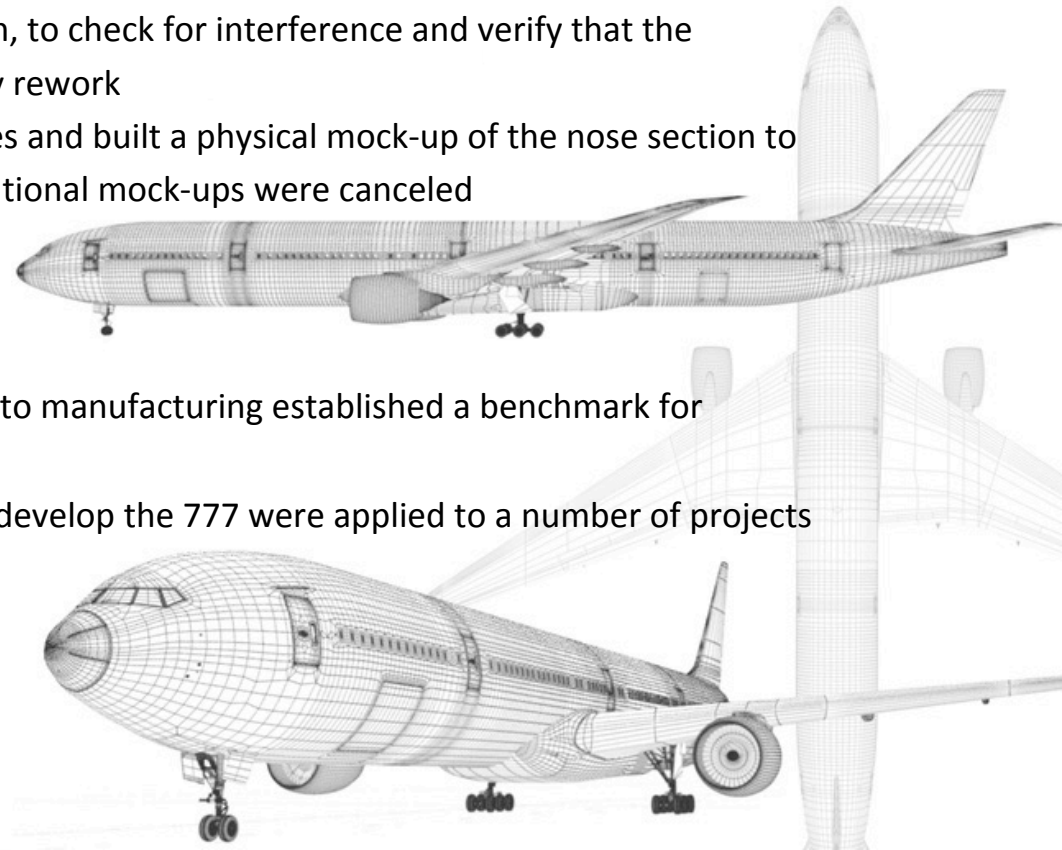
Facts:

•The Boeing 777 was the first commercial aircraft designed entirely by computer

•Each design drawing was created on CATIA, in three-dimensional CAD.

• Engineers assembled a virtual aircraft, in simulation, to check for interference and verify that the thousands of parts fit properly—thus reducing costly rework

•Boeing was initially not convinced of CATIA's abilities and built a physical mock-up of the nose section to verify its results. The test was so successful that additional mock-ups were canceled



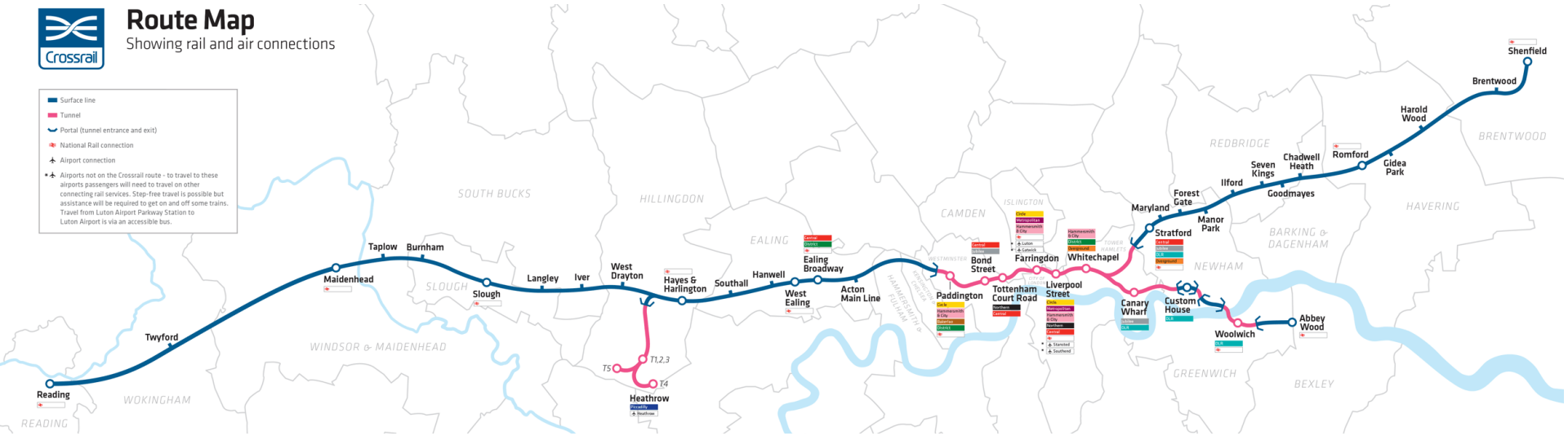
Legacy:

