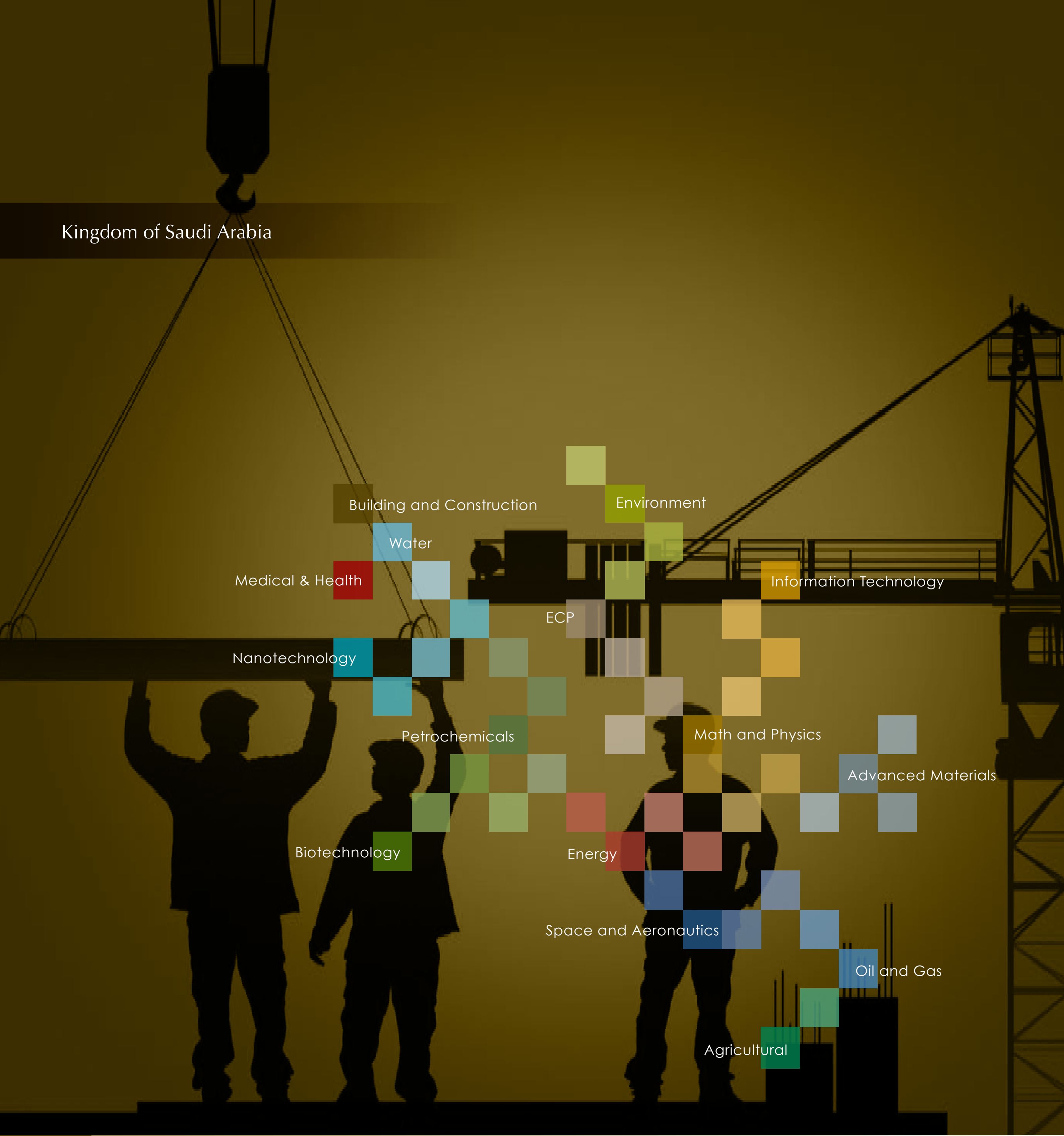


# Strategic Priorities for Building and Construction Technology

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# Strategic Priorities for Building and Construction Technology

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# Executive Summary

The National Policy for Science and Technology, approved by the Cabinet of Ministers in 1423 H (2002 G), defined programs for localization and development of strategic technologies that are essential for the Kingdom's future development. The King Abdulaziz City for Science and Technology (KACST) was given responsibility for developing 5-year strategic and implementation plans for each of these 11 technology programs, in addition to the Building & Construction Technology. KACST also facilitated strategic planning in key applied technology areas that draw upon fundamental technologies and impact human lives.

The building and construction (B&C) sector in the Kingdom has undergone remarkable change in the last few decades. Reinforced concrete (RC) frame structures, combined with modern architecture, have replaced traditional mud and stone-based constructions. Steady economic development has resulted in a vibrant and expanding building and construction industry that uses the country's large reserves of natural resources to produces a wide range of high quality building materials including cement, concrete, bricks, tiles, reinforce steel, ceramics, composite materials and glass. The sector not only generates significant domestic value-add and employment opportunities, it even contributes to export revenues.

At the same time, the sector suffers from many weaknesses. For example, the use of energy-intense manufacturing processes, the lack of advanced know-how, lack of commitment to research have hindered the sector's development. Despite the introduction of a range of new technologies, the country's building systems still depend mostly on old methods using reinforced concrete structures. Notwithstanding the recent expansion of markets and profits, many Saudi companies conduct little research and innovation.

# Executive Summary

Collaboration among research organizations in the Kingdom is relatively weak and university-industry-government linkages are also not well developed. Given these and other challenges, it is a national imperative for the Kingdom to draw appropriate technology road maps and strategies for the B&C sector. Realizing the impending need to address important challenges facing the sector, KACST collaborated with the sector's stakeholders to develop a National Building and Construction Technology Strategy for the Kingdom. This document embodies the product of that stakeholder-driven strategic planning endeavor.

This plan is based on input from the users and stakeholders of B&C technologies in the Kingdom, including government agencies, universities and industry. It was developed in three main stages. The first stage involved the identification of key stakeholders and a review of the present status of the building and construction sector. The second stage focused on key needs of the sector, assessment of emerging trends, benchmarking of research performance and a detailed analysis of strengths, weaknesses, opportunities and threats (SWOT). In the third stage, stakeholders collectively determined the vision, mission, strategic objectives, and priority technologies. A program management structure and an implementation plan for the national B&C technology strategy were developed.

# Executive Summary

Stakeholders identified the following research and development programs in order to fulfill the strategic objectives and the Kingdom's needs in the B&C sector:

1. Safety.
2. Health.
3. Energy.
4. Environment.
5. New Trends.

Initiatives in these program areas must be aligned with one or more of the following main technology themes:

1. Building and Construction Materials.
2. Building and Construction Systems.
3. Building Design, and Quality Assurance.
4. Building Assembly.

For the first five years (1429-1434), the following set of priority project areas have been selected under each of the R&D programs:

- Safety:

1. Durable and serviceable structural systems (design, construction and maintenance).
2. Fire proofing materials and systems.
3. Smart and advanced electro-mechanical materials and systems.

- Health:

1. Moisture and damping insulation.
2. Sound proofing.
3. Advanced materials and systems for floors and walls.
4. Smart windows and openings systems.

- Energy:

1. Solar.
2. Heat insulation.
3. Buildings envelop orientation.

- Environment:

1. Water conservation.
2. Construction/ demolition waste reusing and recycling.
3. Environmental friendly Synthesis materials development.

- New trends:

1. Low cost structural systems (design, construction and maintenance).
2. Fiber composite materials (polymer, plastic, glass, carbon, etc.).
3. Smart (concrete, masonry and composite) materials and systems.
4. Advanced ceramics and alloyed materials and systems.

To facilitate the implementation of the B&CT strategic plan, a National Building and Construction Technologies Center (NBCTC) will be established at KACST. The NBCTC will take responsibility for the overall management of the plan and for the coordination and evaluation of program components at the national level.

A B&C Advisory Committee will be established, with stakeholder membership, to oversee the implementation of the plan. The Committee will report to the National Strategic Technologies Committee, which oversees all of the strategic technology programs.

# Introduction

## Background

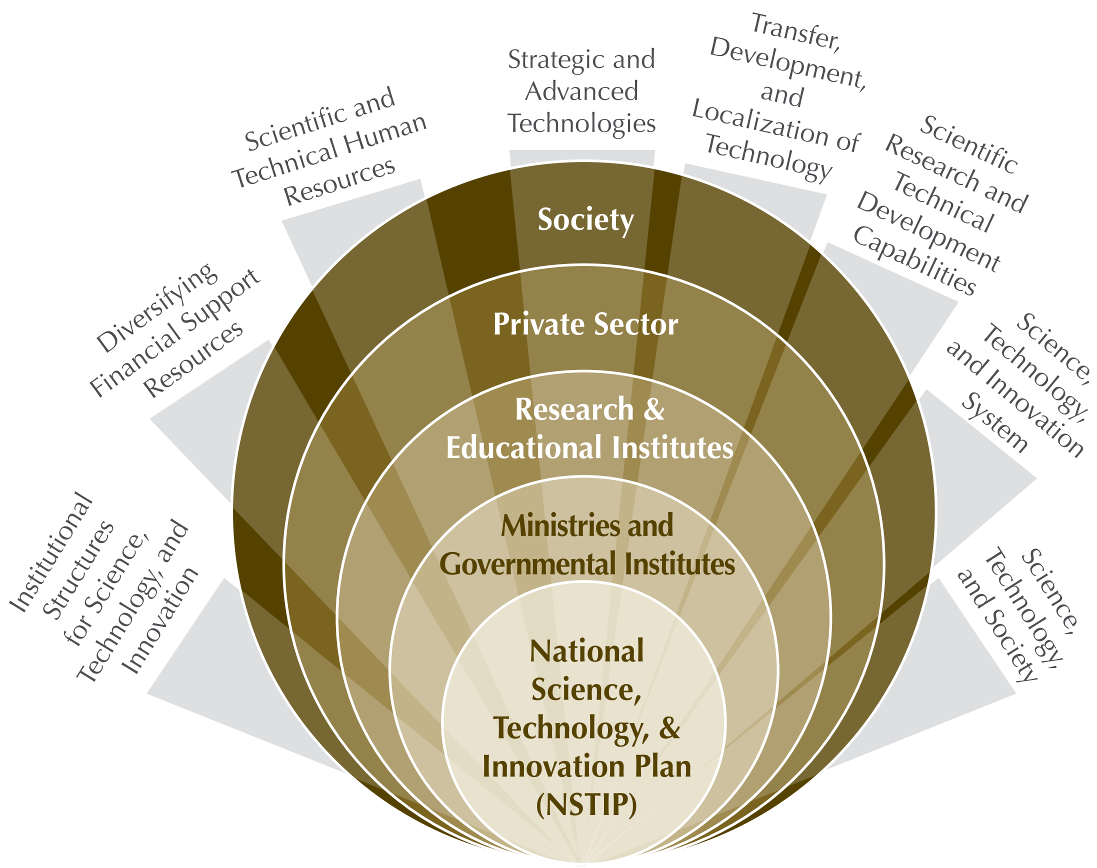
The King Abdulaziz City for Science and Technology (KACST) was directed by its charter of 1986 to "propose a national policy for the development of science and technology and to devise the strategies and plans necessary to implement them."

