Photo-realistic Visualisation of 3D City Models

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Abstract

Three-dimensional (3D) city models, or Digital Terrain and Building Models (DTBM), can often be derived easily from existing topographic base map data. DTBM have a growing number of applications, including in telecommunications as a basic dataset for antenna network planning, or in environmental studies for modelling the propagation of noise and air pollutants (e.g. from car traffic). Only building geometry, but not facade visualisation is required for such applications. Today, Computer Aided Architectural Design (CAAD), defence and homeland security studies, latest generation car navigation, flight simulators, or tourist information systems increase the demand for visual information added to DTBM, in particular visual impressions of building facades. Two different solutions are applied to generate virtual 3D city models. To cover large areas fast, photographs from an image library are rendered randomly upon the vertical planes of DTBM. For smaller areas and where more realistic results are required, terrestrial photographs of real-world facades are used, and every facade is pasted with its proper photograph. This paper shows examples of visualised DTBM. Possibilities for applications in Kuwait are discussed.

Keywords

3D City Models, Digital Terrain and Building Models (DTBM), Visualisation of building facades

Introduction

The Kuwait Ministry of Public Works has recently announced several mega-construction projects, including the development of Boubyan Island, and several housing projects in four new cities (US-$ 51 billion total investment). Edifices to a maximum height of 100 storeys are now permitted inside Kuwait City's Ring Road 1. Construction projects will create a huge demand for surveying and geospatial data, including for 3D City Models.

Kuwait Municipality Survey Department (KMSD) is responsible for the collection, update, administration and dissemination of topographic base data as part of the Spatial Data Infrastructure (SDI). KMSD tasks include mapping by stereo compilation from air photos, the organisation of photo-flights (usually contracted), 'line mapping' projects (usually contracted), data processing and administration, and the dssemination of data to public and private organisations.

In essence, KMSD produces three maps: the Kuwait cadastral map, the Kuwait topographic base map, and the Kuwait map of utilities. Map data are stored in MicroStation J (by Bentley) dgn file format, based on the N.G.N. of Kuwait, 3° Transverse Mercator projection (Kuwait Transverse Mercator, KTM), a result of the Kuwait Utilities And Data Management System, KUDAMS (Konecny, 2005).

The KMSD topographic base map is open to private sector, and is the backbone of the SDI. It is a topographic map showing visible features on the Earth's surface, generated from air photos by photographic line mapping. A catalogue of 70 topographic features is used. The data is stored in 3D dgn files. Terrain and building information (incl. elevation contours and spot elevation) and connective street centre lines are contained in the map, which is disseminated to third parties in AutoCAD or MicroStation file format. The topographic base map represents topographic features with points, lines, polygons and text of different colour, size, and style.

Present uses of KMSD maps include the organisation of cadastral updates, and land use planning (e.g. during the Third Kuwait Master Plan, 3KMP, 1992 to 1997). Possible further uses of KMSD maps may include the derivation of advanced geo-data products from air photos and base map data, such as a Digital Terrain Model (DTM), Digital Terrain and Building Model (DTBM, or 3D City Model), Digital Orthophotos (DOP), orthophotomaps, and a land use map. Possible applications of geospatial data in private industries include the use of street centre line information in car navigation, the use of DTM / DTBM in GSM signal propagation planning, environmental studies, and Computer Aided Architectural Design (CAAD) studies.

Objectives

Objectives of this feasibility study are to explain how KMSD topographic base map data is processed in order to generate a Digital Terrain and Building Model (DTBM, or 3D-City Model), and to show examples of how DTBMs are used in technical applications and planning in the telecomm industry (GSM signal propagation planning), environmental studies (modelling of the propagation of air pollutants and noise), and in CAAD studies.

