Planning Sustainable Cities

An Infrastructure-Based Approach

DIRECTED AND EDITED BY SPIRO N. POLLALIS

ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE
Harvard University, Graduate School of Design

ROUTLEDGE

PLANNING SUSTAINABLE CITIES

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CONTENTS

PREFACE

This publication fills a gap between the professions of planners and engineers, both contributing to the fundamental process of planning and building infrastructure for cities. It responds to the urgency of integrating these practices, with the objective of creating sustainable urban environments. As cities collectively start to respond to the magnitude of global urban changes and especially to the climatic risks (seen, for example, in the impact of Superstorm Sandy on New York City), there is an overall awareness that key professionals need to work in an integrated manner in order to achieve sustainable urban solutions. With this awareness, there is a need as well as a demand for a framework that can create a collaborative platform for different stakeholders involved in cities to work in unison. This need is widely acknowledged by more and more professionals working in the planning and engineering sectors.

Due to the size and complexity of infrastructure systems, multiple stakeholders with different issues and agendas are involved during planning. This book is intended to form the foundation of a common collaborative platform, primarily among public authorities, planners, and engineers,enabling those who have traditionally functioned in silos to work closely together in infrastructure planning. Establishing shared knowledge that responds to the language of these professionals is integral to our approach. The content of this book should be resourceful and broad enough to create an informed knowledge of the infrastructure systems of the city, and goes in depth to a level that is comprehensible to professionals engaged in practices of public policy, planning, and engineering, as well as to community organizations.

Professor Spiro N. Pollalis
Zofnass Program Director
Professor of Design, Technology and Management at the Harvard Design School

ACKNOWLEDGMENTS

This research was made possible by the generous support of Paul Zofnass and Joan Zofnass, whose determination and commitment to sustainability led to the establishment, in 2007, of the Zofnass Program at Harvard University (research.gsd.harvard.edu/Zofnass, or www.zofnass.org). The founding objective of the Program was the creation of a sustainability rating system for infrastructure projects in close collaboration with the Harvard professional schools and with industry.

In 2007, Professor Spiro Pollalis was appointed the first Director of the Zofnass Program and assumed the task of formulating and implementing the vision. A team of researchers and students was assembled to carry out the research and the Planning Guidelines is the direct or indirect outcome of a multi-year effort on sustainability of the researchers throughout the years who have been part of the Zofnass Program. The Zofnass Program has also been supported by Harvard University faculty advisors from the School of Design, the Center for the Environment, the School of Public Health, the Business School, and the Law School, who bring a wide range of expertise to the Program.

In parallel, the Zofnass Program established the Sustainable Industry Advisory Board (SIAB). SIAB members support the Program financially and, equally important, with the commitment of the firms' leadership share their professional expertise and provide valuable feedback to the Program's research. ARCADIS, Autodesk Inc., exp., Golder Associates, Granite Construction, CH2M, HNTB Corporation, MWH Global, NV5, Power Engineers, and Stantec are the SIAB members.

The Program organizes quarterly workshops, by invitation only. The researchers of the Program, Harvard faculty advisors, SIAB members, and guests attend these workshops, led by public authorities and private parties involved in large-scale projects. The workshops allow intense interaction on complex issues that require utmost expertise and understanding of state-of-the-art practice. We attribute to these workshops the results of our research, the successful outcome of both our rating system and our Planning Guidelines.

The Zofnass Program maintains a close ongoing relation with the Institute for Sustainable Infrastructure (ISI, www.sustainableinfrastructure.org). ISI was established in 2012 as a nonprofit organization with three founding members: the American Society of Civil Engineers (ASCE), the American Council of Engineering Companies (ACEC), and the American Public Works Association (APWA). After its founding, ISI adopted our Zofnass rating system, giving it a new life after the research phase, and has transformed it into Envision®, a commercial-grade product for self-evaluating the sustainability of infrastructure projects, for rating them, and for training Envision® certified professionals (ENV SP). Our interactions with ISI have had an impact on our work.

The Planning Guidelines were presented, discussed, and scrutinized in all our workshops over the past two years. The Harvard faculty advisors and SIAB members provided feedback on the research and reviewed the manuscript of this book. SIAB members contributed introductory essays for each chapter, sharing their valuable professional perspectives.

It should be noted that the Water Infrastructure chapter was partially supported by a two-year grant of the Surdna Foundation to the Zofnass Program (www.surdna.org).

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The work presented in this book is the result of the research effort of the Zofnass Program at the Harvard Graduate School of Design in the period 2013-15. The entire team seamlessly contributed to the methodology, graphics and texts, with specific tasks:

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PLANNING SUSTAINABLE CITIES

An infrastructure-based approach

PART 1

SUSTAINABILITY, INFRASTRUCTURE, AND CITIES

Part 1 introduces the Zofnass Program, its activities, research scope, and approach, as well as key factors affecting the sustainability of urban infrastructure systems and aspects of infrastructure planning.

Zofnass Program Events

Sustainability, Infrastructure, and Cities

the Zofnass Program for Sustainable Infrastructure

Chapter 1

1.1 | **THE PROGRAM**

Paul Zofnass
Zofnass Program Founder
President, Environmental Financial Consulting Group, Inc. (EFCG)

Zofnass Program Workshop, October 2014.

Having grown up in a beautiful suburb of Boston, surrounded by forests and farms, I developed at a very young age a passion for preserving our natural world. I have also gained an appreciation for how effectively measuring performance or quality can influence and incentivize human behavior. Give performance a rating, and we compete to do better. Consider, for example, how school grades push students to study harder; or how athletic teams or individuals strive to improve their performance to the extent that it can be measured. Corporate goals and metrics incentivize revenue or earnings growth. In hybrid cars, by making the miles per gallon achieved by the driver (in five-minute increments!) clearly visible, manufacturers have leveraged our innate human desire to improve to encourage better fuel economy. Consider how the US Green Building Council's LEED® rating system for sustainability in building design has sensitized people to the meaning, importance, and benefits of "green building" and encouraged them to build more sustainably.

For the past 25 years I have been working with the engineering/consulting industry as a financial and strategy advisor. Observing the effectiveness of LEED, I began to wonder why a similar type of rating system had not been developed for the design and planning of public infrastructure. One reason may be that the scope and range of issues that need to be taken into consideration for public infrastructure are generally far more complex than for a single building. (Consider for example the impact of a new airport, railroad, highway, urban development project, sewer system, bridge or tunnel complex, waterway, power grid, or even new community or city, any of which can affect hundreds of thousands, in some cases millions, of people. These all have major effects not only on the environment but on many other aspects of society.) If we are going to make the world more "sustainable," don't we need to develop and apply a set of standards by which to analyze, define, and measure "sustainability" as it applies to these large infrastructure programs? And don't we need to continue improving our understanding of the underlying sciences and meaning of sustainability? But where do we begin?

I noted that many of my engineering clients were developing their own tools and methods to measure "sustainability" as it might apply to the kinds of projects they were designing. But there was no commonality in their approaches to these metrics. And in fact, as each firm leveraged its proprietary tools and systems to demonstrate expertise and drive for sustainability in the marketplace, project owners found it difficult to compare the benefits between one tool and another. It was also hard, if not impossible, for a wider consensus to be developed or agreed upon. Yet it was clear to me that such a consensus approach could offer a very beneficial, productive path forward.

It also occurred to me that an approach driven primarily from an engineering perspective would likely fail to take into consideration many other factors in which engineers are not well versed, but which are still critical in understanding the broader scope of "sustainability." Consider, for example, impacts on human health, social communities, and natural ecology, as well as the role of politics, economic development and human well-being, social justice, and obligations and goals of government. These issues go far beyond the resources or knowledge borders of any single engineering firm, or even group of engineering firms. They also cut across all aspects of the social and physical sciences, as well as our overall body of scientific knowledge.

These thoughts suggested to me that to create an effective measurement system for infrastructure sustainability, it needed to be developed by a wide range of sources. These included:

a) A broad and diversified base of participating design and engineering firms,

b) A globally recognized and respected, and multidisciplined, educational institution that could bring to bear all the academic disciplines required to define the concept of "sustainability,"

c) An array of senior government infrastructure directors who could help us understand their needs and issues, so that they could support funding for and use of sustainable design,

d) The support of the major professional associations affiliated with the engineering and design industries, to encourage the use of sustainable design in their work.

In 2007, I approached Harvard University (my alma mater) with an offer to fund 18 months of research to see if they could develop a conceptual framework by which to define sustainability as it might apply to major infrastructure projects, and create an initial set of metrics by which to measure this concept. The Zofnass Program for Sustainable Infrastructure was housed in the Harvard Graduate School of Design, under the direction of Professor Spiro Pollalis and leadership of Professor Andreas Georgoulias, and brought together roughly 30 professors from six different schools within Harvard (Design, Business, Public Health, Government, Sciences, and Law) and over 100 graduate researchers. Over the next two years they met quarterly with sustainability leaders of 30 major engineering/consulting (e/c) firms, and roughly 50 senior government infrastructure staff from different government sectors (federal, regional, state, and city) throughout the country, to attempt to develop a consensus-based set of sustainability parameters.