• The 777 design, innovative features and approach to manufacturing established a benchmark for development of aircraft in future

• The management and technical approach used to develop the 777 were applied to a number of projects including the International Space Station

Crossrail – London

Crossrail is currently Europe's biggest infrastructure project under construction and a pioneer on the use of Building Information Modeling for infrastructure mega-projects



Project facts: The £14·8 billion Crossrail project to deliver the 118km east–west Elizabeth line railway across London, UK, comprises ten new stations, 42 km of tunnels, works to surface railways, and associated depots and maintenance facilities.

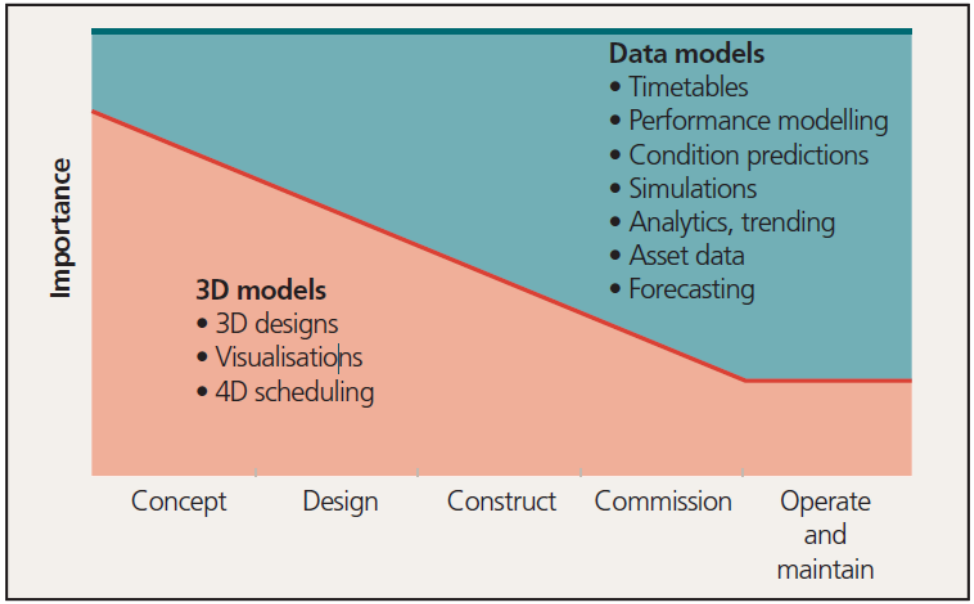
As a public transport project, Crossrail delivers sustainable outcomes by:

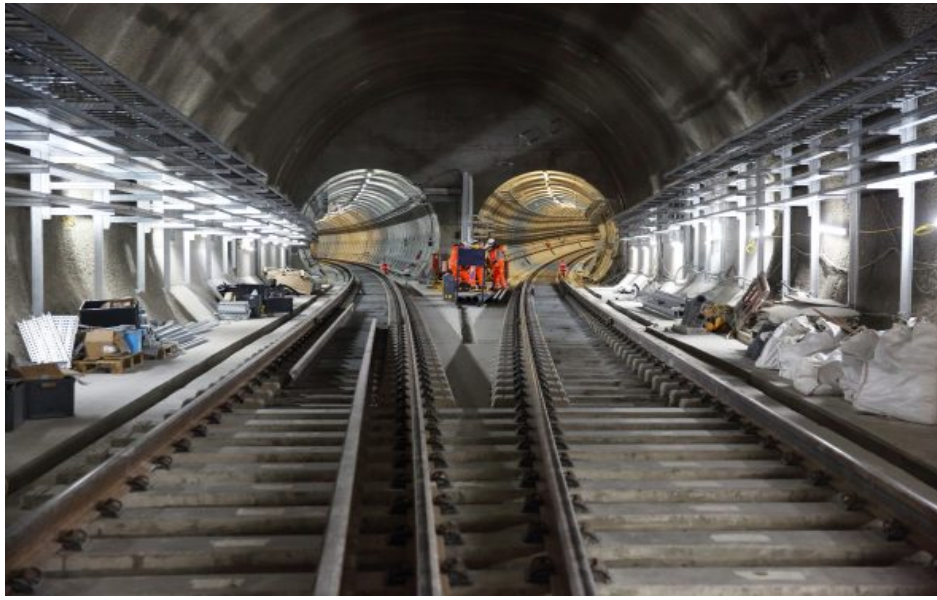
- relieving overcrowding on existing underground and train services
- adding 10% extra rail capacity for London
- decreasing journey times across London.
- secure a £42 billion net benefit to the UK economy in present value terms over a 60-year period

Crossrail – Two Models

The Crossrail project involves building two railways: a virtual one and a physical one. The virtual version was used to facilitate design, construction and subsequent operation of the actual railway, and they had to be achieved together.

