Support of Infrastructure Project Phases by GIS Technologies

- Data Management and Opportunities for Contractors in Lifecycle of Civil Projects -

Master Thesis

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DISCLAIMER

The results presented in this thesis are based on my own research in the Department of Geographical Information Science & Systems at Paris Lodron University Salzburg. All assistance received from other individuals and organisations has been acknowledged and full reference is made to all published and unpublished sources used.

This master thesis has not been submitted previously for a degree at any institution.

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Signed

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Andreas Hesterkamp

Gelsenkirchen-Buer in North Rhine Westphalia, August 2005

Abstract

The construction industry has used geographical data and information for a long time in a traditional way. As a worldwide acting constructor for civil projects HOCHTIEF Construction AG depends on actual definite technical and environmental data for construction sites and their adjacent environs in order to support the decision making processes within its departments for steering the activities and cost evaluation during the pre qualification-, the tender-, the setup-, the execution- and (after sales) usage phases of infrastructure building projects.

During these project stages the amount of technical and commercial data is increased according to the demanded granularity of detail. This data has to be managed in an economic manner for realizing the project. The basic logic of data storage in GIS-systems can form a platform for work preparation, time scheduling, estimation and monitoring during the lifecycle of a project. As well it could also build a foundation for personal and commercial issues.

This thesis will mainly focus on the integration and analysis of technical data by the joint use of existing proprietary systems Geographical Information Systems and Computer Aided Design (GIS & CAD). It will show opportunities for worldwide data acquisition (Remote Sensing). The applicability and limits of this free available data for engineering and construction processes is pointed out. Further standardized data dissemination for the construction business with recently established or in the near future coming up methods of Intranet - Internet technologies organized by the Open Geospatial Consortium(OGC) (Geographic Mark-up Language, GML) or by the International Alliance for Interoperability (IAI) (Industry Foundation Classes, IFC) with a certain level of detail will be demonstrated. A discussion about the new opportunities and the value added by usage of GIS technologies during the construction phases in infrastructure projects summarizes the thesis.

Zusammenfassung

Bauunternehmen setzen traditionell geographische Informationen ein. Als weltweit agierendes Unternehmen für Infrastruktur Projekte und deren Umfeld benötigt die HOCHTIEF Construction AG aktuelle definitive technische sowie raum- und umweltbezogene Daten. Für zielgerichtete Entscheidungsfindungen, zur Steuerung der Aktivitäten in den einzelnen Abteilungen/Unternehmensbereichen und zur Kostenabschätzung während der einzelnen Projektphasen (Pre-Qualifikation, Ausschreibung, Arbeitvorbereitung und Ausführung und Nutzung) werden verschiedene Ausgangsdaten benötigt. Die zu bewältigende Datenmenge erhöht sich mit der je nach

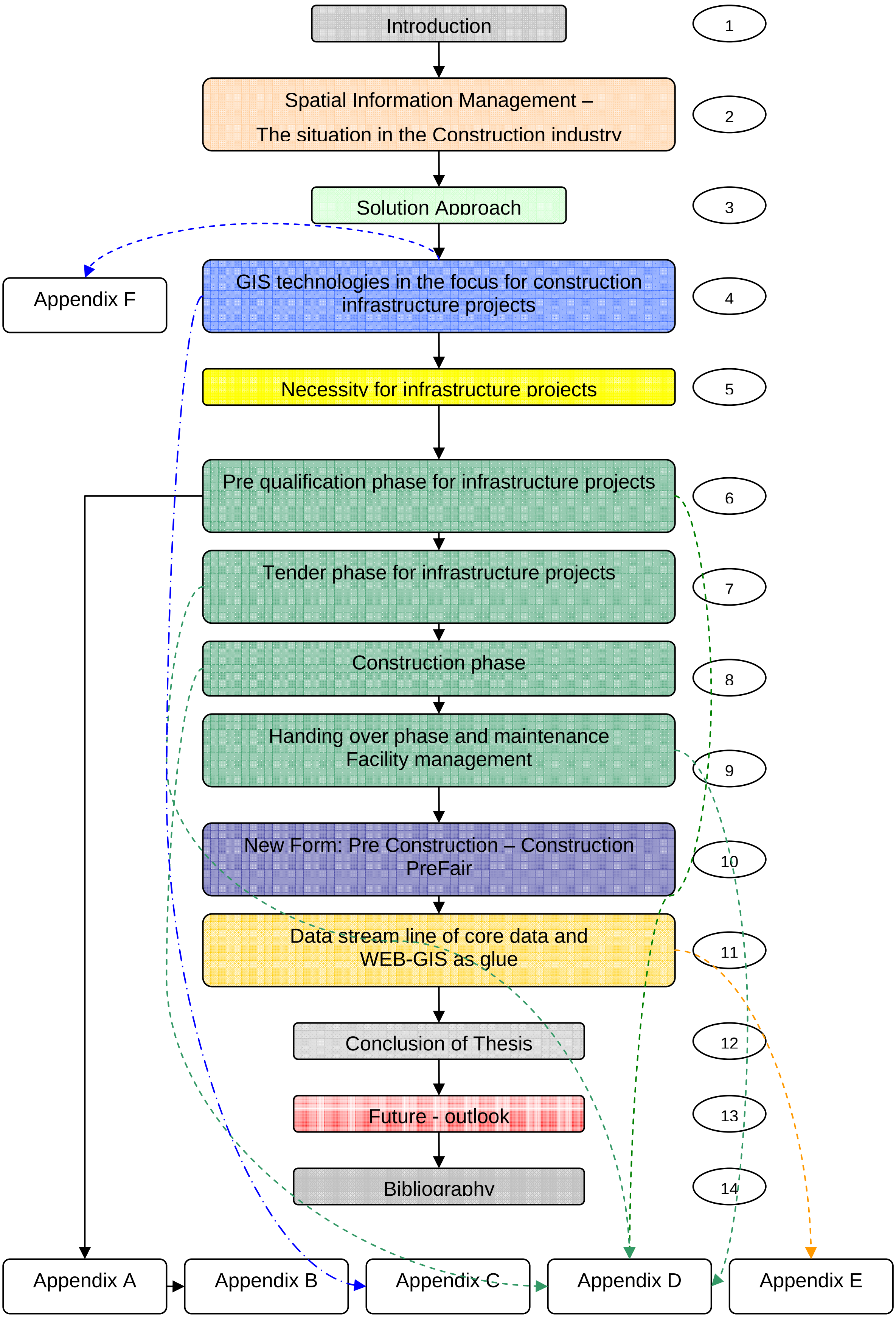
Projektphase benötigten Detailauflösung (Granularität). Diese Daten sind wirtschaftlich und überschaubar bis zur Projekterstellung und darüber hinaus zu verwalten. Die Grundidee für das Datenmanagement eines GIS bildet eine gute Basis für die Arbeitsvorbereitung, Zeitplanung, Kalkulation und das Monitoring (Controlling) von Projekten.

Diese Arbeit setzt sich vornehmlich mit der Integration und Analyse von technischen Daten durch Nutzung existierender proprietärer Systeme (GIS & CAD) auseinander und wird Möglichkeiten für die Beschaffung von raumbezogenen Daten (Fernerkundung) aufzeigen. Weiterhin werden standardisierte Möglichkeiten (OGC – IFC) der Datenbereitstellung während der Projektphasen im Baugeschäft dargestellt. Eine Diskussion über die neuen Chancen und die Wertsteigerung durch die Nutzung von GIS –Technologien während der Bauphasen rundet diese Arbeit ab.

List of Figures:

List of Tables:

Structured Layout of the Master Thesis



Abbreviations

ALS	Airborne Laser Scanning
BOOST	Build, Own, Operate, Subsidies, Transfer
BOT	Build, Operate, Transfer
CAAD	Computer Aided Architectural Design
CAD	Computer Aided Design
CGI	Common Gateway Interface
COM	Component Object Model
CORBA	Common Object Request Broker Architecture
DBOM	Design, Build, Operate, Maintain
DBOT	Design, Build, Operate, Transfer
DTP	Document Type Definition
EPSG	European Petroleum Survey Group
ESRI	Environmental System and Research Institute
FBOOT	Finance, Build, Own, Operate, Transfer
GIS	Geographic Information System
GML	Geography Mark-up Language
GPS	Global Positioning System
HTTP	Hypertext Transfer Protocol
IAI	International Alliance for Interoperability
IFC	Industrial Foundation Classes
IWD	Inverse Distance Weighting
INS	Inertial Navigation System
JPEG	Joint Photographic Experts Group
Kriging	Kriging Interpolation
LBS	Location Based Services
METADATA	Data about data (Metadata describes content of spatial data)
OGC	Open Geospatial Consortium
OWS	OGC Web Service
PDS	Project Management System
PNG	Portable Network Graphics
SAR	Synthetic Aperture Radar
SOAP	Simple Object Access Protocol
SRTM	Shuttle Radar Topographic Mission
SVG	Scalable Vector Graphics
TIFF	Tagged Image File Format
TIN	Triangulated Irregular Network
UML	Unified Modelling Language
URL	Uniform Resource Locator
VBA	Visual Basic for Applications
VRML	Virtual Reality Modeling Language
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Server
XML	Extended Mark-up Language
XSL	Extensible Mark-up Language

for

Josefine and Johannes

1.0 Introduction

In the construction industry the use of geographic and spatial information is usually done in the traditional way to study topographic maps, plans, charts and drawings from different disciplines (Geology, Survey, Civil Engineering, and Mechanical Engineering). These maps are describing and explaining the environment in means of models, which consist of object descriptions as well as object links and have a special feature the spatial relation on certain points, places and regions. Due to the realisation that spatial information distribution has changed in the last few years and will go on in developing new features of spatial data management and dissemination it is the right time for a jump to these new coming up technologies ("There is nothing permanent except change" Heraclitus (Heraclites) of Greece 513 BC, (Rogers)). Following the path of the development of infrastructure projects from the advertisement to the construction and transfer to the client, this master thesis will show integration possibilities of the GIS technologies (how and where GIS can be included) in the engineering and commercial workflow to serve all the stakeholders expectations.

Beginning with the illustration of the common phases of infrastructure projects, which have commonly agreed always a unique character, and by observing the kind of contract which is negotiated between the client and constructor (BOT, BOOST, DB) it will be demonstrated that a value can be added into the concept-, design-, construction- and maintenance process of civil projects by a consequent setting up and administration of evaluated spatial data.

As civil infrastructure projects are due to financial matters becoming more and more a cooperation between public authorities and the private business (PPP projects) - instead of having the traditional kind of client and constructor relation (contract) - a sustainable spatial data record and data distribution would support the work of all involved parties. A part of this thesis shows new opportunities in which kind of spatial data can be shared in an interoperable standardised (OGC – IFC) manner between the partners in a civil building project.

Taking notice of a worldwide/national/regional advertisement for a civil project is commonly the first contact and initiates the pre qualification phase within the sequence of project phases. The collections of technical and spatial data differ from project and country. In some cases technical data up to a certain level of detail is available, in other cases only rough information is made public. In pre qualification steps for taking a civil project documents have to be prepared, which demonstrate and approve the ability of the contractor (qualified staff and experience) to realize the specific kind of civil project. The constructor will take similar already established example projects from the past to show his capability in project management and execution.

Remote sensing in conjunction with geographical - topographic maps can give the first impression of the project areas environment and a first attempt to determine and handle the logistic character of the project (transportation, board and lodging) can be undertaken. Without having been in the project area – being better prepared for site visits.

In a second step (Tender Phase) when already being a member of the preferred bidders the tender documents have to be prepared and delivered within the submission time introducing the construction method as well as the cost estimation of the infrastructure building to the client. A variety of technical data has to be evaluated up to this stage.

The simple question at the beginning of a project - whereabouts a project is located [in the world] - causes further data survey and analysis in several disciplines in order for risk management, a better support of determination the time schedule, equipment employment and overall resulting cost estimation. Major technical aspects for (worldwide) realization of civil projects are the geology underneath the civil structure, the climatic conditions acting upon the civil structure, the terrain structure and the surface condition in the project area. Influenced by these parameters the time schedule and the cost estimation will be formed. In addition to these factors the transportation logistics, the available personal (qualified staff) and the support of the local authorities has to be taken into account and evaluated. A first easy and fast site visit by the project managers and technical experts will be undertaken to assess the situation. (GPS – Palmtops, PDA for quarry – site installation area, project area)

In a third step a construction company is awarded to take the civil project (Construction Phase). This event will start the mobilisation phase within the Construction Company. Overview maps are created to lead people to project places. People have to travel to the site area with the task to start-up the project. The construction will commence.

On large infrastructure sites multidisciplinary groups work together with the target of project finalisation. All technical participants need spatial information and a platform for sharing their knowledge. One major part in the beginning of the project is the original ground survey of the site area and borrows pits in order to determine all construction relevant spatial features and give a base for the detailed design. The construction borders have to be defined in assistance with the client and an original digital terrain model has to be calculated. Soil and geological investigation points (drill holes, boreholes) have to be fixed measured and analysed. The surrounding terrain of the project has to be taken into account for the investigation of storm water (watersheds) to prevent the case of site flooding and the groundwater level has to be observed due to water loan for the site.

During the construction phase a huge quantity of technical – spatial - data will be created, evaluated, analysed, valuated and stored due to the permanent observing obligation of a general constructor. Spatial features with an amount of technical and commercial attributes play a key role in this period. Next to a survey of quantities, a set of soil compaction tests according the quality standards have to be executed. Several features have to be placed in their spatial design position. At the end of the day the as-built documents have to be produced for presenting the final status of the project and to show differences from the previous design drawings. Design drawings can be integrated in as built documentation if no change of the design has taken place. The GIS technology for handling, storing and distributing huge amounts of spatial data (model server) can convey advantages to the participants of a project.

The handing over of a project to the client involves, due to international regulations (FIDIC; International Federation of Consulting Engineers) a set of drawings and descriptive documents which show the as-built status of the project. The idea of this master thesis is to build a model during the construction period (serving the client's claims in organisation and maintenance) in which the client can observe during construction and which can be handed over to the client at the end of construction. Due to the fact that there are construction companies in new forms of business which are financing and operating civil buildings, it will be advantageous to them as well. The client can use the model for better organisation and maintenance scheduling as well as for facility management aspects. This thesis should help to draw up a line for bridging the gap (construction and as built documentation) between the cooperative project design and the usage of an infrastructure project as [HUBER] has stated on the Update 2005.

This master thesis should direct towards new opportunities for the construction industry by using the GIS technologies in conjunction with new technologies for building models and show, or give some ideas for a further integration GIS in construction workflow. The integration of GIS- and current model oriented CAD-Software will build a strong base for modelling our world.

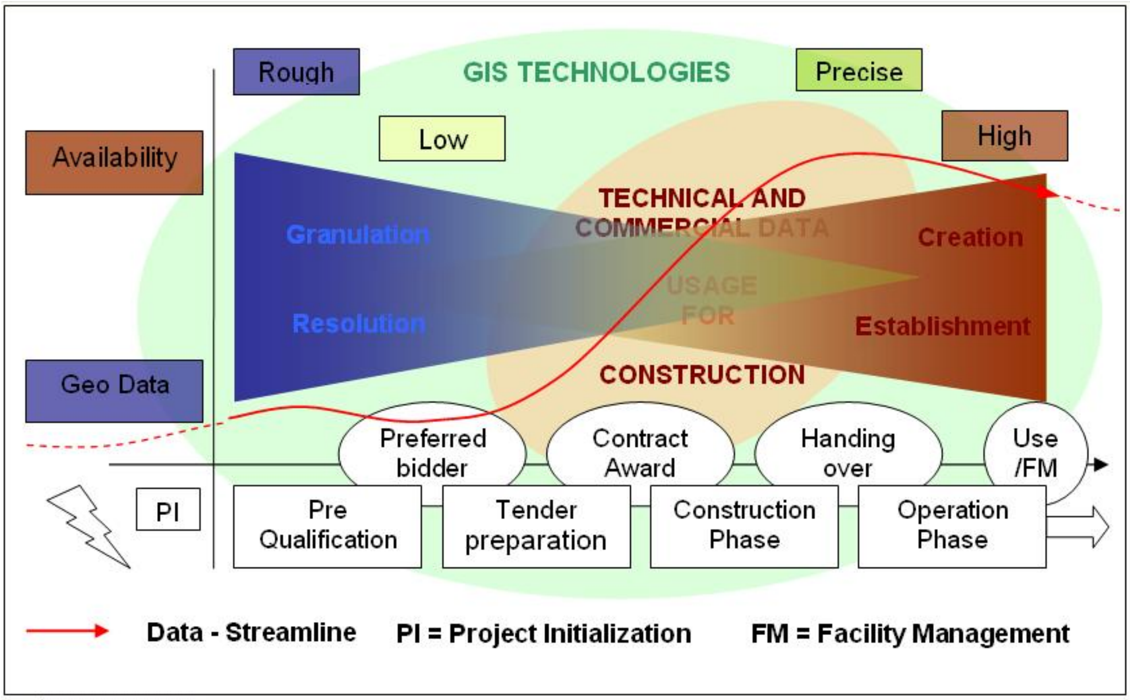


Figure 1.0 Project phases and technical data streamline (AM/FM) [Hesterkamp, 2005]

2.0 Spatial Information Management - The Situation in Construction Industry

The status of information acquisition and treatment (handling) in the construction industry is mainly stamped by the kind of delivered and available technical – spatial – information for planed infrastructure projects in the respective country. The commercial and technical, spatial information provided by the client of a civil project can have varying forms of quality, which depends on the depths of the previously undertaken feasibility investigations and its environmental impact study.

The variety of documents ranges from analogue data like printed lists, sketches and maps to digital data in the form of single CAD drawings and tables (Excel, Text files). Recently it has become more common to deliver project descriptions, tables for the bill of quantities, lists and technical drawings in the form of PDF (2D) files. On one hand this is an advantage for fast information distribution, on the other hand a reconverting of this data back to the original data for preliminary volume calculations, cross checks and analysis is only possible with a time-consuming effort. An amount of converting tools next to the originally required programs has to be obtainable in a software pool in order to transform the data in an enterprise-wide useful format. Recently a new version of PDF had been introduced. This version has the ability to contain complex curves like transitions curves, splines, clothoids and 3D information. Acrobat and Bentley Systems have produced this software in cooperation.

Apparently a lack of international common data exchange standards for civil projects is responsible for this unwanted situation. Historically conditioned there are quasi standards like AutoCAD DWG, or DXF and MircoStation DGN files but a proclaimed full exchange of data between these vendors is usually focused on the simple geometric data (simple features). The data with engineering value (complex features) is stored mostly in separate files, and is vendor dependant. The exact exchange of these data involves considerable time.

During every project phase newly appraised data will be added in order to refine the original data to the demanded progress of construction, according to the available project budget.

Beyond the previous description, by the company, measured, evaluated and created information has to be incorporated into the information from the client in turn to build a base for decision on construction method, equipment purchase, personal recruitment and overall cost estimation. This information is due to historical reasons and separations of work sequences in departments usually stored in excel files or single (individual) databases and technical CAD files. From this it follows that there are a lot of redundancies in these information sources. Files with financial information from the estimation department are stored with a limited user access. There is no information or technical connection between the excel files and the drawing files. The possibility of using attributed data in the CAD drawings is difficult to establish because of the limited time period for the preparation of pre-qualification and tender documents and the unique nature of each civil project. It might either be a lack of knowledge spreading respectively a missing recognition of possible interfaces within the different programs used in the diverse departments of a construction company, or an intentional omission. However, distinguished by an excellent experience in their discipline the departments execute highly sophisticated work under the pressure of a project.

Combining the assessed and construction method forming results in compressed information packages as tender documents for the client, the construction company is obliged to follow the executable construction method according to their technical and commercial comprehension.

Until this stage this established and memorised information will lay the base for the expected construction phase after a positive project award. When the project is awarded then the existing data will be delivered transferred to the site for further use. In the beginning usually a small thin network will be created and later on an independent project wide network with several servers is established. Until today a file based system for information distribution will be established on site. The technical data filing system will be established according to the main categories Architecture, Civil Engineering, Landscaping, Machinery and Equipment, etc of buildings (in general) which have to be constructed in a specific project. The filing structure contains the core data for the project. This means that only the approved versions of drawing files will be memorised into the filing system. Next to the technical data the commercial data is also stored. This kind of information is prepared by the procurement and cost control departments.

During the construction phase and as in the detailed design phase several subcontractors (third parties) will be engaged to create solutions for technical questions. The delivery of their thoughts and solutions in the form of drawing files as well as list files has to be organized and a common agreed standard transmission format has to be defined. The subcontractors are using specific engineering solution applications for their tasks.

Mostly the quasi common standard for data drawing exchange format DXF/DWG will be used for transfer of technical information. The problem which rises up here is the loss of descriptive and additional information. The special information is not transformed and has to be transferred in a different way. The internal connection between the drawing elements and its special data is lost and has to be re-established after data transfer. A higher grade of data exchange can be succeeded by a data exchange manual (modus operandi) which contains rules for data creation and x-data exchange.

The construction of relevant technical data is collected and stored on servers for a faster access and distribution. This is an ongoing process during the entire construction, because of monitoring, progress control and duty of evidence to the client. The construction will go along the prepared time schedule. The construction parts, which have to be built in, have to be ordered or purchased and delivered (at a certain time) to the site. The commercial data resulting out of the technical data will be extracted by a host of people who count the construction parts from the drawings for the procurement department. When the parts have been built in, an acceptance protocol will be prepared. Herein the spatial correct placing and the technical quality of the construction is stated. These above mentioned tasks will be followed until the end of construction and are stored as a proof to the client. The data can be used as well for the follow up maintenance.

At the end of the day a so called AS-BUILT, has to be handed over to the client. These documents contain all as-built drawings of the built construction and all built in parts, documented and protocol (taken minutes of) deviations from the original design and all descriptions of the build in parts. The form of handing over is done by analogue drawings, maps, and technical descriptions.

The construction pertinent information is generally available but the type of data varies from project to project and country to country. The master thesis will show on some small examples (in some way) how the GIS technology can support the project phases and how a structured data stream can be built up. At the end the time saving and cost saving are to be discussed.

3. 0 Solution approach

In chapter 2 the situation of spatial data lifecycle on civil project phases was explained and examined. As one result of chapter 2, it is recognizable that the data stream is broken often due to several conversions which have to be undertaken during the data sharing and exchange between the involved participants and departments during the infrastructure project phases. Chapter 5 will give some information about data and information which are available due to some environmental study investigations and reports.

Beginning with a small collection of spatial data in the pre qualification phase, the data will start to increase in the tender phase and will have its high peak within the construction phase. At the end of the construction phase a huge amount of data is established and available, which can be used for the operation phase (Asset management AM / Facility management FM) of the infrastructure building.

In the pre qualification stage the data according to the figure 1.0 the amount of data which is available for construction is poor. A rough description of the civil infrastructure will be given either by the government of a country, the regional or the local authorities. Information about the project will be given usually in form of analogue data type. The content of this information is handling the circumference of the project and the impact of the project to the environment. Detailed evaluated technical data will be available sometimes for soil investigations and the climate.

The thesis will introduce the importance of evaluated, measured, analysed and memorised information as a sustainable and project wide value.

Another outcome of chapter 2 is the dilemma of the inexistence of homogeneity in the data and their diverse structures because of the different source applications which have originated the information. This master thesis will give information how data can be stored in a unique way which can be used by a host of people.

The exchange or disposal of and access to complex project models haven't emerged yet in the construction industry. Some attempts for establishing project models are on the way as research projects, so that a first step is taken (European Network of Construction Companies for Research and Development - ENCORD). In the civil construction (Roads, Dams, Airports, Ports, and Civil Buildings) and GIS environment two standards for engineering data exchange are beginning to be established – on one hand it is the LAND-XML for civil engineering information and its equivalent on the GIS side is the GML (Geographic Markup Language).

The Open Geospatial Consortium (OGC) has defined several specifications for common spatial data storage and access. There are specifications starting from simple features to complex features types in GML format (derivate from XML). As most vendors for civil construction software are also members of this organisation it will be expected that they will support the ability for spatial data exchange.

In [FISHER1999] GIS is placed firmly in the Information Systems / Information Technology (IS/IT), Management Information Systems (MIS) category within the complex dynamic group of organisations who produce complex systems, i.e., high-tech aircraft, ships, defence items and computers. MIS and GIS are synonymous and relative to information systems also. MIS manages multi-functional databases such as GIS. Both systems function in the following ways:

- as routine processing systems; i.e., data entry of attributes
- as information systems dealing with unanticipated queries & solving them
- as decision support systems (DDS) for all levels of enquiry
- as production systems, producing reports and managing databases
- information is processed efficiently and disseminated quickly [CLELAND]

A further advantage of GIS compared with CAD models is the topological structured data.

The implementation of GIS in construction companies and their project driven workflow is a complex development, which requires a careful process of assessment when setting up a project for implementation. Such a process requires a well developed, proprietary or specific methodology with which to manage the project. The variables involved with the development process, coupled with differences in applications makes it virtually impossible to have one single methodology for the whole industry. Essentially, all stakeholders, project managers, team members, vertical line managers, executives and clients must have a broad knowledge base before developing a system. The importance of the organisational and personnel aspects cannot be understated, as these are critical issues to a project success.

4.0 GIS technologies in focus for construction infrastructure projects

Answering the question what are GIS technologies first GIS have to be defined. In several publication GIS is defined as computer software which links geographic information (where things are, spatial pinpointing) with descriptive information (what things are). In addition or contrast to the traditional mapping philosophy many layers of diverse information can be presented. Real world features are represented as points, lines, and areas and lately also as three dimensional objects.

The representation can be easily directed due to the reason, that each particular theme has its own layer. These layered displayed themes can be laid on top of one another, creating a stack of information about a specific geographic region. This enables the user to control to the amount of information which will be represented at one time. The combination and the relation between the given features can be analysed at the same time and displayed (Note, according the statement: “A picture says more than a thousand of words”).

The sources for the represented information are databases. The representation is not limited to geometric features like points, lines, areas, 3D elements (vector information) because GIS contains a further opportunity to display raster information like satellite images and aerial photographs as background information. Remotely sensed information is enclosed next to the visible picture the information of the non visible range of light, which can be used for spectral analysis. Thus raster information can be analyzed according to their spectral information content. By additional spectral analysis recognition of surface material is possible. Terrain model can be generated using radar techniques (Shuttle Radar Topographic Mission; SRTM, TerraX-SAR) for a rough representation and more precise with airborne based LIDAR. Raster layer can also be the result of data analysis like terrain modelling, slope analysis, direction analysis or an interpolation algorithm like IDW, Kriging. Spatial analysis and particular map algebra is able to support decision making by creating of cost layers, which can help to find the path with the lowest resistance – lowest cost.

Geography is helping governments and organisations to make better integrated information based decisions in various disciplines. Spatial related data can be congregated and organized to support the generation of information products that are integrated in the business strategy of any organization. Geographic information systems support the creation of useful information, which enables institutions to run better. Due to the kind of data integration, analysis and distribution these information systems are saving time and resources in the organizations. The geographic aspects matters in infrastructure projects and have an impact to the project controlling and projects financial part.

Civil engineers and surveying engineers (surveyors) understand the collection of spatial related features as a major part of their work. Surveying engineers determine the precise location of real world features either for representing the features on a map or they give positions for manmade designed objects in the real world. Engineers design and build structures and infrastructures on features measured by surveyors. GIS helps both disciplines to integrate a variety of data sources and types, it enables the user to maintain and manage inventories, and give the opportunity for visualizing data and related information on active maps.

For construction of civil projects there is the necessity to understand where geologically the best suited places for structures are. After determining the best places geotechnical engineers will investigate the underground of the intended civil structure in detail. Drill holes or boreholes will give answers to the question which kind of soil (layers) are involved, on which material the structure will be placed and how deep the foundation has to be placed to get static stability. GIS techniques from the exploration can be used for this task [ARCGISGEOLOGY].

GIS does not end on the shoreline, as one might think. In specialised GIS (Marine GIS) [ARCGISMARINE2003] records from oceanography to hydrography, the coastal shoreline to the bathymetric bottom can the organized and accumulated. As GIS helps to visualize, analyse and to map the topographic features onshore GIS allows as well executing similar tasks for the large regions of the planet which are underwater. The most interesting statements for the construction industry are the mapping of the seafloor and the nautical charts to have a three-dimensional view of their actual position in relation to a new marina construction. The underwater construction progress control might be another opportunity which can be handled in these systems to visualize and report the change during construction time.