By 2009, the Program had developed a set of guidelines and metrics to define and measure sustainability as it relates to infrastructure that was sufficiently defensible to warrant further research and development. Twelve organizations (including 10 leading e/c firms) committed to provide significant funding for the ongoing development of this system, as members of the Sustainable Infrastructure Advisory Board at Harvard or SIAB. The SIAB members actively participated in the refinement and application of the system; they included: CH2M HILL, MWH Global, HNTB, Stantec, Golder, Power Engineers, Arcadis, exp., NV5, Granite, Autodesk, and the Inter-American Development Bank (IDB).

In 2011, the Program was approached by the Institute for Sustainable Infrastructure (ISI), a joint venture between three leading professional engineering associations, ASCE, ACEC, and APWA, which was on a similar path to develop a set of infrastructure sustainability standards. Given the need for a single consensus standard, the two programs made the decision to combine their individual systems into one, selecting the best characteristics from each. The combined system is called Envision®, and the two groups work in tandem to continue to improve this combined system. The Zofnass Program at Harvard focuses on further research and development for sustainable infrastructure and for the Envision® system, working to keep it current with the advances in the underlying sciences and knowledge. The Program also holds quarterly workshops that bring together the practical expertise and experience of the SIAB firm members with members of Harvard's faculty and graduate schools and with representatives from governments and NGOs committed to making the world's built infrastructure more sustainable over the long term. The Zofnass Program continues to work with the ISI, helping them to integrate this research and knowledge into a constantly improving Envision® rating system. While the Zofnass Program focuses on R&D and working with governments and NGOs, the ISI focuses on the training, credentialing, and marketing of Envision®.

With Envision®'s integration into the infrastructure marketplace accelerating and roughly 3,000 Envision® Sustainability Professionals, or ENV SPs, in the US and abroad, the Zofnass Program's research is now moving toward the next logical step in creating a more sustainable world, integrating each component of sustainable infrastructure into a system applicable to whole-city design. This work, already seeing initial pilot implementation efforts, is very complex and highly interconnected, but offers a promising vision for how infrastructure of the future might be designed and built.

This textbook, the second since the initiation of this Program, presents our city-scale research results to date. It incorporates sustainable project analyses and case studies, covering many different fields and sectors of infrastructure, with contributions by professionals from the SIAB members and members of the Harvard University faculty.

I strongly believe that if we don't start creating a more sustainable world today, we will not have one in the future. Our sincere appreciation goes to all those who have helped develop this system, who will help us continue to improve it, and who will be using the system to create a better world through sustainable infrastructure.

1.2 | **PRODUCED RESEARCH**

William J. Bertera
President and CEO, Institute for Sustainable Infrastructure (ISI)

Planning for sustainable infrastructure has been practiced for decades, though often in a context in which the word "sustainability" has rarely appeared … until recently. Planners, engineers, architects, contractors, and public administrators have, nevertheless, been planning, designing, constructing, operating, and maintaining civil infrastructure using best practices that promote efficiency, safety, longevity, cost-effectiveness, and community values and priorities.

Many of these best practices also promote sustainability as we have come to define it, but none assure that sustainability as a strategy, objective, or goal is considered routinely in the development of civil infrastructure. When it has happened historically, it has occurred as a fortunate by-product of good planning or engineering. But the world is changing, and sustainable infrastructure is no longer, if it ever was, only a choice or a happenstance.

Population growth, its uneven distribution, increasingly taxed natural resources, the sensitivity of the natural world to external alterations, unpredictable weather patterns, and the challenges posed by the threat of global warming and attendant climate change all make doing business as we have in the past untenable. Planning civil infrastructure has become more complicated still. Our infrastructure's claim on resources, its effects on the environment, its contribution to the creation of societies where humans can live in comfort and dignity have magnified and made more obvious its importance.

Infrastructure generally, civil infrastructure in particular, provides for personal security, the public health, economic stability, and quality-of-life benefits. It makes possible concentrations of people in dense environments and the transport of materials and people in pursuit of commercial and social goals: in short, it makes modern societies possible. That this infrastructure be sustainable, that the decisions associated with its planning, design, construction, and operation also be sustainable, i.e., justifiable in the context of an increasingly taxed natural world, has become an essential and critical element of the planning function.

The Brundtland Commission articulated a definition for sustainable development in 1987 that embodies the spirit of the challenge; phrased loosely, "do as little harm as possible and remember that our children walk in our footsteps." In truth, sustainability, especially as it is applied to our civil infrastructure, is a way of thinking about the future more than a precise formula of how to create or reach a precise goal. In this context, what we build is at least as important as how we build. In a world without limits, without scarcity, without diminishing natural resources, without environmental challenges, there are neither reasons nor incentives to preserve and protect. We no longer live in such a world.

If thinking about sustainability has now become a conscious necessity in the development of civil infrastructure, we need tools to help assure that sustainability is not just a random outcome but a planned outcome. The Zofnass Program for Sustainable Infrastructure at the Graduate School of Design at Harvard University in partnership with the Institute for Sustainable Infrastructure (ISI), a Washington-based not-for-profit organization, have developed a tool called Envision® to help planners, engineers, political scientists, sociologists, contractors, and public officials produce civil infrastructure that is demonstrably and intentionally sustainable.

While Envision® can be used to help make single infrastructure projects more sustainable, its more important application may be in its ability to link whole families of infrastructure projects of different kinds into a community-wide web of sustainability. In this context, Envision® is a very powerful planning tool, especially when applied at the early stages of project or community planning.

Although the tool is most productively applied at the early stages of development, it is applicable at any point in a project's life cycle. This is critical because of the extended life cycles of much of our civil infrastructure. Bridges and sewer systems, designed for much shorter lifespans, not infrequently are in use seventy-five and even one hundred years after construction. During the course of its lifespan, all infrastructure undergoes repairs, alterations, rebuilding, and operational changes. Best practices are improved, new materials and processes are developed, and resource and environmental changes occur. Civil infrastructure is not static, nor are the circumstances or communities in which it is located.

The concept of what constitutes sustainability is changing. What was considered sustainable fifty years ago might not be today; the same will be true fifty years hence. Envision® allows us to take advantage of new information and changing priorities every time we consider altering a piece or system of infrastructure. The tool is not prescriptive, however. It encourages the application of local solutions that reflect community values, priorities, and resources. In this context, it recognizes that infrastructure is about more than engineering and design and construction. It is also about a host of other, sometimes difficult-to-quantify variables.

The triple bottom line is an articulation of some of those most important variables. It includes the trifecta of social, economic, and environmental needs and aspirations that are embedded in every decision associated with an infrastructure project ... but which often are not manifest at the point of procurement for lack of a way to measure their importance and to monetize that evaluation in a set of costs and benefits reflected in a return on investment.

Returns on investment are a clear measure of success in the private sector, and cost/benefit valuations matter as much in public-sector infrastructure projects as in those for the private sector. Sustainability is a positive public good, but doing good is not enough when there are more needs than resources. There have to be commensurate benefits, those benefits must be clear, and they must be financially obvious. Sustainability can cost, but it can also deliver financial rewards. The Envision® tool helps decision makers evaluate both costs and benefits at the critical point of procurement, where it matters most.

Importantly, Envision® is a web-based tool available in the public domain. There is no charge for its use. It is easily accessible to both public- and private-sector users. The program itself has several parts, but the most important aspect of the program is its intention. Both Harvard University and the Institute for Sustainable Infrastructure have a goal of making a usable tool available to decision makers to help them create, construct, and operate more sustainable infrastructure projects.

The tool itself comes in two forms. The first is an easy-to-use checklist that requires little time or experience to use and is best applied to test the sustainability of large projects or for use on small projects where quick, easy, and inexpensive analysis is desired. The second and more comprehensive form is an extensive web-based self-assessment worksheet that can require extensive time and experience for its most productive use. ISI provides a web-based course, for a fee, that helps users better apply Envision® and which includes a web-based exam, the successful completion of which results in a professional credential (ENV SP). In either instance, there is a comprehensive user's manual that is also free of charge and can be downloaded.

Although the tool is intended primarily as a self-assessment evaluation for project planners, ISI also offers a Project Recognition and Awards Program to acknowledge successful levels of achievement for those self-assessments submitted for verification by third-party reviewers employed by ISI. Self-assessments and evaluations alike are conducted using sixty different best practices, though not all of the credits are applicable to every project. An important aspect of the awards program is that it is an evaluation of the application of the Envision® tool to the project, not an evaluation of the project itself.

The self-assessments are conducted within five broad categories: Leadership, Quality of Life, Resource Allocation, Natural World, and Climate and Risk. The intention is not to force any particular prescriptive outcome, but to help planners organize their thinking to consider sustainable concepts at every stage of a project's development, and to cause a reassessment of existing best practices in the context of new circumstances, materials, concepts, and priorities.

Envision® was originally designed as a rating system, a way to systematically evaluate both existing and planned projects for their sustainability or their sustainability potential, and it can be used in that way. But it is also a very powerful planning tool that can be used to embed sustainable thinking into each and every decision point in the development of a project. Beyond even this application, it has significant potential for public administration and even good government.

Infrastructure development, sustainable or not, is a complicated subject. It is difficult to capture the public imagination with projects whose costs and lifespan are out of proportion to the daily human experience of most voters and taxpayers. Envision® creates a language with which to talk about these complicated subjects in a way that those most affected by them can understand and appreciate. In this sense, Envision® has the capability of elevating the public dialogue and ultimately changing the priorities used to allocate scarce public resources. In a global community where infrastructure of all kinds is a critical differentiator in commercial competitiveness, this is no small accomplishment.