In accordance with this charter, KACST launched a comprehensive effort in collaboration with the Ministry of Economy and Planning (MEP), to develop a long-term national policy on science and technology. In July 2002, the Council of Ministers approved the national policy for science and technology, titled as "The Comprehensive, Long-Term, National Science and Technology Policy."

KACST and MEP embarked on a national effort in collaboration with stakeholders to develop the national plan for science, technology and innovation (STI), which drew up the broad lines and future direction of science, technology and innovation in the Kingdom of Saudi Arabia (KSA), considering the role of KACST as well as that of universities, government, industry, and society at large. The plan encompasses eight major programs, as depicted in Figure 1:

1. Strategic and advanced technologies
2. Scientific research and technical development capabilities
3. Transfer, development, and localization of technology
4. Science, technology, and society
5. Scientific and technical human resources
6. Diversifying financial support resources
7. Science, technology, and innovation system
8. Institutional structures for science, technology, and innovation

**Figure 1: Science and Technology Plan**




In the strategic and advanced technologies, KACST is responsible for developing a 20 years (divided into 5 years operational plans) national strategic plan for the transfer, development and localization of 11 technologies with main stakeholder collaboration. In addition, KACST facilitates strategic planning in key applied technology areas that draw upon fundamental technologies and impact human lives.

In keeping with this responsibility, KACST collaborated with relevant stakeholders to develop a technology strategy for the building and construction (B&C) sector of the Kingdom. This document embodies the product of that stakeholder-driven strategic planning endeavor.

# Introduction

## Scope and Plan Development Process

The scope of this strategic plan is national: it is a plan for research and innovation in the building and construction sector of the Kingdom of Saudi Arabia. The plan involves and affects independent research organizations, universities, industry, KACST and other government organizations related to the sector.

The plan establishes a mission, vision, objectives, identifies stakeholders and users, and determines the highest priority technical areas for the Kingdom. In alignment with the 20-year National Policy for Science and Technology, the plan's time frame covers 20 years, divided into 5-year operational phases.

The development of this strategic plan comprised the following logical steps:

- Identification of stakeholders and their representatives.
- Assessment of the present status of building and construction related technologies in KSA.
- Assessment of the size and capacity of building and construction industry in KSA including the demand on buildings, manpower and technologies.
- Identification and prioritization of R&D programs and key technology areas needed to address the Kingdom's needs in the B&C sector.
- Review of the size and capacity of global building and construction industry.
- Review of research performance including an analysis of KSA universities and research institutes, publications and patents, and an assessment of international research institutes.
- Identification of emerging technologies and other trends in the building and construction sector.
- Development of a mission, a vision and strategic objectives for the Kingdom's building and construction technology strategic plan; and
- Identification of regional and international partners.

## Current State of KSA's Building and Construction Sector

### Building Systems

Building systems in the Kingdom have undergone remarkable change in the last few decades. Prior to the oil revolution, buildings were marked by load-bearing walls made of mud or stones, and roofs made of wooden beams and sheets. Use of local material and local building skills and knowledge gave distinct characters to buildings in each region of the country.

With the discovery of oil and development and import of new construction materials and techniques like concrete, the locally built, distinctive character of buildings gave way to uniformity in style and characteristics throughout the Kingdom. For example, reinforced concrete (RC) frame structures are currently the most prevailing structures in residential complexes and infrastructure projects, whereas steel-frame systems are more common for industrial structures, warehouses and a few other public and commercial buildings.

In fact, reinforced concrete is the most common structural system used in the world. Approximately ten billion cubic meters of concrete are made each year, amounting to more than one cubic meter for every person on earth. There are various types of structural systems categorized under concrete structures including cast-in-place, pre-cast, pre-tensioned and post-tensioned systems.

Load-bearing system is one of the earliest forms of construction. There are many different types of load-bearing systems, including RC cast-in-place, RC pre-cast, reinforced masonry system, un-reinforced masonry system, and combined system. Bending structures such as plate girders and truss systems originally developed for bridges are currently used in long-span buildings and skyscrapers. Steel is a major material for these structures. There are different

types of steel forming systems, such as pre-fabricated systems and in-place fabricated systems.

Despite the introduction of a range of new technologies such as the earthquake resistant monolite, the light-weight, load-bearing siporex and the insulated concrete form (ICF) systems, the construction industry has been a slow adopter of these innovations. Building systems still depend mostly on traditional methods using reinforced concrete structures.

### Building Materials

Saudi Arabia has a vibrant and steadily expanding building materials industry that uses the country's large reserves of natural resources to produces high quality materials including cement, concrete, bricks, tiles, reinforce steel, ceramics, composite materials and glass. High quality and competitive pricing by local producers has led to a reduction in import of building materials, including iron ore and other solid raw materials, from 26% to 21.1% of the total imports in recent years.

Data from industrial census indicates that there were 533 factories producing building materials in the Kingdom in 2004. As shown in the following table, these factories had a total investment of over SR 22 billion, led by the cement subsector. While the large capital requirement of this subsector has led the Saudi government to play a bigger role in its development, the cement sector generates significant export revenue. Factories producing building materials employed over 42 thousands people, most being non-Saudi nationals.

**Table 1: Factories and labor force by building materials segment**

| Description | Factory (No.) | Labor Force (People) | Investment Value (Million $) |
|---|---|---|---|
| Mosaic and pavement tiles | 59 | 3350 | 521.13 |
| Stones, marbles and granite | 90 | 7202 | 1106.51 |
| Cement | 9 | 7666 | 14258.45 |
| Gypsum products manufacturing | 12 | 1058 | 431.74 |
| Precast concrete panels, posts etc. | 67 | 6860 | 1417.62 |
| Fiberglass, Rockwall and glass | 63 | 5322 | 1780.2 |
| Clay, sand & cement bricks, and curbs | 233 | 11103 | 3069.73 |
| **Total** | **533** | **42561** | **22585.38** |

# Strategic Context

The total yearly production of Saudi factories increased from 22 million tons of clinker and 24 million tons of cement in 2003 to more than 27 million tons of clinker and 30 million tons of cement in 2007. In four years, clinker production increased by 22% whereas cement production went up by 25%. Cement export from Saudi Arabia increased from 2.2 million tons in 2006 to 3.5 million tons by the end of 2007. On the other hand, export of clinker decreased by 51 % in 2007.

Portland cement concrete leads all construction materials used in the Kingdom. Economic and widespread availability of its constituents; and its versatility and adaptability to different construction environments are key factors behind its high degree of use. However, extensive use of concrete points to the fact that most problems in construction are related to concrete including low energy performance of concrete, deteriorations and other problems warranting costly repair, and wastage of construction material.

While concrete is also used in producing bricks, blocks and tiles for structural and non-structural construction, clay bricks and blocks are produced using clay as main raw material. Their quality, combined with high strength and low heat transfer properties, drives the use of clay bricks and blocks in buildings requiring insulated walls. Ceramic tiles and glass sheets, also used extensively in the Kingdom, are manufactured in the country using limestone, silica, sand, feldspar and dolomite from Saudi sources. Steel, aluminum and other alloys are also used as structural or architectural materials. Steel is used as hot- or cold–rolled bars, galvanized bars, pipes and tubes steel whereas aluminum sheets and frames are extensively used. Saudi Iron and Steel Company (Hadeed), the only local producer, produces about 4 million tons of steel per year.

Relatively new materials in use include petrochemicals-based products such as the PVC pipes, panels, doors and windows, plastic sockets and breakers etc. as well as several insulating materials including rock wool, and polyethylene and polystyrene sheets produced from local raw materials in relatively simple manufacturing processes.

Fiber reinforced polymers (FRP), a composite material with superior engineering properties such as strength to weight ratio, corrosion resistance and high fatigue strength, has gained attention in the field of structural engineering. Available in three forms, namely, rods, flexible sheet and rigid laminate (pre-cured), FRPs are categorized as Aramid Fiber Reinforced Polymers (AFRP), Glass Fiber Reinforced Polymers (GFRP), and Carbon Fiber Reinforced Polymers (CFRP) based on the type of reinforcement used. CFRP is the most commonly used form in the construction industry given its superior properties over the other two. However, since FRP's are relatively new materials, their use in Saudi Arabia is limited to special applications of strengthening and repair of concrete bridges and other infrastructural components. Need for higher skills, lack of awareness among builders and engineers and, to some degree, higher costs over alternatives such as steel, limit the use of FRPs.

The construction sector in general and the building materials segment in particular, suffers from the lack of advanced know-how, use of energy-intense manufacturing processes, lack of commitment to research, and disregard to improvement of material properties to meet Saudi Arabian Standards Organization (SASO) standards. Some technologies in use have high maintenance cost and others involve semi-automated and manual production systems that require skilled or semi-skilled labors.

### Size of the Construction Sector

The Kingdom's population is estimated to be approximately 27 million, and growing at an annual rate of 2.9%. Such high rate of growth, coupled with the fact that nearly 70% of the population is under 30 years of age, implies a growing demand on residential and commercial buildings.

Rapidly increasing demand for housing is one of the government's primary concerns. During the Seventh Development Plan period 2000–2004, the number of housing units completed or under construction topped 300,000 of which about 240,000 units were financed and implemented by the private sector, and the remaining by the Real Estates Development Fund (REDF). In addition, the Ministry of Municipal and Rural Affairs (MOMRA) issued about 150,000 building permits for construction of private and investment housing units. REDF could not meet a total of 270,000 requests up to the end of year 2004. The highest unmet demand for housing units is seen in Makkah, followed by Riyadh and Assir. Between 2005 and 2009, the cumulative demand for housing units has exceeded one million and it is estimated that over the next 15 years, Saudi Arabia will require double the number of housing units available currently.

Data indicates that spending on construction of the residential units increased by approximately 5%, from SR 78 billion in 2006 to SR 82 billion in 2007, and may further increase to SR 112.125 billion by 2016. Spending on non-residential construction increased by 8% from SR 42 billion in 2006 to SR 46 billion in 2007, given the government's focused promotion of foreign investment opportunities and removal of the minimum capital investment rule for foreign investors. Spending on non-residential construction is expected to grow further to SR 73 billion in 2016. Infrastructure spending, which increased from SR 82.5 billion in 2006 to SR 90 billion in 2007, is expected to grow to SR 171 billion in 2016 backed by the government's privatization initiatives.