GIS usage has exploded across the world with the recent advancements in computer hardware and software. The World Wide Web has also played a vital role in the availability of data for GIS and the distribution of GIS analysis results. Thousands of communities, agencies, companies, and individuals are now using GIS technology for data management and analysis. The purpose is to provide GIS related skills to civil engineers that are discipline specific. The application of GIS technology will help civil engineers to create solutions founded on integrated informed based decisions.

There are three main ideas for using GIS technologies:

- Implementation of GIS technology is occurring around the constructors work and data evaluation and distribution is undertaken in digital form
- Deals with an extremely large amount of data that is geographic related with the focus on a civil infrastructure project
- Representing condensed information in form of maps and uses integrated scientific analysis

To focus on the GIS technologies, which are applicable for the construction industry, a compound will show the scientific disciplines that are involved in or using GIS (see figure 4.0a) and which departments of a construction company are involved in the preparation creation of a civil infrastructure project (see figure 4.0b). The figures should demonstrate the resemblances and differences exist in both configurations. Relations in the configuration are the business (business geographic) on the GIS side and the finance, estimation and procurement on the infrastructure project side. Surveying, geodesy and civil design as well as landscaping can be connected with the navigation, remote sensing and cartography. The structural engineering depends on the climate and the geotechnical investigations, which are influenced by the geo-physical measurements and investigations by the help of geo-statistic analysis. Colours in figure 4.0a and 4.0b give an indication of the parallelism in the structures.

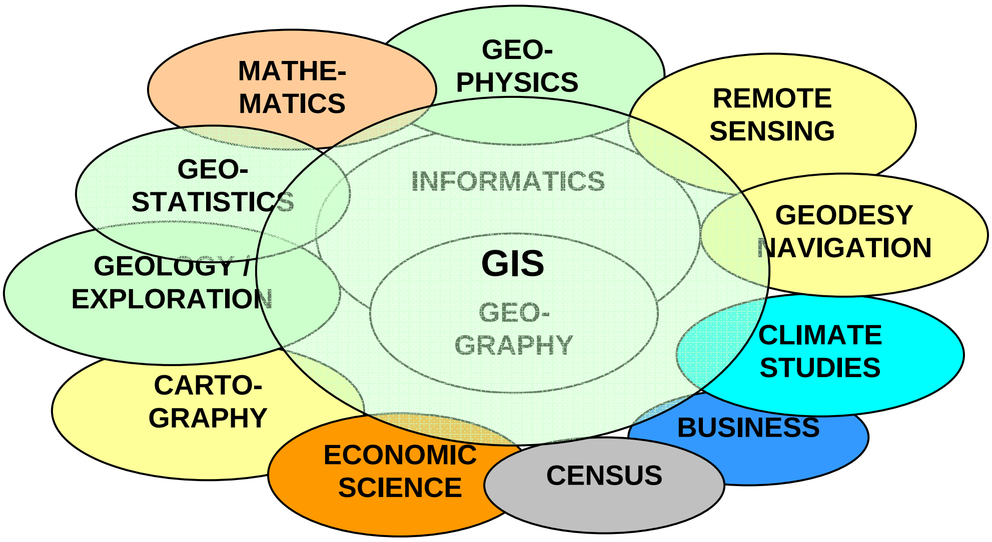


Figure 4.0a Scientific disciplines involved in or using GIS [UNIGIS Module 1 GIS overview, Hesterkamp, changed]

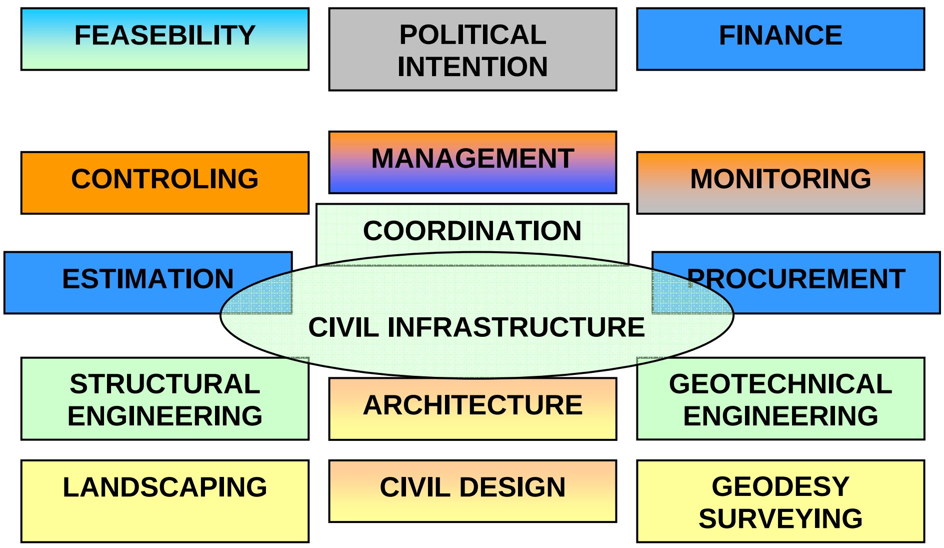


Figure 4.0b Involved construction company departments for civil infrastructure projects [Hesterkamp]

Interpretation of figure 4.0a in combination with figure 4.0b gives an overview about the parallelism with the scientific disciplines which are involved in or make use of GIS technology and the involved parties on an infrastructure project. As a result it can be stated, that the efforts which will be undertaken by governments, institutions, and universities can be reflected during the construction of an infrastructure project. Thus a possible implementation of GIS technologies can be established on a construction project although the extent will be in a smaller scale.

In [DANGERMOND2004] mentioned that "*GIS is also being used as a framework and process to apply geospatial information to a host of applications. This framework allows us to observe, measure, and analyze, then plan and take action. As a result, GIS is helping us create the future by integrating information from many sources*".

Another idea from [DANGERMOND2004] is that information should be shared through GIS. The core statement is "*Sharing Knowledge through GIS*".

As in other organisation this occurrence happens every day on a construction site. At the beginning of a civil project the construction relevant data is collected and passed to a couple of people who are involved in the engineering workflow for the new infrastructure project.

4.1 Remote sensing – Satellite images - Aerial photographs - Radar (InSAR)

Remote sensing is one of the technologies which are used for data collection. The advantages of this technology are the up-to-date and the synoptic of the data. As the global positioning system (GPS) this technology is created by use of multi spectral satellite sensors geo related data with increasing spatial, spectral and temporal resolution. The handling and storage of immense remote sensed data will be captured by geographic information systems. Remote sensing of aerial images can be differed by the possible use and analysis of the non visible light which is recorded by the satellite sensors of the digital photogrammetric units. For traditional aerial images the visible part of the light is used for analysis. In addition to the range of the visible light the satellite sensors also record the non visible spectrum of the light (infrared and microwave).

The geometric resolution has to be separated in the part for the multi spectral plus thermal and the panchromatic range. The panchromatic range of the light has a better geometric resolution than the multi spectral range. Table 4.1a and 4.1b show a compilation of some civil used sensors and their resolution. The sensors, which are usable for infrastructure projects, are dependent on the extent of the project and the project phase as well as the demanded resolution. For large areas (30 km * 30 km) and for presentation purposes and visualisations in the pre qualification phase a geometric resolution of 15 m is good enough for recognizing the different classes of land use and to differentiate between rural and urban regions. For the tender phase and for planning purposes a resolution 2 to 1 m will be sufficient. For a detailed design in the construction phase airborne based platforms have to be used for volume calculations and terrestrial laser scanners for detailed feature locations in order to reach the engineering demanded precision. Information about the airborne platforms will follow afterwards.

Example: Multi-spectral Systems of high and middle range resolution (selection)

System	Landsat 7 ETM	NASA, USA	Spot 3 / 4 HRV	CNES, France	IRS 1C/D	NRSA, India
Modus	Pan	MS + Thermal	Pan	MS	Pan	LISS III
Geometric Resolution	15 m	30 m (60 m tir)	10 m	20 m	5,8 m	23,5
Spectral Resolution (nm)	520-900	450-520 (b) 530-610 (g) 620-690 (r) 780-910 (nir) 1570-1780 (mir) 10420-12500 (tir) 2080-2350 (mir)	610-680	500-590 (g) 610-680 (r) 790-890 (nir) 1580-1750 (mir)	500-750	520-590 (g) 620-680 (r) 770-860 (nir) 1550-1700 (mir)
Scale for Applications	1:100.000		1:50.000		1:25.000	
Swath Width	185 km		60 km		23 km or 70 km	
Image size	185 * 185 km²		60 * 60 km²		23 * 23; 70 * 70 km²	
Orbit height	704 km		832 km		817 km	
Approx. Cost per Scene €	1500 (Pan + MS)		3900 (Pan + MS)		5200 (Pan + MS)	

b=blue g=green r=red nir=near infrared tir=thermal infrared mir=microwave

Table 4.1a Pan = Panchromatic, MS = Multi spectral [EHLERS2002, changed]

Table 4.1a is showing the sensors which can be easily compared with the scale of the map they are applicable to. SPOT and IRS are comparable with the topographic map the scale 1:50.000 and 1:25.000 is sufficient for an overview of a long or large area consuming civil infrastructure project. (Rough road alignment, purposed Dam flooding area, purposed lines for tunnels)

Example: Multi-spectral Systems of ultra high resolution (selection)

System	Quick Bird 2	Digital Globe	Ikonos II	Space Imaging
Modus	Pan 11 bit	MS 4 bands 11 bit	Pan 11 bit	MS 4 bands 11 bit
Geometric Resolution	0,61 m	2,50 m	1,0 m	4,0 m
Spectral Resolution (nm)	450-900	450-520 (b) 520-600 (g) 630-690 (r) 760-890 (nir)	450-900	450-520 (b) 520-600 (g) 630-690 (r) 760-900 (nir)
Scale for Applications	1:25.000 – 1:5.000		1:25.000 – 1:5.000	
Swath Width	16,5 km		11,0 km	
Image Scene size	17 * 17 km² Strip: 16,5 * 165 km²		11 * 11 km²	
Orbit height	450 km		681 km	
Approx. Cost per Scene €	*70 – 100 €/km²* *(by request from several vendors)*		40 -220 €/km²	

b=blue g=green r=red nir=near infrared tir=thermal infrared mir=microwave

Table 4.1b Pan = Panchromatic, MS = Multi spectral [EHLERS2002, changed]

Table 4.1b is representing the satellite sensors with a ultrahigh resolution of 1,0 m down to 0,61 m in the panchromatic range, which is more suitable for construction purposes as these sensors distinguish themselves with a better resolution. According to the information value of the image itself, which contains the status of the untouched area with the background for restoration after project finishing, due to the sharpness and the high rate of reproduced details in the image it can be used for site installation planning and design in urban areas.

Another advantage of the satellite images is the possible interpretation of the multi spectral range of the light. Software packages like Leica`s ERDAS , Clark Labs IDRISI Kilimanjaro or Definiens eCognition next to several others (which are not mentioned here) offering a lot of tools for loading the sensor data, to analyse them in conjunction with readable vector information and to produce ortho-photographs which are rectified. Classifications dependent on the amount of multi spectral channels are realizable. With this classification - information an overview about the amount and kind of vegetation within the infrastructure project area can be estimated. This estimated information is useful before the removal of the topsoil (upper surface) will take place and to calculate either how much financial compensation has to be paid or what type of extension the replacement area for planting must have. For huge projects the topsoil will be used for a later landscaping as such the soil has to be treated during the construction time in the proper way in order to use it for topsoil filling and planting in the final stage of the project.

The question is “How many plants trees have to be removed, that are standing in the area where the project is placed”.

Further information for not easily reachable project areas can be easily retrieved from official organizations like the NASA, DLR up to a certain level of detail. The NASA is offering due to its Freedom of Information Act (FOIA) several digital elevation data as public domain, which can be converted by the use of geographic information system software to digital surface models. The terrain data is captured in raster information which has been measured by the Shuttle Radar Topographic Mission (SRTM) which took place in the year 2000 (11-22 February 2000) by the space shuttle Endeavour. Two different radar systems have been used – the X-band, organised by the German Aerospace Centre (DLR) together with Italy and the C-band organised by the NASA. SRTM-3 (3 arc second, 3” = 90m) is the currently best globally available source of elevation data and is obtainable between the latitude 60° North and the latitude 58° south around the world. The X-band does not cover the entire earth.

Mission Sponsors
- National Imagery and Mapping Agency (NIMA)
- National Aeronautics and Space Administration (NASA)
- German Aerospace Center (DLR, Deutsches Zentrum für Luft- und Raumfahrt)
- Italian Space Agency (ASI, Agenzia Spaziale Italiana).

Information of the digital elevation products delivered by the United States Geological Survey (USGS) can be found at EROS data centre (http://edc.usgs.gov/products/elevation.html). The National Geospatial Intelligence Agency has developed standard digital datasets (Digital Terrain Elevation Data – DTED) which is a uniform matrix of terrain elevation values which provides basic quantitative data for system applications that require terrain elevation, slope, and/or general roughness information.

DTED Level	Post Spacing [sec]	Ground Distance [m]
1	3.0	~ 100
2	1.0	~ 30
3	0.333	~ 10
4	0.111	~ 3
5	0.033	~ 1

Table 4.1d Digital terrain elevation data

Attention to the definition of digital elevation model has to be paid. A digital elevation model achieved by the radar mission represents the highest point of the observed terrain. This can be the surface but also the top of vegetation or man made e. g. civil constructions. Another fact which has to be regarded by looking in detail to the data one can examine that there are also some voids in the data collection which are caused by the water bodies' reflection of the radar. These voids have to be found and replaced with other available terrain data. The differences to the DTED standards are as follows [CZEGKA]:

- dataset can contain voids as well as spikes and wells
- coastal lines are undefined and water bodies are represented rough – not flat
- SRTM-3 data are not adjusted with available terrain data
- The data format looks like the DTED standard but it is not equal to it
- The elevation data are relative to the WGS84 ellipsoid (not geoid) or to the surface which was used for determination of the ground control points

The advantages of radar measurement are:
The measurement is dependent neither on cloud coverage of the observed area by nor on the time and secondly the measurement can be executed by day and night due to the active transmitting of radar.

Accuracy achieved by the SRTM C-band DEM (Salamonowicz 2003) in [JACOBSEN]:

Area	Elevation [m]	Vegetation	Bias [m]	SZ [m]
Guatemala	408 – 2432	Heavy	-1.7	12.1
Venezuela	118 – 229	Moderate	0.0	2.5
Stennis	0 – 52	Heavy	0.5	2.6
Red River	252 – 293	Light	2.6	1.5
San Diego	70 – 478	Light	1.4	3.5
Panama	502 – 2153	Heavy	-3.1	25.2
White Sands	1355 – 2066	Scrub	2.4	3.2
Nevada TR	1433 -1813	Scrub	-1.5	3.1

Table 4.1e Accuracy achieved by the SRTM C-band DEM [JACOBSEN]

Further information about a validation of SRTM and X-SAR digital terrain models can be found in [MOLL].

The next table is showing a classification of methods for DEM determination according to the project phase.

Project Phase	DEM resolution accuracy horizontal / vertical required	Method for Creation	Instruments	Further information
Pre Qualification	30 m / 2-6 m SRTM 15 m / 11 m ASTER	SRTM, ASTER, Positioning Satellites	Shuttle mission, ASTER, various satellite sensors, , GPS	Rough determination and evaluation of features
Tender Phase	1-2 m / 1-2 m 0.1-0.3 m / 0.2-0.6 m	Photogammetry, Airborne Laser scanning LIDAR, Satellite images	Cameras station, Differential GPS, Real time kinematic GPS	For background information images of Spot, Ikonos, Quick Bird according to the project size
Detailed Design (Shop drawing), Construction phase	<0,01-0,05 m / <0,005 m	Topographic survey, Terrestrial Laser scanning , precise surveying and levelling ,	Laser Scanner, Total Stations, Levelling instruments, Differential GPS, Gyroscope	For Volume calculation of earthworks laser Scanning (airborne terrestrial)
Operation, Maintenance, FM	<0,01-0,02 m / <0,005 m	Same as construction	Same as construction	Design new facilities in existing structures.

Table 4.1f Project phases and methods for determination of DEM

In the range of generation technologies for digital elevation models by remote sensing a few more methods have to be announced. These are namely the photogrammetry, the airborne laser scanning (ALS) and the already explained radar interferometry (InSAR). Photogrammetry is a passive system which detects the reflected solar radiation from ground surface and records the returns digitally or on film. Unlike photogrammetry, ALS and InSAR are active signals that provide their own energy source for transmitting signals, the reflected signal then being recorded digitally. ALS and InSAR are all-weather, 24-hour systems, while the photogrammetric method is more restricted by time of the day and weather conditions.

The photogrammetric method is commonly well known in the construction industry respectively there will be no force for explanation.

The ALS will be explained in short words. ALS is a member of the so-called “Light Detection Ranging” (LIDAR) group of surveying methodologies that include airborne laser profiling and terrestrial laser scanning. Data is collected by the laser scanner mounted on the airplane as a stream of discrete reflected laser points from the ground. The system also exploits GPS, and usually an inertial measurement unit, to precisely position, attitude and acceleration of the aircraft. At least two recordings, the first and last received signals, of each of the reflected laser points are recorded. By determining the difference between the two received signals, the height of objects such as trees or buildings can also be measured. In general ALS derives height accuracies of grid points ranging from 0.1 to 0.5 m, and horizontal accuracies ranging from 0.3 – 1.5 m, with typical point spacing ranging from 0.2 to 4.0 m [TURTON]. These accuracies are dependent upon the properties of the terrain. In the cases of hilly or flat land densely covered by vegetation, accuracies tend to decrease [HUISING].

Explanation: LIDAR = Light detection and ranging uses the same principle as RADAR. The LIDAR instrument transmits light out to a target. The transmitted light interacts with and is changed by the target. Some of this light is reflected back to the instrument where it is analysed. The change in the properties of the light enables some property to the target to be determined. The time for the light to travel out to the target and back to the LIDAR is used to determine the range to the target.

Synthetic Aperture Radar (SAR) is a side-looking active radar-ranging system. It uses the microwave portion of the electromagnetic spectrum, encompassing frequencies in the range 0.3 GHz to 300GHz (or in wavelength terms, from 1m to 1mm). Each SAR image contains information of both amplitude and phase of the reflected signals.

InSAR requires two SAR images acquired over the same scene. These two images can be acquired either at the same time by using two separate antennas mounted on the platform (airborne or spaceborne), or acquired separately in time by revisiting the scene with a single antenna (satellite radar systems). The two images are then co-registered precisely to each other so that the phase difference between the pixels in the two images can be calculated. This phase difference, or so called interferogram, can be used to derive the DEM of the image area.

The SRTM mission used InSAR with signals in C (5.6 cm) and X (3 cm) bands of the microwave spectrum to created the first global DEM of the earth, in the latitude band 60° N to 57° S. STRM used two antennas to scan the earth’s surface instantaneously.

A further European example for a terrain model is the InSAR Tandem:

For the creation of digital terrain models for Europe the ixl-AG a spin-off company of the DLR has used raw data of the European radar satellites ERS-1 and ERS-2 which were acquired from the European Space Agency (ESA) during the tandem-mission.

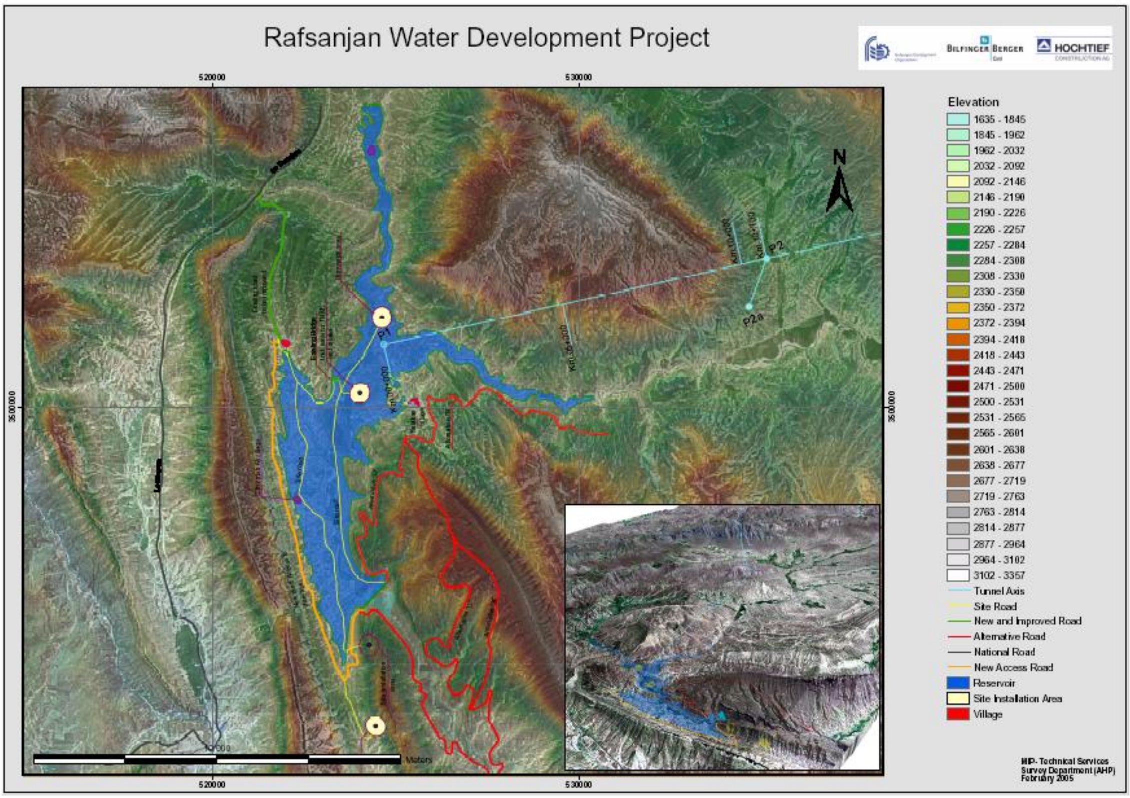


Figure 4.1a Map for Site installation places (Surface STRM + draped Satellite image)
Satellite image by satelliteimaging.com [Hesterkamp]

A list (without claim of completeness) of satellite image providers with image search functions for various image resolutions can be given with the following

- Space Imaging (www.spaceimaging.com)
- Eurimage (www.eurimage.com)
- The GeoInformation Group (www.geoinformation.co.uk)
- DigitalGlobe (www.digitalglobe.com)
- Earth Satellite Corporation (www.earthsat.com)
- GlobeXplorer LLC (www.globexplorer.com)
- WorldSat Internatonal (www.worldsat.ca)
- Spot Image (www.spotimage.fr)
- DLR Earth Observation Centre (Cluster Angewandte Fernerkundung) (www.eoweb.dlr.de)

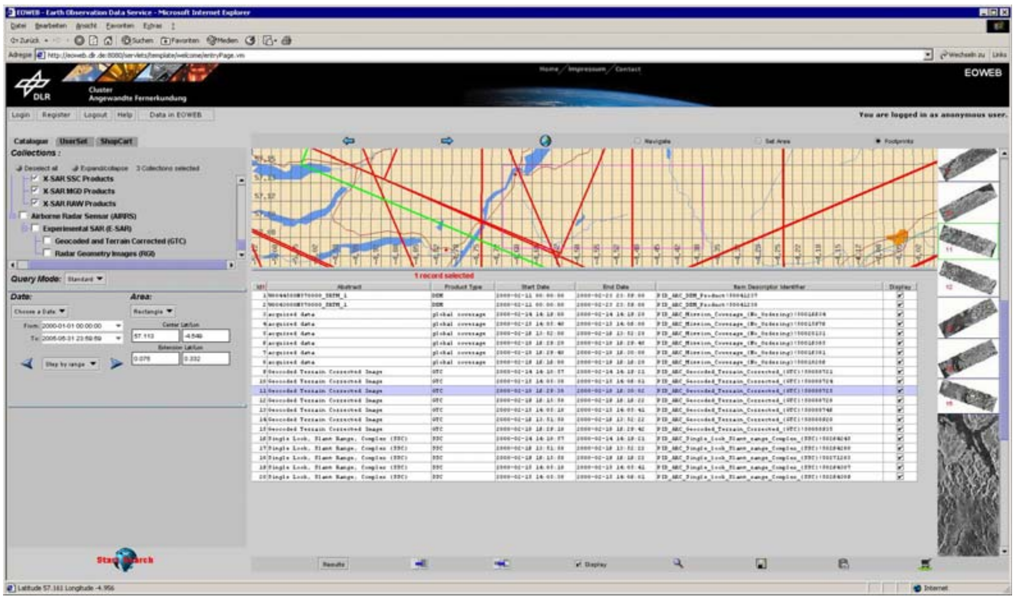


Figure 4.1b X-band SAR Data search and request on DLR webpage EOWEB for an area in Scotland Glendoebeg - Fort Augustus (dam + tunnel project)

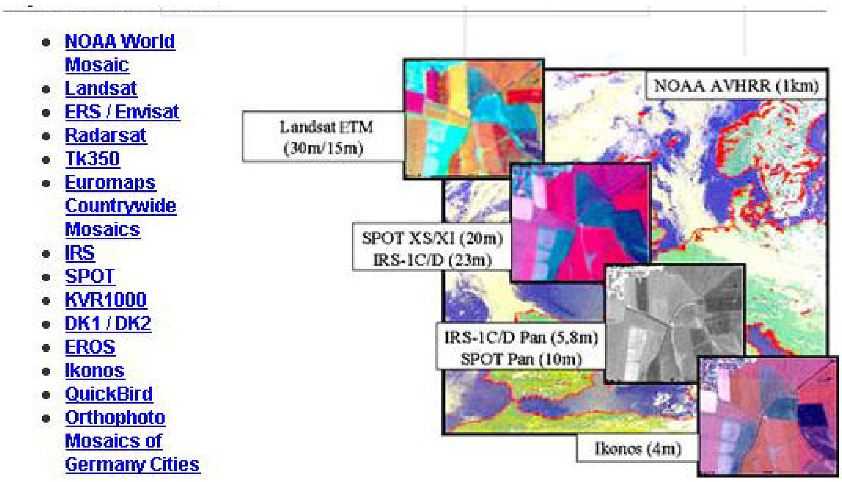


Figure 4.1c Satellite images and resolutions (GAF Company) (http://www.gaf.de/main/data_imagery.php?mainKat=/main/data.php)

This section should close with the look to the new technology of the High Resolution Stereo Camera (HRSC), which belongs to the category of optical remote sensing systems. This system delivers highly precise panchromatic and multi-spectral ortho-photographs as well as extremely precise digital surface models. The original idea for the development of this system was the Russian Mission "Mars 96". The systems concept airborne based. Today three cameras of this type are available HRSC-A, HRSC-AX (tele camera) and HRSC-AXW (wide angle camera). The geometric resolution is indicated with 10 cm to 40 cm depended from the flight altitude. The system can be used for remote sensing tasks as well as for photogrammetric applications. The advantages and the achieved accuracy are given in [REICHEL].

Altitude	Geometric resolution (cm)	Absolute accuracy of points in layout (cm)	Absolute accuracy of height (cm)
1500 m	6 / 17*	10 - 15	15 - 20
3000 m	12 / 17*	15	20
5000 m	20 / 20*	15 – 20	20 - 25

* Ground velocity 280 km/h, Scan frequency 450 Hz for HRSC-A

Table 4.1g Absolute accuracy of x/y (cm) and absolute accuracy z (cm) [REICHEL, page 124]

The main advantages are:

- Direct access to the digital data with high radiometric resolution
- Stereo channels (panchromatic)
- 4 multi spectral channels (blue, green, rot, near infrared)
- One scale – no central perspective
- Digital elevation model is automatic generated
- Easy mosaiking of scenes (automatic)
- Very high vertical and horizontal accuracy
- Customer specific digital data preparation

The HRSC is working with the push-boom principle. Nine CCD-rows are mounted parallel in the focal plane of the instrument behind the optic. Due to the forward movement of the airplane nine overlaying stripes are recoded simultaneously. The camera platform is equipped with POS/DG Navigation System (applanix) which contains GPS and INS tools which enables a control of the nadir point and the advantage is the full automatic workflow process of the data.