Materials & Data

The study area comprises 1,000 m by 1,000 m urban residential area in Kuwait in flat terrain (one mapsheet of a 2004 line mapping project). The processed data comprises digital scans at 14 microns of three colour air photos, taken at scale 1: 6,000 with a 300 mm lens analogue survey camera and 60% overlap between photographs. The images were scanned at a radiometric resolution of 24 bit. Further data includes camera calibration information, parameters of image interior, relative and exterior orientation (results of an aerial triangulation calculation), stereoscopically vectorised topographical data in DGN-file format (CAD- data model), and the KMSD feature code list required to interpret the vector data.

Methodology

Elevation information is separated from the vector data to generate a DTM. The following information from the feature code list is used:

	No.	Colour	Level	Feature
Point features	16	70	0	Spot ground height symbol
	26	82	0	Traffic light symbol
	27	83	0	High tension tower symbol
	32	230	0	General manhole symbol
Line features	13	70	1	5 m contour line
	14	70	2	1 m contour line

A TIN is derived from the separated data and is transformed into a GRID of cell size 2 m.

A DTBM (3D-city model) is generated by stereoscopic measurement of roof top elevation. The following rules are applied: (i) Roofs > 5 m² of area are separated into sections when ?h between the sections is larger than 2 m. (ii) On roofs which are covered to more than 50% with roof top assemblies, the height of assemblies is measured rather than the elevation of the roof. Results are stored as absolute (above sea level) and relative (above terrain) elevation.

3D-flythrough animations are generated in three versions:

- DTBM + landuse map
- DTBM + orthophoto mosaic
- DTBM + orthophoto mosaic + terrestrial photos of building facades and vegetation

Fly-throughs are stored in Audio Video Interleave (avi) file format.

Results & Discussion

Kuwait test area

DTM: The Kuwait DTM grid (cell size 2.0 m, 500 rows x 500 columns, Xmin: 514,000.00, Xmax: 515,000.00; Ymin: 205,000.00, Ymax: 206,000.00) is shown in Fig.1. The terrain is almost flat, with some road embankments visible in the northern part. The highest point is at 37.63 and the lowest point is at 24.00 m above sea level; average elevation is 30.44 m. We list these values to demonstrate possibilities of numerical applications, such as those described below.

3D City Model: The Kuwait DTBM is shown in Fig.2. A cell size of 0.5 m is used to conserve sufficient building details for DTBM applications. The model fulfils criteria as required by the telecomm industry.

In Fig.3, a subset of the DTBM is shown, superimposed with building polygons from the vector data (with roof elevations measured stereoscopically). Dark yellow polygons represent low, and bright polygons represent high buildings. Lengths of building shades correspond to building elevation.

The DTM and DTBM of the Kuwait test area fulfil telecommunication industry criteria as listed in the methodology section. In the following section we will demonstrate examples how comparable elevation models of other cities are used in a number of different applications. The Kuwait DTM and DTBM can be used in similar applications.

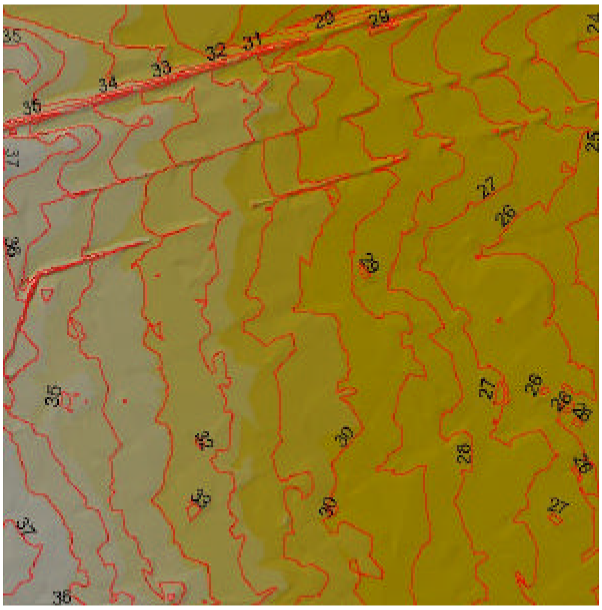

Fig.1: Grid DTM (shaded relief view) of the Kuwait test area with automatically generated contour lines (values in m above sea level). Top is north.