Although initially available in the United States and Canada, Envision® was developed for the global marketplace. Its flexibility and reliance on accepted best practices make it universally applicable.

1.3 | EXPANDING ON CITY-SCALE RESEARCH

Spiro N. Pollalis
Zofnass Program Director
Professor of Design, Technology and Management at the Harvard Design School

The Zofnass rating system for sustainable infrastructure and subsequently Envision®, the evolution of our system as developed by ISI,[1] are toolkits for the various stages of a project, including the very first steps of the decision-making process, before even the engineers start designing. The intention has always been the selection of the best and most suitable type of project for solving the problem at hand. Making sustainable the particular design of a project is the next, equally important consideration.

Our rating system gains built-in flexibility by separating the aspects that define the sustainability of a project. These aspects are (a) the impact on the natural world, (b) the use of resources, (c) the relation to the risks of climate change, and (d) the impact on quality of life. A fifth aspect, the commitment of the leadership to sustainability, is evaluated in terms of the development and implementation of sustainable features. All five aspects are individually rated in order to be able to identify the project's sustainability in each section. The sum of the individual ratings provides the total sustainability rating of the project.

Because of its structure, our system serves as a guide in the early planning stage toward making the right decisions to ensure the sustainability of a project. Using it in a reverse process, it provides "planning guidelines" toward a sustainable project and thus achieving the highest rating in our system. Furthermore, the training of specialists to become Envision® Sustainability Professionals (ENV SP) gives ample understanding of fundamental sustainability concepts and guides them toward making the right decisions in a project.

Having completed the rating system for infrastructure projects, the next research effort in the Zofnass Program was the sustainability of entire cities, quite expected for a research program in the Harvard Design School with its legacy in urban planning and urban design. In addition, it was a time when members of the Zofnass Program were actively involved in planning new cities, with a strong desire to plan sustainable cities but without having tools that offered objective and measurable processes.

There is a significant need for expansion of cities and the development of new cities. Both the increase of population and the concentration of people in cities drive the need. Pakistan, for example, sees an annual population increase of more than 3.5 million people. A large part of them will live in cities, and the existing cities lack both amenities and capacity. Even while many people will remain in rural areas, we can conclude that there will be a need for another Karachi in less than ten years!

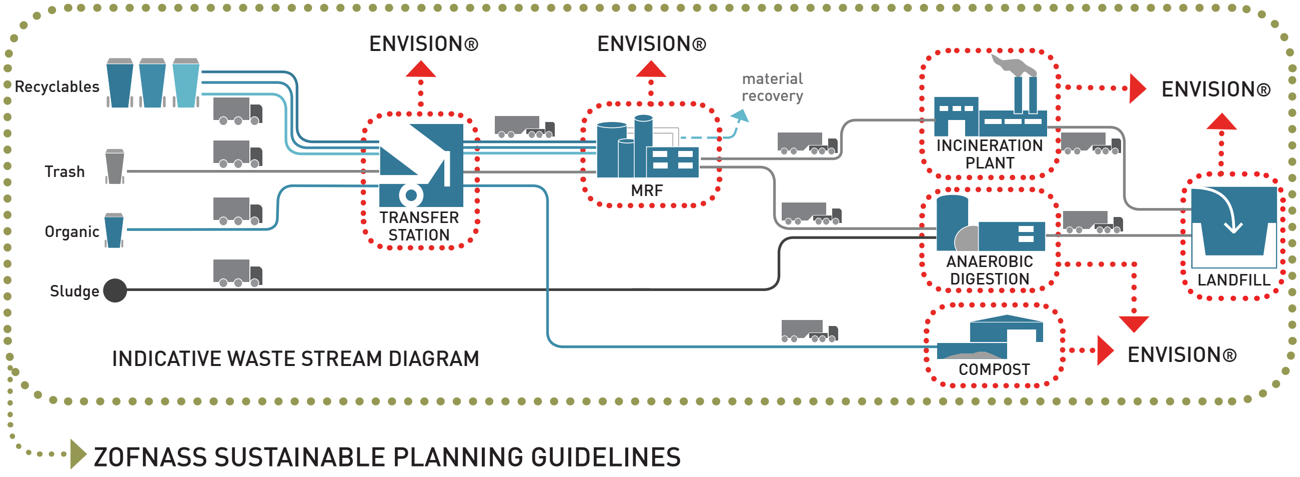
However, creating new cities and major expansions to old cities is only half the story. The planet cannot support more people living the way we live today, and has even less capacity to withstand the current trajectory of growth. A sustainable way of life is a must, and cities provide amenities at a cost of fewer resources and less damage to the natural world and the environment at large. An increased percentage of the population living in cities is a step in the right direction. The next decisive step is the development of sustainable cities.

Cities are made of infrastructure and buildings, so a first approach to the sustainability of cities might focus on individual sustainable buildings and sustainable infrastructure projects. Such a simplistic approach is not sufficient, however, as it bypasses the systemic relationships not only within infrastructure but also among the infrastructure systems and buildings. Such a systemic approach has been advanced over the last 20 years in discussions with leaders of architectural and engineering firms at Harvard University, focusing on a systems approach for better planning and higher efficiency.

At the Zofnass Program, the completed rating system for sustainable infrastructure projects was set as the point of departure for assessing the sustainability of cities. Its overarching approach addressing the essence of environmental, social, and economic sustainability, combined with its flexibility for application to diverse types of projects, made it suitable for the big picture.

The decision was made to consider the sustainability of each infrastructure type at a systems level. The seven types of hard infrastructure had been defined in the Zofnass Program as Transportation, Energy, Water, Solid Waste, Landscape, Information, and Food. The decision to consider them separately eliminated undue complexity, while not precluding integration later. This should not be seen as a different methodology from Envision® which does not distinguish the types of infrastructure. Envision® applies to a single project, while at a city level we consider

ZOFNASS PLANNING GUIDELINES IN RELATION TO ENVISION® RATING TOOL



entire infrastructure systems consisting of many projects.

An example of the approach is shown in the graph above for Solid Waste infrastructure. Envision® applies to the individual projects: transfer stations, material recovery facilities, incineration plants, anaerobic digestion, compost, and landfills. However, the sustainability of the city is based not only on the sustainability of each project (and building) but also on the overall planning of the entire infrastructure system and its own sustainability.

In the planning of infrastructure systems, we identified four "system levels," consistently applicable to all seven types of infrastructure. The first level addresses the system's end users and their demand. The second level refers to core strategic decisions. The third and fourth levels address the facilities and operations as prescribed by the strategic plans of the second level. The larger facilities, functioning as nodes and feeding into the infrastructure networks, constitute the third level, while the networks that cover the spatial distribution needs of the infrastructure are the fourth level.

For each infrastructure type and for each of its four system levels, we analyzed the sustainability dimensions and we proposed objectives, planning guidelines, and actions.

After the systematic analysis of the infrastructure systems, we focused on the synergies and interdependencies among them. Energy and Water are directly related. Transportation and Energy are also related. Information is related to all other types of infrastructure. Thus, we concluded this part of the research by providing synergistic planning guidelines leading to an integrated model of the entire infrastructure of a city, as it should be.

The detailed methodology is presented in section 3.2, while the seven infrastructure types are presented in chapters 4 to 10. This book adopts an integrated model, so the synergies are part of each infrastructure system and not an add-on. The objectives, planning guidelines, and actions have been applied to the two cities planned by members of the Zofnass team, with their planning not immediately related to the research itself. These two cities serve as examples of the applicability of the methodology (chapters 11 and 12).

The Planning Guidelines link the buildings to the infrastructure of the city, not only as consumers, as in the current planning guidelines, but also as suppliers of services (i.e., nodes in level three). In the Program's future research, buildings will also be subject to rating using an adapted version of the Envision® credits on how well they fulfill their sustainable role, very much as the infrastructure facilities in the diagram above are rated using the current version of Envision®.

NOTES

1. For the remainder of this essay, we will not distinguish between the Zofnass rating system and Envision®

Photograph by Eleonora Marinou

Planning Infrastructure

Chapter 2

2.1 | CHALLENGES IN INFRASTRUCTURE PLANNING AND IMPLEMENTATION

Spiro N. Pollalis
Zofnass Program Director
Professor of Design, Technology and Management at the Harvard Design School

Our approach considers sustainable infrastructure as a starting point for sustainable cities. The overall city planning must support sustainability, and the individual buildings must be sustainable to help lower the demand on the infrastructure systems. The challenges in starting with infrastructure lie in its interrelations to city planning and to the city's buildings, in the need for sustainability both in new and existing cities, in addressing resilience, and in securing financing.

Sustainable Infrastructure and City Planning

The planning of infrastructure is an integral part of the overall planning. Infrastructure requires space. The size of infrastructure systems depends on the demand from the city's occupants, which translates to the demand from buildings and from the other infrastructure systems. For the cities of the past, it can be argued that this was an ordinary linear process. However, it becomes an iterative nonlinear process in planning sustainable cities, as shown in the next page graph. Preliminary planning data and sustainability considerations drive the initial decisions related to the required infrastructure. Then the infrastructure data and sustainability decisions become part of the planning process and more detailed data are extracted and feed the planning of infrastructure, always under the prism of sustainability and finance. The synergies among the infrastructure systems introduce another level of iterations for even more optimal planning. After the needed iterations and the necessary changes in assumptions and decisions, the system reaches equilibrium, meeting planning, sustainability, and financial objectives. The process is complex and is driven by the expertise and values of the stakeholders. The Zofnass Planning Guidelines do not directly address spatial planning. However, they can serve as a framework and a tool to help the stakeholders work together.