4.2 Geo Spatial Data Storage (Geo Database Management Systems - GeoDBMS)

Geographic information systems have been handling since their initiation a huge amount of different geo spatial related data. In the beginning the data was stored in vendor dependent files as it longs up today. The development in the information technology of relational database management systems (RDBMS), which were prior designed for powerful middleware - mainframe computers, are now available even on a commercial quality desktop computer that enable the combination of the spatial related features and their inner relations as well as the optimal access performance due to the database technology. As a simple assertion the combination of GIS and RDBMS is ending in Geo(R)DBMS, which enables the commonly storage and analysis of spatial data. In order to elucidate the terminology of DBMS the main characteristics of DBMS and GIS are noted accordingly [UNIGIS04]:

DBMS:

- Storage system for structured filing of alphanumeric data.
- For analysis, structuring and querying the data of a DMBS a unique standard is defined – Structured Query Language (SQL), it is a common implementation for DBMS
- The data and the results of analysis are represented as tables and charts
- DBMS are commonly used as relational Database Management Systems. In this Systems the organisation to the data and the access to the data in form of relational algebra. The principles for access, joins and analysis are implemented in SQL
- DMBS are created for querying and analysis of extensive amount of data under the condition for consuming a minimum of time

GIS:

- GIS is a computer System for Storage, Management, Analyse, Modelling and Presentation of collected spatial data.
- Spatial Phenomena are represented in structured forms of IT systems by GIS GIS contain data models to adopt various spatial phenomena. As GIS enables the user to store spatial related discrete objects (parcels, administrative borders, road network), it also allows storing spatial phenomena which appear as continuums in form of field-functions (digital elevation models, satellite and aerial images, temperature, etc.).
- GIS leaves the mark due to an extensive collection of functions of spatial modelling and spatial analysis functions (map algebra).
- GIS offers an extensive set of functions for a structured evaluation of spatial data.
- The data illustration and the analysis results and models are represented by cartographic functions.

The origin of both developments GIS and DMBS are the 70^{th} of the last century. The development of the system had been carried out parallel. The vendors for DBMS concentrated on the commercial use of databases and they pushed the development of relational database management systems (RDBMS). The missing data types for storing for of geometric information and the lack of manipulation as well as analysis functions in the DBMS made the GIS vendors storing their geometric information in form of files. The GIS vendors were concentrating on the development of interfaces to various DBMS. Along the steady growing demand for information technology to the geographic information systems, the DBMS vendors offered more and more functionality. Slogan of DBMS vendors was to have a universal or enterprise wide database.

The RDBMS was the technology for storing and administrating and analysing alphanumeric information but the data like texts, images and video was still a domain of file based administration. The further development was concentrated on integrated GeoDBMS and the target was gained with the placement of object-related DBMS (OR-DBMS) on the market in the 90^{th} (Oracle 8, IBM DB2). In our days various vendors offering OR-DBMS with a more or less opportunities for storing geometric or spatial related data and the creation user defined data types, which is a cardinal feature of these databases. This method offers the opportunity to integrate geometric models in the form of special user defined data types in one field – so called spatial data types. Parallel to the establishment of the new spatial data types the functions of SQL were extended accordingly. In conjunction to the object relational data structures in which the geometry is administrated and the provision of corresponding functions, which use the structure of this spatial data types will extend the SQL to SPATIAL SQL.

Due to the explained approach the flexibility of implementation of spatial information systems and the number of advantages are numerous. The connection of GIS with GeoDBMS enables the choice of initiating a function either from the GIS or through the database. Another advantage is the reduction of data traffic between client server and database server. The CPU processes can be spread to existing capacities. This is a fundamental demand for the implementation of web based GIS solutions.

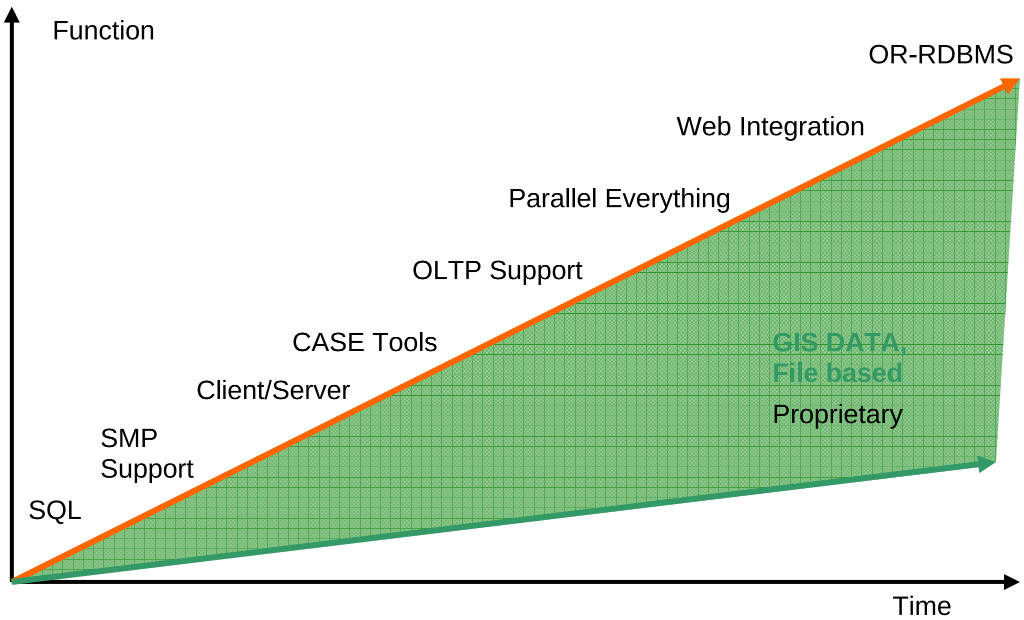


Figure 4.2a Comparison of function development in traditional system architecture and in GeoDBMS [UNIGIS04]

As a summary of the above the definition of GeoDBMS (see Shekar, Chawly, 2003 in [UNIGIS04]) - A Spatial DBMS is a software module that:

- can work with underlying DBMS
- Supports spatial data models, spatial abstracts data types (ADTs) and a query language from which these ADTs are callable.
- Supports spatial indexing, efficient algorithms for processing spatial operations, and domain specific rules for query optimization.

Information in the construction industry is a central resource. The departments of a construction company were collecting information relevant for phases of the infrastructure project in department wide spreadsheets. Today a change is observed due to the desktop applications in the form of databases enhancing the put through of a host of technical and commercial data and due to the demand of data fusion consequently reduces administrative costs. Almost 80% of the technical data which is stored in RDBMS do have a spatial reference. In the departments the development of technical databases is increasing. The connection between the departments is realized by a computer network with the heart consisting of an enterprise wide spread servers. The databases are stored on the servers and are worldwide accessible according the users access rights. The databases are established in form of RDBMS.

As a reaction on the business market demand the internal organization of construction companies have changed their information technology structure. The illustration of workflows and processes of business has to be represented and the installation of the information structure has to be flexible enough to react to changing demands. One requirement for enterprise wide information processing is the common data use. This can be realized by an enterprise wide database, which means a more logical structure of an enterprise wide concept for databases than one database server. Open systems would be a solution for these demands.

4.3 Dissemination of Geo Spatial Data – Administration – Mobile Computer Technologies (PDA)

An interpretation of figure 4.2a is that *“the Web-based GIS technology is a fast growing area for planning, designing, building and operating “land based” infrastructure projects: transportation, telecommunications and the construction industry at large. Although GIS is traditionally confined to the planning stage, geographical information is actually required in phases of the infrastructure life cycle. Making that information available over the internet runs the risk of unleashing a deluge of redundant, outdated,* *incorrect, disorganized and incomplete geographical and project related CAD information. An essential element of internet GIS for infrastructure projects is engineering information management – powerful project control structure that gets the right information to the right person at the right time. This structure, serving a wide new audience of information consumers with current and precise geographical data integrated in to all the technologies used for engineering, construction and operations – is geo-engineering*" [MONNIER].

Geo spatial information was and is collected traditionally by the governments and institutions as well as by a number of private business and companies in order to fulfil the overall demand for a better planning of all kind resources, and easier organisational logistic planning. The change in the information technology and the wide usage of the internet technology, which has become the favourite information exchange platform, inaugurates new ways for data communication either internal enterprise wide but also external for the wider audience. The realisation for dissemination of geospatial information was initiated with the founding of the Open Geospatial Consortium (OGC) in the year 1994. The OGC is a union of geographic information systems users and vendors in the United States with a participation of European and Asian institutions.
In most of the countries similar institutions were founded with the objection to organize and develop the national geo spatial data infrastructure (Example: Geo Daten Infrastruktur Nordrhein Westfalen; GDI NRW). Since the founding several specifications from the OGC where published, that include the standardisation and distribution of geospatial data and in general supporting the interoperability of the geo data. In cooperation with the OGS, whose task is the technical realization and implementation of the specifications, the Technical Committee (TC) 211 of the International Standard Organisation (ISO); the ISO TC 211 is responsible for the achievement of international agreements and fulfilment of regulations for geographic information. Some major specifications will be mentioned here:

- Web Map Service (WMS): enabling the creation of maps by the internet in common raster formats (GIF, JPEG, PNG etc.)
- Web Feature Service (WFS): enables the access to the originally geo data, the standard exchange format is the geographic mark-up language (GML) which is an XML language for description of geo spatial information.
- Web Coverage Service (WCS): Enables the access of raster data (images)
- Web Registry Service – e.g. Web Catalogue Service: enables searching in metadata information in order to identify geo referenced data and services.
- ISO 19115 Geographic Information – Metadata.
- ISO 19119 Geographic Information – Services.

Information about the OGC specifications and their implementations as well as the latest publications can be found on the web page of the Open Geospatial Consortium OGC; http://www.opengeospatial.org. Information about standardisation are published on the ISO/TC 211 internet link; http://www.isotc211.org.

To illustrate the specific functions and advantages of WMS, WFS, WCS a collection of short explanations are given. The web map service (Web Map Server) supports the visualisation of geo spatial raster and vector information, which will be shown as a common browser display. Dependent on the strength and power of the client-server structure additional information can be retrieved from the simple map objects. The OGC defines a map as a visual representation of geo data without being itself a geo datum. According to the specifications this can be made available in various picture formats, normally as portable network graphics (PNG) and JPEG, or as vector based elements – scalable vector graphics (SVG).

The major advantage of the WMS is the reachable and effortless integration to broaden existing map information accessible through the net. Pictures with the identical geo reference will be retrieved from different servers in order to overlay them. The possibility of switching specific layers transparency enables a presentation of more than one geo spatial information simultaneously. It is also possible to cascade the WMS, which means that one web map services is accessing to another web map service. A chain of services can be established, which are not transparent for the user and the cascaded WMS integrates the maps of the connected services. This concept allows the creation of complex maps. A so-called styled layer description (SLD) facilitates the user to control the graphical representation of the map. Minimum WMS requirements vendors have to fulfil are the specifications of the OGS are

- GetCapabilites
- GetMap
- GetFeatureInfo.

The function GetCapabilities will retrieve the Capabilities Instance Document – which is a XML-coded information about the metadata and the services. Information like the available data layers of the geo data with headlines and descriptions as well as the spatial extension of the data. Due to the fact that geo data are delivered in several spatial reference systems a minimum request for solving this matter is the support of queries based on geographical coordinates (EPSG: 4326; European Petroleum Survey Group). Spatial reference systems are important for the creation of complex maps. Maps with an identical spatial reference system can be overlaid for the creation of complex maps, for maps with different spatial reference systems special processes are necessary. Further information about the combination of various web map services can be found in [DEPHOFF] and [ERSTLING].

Web map services have different sources for geo data subscription. OGC specifications defining simply implemented interfaces. Two types of web map server can be differentiated according to their data access concept. The first type is accessing directly to databases or data files. The other type is accessing the geo data by geo data integration from network points (node). Usable services are especially the web feature services, the GML for vector information based on XML, the web coverage service for raster data and additional services. A small not complete list of software products which allow both types of access are:

- ArcExplorer (ESRI)
- MapGuide (AutoDesk)
- UMN MapServer (Open Source, University of Minnesota)

The operation GetMap requests an actual map wherein the geographic position of the target area, the representation format and the size of the map next to the selection of data layers has to be defined. A set of parameter for the GetMap request is available in [WMS1.1.1] or [WMS1.3.0].

Alphanumeric information can be retrieved within a web map by the GetFeatureInfo, which is an optional service of the web map service. It makes it possible to broadcast object structured vector data. Standard transfer format is the geographic mark-up language (GML). The client of the WFS is able to visualise and analyse the delivered data. A web feature service captures the functionality in form of possible thematic and spatial selections – a so called filter. An introduction about the various specifications and the available elements of OpenGIS will be illustrated in form of Use-cases in [ANDRAE, chapter 5-7].

The summarized general advantages of these techniques are the worldwide availability, the easy access to the geo spatial data by a plain internet connection, no extensive specialized GIS knowledge is required to handle the data and the cost for the necessary hardware is low. The representation of the map can be controlled by the user via the styled layer description.

Further efforts of the OGC are undertaken in the standardisation of location based services. Open Location Services Specification (OpenLS) is the new catchword which should facilitate the use of geospatial technology in the wireless internet industry. These services provide real time location information combined with location enabled content to help to answer basic questions about the current location, about features around that location and information how to get to these features. This information should be available on handheld or personal assistant computers.

Only recently have companies begun to experience the benefits of sharing geospatial data with field crews. For crews in an outage situation or maintenance and inspection teams access to geographic data and asset information is essential. The challenges that have limited use of geospatial data until recently are that the mechanisms of ensuring field data are concurrent with information held in the office. How can these changes be relayed to crews in a timely manner to ensure that they have access to the latest data? Improvements in communication technologies have made it possible to transfer data among the office and the field using wireless technology and other communication mediums.

The advantage of making data available to field crews is double sided. It's possible for crews to check the validity of the data in the field and for discrepancies to be reported back to the office. This ensures that the data in the central system is kept up to date. Another advantage is the time it takes for changes occurring in the field to be reflected in the central system. Previously, changes would have been annotated onto paper maps, which would have been handed into the office for input into the central system.

The ability to share geospatial data with various field workers has broadened the scope of users. Historically any design would have been completed in the office with the designer perhaps going out to the site with paper maps. Now, it is probable to take the geospatial data into the field to create the designs with the ability to insert the correct equipment, estimate costing and moving colder to the best fitting design while on location. The solution is the wireless local area network (LAN) and mobile computing technology which have evolved in the last years to a mature level. Handheld personal computer (HPC) and personal digital assistant (PDA) due to their speed, memory capacity, communication possibilities, reliability, small size and long power independence as well as their level of hardware and software standardization enables a powerful potential in the information chain of a construction project at a site. However, these devices will not work on an isolated individual level, but rather in an integrated and systematic way, which means an organized combination of PDAs, mobile phones providing wireless data transmission, and network-based document management. For illustration of the possible instances for workflows see use-case two in [ANDRAE, chapter 7]

General today available software packages for PDAs of the areas CAD, PMS, GIS are according [JADID]

- Island applications
- Wickes lumber constructions-management software (ordering material)
- SHERPA (pipling operations)
- Bidcom (recording project data)
- AirWavz,
- Job cost.

Mobile Computing in the construction industry will help to automate the tasks, workflows on construction sites and increase the quality of documentation. A range of tasks which can be supported by mobile computing are indicated in [JADID].

- Dispatch of construction crew to a job site
- Project status monitoring and reporting
- On site estimation of small jobs
- Scheduling of construction equipment like graders, trucks, etc.
- Ordering of rental equipment to meet sudden demands
- Transfer of equipment from one site to another
- Tracking of material used for cost plus projects

GIS will play the part for localisation of crews, equipment and linking built in parts with a selected group of construction relevant time schedule items, descriptive and estimation information. Construction management will be achieved by using current mobile computing and web services. The efficiency while collecting data and accessing important information by the staff on the construction site will be increased [SCHWEIGEL].

4.4 Spatial Modelling and Spatial Data Analysis

Spatial analyses are the central features of geographic information systems. The use of analytical methods is the focus for various workflows. The motivation for employment of GIS is the wide range of analytical potential. Analysis of existing geo data will support decision processes. The analysis methods, which are obtainable, ranging from descriptive diagnosis of the data and integration of manifold data and include the providing of trends as well as the assessment of design alternatives or variants. Connections of previously independent information will be made recognisable through the process of creation of spatial relations in a unique spatial reference system. Evaluation and interpretation of the spatial relations of integrated information enables to generate new predictions and to acquire profound findings. The analysis methods will be differentiated in categories [STROBL]:

- Network analysis
- Geometric and topologic analysis
- Selection and aggregation of spatial objects
- Structural analysis – pattern analysis and descriptive metrics
- Model set-ups or model builder
- Surface analysis

And their realization by

- Cost surface analysis
- Analysis of topologic relations like connectivity, vicinity, overlap, and isolation
- Spatial queries and selections
- Distance based analysis
- Diffusion analysis
- Map algebra and cartographic algebra
- Spatial interpolation (inverse distance weighting, Kriging, minimum curvature)
- Overlay

A structure of the analysis methods is made in [STROBL] geometrical – topological, vertical – horizontal, discrete – continuously and map algebra. Whereby the geometrical methods the quantitative geometric value will be the centre of interest, whereas the topological methods will focus on the binary valuing of the topological properties. The main thought for the vertical analyses is the multi-thematic integration of information based on spatial overlapping (coincidence). Horizontal analyses are concentrating on lateral relations like distance and vicinity. The discrete view of the world is the major aspect for the vector based model instead of the more continuous view for the variations of phenomena (surfaces) which are apt for the raster based model. Map algebra works mainly on raster information, although the validity of the schema is not connected to a specific data model. Map algebra is working with

Local operators = transformation or combination of geo-data on the specific location without consideration of the other positions in the investigation area

Focal operators = the near vicinity of one location will be taken in consideration for the analysis (in special cases the operation will take anisotropic dependency into account - incremental operations)

Zone operators = aggregation of values of one theme due to the zones of another theme

Global operators = potential consideration of the entire investigation area

in order to put a higher value to the existing and evaluated geo-data.

From the above mentioned broad range of analyses methods only a few will be picked up and connections the construction workflow will be drawn up, although all are of interest for the infrastructure project phases. The geometric and topologic analysis, the surface analysis and the spatial interpolation (IDW, Kriging) are methods which can be easily adapted to the work sequences for an infrastructure project as they assist in understanding geomorphologic forms of the terrain surface and help to estimate the sub layer structure of the terrain. Surface analysis and distance based analysis will help to support the interpretation and evaluation of boreholes (see figure 6.2.3c). A first estimation for the bulk materials, which have to be moved, can be determined by cut and fill calculations.

Slope and aspect analysis from the original ground and especially for the design surface of an airport are important for the correct function of glide path equipment – navigational aids. GIS delivers a rapid solution by the calculation of slopes and is visualising the result in a kind of raster layer. With the visual interpretation of this layer, areas which will not fulfil the technical requirements for the navigational aids are determined in a fast and easy way. A redesign of the design surface, which will be done mostly by specialists in CAD programs, can take place in these areas. A recheck of the new design is natural. With this circumstance of designing in CAD system another advantage of GIS as a data integrator plays a leading role.

CAD data can be linked to the GIS system and analysed. After redesign a simple reload of the CAD file can be executed to start the slope calculation process again. With the new approach of object orientated software the user will be informed automatically when the redesign is finished. The calculation of the slope layer will be started either automatically or on user demand. New versions of CAD programs (AutoDesk MAP 3D and Civil 3D, MicroStation - InRoads) including a number of GIS functionalities especially for terrain analysis or the vendors have a specific GIS module (see figure 4.4a Example for slope analysis; Airport Athens slopes of runway, taxiways, shoulders and embankment, untouched areas).

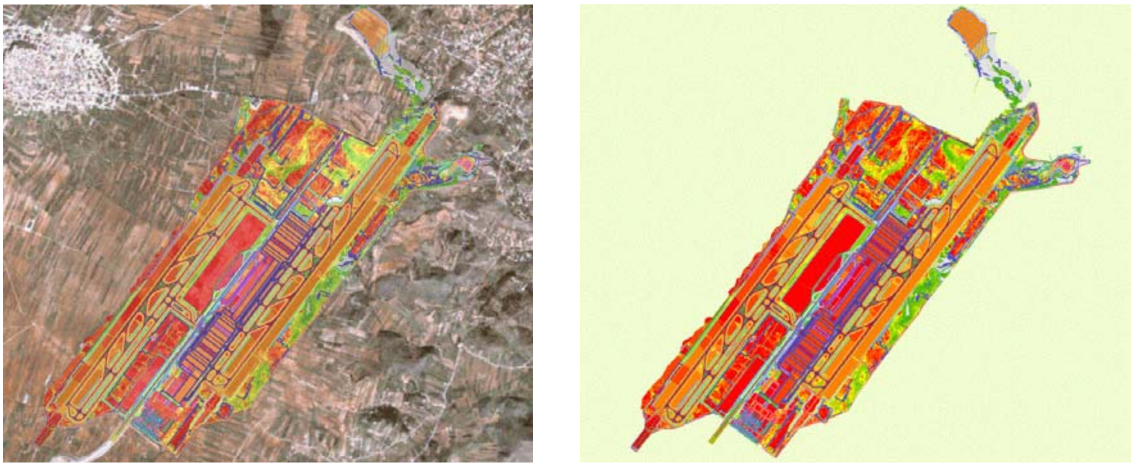


Figure 4.4a Slope analysis New Athens International Airport (classification by degrees), red = flat areas; green = rough areas; grey = very rough areas

Huge infrastructure projects are changing the terrain surface noticeably. During construction phase the soil material will be moved around the site. Material will be borrowed from borrow pits and quarries. The knowledge of the watersheds and water bodies within the terrain of the infrastructure project is important before starting with the bulk earthworks for an infrastructure project to be prepared for expected flooding caused by heavy rain. The steps of material movement can be simulated and critical phases during earthworks reflecting a possible flooding of the site can be determined. GIS supports the determination of watershed and catchments areas [SUMMERSCHOOL2004]. As a result of the calculation and simulations temporary storm water channels can be constructed and utilities can be put in place to prevent a flooding of the site.

The network analysis might be interesting for the utility systems, which will be placed during the design and construction of infrastructure projects like industrial plants, power plants, railway, roads, and airports. First of all the storing of the system in a GIS database at the beginning of the design will support the constructor in quite a few tasks. During design phase clash detection can be executed, information about the fittings can be extracted and used for estimating and later for the maintenance, and in a case of a redesign the information can be recreated in a prompt way. During the construction phase the information can be used for coordinating the work for the different utility systems. The aspect of monitoring the work on site can be done with some simple extension of a few attributes to the segments of the utility system - start time and end time for each utility segment – which will be keyed in by the people on site allowing the controlling of the progress. The constructed and geometrically checked draining system can be examined to prove its functionality (see figure 4.4b New Athens International Airport - utilities).

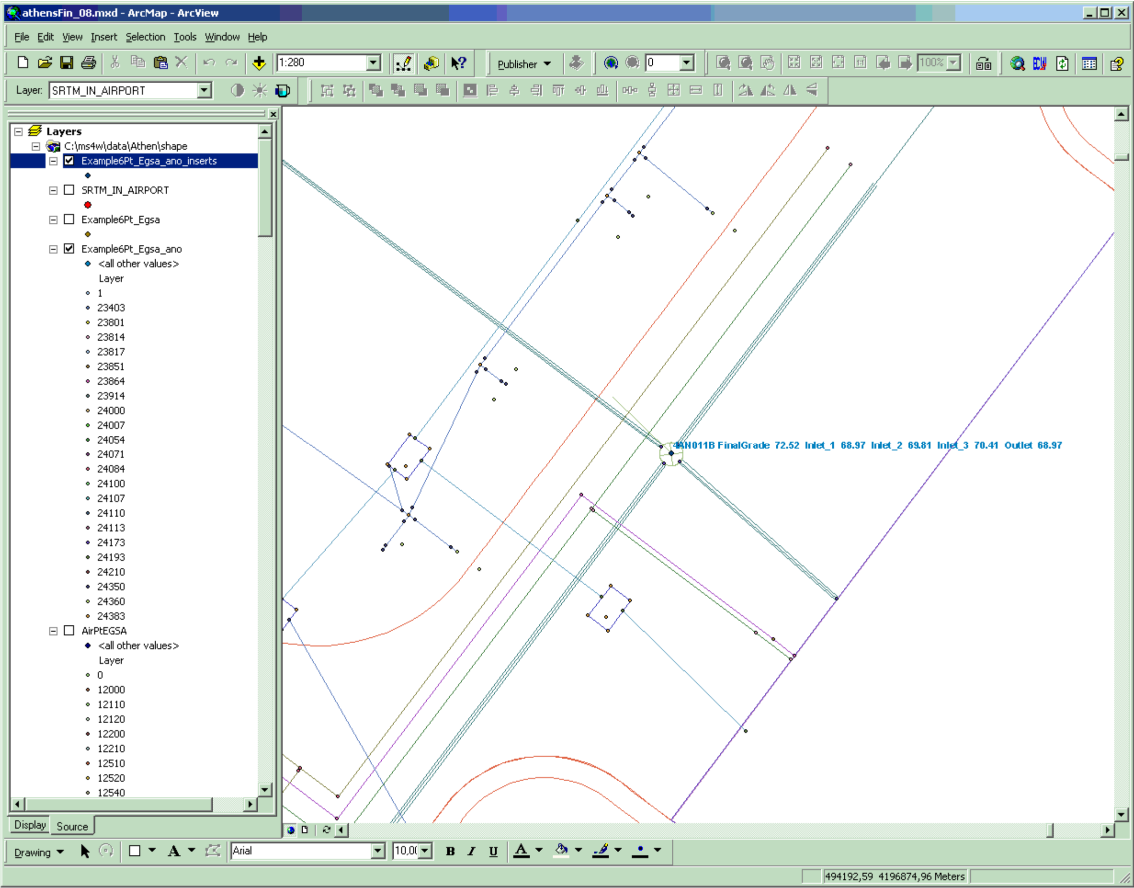


Figure 4.4b Example for utility system on New Athens International Airport (storm water drainage; manhole) labelling by expression in ArcGIS.

Network analyses are important also supporting the transport of material and equipment to the site. The question is to find the right way for heavy machines or transport corridors for an undisturbed material delivery.

In rural areas (dam projects), it is necessary to construct firstly access roads to the construction site - dam area. GIS can support the search and can fix the definition of corridors even with several conditions like avoiding steep slopes, keeping a minimum of distance from (habitats or hazards, forests, slope slides), preferring tracks along soft material, connecting main points of delivery like railway stations or ports. These demands can be combined in so-called cost layers by the use of map algebra that in the end of the analysis will result in a track of the lowest cost – shortest path. This path can be used afterwards for the detailed road design. To reinforce this statement why it is important to consider for example about the slope of the terrain for an access road will be done on an exemplary cycle time calculation for trucks. The figure 4.4c shows the dependency of driving time influenced by the terrain slope items are listed below. The steepness of the road is the main factor for the consumption of petrol and the intervals for the machines maintenance. Cycle times for passing from one location (quarry) to another (dam area) are influenced by the altitude of the locations. If the dam is on a higher altitude than the quarry the cycle times for material delivery and consumption of petrol and mechanical parts will considerably increase. The roll resistance is correlated with the steepness and the maximum load of the vehicle (Example: Assessment of cycle times for dam construction side, complete example; see Appendix F).

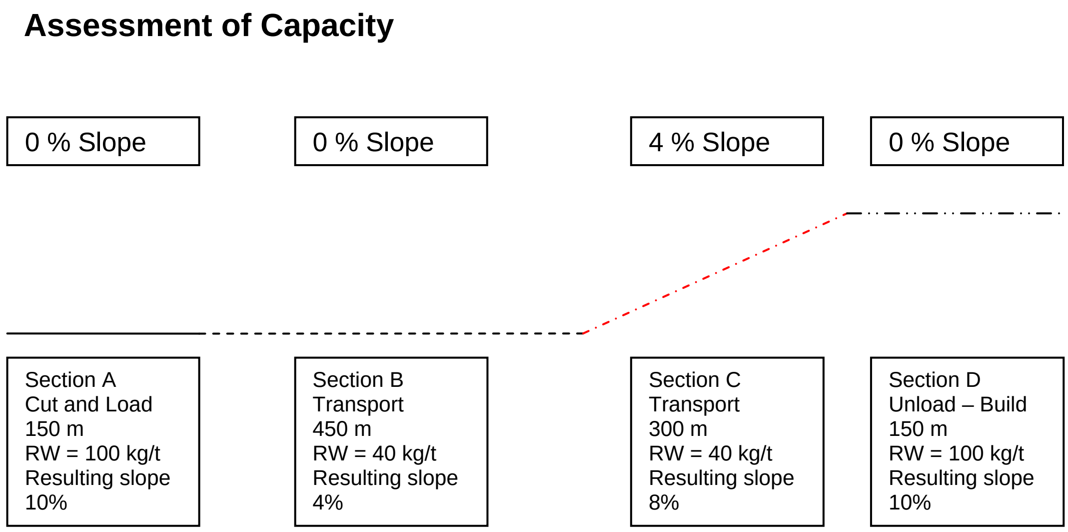


Figure 4.4c Assessment of capacity for dam construction site; RW = roll resistant

As a conclusion it can be stated that several tasks are existing during the infrastructure project phases where GIS analysis technology can support the design and construction workflow. In the following sections the analysis of terrain models will be regarded exemplarity.

