SUMMARY

BUILDING ON KNOWLEDGE

AWT FACT-FINDING COMMITTEE BUILDING & CONSTRUCTION

JANUARY 2000

Objective

The Advisory Council for Science and Technology Policy (AWT) has the objective of formulating a vision of the role of public knowledge infrastructure and publishing recommendations on relevant matters of content and organisation. In conjunction with the Advisory Council on Technology Policy in the Construction Industry (ARTB), the AWT set up a Fact-finding Committee at the end of 1998. The Committee's brief is to bring out a report laying down the key future knowledge themes for the construction industry, followed by recommendations for education and research to be structured accordingly.

Scenarios

The Committee has opted to produce three future scenarios to identify the key questions facing construction in the next century. The intention is to give a qualitative outlook, not a precise forecast. The Committee has not allowed itself to be side tracked into producing spectacular images, unknown technologies or dramatic shifts in trends.

Each picture of the future in the form of scenarios is based on driving forces economic and political developments, cultural changes and technological advances. In this sense, the Committee is complying with the scenarios drawn up by the Netherlands Bureau of Policy Analysis (CPB).

Apart from the CPB scenarios, the Committee has also drawn inspiration from scenarios and visions of the future developed elsewhere.

The following four groups of characteristic parameters apply to the three scenarios developed by the Committee (for details see next page):

- **Government action and land-use planning.** Land-use planning is closely connected with the role assigned to the government. This could be a very active one (creating conditions for optimal transport, recreation crousing etc.) or a very cautious one.
- **Characteristics of demand for construction.** The demand for building may be very detailed, and tailored-made or conversely very generic in terms of functionality or ambience.
- **Supply structure.** The construction industry may assume various forms: highly segmented, or conversely integrated. One of the sectors of the value-chain may be dominating or precisely the opposite could be the case.
- **Contracts and competition.** Various forms of contract and competitive relationships are conceivable: competing on price, concept or product, or service aspects. This also applies to forms of contract: traditional or non-traditional. Companies may compete fiercely or show a co-operating behaviour. These four parameters establish three scenarios. "Golden Ages", "Delta Metropolis" and "As you like it" "Golden Ages" is deeply rooted in the Dutch culture of mutual dependency and co-ordinated behaviour (the

“Polder Model”). Delta Metropolis is an extrapolation of the traditional position of the Netherlands as the European gateway. “As you like it” is an elaboration of footloose tendencies which are visible in Holland nowadays.

SCENARIOS IN DETAIL

1 Government action and land -use planning

'Golden Ages'	'Delta Metropolis'	'As you like it'
• Regional identity • Complex decision-making • Support to government as conflict manager • Building in under-developed areas • Building as social engineering • Government as indirect client •	• Awareness of unique location in the Netherlands • Government assumes a role as spatial planner • Maximum exploitation of limited number of building sites	• Demographic move away from the Randstad • Ample scope for mobility • Minimal government involvement • Surfeit of building plots • Government is seldom client

2 Characteristics of building demand

'Golden Ages'	'Delta Metropolis'	'As you like it'
• Central problem: what should we build? • Much re-use of existing sites, building works and infrastructure • Many stakeholders • Low management costs and building costs come first • Detailed planning policy • Sustainable building important	• Government key financier of large building projects (infrastructure, coastal and bank works, soil clean-up, etc.) • Private clients only interested in functionality • Flexible use of buildings • High demand of comfort and security • Speed of building is important	• Government building requirements fully dependent on economic cycle • No difference between public and private awarding of contracts • Entourage, atmosphere ambience, convenience, define building demands • Throw-away culture • Energy saving is not an item any more

3 Supply structure

‘Golden Ages’	‘Delta Metropolis’	‘As you like it’
• Specialised services around construction, management design, letting, sale. Much competition and innovation. • Separation of design and management • Scarcity of skilled workers in construction • Actual building very much capacity-driven	• Room for suppliers of total concepts • integration, design, implementation and maintenance (‘total approach’) • Long haul (vision, networking, financing) important	• Direct suppliers to the end market • Many small specialised design- and build companies in alliances • Declining role of main contractor and design sector • Internationalisation of production, local sales.

4 Contracts and competition

‘Golden Ages’	‘Delta Metropolis’	‘As you like it’
• Price is the competitive edge • Traditional contracting agreements • Little international competition • Local building habits and networks important • ‘Proven technology’ important • Segmented business chain	• Concepts are the distinct competitive advantage • New contract forms (alliancing, partnering) • Large international players and international competition • Local subcontracting • Access to knowledge important • Life-cycle costing	• Competition on service and customer-oriented approach • Supply from outside the building sector • Building is primarily marketing, sales and logistics.

