

Infrastructure construction in change – what is the sensible path forward?

Eero Nippala¹, Terttu Vainio²

Abstract

Infrastructure construction is changing. The formerly closed domestic markets have opened up and become international in Finland like in many other countries. The transformation of a closed public sector into an open market has proven a challenge both to the public sector and enterprises. Infrastructures themselves are also changing. They can be made to include technology that gives extra value to clients. Infrastructure is never complete, but despite its static nature must be modified along with changes in regional structure, society and structural changes of industry.

The importance of competitive intelligence has increased in market-based operation. It is needed by the clients of infrastructure construction and the service providers, both in short-term planning of operations and long-term strategic planning.

This paper focusses on research delving into the long-term changes and challenges of infrastructure construction. The research assessed the future changes in infrastructure construction and their impacts on the basis of LoNGPESTEL analysis. The research was done in co-operation between the state, local government and the university and research organisations.

Asset management, financing of infrastructure maintenance, structural changes in the public sector, labour availability and competence, EU directives and environmental legislation, soil materials and recycling of materials, as well as urbanisation have been put forward as the greatest challenges to infrastructure construction.

Keywords: civil engineering, local impacts of trends, future challenges

¹ Lecturer; Construction engineering; Tampere University of Applied Sciences (TAMK); Kuntokatu 3, FI-33520 Tampere, Finland; eero.nippala@tamk.fi.

² Senior Scientist; Eco efficient district solutions; VTT Technical Research Centre of Finland PO Box 1300, FI-33101 Tampere; terttu.vainio@vtt.fi.

1. Introduction

Enterprises and organisations are operating in a global, changing environment. Changes form into global giga-trends and mega-trends. Internationally and nationally significant sectoral trends can be derived from them.

One aim of the 'Infrastructure sector in change' project is to derive such sectoral trends to allow concretising global changes for sector organisations and companies. Public sector organisations and enterprises, which react slowly to changes, need long-term forecast data.

Usually forecasting of future development is done by scenario techniques. For example Kast (1985) present relationship of general and task environments to the organisation. These relationships help our project to find changes and challenges of business environment and each company's activities to meet these changes (table 1).

Table 1: Relationship of general and task environments to the organisation (Kast, 1985)

1	General environment	Task environment
2	Economic	
3	Sociological	Customer
4	Demographic	
5	Natural resources	Technological
6	Legal	
7	Political	Sociopolitical
8	Educational	
9	Technological	Suppliers
10	Cultural	

Planning for uncertainty increasingly poses the question: "What is most likely to happen?" (Drucker, 1995) A generic approach to describing a comprehensive foresight project has been suggested by Peter Bishop et.al 2007 as in the following table (table 2).

Table 2: Approach to a foresight project (Bishop, 2007)

	Step	Description	Product
1	Framing	Scoping the project	Project plan
2	Scanning	Collection the information	Information
3	Forecasting	Describing alternative futures	Scenarios
4	Visioning	Choosing a preferred future	Prospective
5	Planning	Organising resources	Strategic plan
6	Acting	Implementing the plan	Action plan

Table 3: Scenario techniques have been categorized into eight basic types (Bishop et. Al., 2007)

1	Judgement	Including genius forecasting, visualisation and role playing
2	Baseline	Producing only one scenario, the expeted future, and conducted by trend extrapolation, system scenarios or trend impact analysis
3	Elaboration of fixed scenarios	In explicit consideration of multiple scenarios previous prepared using “incasting” or the popular SRI matrix method
4	Event sequences	Employing such approaches as probability trees, sociovision or divergence mapping
5	Backcasting	Adopting horizon mission methodology. Impact of Future Technologies or future mapping
6	Dimension of uncertainty	Using morphological analysis, field anomaly relaxation, GNB matrix or MORPHOL.
7	Cross-impact analyses	Calculating the relative probabilities of occurrence of future events and conditions in alternative scenarios employing a computer programme
8	Modelling	Having resource to trend impact analysis, sensitivity analysis or dynamic scenarios.

Even there are several scenario techniques (table 3) project group chose for the first step the PESTEL analysis. The reasons for that were quite short focus period, 5-7 years and also the need to tie future development to business environment analysis. If the forecast period become longer it is possible to carry out study with scenario techniques described at introduction.

2. Subject of research and theory

2.1 Operating environment of enterprises and organisations

Civil engineering produces all structures of the built environment except buildings. Its end products can be divided roughly in two groups: communities and communications between communities.

Communities are built to serve the needs of people. Water supply and sewerage is the community structure that serves an extreme basic need according to Maslow’s hierarchy of needs. Other community structures are streets, energy supply networks and green areas. Communities are linked to each other – as well as to areas beyond national borders – by roads, rail lines, harbours, airports, telecommunications networks and electric power transmission networks.