Fig.2: DTBM (shaded relief view) of the Kuwait test area.

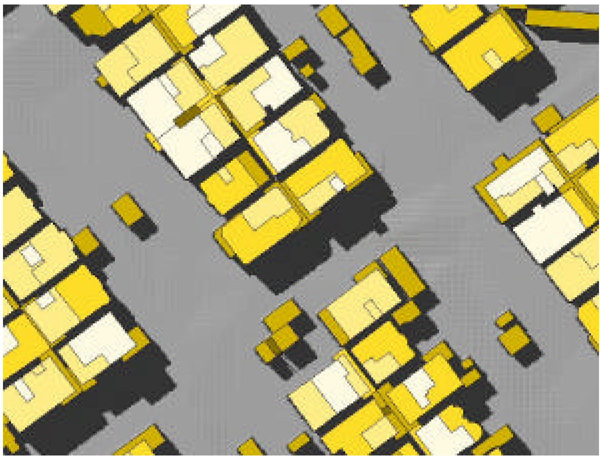

Fig.3: Enlarged subset of the DTBM (grey-scale shaded relief view), superimposed with building polygons.

Examples of possible DTM and DTBM applications:

GSM base station visibility: Planning GSM (Global System for Mobile communications) and comparable mobile communication antenna networks is an important application of 3D city models. Telecomm companies realise the bulk of their business and turnover in highly developed urban areas where high rising buildings are common. Mobile phones never communicate directly with each other, but through the closest base station of an antenna network. GSM signals travel best along visible lines between the closest base station and the mobile phone, but signals are absorbed and reflected by building materials. The aim of antenna network planning is to minimise areas with no reception, i.e. areas shaded by edifices from base station visibility, while minimising areas of signal overlap to reduce network operation and maintenance costs. An example from the City of Bremerhaven in Germany is shown in Fig.4 (a and b). Proposed base station locations are in the centres of the two circles, 1 and 2 (Fig.4a).

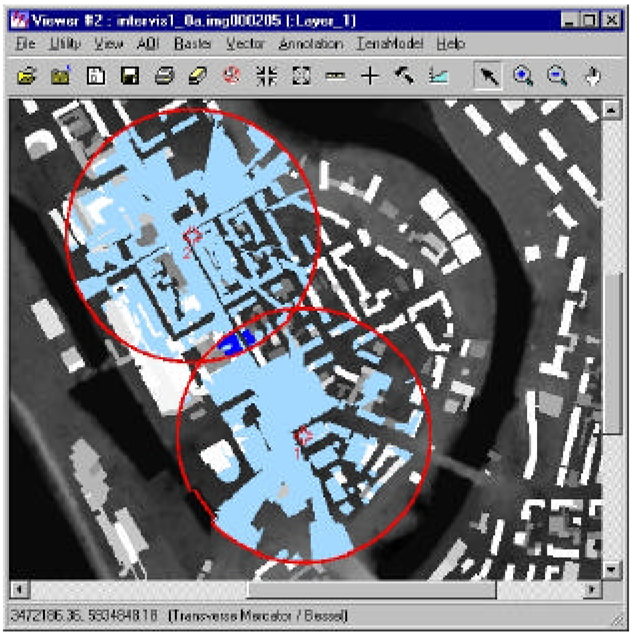

Fig.4, a: Modelling GSM base station visibility in a DTBM (2D view, image by PHOENICS GmbH).