**Table 2: Unsatisfied housing demand by region**

| Region | Unsatisfied Demand (%) | Unsatisfied Demand (thousands) |
|---|---|---|
| Riyadh | 18.2 | 40 |
| Makkah | 18.4 | 44 |
| Al-Madina | 33.9 | 20 |
| Qassim | 32.4 | 12 |
| East Region | 16.4 | 27 |
| Assir | 47.8 | 32 |
| Tabuk | 40.7 | 12 |
| Hail | 51.4 | 19 |
| Northern Borders | 48.5 | 8 |
| Jizan | 46.2 | 30 |
| Najran | 47.1 | 8 |
| Baha | 33.3 | 8 |
| Jouf | 41.7 | 10 |

Despite the growth in demand, the construction sector in the Kingdom faces several difficulties. The most critical ones include the absence of advanced standards, specifications, construction equipment and materials, lack of enabling financing systems, scarcity of Saudi professionals, skilled and non-skilled workers, and the general lack of incentives to use latest technology and non-conventional building materials.

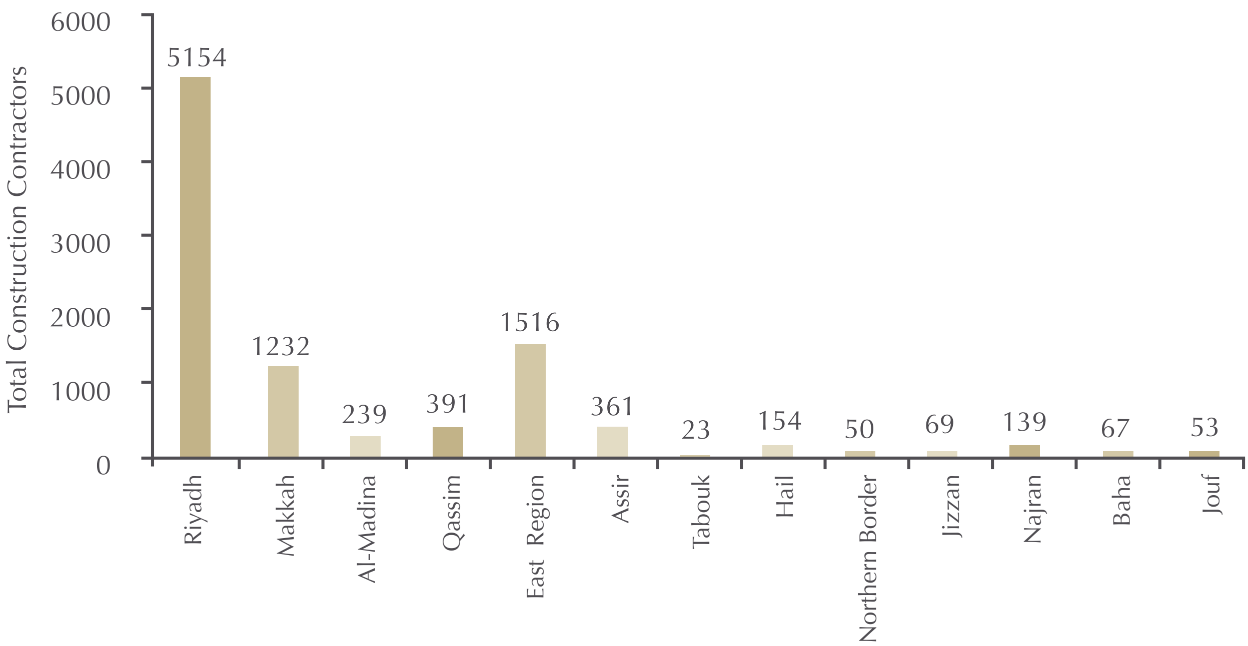
### Firms in Construction

In keeping with the increase in construction-related spending, the number of registered contactors increased from 3,690 in 2002 to a total of 9,448 in 2007, representing 27.7% of the total registered companies in the country that year. Most of the classified contractors are concentrated in Riyadh, Eastern province and Makkah region, constituting 54.5%, 16% and 13% respectively of the total registered contractors in the country. The following chart presents the distribution of construction contractors by region.

Large contractors are limited in numbers compared to their medium and small counterparts in Saudi Arabia. Only 216 large contractors, classified as degree (1), were registered in the country and located in four regions. Small contractors classified as degree (4) and degree (5) and totaling 7,964, represent the majority (84%) of the total number of contractors operating the construction sector.

Inadequate access to financial resources, in conjunction with bureaucratic financing systems, impedes the quality of work and productivity of most small and medium-sized construction firms. These firms, perceived to have higher risk than large firms, find it hard to receive timely finance from commercial banks. Developing the financial structure through introduction of standard evaluation criteria, and adoption of mandatory licensing for all contractors on the basis of specific qualification and objective performance criteria will improve the overall growth prospects for the construction sector.

**Figure 2: Construction contractors by region**



# Strategic Context

Despite the evolution of the national economic structure, the unprecedented construction boom of recent times has led to the reemergence of the problems and challenges seen in the construction sector during the previous boom era of the 70's and 80's. These challenges may be summarized as:

1. Weak capabilities and low capacities of local contractors.
2. Scarcity and increasing cost of manpower.
3. Shortage of construction and building materials and consequent inflation of material prices.
4. Slow construction process.
5. Higher cost of construction.

## Saudi Arabia's Current Position in Scientific Research

Most recently, SRI International (2007) assessed KSA's current position in science and technology through a combination of literature reviews, interviews, and bibliometric analyses. While a specific assessment for building and construction technology fields was not conducted, the overall assessment of Saudi Arabia's scientific performance was instructive for this planning effort.

Scientific publications are commonly used as an indicator of scientific output. The number of papers published in peer-reviewed scientific journals is considered to be an indicator of overall production of new knowledge. The number of times papers are cited by other scientific papers provides a measure of the impact of the paper. The number of patents produced provides an indicator of new technology developed.

The Kingdom's science and engineering output, as measured by publications, has been relatively flat over the last 20 years. Its performance in science and technology is stronger than that of many countries in the Middle East region but is far behind others, such as Egypt, Israel and Turkey. The contrast with Turkey is especially illustrative. Turkey's scientific output was comparable to that of Saudi Arabia in 1988, but it has grown rapidly as Turkey has become better integrated with Europe. Turkey's growth was a result of concerted policies that increased R&D as a percent of gross domestic product (GDP) from 0.32 percent in 1990 to 0.67 percent in 2002. Saudi Arabia's publications exceed those of Jordan, Kuwait, Lebanon, Morocco, Algeria, Oman, Syria, and the United Arab Emirates. As with other countries, Saudi Arabia-based scientists and engineers increasingly collaborate with colleagues in other countries. By 2006, around 50 percent of articles were internationally coauthored. KSA-based scientists and engineers collaborates the most with their counterparts in the United States, Egypt, and United Kingdom. Science and engineering publications are concentrated in a small number of institutions in Saudi Arabia.

Patents are a measure of inventive output – how much new technology, as opposed to new knowledge measured by publications – that a country or organization produces. For this indicator, SRI examined patents in the U.S. Patent and Trademark Office (USPTO) database. Although this is an incomplete measure as it does not capture all patents filed in all patent offices, it provides a good measure of significant inventions, because generally all internationally significant inventions file for U.S. patents.

As indicated in U.S. patents from 1976 to 2006 in the USPTO database, Saudi Arabia has more patents (374 patents) than many countries in the region, but it lags far behind India (3867 patents) and Singapore (4985 patents). It is interesting that Saudi Arabia patents are more than Turkey, in spite of Turkey's impressive growth in publications. It was shown that, relatively few Saudi organizations are involved in the great majority of Saudi patenting activity. Only three organizations namely, Sabic, Saudi Aramco, and King Fahd University of Petroleum and Minerals Research Institute, are responsible for 90 percent of KSA-based patents assigned by the U.S. Patent Office. This indicates that very few Saudi companies or research institutes are currently creating new-to-the-world technologies.

KSA has a relatively small number of institutions that are responsible for most of the Kingdom's research, and even smaller number that are responsible for the majority of the Kingdom's patents. Applied research and technology development has not been highly valued in the Kingdom. Despite a steady expansion of markets and profits, many Saudi companies conduct little research and inventive activity. Collaboration among research organizations in the Kingdom is relatively weak. University-industry-government linkages are also not well developed. The above qualitative findings support the overall conclusion that Saudi Arabia has capabilities in science and technology, but these capabilities need to be further developed.

## Key Research Performing Organizations

### Industries

Saudi Arabia's building and construction sector includes materials processing and manufacturing firms in addition to builders and contractors. Many manufacturing firms set up in various industrial zones focus primarily on production and fabrication of products for the Saudi market. These companies have generally benefited from import protection and cheap foreign workers. With WTO accession, drive toward Saudization and constraints ensuing from immigration laws, these advantages are slowly eroding. Saudi manufacturers need to compete on innovation and value addition through new technologies. These firms will benefit from research on materials, especially on materials processing, advanced materials, prefabrication and production techniques.

### KSA Universities and Research Institutes

Saudi Arabia's universities and research institutions play a very important role in engineering and architectural education and research relevant to the building and construction sector. This section outlines the most important universities and research institutions.

### Universities

King Saud University (KSU) in Riyadh is the largest university in the Kingdom and has the largest number of scientific publications among all KSA universities. It has strong engineering and architectural schools. King Fahd University of Petroleum and Minerals (KFUPM) in Dhahran is strong in many areas related to the building industry. After KSU, it stands second in publications. KFUPM has a research institute that conducts applied research in economics and management systems, engineering, environment and minerals.

King Abdulaziz University (KAU) in Jeddah is a major university with competencies in architecture, engineering and environmental science and technology. In addition to these and other existing universities, such as King Faisal University in Dammam, Umm Al-Qura University (UQU) in Makkah, Al-Qassim University (QU) in Qassim, and Taibah University (TU) in Madinah, several new universities are under establishment. Notable among those are the King Abdullah University for Science and Technology (KAUST), and universities in Taif, Jazan, Hail and Al-Jouf.

There are other independent, non-profit private institutions offering undergraduate education in the Kingdom.

The top-tier KSA universities rank among the best in the region, but none of them are among the world's leading universities in terms of research performance measured in terms of publications and patents, or in terms of broader, composite measures such as the Shanghai rankings. Lack of incentives for research, lack of availability of doctoral and post-doctoral students, teaching overloads and weak interaction with industry are cited as top reasons for such poor performance.

### Research Institutes

There are four major building and construction technology centers and research institutes scattered within the Kingdom. The General Director of Building Research of the Ministry of Municipality and Rural Affair is one of the major building research centers in the Kingdom. It has programs on major aspects of building components, such as soil foundation, concrete and concrete structures, cement, ceramic, fire resistant materials and other. The center is mainly specialized in testing materials and its properties.