In the outcome, infrastructure systems take a large area of the city, so process integration is a must. The road network takes an average of almost 30% of the city's area. Public open space is rarely lower than 10% and often much more. Energy and water treatment facilities take significant space. Infrastructure networks also take underground space and elevated space. Crossing networks requires special attention. Equally important, the location of infrastructure facilities has an impact on city planning, based on their required proximities to buildings and other infrastructure facilities for efficiency and effectiveness.

The planning of infrastructure systems in a city is like what engineering is in architecture. In buildings, structural and mechanical systems define and require space and cannot be seen as separate from architectural design. In ordinary buildings they were beginning to seem an afterthought. Recently, on the other hand, with an increasing demand for sustainable buildings, engineering systems and especially mechanical systems have been integrated with architectural design and often drive design decisions, both for mechanical solutions as well as in using building physics.

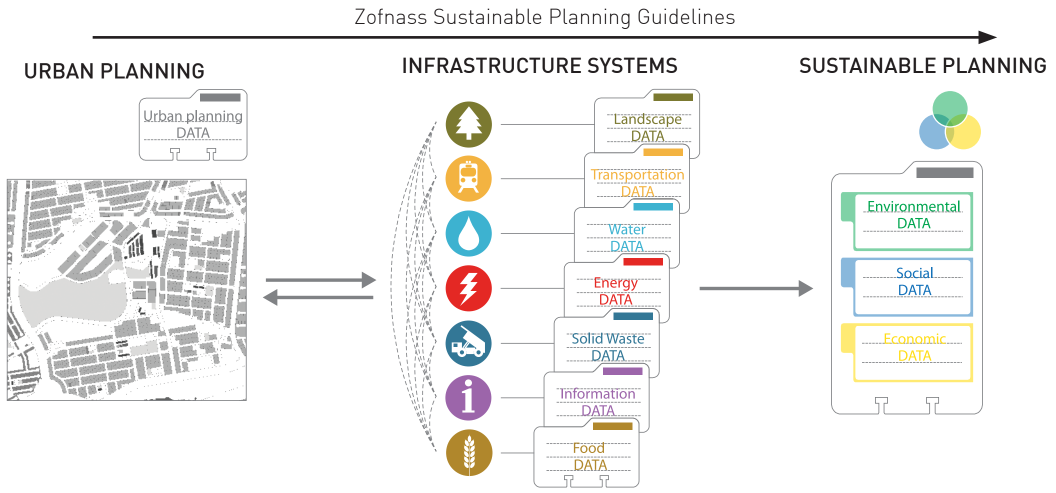
Similarly to the way a truly sustainable design is an integral part of the architectural design, truly sustainable city planning is an integral part of city planning. City planning sets the upper boundary of what is possible for all five sections of the Envision® assessment: (a) Quality of Life, (b) protection of the Natural World, (c) responding to the risks of Climate Change, (d) Resource Allocation especially during operations and (e) Leadership.

Planning Guidelines in Existing Cities

In the western world, new cities are infrequently planned. Instead, the focus is on city expansions and on upgrading existing aging infrastructure systems. The Zofnass Planning Guidelines are equally valid for making decisions to improve the sustainability of existing cities. However, the existing conditions define the latitude of options for the planners. The four levels of infrastructure systems provide an insight for each infrastructure type into what is possible and under what circumstances.

The first system level defines the demand for each type of infrastructure system. The demand for energy and water is higher for an existing stock of buildings of older technology and, in the large scale, upgrading the buildings can slowly reduce this demand. Demand for transportation is also difficult to reduce once the choices of prior urban planning have been made. The demand for solid waste handling is more flexible as it depends less on fixed assets. Analogous observations can be made for all seven types of infrastructure systems.

EXPANSION OF RESEARCH TO CITY SCALE



The second level defines the strategic decisions for the infrastructure systems. Plenty of interventions can be made at this level. Decisions for the development of new energy sources, for more efficient water treatment plans, for switching to public transportation can be made with manageable consequences for the existing urban fabric. Strategic decisions on sustainable infrastructure can also be implemented within the urban fabric or in the hinterland of the city. Within the urban fabric, they are bound by the available space, and implementation usually has a higher cost than in new cities. On the other hand, for nodes in the hinterland, the difficulty lies with remoteness and the added requirements of transport.

The third level defines the nodes of the infrastructure systems. Usually nodes can be upgraded as they take up limited space. IT centers, transportation stations, power production units, and material recovery facilities are in this category.

The fourth level defines the network of the infrastructure type. These are usually more complicated to upgrade as access may be difficult or there may be no available space for expansion. Water pipes, electric power distribution networks, railroad tracks, and roads are in this category.

Despite the external constraints on interventions to make existing cities more sustainable, the Planning Guidelines still provide a basis for considerations and actions. On the positive side, there are beneficiaries in existing cities who demand that their cities be more sustainable, and they can undertake the financial burden, either through taxation or with pay-as-you-go models of public-private partnerships.

Planning Resilient Cities

Defining resilience as the ability of a system to retain processes and performance by adapting to change and dealing with undesirable events, the Planning Guidelines ensure the resilience of the infrastructure systems in the sustainable city.

The Climate and Risk section of the Envision® credits addresses the risks associated with climate change, namely extreme weather conditions leading to both scarcity of water and flooding and sea level rise. The Planning Guidelines, based on Envision®, caution and specify actions to face such conditions and address the security of supply to retain processes and performance by adapting to change and dealing with undesirable events. However, resilience is also needed for non-climate-induced disasters, such as earthquakes, oil spills, and fires. The Envision® credits address these at a higher level of abstraction. The "innovation credit," the last credit in each section, pushes the stakeholders to think proactively and address potential disasters before they happen.

The Planning Guidelines address social resilience indirectly through the sections on Quality of Life, the Natural World, and Leadership. Prudent planning reduces social stresses. Envision® and the Zofnass Planning Guidelines have the ingredients to effectively address resilience. However, further research is needed to provide a complete framework of guidelines on ensuring resilience to cities.

Financing Sustainable Infrastructure Systems

The Planning Guidelines, as presented in this book, do not address financing, which is central to any project. The overarching approach is to define the technical approach first and then introduce financial considerations. In any case, the question is not whether we should plan sustainable infrastructure systems but their optimal form based on a series of considerations including financing, especially since preliminary studies show that sustainable planning increases a project's longevity and costs less over the life cycle of a project. The link of the Planning Guidelines to financing is a subject for further research.

2.2 | FINANCING SUSTAINABLE INFRASTRUCTURE

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With governments cutting back on infrastructure spending due to budgetary constraints and banks tightening on credit, infrastructure investment has declined sharply. According to data from McKinsey & Company and the World Economic Forum, an estimated $57 trillion will be needed to finance infrastructure development worldwide between now and 2030.[1] This amount does not take into account the cost of repairing existing infrastructure, renewal backlogs, or increasing infrastructure's resilience to the impacts of climate change. In Latin America and the Caribbean (LAC), the shortfall is enormous, with an annual need of over $250 billion of investment for the next few years.[2] According to research from the OECD, the existing amount of paved road and railroads in the region is just 25 percent of what it should be expected given the region's socioeconomic characteristics.[3]

Latin America has become the most urbanized of the emerging market regions, with 80 percent of the population already living in cities and the proportion expected to rise to 90 percent by 2050.[4] According to the UN Population Division, Bogotá (Colombia) and Lima (Peru) will have more than 10 million inhabitants by 2030, joining the four current megacities of the region: Buenos Aires, Mexico City, Rio de Janeiro, and São Paulo.[5] In this context, existing infrastructure is not only unable to meet current and future needs, but it is under considerable strain causing costly bottlenecks, shortages of services, and environmental problems. Increasing the resilience of the region's urban infrastructure will be critical to improve quality of life and social inclusion in cities.[6] Infrastructure investment in the LAC region exceeded 3 percent of GDP in the 1980s, but since then it has declined sharply.[7] To plug the existing infrastructure gap, it is estimated that the region should invest around 5 percent of GDP per year, compared to the 1.7–2 percent that is currently being invested.[8] This funding shortfall has notable implications for economic growth, competitiveness, and social well-being.