The replication of the physical by digital information is critical as the virtual railway will be used to manage and maintain the physical for its projected life of at least 120 years.





Importance of different model types at different lifecycle stages
Source: "Crossrail project: building a virtual version of London's Elizabeth line"

Crossrail – Information Academy

In order to change the mindset on mega-projects and to boost innovation Crossrail created an Information Academy

- The Crossrail-Bentley Information Academy objective is to **enhance internal and supply chain's knowledge, to drive improvements, encourage best practice and facilitate the transfer of knowledge to other infrastructure projects**.

- The academy provides an enabling force to all attendees to understand how Crossrail is managing information across multiple of linked technology platforms to create a **'Single Source of Truth'** within a **Common Data Environment.**

- Due to the **virtual nature** of the academy environment, it is **ideal for testing innovative ideas**

Digital Cities

Digital innovation can also be adopted at the municipality and city scale

Municipalities and public institutions can collect big data and create digital and data models that can be used and interact with the infrastructure

Digital Cities – An Example

The Project Iceberg is an initiative building a Digital Picture of the ground beneath the UK cities

Project Iceberg has been launched by the Ordnance Survey, British Geological Survey and Future Cities Catapult and **has the long-term aim being to help increase the viability of land for development and de-risk future investment through better use of subsurface information.** To realize the full potential of subsurface data, Iceberg has investigated ways to join up data and services delivered by a range of organizations and integrate it with other city data.

Today there is a great deal of data about the subsurface and there are various standards that set out how information should be captured but the information is dispersed amongst many different parties. **This lack of coordination and collaboration has costs**. For example the direct costs associated with 'normal' maintenance of underground electricity, gas and water assets runs into the billions of pounds a year without considering indirect costs such as increased road congestion during ground works.

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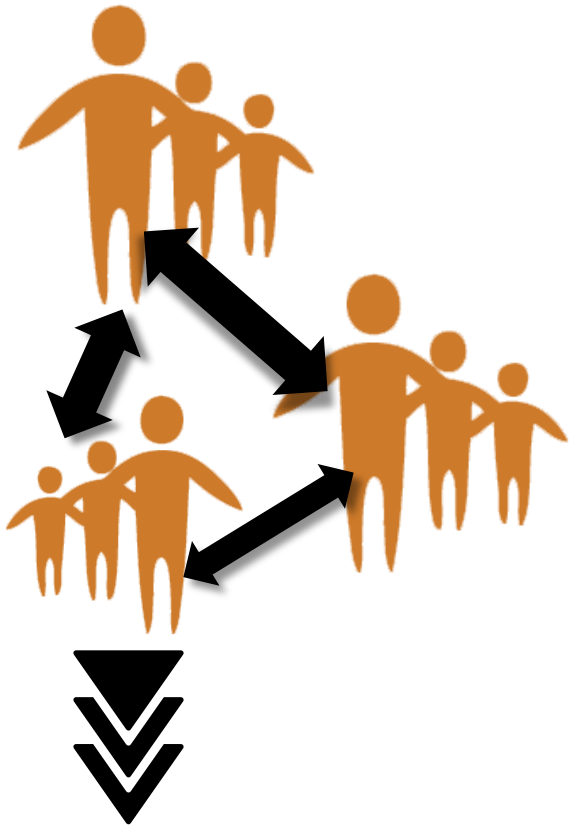
Enabling Innovation through the Procurement Process

The procurement process is key towards establishing sustainability as a core guiding principle and provide space for innovation and creativity.

Sustainability as integrated component of the procurement process **from start to finish**

Enabling Innovation through the Procurement Process

Establish continuity across all stages to secure result



Early engagement of all affected stakeholders

e.g. Series of workshops to define and analyze the problem, set the project scope and develop technical solutions engaging all affected stakeholders and allow them to actively participate in the decision-making process.

Performance-based VS. Prescriptive scope setting

How not setting the typical infrastructure engineering requirements (defined in terms of what is required) but rather setting the performance that is needed, can redefine a projects' development.

make space for creative innovative design

Performance-based VS. Prescriptive scope setting

Defining requirements in performance terms allows truly creative planners and designers to innovate to solve bounded problems. This requires a strong methodology for arriving at measurable metrics and acceptable quality levels when developing the scope

Innovation unleashes the true sustainable solutions

Project Team qualifications-based selection vs. lowest bid

Perhaps most important is how the client defines the project team selection criteria that will shape financial proposals. Services based upon qualifications-based selection and life cycle value criteria rather than lowest bid.