The Research Center, College of Engineering, at KSU hosts research conducted by KSU faculty members in theoretical and applied areas. The Center provides the researchers with financial, technical and administrative support. Recently, a Center of Excellence for Research in Engineering Materials was established within the College of Engineering at KSU. It aims to support short and long-term material research and development leading to potential breakthroughs in building materials.

The Center for Engineering Research at KFUPM conducts high quality contract and applied research and to provide outstanding consultancy services to the industry in materials, energy systems, corrosion, and construction technologies and related engineering fields.

King Abdulaziz City of Science and Technology (KACST), the national science and technology agency, conducts research and provides grants to university researchers. KACST operates several national research institutes that perform, materials related research, including, Institute for Petroleum and Petrochemicals Research, the Energy Research Institute, the Institute of Natural Resources and Environmental Research, the Institute of Atomic Energy Research, and the Space Research Institute. Through its extramural research arm, KACST funds research at universities in building materials properties, building systems, construction and maintenance cost analysis and other construction or material related problems.

In 2007, the Custodian of Holy Mosques King Abdullah Bin Abdulaziz approved three major nanotechnology centers in KAU, KSU and KFUPM. In addition, KACST established a national research center for nanotechnology. Development of cement-carbon and other building materials are part of the center's research agenda. The College of Engineering in KAU established a consultant center to build relationships with the private sector, especially in the building and construction industry.

## Key National Needs

The stakeholders of the building and construction technology strategy have identified the following as the most pressing national needs of Saudi Arabia:

- Optimizing building design, construction, and operation and maintenance cost.
- Enhancing and developing new affordable and durable local building materials, utilizing local raw and waste materials.
- Enhancing and developing new affordable building systems.
- Developing sustainable and secure buildings;
- Safeguarding the environment and improving quality of life.
- Developing building capacity and infrastructures, and diffusing scientific and technological knowledge.

- Enhancing the current status of research and development (R&D).
- Enhancing the manpower needed to achieve the objectives through clear training policies and structured programs aiming at building local expertise in required specializations with due respect to priority areas.

### Stakeholders Roles

Construction is a major industry in Saudi Arabia. It requires a multidisciplinary approach involving experts from materials research, engineering, architecture and a host of other fields. It also requires regulation, and enforcement of standards at the national and local levels. Given the country's aspiration to transform itself into a knowledge-driven economy, and given the importance of the construction sector to the national economy, it is important that all relevant stakeholders in the construction sector coordinate their efforts in a systemic manner.

The stakeholders for B&CTS include KACST, universities, various Independent or specialized research institutes, Ministries, other government agencies, and private companies. The following table shows the roles of these stakeholders in the program.

## Analysis of Regional and International Universities and Research Institutes

For Saudi Arabia to excel in building and construction technology research and innovation, collaboration with regional and international research centers and universities is a prerequisite. This section elaborates on some of the current trends at leading centers and universities.

### Regional and International Universities

There are about 254 universities in fifteen countries in the region and more than 4,000 universities around the world. Most of these universities teach and carry out research in building and construction-related disciplines. The main departments related to the building and construction field are:

- Architectural.
- Structural engineering.
- Civil engineering.
- Mechanical engineering.
- Electrical engineering.
- Environmental engineering.
- Material engineering.
- Chemical engineering.
- Building and Construction engineering and management.
- Fire engineering.
- Industrial engineering.

A wide range of innovative research is being carried out at various international universities in sustainable construction and development. Global awareness toward climate change, sustainable development, energy efficiency, smart communities and other related issues, is driving research and shaping education in the building and construction field.

### Regional and International Research Institutes

Internationally, there are more than 400 building research centers and institutes supported either by government or private sector. In the region, there are seven building research institutes supported by national governments of the KSA, Jordan, Kuwait, Egypt, Sudan and Israel. Most of these regional and international research institutes perform long-term strategic research and applied research directed specifically to building and structural materials, systems and performance. The main research activities carried out in these institutes include:

### Building Materials and Technology

Under this category, research is primarily concerned with:

- Utilization of wastes and by-products in building materials.
- Improvement of cement;
- Concrete and fiber reinforced concrete properties.
- Masonry, glass, wood, plastic, ceramics and new innovated materials.
- Analysis and development of new building materials and components.
- Polymeric and bituminous materials for coatings and waterproofing.
- Durability of building materials and building elements.
- Corrosion of steel in concrete.
- Repair and maintenance.
- Microstructure and properties of building materials.

**Table 3: National stakeholders and their roles**

| Stakeholder | Roles |
|---|---|
| KACST | ■ Plan, coordinate and manage the strategic plan.<br>■ Conduct applied research, technology transfer and prototype applications development.<br>■ Manage and participate in national projects.<br>■ Provide support for university and industrial participation in national projects.<br>■ Provide support for national research facilities.<br>■ Provide advice and services to government on science and technology. |
| Universities | ■ Host and participate in Centers of Excellence for technology development and Innovation.<br>■ Conduct applied research, technology transfer and prototype applications development.<br>■ Teach and train students in science and engineering.<br>■ Create new basic and applied scientific knowledge.<br>■ Participate in collaborative projects.<br>■ Provide technical advice and services to government and industry. |
| Independent or Government Specialized Research Centers | ■ Create new applied scientific knowledge.<br>■ Participate in collaborative projects. |
| Ministry and Government Agencies | ■ Operation and implementation of technologies and projects.<br>■ Provide input to program on government R&D needs.<br>■ Reduce regulatory and procedural barriers to R&D and innovation.<br>■ Unifying and standardizing governance systems (laws, regulations, code, specs…).<br>■ Support R&D in universities and industry.<br>■ To participate in practical training through their specialized training centers such as Engineering Training Centre in MOMRA.<br>■ To monitor and enforce updated codes, regulations,…etc. |
| Private Sector | ■ Develop and commercialize products & processes resulting from the research and development program.<br>■ Communicate company needs to the research and development programs.<br>■ Support and participate in collaborative R&D projects.<br>■ Support and participate in the Technology Innovation Centers. |

- Solution of problems in application of prefabrication technologies.
- Industrialization of finishing work in buildings.
- Adaptation of materials to special uses in buildings and infrastructures.
- Advanced and Nano-materials.
- Rehabilitation of structures using composite materials.
- Use of pre-cast concrete elements in buildings.
- Use of autoclaved concrete in construction.

### Structural Engineering

Research under this category primarily includes:

- Earthquake engineering.
- Damage and repair of buildings.
- Assessment of existing structures.
- Strength and serviceability requirements of concrete and steel structures.
- Behavior of Steel structures.
- Optimization of design.
- Composite structures.
- Prefabricated systems.
- Lightweight elements.
- Masonry.
- Prestressed elements.
- Structures for special loading conditions (wind, snow, temperature, vibrations, dynamic and impact loading).
- Structural stability.
- Computer implementation.
- Cost-effectiveness of building codes.
- Structural damage and fracture mechanics.
- Structure foundations and soil-structure interaction.
- Special purpose structures.
- Protective structures.
- Modeling of structures.
- Structural safety and reliability.
- Smart structures.

### Building Performance

Research under this category includes:

- Hydrothermal analysis and properties of materials, components and buildings.
- Air quality and moisture problems in buildings.
- Building climatology and thermal analysis of buildings and of urban areas.
- Passive thermal control systems and means.
- Ventilation and wind effects.
- Acoustic performance of components and spaces.
- Effect of environmental noise on buildings.
- Fire safety, building services, intelligent buildings, etc.
- Development of criteria and evaluation methodologies for overall performance of buildings.
- Development of test methods.
- Building systems and components.
- Building envelope testing.
- Energy and water conservation systems.
- Ecologically sustainable development (ESD).

### Construction Management and Engineering

Research subtopics under this category include:

- Industrialization, automation and robotics in construction.
- Computerized information systems.
- Expert systems.
- Neural network in constructions.
- Management techniques in construction planning, organization and control
- Management under uncertainty.
- Construction equipment and site organization.
- Life-cycle costing of building systems and building equipment.
- Computer-aided design for building construction and site management.
- Production rates control.

Some of the leading research institutes around the world that offer promising collaboration opportunities are presented in the following table.

### International Trends in Building and Construction Technologies

The building industry represents one of the oldest, largest, and most important economic sectors in the world. However, this sector is facing new challenges manifested in consumer demands for lower cost, more adaptable, smarter and lower maintenance buildings while simultaneously reducing the impact on the environment. Major challenges derived from social, economic and environmental factors and trends are necessitating new advancements in technology for the sector. For example, key environmental considerations driving technological change include reduced energy consumption, conservation of primary resources, reduced use of water, and climate change effect (the need to reduce GHG emissions). Social factors driving change includes demand for new homes, greater variations in the make-up of households, changing demand for different types of buildings at lower costs, and demand for reductions in risks to health and safety. Integration of new technologies into the building's fabric and construction is also an emerging change driver.

Global trends point to a paradigm shift in characteristics of buildings. These trends indicate that the buildings of the future will tend to be:

- Energy-positive: minimizing energy use; providing heating, cooling, and electricity; and storing or returning excess electricity to the grid.
- Adaptable: designed for movable walls, convertible rooms, flexible systems and future technology innovations.
- Affordable: cost-effective in terms of comprehensive home ownership, spanning first cost, maintenance cost, life-cycle cost, and resale value.
- Durable: offering enhanced safety and resistance to natural hazards, including moisture, fire, and disaster, as well as decreased maintenance needs.
- Environmental: harmless to the natural environment, resource-efficient, and appropriately balanced between embodied energy and durability.
- Healthy and comfortable: harmless to the well-being of construction workers and occupants and providing good air quality and flow, thermal and visual comfort, natural ventilation and light, and protection against fire, moisture, chemicals, radon, and noise pollution.
- Intelligent: using advanced sensors, monitors, controls, and communication technologies to improve resource efficiency, comfort, affordability, adaptability, durability, and environmental harmony.

The concept of "sustainable building", "green building" or "carbon-neutral development" is getting a lot of policy attention around the world. For example, the British government's call for all homes to be zero carbon by 2016 has sent the construction industry into a green overdrive. Related to this subject, the Germans have developed and practiced the use of renewable energy sources at homes, incentivizing the home producers of energy to trade excess energy through a national energy exchange. These initiatives are an indication of possible future trends in building technologies in general, and the green building concept in particular.

Green building could involve the practice of increasing the efficiency with which buildings use resources --energy, water and materials-- while reducing building impacts on human health and the environment through better sitting, design, construction, operation, maintenance, and removal (the complete building life cycle). Generally, it incorporates five major components: sustainable design;

safeguarding water and water efficiency, energy efficiency and renewable energy, conservation of materials and resources, and indoor environmental quality.