2.2 Research theory and methods

LoNGPESTEL analysis was the applied research theory which examines simultaneously broad global, national and local factors. Changes in the operating environment and factors affecting the infrastructure sector were culled from among them (Gillespie, 2011).

The factors considered in PESTEL analysis are:

1. Political factors (impact of the public sector on the economy): public subsidies, procurements, education, maintenance strategy and development strategy of infrastructure (road and rail network).
2. Economic factors: economic growth, inflation, availability and cost (interest on financing, exchange rates, tax rate, etc).
3. Social factors: Ageing of population, unemployment, etc.
4. Technological factors: Economic regeneration with the help of new technologies (new products and processes). E.g. BIM-based design combined with GPS control of earthmoving machinery enables a technology jump in earth construction. Technology can lower costs and improve considerably the quality of the end product.
5. Environmental factors: Preparing for and mitigating the impacts of changes in weather and climate conditions. The increasing role of environmental protection will cause changes e.g. in taxation of transport and transport technology (hybrid cars). Environment-friendly products are capturing market share.
6. Legal factors: Laws and decrees governing the operations of enterprises, accessibility, minimum wage, recycling requirements. Changes in these affect the operations of enterprises.

The version of PESTEL analysis that takes into account local, national and global factors is called LoNGPESTEL.

1. Local factors include protection of highly endangered animal species near construction sites.
2. National factors like the Euribor rate in Europe or Russia's joining of the World Trade Organisation.
3. Global factors like crude oil price changes.

Changes and challenges have been examined and produced in a workshop of the project steering group (12 participants) and a seminar (INFRAEXPO 12 in FINBUILD exhibition) for sector professionals (120 participants). The next phase involves scrutinising emergent trends by sub-sectors at workshops and concretising them into infrastructure sector changes.

3. Forces of change

Mega-trends are global change processes at work everywhere. Giga-trends are the drivers behind mega-trends that change very slowly. Mega-trends, for their part, create national, regional and local trends that may be different, even opposite, to each other. Trends may also be studied from a sectoral viewpoint (Ahvenainen, 2009).

Giga-trends, mega-trends and trends indicate the direction in which the operating environment and a sector are moving. Giga- and mega-trends also change. New opportunities announced by weak signals are called meta-trends. Meta-trends can develop into new mega- and giga-trends (Ahvenainen, 2009).

This article seeks to find infrastructure meta-trends, i.e. possible new trends.

3.1 Giga-trends – drivers of mega-trends

Population growth: stable in industrialised countries, but large differences between countries. Population growth in Europe is slow while the populations of Asia and Africa are growing fast. European population is ageing and the birth rate is low. This giga-trend is not in line with natural resources and under pressure for change (Ahvenainen, 2009).

Economic growth: Though the financial crisis has caused economic turbulence in recent years, the long-term growth of the world economy has been quite steady. The slowing of economic growth due to an increase in the price of oil and certain key metals may have an impact on this giga-trend. (Ahvenainen, 2009)

Technological development: Technological development is a significant factor contributing to globalisation. Changes in sustainable development and global economy require new technology and a new type of infrastructure. The probability of a technology jump is increasing. (Ahvenainen, 2009)

3.2 Global mega-trends

Giga-trends cause mega-trends. The latter include scarcity, environmental problems, internationalisation and an increase in the number of disturbances and conflicts. (Ahvenainen, 2009)

Scarcity is the result of consumption growth in our finite world. Scarcity drives up prices of raw materials creating shortages of energy, food, water and land. Related environmental risks consist e.g. of pollution, depletion of natural resources, loss of biodiversity, environmental accidents and uncontrollable effects of genetic manipulation.(Ahvenainen, 2009)

Internationalisation and globalisation will continue. The increasing number of crises and conflicts will require international co-operation. That has increased and complicated

interdependencies. International decision making is becoming harder, protectionism is arising.(Ahvenainen, 2009)

3.3 European trends

In the next few years Europe will focus on restoration of economic health and overcoming the cost crisis of public administration. The recession may lead to economic exile within the EU. At the same time, the EU is becoming bureaucratic and is functioning more slowly. It is difficult to agree on what is in the common interest due to complex economic interdependencies.(Stevens et.al, 2006)

The pace of change in Europe is picking up. Enterprises, even entire sectors, are born and die at an ever increasing rate. So-called butterfly economies are emerging whose competitiveness is based on ability to change. The challenge is to make the existing linear operating model non-linear. (Stevens et.al. 2006)

3.4 Meta-trends

Meta-trends are change factors and drivers that change giga-, mega- and trends, i.e. the direction of change. Meta-trends include increasing polarisation and inequality. Both poverty and wealth are increasing. More natural resources are being consumed. As a result, it is becoming more difficult to understand entity management and change. (Stevens et.al, 2006)

Economic and population growth are giga-trends that can cancel each other out. They are also in contradiction with sustainable development and can lead to scarcity and environmental problems.