At a time of fiscal restraint and weak debt and equity markets, tapping private capital is essential to bridge the gap between available public funds and necessary infrastructure investments. Public-private partnerships (PPPs) can be a way to generate and harness synergies, leverage financial resources, and use the expertise of the private sector in designing, building, and operating infrastructure across the life cycle. However, regulatory changes under Basel III have established higher capital reserve requirements and tougher liquidity standards, discouraging traditional long-term bank lending to infrastructure projects. This poses a major challenge for infrastructure financing, but it also creates an opportunity for new players to fill the funding gap. Long-term, nontraditional lenders such as pension funds may be a good match, given their long-term liabilities and the long-term cash flows of infrastructure projects. According to *The Economist*, these institutional investors are well resourced and have over $50 trillion to invest, but only 0.8% of their assets are currently set aside for these projects.[9]

To attract capital from these lenders, it is essential to understand their risk-averse nature and the need for stable and reliable cash generation at a project level. Some incentives that can entice institutional investors into funding projects include a clear and predictable regulatory framework that is able to outlive a particular government, greater transparency in the allocation of resources, bankable key project contracts with clear allocation of responsibilities, as well as visible and reliable information on performance expectations. Financing structures can also be adjusted based on timing of investor's participation in order to best address its risk appetite. In this sense, guarantees could be considered during construction phases, or during operations, covering certain risks. Also, projects could be structured with governments taking on the riskier elements and leaving the more stable part for the private sector to finance.

Sustainability may also be part of the equation. According to the international financial services holding corporation State Street, increased awareness of environmental, social, and governance concerns is influencing more and more the investment decisions of institutional investors.[10] Although it is perceived to make infrastructure projects more costly, sustainability can de-risk infrastructure projects, enhance performance, and provide better risk-adjusted returns in the long term.[11] To underpin tomorrow's economic growth, we have to adapt today's infrastructure to the impacts of climate change. For this reason LAC countries should not only invest to increase their stock of infrastructure, but also in innovative solutions to promote cross-sector synergies, increase resilience, improve the quality of infrastructure services, and boost their positive impacts on social inclusion and poverty reduction.[12] Unpredicted extreme weather and geophysical events pose a major challenge to the region's highly vulnerable infrastructure. Unless current trends are reversed, carbon dioxide emissions in the LAC will increase by 60 percent through 2050, entailing a cost of up to 2.5 percent of GDP.[13] To mitigate climate change, the region has to develop a sustainable economy with a low-carbon infrastructure network that reduces greenhouse gas emissions and ensures energy efficiency. Projects should be designed and implemented based on the concept that infrastructure is an asset that must be properly built, managed, and maintained.[14] Mainstreaming sustainability into infrastructure planning, design, construction, and operation may also reduce project risks through increased transparency, stakeholders' involvement, inclusive practices, innovation, and leadership. Hence it may contribute to further attract much-needed long-term sources of funding.

NOTES

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2.3 | SYNERGIES AND SUSTAINABLE INFRASTRUCTURE PLANNING

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In the context of urban infrastructure, one plus one often leads to three, four, five, or more. This implies that the conventional way of seeing infrastructure units in relative isolation has underappreciated their connections, interactions, and effects on the larger array of infrastructure components. This long-standing isolationist approach is characteristically conveyed by the typical characteristics of siting decisions and planning or design requests for proposals (RFPs). Until recently, did we ever see wastewater treatment facilities proximate to the energy utilities that could use their cooling discharge water or that considered distances for transport and disposal of sludge? Did conventional highway plans and designs pay much attention to stormwater quantity or contaminant impacts on water treatment facilities, much less the placement, capacity, and future demands for schools, shopping, or energy utilities in newly accessible but undeveloped areas? And what about quality-of-life implications from urban sprawl begetting increased commute times, noisy trucks carrying sludge through residential neighborhoods, or parklands cut off by highways from pedestrian or bicycle access?

In this era of growing interest in and sensitivity to urban sustainability, we could quickly take a narrow approach and focus merely on localized resource or energy efficiencies and reduced environmental impacts. These changes are good things—increased use of recycled or reusable materials, increased energy efficiency, better contaminant containment and treatment, etc. But these are a step removed from comprehensive, integrated infrastructure planning and design that accepts the premise that there are inevitable, inextricable, and multiple interactions and potential connections between the infrastructure systems of Energy, Waste, Water, Transportation, Landscape, Information, and Food. Even further, these infrastructure systems have significant interactions and impacts on other dimensions of urban communities—education, health, recreation, and commerce, to name only a few.

It may be easier to grasp the significance of synergism in infrastructure if for a moment we shift our attention from civil works to the human body. We instinctively understand that the body is an integrated system. All parts are interrelated and interdependent. Each finger is connected and interrelated both materially and functionally to virtually every other part of the human system, with obvious neurological, sensory, cardiovascular, and even psychological connections. Simply put, we can scratch behind our ear, feel and respond to a splinter, understand how cold it is, and shake hands warmly, all through the activity or sensory dimensions of an index finger. Today's spicy meatball and double dose of wine may become tomorrow's headache, indigestion, and heartburn. This morning's missed stretches may be the forerunner of this afternoon's backache and stress. The rapid adoption (at least in western developed cities) of healthy diet and exercise materials, training, and resource "infrastructure" is a direct result of the correlation that has been accepted between healthy lifestyles and longer, more vital lives. I suggest we think about infrastructure in a similar organismic fashion, appreciating that our transportation, waste and wastewater, and other civil infrastructure are basically the circulatory, digestive, and skeletal systems of society. At the level of body we easily experience that health, vitality, and longevity are optimized when each system is healthy and when the relationships between them are in balance. Can we take a similar synergistic approach to infrastructure systems?

Such an approach will ensure that discrete elements within the urban infrastructure function to their highest and most efficient potential individually and in relation to all other infrastructure components. Synergies are seen as two-way associations between different systems. Within infrastructure categories, each infrastructure component is intended to be managed as an integrated element within its extended system. Perhaps even more significantly, persistent attention is paid to the functional relationship between infrastructure types, which are therefore considered subsystems of the city. This necessarily requires extensive cross-disciplinary understanding and dedicated attention to design, planning, and operations that are interwoven, aligned, and complementary.

Infrastructure systems are consumers of resources themselves, but mainly managers and providers of resources and services for their end users. How they fulfill these functions is as important as the fact that they do. Integrating flows and components between the different infrastructure systems is necessary to achieve efficiency, resilience, quality of space, and growth. This is even more pressing given rapid global urbanization. We must reflect on the fact that almost half of today's global population is living in cities, a trend that continues to accelerate. Therefore the role of urban infrastructure systems becomes even more critical to supporting healthy, functional human societies, avoiding harmful pollution and environmental degradation, and strengthening resilience and adaptive capacity against seemingly more frequent and powerful natural calamities. The performance and stability of infrastructure is the backbone of the operation and development of cities, affecting the availability and allocation of resources and health, social, and surrounding natural conditions. This requires integration on multiple levels, transforming practices of urban planning and engineering, the decision-making processes of stakeholders, and harmonization between natural and built systems and of course between infrastructure elements themselves.

By now we have largely accepted the principle of avoiding, minimizing, or mitigating the adverse environmental effects of human works. Environmental impact assessments, protection plans, and strict regulatory or permitting requirements are a fact of engineering and planning life. The further step will be adapting the management of infrastructure systems to the needs of the natural systems themselves by seeking opportunities for restorative, genuinely symbiotic, and even mutually enriching interrelationships. Beyond the aspiration for an ecologically grounded humanity, enhanced adaptation of infrastructure to its related natural systems typically contributes increased resilience and efficiency and reduced need for new infrastructure.

One further dimension is worth mention. While infrastructure may generally reside beneath the consciousness of most citizens, in recent decades stakeholders and citizens have increasingly been active protagonists in infrastructure-related controversies. The spheres of "not in my backyard"—prospective adverse effects on property values, human health, aesthetics, and the natural environment—have all illuminated the important relationship between citizens, governments, engineers and planners, and the laws or regulations we construct to define them. Whereas in the past, the responsibility of proponents and designers may have given nodding acknowledgment to these citizen interests, they have often been framed as "interveners" (read that as "getting in the way") or opponents, with public consultation and engagement generally viewed as merely a necessary hurdle. In the past decade or more, this view has generally and radically evolved, to the point where stakeholders are occasionally if not regularly considered constructive collaborators. This synergy can actually contribute to better projects, to doing projects right and only the right projects.

If a synergetic outlook is now a fundamental of good practice, we have long needed a transparent, commonly communicated and readily understood language and framework for addressing issues, options, and choices. The integrated framework outlined herein goes a long way to meeting this need, in part by recognizing that city planning and infrastructure planning should be performed in parallel. Land use planning determines the end users and their needs for services and resources that infrastructure should supply. Similarly, the requirements and characteristics of infrastructure affect the configuration, form, and structure of the urban fabric. These may both have immediate effects and substantially influence future prospects and directions for development, settlement, and community quality of life. The quality and type of services provided by infrastructure can therefore influence and even determine the financial development and social environment of a city.

In sum, a synergistic approach to infrastructure planning intends to improve or facilitate the function of other systems by reducing the initial demand of other systems, connecting by-products and feedstock needs, optimizing placement of entities, combining entities, and mitigating negative impacts of processes. Planning analysis should prioritize integrated, systemic, and high-level planning while advancing the crucial issues of each system. This typically leads to engagement with a broad range of interrelated issues, since city systems depend upon their interconnectivity to function.

Addressing these complexities will require extensive and detailed cross-disciplinary understanding of multiple issues, across multiple domains. All infrastructure systems are interconnected through synergies, but some have a stronger and inherent synergetic nature which will be explored in subsequent chapters. The important work of the Zofnass Program highlights and is addressing these implications, which are at the core of its objectives and methodologies as it works to understand, map, and create tools to optimize systemic synergies at the city level.