KNOWLEDGE THEMES IN OUTLINE

The Fact-finding Committee does not anticipate any extreme changes but rather evolutionary progress for the construction. Nevertheless, the construction industry will have to respond to those changes in the near future. The Committee sees the following three main themes in the scenarios, which imply a demand for new knowledge, summarised under eleven knowledge themes and skills.

- The government's role is changing in major land-use interventions and in legislation and, prompted in part by the ongoing integration within Europe. The interaction between players and interest groups, of which the government itself is one, is on the rise.
  This demands new skills at operational and political level alike (knowledge theme III Influencing and Decision-making and knowledge theme II Government intervention). Sateguarding the Dutch Delta a governmental role remains unchanged in the coming century (knowledge theme I Delta technology).
- The shift from a project-oriented approach to building to a process-oriented approach. Like many other industries, the industry is now facing the challenge of better coordinating the various process phases. Process integration is a deeply felt need in industry. This need is leading to new knowledge questions (knowledge theme IV Building process integration, knowledge theme V Contracts, knowledge theme VI, Management of Projects and knowledge theme VII Industrial Building).
- The content – notably the functionality – of demand for building products is changing. Meeting this different type of demand means that designing will have to become methodological and the approaches on the basis of existing formulae and proven technology will change.
  Knowledge themes VIII Functional Design handles this topic in a generic sense. Some topical themes for the future are dealt with in knowledge theme IX Durability, knowledge theme X Portfolio management and knowledge theme XI Maintenance and Inspection.

The Committee has identified three other themes that are relevant to the technological and organisational development of the construction industry, but which lie beside the knowledge field of the construction industry itself– and thus its terms of reference.

- The theme Traffic and Transport with the knowledge questions regarding integrated transport concepts, vehicle technology, traffic control, route planning, etc.
- The theme Modelling and Computing identifies the dominant technological trend for the sector: the application of ICT in all its aspects (building models, data acquisition, algorithms and VR techniques). The challenge for the construction industry here lies in the application of knowledge developed elsewhere in the form of tools for its own knowledge domain.

- The theme Europe. The growing influence of European legislation on numerous policy areas is evident. European legislation has gradually become palpable in the construction industry. Competition in the sector is also increasingly displaying European features. The Committee does not, however, see any specific knowledge questions for the sector here to justify a separate theme.

ELEVEN KNOWLEDGE THEMES IN DETAIL

KNOWLEDGE THEME 1 DELTA TECHNOLOGY

Three quarters of the buildings and infrastructure in the Netherlands has been created on a loose subsoil and located in an area with risks of flooding. Knowledge questions are:

- **Morphology of coasts and rivers.** More knowledge must be accumulated on the long-term effects of soil settlement and rise in sea level and statistical variations in precipitation and storm patterns. This knowledge provides the basis for reliable estimates of risk of flooding its effects on safety levels and expected economic damage.
- **Knowledge of the soil.** A second group of questions is closely connected with the construction of major infrastructure works, water defences and the inner city problems (pipeline routes, undertunnelling, sewer systems). This leads to knowledge questions such as the long-term settlement and deformation behaviour of constructions and the failure behaviour of dykes and water defences.
- **Underground Management.** More intensive use of the subsoil demands legal design of efficient management and use of the subsoil (underground zoning plan) and alleviating the uncertainty surrounding legal ownership of the underground constructions.

KNOWLEDGE THEME II GOVERNMENT INTERVENTION

The government has a major influence on building: as legislator and client. This dominant position will remain in the future but the relationship between government and the construction industry will change in numerous respects (awarding of contracts, regulations, manpower services, environmental policy) in terms of content and decision-making procedures. Government intervention should not be approached as 'given facts' for participants in the building process. They are variable to a high degree and even readily amenable to influence for certain stakeholders.

Knowledge questions are:

- **Regulation and voluntary regulation.** Regulations in the construction industry are too detailed in their technical ramifications. This hampers the scope for innovation.
- **Forms of cooperation.** European tender directives imply competition on price. It is worth the effort to investigate which forms of tendering are acceptable in the European context and which new variants should be actively promoted in the Netherlands. Special attention should be given to ownership of conceptual solutions to large construction projects at the tendering phase.
- **Competition and cooperation**. Competition legislation is focused on promoting competition by prohibiting 'parallel behaviour of companies'. In view of the importance of vertical cooperation in the business chain, it makes sense to investigate which cooperation is permitted.