Select the right contractor

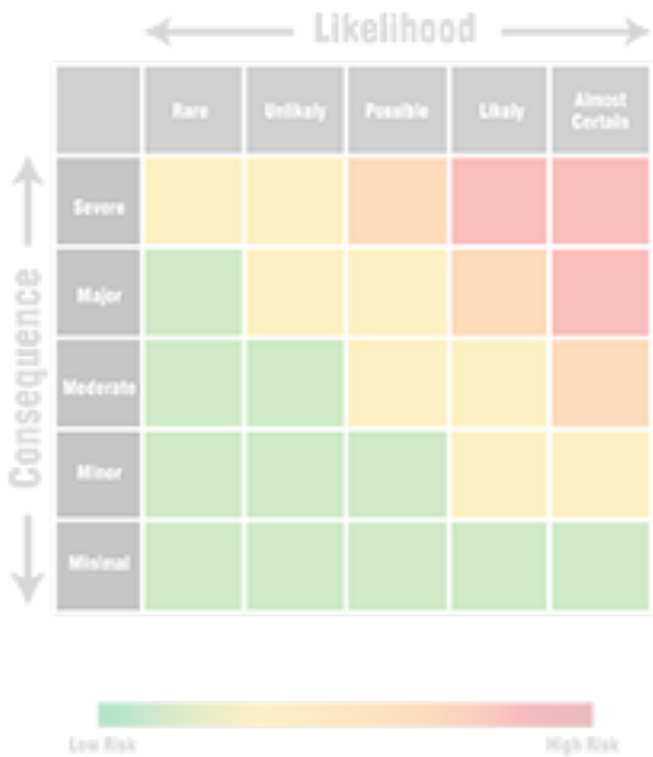
Conventional vs. Alternative delivery methods

Project delivery methods strongly affect the way teams are brought together, thus impacting the quality of decisions made.

The traditional price-based Design-Bid-Build minimizes the use of contractors expertise by using owner-driven specs. Design-Build introduces construction input into design to improve project performance. Design-Build-Operate-Maintain (DBOM) brings critical O&M input into design.