4.5 Sustainable data for construction workflow

The evaluation of data for infrastructure projects that will be of importance for all he project phases starts during the initialisation of an infrastructure project. The information is collected due to the responsibility and duty of the governments in order to facilitate their society with trade institutions, transportation services, health institutions, education organisations, energy supply and agricultural products, goods and housing as well as cultural institutions. This demand will be done by long lasting evaluations and studies as well as long term collection and administration of economic and demographic data.

The result of the analysis of the collected data will be a change of the existing environment to change the current situation. For huge infrastructure projects the legal process of environmental impact studies - that include all physical, chemical, biological and socioeconomic factors - will be done to estimate the expected influence on nature, individuals or communities. Environmental impact assessment (EIA) is a logical method of examining the actions of people, and the effects of projects and policies on the environment, in order to help ensure the long-term viability of the earth as a habitable planet. The EIA is used for obtaining projects, planning approvals and voluntarily as part of general project preparation and evaluation.

The data which are collected during the time of EIA can be used during the realisation and implementation of the project. Rough information about the terrain surface and land use classification, the probable existing water resources which have to be protected, habitats in the project area surrounding which requires a specific dealing with during the construction phase, the overall geologic situation, and the hydrologic facts are of importance for the implementation of the project and consequently of interest to the constructor.

As this information and its collection is supported by GIS the handing over could be done in a comfortable digital manner. The exchange of standardized data or better the provision of data on GIS server would reduce the period for printing and conversion for all participants of an infrastructure project.

4.6 GIS core technology for integration of Construction data

Summarizing the statements in chapter 4 the core items of GIS technology are the

- Storage of information in databases with international standards (OGC, ISO)
- Integration of several information sources (raster, vector, tables and lists)
- Support of queries with spatial relation
- Analysis functions for spatial and non spatial data
- Strong cartographic tools for presenting analysis results
- Presentation of information and results by overlay techniques
- Distribution and collection of data by internet technology (Web Map Server, Web Services)
- Common access language (GML)
- Support of form functions for the individual representation of result (SLD, SVG)
- HPC or PDA supporting people on site (OpenLS, Location based Services)

This central or core technologies can be used in enterprise construction organization and more for the disposal of technical data and commercial data. Central data based holding the data and information for an infrastructure project and the network whether the intranet or the internet platform realizing the worldwide user dependent access to the information. The creation of the data will be made from distributed design and constructions departments and the access can be enabled at the currently highest completion level via wireless local area network (LAN) on the construction site.

5.0 Necessity for Infrastructure projects

With the intention to create a better world for all human beings with respect to nature and the environment a wide range of infrastructure projects have to be developed and implemented to reach this target.
The basic elements for the creation of new infrastructure facilities which enable the community to generate a better and healthier life are the recognition, exploration and analysis of any grievances. The collection and representation of the data responsible for the grievances in maps and in charts is one strategy to rectify the circumstances for the bad conditions and problem sources. Maps, as history shows, are playing a major role in representing a current situation. A message can be delivered to the recipient in an easy understandable way and the facts will be faster absorbed (a picture says more than a thousands words). Topographic maps as background and thematic maps for demonstrating the analysis result will demand a change. The desired change will be presented in maps showing the solution design in its environment (new project). Technical drawings will afterwards subdivide the solution design for the project implementation.

"*To be sure, this doctrine confuses culture with quantitative thought, the whole with the part; but it conveys at least one truth, that for many centuries, geometry was part of high culture as well as an instrument of practical utility." [HEILBRON, Preface]*

5.1 Initialization (Phase) for Civil Infrastructure Projects

Each civil project has a cycle of activities, starting with initial study of ideas about what may be needed and how it might be achieved, and ending with a much more intense concentration of resources to complete it.

Steps of work as indicated in Figure 5.1a are therefore typical of engineering projects. Every step results in a variation in character, difficulty and speed of the activities and the resources employed as a project proceeds.

An infrastructure project *“is likely to be initiated when whoever is its promoter predicts that there will be a demand for the service that this specific project might produce. The ideas for the project should then draw on record and experience of previous projects and the result from research indicating new possibilities. These three sources of information ought to be brought together at this stage of a project. Usually at this stage there will be alternative ideas of schemes that seem likely to meet the demand. Proceeding further requires the promoter to authorize the use of some resources to investigate these ideas and the potential demand for the project. The term sanction is used here to mean the decision to incur the cost of these investigations. The cycle then proceeds to appraise the ideas to compare their predicted cost with predicted value*.” [SMITH, chapter 1, page 5-6]

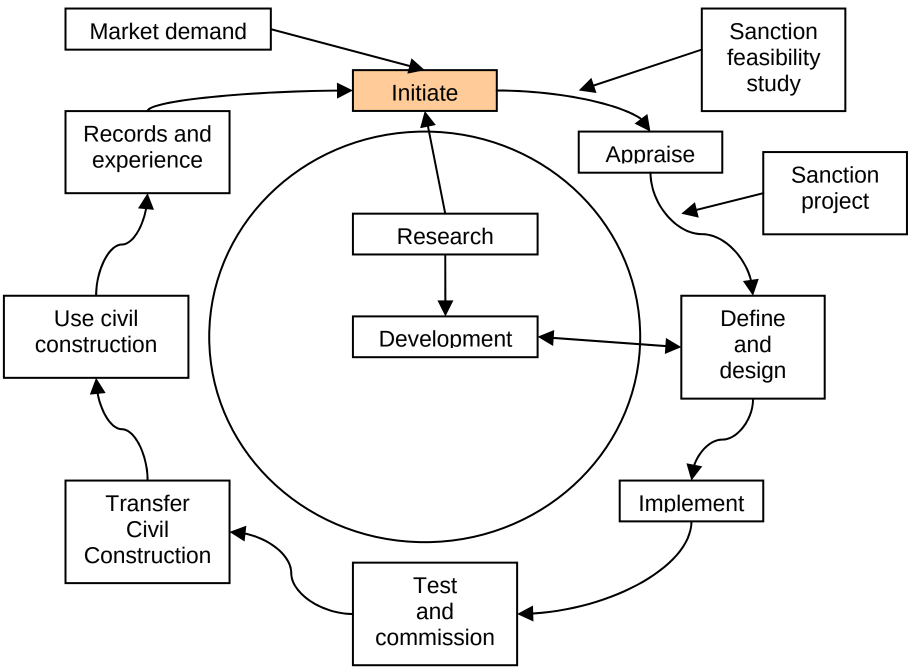


Figure 5.1a Cycle of steps of work for a civil project [SMITH, chapter 1, page 5, changed]

The demands for changes in our world are determined on one hand because of socio-demographic changes, business aspects (expanding, growth) and on the other hand because of international agreed commitment of better care of the natural resources (reduction of emission, integrity of water sources). According to the figure 5.1a and the Figure 5.1b there are market demands and results from research which will drive the changes in the world. In Figure 5.1b the Impact review and reaction can be seen as a cycle process, which will exist generally. The not foreseen impact of constructions will demand new environmental studies which will have their influence of changing the current situation to create again a better environment.

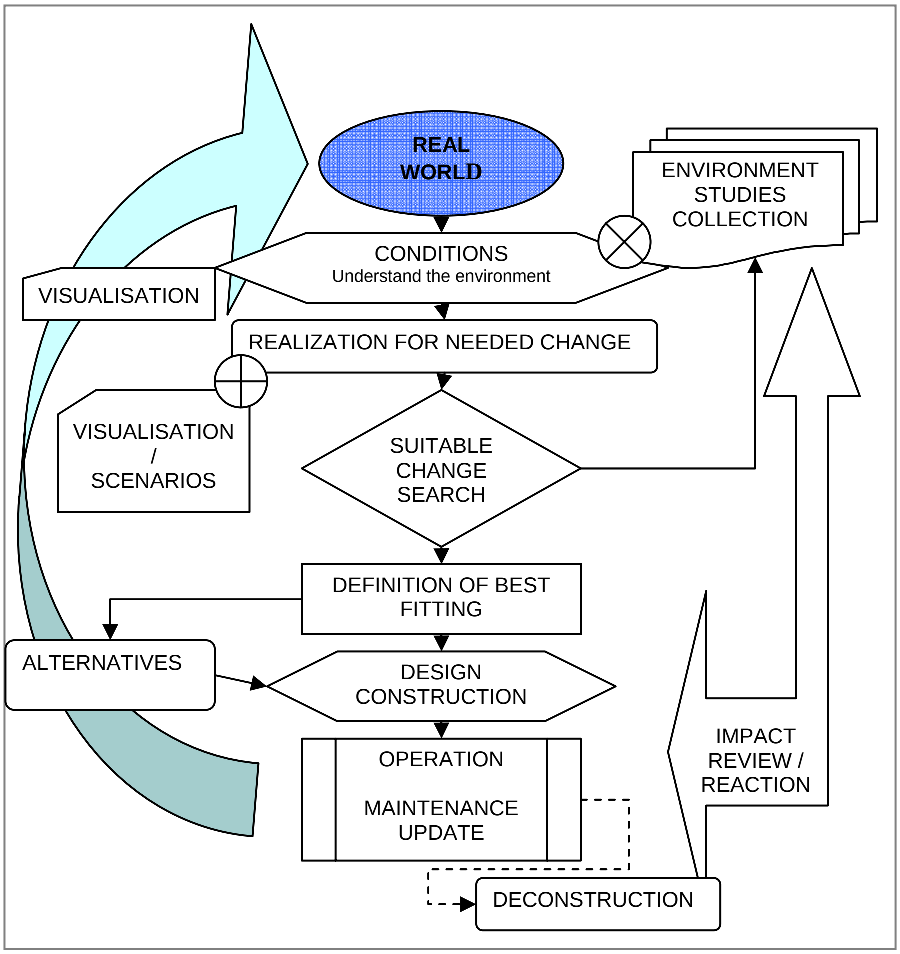


Figure 5.1b Cycle of demand for Infrastructure Projects [Hesterkamp]

Following the flowchart 5.1b there will be a change in the real world due to the necessary needs investigated by research of environment studies. This will be influenced by market requests. A model of the real world will be created in a virtual frame with the intention of a better understanding of the environmental connections. This task will be done by environmental investigations and environmental impact studies. Hence the need for geographical information is obvious. Spatial related data has to be collected and stored for further analysis and interpretation.

In recent years the information technology has improved a lot due to better hardware and operating systems. The software has made a big step forward to a better performance for spatial tasks, an assistant user support and has gained user acceptance. Systems are established which realize a handling of massive spatial data on the normal personal computer. As a common information integrator the commercial available GIS systems are used for environmental data collection and integration. Usually the governments of a country and private institutions use these GIS systems for their information means. The following information is collected and saved in these systems:

- Real estate (cadastre - with be background to build the basic data)
- Geological
- Climate
- Hazards
- Demographic
- Utility network - Infrastructure
- Ground water
- Transport
- Energy supply
- Etc.

Special applications according to above mentioned items support the spatial analysis within the GIS-system. As examples the statistical methods and geo-statistical algorithms inverse distance weighting (IWD) and the Kriging Interpolation is mentioned here. These algorithms are used in the exploration of material and in geology. Further algorithms have been developed for a better visual representation of spatial phenomena analysis results. Because of the spatial connection of the data the cartographic illustration is mainly used for decision support.

5.2 Data in project initialization phases with focus on construction matter

The first question for an international operating construction company is the spatial location of the project. The answer to this question traditionally can easily be given when the layout maps showing the location of the project within the contours of the country and in detail within the local region. The most common technical description for a location is the longitude and latitude in degrees. A geographic definition of the project location by will be understandable to a majority of the public. The answer to the question “where” will cause further questions about the climate and the general geology of the project area. The climate is necessary for the materials which will be used and the kind of construction method. During construction special treatments to the material have to be investigated as are outcomes of previous experiences of projects in similar climates. For example the construction of an airport will claim several observations for direction and strength of the wind and the rain- and snowfall of the designated airport location. The pouring of concrete for building parts can only be done on certain temperatures due to the regulations of international building specifications (stability and consistence).

The geology is of great importance to any construction. On a large scale the tectonic region and zones have to be respected. The National Geological Institutes of the countries will determine the seismic code for the project area. This seismic code is an outcome of continuous observations and measurements of the geological activity within a specific spatial area. The seismic code has at the beginning influence on the placement or alignment of the infrastructure project and forces the way of structural design (reinforcement, use of steel) as well as the engineering structure (static of the building, foundations). The geological structure and the material underneath the designed infrastructure construction has to be investigated in detail, because of the kind of building (pylon of bridge, building, dam, civil infrastructure) which will be placed on the geological layers. The geology and the climate consequently have spatial aspects.

5.2.1 Technical data availability during project initialization

The technical data availability for the initialization phase of an infrastructure project is limited to the information which is evaluated in the environmental studies due to the fixed budget and technical specifications and experiences from similar projects. The data will give a rough impression of the situation for the proposed area of the planned infrastructure. Technical data for the project can be gained in a first step from a similar infrastructure project. This technical data have to be as far as possible adjusted to the conditions of the current project.

5.2.2 Technical data evaluation during project initialization

To gain data for infrastructure projects several mechanisms are available. A wide range of possibilities are given by new aerial and satellite images, new survey techniques like photogammetry with high resolution cameras or laser scanning especially light detection and ranging (LIDAR) [VENEZIANO] and new methods for soil investigations. The products of these techniques, which are gained of gradually scientific analyses and interpretation processes, offered by state departments or by private companies. These products can give information about the surface of the chosen terrain. The geomorphology of the terrain in which the project should be placed is one the first required information which is necessary for further soil and geotechnical engineering questions. The information which is gained from the evaluation techniques will be represented as digital terrain and surfaces models. This can be done by contour lines or by more realistic 3D models. Analyses based on the digital terrain model and additional interpretation procedures of the images (classification) will serve the engineering workflow and subsequently refined the decision making process. The terrain model can be used for example to analyse watersheds and the sub surface layers of the geology help the support decision for the alignment of new linear infrastructure developments and the foundations for specific building parts (bridges, buildings) in certain areas.

5.2.2.1 Environmental data

As mentioned in section 5.1 the governments and the local authorities of the countries are collecting environmental data according to their planning and observing duty. A pool of data has been already established and the collection of actual data is an ongoing process. The data pools are kept up to date. A validation of this statement can be done for most industrial countries (America, Europe, Australia, Middle East, Asia ...) by looking at the existing publications and web pages of the governments. For developing countries a collection of data is not obtainable in such detail as for the industrial countries. With new remote sensing techniques this lack of information can be overcome and bypassed until these countries have a proper pool of environmental data established themselves. The evaluation of environmental data which has relevance for construction is given in 5.2.

The search for information and the knowledge about the kind of stored data is important to the construction industry. As the information of environmental evaluations is stored on internet accessible platforms and made public in this way the overview of the available data is given in so called catalogues. The user can find information with simple queries by keyword or by a location query. The result of a query will be a list of available dataset of data vendors according to the query. Combinations of queries by location and queries with keywords are possible. The navigation aid is simple due to the qualification of the variety of users.

Detailed information about the data content is given in form of metadata. This information is data about data. Roughly it can be stated that this information offers the location (Spatial Reference System - SRS, Coordinate Reference System - CRS, projected coordinate system) and the covered area (geographic coordinates) of the data set, the content of the data (description, purposes) and a list of the shipped attributes. The complete content and size of this data can be found in the ISO NORM 19115/19119 “Metadata” and in the OGC CS-W – Catalogue Service Web.

5.2.2.2 Socio demographic data influence on infrastructure projects

Socio-economic data is data about humans, human activities, and the space and/or structure used to conduct human activities. Socio demographic data is relevant for civil projects to determine the average prices for material and the average wages for the employees in a construction project. It is necessary to know how the salary is structured in dependency to the education of available possible employees. This information is in principle of importance when the tender phase of a civil project starts and the first estimation has to be generated. The influence of monthly wages and salary of labours and clerks to the project estimation and its execution has to be taken into account in the pre qualification phase and especially in the tender phase, as here the offer to the client will be predetermined.

The internationality of the infrastructure projects will demand from the involved partners construction Companies a good behaviour of the countries culture, the mentality and the traditions. To note some items which have to be taken in consideration are [EUROGIS]:

- Demographics (age, sex, ethnic and marital status education, religion)
- Housing (rent, average cost for flats)
- Education (general),Qualification (specific)
- Employment status
- Economics (personal incomes, occupations, industry, regional growth)
- Transportation (Logistic)
- National holidays
- Store sites (material delivery)

Construction companies are using socio-demographic data which is collected by the governmental authorities. The above mentioned items will have to be taken in to consideration in the cost project's estimation plan - respectively some of these items will form the frame for the time schedule. Religion and National holidays will have their influence on the working days and hours and the general education and specific qualifications will determine how many employees can be recruited from the certain country (local employees). The location of stores will have their influence on the delivery times of material. Transportation of materials will be enhanced through existing infrastructure e.g. road and railway networks.

5.2.3 Usage of available and evaluated data for construction workflow

A summary of this chapter which has thrown light on the established geospatial infrastructures and the amount of data that is collected by the responsible authorities before an infrastructure project will be initiated, implemented and operated are the statements that

- Geo - spatial data is on stock or is on the way to be stockpiled
- Geo - spatial data is accessible
- Geo - spatial data can be achieved through clearinghouses
- Technologies for fast tracking of geo - spatial data exists
- Geo - spatial data will be distributed by new techniques (WMS)
- The knowledge about the existing geo - spatial data has to be announced to a broader public
- Sustainable integration of geo - spatial data in the infrastructure project workflow increases the value chain

A good example for these above mentioned statements and an introduction is the lately in the magazine GEO*informatics* published article about the "Alp Transit – The Railway Link of the Future" [TRIGLAV2005]. Herein the sequence of a infrastructure project phases are reflected starting with the outcome of socio demographic interpretation supported by geo-spatial analysis that are initiating the process of the project idea and development up to the implementation of this civil infrastructure project and its construction in our days. The amalgamation of several disciplines which are the landscape planning, the responsible authorities for environmental protection and ecology, the geological institutions, the geodesy authorities and the later organisation for operation in order to manage safety and risks is highlighting the teamwork on such projects.

6.0 Pre Qualification phase for infrastructure projects

A description of the Pre Qualification procedure is given in [SMITH, N., J., page 213-215]

"The principal choice is whether to adopt a full prequalification procedure specific to each contract or whether to develop standing lists of suitably qualified contractors for various sizes of contract and types of work. Any form of prequalification is not a straightforward matter as it involves subjective judgement. A full prequalification procedure may include:

- *Press announcement requiring response from interested firms or direct approach to known acceptable firms;*
- *Issue by the promoter of brief contract descriptions including value, duration and special requirements;*
- *Provision of information by the contractor including affirmation of willingness to tender, details of similar work undertaken, financial data on number and value of current contracts, turnover, financial security, banking institutions, and the management structure to be provided, with names and experience of key personnel;*
- *Discussions with contractor’s key personnel;*
- *Discussions with other promoters who have experience of the contractor.*

The evaluation may be done qualitatively, for example, be a short written assessment by a member of the project manager’s staff to narrow down the number of suitable contractors. After the potential bidders have been interviewed and evaluated, the project manager should recommend a bid list for the promoter’s approval. This should be a formal document, which provides a full audit trail for the selection process. (…) It is the usual practice to pre-qualify about 1.5 times the number of contractors to be included at tender. This is often achieved by a combination of quantitative and qualitative methods, as no standard procedure exists.”

In this phase the construction company has the first contact with the announced civil infrastructure project. The workload in this phase will be the production of drawings and preparation of letters. The drawings should show the location of the project and the amount of work for the creation of the civil building project. Occasionally the working procedures are provided for a better understanding to the client. The drawings are not going too much into detail, but they contain the information about the materials and equipments, which are necessary for the construction method. Furthermore they contain other terms that matter to the parties stated in the letter.

The set of documents traditionally used are:

- Drawings
- Specifications
- Conditions of contract
- Agreements

The time schedule and the Bill of Quantities (BoQ), which will define the scope of work and forms the basis of the terms of payment are additional typical documents.

6.1 Data Availability

Commonly the client (promoter) of a civil building will provide the contractors with all basic technical information in this stage of project. Governmental or huge private institutions are the main clients for vast infrastructure projects. These organisations are the leaders of the desired change so they will give the order for investigations and delegate the work to the sub organisations. When the necessity for changing a situation is recognized by a community, the in charge authorities will have already started to investigate the environmental conditions and the possible environmental impact of the design or a new construction which will change the current situation. At least this evaluated information is available parallel to the base data (geo basis data) for planning task, which has to be collected by the government for several reasons.

Geographic information systems (GIS) are an important technology for managing spatial information at local, regional, national, and global levels (see figure 6.1a). Digital map data is used for managing the natural environment, economic planning, emergency response, environmental conservation, public health programs and a variety of other challenges facing society in the current century. This geo basis data, which is founded mainly on topographic maps and cadastre evidence (cadastre maps for real estate) will be established in the next few years or has been already established as a common duty of the governments according to their tasks of recording data for planning, taxation and administration.

Due to the international agreement of building a Global Spatial Data Infrastructure (GSDI) the governments and their sub organization are on the way to establish models for Spatial Data Infrastructure (SDI). More or less this is done by new information technologies due to the rapid changing of possibilities on worldwide accessible information platforms. The past or maybe the current situation in some countries is that information was and is collected (at least in the industrial countries) on proprietary information systems, which could only be accessed by professional users. In some countries there is no data or simply rudimentary analogue data available.

The current situation is that more and more the information will be stored and made public on the World Wide Web. The rules and access rights for will be regulated due to the culture of the particular country and will also be market driven. The data is stored on Web-Map-Servers which will build the foundation for spatial related information (the working principle is be explained in chapter 5.3). Search machines for positioning and data catalogues and data specification are installed, to easily enhance the users discovery of the information he is looking for.

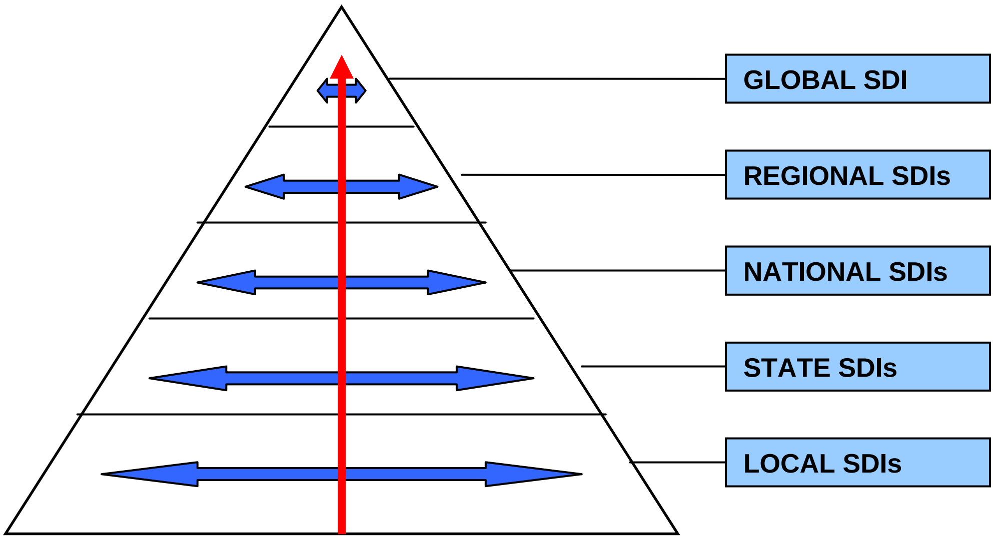


Figure 6.1a Vertical and horizontal relation in a hierarchy of geo data infrastructures [BERNARD]

A small collection of information projects which are on the way to be established or are already components of the spatial data infrastructure and which will be available on modern platforms:

- Global Spatial Data Infrastructure (GSDI) ([NEBERT2001])
- Administration boundaries (Seamless Administration boundaries of Europe, SABE)
- Coverage (CORINE)
- Soil information system (European Soil Information System, EUSIS)
- NASA Satellite Data for Elevation models (Shuttle Radar Topographic Mission, SRTM)
- Infrastructure for Spatial Information in Europe (INSPIRE)
- Environmental European Spatial Data Infrastructure (EESDI)
- United states Geological Survey (USGS)
- Geo Data Infrastructure North Rhine Westphalia (GDI-NRW, regional for Germany)
- European Spatial Data Infrastructure (ESDI) based on the European Terrestrial Reference System (ETRS89)

For the pre construction phase the satellite data (IMAGES and Radar Data) for digital surface models (DSM) are especially in countries where digital information are hard to find a good basis for the first impression how the civil project is embedded in the terrain. Some types of data of digital surface models are accessible public and the accuracy is due to the stage of the project sufficient for the first impression of the expected geomorphology. The resolution of the satellite images ranging depending on the sensor and the amount of existing spectral channels from 30 meter to 4 meter ground resolution for multi-spectral sensors and from 15 meter to 0.61 meter for panchromatic range of the light. (See Table 4.1a and Table 4.1b) (Example: IRAN)

The location of the civil project in terms of:

- in industry countries (all essential facilities obtainable)
- in development countries (facilities hard to discover and to find)
- next to a urban areas (Transportation of employees and supplement of side)
- in the rural areas

are interesting for a construction company.

6.2 Data collection

Almost all technical data which are available are of importance for the successful transaction of construction sites. The technical data are necessary for valuing the properly consumed construction period (time), as well to consider about the construction method and to have in idea about the estimation of the financial effort which has to be invested for reaching the near project target and it‘s implementation - operation. The project first estimation in the tender phase will be the base for the cost control and calculation during the construction period. Once the estimation has been fixed it will settle the limits for the overall project budget.

During the phases of an infrastructure project technical data will be collected or submitted by or to the client in order to figure out sophisticated construction solutions which will fulfil international rules. The next sections are giving some insights in the workflow during pre qualification phase starting with the first site visit and follow the path up to the situation of being a preferred bidder for an infrastructure project.

6.2.1 Site visit

GPS – technologies – Digital Images – GPS Orientated pictures

After the construction company has achieved the information about an offer for a new site or a civil construction project all existing technical documents will be collected and reviewed by a project team. In this stage of the project the client gives mostly rough information. To get a better impression of the project area a selected group of employees from the construction company will be engaged to visit the site and the surrounding area. The tasks of this group of people are to investigate the existing infrastructure in the project area (roads to the construction site, existing quarry, site installation areas, place for housing of expatriates, stores for delivery of construction material) and to find out the probable construction conditions in the country, means what kind of subcontractors are available. The documentation of the visit will be a list of detailed information about the site area itself and further information about the places for material loan. To make this information available and transparent for a public it will be prepared in digital format.

Several digital terrestrial images will be taken to support the documentation and the investigation (site visit) report. The new technology of GPS allows an easy and precise determination of features for the investigation subjects in the studies. For example the place of a dam can be localized within a few meters by a handheld GPS receiver to realize a connection between the real world features with their object representation in the digital model. This new handheld GPS receivers are enabling the user to store point, line and area features (GeoExplorer XT, GARMIN). Each of these features encloses a list of attributes defined by the user (see figure 6.2.1a). The attributes are containing multimedia information – for example a recorded statement about the soil condition or digital images of the quarry – related to a specific location. The information is stored in files which contain the location (mostly WGS84) and the filled list of attributes recorded to the specific feature. As the files with the information are of small size the can be send to the headquarters by mobile phones or via e-mail. The simple way to load this information into a geographic information system (GIS) and create maps in combination with previous received project layouts from the client will open the way for a multi user project discussion and it could be the base for project coordination. As well it is effortlessly to publish this information on the construction company's intranet or for a wide dissemination on the internet. All project participants are able to view the evaluated data by simply browsing the data in the internet (Map Server - Open source, Arc Explorer or AutoCAD Map Guide – vendor dependent). The use of location based services or better location based information generation (mobile phone with camera) has to be figured out, but seems to be a feasible option for the future.