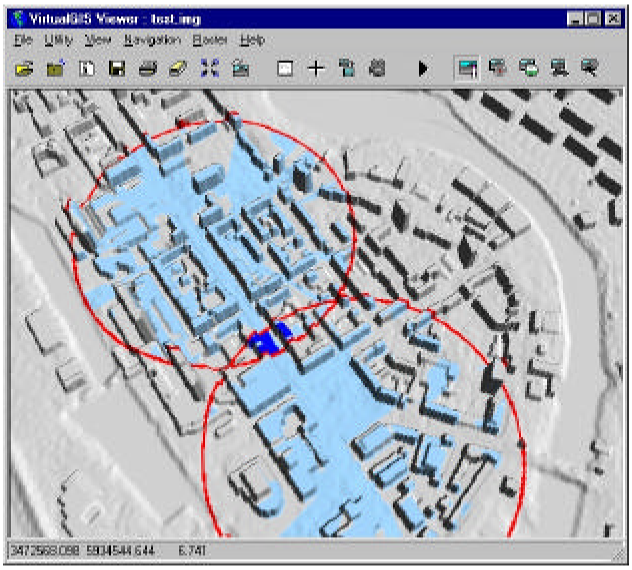

Fig.4, b: Modelling GSM base station visibility in a DTBM (3D view, image by PHOENICS GmbH).

Base station network planning is carried out with use of DTBMs. Co-ordinates (X, Y, and Z) of the proposed base station location are selected in the 3D city model, and a circular buffer is defined around the location to describe the area covered by the station. Spatial trigonometry is applied to determine DTBM raster cells inside the buffer visible from the proposed location. A colour code is assigned to all visible cells. An offset of the base station over the roof top at its proposed (X,Y) location can be described by increasing the Z-co-ordinate, simulating the effect of a base station mast.

More advanced models of GSM signal propagation take into account the flux density of the signal field strength (indicated in W m^{-1}). Signal strength does not break down rapidly when a buffer area around the base station is left (as is suggested in Fig.4), but rather it decreases continuously as the distance from the base station increases. In combination with signal absorption and reflection on building materials in urban areas, this results in a geographical distribution of signal reception which is more complex than suggested by base station visibility alone. An example from the City of Dachau near Munich in Southern Germany is shown in Fig.5.