Research and development related to energy efficiency and renewable energy, comprise the main activities in green building development initiative. The creation of an energy-efficient building starts with the design process itself. Research related to this stream covers building envelope, orientation, materials, heating, ventilation and air conditioning systems, as well as the use of artificial intelligence to reduce the energy consumption of a building.

**Table 4: Some of the leading research institute in the world**

| Country | Organization Name |
|---|---|
| USA | National Science Foundation |
| UK | Building Research Establishment |
| Japan | Building Research Institute |
| Denmark | Danish Building Research Institute |
| Jordan | Building Research Center, Royal Scientific Society |
| India | The Central Building Research Institute |
| Canada | National Research Center |
| UK | Central Research Institute for Building Structures |
| China | China Academy for Building Research |
| China | China Building Technology Development Centre |
| Austria | Austrian Institutes for Building research |
| Korea | Korean Institute for Construction Technology |
| South Africa | National Building Research Institute |
| Germany | Academy of Building |
| USA | Green Building Research Center at the Univ. of California-Berkeley |
| USA | Building Technology Center at Oak Ridge National Lab rotary |
| USA | Construction Research Center, the Univ. of Texas at Arlington |
| Germany | German Research Community (DFG) |
| Egypt | Housing and Building Research Center |

# Strategic Context

Renewable energy sources such as solar, wind, and geothermal can be used to reduce the carbon footprint of a building. Conservation of materials and resources is another research area in green building approach. This area of research focuses on technologies that are made from environmentally attractive materials (salvaged products, postconsumer or post-industrial recycled content, rapidly renewable products, minimally processed materials), green products, engineered materials and reconstituted materials.

Indoor environmental quality is a major technological challenge. Reduction of potentially harmful chemicals and biological agents, including carbon dioxide, volatile organic compounds (VOCs), molds, various allergens, and infectious agents utilizing nanotechnology, organic based substance and advance material technology is a priority area.

A green building approach also embraces not just how we build but also where we build, taking into consideration site selection, development density, transportation, and other factors that contribute to the sphere of the approach. Until recently, the concept of high-performance "green buildings" was difficult to define and the practice even more obscure. Today, advances in technology, combined with growing industry awareness and attractive financial incentives and benefits, are rapidly transforming the green building landscape.
The search for affordable, less time-consuming, and maintenance-free buildings and constructions have led to the promising Advanced Panelized Construction (APC) technology. Panelized construction is a method where the building is subdivided into basic planar elements that are typically constructed offsite through mass production, and then shipped directly to the construction site for assembly into the finished structure.

Technology transfer from other fields of science into the building and construction field is beginning to have significant impact on construction around the world. For example, nanotechnology is altering material properties in unprecedented ways. In the United States of America alone, 130 startups and established companies are offering or developing nanomaterial for green buildings, 54 projects are underway at universities and research centers, and 43 recent patents are available for licensing. A case in point is the use of nanotechnology to develop Aerogel "frozen smoke," which has been used to develop organic light-emitting diodes (OLEDs). OLEDS make light ten times more efficient.

Advanced composite material is another technology that has been transferred into and utilized by the building and construction sector. New and improved materials with better thermal and structural properties are enhancing building efficiency and reducing environmental impacts. An example of use of improved material is "Pixel Panels" that are a mix of 92.5% concrete and 7.5% polymers that allows light to penetrate, thus reducing electricity bills. Transparent ceramics is another innovative material that could be widely used in buildings. These ceramics are durable and super-strong, and at the same time they are also transparent, meaning they can be used for highly durable windows including rich, "jewel-like" colors.
In addition, carbon or glass fiber reinforced plastic sheet and rebar are being used in strengthening and rehabilitation of buildings and structures. These are a few of the emerging trends in technology shaping the building and construction sector.

## Benchmarking of Research Performance

### Publication Activities

There is a general agreement that publications and patents strongly correlate with scientific research capacity, although publication and patent counts alone do not fully represent the quality or scope of research. Nonetheless, publication and patent activity have long been used as indicators for knowledge creation and research output.

Research in building technology is published by several thousand public and private institutions of higher education in more than 140 countries. A limited assessment of research publication was carried out as part of this planning effort. This analysis covered articles published by each country in tier 1 journals in related subject between the year 2005 and 2008.

The journals on which the study was based included:

- Journal for Construction and Building Materials;
- Journal for Composite Structure;
- Journal for Energy and Building; and
- Journal for Building and Environments.

A factor for comparison was calculated by dividing the number of articles published over the number of higher education institutions in each country. Also, a referenced factor was calculated by dividing the number of articles published by each country over the number of articles published by KSA.

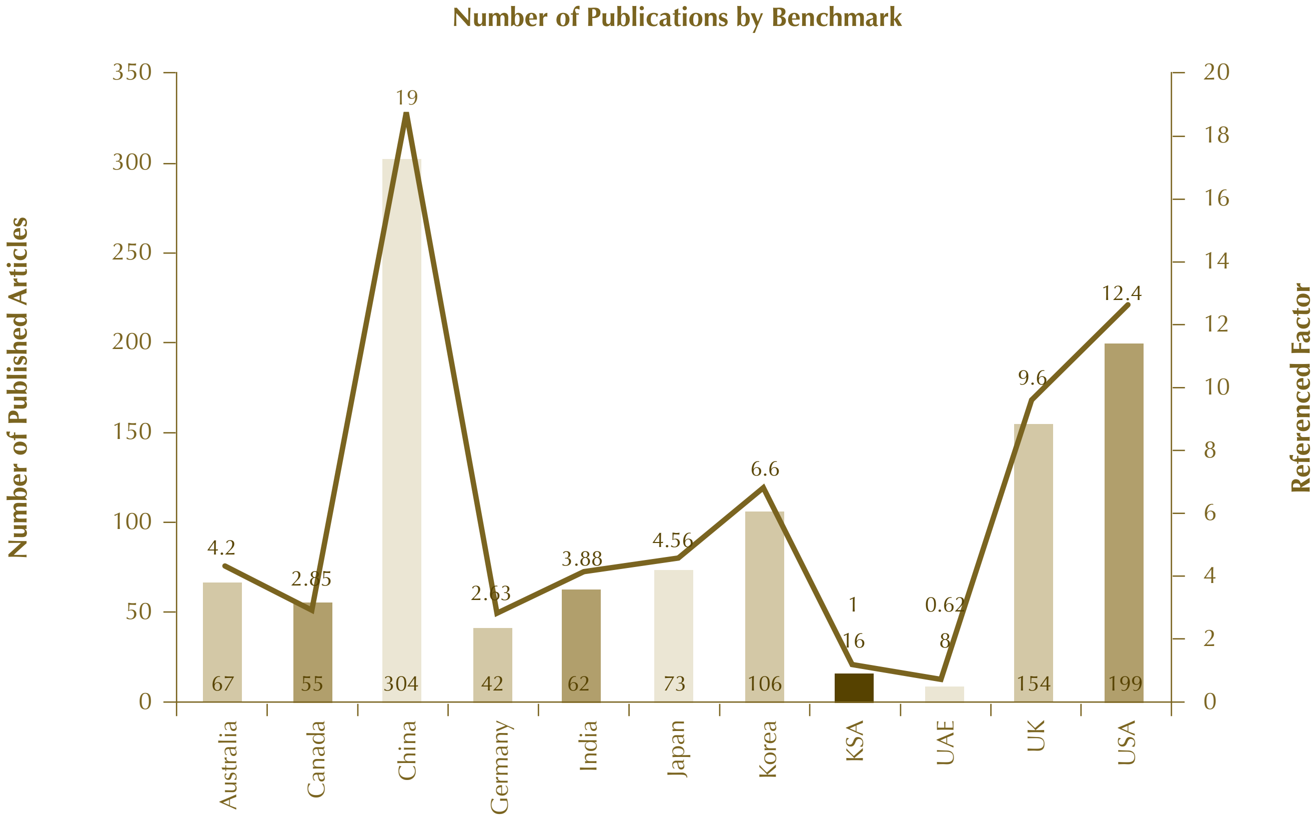
As presented in the following tables, China was the largest producer publishing 304 related articles, followed by the USA (199) and the UK (154). KSA institutions published only 16 articles. However, when the number of articles were normalized over the number of higher education institutions in each country, (4th column in table), Korea was the largest producer of research papers (1.04) followed by Australia (0.85) and UK (0.68).

The following chart depicts data on total number of research articles by each benchmark country.

**Table 5: Building and construction technology publications (2006-2008)**

| Country | Higher Education Institutions (No.) | Articles (No.) | Articles/HEI Factor | Referenced Factor |
|---|---|---|---|---|
| Australia | 79 | 67 | 0.85 | 4.20 |
| Canada | 205 | 55 | 0.27 | 2.85 |
| China | 891 | 304 | 0.34 | 19.0 |
| Germany | 390 | 42 | 0.11 | 2.63 |
| India | 326 | 62 | 0.19 | 3.88 |
| Japan | 671 | 73 | 0.11 | 4.56 |
| Korea | 102 | 106 | 1.04 | 6.63 |
| KSA | 42 | 16 | 0.38 | 1.0 |
| UAE | 33 | 8 | 0.24 | 0.62 |
| UK | 228 | 154 | 0.68 | 9.6 |
| USA | 3348 | 199 | 0.06 | 12.4 |

**Figure 3: Publications by country**




**Patent Activities**

The building and construction sector is marked by a high degree of intellectual property creation and protection. As shown in the following table, there were several patent applications filed between 2006 and 2008 with the International Patent Classification (IPC) and listed by World Intellectual Property Organization (WIPO) Statistics Database in July 2008. The majority of these patents are related to engineering and building fields. KSA shows the second lowest number of patents as compared with other benchmark countries (see Figure 9).

It can be seen that the USA was the largest producer with 116,975 related patents, followed by Japan and Germany with 62,336 and 38,786 patents respectively. Saudi Arabia produced only 150 patents over the same period. However, when the number of patents is normalized over the number of higher education institutions in each country, Korea was the largest producer of patents (145) followed by Germany (99.5) and Japan (93).

The following table shows the technical fields of PCT international patent applications published for 2006-2007 and annual growth in 2007. The fastest growing technical fields included environmental technology (12.3%) and civil engineering and building (6.6%).

The following chart depicts data on total number of registered patents by benchmark country.