PART 2

SUSTAINABLE INFRASTRUCTURE PLANNING GUIDELINES

Part 2 is the core of the book. Chapter 3 describes the scope and methodology of the research that led to this publication, and serves as a manual guiding the reader through the book. Individual chapters are then dedicated to the infrastructure systems of Landscape, Transportation, Water, Energy, Solid Waste, Information, and Food. Each chapter discusses the basic sustainability challenges and principles for that system, and concludes with Planning Guidelines organized in tables.

General Framework

Chapter 3

3.1 | **SCOPE**

This book provides an analytical framework for achieving urban sustainability, focusing on the services and the performance of infrastructure systems. The concentration of people and economic processes that defines the urban condition requires the sustaining of continuous and reliable flows of resources; infrastructure is the backbone of these flows. Urban planning and infrastructure development are intertwined. Planning determines the end users and thus the demand for services and resources that infrastructure should respond to. On the other hand, the space requirements and distribution of infrastructure facilities and networks affect the configuration of urban areas and the morphology of the urban fabric. Planning and infrastructure development should proceed in parallel to ensure efficiency, high living standards, and resiliency. Urban concepts like mix and distribution of land uses, density, compactness, and centralization versus decentralization need to be negotiated in terms of the infrastructure concepts of services demand, system hierarchy and distribution, efficiency and effectiveness, supply chains, and routing of networks.

Infrastructure systems are mainly considered to offer *provisioning* services covering specific demands for energy, water, food, mobility, information, etc. However, the complex and heterogeneous processes affected or set in motion by urban infrastructure call for the consideration of *regulating* services as well. Examples include the control of contaminants, the preservation of habitats, and protection against extreme phenomena. At the same time, infrastructure is very much present in the public space, constantly interacting with communities and creating the framework for their development. This signifies the *sociocultural* as a third type of service that should be covered by infrastructure planning. Infrastructure configuration has the ability to affect quality of life, promote different lifestyles, and form consumer habits. For example, the available transportation and telecommunication options create interfaces for the interaction of individuals and groups, while the options for waste management can change how consumers use and dispose of materials and products. It is crucial for infrastructure planning to identify and respond to the needs for all three types of services: provisioning, regulating, and sociocultural.

Urban infrastructure in this book is organized into seven basic systems: Landscape, Transportation, Water, Energy, Solid Waste, Information, and Food. Classification does not mean separation; the approach is intended to be a first step toward high-level, integrated planning. The next chapters approach urban infrastructure as a series of systems that should function in synergy and be directly linked with urban planning. "Infrastructure system" in this context includes not only physical structures but also operations, procedures, administration, bylaws, natural processes, and not least the end user. The aim is a collaborative and integrated planning process, an enabling framework that will help identify choices and opportunities, help guide decisions, and justify the final choices while offering simplicity and flexibility in the context of urban complexity.

LANDSCAPE INFRASTRUCTURE

Landscape infrastructure is the system of open spaces inside and around the city, offering a wide range of services tailored to the needs of the specific context. Landscape differs from the other infrastructure systems as it is not defined by its response to a specific demand. It is an alternative, soft, flexible infrastructure with the inherent potential of multifunctionality. Landscape adds to local identity, offers opportunities for recreation, supports habitats and natural processes, provides water, food, and material resources, mitigates and compensates for the negative impacts of other infrastructure systems, and increases city resilience against natural and man-made threats. In the context of this book, Landscape infrastructure is the key tool for protection against coastal, river, and storm flood risk. It is imperative for sustainable urban planning to manage the system of open spaces as components of an integrated system, configured to offer targeted services. The boundaries of this system are flexible and should be defined after careful analysis and study of natural connections, flows, and the city's needs. For example, the need to improve water quality can expand the Landscape system to include the city's watershed.

TRANSPORTATION INFRASTRUCTURE

Transportation infrastructure includes the facilities and processes in place to serve the mobility of passengers and freight. It is a basic catalyst for development, as it is closely interrelated with urban and rural economies. Its strong physical presence and the resulting large footprint create a range of challenges: it creates connections, but often also creates unintended barriers in the natural world and local communities. Sustainable Transportation infrastructure should therefore aim to avoid, minimize, and compensate for negative impacts on individuals, communities, and ecosystems in the process of its inevitable expansion to meet increased user demand. It is important to stress that sustainable transportation cannot be seen independently of sustainable urban development. The configuration of the road network, in particular, has a direct impact on the morphology of the urban fabric. Collaborative planning efforts should emphasize defining land use distribution, density, and compactness to support optimal transit options.

WATER INFRASTRUCTURE

Water infrastructure provides for the treatment, collection, and distribution of potable water, rainwater, and wastewater. The availability of potable water and the management of wastewater are, historically, key factors in the establishment and development of human settlements. Water infrastructure both extracts water from the natural world and returns it with minimum impact. So, in addition to securing and optimizing the performance of networks and facilities, sustainable Water infrastructure planning should include watershed and natural processes management, aiming to actually reduce the built infrastructure required. Control of contaminant sources and recharging of groundwater are part of the Water infrastructure, along with striving to reduce overall water consumption instead of just providing for it. Offering natural drainage and harvesting strategies for rain and stormwater management is another key function, particularly in urban environments where extensive water-impermeable surfaces are found. The planning for expansion of urban areas within the watershed, the distribution of land uses, and the configuration of urban fabric and surfaces should take into consideration their impact on Water infrastructure performance.

ENERGY INFRASTRUCTURE

Energy infrastructure manages and converts available natural resources into energy carriers like electricity, heat, and fuel, delivering them to end users. Energy security is fundamental for quality of life, economic development, and by extension social stability. Energy generation, however, is currently the leading source of greenhouse gas emissions worldwide. This has brought energy to the forefront of efforts for sustainability and resiliency. Sustainable Energy infrastructure should, therefore, secure constant and equal access to energy carriers for all individuals and businesses, while promoting rational use and efficient practices. It should use natural resources within the environment's regenerative capacity, providing renewable and low-emission alternatives.

SOLID WASTE INFRASTRUCTURE

Solid Waste infrastructure includes all the processes and facilities required for the collection, treatment, and final disposal of waste. Practices that largely depend on landfilling as a means of final disposal, however, have significant social and environmental impacts. Planning should therefore focus on source reduction but also on developing strategies that treat solid waste as a valuable resource. Waste management should be structured in close synergy with the supply chains of other systems, catering where possible to their needs for energy and materials. Waste has strong social and political dimensions as it is closely related to the production and consumption patterns and potential of a society. Engaging consumers in developing habits that will support the objectives of source reduction and diversion from landfills is therefore essential.

INFORMATION INFRASTRUCTURE

Information infrastructure supports the flow and processing of information. It consists of different subsystems that people and organizations use to produce, collect, filter, process, and distribute data. It can be characterized as a "next-generation public infrastructure" supporting human operations, decision making, and action. In recent decades, the availability of solid and high-capacity Information infrastructure has emerged as a cornerstone for growth and high-quality services. This book uses a twofold definition of information as infrastructure: first, it is approached as infrastructure per se, including telecommunication and internet services, and second, as a support system of all other infrastructure systems, to interconnect and assist them in achieving high performance. As such, Information infrastructure is flexible and inherently synergistic.

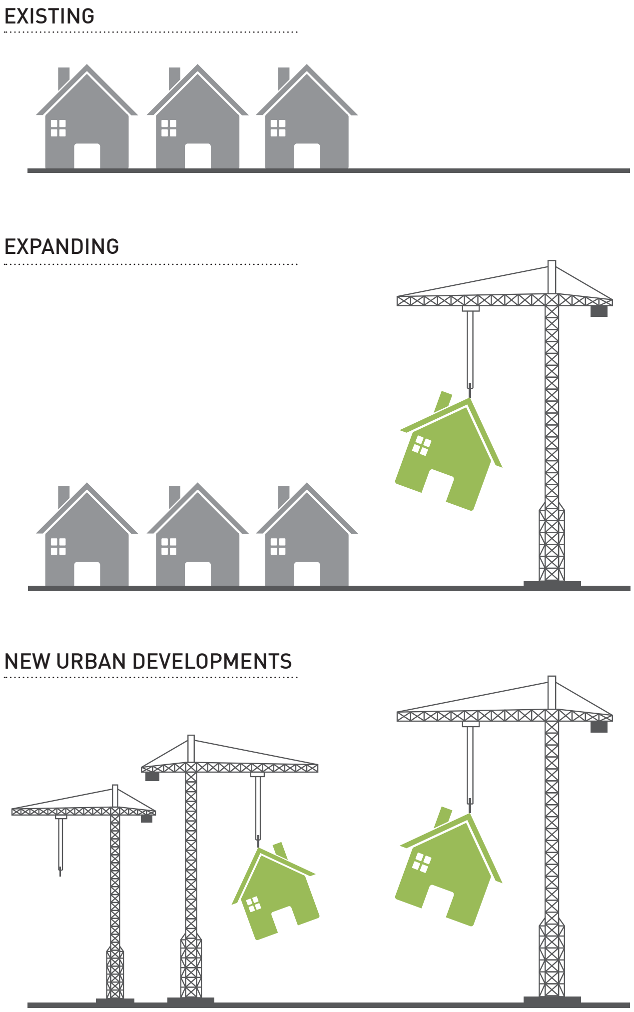
FOOD INFRASTRUCTURE

Finally, Food infrastructure involves the structures and processes used for the production, processing, distribution, and trade of food. It is quite different from other systems such as Transportation, Energy, and Water in that it has a more decentralized and private character. However, rapid population growth in combination with urbanization trends and changing consumption and diet patterns is expected to lead to an increased demand for food in the near future, also resulting in increased freight transportation. Intensified food production already puts pressures on the planet's natural resources and generates significant greenhouse gas emissions. In turn, climate change strains the capacity of existing food production. These conditions urge cities to make food management part of their overall planning, coupling ornamental landscapes with food production and thus becoming more self-sufficient and resilient. Planning should aim to protect the food-productive landscape near cities, improve the efficiency of the food supply chain, and ensure consumers' awareness.