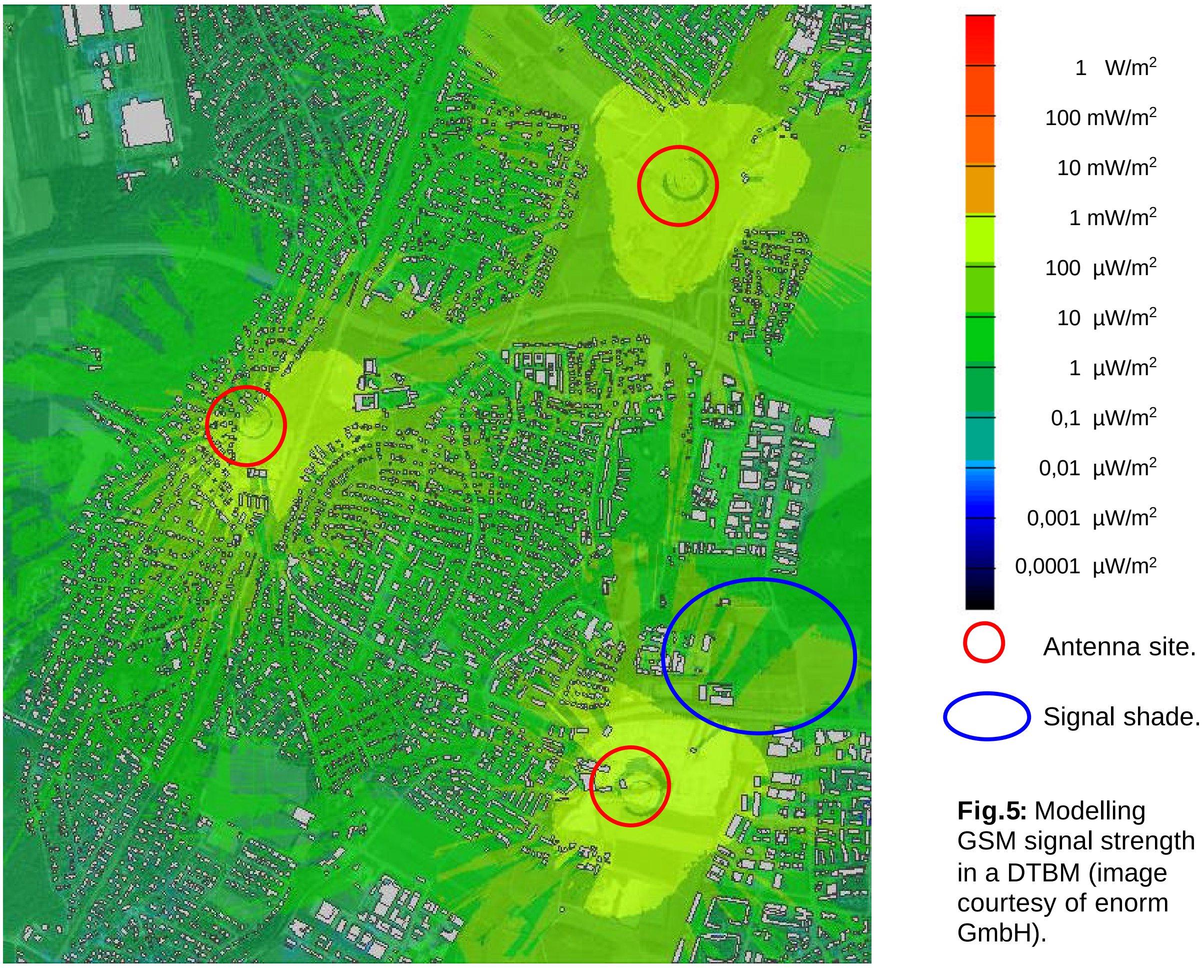

Fig.5: Modelling GSM signal strength in a DTBM (image courtesy of enorm GmbH).

Distribution of air pollutant concentration and noise: Car traffic is often dense in urban areas, and causes emissions of noise and air pollutants (dust particles, carbon-particulate matter, nitrogen oxides, etc.). Objectives of planning an urban road system should be to direct car traffic efficiently (i.e., to minimise traffic congestions) while keeping through-traffic away from residential areas and densely developed inner cities. For new settlements and extensions of the road system the amount of pollutant emissions can be estimated from expected traffic densities (number of cars or trucks per hour). For existing roads, emissions can be estimated from traffic census. Numerical algorithms and computer software are available to calculate pollutant concentrations and noise levels under various atmospheric and wind conditions. Pollutants have a tendency to accumulate in “urban canyons” along narrow streets between buildings. Therefore DTBMs need to be included in computations of concentration distributions. An example is shown in Fig.6.

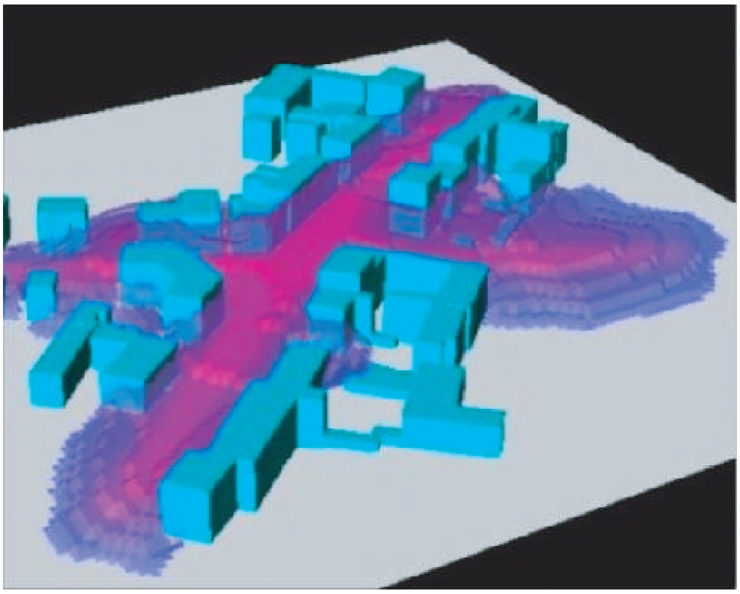

Fig.6: Modelling air pollution caused by car traffic using a DTBM (image courtesy of GeoNet Environmental Consulting GmbH).