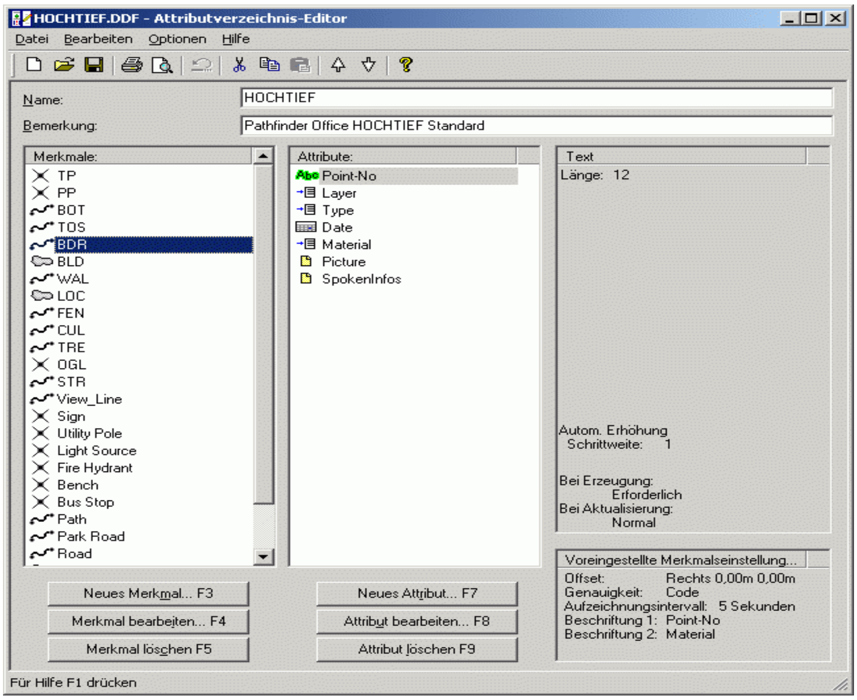


Figure 6.2.1a Data dictionary for GeoExplorer XT (Trimble) - HOCHTIEF Site visit dictionary.

New special digital cameras offer the opportunity [GEOINFORMATICS-2-2005] to save the position and the direction of the view which is important in some cases. The advantage is that the producer of the layout (overview map) will be supported to give a direction of the digital image. The geo-images are automatically converted to shape files or merged into the geo-databases for instant integration in geographic information systems. Even if the connection to the GPS satellite is lost a position can be obtained by the use of inertial systems, which are adapted on the camera [Tag der Geoinformationswirtschaft im Landtag NRW, Düsseldorf 23.11.2004]. This is an advantage for areas with low satellite coverage and for sites which are not accessible to satellite signals (gorges, tunnels, buildings).

6.2.2 Published Data on the Internet

In the pre-qualifying stage of an infrastructure project the technical data which is given by the client has more informatively character. Decisions and financial dependencies for the construction company are of low risk, because only a choice for giving a tender offer or not, has to be undertaken. Precise and detailed information for an infrastructure project will be handed over in the Tender phase of an infrastructure project. The client submits a statement for a proposed new infrastructure.

In a first attempt to get data of the local environment for a new site location the internet provides tools for finding information according to an infrastructure project. These tools can be separated in two general categories which have more or less geo based linkage. These tools are

- General or common search machines like:
  Google,
  Lycos,
  Copernic,
  AltaVista,
  MSNWebSearch
  Yahoo!,
  NetScapeNetcenter

and

- Special catalogues for geo spatial services like
  NASA,
  USGS,
  GEOmis,
  Maps Worldwide (http://www.maps.ethz.ch/map_catalogue.html)
  Services (http://www.sourcepole.com/sources/software/giscomp/wms_list/xml)
  Google Maps (http://maps.google.com)
  Google Earth (http://earth.google.com)

The first category gives almost all information about a project which has been ever published on the internet. This tool is helpful to get information about the background of the project and as well related environmental impact studies and discussions. A further advantage is that due to a connection to the second category this information service will be found as well. Disadvantages are the tangled mass of information which is not relevant for the project. Due to this fact the person who is searching will lose the control and the internet sources that are given are rather old or not useable for integration in the direct workflow.

The second category is more specialist tools compared with the first category. They are organized into catalogues and therefore it is easier for the user to discover his desired information. This catalogue service summarizes geospatial related information and links where geospatial data can be found. For construction the information on the geo base data, the geological data and the climate, atmospheric data are important. Some of the presented links contain data for the entire world; some are national or regional information databases. Datasets at least are viewable and available for a fee.

To announce some

- Bundesamt für Kartographie und Geodäsie BKG (http://www.bkg.bund.de)
- Interministerieller Ausschuss für Geoinformationen IMAG*I* (http://puppis.geomis.bund.de/geoportal/index.jsp)
- Global Change Mater Directory (http://gcmd.gsfc.nasa.gov)
- Geography Network Explorer (http://www.geographynetwork.com)
- Centre for Geo-information (http://www.geocatalog.de)
- Etc.

6.2.3 Infrastructure project related data from the client (CAD)

Datasets referenced to the infrastructure project from the client are usually handed over in analogue format. Once the data is published the second step will be an inquiry about digital data - normally CAD files for the project’s layout and excel sheets for bill of quantity (BoQ) - will be handed over. CAD files are useful for merging the information of the constructor and work preparation sequences on top of the project drawing. Dependent on the origin of the drawing – Architecture – Steel construction – Civil construction - the construction company will face the effort for incorporating the data into a homogenous format, especially to a homogenous coordinate system. For example the architecture will be given in inches and in local coordinates. There is no given connection to the regional or national coordinate system; the units in drawing for a steel plant are based on millimetres and a local coordinate system is used; the incorporation of the borehole sketches with national coordinates have to be transformed.   Aerial images showing the original project area status have to be transformed to national coordinates to enclose them as background information.

(Example: Brazil)

Figure 6.2.3a Scanned Plot of the claim delivered by the client.

Figure 6.2.3b New location for Steel Plant in Brazil (EarthSat NaturalVue, http://www.earthsat.com, 2000)

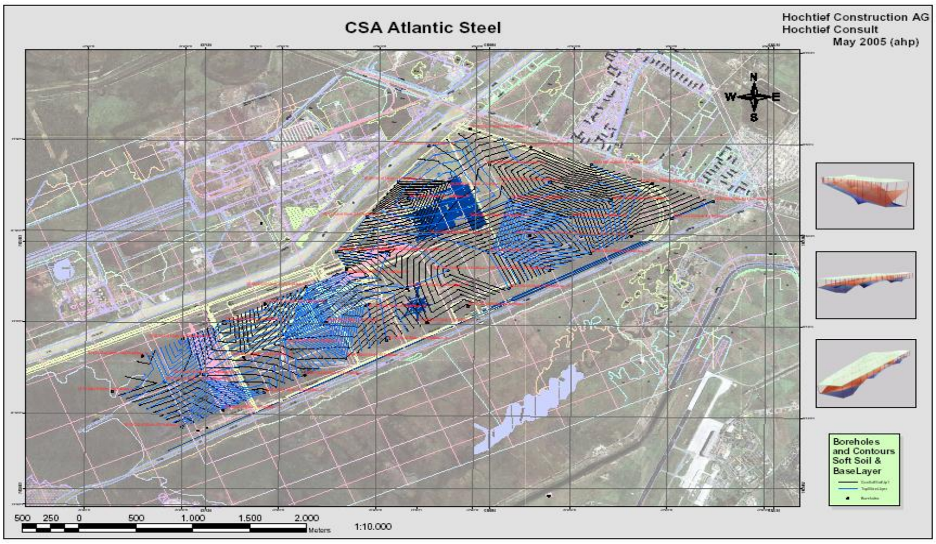


Figure 6.2.3c Combination of CAD, borehole information, Layer and Scanned Aerial photography/image

Geographic information systems are very suitable for these kind of tasks. Integration of vector data and data in raster format can be merged. Vector data like CAD files can be loaded directly and translated, transformed, scaled to national coordinates (see figure 6.2.3c). Raster information like aerial images or satellite images can be loaded and transformed with scientific algorithms to their location on the national grid. The images can also be converted by a process called rectifying to a new image with consideration the change in each pixel and its circumference. A distinction between continuums and discrete data according to the source and reason of the raster information can be acquainted. In the example the results of the borehole investigations are represented as sets of contour lines. The two important soil classes' - soft soil and base layer - for construction were determined by the Kriging interpolation. Three dimensional views showing these both layers additionally.

For a dam project in the state of Iran, Rafsanjan, the tasks were to visualize the three variations for a water conveyance tunnel and to show the flooded area after dam construction (see figure 4.1a). The accuracy of the SRTM data loaded from USGS and the data from the client handed over as CAD drawings was compared. The SRTM data for the area has been converted and transformed to points with elevations of the national coordinate system. A triangulated irregular network (TIN) was created out of the points. A raster layer was created by the function TIN to Raster. For the elevation model of the client the same procedures followed. By the map algebra function the resulting layers were subtracted from each other. The simple result is the difference between both elevation models. The results were joined to the SRTM points. The simple statistic is showing the maximum deviation (-24.45 m and 32.08 m) and a mean deviation of 2.71 m. The result is within the expected values that are given in the table 4.1c. A visualisation of the mean and its statistics can be found in figure 6.2.3c and 6.2.3d. The elevation range in the observed area and the vegetation class are similar to the area of Nevada and White Sands with are given in the table 4.1c.
The advantage of the STRM data in contrast to the data handed over by the client is the homogenous distribution of the benchmarks/points and the accessible amount of points for the study area which extensions are 30 km north to south and 60 km west to east for the three tunnel solutions.

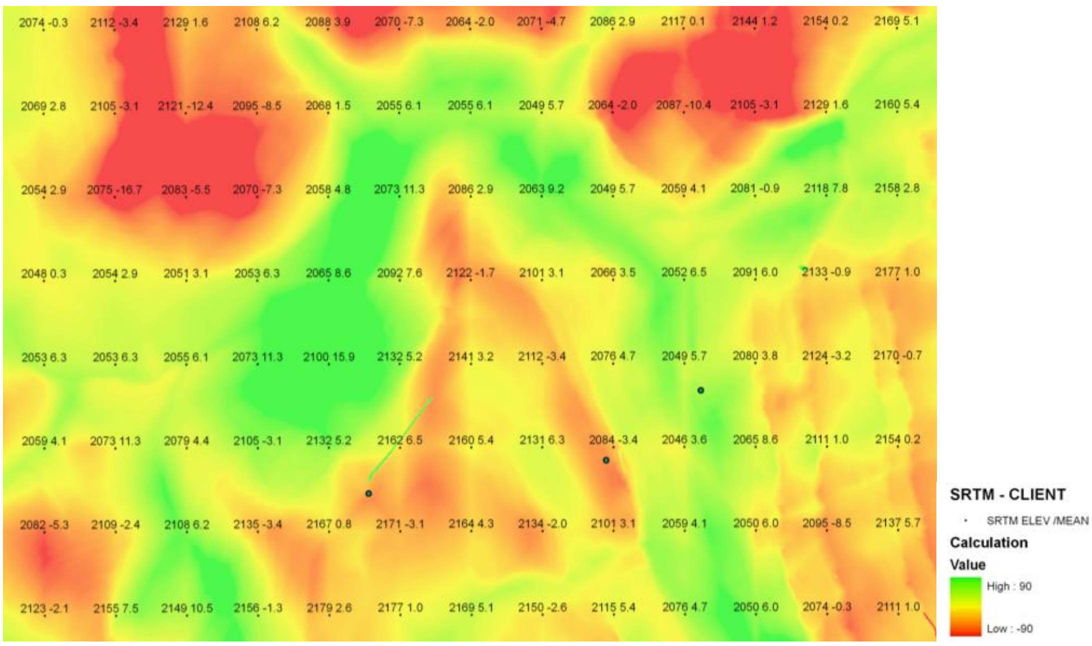


Figure 6.2.3c Deviations SRTM elevation to Clients handed over elevations.

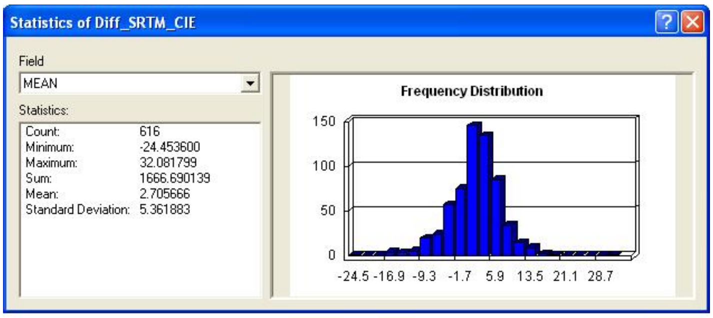


Figure 6.2.3d Statistic of deviations

The disadvantage of the SRTM data is the uncertainty of the accuracy at each point, compared with the other higher accurate measurements methods. The values are getting out of time each year beginning form the year 2000. The current satellite images for visual impression products are not fitting to the terrain point. These facts claim attention when using the SRTM data. For visualisation tasks for large districts and to get a project overview as well as to present the incorporated technical information from the construction company into the model it is a fine tool – especially in areas were the access is difficult or prohibited. The accuracy will play a subordinate role in the case or visualisation.

6.2.4 Construction Company evaluated data and construction constrained information

The technical data for construction facilities like site installations, site road, crushing plants, power supply and office areas, which will be represented as and in drawings are in the prequalification stage of the project of simple structure. The main intention is to show and explain to the client were the temporary site facilities will be installed and how much ground will be covered. Then a priory given installation area of the client will be taken into account (depends on the depth of the clients documents) nevertheless some adjustments due to the kind of construction method have to be included.

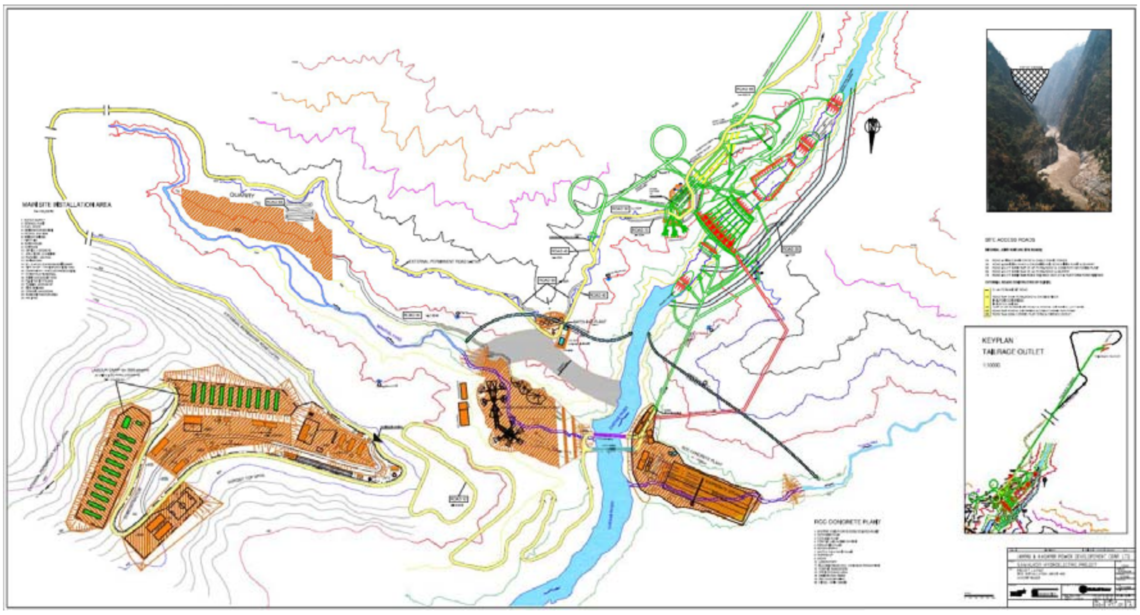


Figure 6.2.4a Simple site installation drawing (India: Dam Project)

The information about the determined areas for the site installations and the office areas will be a conclusion of the data which have been evaluated during the site visit, their subsequent interpretation and technical information handed over by the client.

6.3 Filter construction relevant data

After the preparing and summarizing of all data for the prequalification the pre qualification documents will be sent to the client. The items in the constructions methods which might strongly influence the time schedule will be examined and further information will be acquired in order to investigate the conditions. The submitted bid will be internally reviewed. Only this data which is construction relevant will be kept until the bid is rejected or the construction company have the chance to prepare tender documents.

6.4 Become a preferred bidder

The bids from the various contractors will be opened by the client’s project manager. The bids evaluation would include examination of the following:

- compliance with contractual terms and conditions
- corrections of bid prices
- screening of bids for detailed analysis
- pre-award meeting (optional)

- selection of the best bid and recommendation to the owner for contract award

The client considers that bidders may offer alternatives of genuine benefit to both parties and hence consider all submissions. This forces the contractors to submit a conforming bid as well as variants to allow comparisons to be made. After comparison out of the list of all bidders about 3 will be chosen to receive a letter with the invitation to tender. This letter simply invites the contractor to submit a tender for the performance of certain work. The letter lists all tender documents attached and requests the contractor to acknowledge receipt of the documents and their willingness to submit a tender. Instructions to tendering contractors inform the tenderers what is specifically required of them in their tender and usually comprises the items

- tendering procedures
- commercial requirements
- information to be submitted with the tender

With the invitation to tender the contractor will be on the inside of the inner circle for tendering.

7.0 Tender phase for infrastructure projects

There are two stages at which the client can control the selection of contractors:

- first, before the issue of tender documents
- second, during tender analysis – before contract award

There are different objectives in these evaluations.

Pre-tender: to ensure that all contractors who bid are reputable, acceptable to the owner and capable of undertaking the type of work and value of contract

Pre-contract: to ensure that the contractor has fully understood the contract, that his bid is realistic and his proposed resources are adequate (particularly in terms of construction plant and key personnel).

The contractor should pay attention to the fact, that the tender submission should be based on the ‘scope of works’ contained in the contract documents. Alternative tenders are submitted with a conforming tender as set out in the original tender documents so that the client may compare the two. Where the client will not consider alternative tenders, this should be expressly stated in the instructions to tendering contractors.

The tasks or items which have to be included in the tender procedure from the client point of view are according [SMITH, pages 220-224]:

- Conditions of contract (articles of agreement)
- Brief description of the works
- Programme for the works
- Indexes of drawings and specifications
- Drawings and specifications
- Item to be provided by the client
- Contract coordination procedures
- Form of tender
- Contract price
- Assembly of tender package
- Review of the tender package
- Collation and issue of tender packages
- Queries from tendering contractors.

The tender documents will be sent to the contractor contract department (Construction Company, contract administration - HOCHTIEF) with the indication of the final date for the contractor’s offer. On receipt of the tender documents the distribution procedure will start of the tender documents to the certain departments of the construction company (see table 7.2a). In the specific departments a processing of the data will be initiated. Technical details, construction methods, rough work sequences will be worked out and the finances evaluated. Meetings will take place for information exchange and probable optimisation procedures during construction. Finally the offer will be prepared according to the clients requested form and submitted on time.

7.1 Types of contracts

In the construction industry several different contracts are common for the implementation of infrastructure projects. The amount of time which the contractor spends on the lifecycle of the infrastructure project determines the kind of contract. The turnkey type of contract is used widely for the delivery of projects. In this case literally all the client would have to do would be to ‘turn a key in the door’ and the project would be operational. Another variation of this form is the concession project which is also known as Build Own Operate and Transfer (BOOT) contract. In this form the contractor effectively becomes the promoter and in addition to the role of turnkey contractor, also finances the project and operates and maintains the project over a period of time to generate sufficient income to provide a commercial return. Finally the facility will be transferred at no cost to the principal (governments, regulated monopolies) as a fully operational facility.

As many turnkey contractors have been responsible for operating and maintaining facilities for a number of years after commissioning, this has resulted in many turnkey contractors gaining all the necessary expertise to take the role of promoter in concession projects.

The form of BOOT contract has increased in the latter years. The maintaining of the facility is the responsibility to the contractor. This gives a new emphasis on the importance of data collection and administration for the contractor. The focus for the information is no longer reduced to the construction period rather it is widened to the complete life cycle of the project. The contractor has to take the facility management during design and construction into account. Experienced facility management departments will suggest specific materials and equipment for the operation of the facility in order to reduce the operational costs.

7.2 Construction Company Departments involved in Tender preparation

Large global acting contractors have several internal organisations which they can use for the development and implementation of civil infrastructure projects. There are special departments dealing with the commercial part of the contract and others developing the technical realization. Several departments which might be spread all over the world are invited to work out solutions in their specific discipline for the tasks of the project.
In particular the contract department liaises and coordinates with the following departments within the construction company. The participating departments are listed in table 7.2a.

Department	Tasks	Output
Engineering	Extracting built in parts list, planning site installation including necessary facilities, preparing drawing for site set up	Drawings, list of parts
Quality Assurance QA / Quality Control QC	Method statements, Work procedures	Textural Documents

Department	Tasks	Output
Materials / Procurement	Checking market and available dealer for the build in parts in the country	Spreadsheets and tables
Construction / Production	Suggestion for construction methods and implementations , experiences from similar projects	Technical Drawings, sketches, lists
Legal and insurance	Checking legal and insurance situation in the specific country	Textural documents, Spreadsheets
Planning and Scheduling	Works preparation, generation list for parts, master project time schedule in close team work with procurement and engineering.	Layouts, Graphics showing the workflow, Overviews, Databases
Cost and Estimates	Preparing cost summary for labour and clerks and estimation of project cost	Tables, Spreadsheets
Accounts and Payment	Clarifying the loan and wages for the probably involved people	Spreadsheets, employee contract documents

Table 7.2a Departments in a construction company involved in tender preparation

In the departments a lot of data will be produced. The departments prepare spreadsheets, drawings, lists, tables and documents. Every department is producing data in their favourite form and is delivering it in paper form. One interface between the departments apart from the usual ones like telephone and fax is the information technology network. This kind of information exchange is reducing the performance of the workflow. A better way would be one common place for the tender information.

As mentioned in chapter 4 one advantage of GIS is this kind of data storing. The data of GIS is stored in databases and will be represented through maps and charts. The abundance of information which will be analysed and created during the tender phase in the departments of a construction company can be filed in databases. The most technical information is prepared in spreadsheets which are common for the construction process. The disadvantages due to the use of spreadsheets are the limited number of entries and the administration effort to keep the documents up to date and handle the distribution of sheets in the participating departments. A solution could be a department wide database which is placed on the network. The connection within the departments could be realized by one central project database that holds the unique key for the built in parts and items.

Map server technology could be a realization for a common access and possible analysis functions for drawings and maps related to a civil infrastructure project. The drawings usually have no connection to lists, tables or spreadsheets. An establishing of a link between the drawings, maps and the tables and lists would support clear definition of the items of an infrastructure project. Communication about items of the project could be easier due to the fact that both or more partners are looking on the same - up to date - map on the map server on the internet. This kind of communication saves time and resources. Another advantage is that there is no specific software necessary – only a plug in - on the client side and the discussion partners do not necessarily have to be in the same place (spatially together).

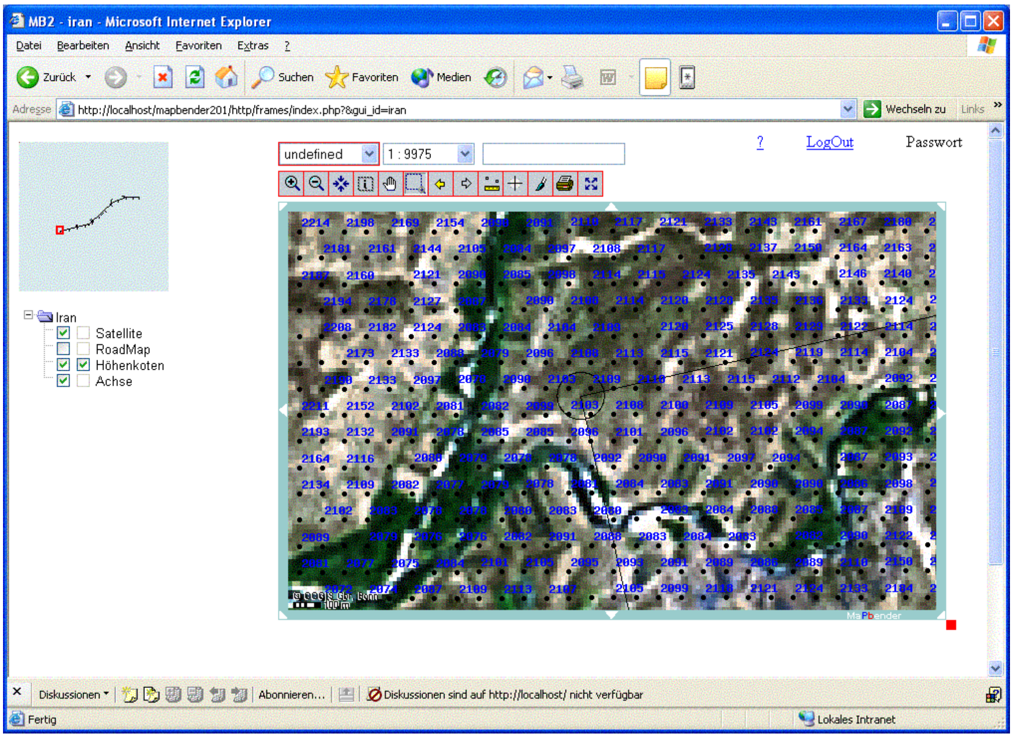


Figure 7.2.a Open Source Map Server (Example: Iran Dam + Tunnel Project, SRTM + 15m ground resolution Satellite Coverage)

Vendors of GIS software like ESRI and AutoDesk provide viewers for various file formats and offer the possibility of establishing links to map servers either vendor specific or OGC conform. These viewers offer a certain range of analysis functions and spatial queries. (ArcExplorer see figure 7.2b and 7.2c)

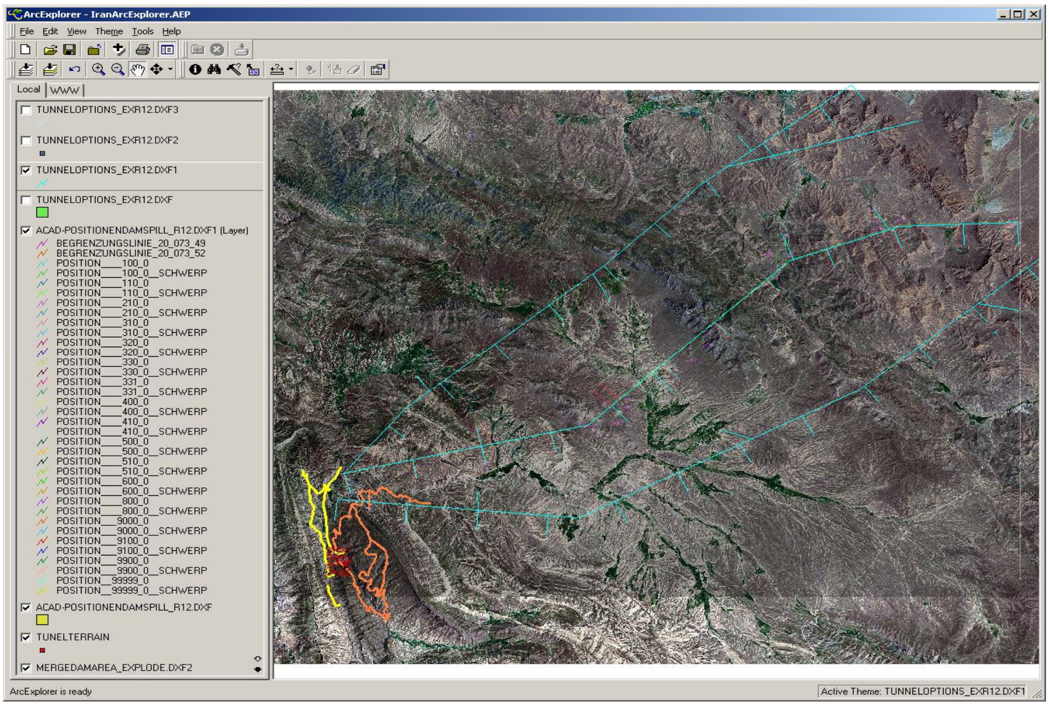


Figure 7.2b View of Project in Arc Explorer 2.0.800; (Iran Dam Area + Tunnel Variants, Access Roads, Satellite Image)

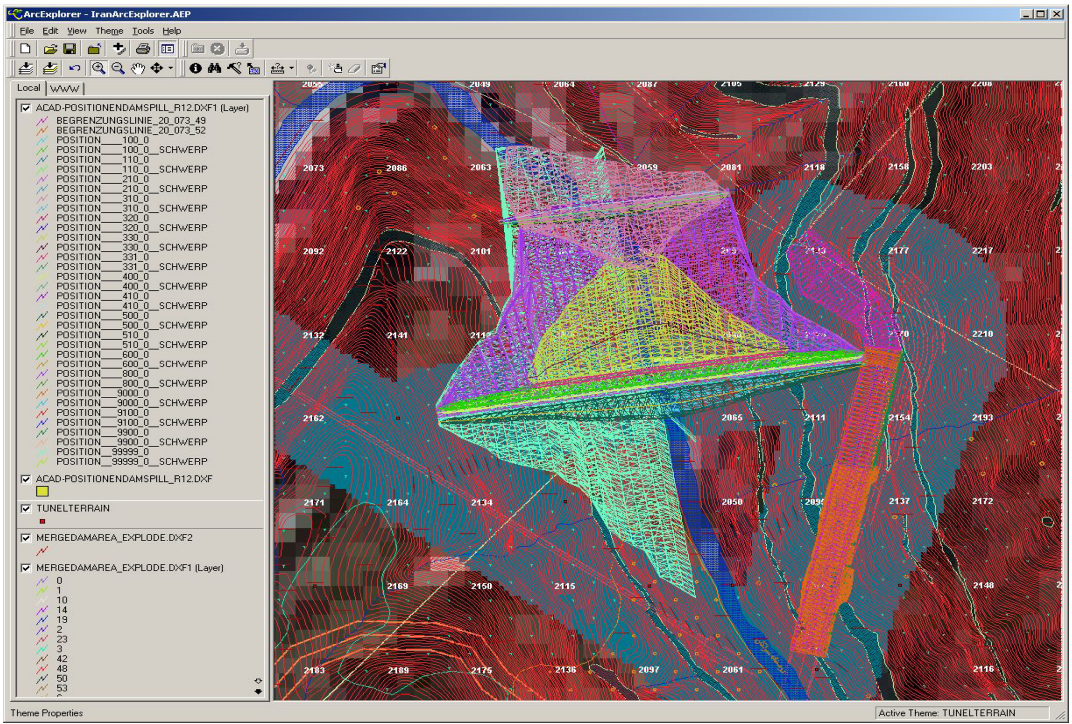


Figure 7.2c Detail view of project in Arc Explorer 2.0.800; (Iran Dam Area, 3D Elements and handed over data from the Client)

7.2.1 Technical Services

Almost all departments of a construction company which are involved in the infrastructure project tender works are listed in table 7.2a. The technical service departments will be in the focus of the next sections due to the more technical background of this thesis. The technical services are the departments for planning and scheduling, engineering and construction and production. A hint will be given for the use of this information platform for the commercial departments like procurement and cost control and estimation.