In the scope of this book, collaboration and integration are pursued along three basic axes. First and foremost is the axis of stakeholders' efforts and objectives. Due to the size and complexity of infrastructure systems, multiple stakeholders with different priorities and agendas are inevitably involved during planning. This book aims to form the foundation of a common collaborative platform, primarily among public authorities, utility companies, financial institutions, planners, and engineers, to closely involve planning practices that have traditionally functioned in silos. Establishing shared knowledge that responds to the language of these professionals is integral to the approach. The second axis of integration runs between infrastructure and natural systems. Infrastructure occupies vast expanses of land, extracts large volumes of natural resources to use as feedstock, and produces by-products that are returned to the natural environment. These interactions can cause the alteration of climate patterns, the degradation of habitats, and the disruption of water and nutrient cycles and other processes. The impact can extend far beyond the boundary of a city, with significant and nonreversible effects. Infrastructure planning should therefore include a thorough understanding of the affected natural systems, in order to preserve or restore them or compensate for their disruption. The third axis of integration involves the infrastructure processes themselves. Planning decisions must identify and support linkages and interactions among infrastructure systems, aiming for efficiency, resiliency, and reduced impact. These linkages are referred to in this book as synergies. They can be used as opportunities for each infrastructure system to assist or be assisted by others, in order to resolve operational challenges, optimize placement of facilities, secure feedstock, resolve the management of by-products, and more. The synergies map how each system relates to the others, providing decision makers with a better understanding of the repercussions planning strategies can have across the city's operations. In this way they highlight potential traps and vulnerabilities and facilitate risk management.

These notions of integrated, systemic, and high-level planning, along with the crucial issues of the seven infrastructure systems, are presented through text and graphics and are encapsulated in the Planning Guidelines at the end of each chapter. Forming the core content of this book, tables of guidelines for Energy, Landscape, Transportation, Solid Waste, Water, Information, and Food are given, supporting a unified and cross-disciplinary process for improving existing urban developments or developing new ones. The guidelines can be used both as a practical tool for decision makers to optimize the contribution and interaction of various experts in the planning process, and as an educational tool for all related stakeholders independent of their degree of involvement with sustainable infrastructure. The result should be sustainable urban planning.

APPLICATION OF PLANNING GUIDELINES



3.2 | METHODOLOGY

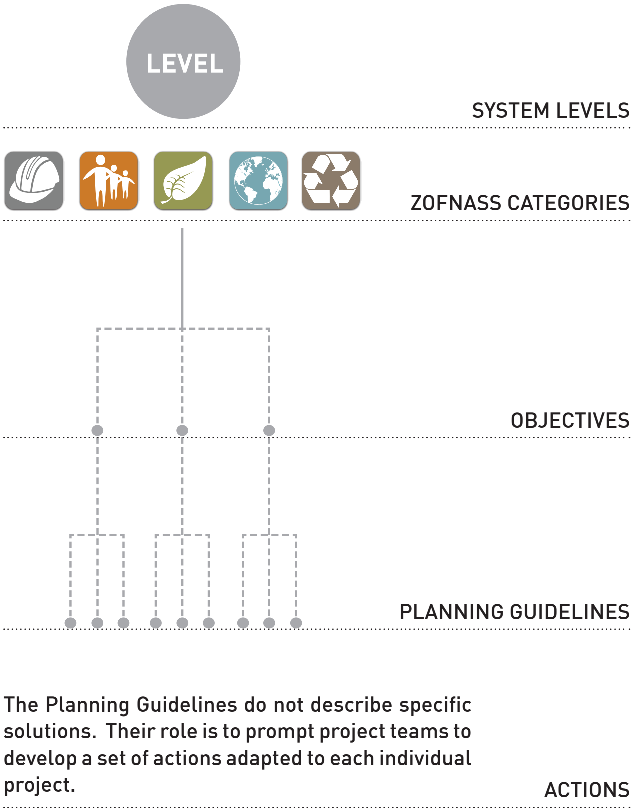
Cities can vary significantly in terms of their size, age, natural context, social and economic circumstances, and administrative structures. Urban environments are always works in progress, encompassing endless procedures and flows that often change rapidly. For these reasons urban planning projects present certain particular challenges. They have timeframes that often expand across decades, requiring initial plans to be constantly revised and adapted to ever-changing conditions. Numerous stakeholders from different backgrounds need to collaborate and reach consensus. The Planning Guidelines are therefore structured to provide a framework that can be applied to vastly different cities by stakeholders of varying expertise. They offer clear guidance for high-level planning, toward specific objectives, without repeating the complete set of requirements that should be met at project level. They provide flexibility in the face of the ever-evolving status of cities and the changes in available technologies and know-how. Users are free to define the boundaries of the system they are studying and use the guidelines for smaller or larger projects and for long-term or short-term planning.

As a method to streamline and guide the planning process, offering consistency while still highlighting particularities, each of the seven infrastructure systems is decoded in terms of four "system levels." The system levels are used to group the processes and various infrastructure facilities found within the systems and, most importantly, to structure a high-level planning and decision-making process. The definition of levels is consistent among infrastructure systems. The first level represents the main demand or consumption that must be covered by the system. It is crucial to base the design of any system on an understanding of realistic and up-to-date demand estimates and projections. The second level addresses the strategic approach and the resources employed in order to meet the demand as defined in the first level. The third and fourth levels represent the specific facilities and operations that will realize the strategic plans of the second level. Specifically, the third level refers to facilities performing as nodes of the system and the fourth to the networks set in place to cover the spatial needs. The only exception to this structure is the Landscape system. Time has a very strong effect on Landscape entities. While other systems start to decline after implementation, due to wear and tear, a well-planned Landscape system only becomes more established with time, adding value. The fourth system

ZOFNASS PROGRAM CATEGORIES

- ● LEADERSHIP
- ● QUALITY OF LIFE
- ● NATURAL WORLD
- ● CLIMATE AND RISK
- ● RESOURCE ALLOCATION

PLANNING GUIDELINES STRUCTURE



The Planning Guidelines do not describe specific solutions. Their role is to prompt project teams to develop a set of actions adapted to each individual project.

level of Landscape infrastructure is therefore defined as Maintenance to address the need for adaption to natural cycles and patterns.

For each system level, a set of objectives is defined, indicating the general goals for planning decisions. The objectives for the first system level typically call for a clear analysis of the primary demand on the infrastructure system, and its optimization through the engagement of end users. For the second system level, the main objectives refer to the selection of context-adapted management strategies, diverse and secure supply resources, efficient technologies, and adequate allocation of by-products. In the third and fourth levels, core objectives address the placement, distribution, and management of facilities and networks for optimum, secure, and flexible operation. The objectives are drawn from the five focus areas for sustainability used by the Zofnass Program: Leadership, Quality of Life, Resource Allocation, Natural World, Climate and Risk.

Leadership encourages the development of holistic strategies for high-level planning through innovation, integration, and stakeholder engagement. Quality of Life addresses the physical, economic, and social impact of planning decisions on the affected communities. It includes the concepts of health, well-being, community involvement, and local identity. Resource Allocation refers

INFRASTRUCTURE SYSTEM LEVELS

LANDSCAPE INFRASTRUCTURE	TRANSPORTATION INFRASTRUCTURE	WATER INFRASTRUCTURE	ENERGY INFRASTRUCTURE	SOLID WASTE INFRASTRUCTURE	INFORMATION INFRASTRUCTURE	FOOD INFRASTRUCTURE
L1. LANDSCAPE DEMAND	T1. TRIP GENERATION	W1. WATER CONSUMPTION	E1. ENERGY CONSUMPTION	SW1. SOLID WASTE GENERATION	I1. INFORMATION DEMAND	F1. FOOD DEMAND
L2. LANDSCAPE PROGRAM	T2. TRANSPORTATION MODES	W2. WATER SUPPLY	E2. ENERGY SUPPLY	SW2. SOLID WASTE DIVERSION MODEL	I2. COLLECTION & COMMUNICATION MODES	F2. FOOD PRODUCTION
L3. LANDSCAPE PATTERN	T3. TRANSPORTATION NODES	W3. WATER TREATMENT	E3. ENERGY GENERATION	SW3. SOLID WASTE TREATMENT AND FINAL DISPOSAL	I3. INFORMATION NODES	F3. FOOD TRADE
L4. LANDSCAPE MAINTENANCE	T4. TRANSPORTATION NETWORKS	W4. WATER NETWORKS	E4. DISTRIBUTION AND TRANSMISSION	SW4. SOLID WASTE COLLECTION AND TRANSFER	I4. INFORMATION NETWORKS	F4. FOOD PROCESSING AND DISTRIBUTION

to the energy, water, and physical materials required to build an infrastructure system and operate it, as well as to the by-products and residues that leave the system. Each of these should be treated respectfully and efficiently. Natural World encompasses the habitats, species, and nonliving natural systems that interact with an infrastructure system. This area focuses on understanding and minimizing the negative impacts of infrastructure while incorporating natural systems in a synergistic way. The scope of Climate and Risk is to minimize greenhouse gas emissions and other pollutants and to ensure resiliency for infrastructure and city against changing conditions and natural and man-made threats, both short-term and long-term. Each planning objective is primarily attributed to one of these focus areas, though it might be relevant to other areas as well.