Computer Aided Architectural Designs (CAAD):

From around 1950 to the year 2005 Kuwait has developed from a small mud brick town of 75,000 to a contemporary metropolis with a population of about 2 million (Al-Jassim, 1996 and 1997). Many cities in the Gulf area have similar growth rates, posing serious challenges to architects and urban planners. When new buildings and settlements are planned, buildings already existing around the construction site should be taken into account. Existing buildings are included in DTBMs, which can be altered to also include the dimensions and elevation of the newly planned buildings. Terrestrial photographs of building facades can be rendered onto the ‘walls’ of edifices in the DTBM, and Digital Orthophotos (DOPs) can be used to visualise the street level around the buildings. The result is a photo-realistic, virtual visualisation of the real-world situation of the construction site and its surroundings, which can be presented to decision makers and construction principals to give them a visual impression of the proposed architectural design. Architectural computer models using DTBMs help architects and planners to compare visual effects of different planning alternatives, and to save time and costs of planning by reducing the number of field visits to the construction site required during the planning phase. Computer animations software is used to generate walk-through or fly-through animations, which enable visibility of the planning area from all sides, including bird’s eye perspectives which in the real-world can only be achieved with expensive helicopter rides – an option hardly applied in architecture and urban planning.

Figure 7 (a and b) shows screenshots of 3D-flythroughs from the Kuwait test area. Building facades and vegetation are rendered into the DTBM. In Fig.7a (left image) the orthophoto mosaic of the test area is used to visualise street level. In the right image (Fig.7b), the land use map is used.

Fig.7: Screenshots from 3D-flythrough animations of the Kuwait test area.

Only five different terrestrial photographs of Kuwait building facades are repeated over the DTBM building walls in Fig.7. Although these 'synthetic facades' already provide a photo-realistic impression of the real-world situation, this impression can be much enhanced when terrestrial photos of the real facades are used. An example is shown in the following Fig.8 (a and b), which uses a DTBM and terrestrial photographs of real building facades of the City of Bremerhaven in Germany.

While in most cases of DTBMs covering large geographical areas it will be too expensive to use terrestrial photos of real facades for animations, this may be an option for limited geographical areas which are frequently looked at in Computer Aided Architectural Design for individual buildings or smaller settlements.

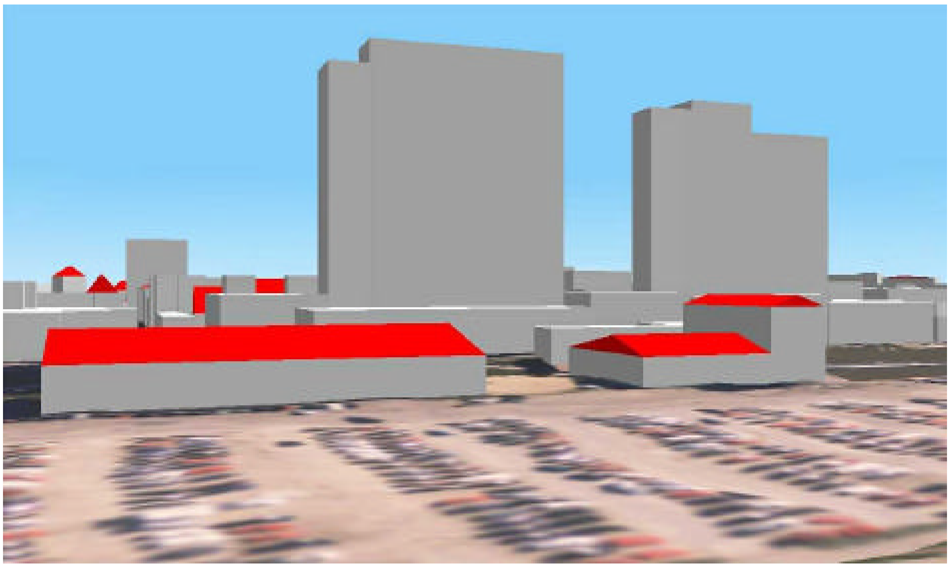

Fig.8a: DTBM for Computer Aided Architectural Design (by PHOENICS GmbH).