Select the right delivery method for informed decisions

Risk Management/ Risk Matrix

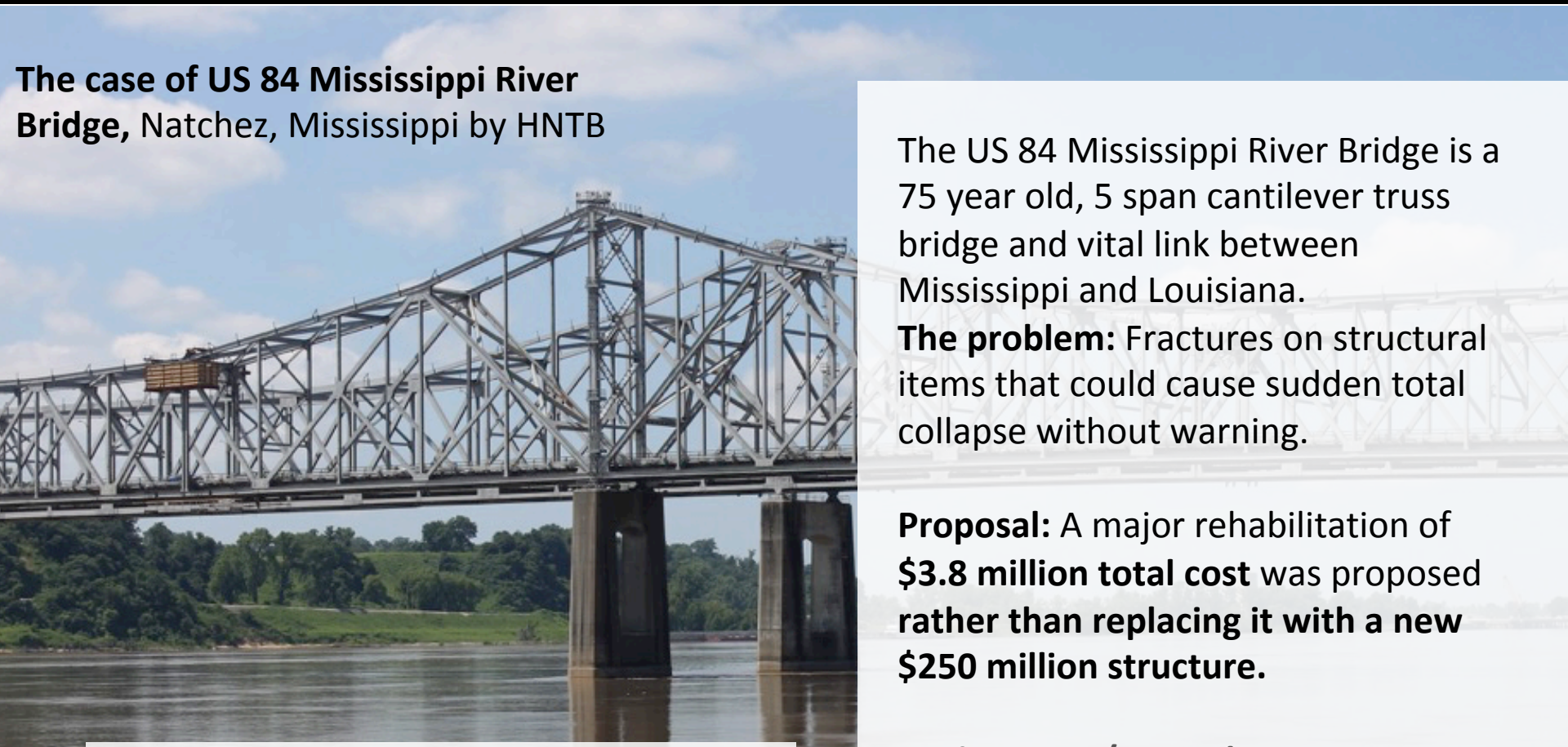


Risk Score	Risk Level	Acceptability of Risk	Recommended Actions
< 3	Low Risk	Acceptable	No additional risk control measures required. Risk level is acceptable and should not escalate to a higher level.
3 - 4	Medium Risk	Acceptable	Control measures must be implemented to reduce the risk; however, tasks need to be reviewed to bring risk level to as low as reasonably achievable. Control measures must be implemented to reduce the risk. Supervisory oversight is required.
> 4	High Risk	Not Acceptable	Experiment cannot be performed until the risk level is reduced to the medium risk level. Control measures must be implemented to reduce the risk. Control measures must focus on elimination, substitution and engineering controls. Personal Protective equipment cannot be the sole risk control strategy. Immediate management intervention is required to ensure the risk is reduced to at least medium level prior to initiating the experiment.

The Risk Matrix as a decision-making tool in relation with sustainability strategies **to rate alternative solutions and manage innovative, not-tested solutions**.

Enabling Innovation through the Procurement Process

The case of US 84 Mississippi River Bridge, Natchez, Mississippi by HNTB



The US 84 Mississippi River Bridge is a 75 year old, 5 span cantilever truss bridge and vital link between Mississippi and Louisiana.
The problem: Fractures on structural items that could cause sudden total collapse without warning.

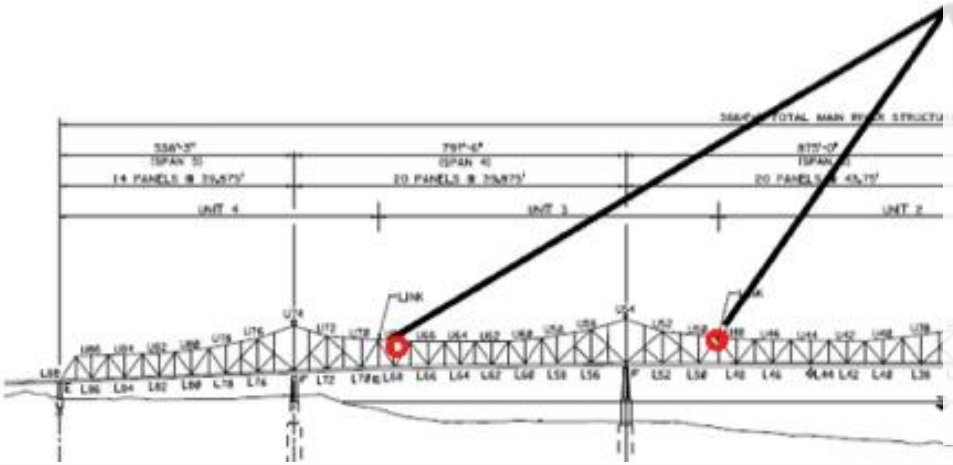
Proposal: A major rehabilitation of **$3.8 million total cost** was proposed **rather than replacing it with a new $250 million structure.**

Design team/ Consultant: HNTB
Client: Mississippi Dep. of Transportation (MDOT)
& Louisiana Dep. of Transportation & Development (DOTD)

- ☑ **Early Participation of the Consultant**
- ☑ **Risk Matrix as Decision-making Tool**
- ☑ **Project Team Qualifications-based Selection**

Early Participation of the Consultant

Doing the right project required out-of-the-box thinking, the consultant being next to the client and advising early in the process before the RFP was issued.
Without HNTB's insight the client would consider as only option the bridge replacement with a new one; option with higher social and environmental impact and cost.



The consultant envisioned **a first-ever approach** of pin-and-link replacement that proved successful and will allow the structure to provide another **40 years of service**

Risk Matrix as Decision-making Tool

US 84 MISSISSIPPI RIVER BRIDGE PIN REPLACEMENT RISK MATRIX (BR-0015-01(120) 160487/30100)