The Planning Guidelines are given as guidance for reaching each objective. This structure serves several purposes. Objectives encapsulate the core issues for the sustainability of each infrastructure system, allowing for a quick grasp of the challenges ahead. They provide a general framework for assessing the overall direction and priorities of planning and provide flexibility as they apply to all contexts. At the same time they work complementarily to the guidelines, better illustrating the purpose of each. The guidelines do not prescribe specific actions in order to reach the objectives; rather they determine the direction of planning through objectives and they leave specific actions open-ended. Thus, the guidelines approach facilitates the creation of plans customized to each city's unique context, conditions, and priorities. It promotes innovation, allowing for the incorporation of new or improved technologies as they evolve. Project teams can select from a wide spectrum of actions: technical, administrative, educational, regulatory, etc. The decision-making process using the guidelines is not linear but an iterative process. While the system levels structure indicates a sequence in planning, the entire set of objectives and guidelines should be taken into consideration before finalizing decisions.

In addition to guiding planning, the guidelines can be used to assess existing cities and systems, identifying areas for improvement or monitoring the effect of plans already in place. They can also serve as a framework against which to compare the effect of smaller projects on overall city goals. Their modular structure provides further versatility. They can be applied to all seven infrastructure systems, covering the majority of processes within a project, or to one specific infrastructure system, or can even be used to analyze a specific system level. However, it should be stressed that integrated planning requires consideration of all four system levels. The flexibility of the guidelines is further enhanced by tracing and highlighting the synergies among systems. When a guideline is relevant to another system, the connection is highlighted, as shown in the graph below. At the end of each chapter these connections are identified in tables that reference specific relevant guidelines from the other systems. Relevant guidelines facilitate developing integrated and multifaceted action plans, tailored to the needs of each project, by drawing elements from different sectors.

Two types of synergies are identified (TO and FROM), based on whether a guideline can assist another system or be assisted by the other system. Thus, project teams can identify how their decisions impact other infrastructure or whether actions in other systems should be included for integrated sustainable planning. Not all interactions among infrastructure systems are noted; the emphasis is on highlighting strategic connections with significant impact that are relevant to high-level planning. A third type of synergy (WITH) is identified in relation to Information and Landscape infrastructure. (WITH) indicates that a certain guideline might require planning for an Information or Landscape subsystem following multiple guidelines from these systems. Both Information and Landscape constitute highly synergic systems, able to offer a multitude of supporting and regulating services, determined to a significant degree by the needs of other systems. Information in particular can constitute a subsystem of all other infrastructure systems, assisting in operations and management, while Landscape elements can be used to provide feedstock or mitigate the impact of processes on communities and the natural word.

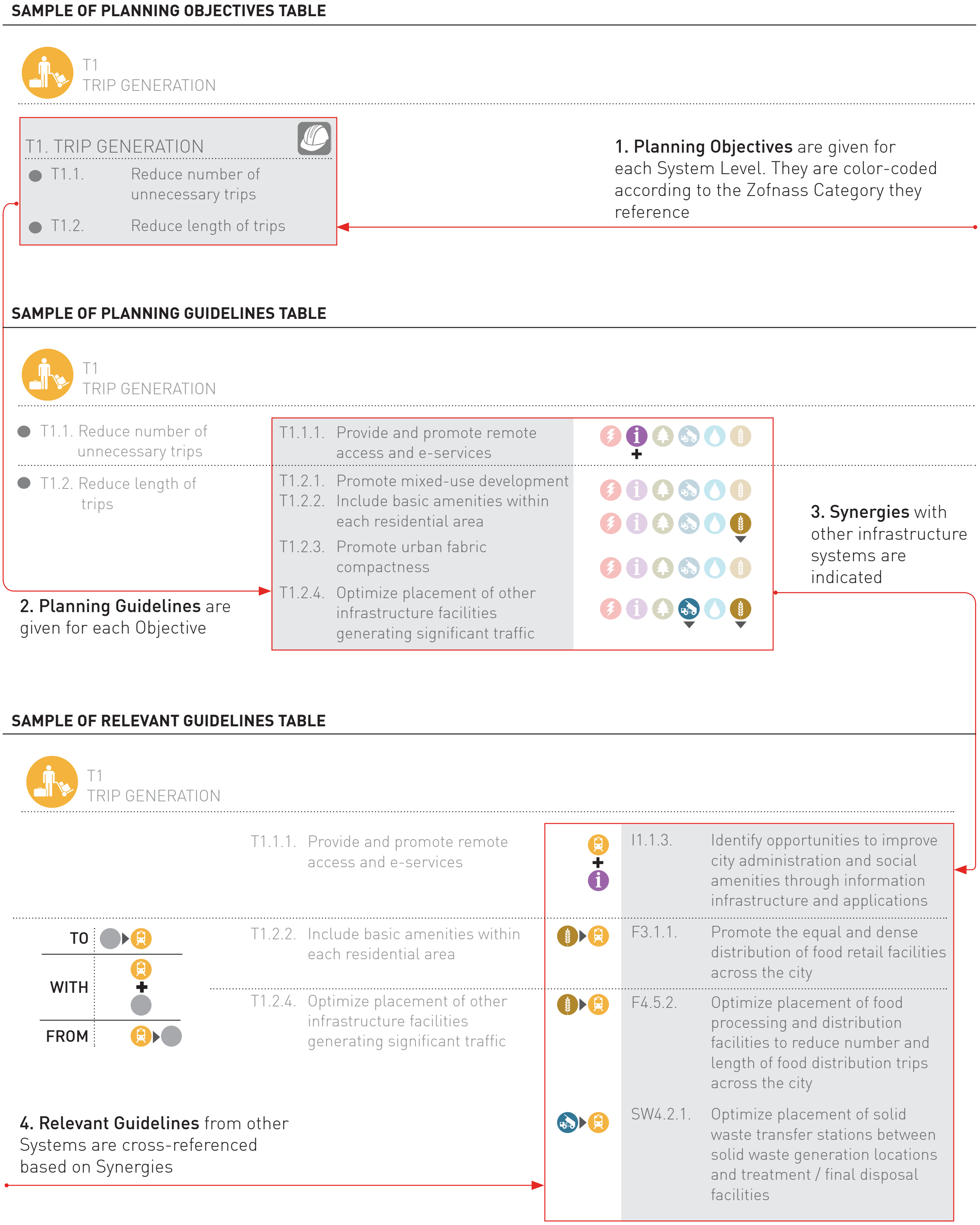
ABBREVIATIONS OF INFRASTRUCTURE SYSTEMS

L → **Landscape**
T → **Transportation**
W → **Water**
E → **Energy**
SW → **Solid Waste**
I → **Information**
F → **Food**

OBJECTIVES AND GUIDELINES IDENTIFICATION

T → Infrastructure System
T1 → Infrastructure System Level
T1.1. → System Level Objective
T1.1.1. → Planning Guideline

SYNERGY INDICATIONS



SAMPLE OF PLANNING OBJECTIVES TABLE

T1
TRIP GENERATION

T1. TRIP GENERATION	
● T1.1.	Reduce number of unnecessary trips
● T1.2.	Reduce length of trips

1. Planning Objectives are given for each System Level. They are color-coded according to the Zofnass Category they reference

SAMPLE OF PLANNING GUIDELINES TABLE

T1
TRIP GENERATION

● T1.1. Reduce number of unnecessary trips	T1.1.1.	Provide and promote remote access and e-services
● T1.2. Reduce length of trips	T1.2.1.	Promote mixed-use development
	T1.2.2.	Include basic amenities within each residential area
	T1.2.3.	Promote urban fabric compactness
	T1.2.4.	Optimize placement of other infrastructure facilities generating significant traffic

2. Planning Guidelines are given for each Objective

3. Synergies with other infrastructure systems are indicated

SAMPLE OF RELEVANT GUIDELINES TABLE

T1
TRIP GENERATION

T1.1.1. Provide and promote remote access and e-services	I1.1.3.	Identify opportunities to improve city administration and social amenities through information infrastructure and applications
T1.2.2. Include basic amenities within each residential area	F3.1.1.	Promote the equal and dense distribution of food retail facilities across the city
T1.2.4. Optimize placement of other infrastructure facilities generating significant traffic	F4.5.2.	Optimize placement of food processing and distribution facilities to reduce number and length of food distribution trips across the city
	SW4.2.1.	Optimize placement of solid waste transfer stations between solid waste generation locations and treatment / final disposal facilities

TO
WITH
FROM

4. Relevant Guidelines from other Systems are cross-referenced based on Synergies

IMAGE CREDITS

P. 27: Infrastructure Systems' Levels icons designed by Alexandra Papagianni.