KNOWLEDGE THEME III INFLUENCING AND DECISION-MAKING

Planning and building affects every person in the Netherlands. In many a construction project, a growing number of players directly involved can be identified. Complexity is on the rise in large projects in particular. Often this is political in nature because planning happens to go hand in hand with the weighing up of public and private interests. Numerous governmental authorities are facing the question of how they can achieve their objectives in an environment which is becoming ever more complex and above all more intractable. Those questions are:

- **Interactive policy-making.** There is a need for an open interactive style of policymaking for large civil engineering projects, construction projects and development locations. This requires a satisfactory training of policy officials who, are being confronted with an intractable environment which is difficult to control.
- **Network management and strategic influence** Equally, society in which the government does not have exclusive control is asking for new forms of influence by companies seeking to play a part in this environment. Within these companies, the skill must be present to recognise opportunities in complex policy matters and to come up with manageable compromises.

KNOWLEDGE THEME IV BUILDING PROCESS INTEGRATION

In the current building process a distinction is made between design and construction.This distinction enables the client to pick the most efficient builder. There are however drawbacks to this division: high failure costs, sub-optimisation and the absence of learning effects and options for improvement. They often have their cause in faulty communication, between design and construction. With complex major projects there is no one overseeing the entire undertaking. But stepping up the building speed is necessary in some cases and can only be achieved by integrating design and construction. Knowledge questions are:

- **Integration through ICT applications.** As a result of an increase in the capacity of software and computers, comprehensive computing and drawing programs can be used for all construction tasks, including areas where it is still the exception (e.g. electronic building site simulator). Special problems arise with the integration of stand alone programs and the validation of data and results.
- **Concurrent Engineering**. Apart from shortening the elapsed time of design, it must be possible to have various phases of design proceed more or less simultaneously (concurrent engineering). More variants may be studied in the design stage. Advanced management of the enormous quantity of data associated with the building process is a pre-requisite here.
- **Evaluation methods.** Empirically based design methods may be supported by developing and using systematic evaluation methods focused on logging experiences of existing buildings. This gives rise to options for improvement and delivery.

KNOWLEDGE THEME V CONTRACTS

The construction industry has traditionally had forms of contract for various phases of the building process: design, supply and construction. These forms of contract correspond to the responsibilities of the players involved. They reflect situations in which the state of the art is virtually unchanging and the risks are manageable.
But the demand side of the construction market is changing. The ability to deliver construction or design capacity is no longer adequate for situations in which additional services (maintenance, operation, advice) are asked for. Experience in large projects, in such areas as the process industry and offshore, reveals that, provided there is a solid specification of requirements available, and contractors are able to formulate a suitable legal form for their tender, the overhead costs (risk, consultation, arbitration) and direct project costs can be sharply reduced to benefit profitability and reduce the total contract sum. Knowledge questions are:

- **Knowledge of other contract forms.** There must be knowledge in companies to be able to assess new forms of contract. Tenderers will have to deal with varying forms of contract. The scope for passing on risks will be sharply reduced. Further securities (guarantees, penalty clauses) will be asked for.
- **Risk analysis and risk management.** Tendering parties must be able to operate within varying forms of contract, on the basis of a sound analysis of technical and financial risks. The ability to translate the risks identified to a managed production process (systems engineering, risk management) is indispensable to successful operations.
- **Contracts.** Contracts do not provide any guarantee of good cooperation. That lies in the cooperative capacity itself, and having understanding for the position of partners and their room to manoeuvre. This demands training in suitable social skills.

KNOWLEDGE THEME VI MANAGEMENT OF PROJECTS

Building is traditionally a project-related activity which is reasonably demarcated from it surroundings. The situation is changing as a result of various causes. Initiative and design are becoming interwoven. In complex projects where there are great many interested players, the design is not so much the completion of the decision-making phase but mainly serves to identify the consequences of a possible decision. In its construction phase building is becoming much more the coordination of activities and flows of materials on an ever-smaller construction site within a diminishing timeslot. The content of the coordination itself is changing. Responding to unexpected disruptions (local residents, adjacent activities) and negotiating (subcontractors, suppliers) require the growing attention of construction management.

Knowledge questions are:

- **Building management.** Good project management is becoming a very important factor. This applies to managing a building project itself and managing the processes of which the projects are just a part.
- **Social skills.** Negotiating techniques, customer focus, capacity for cooperation, the ability to deal with conflicting interests are becoming important skills in managing complex projects.
- **Industry culture.** Building is a comprehensive activity with many types of companies and occupations. Knowledge of this sector, as a basis for seeing the relative position of one's own profession is indispensable to the effective operation of individuals and the evolution of the sector.