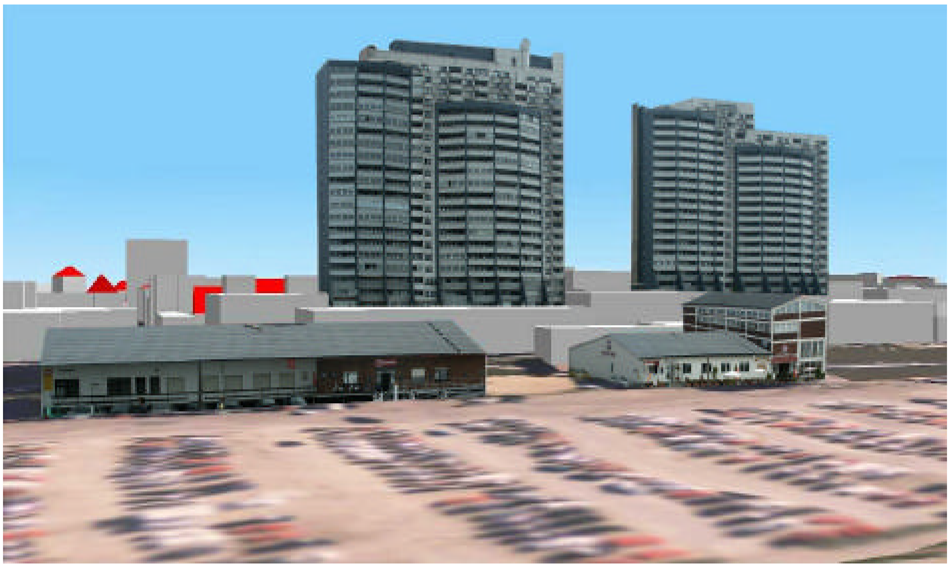

Fig.8b: DTBM and photo-realistic facades for Computer Aided Architectural Design (by PHOENICS GmbH).

Conclusions

A wealth of up-to-date, accurate, and consistent geo-data exists in Kuwait, predominantly as a result of the KUDAMS project and succeeding, regular data updates at KMSD. The data is well prepared, and the topographic base map is disclosed in CAD file formats to private industry uses. Relatively small alterations of the data, such as data transfer into a GIS environment and a review of elevation information, open access to a large number and variety of possible data applications. Elevation information is appropriate to generate Digital Terrain Models (DTMs) and 3D city models (Digital Terrain and Building Models, DTBMs). DTMs and DTBMs are useful base data for applications in telecommunications, air pollutant and noise modelling, and CAAD studies.

The example of the Kuwait test area 3D city model shows that both the topographic base data (as part of Kuwait's SDI) and the software technology exist for use in private industry applications. The examples presented of such applications show how topographic base data can help to direct the rapid development of Kuwait City.

Phoenics GmbH (www.phoenics.de) provides digital photogrammetric and GIS services to generate 3D City Models and animations for a great number of applications.

References

Al-Jassim, W.K. 1997. Dynamic planning using GIS: the Kuwait experience. Paper presented at the GIS/GPS Conference held in Doha, Qatar, March 1997. Available on the Internet under www.gisqatar.org.qa/conf97/links/p10_e3.html (verified 03/16/2005).

Al-Jassim, W.K. 1996. New master plan for Kuwait. Paper presented at the 1996 ESRI User Conference, 20 to 24 May 1996. Wyndham Hotel and Convention Center, Palm Springs, California / USA. Available on the Internet under http://gis.esri.com/library/userconf/proc96/TO350/PAP331/P331.HTM (verified 03/16/2005).

Konecny, G. 2005. Creation of a national cadastre map of Kuwait at Kuwait Municipality. Paper presented at the Kuwait 1st International GIS Conference and Exhibition, 05 to 07 Feb. 2005, Crowne Plaza Hotel, Kuwait.