7.2.1.1 Surveying department (GIS)

The surveying department is embedded in the technical service department and supports all other departments with overview layouts, coordination and implementation of information from the site visits, volume calculations according to the tender documents, preparation of design and volume calculations for the variants of construction methods in the optimization phase. Another important task is to merge various sources of data in a kind of format that a clear introduction of the project and its conditions are clear to all participating departments. The most important information in the merged maps is the location of the project, which is given in geographical coordinates. The national coordinate system is included to establish the link to the design drawings. The GIS tool for grid labelling several coordinate systems enables this opportunity. Figure 7.2.2.1a gives an example for a layout of a project of the 36 km bridge in Kuwait which was used for the first discussion about the construction method which could be used to realize this project. A major constraint in this project is the seabed level – especially the water depth. Because of the depth the use of a huge floating crane has to be considered to place the pre-cast elements or the use of small barges as an alternative solution has to be taken into account.

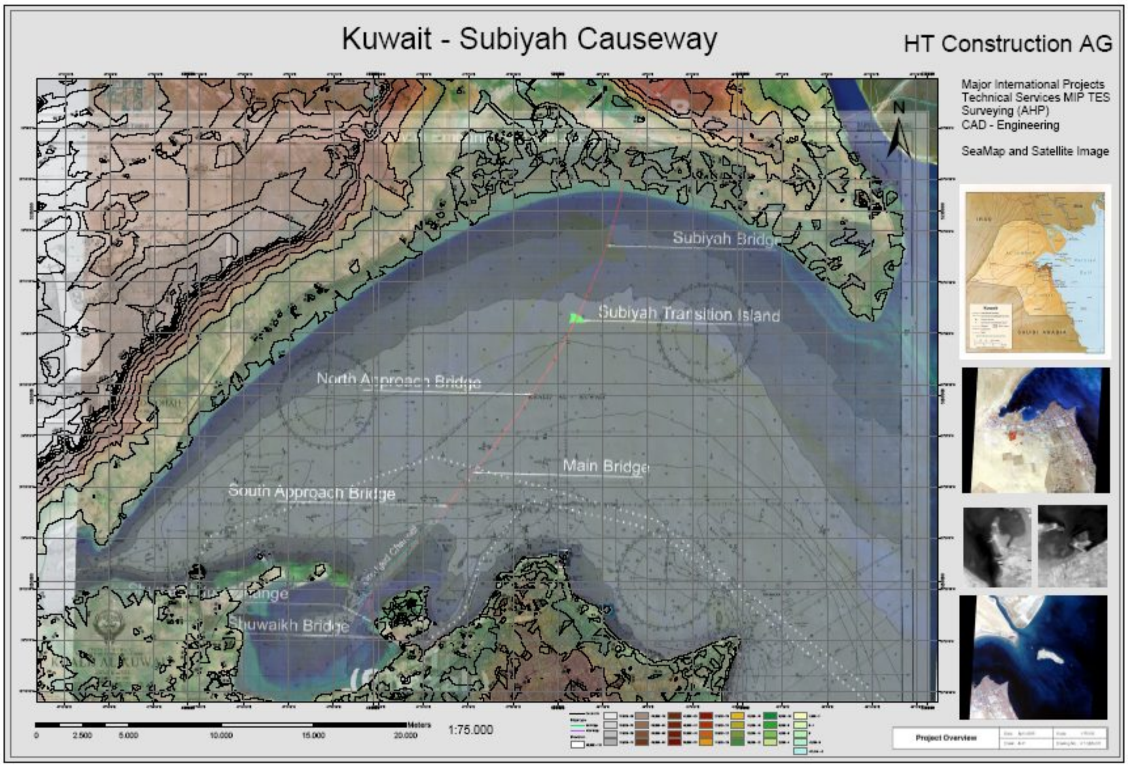


Figure 7.2.2.1a Bridge project in Kuwait (Merged raw Information: Digital Terrain Model from SRTM data, Seabed level from Ministry of communications of Kuwait, Alignment for bridge and connection points, Satellite images).

A first volume calculation in this phase has more the character of checking the information handed over by the client and comparing the results with the information stated in the bill of quantities (BoQ). The volumes of cut and fill are important for production and construction methods respectively the cycle times for the machines. Further, the procurement of material from quarries of borrow pits must be checked. To clarify if the required amount and quality of material is available in the vicinity of the project.

The preparation of documents in the survey department will include further investigations of the design documents and conversion of the data to dynamic digital formats and parameter driven calculations in order to be prepared for a positive contract award. As an example one should think about the different slanted slopes left and right along a road – slopes changing because of the kind of soil or rock material. The reason for this is to enable the fast tracking of targets to be ready for production at the beginning of project implementation.

The survey department prepares the first basis for the settlement calculations. The cut and fill calculations which have to be done at the beginning of a project to give an idea of how extensive the earthworks will be and the permanent observation of material placing and removing. The first thoughts about the coordinate system, the geodetic network and the original ground survey will be done to check visibility between the survey pillars and it will be investigated if the geodetic net covers the whole area of the project circumference. For these tasks GIS can be used preferably because of its functions for checking visibility it offers a good tool for the placement of survey pillars especially in rough terrain and allows the checking if the entire project area is covered by the pillars [MCCOY].

The implementation of geographic information systems in the survey department is uncomplicated because surveyors have the basic idea and advanced knowledge of applying the system for specific use cases and for the project’s benefit.

7.2.1.2 Planning department

The focus of the planning department is the preparation of pre-qualification documents, documents for works preparation, time scheduling, construction logistics, material procurement, environmental protection, quality management and quality assurance and the utilising of knowledge which was experienced during construction phase. The pre-qualification section is processing customer and project specific pre-qualification inquiries from external and internal departments and branches in teamwork with all project participating branches and joint venture partners with support of the departments with their particular disciplines.

The works preparation is executing contract checking, feasibility studies, vicinity analysis and structuring of further tasks during the groundwork, when the documents are received. The second part will be a first site visit and arrangement of coordination meetings and a suggestion for a project structure. The project structure and the tasks structure will initiate the internal process for construction method planning, the equipment use, the determination of material, inquiries of and to subcontractors, time scheduling and creation of cycle time tables. Variants and the final declarations will be discussed and will be summarized in method statements, time schedules, histograms and budget plans as well as time-way diagrams (technical offer). These technical processes will be extended and refined (construction logistics) in the case of a positive contract award.

The QA and QM sections permanently assist the process either during the tender phase or at construction time. Quality assurance plans, method valuation, method and process optimization supported by test, analyses, experiments and their documentation will be established. The QA and QM use laboratories, which test the situation before and after the installation.

QA and QM could be elegant supported by GIS functionality. All test (drilling cores, proctor density) which will be executed on a construction site like an airport, must be collected and presented to the client’s engineer. With the help of small handheld computers the location of the test can be pinpointed by GPS technology within a necessary accuracy and stored in a GIS (in a broader sense on a site specific Map Server) with the attached results and date of the test.

7.2.1.3 Estimation department

The goal of the estimation department’s main tasks, the preparation of tender estimates, is to achieve cost covering contracts. For this purpose, it is necessary to check the contract document’s regard to their technical, financial and contractual conditions. During estimation project- and country-specific information has to be obtained on wage and salary costs, material, equipment and subcontractors. If required on-the-spot inquiries are executed. These inquiries have to be discussed and agreed with the local partners. The methods in each individual case have to be concurred with the project management. The result of the tender estimate is presented to the project management at the so-called top sheet meeting at the latest. The project management examines the result and determines the final bid price.

The estimation department’s main tasks are the

- Preparation of bid calculation (Tender Estimate)
- Bid calculation (Estimation after Contract Award)

Further tasks include, among others:

- Support of cost control activities
- Support for construction sites with claim management
- Calculation of variation orders and additional works for sites
- Support for local competence units in handling projects abroad
- Technical audit service
- Support for third parties with estimating related works.

After the top sheet meeting the estimation department provides support for the preparation of the bid documents such as bill of quantities, payment plan, equipment list, material list, personnel curves, etc.

7.2.1.4 Plant and Machinery

The plant and machinery engineering department deals in close cooperation with the project teams, in all plant- and machinery related tasks in all project phases. During pre-qualification the department provides support to the market division for the compilation of required documentation. This includes

- Creation of plant concepts tailored for the individual project
- Conciliation of requirements with plant items available within the construction company or joint venture partners.

In the tender phase it will select the required equipment and will determine the cycle times for the equipment as well as planning necessary manpower involved.
In the construction phase the support for equipment procurement, plant and machinery erection and establishing of site infrastructure (power, water, sewage, and communication) is the task of the staff deputed to the construction site. At the end of construction the department is responsible for the dismantling of temporary plant items and temporary site installations.
An example for the implementation of GIS could be the documentation of temporary cable routes, water pipes and communication wires which have to be removed or transferred to the client after end of construction.

7.2.2 Tender team

The tender team consist of members of the departments mentioned in chapter 7.2.1.1 to 7.2.1.4, which will work as a team to generate solutions for the demands of the infrastructure project. The technical data and the resulting commercial data (budget) will be filed mostly separately in department wide spreadsheets and drawings. A solution - like GIS - would be a network of distributed databases for the department tasks, each item linked for the specific project processing. An advantage would be the use of an intranet - internet based platform for information placement. The use of Open Source map server technology could be a first attempt to show the cheaper advantages of providing information in this way.

7.3 Technical and commercial data collection

The combination of technical and commercial data represents the tender documents at the end of the tender preparation. Close teamwork between the construction company departments these documents are created, examined and presented to the internal construction company’s management board which will audit and decide about the handing in of the tender.

7.3.1 Types of technical data

Before an infrastructure project will be realized some studies will be executed in order to examine suitable places which are an outcome of the feasibility studies. During these studies relevant data is collected, produced and processed. Documents clarifying the extent of the project are created. Common kinds of information medium are maps or drawings that are created either by GIS or CAD systems, spreadsheets and specification documents.

At present a usual form of digital technical information is mostly delivered in the form of the de facto standard DXF/DWG, which actually represents a CAD file and is loadable in various graphical systems. The interpretation of information of these files is limited to the graphical appearance together with the given legend. The force of using a world wide common low standard for graphical data exchange (DXF= drawing exchange format) is being paid with the lack of sophisticated enhanced data delivery and thus knowledge transport. The formerly intelligent data is smashed due to the reason of readability for any graphic software as well as a broad data distribution. The receiver of the data will have the effort to rebuild the data for his own purposes and will add a sophisticated structure to the data again.

The information for the amount of materials and built in parts will be delivered in spreadsheets. A count has taken place either automatically or manually. In the first case the information handed over has no connection to the drawing anymore. The single part cannot be identified because only a summery of parts is delivered.
The same situation can be recognized to the specifications. Technical descriptions and specifications and illustrations are referring to indexes in the drawings.

The most recent kind of handing over information from the client to the tender members will be done in PDF format. The effort of conversion to a readable format for engineering tools is enormous and is unnecessarily time consuming.

A solution for the exchange or handing over of homogeneous and intelligent data for infrastructure projects to all tender members could be the integration of international standards like GML (OGC), LandXml (Landxml.org) and IFC (International Alliance for Interoperability) standards into the tender documents. This would enable to deliver sophisticated data and structure of data at the same time.

7.3.1.1 Surveying data: Topographic Information – Terrain data, Design objects

The graphical documents (CAD) deliver the topographic and terrain information around an infrastructure project. The data is either provided in the form of the measured features like surface points -xyz, constrain lines, areas or in the form of contour lines as a result of the terrain modelling. The internal structure of the terrain modelling will be not delivered. Further features for points of interest are stored according to the CAD standard in different layers and with different graphical attributes.

The original terrain model will be rebuilt for volume evaluation of the different materials which have to be placed according to achieve the design objectives. The accuracy of the measured points and break lines which will constrain the shape of the terrain is achieved by photogrammetric or terrestrial methods. It will reach in the case of photogrammetric measurements the value of 0.1-0.2 for the placement and 0.15-0.30 for the elevation. The terrestrial measurements have an accuracy of 0.01-0.05 in layout and elevation determination. New technologies like laser scanning which can be either airborne based or terrestrial based are equally precise as illustrated before, but the density of measured points is essential for description of the surface.

Design information contained in the drawing can only be reconstructed. The exchanges of design parameters are limited to the plain text descriptions for the design objects and their graphical representation in handed over layouts and sections. The CAD drawings, which are created to show the design, transport only the graphic result. The used and prescribed formulas for the design objects are mentioned in the specifications. The design parameters will be used for the construction of the design model, which are a collection of points, lines, compound poly lines and polygons. New data formats allow the storage of so called multi patches which consist of a network of points. Recently published software products support the storing of vendor specific design models (AutoDesk Civil 3D, Augustus V10), which contain all necessary design rules and parameters. The data is captured either in a drawing file or in a database. The dynamical change of design parameters is a major demand of civil engineering design software. The LandXml is a common interface for data exchange and will be supported by most vendors.

The main reason for creating an original ground model and a design model is the overall volume calculation, the volumes of specific layer volumes and the specific quantities for construction methods or variants because of their influence to the time schedule and equipment employment.

7.3.1.1.1 Analogue topographic maps

Reliant on the projects documents, this can be digital or analogue maps or drawings it is necessary to transform the analogue data into a digital format for illustration of the project, the appraisal of required volumes and the enterprise internal distribution. The scan technique will be used. The resulting file in raster format will be loaded and geo spatially placed (rectified). This task of rectifying is best supported in GIS systems, as these systems have to include existing maps and past information. The process is done by special transformation algorithms. The result of the process can be placed for CAD disposal.

Vector information extraction out of raster data is necessary when volume calculations have to be executed. Special modules of GIS software support the extraction of lines and recognition of patterns and texts. Transformations from the raster grid to the national grid systems are possible. An export to common vector based files realises the further processing of the information.

7.3.1.1.2 Digital drawings & maps – internal structure - CAD-standard

Most documents in the tender phase are technical drawings, which represent the infrastructure project in layouts, sections and thematic maps. The either analogue or digital information is produced by observance of standards. As the analogue information is mostly the printed result of digital drawings it will be not discussed in this section. Digital drawings – when made in a proper way – follow underlying common rules for specific engineering disciplines. Either the drawings are created by a draftsman or they are semi automatically created according to CAD standards by engineering programs like road calculations. The drawings which were derived from engineering programs are structured by layers, line type and line width or symbols and are created in three dimensions.

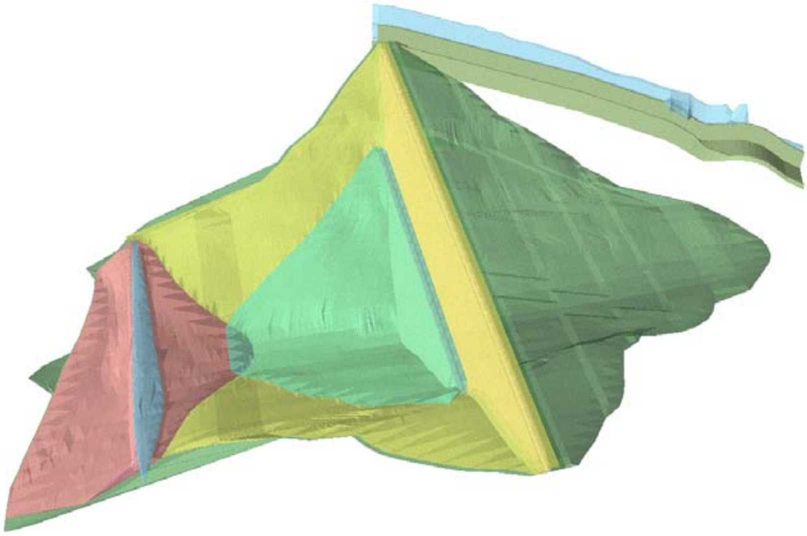


Figure 7.3.1.1.2a Dam Project Iran – core, filter material and spillway objects. Designed in Object oriented CAD Augustus and converted to ArcScene 9.0 – multi patch

For a future use of CAD drawings in GIS the observance of some rules, listed below, can organise the exchange between the systems in an easy way.

- Spatial Reference for CAD-Files: CAD stores the geometry in a Cartesian coordinate system, using x, y, z coordinate values when representing the position of the object in design space. The user should take care that the projection system between CAD and GIS are identical.
- Organize CAD Data: CAD data is commonly structured in layer names, different graphic properties such as line or colour style, force a clear structure for the geometric types like points, lines, poly-lines, polygons and three dimensional objects like solids.
- Implementation of CAD Standard: This will improve the quality of the CAD data and its use in GIS content. An understandable organization of how objects should be drawn on a specific layer.
- Differentiate different kinds of the same object by using a variation of colour, line style or width of a symbol.
- Pay attention to snapping tools when creating networks; connect line at or through their intersections.
- Be aware of the drawing direction for linear networks.
- Create close polygons when a polygonal network (areas).
- Create objects linked to external database files: The key to establishing a link between objects in a CAD file and records with attributes in a table is to provide

a unique database link value that exists both on the object within the CAD file and in the record of the external database.

- Use cells or blocks with various attribute information – this information can be easily encoded in GIS.
- Do not use multiple text lines.
- Dot not use dimension entities.
- Avoid using grouping methods.
- Avoid using line networks with artificial gaps.

In conclusion, the simplest way of making CAD useful in GIS is to implement and adhere to a strict CAD layering standard. CAD drawings that are well formatted have a greatly improved value as a reusable asset. The element of construction and drafting standard for points, lines and polygons can improve the use of CAD objects in GIS as an information platform. Whenever possible use reliable attributes which are supported in GIS [ESRI2003].

Rarely digital models are handed over, but this situation will change with the new engineering software (AutoDesk Civil 3D, Inroads). The information which is a result of engineering calculations is captured in databases and viewed in the specific CAD system. The exchange can be done by using XML based languages (LandXML-LandGML) [JOHNSON].

7.3.1.1.3 Aerial photographs – satellite images

Aerial photographs and satellite images will give information about the vicinity of a project. The aerial photographs will be delivered by the client or will be undertaken by the construction company. Satellite images can be ordered for specific project areas from vendors on the internet. The cost of one scene is dependent on the ground resolution, the covered area and the processing status (Ortho-photo). The ground resolution is the factor, which determines the mission field. Small scale images are usable for overviews and large scale images for detailed background information in the infrastructure projects area.

To enable an easy use of the aerial photographs or satellite images in the workflow of tender documents attention should be paid to the geo-referencing of the images. Geo-referencing enables a simple loading procedure in civil engineering software like AutoDesk Civil 3D. The geo referencing for the common raster file formats are given with separate and additional files – world file –, which have the extension *.tfw in case of TIF - raster files (Tagged Image File Format), *.jpw in case of JPEG – raster files (Joint Photographic Expert Group) and *.pgw for PNG-raster files (Portable Network

Graphics). The so-called Geo TIFF raster file contains the below mentioned parameters internally, which is usual for processed satellite images. The parameters, included either in the additional files or in the Geo TIFFs are:

Parameter	Value (Example)
X Vector X: Pixel extension in natural units	1,381413
X Vector Y: Rotation parameter	0
Y Vector X: Rotation parameter	0
Y Vector Y: negative Pixel extension in natural units	-1,381413
World Reference Point X: value of upper left corner	3174109,687
World Reference Point Y: value of upper left corner	1336725,298

Table 7.3.1.1.3a Example for World File (Tiff)

Aerial photographs and images are used for classification of land use (urban and rural areas), existing lakes and rivers and human made facilities like roads, dams, slopes, embankments. The aspect of classification differentiates further between the kinds of vegetation and determines the area of vegetation in the direct affected circumference of the infrastructure project for removal during project implementation and replacement after construction ends has an impact on the tender price for the efforts which have to be undertaken for the environmental conservation.
New raster formats like MrSID, JPEG2000 and LuraWave fascinate by their high compression rate although there is no loss of information [BLV].

7.3.1.2 Geological data

The most important geological data for the construction site is the overall geological situation around the infrastructure project. A distinction between construction sites which have an area character and sites which have more a linear character can be done. The first ones are reduced to a place where the overall geology might be of the same character. The second ones cover large districts with different geology structure. The information of the overall geology can be retrieved from or is provided by the national geologic agencies. For detailed information it is compulsory to investigate the geological situation by special investigations, which are carried out by drilling holes. The resulting information from the drill holes is important for civil engineers for evaluation of necessary actions during construction. As this detailed information has spatial reference the storing of the investigation results (points with top elevation and layer thicknesses) is ideal for GIS. The geo spatial analysis tools can be used for modelling the subsurface layer for a better estimation. Special software and experience is necessary for this task. A storing of the data on an intranet - internet based system will accelerate the design and decision process.

(Example: Brazil – Overview map and detail sheet)

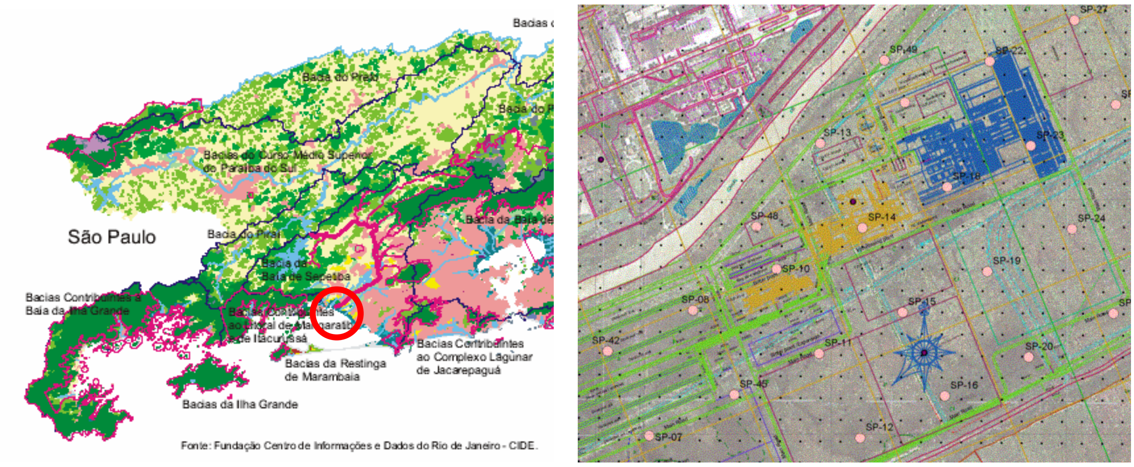


Figure: 7.3.1.2a Overview geology; Brazil steel plant, detailed location of drilling holes

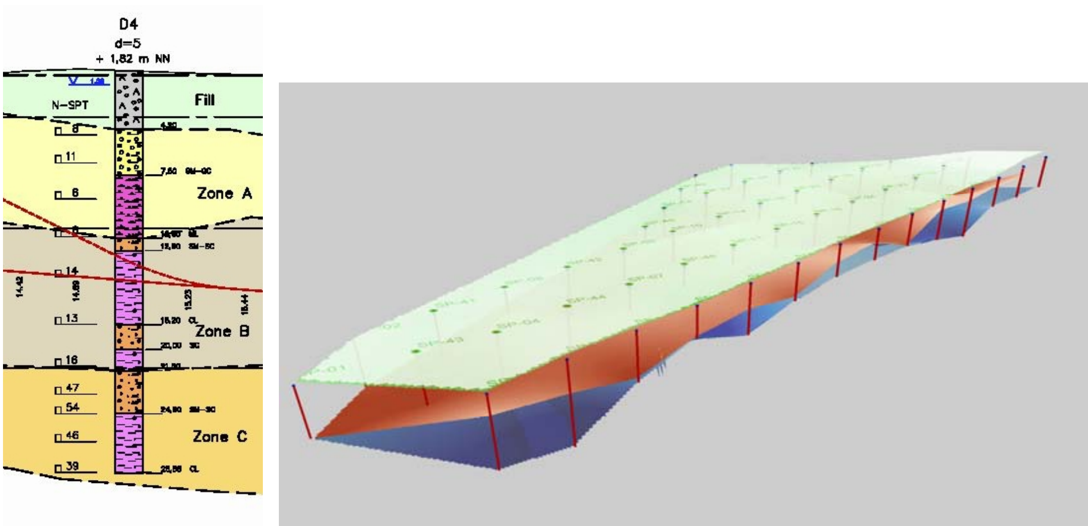


Figure 7.3.1.2b Drilling investigation section and visualisation of subsurface layer (VRML)

GIS can help to integrate the necessary geological data, analyse this data and disseminate the result of the data in an intranet environment for access and further processing in engineering systems. The subsurface conditions can be represented in grid, surfaces and triangulated irregular networks which can be used in CAD systems for dynamical section calculations along line infrastructure projects and volume determination for the different subsurface layer in general. A common system which offers the data in a standard format to the participating applications (GIS and CAD) for direct access would help to save time and resources. Map Server technology is one opportunity for this thought.