KNOWLEDGE THEME VII INDUSTRIAL BUILDING

Productivity improvement is an important factor in the economic development of a sector. Clients are becoming much more demanding and wanting tailored construction. This means more tailoring and a growth in the range of building products and thus prefabrication.
Industrial construction in this sense will prove to be a dominant trend in the years ahead. Moving the building site production to the plant means integrating various functions and sometimes also materials within a component or within a system of components. That sets high requirements for coordination (details, dimensions, finish) between these components. Knowledge questions then are:

- **System development.** Product development will increasingly be marked by a system integration, which means products being designed more in conjunction with one another and from the end-user perspective. The development of dismantleable building systems which allow for flexible use are a special topic here.
- **Connection technology.** Assembling products on the construction site itself sets new requirements for those products. One important aspect is developing semi-permanent connections so that construction work can be simply expanded (without causing any nuisance and in a short span of time) or demolished.
- **Construction technology.** There is a need for construction experts who think in terms of the potential of the building process. This building process is increasingly governed by logistic requirements. One special challenge is to mechanise the process by using devices, machinery and tools, partly to improve working conditions at the site (improvement of image, promoting safety and health).

KNOWLEDGE THEME VIII DESIGN

The design phase of the building process makes use of proven technologies, standard packages of requirements, existing examples, technical standards and computing rules. In practice, highly simplified models of, user behaviour, characteristics of the interior climate, material and construction properties are generally assumed. This use of formulae will no longer suffice as the result of the new and different types of requirements that users are posing.

Furthermore, under the impact of the growing amount of leisure time and the rise of the knowledge economy, the functional use of construction works and infrastructure is becoming variable over time. Approaches that assume fixed patterns in use (m^2 per function) apply ever less in situations in which multifunctionality is called for.

In future, design performance will have to be assessable, so that compliance of the design with the requirements laid down can be established. Knowledge questions are:

- **Functional requirements.** Thinking in terms of performance is only possible if performance can be assessed. This demands the development of knowledge and modelling of varying functional aspects of human behaviour (user profiles) and the conditions under which people function. That applies to common situations (offices, public multifunctional areas such as shopping centres, stations) and extreme situations (large crowds of people, disasters, high density building).
- **Design methodology.** Design methodology should enable the designer to arrive at good results in the design process in a structured manner. It should be possible to translate approaches from other sectors concerned with comprehensive single constructions into identifiable forms for the construction industry.
- **Effects analysis.** Designers should be better able to have an overall picture of the effects of the proposed plans on, construction, use and management of projects and to study alternatives. What is required as a minimum is a design methodology that allows the proposed design decisions to be verified.

KNOWLEDGE THEME IX SUSTAINABILITY

Building means combining varying materials and components into a single end product. With the use of new combinations of materials and products, the number of possible “misfits” is rising accordingly. One special aspect is the unexpected and undesired environmental load of some materials and material combinations.

Society entertains the wish of achieving energy conservation. It is quite conceivable that in the distant future the built-up environment will be self-sufficient to a high degree. In any event, energy conservation means more far-reaching conditioning of the interior climate, excluding unintended health risks.

Building activities establish micro environments and differentiated ecosystems. This differentiation means in principle an increase in biodiversity. This potential can be further exploited by intelligent design. Targeted research, resulting in design rules, is highly limited however. Knowledge questions are:

- **Material saving.** Lightweight construction means building more cleverly and more precisely. Knowledge must be accumulated of the behaviour of “traditional materials” (concrete, steel, wood) used in combination with unique additives or in composite constructions (synthetic, aluminium). The knowledge structure relates to actual behaviour at micro level (needed to be able to calculate such constructions) and to detail and connections (needed to be able to build).
- **Energy conservation.** Energy conservation is possible in further developing installations (components and systems). Special subjects are control technology, energy conservation in conjunction with health risks in the interior environment, system components that use renewable energy sources and the interaction between installations and building-shell.
- **Reuse of materials.** Demolition waste may be reused at a high level if it is processed into materials of reliable quality. Designing advanced separation technology, using fundamental knowledge of materials is a long-term prospect for research.