The so-called 'slow life' is raising its head. Remote work is increasing and populations are ageing. Slow and small systems are gaining ground also in the economy.

Values and feelings have become more marked in working life. Responsibilities are becoming a counterweight to profit responsibility, cost-effectiveness and the knowledge society. Value management has made inroads into working life. That has led companies to use hired labour and transfer ownership to tax havens.

4. Global and local impacts of trends

This paper concentrates on the future changes and challenges of this type of enterprises and organisations operating in the infrastructure sector. The most important working method has been joint seminars of the parties to civil engineering (two have been held by October 2012). The first seminar was attended by 12 project management team representatives from companies and the public sector. The seminar focussed on identifying changes and challenges of the sector. The results were presented for appraisal and completion at another seminar attended by 120 people (Table 4).

Table 4: PESTEL analysis of infrastructure sector, national and international factors (Nippala, Vainio, 2012)

	Local (Infrastructure sector)	National (Construction)	Global
Economic	Networking of companies Securing financing of companies Tax planning	Accrual of government debt Private financing of infrastructure projects Cost of money (Euribor) Credit rating	Globalisation Global financial crisis WTO Economic growth of export countries
Political	Public-service user fees Network user fees, e.g. lane rentals/construction-time incentives	Public financing of investments Asset management and service level	European Stability Fund Global trade agreements, WTO
Technological	Deployment of BIM Machine automation	BIM Smart grid	Standardisation Patenting Innovations within intelligent transportation and infrastructure, carbon free energy
Environmental	Extraction of soil materials Replacement materials Innovations in storm water treatment Hearing procedure Co-operation between town planning and traffic planning	Eco-efficient community Decentralised energy production Renewable energy sources Natural resource conservation Permission procedures	Climate change Energy availability Low-carbon economy
Legal	Environmental permission procedures Road, rail, street safety competencies	Waste Act Soil legislation CE marking building materials	Safety and health requirements EU directives
Social	Labour availability Know-how Work safety Interplay within stakeholders Social license	Training (amounts) Social media Demographic changes, dependency ratio Citizen participation system	Changes in user needs Increase in inequality Immigration

Economic

Global: Development of the global economy has a big impact on infrastructure construction. The economy of many countries is dependent on exports. Public sector tax revenue and its ability to invest are tied to the success of export companies. This foundation is shaken by the tax planning of companies and the financial crisis. Global trade agreements are made to facilitate trade between countries.

On the national level, accrual of government debt reduces construction and maintenance of infrastructure for which the government is responsible. An effort has been made to complement the low level of funding by launching joint ventures between the private sector and local government. Life cycle projects have gained ground.

The financial crisis make it difficult for infrastructure construction companies to get financing which raises costs. Networking is carried out to improve the situation and competitiveness.

Political

The membership of the World Trade Organisation has widened. Russia was finally accepted as a member in 2012. The membership is expected to lower Russian import duties and ease trade when the complicated customs duties are eliminated.

On the national level, state and local governments finance a significant portion of infrastructure construction. Large infrastructure projects are built based on political decisions. Politicians decide whether state and local governments borrow when municipal tax revenue is not sufficient to cover investments. Asset management and maintenance of the service level of the existing infrastructure stock also depend on political decision making. Local government determines network user fees. They may be increased by a maintenance fee. However, the accruing funds are not automatically funnelled into maintenance.

Insufficient maintenance and neglected necessary repairs are leading to restrictions in the use of infrastructure. Life cycle-related repair of structures financed by tax revenue can be postponed, a case in point being the roads in outlying areas. Wear and damage that are a risk to personal safety, on the other hand, is repaired, a case in point being railways. Repairs are also done where related costs can be offset by user fees as in the case of the runways of airports.

The decision whether to charge rent for a lane occupied during the construction period is also a political one. Rent is conducive to a short construction period which cuts costs and disturbances to the environment during construction.

Technological

New technologies related to infrastructure construction include BIM models and global positioning systems (GPS). Wireless data as a tool in transmission in ground improvement or vibration measurement are examples of new infrastructure construction applications.

Intelligent transportation also saddles construction of new transport networks with new requirements and may reduce investment needs. For instance, traffic jams can be eased by controlling traffic lights instead of building new lanes or roads, telematics improve road safety, and sensors can monitor the maintenance need of crucial structures in real time. New materials and recycling of old ones can replace valuable natural resources.