**Table 6: PCT application field (2006-2008)**

| Country | Higher Education Institutions (No.) | Patents (No.) | Patents/ HEI Factor | Referenced Factor |
|---|---|---|---|---|
| Australia | 79 | 4506 | 57.0 | 30.0 |
| Canada | 205 | 6136 | 30.0 | 41.0 |
| China | 891 | 10713 | 12.0 | 71.0 |
| Germany | 390 | 38786 | 99.5 | 258.0 |
| Japan | 671 | 62336 | 93.0 | 416.0 |
| Korea | 102 | 14811 | 145.0 | 99.0 |
| KSA | 42 | 150 | 3.60 | 1.0 |
| UAE | 33 | 8 | 0.24 | 0.05 |
| UK | 228 | 12008 | 52.67 | 80.0 |
| USA | 3348 | 116975 | 35.0 | 780.0 |

**Table 7: Technical fields**

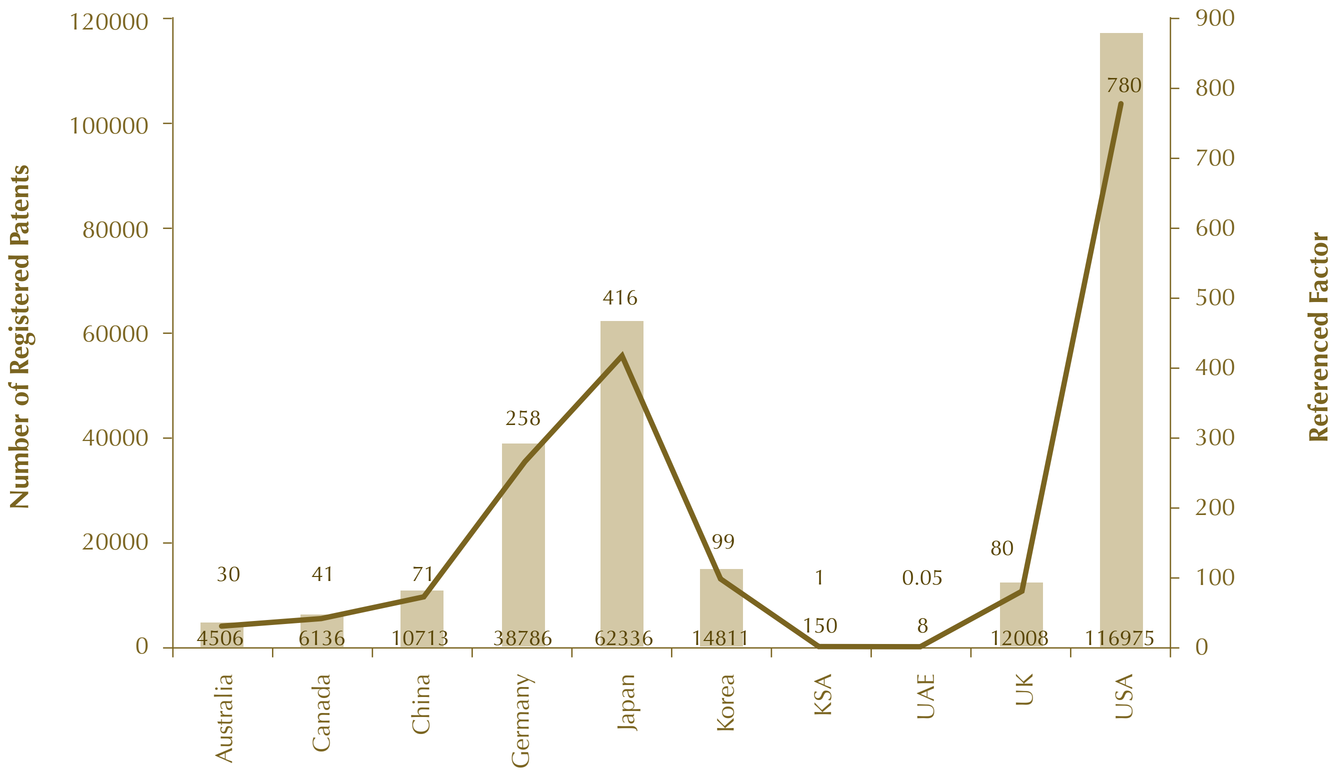
| Technical Field | Year | | Growth (%) |
|---|---|---|---|
| | 2006 | 2007 | |
| Civil engineering and building | 6399 | 6688 | 6.6 |
| Chemical engineering | 5680 | 5863 | 3.2 |
| Materials | 3836 | 4045 | 5.4 |
| Environmental technology | 1585 | 1780 | 12.3 |
| Mechanical | 4748 | 5084 | 7.1 |

**Patents by country**

The aforementioned comparative assessment of research performance should be read in the context of a broader set of demographic and economic factors. The following table shows the total spending on construction for selected countries for the year 2007.

The spending on construction per capita for Saudi Arabia ranked third after Japan and UK. The table also compares relevant demographic and economic indicators such as population, GDP, GDP per capita etc.

**Figure 4: Patent by Benchmark**



## SWOT Analysis

This section presents a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the Saudi Building and Construction Technology Strategic Plan relative to achieving its vision. In a SWOT analysis, strengths and weaknesses are internal to the organization or strategic plan while opportunities and threats are defined as external to the organization.

### Strengths

1. Establishment of Saudi Building Code (SBC), SASO standards and the General Specifications of Building Construction (GSBC) issued by Ministry of Municipal and Rural Affairs (MOMRA).
2. Attention of government (as manifested in the national development plans) and industry to building technology.
3. Present and future promising business opportunities in the B&CTs field.
4. Availability of the technical and scientific research infrastructure.
5. Interest at the national level in developing, utilizing and integrating modern technologies such as nano-technology, biotechnology, advanced materials, and other technologies into building and construction technologies.
6. Government support to stimulate new, value-adding, downstream industries utilizing crude oil.
7. Rapid growth in the construction sector encompassing housing and commercial complexes, new economic cities and industrial zones.
8. Availability of the necessary financial support for technology transfer within the National Science and Technology Policy.
9. Regional and international agreements and collaboration in science and technology.
10. The growing demand for building and construction technologies and the lack of competition in the technology market at the local level.
11. Commitment to implementation of the science and technology policy and its strategic plans.

**Table 8: Economic and demographic indicators for various countries**

| Country | Area (km2) | Population (Millions) | Const. Market (Billion $) | Const. Market /Population | GDP Growth (%) | GDP (Billion $) | GDP /Capital ($) |
|---|---|---|---|---|---|---|---|
| UK | 242,900 | 60.27 | 208 | 3.45 | 2.1 | 1664 | 27,700 |
| Japan | 377,915 | 127.4 | 500 | 3.92 | 2.7 | 4664 | 31,500 |
| Korea | 99,678 | 48.8 | 96 | 1.97 | 5 | 897.4 | 16,291 |
| KSA | 2,000,000 | 25.2 | 85 | 3.37 | 4 | 378.1 | 15,887 |
| UAE | 83,600 | 4.3 | 47.3 | 11 | 6.3 | 113.6 | 26,500 |
| Tunisia | 163,610 | 10.3 | 4.4 | 0.43 | 6 | 27 | 2,600 |
| South Africa | 1,221,037 | 47.4 | 25.6 | 0.54 | 4.8 | 177.1 | 3,700 |

### Weaknesses

1. The slow development and implementation of SBC and SASO standards.
2. Non-unified and standardized governmental systems

(laws, regulations, code, specifications etc.);

3. Failure to activate the scientific and technical infrastructure for transferring and developing technologies at appropriate levels;
4. Poor quality of scientific research in science and technology systems at the local level.
5. Fragmentation of building industry and lack of investment in research and development, as well as in adoption and use of new technologies.
6. Poor utilization of the international cooperation agreements and opportunities related to technology transfer.
7. Shortages of technical research personnel and equipment.
8. Lack of involvement of national specialists in planning, design and project management in both government and private sectors;
9. The difficulty of attracting distinguished experts and scholars to live in KSA.
10. Insufficient Saudi colleges or departments specialized in building and construction technologies;
11. The absence of civil society institutions that would contribute in the awareness of the importance of technology developments;
12. Lack of clear training policies and structured programs needed to enhance local expertise in required areas.
13. Low remuneration (income) for individuals working in research field and educational institutions compared to some other occupations.

**Opportunities**

1. Growing demand, at a global level, for innovative building and construction technologies in keeping with emerging trends related to sustainable developments, green buildings, and durable construction;
2. Enforcement of standards and specifications such as SBC, SASO standards and the General Specifications of Building Construction (GSBC) at the local level;
3. Growing demand for innovative Building and Construction Technologies, to commit and adhere with policy and regulatory drive through international treaties such as; United Nation Framework to combat climate change (UNFCCC) and Basel Convention etc;
4. Presence of international agreements with KSA related to technology transfer of building and construction technologies
5. The growing awareness regarding “environmental security” at the global level and their relationship to international security and integrity of natural systems;

**Threats**

1. Global competition to develop innovative solutions for the building and construction sector.
2. The difficulty in transferring technology from proprietors.
3. Contradictions and conflicts among policies and government regulations.
4. Lack of access to knowledge due to concerns of “technical security ” and “ political controls”.
5. Entry of lower-cost foreign competitors due to WTO agreements.

# Higher Strategy

This section provides the vision, mission, and strategic priorities for the Kingdom's Building and Constructions Technology Strategic Plan.

## Vision

To be recognized as a developer of innovative and knowledgeable solutions in the field of building and construction technologies.

## Mission

To enhance and develop feasible research and development programs that will catalyze the transfer, localization and development of technologies and solutions for the domestic building and construction sector through national and international collaboration.

## Strategic Goals

The strategic objectives of the plan are aligned with the key needs of the Kingdom and the broad developmental goals set forth in the National Policy for Science and Technology:

1. Transfer, localize and develop feasible and cost effective building and construction technologies to improve quality of life.
2. Enhance the quality and productivity of research in strategic areas relevant to safety and long-term service life of the structures.
3. Develop sustainable, durable and environmental friendly structures based on latest research and technological advancements.
4. Encourage construction industry to have professionals who add value to the development of building and construction technologies.
5. Bridge the gap between end users, R&D organizations and private sector to generate new investment opportunities.
6. Involve stakeholder in action plan and decisions making.
7. Develop human resources – in numbers and caliber - to undertake these formidable tasks.

# Technology Areas

## Main Research and Development Programs:

In order to fulfill the strategic objectives and the kingdom's needs, considering national issues, economical impact, optimization and sustainability, stakeholders identified major R&D programs to be:

1. Safety.
2. Health.
3. Energy.
4. Environment.
5. New Trends.

---

The sphere of the programs main R&D activities, generally involve one of the following areas:

a. Enhancement and improvement of an existing technology.
b. Development of a new technology.
c. Localization of an existing or a new technology.

### Principal Initiatives

These main R&D programs are based on and designed to satisfy the following principal initiatives:

1. Affordable and Cost-effective.
2. Adaptable and durable.
3. Safeguarding water and water efficiency.
4. Energy efficiency and renewable energy.
5. Conservation of materials and resources, and
6. Indoor environmental quality.