KNOWLEDGE THEME X PORTFOLIO MANAGEMENT

A major cluster of management issues lies in the development and redevelopment, exploitation and management of large areas, such as redesign of landscapes, creation of nature areas, recreation areas in urban centres, urban renovation locations, infrastructure junctions and major industrial estates. Large management organisations are demanding professional management of their portfolios. With single building objects, it is a question of issues at the boundary between technical intervention and the business organisation. For example maintenance protocols, maintenance decisions, design criteria with a view to maintenance, 'make or buy' issues, determining service levels and the like. Knowledge questions are:

- **Methods of weighing up.** There is a need for methods and techniques which allow various interventions to be weighed up as to their effects (scenario analysis, multicriteria analysis, impact reporting). One special aspect is dealing with aspects of political decision-making and interest groups.
- **Portfolio techniques**. What is needed is the building of models (financial models, exploitation models), closely associated with information systems which store data on the technical state of the known objects.
- **Maintenance strategies.** The need for technical-scientific underpinning of maintenance strategies is increasing. This also applies to planning issues in relation to the use and availability of buildings or installations, financial management focused on risk management, cost minimisation or maximisation of profit or use.

KNOWLEDGE THEME XI MAINTENANCE AND INSPECTION

Restoration and conversion activities have long been an identifiable part of overall building activity. They constitute a market segment with a long history, their own tradition (heritage care), their own special disciplines and skills and a wide range of specialised companies. New materials, composite constructions, mechanical engineering and electrical engineering systems are inextricably bound up with modern building. As a result, the traditionally highly empirical maintenance practice will change, and call upon scientific understanding and new technology to a greater degree. Knowledge questions are:

- **Long-term behaviour of materials and installations.** As a result of the lack of knowledge of ageing mechanisms (degradation of materials and contamination of installations), it is not possible to model long-term behaviour and on this basis to make lifespan predictions (degradation of materials and contamination of installations).
- **Non-destructive research.** Apart from understanding and modelling time-dependent behaviour of materials, knowledge of data acquisition and diagnosis equipment is required to be able to describe the actual situation.
- **Development of restoration technology.** Knowledge questions also arise from restoration and renovation. New materials and means of conservation, devices and auxiliary constructions will have to be developed. Interaction with what is already present must be predictable and the use of existing locations must be able to proceed without nuisance or danger.
- **Modern maintenance technology.** Knowledge gained in maintenance and inspection can also be deployed in formulating design criteria for new buildings, engineering works and installations (design for maintenance).

RECOMMENDATIONS

The new knowledge questions confront the educational sector with a dilemma. On one hand, knowledge areas such as business economics, interactive policy, contract law, portfolio management are requiring greater attention. On the other, technical disciplines are being seen as the basis for teaching. This leads in theory to a choice between education focused on breadth versus one focused on (technical) depth. Arguments can be put forward for both extremes and many interim variants are conceivable.

The Fact-finding Committee believes that at senior vocational level, educational institutes should choose their position according to their size. At the smaller establishments, a general technically- oriented course is the obvious choice, whilst at the larger institutions differentiation is conceivable.

University Faculties have a scale large enough to provide a differentiation in training courses. Apart from training with technical depth, there is also scope for a wide-ranging course. The university establishments must not hesitate to choose for this combination, even if the creation of scope for the broad profile is at the expense of a capacity for existing training courses. The Committee in particular would ask for attention to be given to critically assessing the place and content of design courses.

The Committee believes that the Netherlands with its universities, and research establishments has a good research infrastructure for construction R&D. This infrastructure must be deemed capable of addressing the themes identified by the Committee. Provided there is a clear will at the research establishments to tackle these new themes. In relation to the “established order”, the new themes only have a chance if they are allowed some time to develop.

As regards technical research areas, the Committee is inclined to the view that (international) specialisation will be unavoidable. This can be anticipated by allowing cooperation between the universities, and the research establishments to expand.

Regarding research in the technical knowledge areas, the Committee mainly wishes to focus attention on the knowledge themes of Maintenance & Inspection and Sustainability. Here co-operation is called for on account of their multi-disciplinary nature. The Committee believes it conceivable for some 10% of existing research capacity to be moved towards these themes, without causing any real harm to existing positions.

A similar move should be made within non-technical research areas, on which efforts must be stepped up. The themes of Portfolio-management, Contracts and Influencing and decision-making are important here,

closely related to the theme of Building process integration.

The Committee also observed that new knowledge often does exist, but is not included in the courses offered or is inadequately exploited in practice by users. This would indicate that the interaction between research, education and practice is falling short. The research world in particular must seek ways, in conjunction with the users of research, to increase the yield – the actual return on their efforts. Conversely, the Committee sees it as a particular responsibility of the construction sector to make it clear to the knowledge infrastructure with supporting arguments what education and/or research is actually needed (articulating demand).

The Committee is also aware that even where there is such involvement, it is often focused on the short term. The construction sector and the knowledge infrastructure should reflect on ways of communicating more at a strategic level about the direction of education and research.