On the national level there is need to increase the productivity of infrastructure construction by a technology jump. The building process involves too many unproductive delays. There, a technology jump can be taken e.g. by using the BIM model in production management.

When 3D designs are available for production, diggers and other earthmoving machinery using satellite positioning can be used.

Building of an eco-efficient, low-carbon society requires co-operation between planning, design and implementation.

Environmental

The disputed global warming has an impact on infrastructure construction which depends on geographic location. Rising sea levels threaten both small island nations and many large cities. No preparations have been made for rising water levels. Heavy rains are enough to show the vulnerability of communities.

The depletion of oil and exploitation of difficult deposits increase the price of oil thereby promoting a low-carbon economy.

National environmental issues include the Waste Act, which categorises an increasing share of waste as requiring extra handling, and protection of the eskers shaped by the Ice Age.

New recommendations and instructions concerning storm water treatment will be made to prepare for rainfall growth.

The environmental theme also includes the obligation to hear citizens at various stages of all construction projects. In addition to virgin nature, animals and plants, landscapes will also be protected.

Legal

The legal aspects of global factors are related to the safety and health of people during construction and use of infrastructure.

On the national level, laws and decrees have been enacted to conserve biodiversity. For example, conservation of endangered animal and plant species is governed by legislation. The National Esker Protection Programme is geared to the same goal.

Competencies dependent on the demandingness of the project are required locally of designers and builders of the infrastructure sector and companies. Personal competencies must be renewed at certain intervals (e.g. a blaster).

Social:

People's needs also as infrastructure users are changing globally. For instance, fixed phone lines have been replaced by fibre optic and wireless connections that enable mobile life. Work and study are no longer tied to a certain place or even country. Mobility has increased.

Ageing of the European population affects the need to make all services, infrastructure included, suitable for the elderly.

On the national level population growth and the dependency ratio affect the development of society. Though education is the result of political decision making, it is also a social factor. What share of each age group is to be left completely uneducated, and how many are to receive a university education?

The construction sector is suffering from too few people being trained at all skill levels. The skills shortage among those already working in the sector is also increasing as new IT is being introduced.

5. Conclusion

This study deals with the mega-trends affecting infrastructure construction around the world and derives from them concrete future challenges for local enterprises and organisations. Such concretisation is necessary since changes are usually treated on a much too general level to be of use for sector actors.

The speed of change has accelerated and future meta-trends quickly become concrete local mega-trends to overcome. Forecasting is needed since many organisations and enterprises react slowly to changes.

In future, the depletion of natural resources, population growth, environmental protection and changes in people's needs will place strong pressure on infrastructure.

The supply of soil and rock materials is not unlimited and has to be replaced by something. Population growth creates pressure to develop transportation systems, energy supply and water services. Congestions in cities will increase, energy consumption will grow many-fold from the present level and availability of clean water is under threat.

Infrastructure construction trends are being derived from the mentioned trends. The work has been started but has not yet been finished. The greatest challenges indicated by the intermediate results are infrastructure asset management, infrastructure maintenance financing, structural changes in the sector, labour availability and competence, EU directives and environmental legislation, soil materials and their reuse, and urbanisation.

For the local companies technological challenges are for example use of machine automation and training of excavator drivers. Also staff must have all kinds of competence (rail, road, street) to do certain work. Environmental challenges are to get permission to use soil. Recycling of soil is also growing in the future because there are shortage of good quality soil or rock. Social point of view companies must devote to better breakrooms, safety equipments etc.

Acknowledgement

This article is one part of project financed by Tekes – the Finnish Funding Agency for Technology and Innovation and national civil engineering branch organisations.

References

Ahvenainen M, Hietanen O and Huhtanen H (2009) *Wrapped future (Tulevaisuus paketissa)*. Finland Futures Research Centre, Turun kauppakorkeakoulu, julkaisuja 2/2009.

Bishop P, Hines A and Collins T (2007) *The current state of scenario development*, Foresight , 9(1), 5-25.

Drucker P (1995) *Managing in a Time of Great Change*, TT Dutton. New York.

Gillespie A (2011) *Foundations of Economics*, 2e. Oxford University Press.

Kast FE (1985) *Organisation and management: A system Contingency Approach*. New York, McGraw Hill.

Stevens B, Schieb P-A and Andrieu M (2006) *A cross-sectoral Perspective on the Development of Global Infrastructures to 2030, Infrastructure to 2030*, Chapter 1, 13-49. OECD Publishing.

Nippala E, Vainio T (2012) *Changing civil engineering -workshop (Infra muutoksessa työpaja*, available online http://www.vtt.fi/sites/infra2030/infra2030_ohjausryhma.jsp)

Nippala E, Kilpinen J. (2011) *Infra kuntoon*, Infra r.y. available online <http://www.infrakuntoon.fi/>