### Main Themes

The target of these programs will be accomplished by transferring, developing and localizing selected technologies that could serve either design or construction or/and operation and maintenance O&M projects, and should address one or more of the following main themes:

**1. Building and Construction Materials, Architectural:**

- Structural

## Technology Areas

- Geotechnical (Grid and backfill materials)
- Electrical.
- Mechanical.
- Sanitary.
- Insulation.
- Advance/ composite.
- Other materials.

**2. Building and Construction Systems;**

- Concrete.
- Masonry.
- Steel.
- Composite.
- Other Systems.

**3. Building Design, Performance and Quality Assurance; and**

- Buildings safety, serviceability and durability.
- Structural Dynamics and earthquake engineering.
- Geotechnical aspects ( foundation – soil interaction)
- Hydrothermal analysis and properties of materials, components and buildings.
- Air quality, ventilation and moisture problems in buildings.
- Building climatology and thermal analysis of buildings and of urban areas.
- Passive thermal control systems and means.
- Acoustic performance of components and spaces.
- Effect of environmental noise on buildings;
- Fire safety, building services, intelligent buildings, etc.
- Development of criteria, evaluation methodologies and monitoring overall performance of buildings.
- Development of test methods.
- Building systems and components.
- Building envelope testing.
- Energy and water conservation systems.
- Ecologically sustainable development (ESD).

4. **Building Assembly systems.**
- Electrical;
- Mechanical.
- Electro-mechanical.
- Sanitary.
- Safety, Security and monitoring.
- Other Systems.

## Technology Selection Criteria

Selection of projects (related to improving, transferring and developing building and construction technologies) under each R&D program will be subjected to certain criteria that will adapt to evolving strategic needs of the kingdom. For the first five –year plan (1429-1434H) the criteria for selection are:

1. **Technology's Demand/Need.**
- Impact of technology on existing/Future industry.
- Size of industry benefit from technology.

2. **Technology's Surrounding Environment.**
- Intellectual property issues.
- Accessibility to the technology.
- Availability of local infrastructure and man power.
- Availability of international science and technology cooperation/ Signed agreement.
- Integration with other strategic technologies.

3. **Technology's Competence and Quality.**
- Technology Life Cycle.
- Environmental impact.
- Suitability to local weather and geological condition.

4. **Technology's Economics.**
- Size of jobs it could generate.
- Cost effectiveness.
- Economic shortfall from not using the technology.

5. **Technology's strategic alignment.**
- Alignment with the plan strategic objectives.
- Alignment with the priority programs.

## Priority Project Areas

For the first five years (1429-1434) a priority project areas are identified based on the most pressing kingdom's need in the building and construction sectors, and in alignment with the R&D programs. These areas are:

- **Safety:**

1. Durable and serviceable structural systems (design, construction and maintenance).
2. Fire proofing materials and systems.
3. Smart and advanced electro-mechanical materials and systems.

- **Health:**

1. Moisture and damping Insulation.
2. Sound proofing.
3. Advanced materials and systems for Floors and walls.
4. Smart windows and openings systems.

- **Energy**:

1. Solar.
2. Heat Insulation.
3. Buildings envelop orientation.

- **Environment**:

1. Water conservation.
2. Construction/ demolition waste reusing and recycling.
3. Environmental friendly Synthesis materials development.

- **New trends:**

1. Low cost structural systems (design, construction and maintenance).
2. Fiber Composite materials (Polymer, Plastic, Glass, Carbon, etc.).
3. Smart (concrete, Mansonry and composite) materials and systems.
4. Advanced ceramics and alloyed materials and systems.

# Implementation Structure

## Structure and Strategic Connection

The following schematic depicts the connection among strategy components. It captures the main inputs and outputs of the process for selecting, transferring, developing and localizing building and construction technologies.

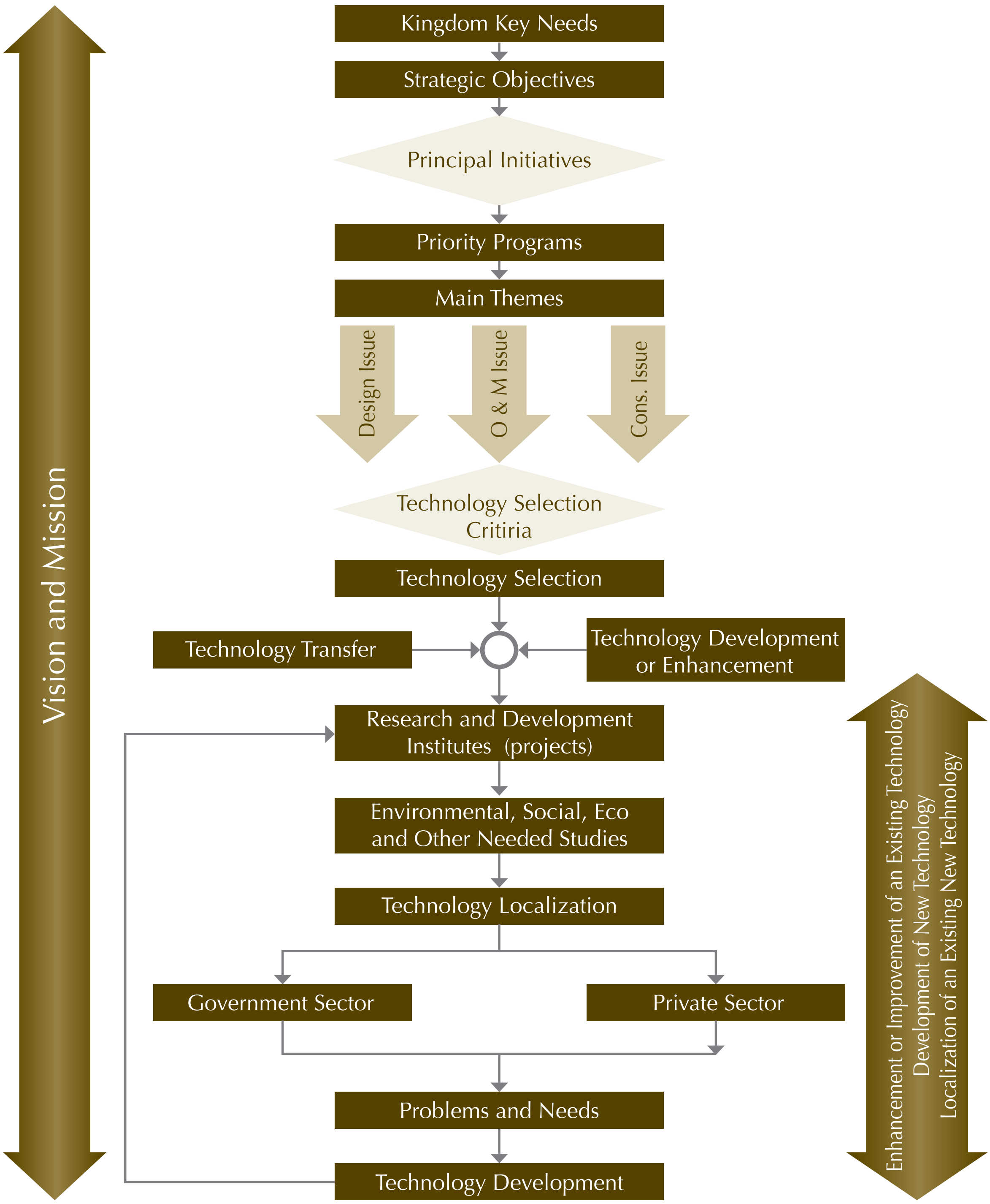
## Performance Indicators

### General Key Performance Indicators

Have been set for assessing and monitoring the operation and implementation of this strategic plan. These indicators are grouped technically and administratively. The administrative indicators include:

- Number and impact of successful applications of Building and Construction to stakeholder needs.
- Expansion of number of research-active specialist in the Kingdom.
- Number of papers published in journals and their impact.
- Number of generated patents.
- Number of products successfully entering the market.
- Number of successfully incubated new companies.
- Number of researchers trained and applications eveloped.
- Number of man-hours achieved in structured training related to the programs of this plan.

**Figure 5: Strategic connections among strategic plan elements**



## Technical Indicators

Technical indicators are presented in the following table.

**Table 9: Technical performance indicators**

| Priorities | Objective | Techniques |
|---|---|---|
| Safety | 1) Transferring, localizing and developing feasible and cost effective building and construction technologies to improve life quality | ■ Conduct applied research and prototype applications<br>■ Strengthen industry's ability to competence in international market |
| Health | 2) Enhancing the quality and productivity of research in strategic areas relevant to safety and long term life of the structures. | ■ Provide support to Universities<br>■ Participate in collaborative projects<br>■ Develop internationally competitive products and processes |
| Energy | 3) Developing of a sustainable, durable and environmental friendly materials based on latest researches, current technological advancements and challenges of building and construction technologies | ■ Sustainable and safe environment<br>■ Conservation of national resources<br>■ Conservation of energy<br>■ Conservation of water |
| Environment | 4) Elevating the construction industries to have the professionals who will have added value to the development of building and construction technologies. | ■ Research-active specialist<br>■ Create new applied scientific knowledge |
| New Trends | 5) Bridging between end users, R&D and privet sector to generate new investment opportunities (business opportunities). | ■ Support and participate by privet sector in R&D projects<br>■ Coordinate privet sector needs with strategy priorities |
| | 6) Involving stakeholder in action plan and decisions making. | ■ Support and participate in technologies centers<br>■ Reduce regularity & procedural barriers<br>■ Participation in the advisory committee for B&CTSC |

# Implementation Structure

## Action Plan

Implementation of the strategic plan for building materials technology will require activities at three levels: the initiation, the transition, and the action levels.

### Initiation level

Enriching the awareness of the importance of building and construction technology for various objectives i.e. healthy environment, energy conservation, and low maintenance cost for long term. Some of the techniques that can be used are:

- Establishing a Building and Construction National Research Center.
- Building a chain of local professional groups including the establishment of a scientific society.
- Developing a detailed roadmap.
- Prioritizing and organizing R&D programs.
- Organizing national and international workshops and conferences.
- Holding international exposition in B&CTs in Saudi Arabia.
- Establishing structured training courses in Saudi universities and colleges and other capable entities such as MOMRA and the Engineers Council.

### Transition level

Developing or inventing technologies in building and construction materials and systems. Examples of techniques that can be used are:

- Initiating funded projects in Saudi R&D institutes with international experts.
- Initiating exchange programs with different professional levels.
- Setting regulations and policies enforcing the use of B&CTs in harmony with the new Saudi Building Code (SBC), with setting the priorities of these technologies.
- Establishing centers of excellence in B&CTs in Saudi Arabia.

### Application level

pplying transferred and developed technologies in the industry sector.

## Implementation Structure

**Implementation Plan**

To facilitate the implementation of the B&CT strategic plan, a National Building and Construction Technologies Center (NBCTC) should be established at KACST. NBCTC will take responsibility for the overall management of the plan and for the coordination and evaluation of the program components at the national level. A network of centers of excellence in building and construction materials and technologies should be established at Saudi universities and institutions to accelerate technology transfer and development.