7.3.1.3 Climate and hydrological conditions - influence on construction

Climate and hydrological conditions have an influence on the material, the construction methods and the actions which have to be undertaken to protect the infrastructure construction from the environment. Climate conditions which influence the project are:

- Average rain fall and peaks
- Average temperature and duration of peaks
- Average wind speed and gust
- Sunshine and mean pressure, evaporation
- Wave heights, water temperature
- Tidal currents and tides
- Subsurface water drainage

Normally this data is collected by the governments or regional authorities of the countries involved in the infrastructure project. Project relevant information can be retrieved either in traditional form of an atlas or in sophisticated GIS based environmental information system format.
(Example: http://www.gisqatar.org.qa/conf97/links/c4.html).

7.3.1.4 Logistic and Equipment data

The plant and machinery department is responsible for preparing a list of required equipment according to the construction method. The use of the equipment is dependant on the volume of material which has to be moved. A further factor is the distance between the borrow places and the construction site and the distance between the establishing of pre-cast element and the construction site. The equipment (trucks, dozer, excavators, cranes, ship, swimming crane, barge, moveable power stations) has to be chosen to satisfy the time requirements. The fixed time for the realisation of the infrastructure project will determine the period for construction tasks and therefore the cycle time for the specific equipment. The construction method, the limitation of loadings for specific equipment, the financial budget for the equipment and last but not least the terrain condition and the existing infrastructure has to be weighed against the time frame for the realisation of the project. A reliable compromise has to be found. Therefore collection of geo information is necessary in order to gain an information based decision for the employment of the most suitable equipment. For delivery of heavy equipment to the construction site it is necessary to find a route through the existing infrastructure network.

7.3.2 Types of commercial data

Commercial data in the tender phase is determined by direct costs on one hand side and indirect costs on the other hand. This section will only discuss the direct cost.

The first aim is to estimate the most probable cost of the work. The cost of one element of the works comprises quantity proportional, time-related and fixed costs. Quantity proportional costs are the direct costs of materials in the permanent works. Time-related costs typically relate to plant and labour. The cost of operating an excavator is a time-related cost. It needs an operator, maintenance and fuel, whatever volume of rock or soil is excavated. These costs usually have to be translated into quantity proportional unit rates in a bill of quantities, confusing control, because if the time taken to carry out the work is longer (but the quantity remains constant) the costs will increase but the payment due will remain the same. These costs refer to the permanent works. Any temporary works must also be covered by the prices charged by the contractor.

7.3.3 Technical and commercial data - mutual influence

The linkage of cost estimation for an infrastructure project and the technical data can be highlighted by the simple example for a road construction. To estimate the cost for the road construction it is necessary to calculate the material which has to be moved. A change in the alignment of the road will force new construction methods and therefore the use of different machines as assumed in a previous stage of estimation. The amount of facilities which have to be placed along the new road will change as well. A first road alignment proposal which can be clearly fixed within a certain corridor by use of GIS functions will limit the variations in the cost estimation.

7.3.4.1 Metadata in tender phase

Metadata in tender phase is all information about the data which was used to prepare the tender documents. This kind of metadata is relevant in the case of a positive contract award and as an example for tender preparation in following similar projects. For construction phase information about budgeting for specific construction items can be found easily by searching in such a tender metadata catalogue. A good introduction for enterprise relevance of GIS Metadata and examples for the content can be found in [BRUNSCHOT].

7.3.4.2 Dissemination aspects using Map Server Technologies during Tender preparation – Interoperability

Infrastructure projects distinguish themselves because of their geographic expansion, especially roads or railways, dams and access, integrated facilities like airports or harbours. The information density is determined by overviews on small scale maps and by detailed drawings on large scale maps. The information content of the maps and drawings is growing with the decreasing of the scale number. The numbers of participants involved in the preparation of the tender documents are dependant on the complexity of the infrastructure project; therefore a dissemination of the information with current simple information techniques is preferable.

Instead of printing all information according to the number of participants the tasks can be shifted to the user by using the map server technology. The user can search and print the information he needs for his workflow. Another advantage is that a structure can be established in a way that the geographic location of the information is always present, so that decisions reflecting the information can be made with awareness about the vicinity of the information's location. The linkage of features, which are then presented in the central map server environment, with technical databases has influence in the workflow in the departments and will keep the data consistent.

A summary of advantages of a centralized database management system on construction sites, which would be an advantageous for a tender database as well, according to [HENDRICKSON, Chapter 14.7] are:

- Reduced redundancy
- Improved availability
- Reduced inconsistency
- Enforced data security

The map server technology is based on databases and can serve the above mentioned items. Additionally specific files – like raster data and vendor specific files - can be loaded into the environment. The map server technology is also based on a network communication thus there is no question about the availability, consistency. The data security will be handled by the network administration and the database functionality.

7.3.4.3 Equivalent developments for building business (Model Server) Interoperability (IFC)

The International Alliance for Interoperability (IAI) has started a project which deals with the business needs in the Architectural Engineering and Construction world and the GIS world. The project is called Industry Foundation Classes for GIS (IFG). The recognition of significant overlaps between both worlds initiated the project. Buildings are constructed facilities that are placed within the world. These two virtual worlds - AEC and GIS - share the concept of lifecycle based information provision and will have similar approaches to portfolio and capital project development, design processes, costing and cost management, asset management, maintenance and other factors. As well the systems share the interest in system development for the purposes of dissemination systems. While GIS signs for the general utility systems within regional infrastructure, AEC are opposed to the local distribution mechanism applied in AEC. The approach for the both systems definition is likely to be notably similar.

The mutual benefits for the project with the GIS interest provided to IFC are given in [IFG-PROJECT]:

GIS provides to AEC

- global location through map information provision
- regional information relevant to building planning and provision
- utility information relevant to the services within a building
- risk information from nearby geographical features

AEC provides to GIS

- facility to be able to see a building and component entities as real objects and not just illustrations pasted onto a map
- real building data for security and emergency services

The interesting items outside of this project for a construction company are the provision of GIS information through IFC by leveraging developments that have occurred within IAI (for AEC community) and ISO TC 211 (for GIS community), the definition of interfaces between AEC world and the GIS world (interoperability and collaboration strategies) and the definition of a model development and mapping approaches that build upon GIS developments within the ISO TC 211.

In detail the demonstration provision scope for GIS to AEC in the IC-3 Project are:

- semantic identification of a ‘site’;
- the geometry of a site in the form of a simple digital terrain model;

- specification of a site boundary;
- Provision of additional properties within property sets as deemed necessary.

In detail the demonstration provision scope for AEC to GIS in the IC-3 Project are:

- semantic identification of a building and the building elements that are relevant for representation within GIS including, amongst others, building, wall, window, door, opening;
- primary elements of the building spatial structure elements concerned
- provision of additional properties within property sets as deemed necessary

The advantage of the integration of both worlds can be described with a reduced effort for construction interface related coordination. Several systems (building element, HVAC-, electrical-, sanitary-, lightning, structural, furniture, spaces, zones, compartments, manholes, grids, draughting, sanitary, etc) can be integrated into a common system. A discussion about connection points can be done on the same database. (Loading IFC data into IFC-Viewer see figure 7.3.4.3a).

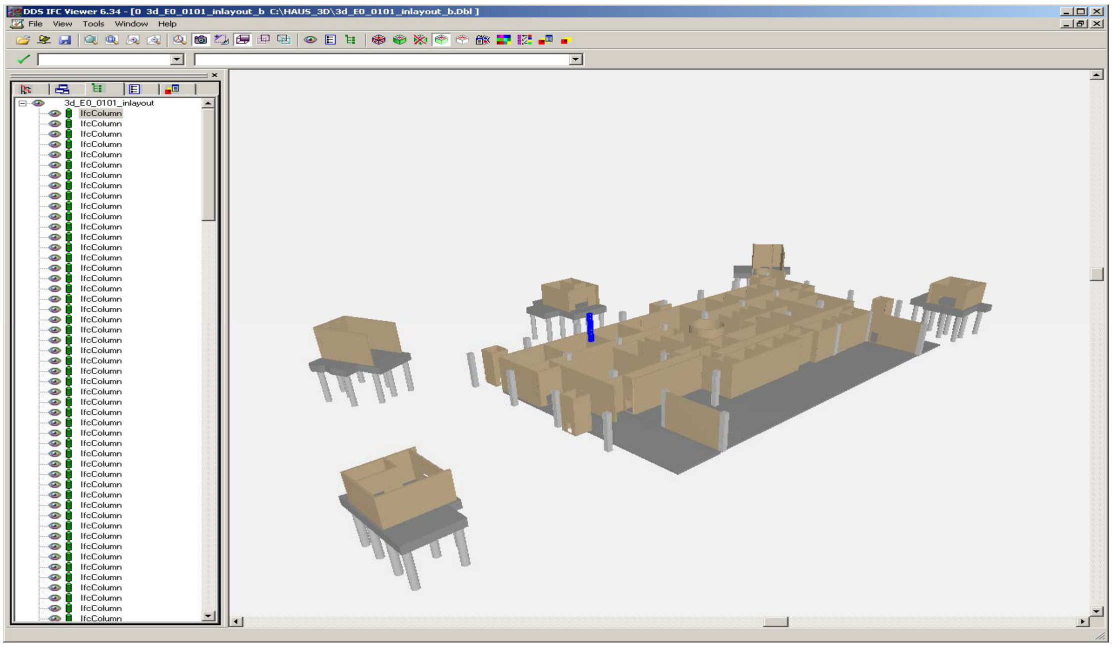


Figure 7.3.4.3a Semantic information import from Architectural Desktop (ADT 3.3) to IFC-Viewer from Data Design System (DDS); Part of Gate B of Düsseldorf Airport.

Further studies related to the integration of Geo-object can be found on the web page of Forschungszentrum Karlsruhe Institut für Angewandte Informatik; http://www.iai.fzk.de/projekte/geoinf/index.html. The application QUASY deals with the integration of building models (IFC) in GIS. Another source of information is the SIG 3D a working group of the Geo- Data Infrastructure initiative of North Rhine Westphalia

(SIG 3D GDI NRW) and the Institute for Cartography and Geoinformation from the University of Bonn. The SIG 3D group is discussing the level of details (LoD0 – LoD4) and the realization by unified modelling language (UML) for city models [KNOSPE]. The Institute for Cartography and Geoinformation is dealing with the CityGML which implementation is based on GML3. The class taxonomy distinguishes between buildings and other man-made artefacts, vegetation objects, water bodies, and transportation facilities like streets and railways. Spatial as well as semantic properties are structured in five consecutive levels of detail, where LoD0 defines a coarse regional model and the most detailed LoD4 comprises building interiors and respective indoor features [KOLBE].

7.4 Data compaction and storage

The final decision finding for the construction method including their estimating the data which was used to create the conclusion will be stored and memorized. All unnecessary information will be eliminated in order to achieve a tidied up version of the tender data, which will be sent to the client. The end result is important at the time of the contract award.

7.4.1 Technical Steering data (design parameters) for tender data model

The meaning of technical steering data can be expressed by all data which will be important to build a model of the new human made facility considering almost all conditions in order to construct the civil construction. Out of a range of examples two will be highlighted to illustrate in a simple way the complexity of civil constructions. For example the parameter for the horizontal and vertical road alignment as well as the parameter for the cross section creation, will contain several conditions.

A change in the horizontal alignment will force a change in the vertical alignment and a change in the bill of quantities (volumes). Further good examples are the parameters which will determine the body of a breakwater dam. The parameters are used for building an estimate of the dam construction model. The model itself is the basis for the volume and material calculation. Due to the circumstances of the rough evaluation and measurement for the sea bed level before the tender phase a change of sea bed level within the first determination and the starting of construction is obvious. The parameters for dam construction enable for example a dynamical adjustment to the situation on site, when a precise survey will determine the sea bed level by echo sounding and the subsurface layer investigations are interpolated to surfaces.

More illustration will not be done, although it could be done to show the necessity and the advantage of a combined solution between civil engineering programs and the huge data storing capacities of GIS.

7.4.2 Preliminary tender data model

All civil engineering program vendors have improved or are improving their software to a more dynamic way of supporting the design workflow. More and more the information is handled in a model which holds the information about the entire project. Software vendors for civil software have realized by stated requirements of the users that an integration of GIS functions in their systems can help to simplify the design works. Spatial analysis of digital terrain models and the integration of the new infrastructure within the model show the holistic vicinity of the infrastructure project and the environment. The model can be used to illustrate the project to technical inexperienced members of decision boards its complexity. For the public the model can be used in discussion. In the enterprise it will be used for communication and solution search and finding (see figure 7.4.2a)

Figure 7.4.2a Animation for a building project in Essen NRW, LoD1 (Virtual Construction support ViCON), CAD Data + 10m grid terrain model + GeoTiff, ArcSecne, Ouput VRML for Navisworks, External Presentation and internal discussion.

7.4.3 Visualisation (VRML)

One more opportunity which should be mentioned is the visualisation of the infrastructure project embedded in its vicinity. When the procedure of designing, producing and storing spatial related information for infrastructure projects according to international standards has been followed, it is only a small step to generate a virtual impression of the project. Most software products offer an interface for export of visualisation files or already include functions to generate views and animations of the new facilities. A common interface which can be used for the visualisation is the virtual reality modeling language (VRML). This language is a description for 3D scenes, their related geometries, their illumination and animations and interaction opportunities. Originally the language was developed for 3D standard in the internet (see 7.4.2a and 7.4.3a; some further examples for civil projects in form of animations and VRML files can be found on the attached CD)

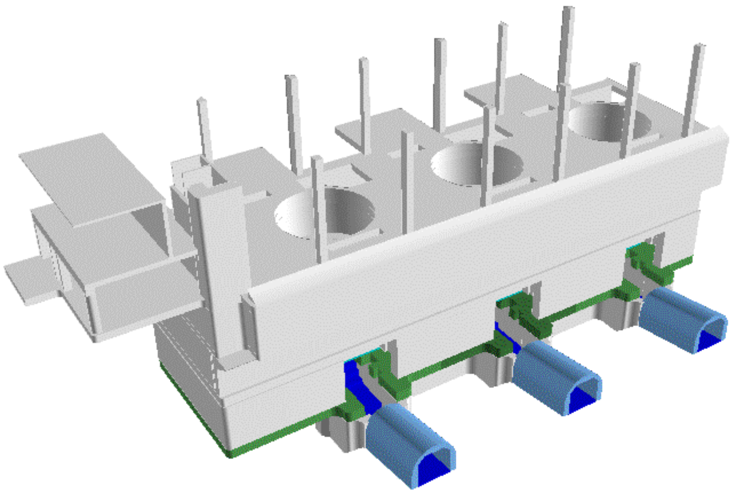


Figure 7.4.3a View of Power House imported to ArcScene 9.0 from AutoCAD (3DS) by 3DM2GDB application.

7.5 Submission of Tender documents

At the end of the tender preparation the tender documents will be compiled and handed over at the submission date to the client. The client will review the offers from all bidders technically and financially.

7.6 Contract award

The contract will be awarded on the basis of conditions of contract containing an agreed payment mechanism, which will cover the works as detailed in the drawings and specifications and any variations to it. The methods to be used for valuing the work are usually stated in the contract documents. After achieving the contract award the mobilisation phase is starting in the construction company. A group of specialists (starter group) will be send to the construction site in order to prepare the temporary facilities and utilities in cooperation with local subcontractors. Site installation places will be clearly determined and the terrain will be prepared to place the machines.

The design group (internal or external) of the construction company will start the implementation of the infrastructure project with a high level of detail. The group will generate detailed design drawings. In order to fulfil this task the basis (geo-basis) data is required, which means first the topographic survey of the terrain with all visible features. Soil and subsurface investigations have to be executed and locally fixed.

8.0 Construction phase

In the planning of facilities, it is important to recognize the close relationship between design and construction. These processes can best be viewed as an integrated system. Broadly speaking, design is a process of creating the description of a new facility, usually by detailed drawings, specifications and constraints; construction planning is a process of identifying activities and resources required to make the design a physical reality. Hence, construction is the implementation of a design envisioned by architects and engineers. In both design and construction, numerous operational tasks must be performed with a variety of precedence and other relationships among the different tasks. At the very early stage of the project life cycle various characteristics are unique to the planning of constructed facilities. A summary of this includes [HENDRICKSON]:

- *Nearly every facility is custom designed and constructed, and often requires a long time to complete.*
- *Both the design and the construction of a facility must satisfy the conditions peculiar to a specific site.*
- *Because each project is site specific, its execution is influenced by natural, social and other locational conditions such as weather, labour supply, local building codes, etc.*
- *Since the service life of a facility is long, the anticipation of future requirements is inherently difficult.*
- *Because of technological complexity and market demands, changes of design plans during construction are not uncommon*.

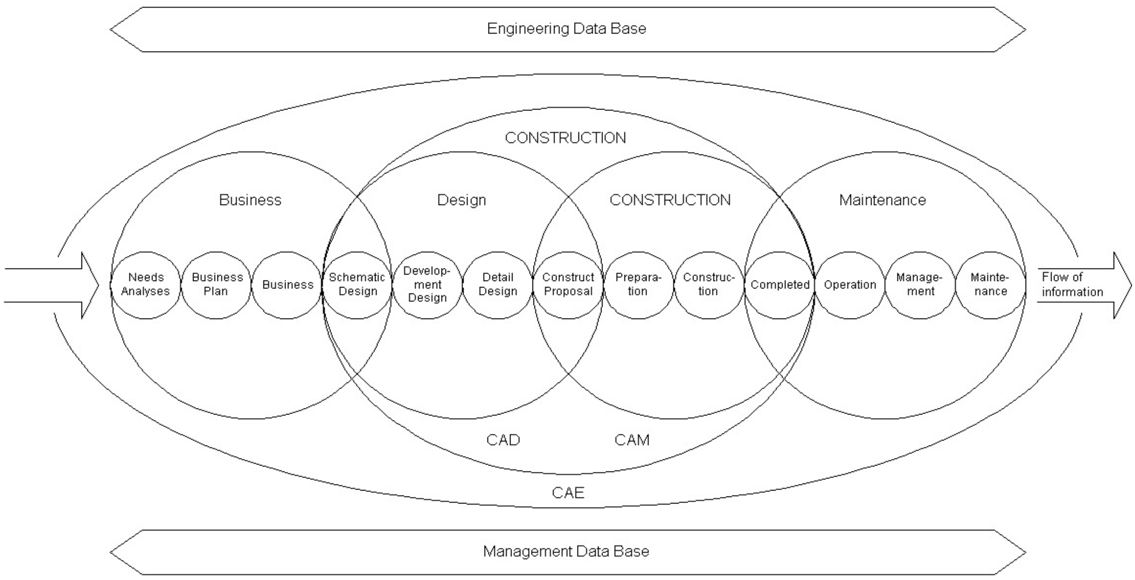


Figure 8.0a Design and Construction process – necessity of information administration [HENDRICKSON, chapter 14; Example 14.5 An integrated system design]

8.1 Departments on construction sites

The department structure on a construction site is built according to the necessity and the portion involvement of the construction company in the infrastructure project. In the case of being the general constructor the organization will be similar to the organisation in the construction company's headquarters. The detailed information for the infrastructure project is captured in the IT network of the construction site. The idea is to establish a Map Server / Model Server which integrates all information for the departments so that information can be shared on site. This idea conforms to the statement from [DANGERMOND2004] which declares that information should be shared through GIS. The core sentence is "*Sharing Knowledge through GIS*".

The typical organisation of the departments is given in figure 8.2a.

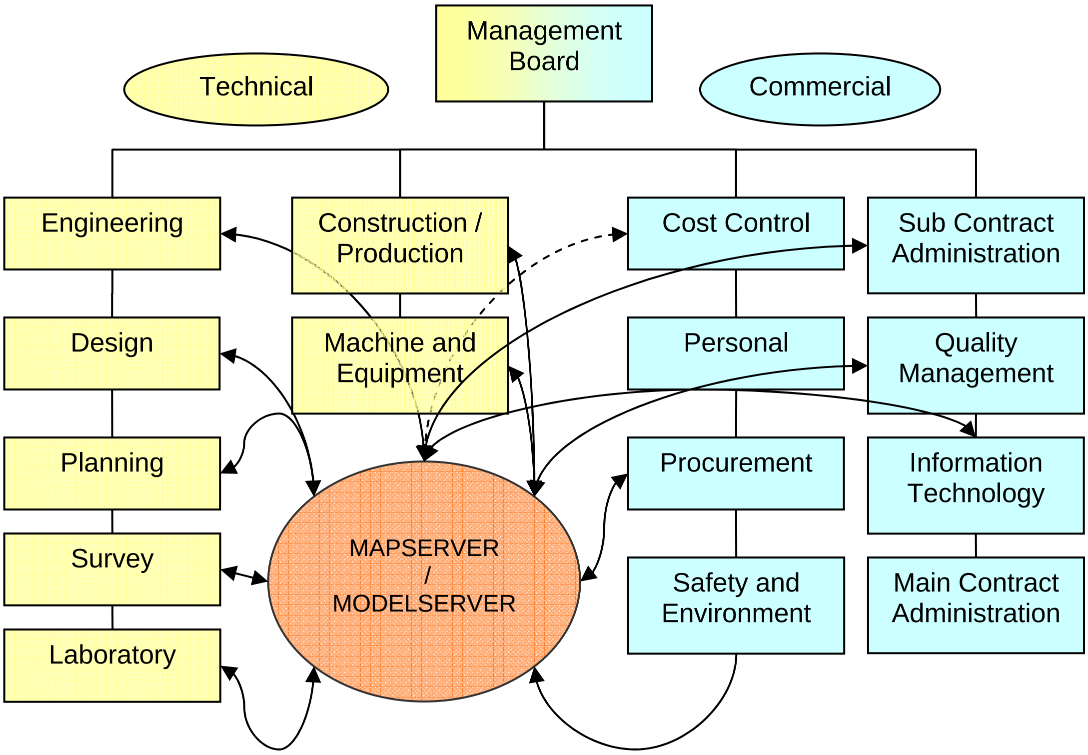


Figure 8.1a Typical organisation chart on site of infrastructure projects during construction phase – Possible links to Map Server (HOCHTIEF, Knowledge Database, Hesterkamp)

By the installation of a common platform for information exchange, which will not be an easy challenge, the annoying effort for conversion of information captured in digital data and the exertion for distribution can be reduced dramatically. With establishing a system like a map server or model server a step towards closer teamwork is achieved. A description about bridging and merging civil engineering and GIS can be found in [TONIAS].

8.1.1 Workflow on construction sites of infrastructure projects

The surveying group is placed within the engineering department and has a central role as an interface between the design office, the engineering and the construction and production departments on site. The surveying group will mediate in questions of how the design data can be transported to the site and how the machines can be lead.

When parts of the design are implemented the surveying group will check the spatial placement and will deliver the As-Built information to the engineering office.

The design office will get information if the placement is incorrect in order to check collisions and to provide a redesign of dependant parts if required. The laboratory will check the subcontractor’s built-in material and parts and will approve the correctness of density and material quality on investigation locations. The approval will initiate the procurement department to the payment of the subcontractor. The planning department will monitor the overall construction progress and will inform the project management about success or deviations from the project’s time schedule.

8.1.1.1 Surveying department’s tasks

The survey department or the survey sub contractors assist the project management and the technical office from the beginning of a project till the end of construction works. Their tasks are listed by time sequence as follows (without claim of completeness):

- Check the geodetic network (handed over by the client’s authorities) (GPS).
- Install new survey pillars/beacons in order to condense the geodetic network.
- Prepare overview maps for orientation.
- Executing the original ground survey and measurement of important features for design purposes and for the creation of basic geo material – base maps for construction sites.
- Base map for the settlement of earthworks.
- Setting out site installation equipment
- Permanent observation of the geodetic network
- Setting out the designed features (buildings – utilities – road – railway)
- Checking the formwork
- Permanently checking of earthwork progress (joint survey general constructor and sub constructor).
- Preparing documents for volume calculations
- Execution of As-Built Measurements and preparation of As-Built documentation (drawings - maps - model) [HAMMOND]
- Calculation of design variants (road works, railway axis, land shaping)

This incomplete list will give an idea about what kind of tasks will be executed from the survey department on a construction site. The new development of instruments either terrestrial or in space allow to put additional information to the measured features in an easy way. Data dictionaries can be built and transferred to the instruments, which include the attributes that are defined by the necessity of the particular task. The interesting part is that this information will be measured on the built in parts, which means that every deviation from the design will be recognised and documented in the as-built drawing or as-built model. Measured information can be placed directly to a site map server (see figure 8.1.1.1a).

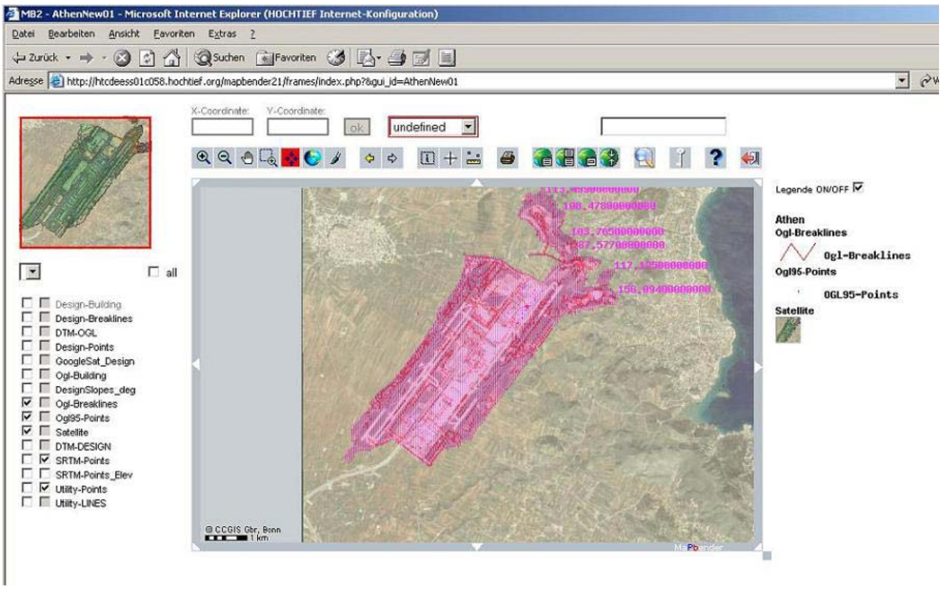


Figure 8.1.1.1a Original ground survey Athens International Airport – Map Server technology

8.1.1.2 New objectives/opportunities for surveying in construction of infrastructure projects

As the surveying team is involved from the first announcement of the project in the construction company and continues with the project during the design and construction phase in all surveying related matters like original ground surveying, determining feature location, placement for construction parts, navigation of vehicles and determine locations of new building parts as well as volume calculation and because of the spatial base knowledge as well the knowledge about various instruments and methods for spatial fixation it can play a central role for the collection and administration of the infrastructure project related data.

In the past features with different information content were coded during measurement in the field and presented in maps, which were generated in specialised CAD systems. Drawings had been printed for dissemination of the evaluated information. Today this work can be handled in a more sophisticated way, by using new technologies like map server technologies combined with the new opportunities of the surveying instruments.

The measured feature can be stored or sent directly to a map server. This will enable a huge number of persons in their departments (worldwide – site wise) to look on the data and will save time, because the data is immediately available, provided that a digital information network for all participants is installed and they are connected to it. Feature codes and topologic information (points, lines, and areas) can automatically by support of the surveying instruments be recorded directly in the field. With storing the data on a database (Oracle 10g Spatial, MicroSoft SQL Server, Map Server) direct access can be established (AutoCAD Map 3D, ArcSDE), which enables the user to proceed with their specific tasks dependant upon surveying data without the need to convert the information into their system.

The first tasks the surveying group will take care of are the establishing of a geodetic network and the ground survey. This will be the base for several processes:

- The civil design will be created on this base
- The payment of subcontractors for earthworks will be based on it
- Monthly progress reported will show the base line, the current production line and the design line in sections.
- Soil investigations will be placed
- Etc.

At the end of construction according to environmental rules the landscape has to be reconstructed in the areas that were not part of the project but which were used during construction time.

8.1.1.3 New instruments and methods for surveying (terrestrial laser scanning)

At the moment a new kind of rapid surveying is on the increase. As the implementation of the GPS technology was a revolution for the surveying sector a few years ago and has established new fast methods for geo-coding location determination of features worldwide, the new technology impresses because of the very fast and simple way it evaluates detailed information about objects in the real world. The accuracy is dependant upon the kind of measurement (interferometry, optical triangulation, amplitude phase comparing method, impulse method) of the instrument, the condition of the target, which influences the intensity of reflection, and the angle of the laser beam to the target. A rough classification of the instrument’s accuracy can be done by the overall distance coverage which ranges from 0.002 m to 0.015 m for short range instruments (inside of buildings 25-50m) and 0.02-0.08 m for wide range instruments (800-1000m).The measurement is done in such a way it does not come in touch with the target. The favourite employments of the instruments are areas where a direct measurement with conventional instruments is dangerous, too expensive (quarry, cleaned rock in dam areas) and where measurements have to be executed in a limited time frame.