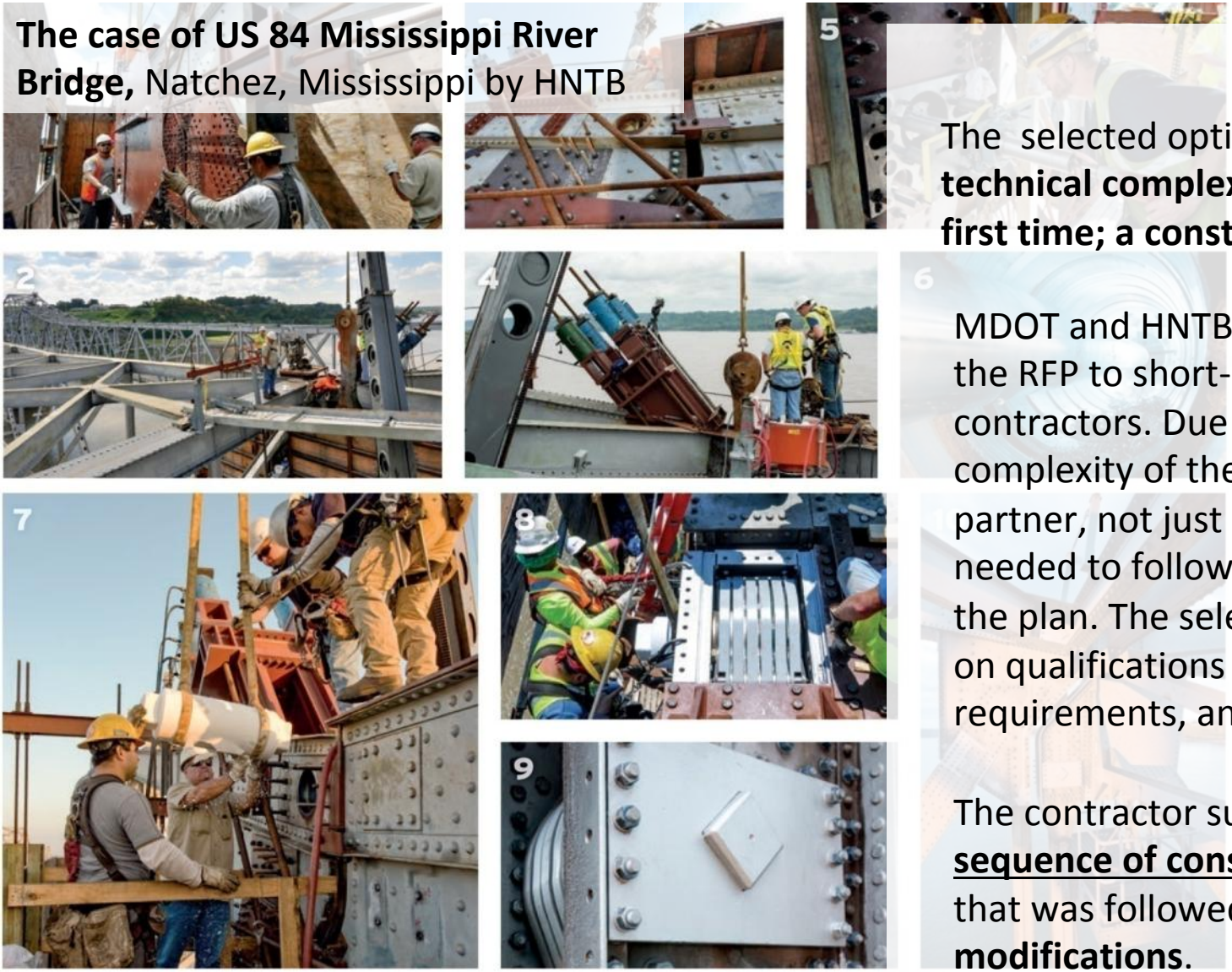
The Risk Matrix listed pros & cons of 5 options.
Options were evaluated according to cost, risk and probability to be successful.

OPTION 1	Restrain and monitor	Low cost option, similar to the "no-built" option	Represented the highest risk that could result in total collapse of the bridge
OPTION 2	Reset pins	Repeat of an earlier approach in 1996 that was not successful	Represented the lowest risk, but the low probability of being successful
OPTION 3	Replace lower pins	Replacing the pins but not the links	Option with high risk of damaging the existing links
OPTION 4	Replace lower and upper pins and links	Option that would entail installing temporary restraints so that the upper and lower pins and link could be removed and replaced.	Option with highest probability of being successful and with risk that could be mitigated through the design of temporary restraints (bypass) in order to remove the pins and links. After the new pins would be installed the temporary restraint would be disengaged and load transferred to the new pins
OPTION 5	Replace Bridge	This option would entail demolishing the existing bridge and building a new	The cost of the new bridge would be $200+ M

Option selected ✓

Project Team Qualifications-based Selection

The case of US 84 Mississippi River Bridge, Natchez, Mississippi by HNTB



The selected option was of **elevated technical complexity practiced for the first time; a construction challenge**

MDOT and HNTB prepared together the RFP to short-list qualified contractors. Due to the risk and complexity of the construction, a partner, not just a contractor was needed to follow and supplement the plan. The selection was based on qualifications of personnel, requirements, and prior experience.

The contractor submitted **<u>a detailed sequence of construction works</u>** that was followed with **minor modifications**.

Enabling Innovation through the Procurement Process

The case of AlexRenew NMF
Alexandria, VA by CH2M Hill

AlexRenew is a Nutrient Management Facility part of an existing space-constrained Water Resources Recovery Facility.

The problem: meet stringent nutrient discharge limits at Chesapeake Bay watershed.