A major task for the first year of the program will be for KACST to develop the necessary governance infrastructure and operational plan. That will require hiring skilled technical staff capable of overseeing large scale technical initiatives that span several different institutions and research centers. It is essential to build the skills necessary to lead and develop these programs, and to plan them carefully. As part of the initial activities under this plan, KACST staff and other stakeholder members will visit programs of a similar nature elsewhere in the world to discuss their management practices and lessons learned.

A Building and Construction Advisory Committee will be established, with stakeholder membership, to oversee the implementation of the plan. It will review performance metrics and provide advice on the portfolio of projects. It will also propose appropriate regulations and government incentives to promote wider utilization of high impact new building and construction technologies. The Committee will report to the National S&T Plan Supervisory Committee, which will oversee all of the National S&T Programs. The Advisory Committee will meet four times a year and review progress in the programs.

The national advisory committee will also sponsor and oversee studies of emerging areas of Building and Construction Technology, to serve as the basis for developing new program areas. This plan will be reviewed and updated annually. In addition to the national advisory committee input, it is expected that workshops with the research community, users, industry and other stakeholders will also contribute to both a continual evaluation of the plan as well as a stronger technology research and development in the Kingdom

# Appendix A: Stakeholders

## Stakeholders and their Activities

| Organization | Activities |
|---|---|
| Ministry of Municipal and Rural Affairs (MOMRA) | ■ The Ministry of Municipal and Rural Affairs is by far the largest stakeholder of all private and governmental entities in the Kingdom. It has 8 deputies which have control over the general land planning and urban development as well as the enforcing of building regulations through granting building and occupancy permits. The Deputy Ministry of "Central Directorate for Development of Projects (CDDP) formerly Public Works" is the Ministry's arm to implement projects in Holy Areas. The CDDP has in the last twelve years supervised the planning and implementation of MEGA Projects in addition to being a party in engineering developments in the Kingdom.<br>■ The Ministry conducts several activities through different deputy and general directorate. This includes: Contractor Classification, Building Materials Research, Engineering training, Re-engineering. |
| Ministry of Commerce and Industry (MCI) | ■ Enhancing industrial competitive capabilities.<br>■ Providing an infrastructure supportive of enhanced industrial development.<br>■ Enacting suitable laws and regulations to ensure a fair, competitive market for industrial products. Building an industrial data base which will monitor & coordinate inter-industry flows.<br>■ Promoting investment in the infrastructure of industrial cities & technology zones.<br>■ Formulating of regional deployment of particular technologies. |
| Saudi Arabian Standard Organization (SASO) | ■ Formulating and approving of national standards. Setting the rules for granting certificates of conformity and quality mark and regulating their issuance and use. |
| Saudi Arabian Geological Survey Authority (SGS) | ■ Utilizing advanced technology to acquire and interpret geo-science information, and develop sustainable mineral and water resources.<br>■ Protecting the environment and monitor geo-hazards to secure a better life for our people. |
| Saudi Arabian General Investment Authority (SAGIA) | ■ Attracting sufficient investment to achieve sustainable rapid economic growth while capitalizing on the Kingdom's competitive strengths as the global capital of energy, and as a major hub between East and West.<br>■ Providing comprehensive licensing and support services to investors in establishing their businesses.<br>■ Identifying opportunities that are linked to the country's competitive advantages and match them to investors fitting a strategic, risk, and financial profile.<br>■ Cooperating with regional authorities to create region-specific investment promotion plans and strategies. |
| Saudi Universities | ■ Host and participate in Centers of Excellence for technology development and Innovation.<br>■ Conduct applied research, technology transfer and prototype applications development.<br>■ Teach and train students in science and engineering.<br>■ Create new basic and applied scientific knowledge.<br>■ Provide technical advice and services to government and industry. |

# Appendix A: Stakeholders

| Organization | Activities |
|---|---|
| Saudi Council for Engineering (SCE) | ■ Promoting the engineering profession, develop and upgrade its standards and those practicing it.<br>■ Setting criteria and standards. Profession development.<br>■ Setting license terms and conditions.<br>■ Setting rules and regulations.<br>■ Conducting examinations for obtaining professional degrees. |
| Royal Commission for Jubail and Yanbu (RCJY) | ■ Promoting, assisting, servicing and otherwise encourage the development of basic, downstream and light industries that would utilize the Kingdom's natural resources to produce value added products for local use and export.<br>■ Planning, developing, constructing, operating and maintaining the various infrastructure and services needed for the above industries and for the people working in these industries.<br>■ Encouraging the use and enhancement of the skills and talents of the Saudi citizens in the above activities.<br>■ Maintaining a balance between industrial development and environmental safety that is compatible with sustainable development.<br>■ Encouraging the participation of local and foreign private investment.<br>■ Working in liaison with other agencies such as Saudi Aramco, the Seaports Authority and others to facilitate the availability of feedstock and other services needed by the industries.<br>■ Functioning as a City Manager responsible for the safety and security of the entire industrial area under its jurisdiction. |
| Technical and Vocational Training Corporation (TVTC) | ■ Preparing and train individuals to perform the required industrial, commercial, agricultural and services activities that contribute to the national economy whether by working in public or private sectors.<br>■ Providing the individual with the Islamic values and general knowledge that help them adopt a good way of thinking and adjust to different environments.<br>■ Creating a scientific base of technical manpower that can easily deal with the rapid development in technology.<br>■ Providing opportunities for individuals who desire to learn a profession or continue training to the highest level that his mental and physical capabilities allow.<br>■ Developing the skills of technicians and update their professional information on a continuing base.<br>■ Underlining the importance of handicraft and vocational work and their role in the prosperity of the society.<br>■ Contributing in halting the movement of citizens to big cities by opening vocational training centers in all Kingdom's regions. |
| Saudi Arabian Building Code National Committee (SBCNC) | ■ Preparing a building code for the Kingdom including criteria of designing building that are resistant to earthquakes.<br>■ Preparing a plan to study the assessment and improvement for the earthquake efficiency of buildings that are currently found in earthquake-stricken areas in the kingdom.<br>■ Proposing regulations that obligate public and private sectors to implement Code requirements and the criteria of buildings design that resist the earthquakes in the Kingdom. |

# Appendix A: Stakeholders

| Organization | Activities |
|---|---|
| Saudi Aramco | ■ Saudi Aramco uses and develops innovative approaches to maximize productivity, efficiency and safety. R&D Center hosts a Technical Exchange Meeting to provide a forum for scientists and engineers to exchange new ideas, identify mechanisms for technology transfer and review the latest scientific developments in a variety of disciplines. R&D Center sponsors membership in scientific societies, where members are encouraged to give presentations and conduct discussion groups. |
| Saudi Basic Industries Corporation (SABIC) | ■ Producing and undertake R&D in chemical, plastic and steel industry. It contributes a vital role in the construction, development and industrialization of some of the world's fastest-growing economies. |
| The Council of Saudi Chambers of Commerce (CSCC) | ■ Representing Saudi building materials and construction traders, contractors & manufacturers. |

# Appendix A: Stakeholders

## Stakeholder Representatives and Plan Participants

| Participant's Name | Organization |
|---|---|
| ■ Mohammed Binhussain<br>■ Mohammed Alhussaini<br>■ Abdullah Alkhalid<br>■ Walid Molla | KACST |
| ■ Badr Alsderi<br>■ Magdi Khalifa<br>■ Lother Powroschnik | MOMRA |
| ■ Khalid Alotaibi | MCI |
| ■ Sami Mirza | SASO |
| ■ Khalid Alfi | SGS |
| ■ Moataz Badawi | UQU |
| ■ Tarek Almusallam | KSU |
| ■ Alfarabi Sharif | KFUPM |
| ■ Faris Alfaraidy | KFU |
| ■ Adnan Alsahhaf | SCE |
| ■ Abdullah Alarainy | RCJY |
| ■ Rajeh Alzaid<br>■ Abdulaziz Al-Negheimish | SBCNC |
| ■ Khalid Alsharif | Saudi Aramco |
| ■ Fuad Bukhari | Ithar Consultant |
| ■ Mohammed Alisa | Plastbau Arabia Co. |

# Appendix B: Research Focus of Local Universities and Research Institutes

| University/Institute | Colleges/Departments | Research Topics and Fields |
|---|---|---|
| King Fahad University for Petroleum and Minerals (KFUPM) | Sciences, Computer Sciences & Engineering, Engineering Sciences & Applied Engineering, Environmental Design, Industrial Management, Civil Engineering | ■ Building Material: raw material, concrete, composite and others.<br>■ Building Systems: concrete, masonry, steel, composite system;<br>■ Building Assembly Systems: mechanical, electrical & safety systems. |
| King Abdulaziz University (KAU) | Electrical and Computer, Mechanical, Civil, Chemical, Industrial Engineering, Urban Design. | ■ Building Material: raw material, concrete, masonry, others;<br>■ Building Systems: concrete, block, steel, mixed system.<br>■ Building Assembly Systems: mechanical system (e.g. HVAC) electrical & safety systems, others. |
| King Faisal University (KFU) | Architecture and planning architecture, construction engineering, urban and interior design, Islamic arch. Research center. | ■ Building Material: raw material, manufacture product. others;<br>■ Building Systems: concrete, block, steel, mixed system;<br>■ Building Assembly Systems: mechanical system (e.g. HVAC) electrical & safety systems, others. |
| King Khalid University (KKU) | Science, Information Technology, Mechanical, Industrial Engineering | ■ Building Assembly Systems: mechanical system (e.g. HVAC) electrical & safety systems, others. |
| King Saud University (KSU) | Sciences, Information Technology, Electrical, Mechanical, Civil, Chemical, Industrial Engineering, Survey, Architecture & Planning | ■ Building Material: raw material, concrete, masonry, steel, composite and admixture.<br>■ Building Systems: concrete, block, steel, FRPS structural strengthening;<br>■ Building Assembly Systems: HVAC, indoor quality electrical & safety systems, others. |
| Um Alqora University (UQU) | Islamic Architecture Electrical, Mechanical, Civil, Computer Engineering. | ■ Building Material: raw material, manufacture product. others;<br>■ Building Systems: Concrete, block, steel, mixed system;<br>■ Building Assembly Systems: mechanical system (e.g. HVAC) electrical & safety systems, others. |
| Qasim University (QU) | Electrical, Civil, Mechanical Engineering, Health Engineering | ■ Building Material: raw material, manufacture product. others;<br>■ Building Systems: concrete, block, steel, mixed system. |
| Taif University (TU) | Computer Engineering | |
| Jouf University (JU) | Civil, Electrical, Mechanical, Computer, Industrial Engineering | |

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