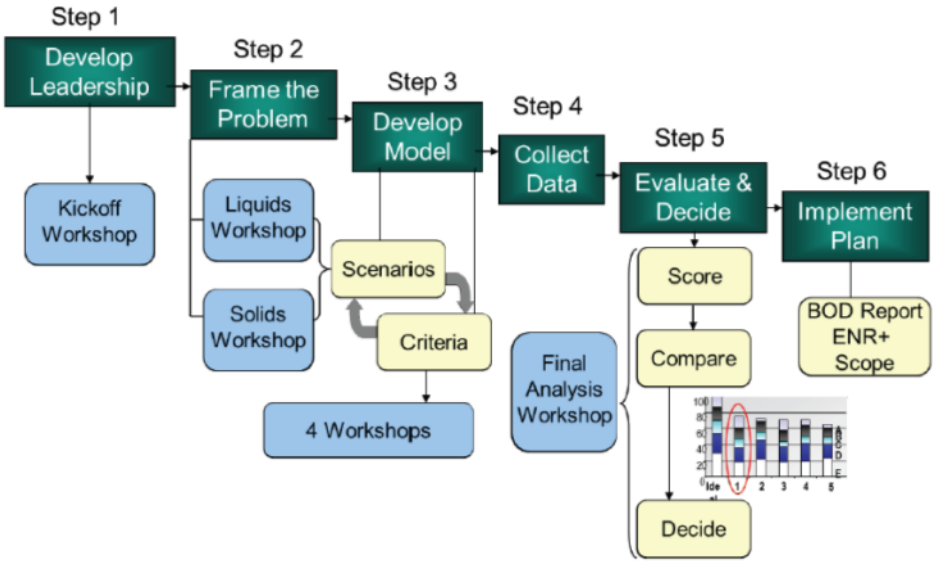
Proposal: Instead of opting for chemicals for nutrients removal a primary effluent wastewater storage tank was constructed to expand the capacity of the existing treatment facility to manage diurnal peak of incoming flow.

Design team: CH2M Hill (now Jacobs)
Client: Alexandria Renew Enterprises

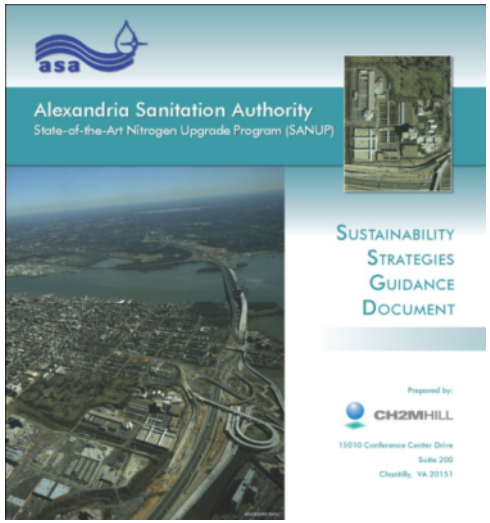
- ☑ **Early Engagement of all Affected Stakeholders**
- ☑ **Project Team Qualifications-based Selection**

Early Engagement of all Affected Stakeholders

Series of Sustainability Workshops



developed the initial list of objectives and strategies. This information was gathered in a 150-page guidance document

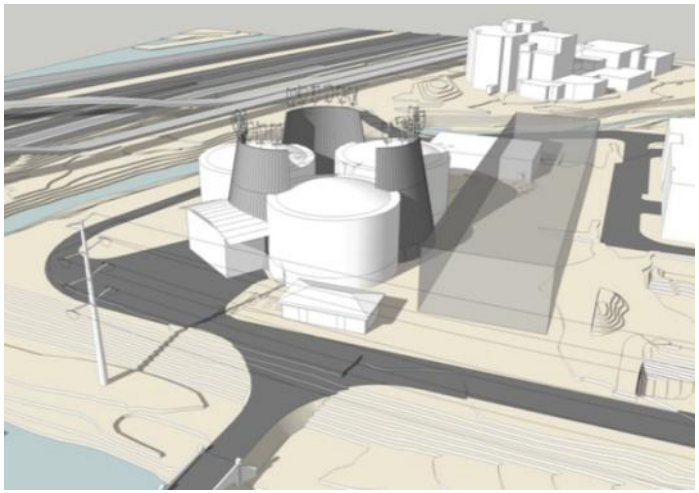


<u>Participants:</u>

City Council
Local Developers
Community Members
Community Non-Profit Organizations

Early Engagement of all Affected Stakeholders

The input from the workshops and meetings was incorporated in the design and transformed it beyond compliance

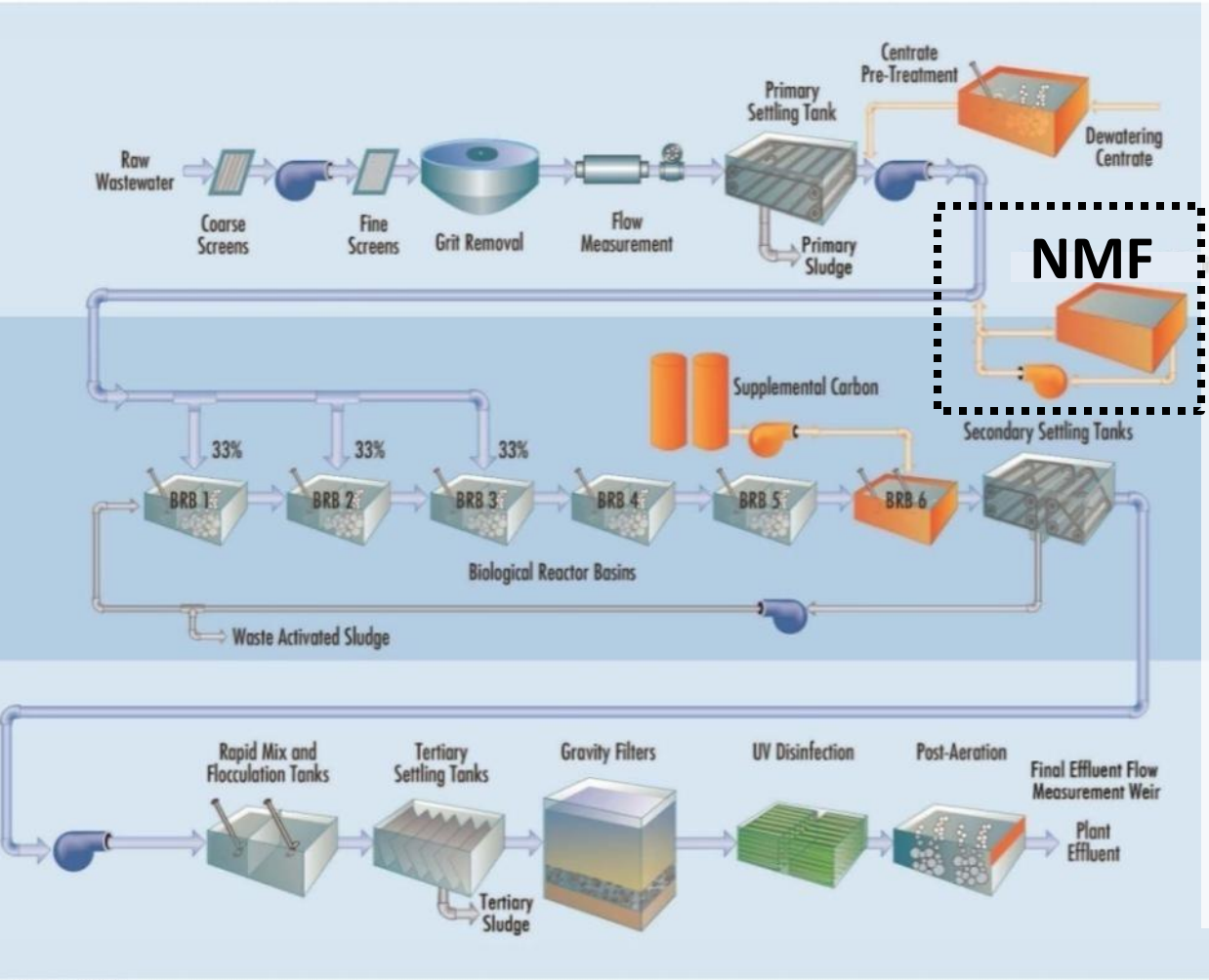


Instead of a conventional engineering solution to extend treating capacity

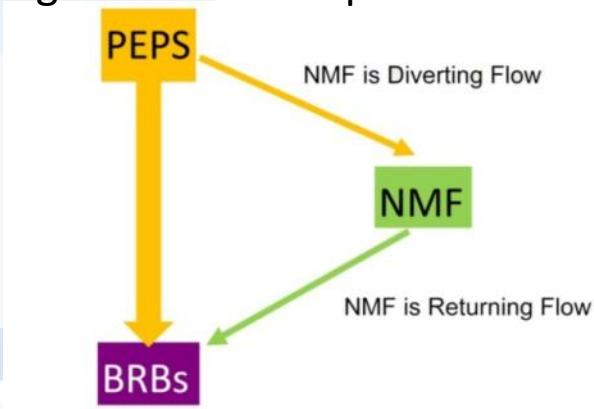
An integrated in the urban context dual-purpose solution:

The project added recreational capacity to the city in the form of a multipurpose sports field on top of the facility, a feature **rarely** accomplished in an urban wastewater utility.

Performance-based scope for out-of-box solutions



The scope required management of nutrient loads during peak flows. Instead of controlling nutrients chemically, "***it is the first time that nutrients loads are managed by introducing storage tanks***". The NMF stores primary effluent to balance the amount of nitrogen that enters the existing biological treatment process.



Infrastructure Innovations
Meeting Environmental Challenges

1. **Tools for Measuring Sustainability**
2. **Synergies for Self-Sufficient Cities**
3. **Disruptive Technologies Redefine Infrastructure**
4. **Digital Design and Simulation Tools**
5. **Enabling Innovation through Procurement**

Thank you

Prof. Spiro N. Pollalis

pollalis@gsd.harvard.edu

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About the Envision Rating System:

http://sustainableinfrastructure.org/envision/