Typical uses are the checking of all kind of surfaces and their smoothness, the support of photogrammetric analyses (better representation of convex and concave surfaces), fast recording of pipes and general facilities of plants, measurements for recording current situation in buildings in order to check possibilities for new design fitting.

The results of the measurements are clouds of points with a local coordinate system. Several of these point clouds are combined by the use of fixed points into one model. The geo referencing will be done by means of the known fixed points in a national coordinate system. The result will be one point cloud in one model which can be used as as-built documentation. Comparing the design model with the measured point clouds, will easily demonstrate the deviations from the designed location.

Another advantage amongst others which will not be discussed here is the creation of 3D building models. Some programs supplied with the instruments support the generation of simple solid elements like planes, walls and pipe and surfaces in common with sophisticated algorithms out of a selected range of points partly supported by libraries for elements. The created solid elements can be easily transferred to a desired system for further processing [for further Information see LUHMANN2002 and LUHMANN2004]. The use of the data and the created models in CAFM systems is practicable.

8.1.1.4 Storing spatial geometrical features with attributed information

The instruments for the classical surveying have changed recently. More intelligent instruments offer the opportunity to store additional attributive information during the measurement of features in the field. The number and kind attributes which can be stored range from pure text information, pictures, and sounds to multimedia information like small movie sequences. The instrument’s main task is the determination of the location of the feature. According to the task of surveying a set of features with specific attributes can be generated and installed to the instruments in order to support and assist the technician in the field and focus his concentration on the specific tasks. As an example representative for all other build in parts the as-built measurement of utility pipes can demonstrate the meaning of the above statements. The attributes of the utility pipe are (selection):

- date of implementation

- kind of pipe (material)
- diameter
- thickness of the pipe
- subcontractor (placing and manufacturer)
- date of backfilling
- slope of pipe (automatically generated by the height of beginning and end of pipe)
- kind of utility (storm water drainage, irrigation water, sewer water, gas, etc)
- coordinates of the armatures
- information about the armatures
- etc.

This additional information can be evaluated directly and attached to the measured feature. A catalogue of features with their attributes for specific tasks will form the basic structure of the evaluation model. The information is collected, made accessible and distributed by GIS functionality. Analyses and interpretation based on the collection can be executed and the workflow can proceed. Some of the information will stay continuously through the project phase and later on, for example the boundary of the project, the untouched areas within the project area, the existing unaffected utility lines, etc.

8.2 Technical data warehouse

The definition of a technical data warehouse in the construction phase is an integrated information basis, which holds all technical data, consisting of drawings, lists, spreadsheets and technical specifications. It should be understood as an information pool where the project participants can get and retrieve knowledge about technical requirements of the project. Drawings normally capture the information for several technical and commercial departments on site.

A centralized kept up to date model based approach instead of drawing related work will reduce the effort for counting technical facilities in various drawings with several revisions. Of course the language of the field engineers is the drawings and they will stick to them, but for the technical offices on construction sites the model based solution (object orientated) should be preferred. Drawings can be created from the model. Object orientated has its advantages when changes have to be incorporated into the model. The change of one object will initiate a change to all related objects (AutoCAD CIVL 3D, Augustus 10 V12). The overall amount of changes can be find out in a fast a comfortable way, and the related departments subcontractors can be informed.

GIS can help to assist the workflow by many functions (see chapter 4 GIS functions) especially for the external or outside works (utility, facilities). The connection to the design will be generation of models with attributive information or at least drawings with attributive blocks, which can be imported to a technical data warehouse (GIS, Map Server, and Model Server) on site.

8.2.1 Type of technical data: drawings – lists – specifications

The technical information about an infrastructure project is captured generally in drawing files. These drawings are created either by the design department of the construction company or the tasks are delegated to design subcontractors. Partly the information is prepared by the client or he has delegated to a consultant company. The designing and preparing of the technical specifications which reflect the current state of the art for the realization of the project will be created by the consultant company. Specifications give the clear information which elements or material should be used for construction, it will advise the way of construction and the quality investigations that have to be executed in order to prove the correctness of the build in element or material. Lists will be prepared from the construction company in order to organize the procurement of the items, which have to be installed (see figures 8.2.1a and 8.2.1b).

DuctBanks : Table

Manhole Start	Northing Start	Easting Start	Bottom Start	Manhole End	Northing End	Easting End	Bottom End	Type	Size
B690-00	9,454.20	22,138.80	73.65	D420-03	9,476.00	22,138.80	74.88	DuctBank	4-10
D330-00	9,675.45	21,814.00	75.10	D330-13	9,661.75	21,774.20	73.85	DuctBank	3-5
D330-17	9,873.75	21,853.50	74.95	D330-18	9,893.25	21,853.50	74.10	DuctBank	2-5
D340-01	9,727.00	21,992.00	76.00	U000-02	9,845.20	21,992.00	73.70	DuctBank	4-10
D340-02	9,699.75	21,991.64	75.60	D340-01	9,724.00	21,991.64	75.35	DuctBank	3-10
D340-03	9,699.06	22,116.25	74.80	B250-01	9,728.70	22,118.00	72.55	DuctBank	4-10
D340-03	9,698.06	22,115.25	74.80	D340-02	9,698.06	21,994.36	75.60	DuctBank	1-10
D340-04	9,699.78	22,120.25	74.80	B250-02	9,728.70	22,120.25	72.55	DuctBank	4-5
D340-04	9,698.06	22,119.25	74.80	D340-03	9,698.06	22,118.25	74.80	DuctBank	3-10
D340-05	9,698.06	22,148.75	74.80	D340-04	9,698.06	22,122.25	74.80	DuctBank	3-10
D340 06	9,700.06	22,148.47	74.80	D340 06	9,842.75	22,146.64	73.90	DuctBank	3 10
D340-06	9,844.75	22,148.36	75.32	B190-02	9,845.60	22,186.25	76.83	DuctBank	2-5
D340-06	9,845.75	22,146.64	73.90	D340-07	9,847.00	22,146.64	73.90	DuctBank	3-10
D340-07	9,849.00	22,148.36	75.12	B190-01	9,848.99	22,186.25	76.83	DuctBank	2-10
D340-07	9,850.00	22,147.00	73.90	U000-01	9,857.62	22,147.00	71.48	DuctBank	4-10
D340-12	9,677.17	22,148.11	75.30	D340-05	9,697.06	22,148.11	75.20	DuctBank	4-5
D340-12	9,675.45	22,147.11	75.30	D340-13	9,675.45	22,073.00	75.10	DuctBank	3-10
D340-13	9,675.45	22,070.00	75.10	D340-14	9,675.45	21,988.00	75.30	DuctBank	3-10
D340-14	9,675.45	21,985.00	75.30	D340-15	9,675.45	21,903.00	75.10	DuctBank	3-10
D340-15	9,675.45	21,900.00	75.10	D330-00	9,675.45	21,819.00	75.10	DuctBank	3-10
D340-16	9,873.75	21,964.00	74.55	D340-17	9,893.25	21,964.00	74.50	DuctBank	2-5
D410-07	9,477.72	21,870.00	73.70	D410-06	9,477.72	21,775.63	73.21	DuctBank	3-10
D410-09	9,390.00	21,814.00	71.53	D410-08	9,390.00	21,773.63	70.30	DuctBank	3-18
D420-01	9,477.72	21,950.25	73.80	D410-07	9,477.72	21,873.00	73.70	DuctBank	3-10
D420-01	9,476.00	21,952.25	73.80	D420-04	9,392.72	21,952.25	71.74	DuctBank	4-5
D420-02	9,477.72	22,040.75	74.63	D420-01	9,477.72	21,953.35	73.80	DuctBank	3-10
D420-03	9,477.72	22,136.44	74.88	D420-02	9,477.72	22,043.75	74.63	DuctBank	3-10
D420-04	9,389.88	21,950.89	71.74	D420-05	9,389.76	21,888.50	71.83	DuctBank	3-5
D420-05	9,391.60	21,886.50	72.42	B210-00	9,413.20	21,886.59	73.20	DuctBank	2-18
D420-05	9,390.00	21,885.50	71.83	D410-09	9,390.00	21,817.00	71.53	DuctBank	3-18
U000-03	9,848.05	21,964.00	74.84	D340-16	9,872.35	21,964.00	74.85	DuctBank	2-5
U000-04	9,848.05	21,853.50	74.19	D330-17	9,827.35	21,853.50	74.95	DuctBank	2-5

Record: 1 of 32

Figure 8.2.1a Example table of manholes and duct banks for procurement, New Athens International Airport [Hesterkamp]

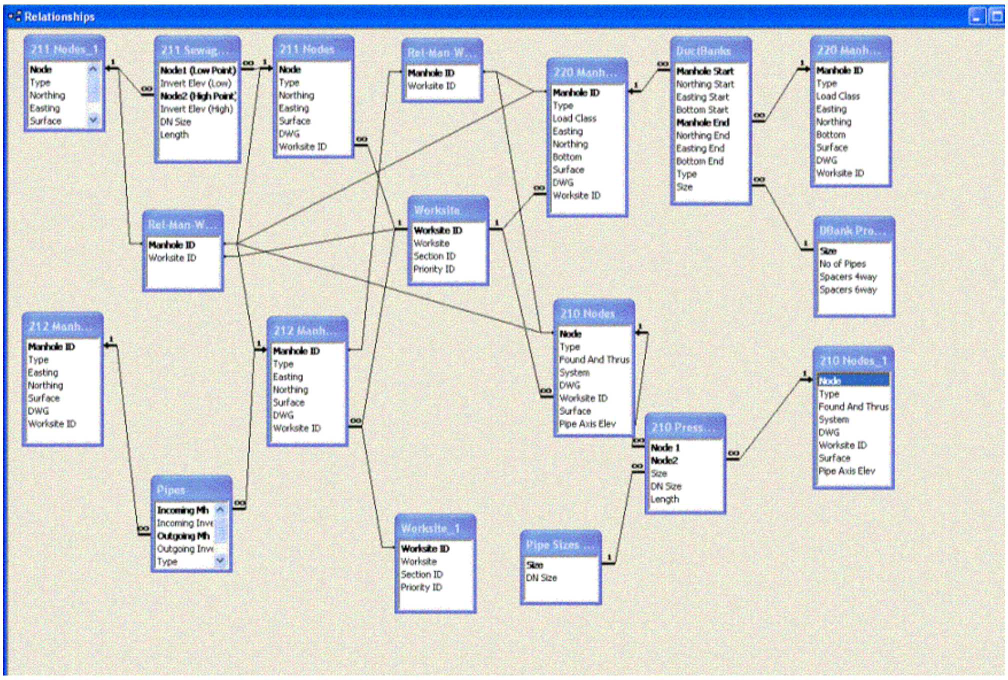


Figure 8.2.1b Example database relationships of utility systems, New Athens International Airport [Hesterkamp]

In combination with the first draft design drawings and the specifications the construction company will prepare the detailed design drawings. The detailed design drawings reflect the specifications. The implementation will take place on site according to the construction method and the specifications for installation.

8.2.2 Ordered and submitted data from subcontractors

A major part of work for an infrastructure project is done by several employed subcontractors. Either they work for the design or for the construction. The task of a general constructor is to lead the members to successfully achieving the target of the project within the time and budget. In the sense of the model based set-up of new infrastructure projects the general constructor has to give odds, which describe how and with which attributes a part in the design should be produced and stored, to the subcontractors.

Another task a general constructor has to do is to settle a unique coordinate system, which can be a temporary local system for the site or a grid for a building. The transformation into national coordinates and the merging of parts from subcontractors into an integrated model will be done by the general constructor. A further task is the checking of the delivered drawings or parts of the model, which can be done with the assistance of new algorithms in the CAD software.

It might be a problem to follow all the versions of the delivered drawings during the design process and the implementation in the GIS model has its effort too, but at the end it will help to serve the up-to-date information needs of a construction site. An example of the use of GIS in combination with CAD during operation and design is given OCSD (Orange County Sanitation District). The use of GIS – here ArcSDE and ArcIMS – for a facility model and CAD – here AutoCAD and MircoStation – for the design task and the mutual exchange of data between both systems has gained advantages for the utilization of the staff and resources and has minimised the changes in the existing workflow (for further information see [BROWN]).

The contract administration department has to organize a new form of subcontractor contracts which have to regulate the access to the information platform and the duty of notification of changes and their implementation to the subcontractors work. Technical regulations for a model base approach could be done by the *setting on hold* of parts of the model, which are currently being changed. The general constructor has to inform the subcontractors. This task can be settled by automatically generated e-mail notifications to the subcontractors involved.

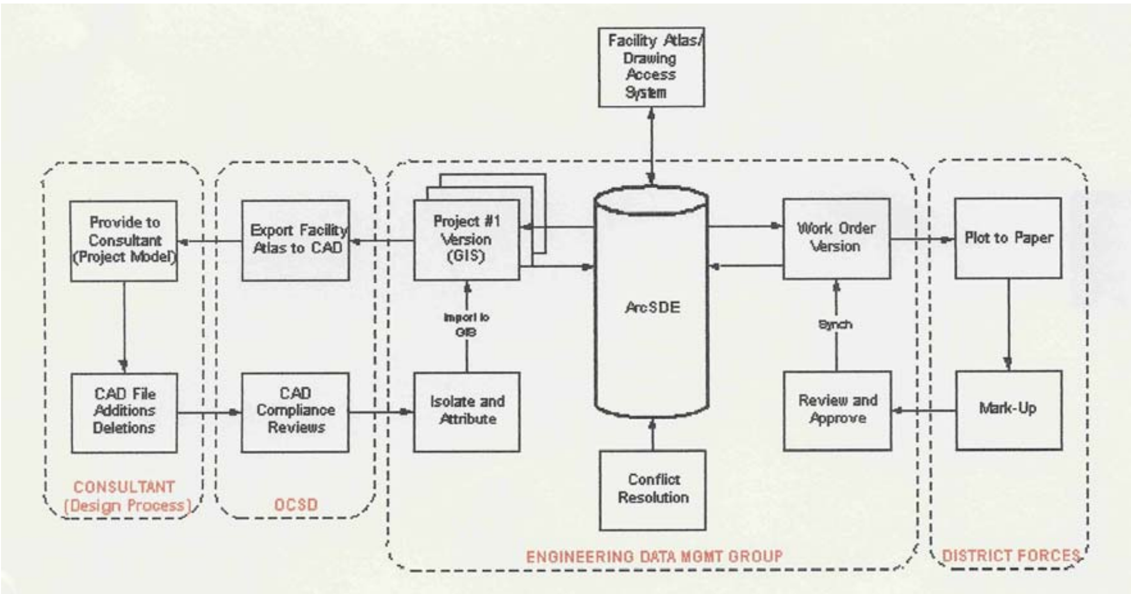


Figure 8.2.2a Example for combination of CAD and GIS in facility managing and design – construction process [BROWN]

8.2.3 Connection to procurement

One of the procurement department's tasks on a construction site is to order material and facilities which are necessary within the construction workflow. The information about the parts which have to be built during the construction process will be evaluated by the works preparation group which is embedded in the engineering department. Commonly the works preparation department will make an extract of the necessary elements, which will be needed for a certain construction phase within the time schedule. This information is gained from the drawings and summarised in lists or spreadsheets that are handed over to the procurement a certain time in advance. The procurement department will order from the dealer. The workload for the works preparation department can be slimmed down by using easy counting functions from GIS and CAD software.

8.2.4 Lack of easy integration of complex CAD files into GIS

The design works for an infrastructure project is moving in the last year more and more towards the three dimensional preparation of digital drawing respective models by CAD. The information content of the CAD drawing files has increased a lot. Next to the geometric information the description and the properties of a designed object is stored in the drawing file or is captured by a link to an external database. The complexity of the infrastructure projects and the available time for their design and implementation is the right challenge for CAD programs. The created objects have additional information e.g. kind of material, dimensions, volumes. The transfer into GIS of this additional information needs the support of additional software and modules; especially for the complex three dimensional objects and their attributes. An easy loading of complex 3D CAD files into GIS without losing the special applications object information is not yet possible, but is only a question of time. Web based solutions drawing up a new way of data exchange and interoperability. This might be a solution for the current time and in the near future: producing the data with complex application software and export to web based international agreed standard formats. The interfaces are available in various CAD and GIS software. The data pool will be the web-model.

8.3 Storing models instead of drawings (advantages - disadvantages)

In the near future the applications software will store the data for civil engineering processes in three dimensional models. The advantages and the disadvantages should be shortly discussed without going into too much in detail. Traditionally the drawing was the language of the engineer. The disadvantage, which results from this two dimensional representation of the design, can be announced with a high coordination effort and high ability for abstraction. Interfaces between outside facilities and facilities inside a building could not be checked on a visual basis. The drawing is still used on construction sites as the field engineer has to communicate with the labourers that have to implement the drawings statement.

Model of the design in 3D will reduce the coordination effort between the disciplines, e.g. interface of utilities (sewer system, electrical, openings in the wall, etc). The abstraction ability will be supported by a perspective view and the possibility to generate sections and layouts in any scale out of the model. Discussions and explanations can be done by means of the 3D model.

8.3.1 Data Storage and Interoperability

A common adage is that the departments should work with their application software or tool which is best fitted to solving their tasks. The departments should use the right tool for their job. Significant investments are done to the systems the organisations are using today with the result that the systems are tailored for the workflow in the enterprise. Departments are producing geospatial data for their purposes. The exchange of geospatial data between the departments is done by conversions.

Till now, interoperability within the enterprise has meant exchanging data between systems based on least common denominator file format. This costs time and money, degrades data precision, and introduces data loss and quality as the data is translated and copied multiple times within the organization. To get around this problem the solution is to share the data on an enterprise database.

Although the applications for producing the data are important, the key investment for organizations that deal with geospatial information is in the data. Interoperability enables organisations to use the right tool for the job while eliminating complicated data transfer and multiple copies of the same data throughout the enterprise. Interoperability centred in an enterprise database, it is the users’ data that becomes the appropriate focus of the system. This high level of interoperability can be achieved only by allowing access to spatial data that is stored in an open, published format and maintained in a secure and powerful database. The centralisation of the data enables the system to apply server-side rules, ensuring that data treatment is consistent regardless of the application that created it or that is used to view it. The database approach also means that SQL queries can be submitted directly to the server, providing consistent results from data queries.

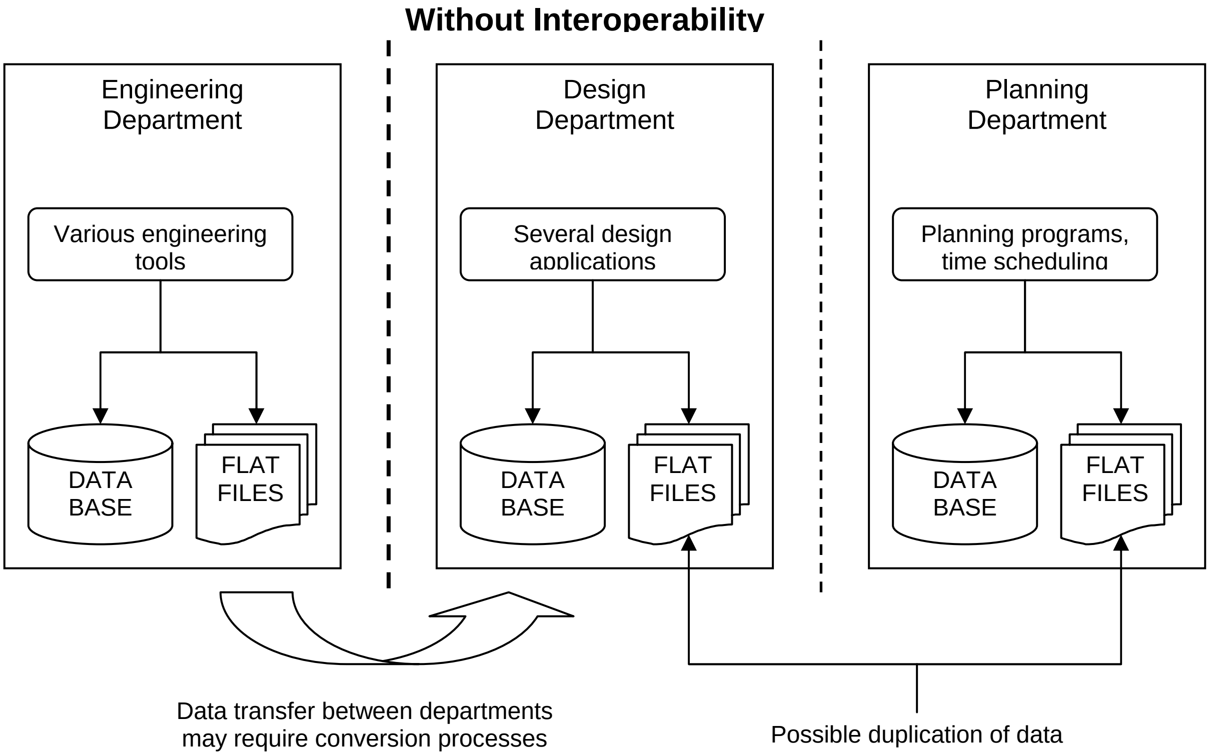


Figure 8.3.1a Disparate technologies and data stores [T-PAPER, changed]

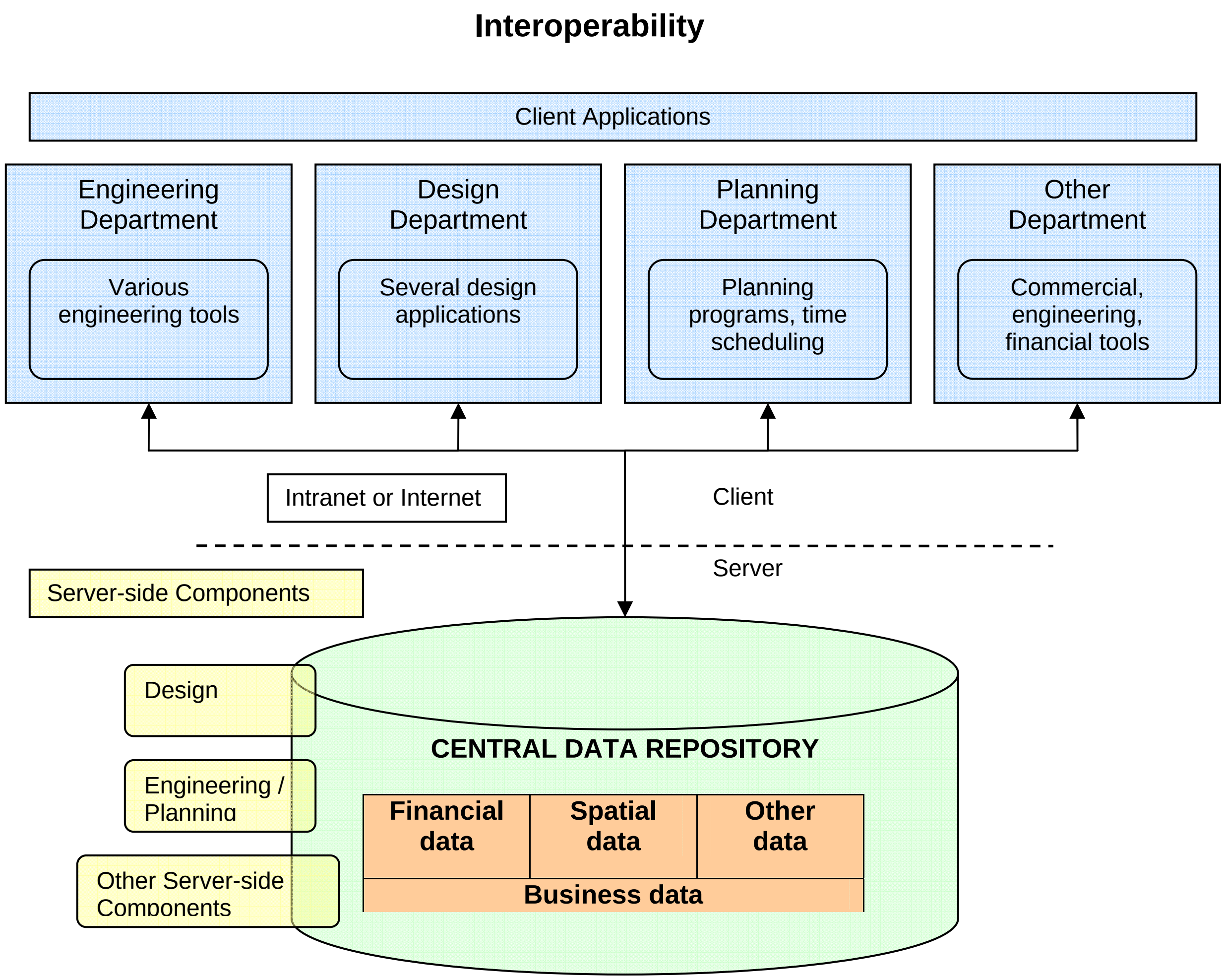


Figure 8.3.1b Interoperability enable all departments to share data via a central repository while continuing to use their existing applications [T-PAPER, changed]

Benefits are the interdepartmental access to the information, the integration of the captured data into the day-to-day work process of subdivided departments and an enormous reduction in conversion and therefore saving of time and resources.

Summery of benefits [T-PAPER, changed]:

- Supporting of multiple applications – each department can use its preferred software and data types, while working from a shared enterprise database
- Increasing productivity – eliminate the time wasted to convert or translate data
- Increasing data accessibility – when data is stored in an enterprise database, all users and key decision makers have quick access to the most accurate and up-to-date data.

- Improving communication among departments – an enterprise system requires that all independent systems communicate quickly and effectively, regardless of data format.
- Increasing data security

8.3.2 Monitoring on construction sites

Monitoring on construction site is the tasks to check the current status of the activities on site against the forecasted and determined estimation. A strong link between monitoring the cost-control, the accounting and the management is usual. A group of specialised investigators will check the execution of work of the constructed facilities in accordance with the estimated cost to complete an activity. From the several existing methods for activity estimation the common factor are the units of activities for completion of a specific work. The units can be linked with the budget for a certain work, so that a unit rate can be established. A simple example is the placing of a pipe activity:

- starting with the excavation of the trench	10 %
- followed by the preparation of the pipe’s layer	20 %
- further placing the pipe and weld the end	40 %
- hangars and trim of pipe complete	20 %
- hydro-tested and complete	5 %
- backfill and compaction	5 %
total completion	100 %

In the monitoring and control stage of the construction process, the construction manager has to keep constant track of both activities durations and ongoing costs, which is done normally by daily worksheets. Constant evaluation is necessary until the construction of the facility is complete. When work is finished on the construction process and information about it is provided to the planner. Project manager must give considerable attention to monitoring schedules.

Construction typically involves a deadline for work completion, so contractual agreements will force attention to schedules. More generally, delays in construction represent additional costs due to late facility occupancy or other factors. Just as costs incurred are compared to budgeted costs, actual activity durations may be compared to the expected durations. In this process, forecasting the time to complete particular activities may be required.

With an established central data repository for all built in parts beginning from the design stage through the construction period the monitoring process can be made easier. A link from the estimated activities and the geometrical model will have the advantage right from the beginning to simulate the process of activities and enable faults to be detected. During construction and monitoring the field engineer can give his input about the status of completion according the estimation of activities. The map server technology enables, due to the possibility of transaction (see [DEPHOFF]), the input for the monitoring so that an execution of the monitoring could be done from any personal computer in the intranet - internet. During the setting up of the systems scheduling and design the experts have to decide and develop a strong link between the geometric representation of the facilities which have to be built and the corresponding item in the time schedule. The unit rates can be interpreted as attributes which are associated to the geometric features that are segmented by the activities.

Some advantages can be announced:

- The monitoring can be done live without time delay
- Just when the acceptance is given (geometric and technical) maybe on a PDA device the server will be updated.
- The geometrical representation is checked by survey and will replace the design to as built.
- Different stages of completion can be visualised
- The difference between the estimated forecast and the current status can be shown.
- An aggregation of the total completion of work can be visualised in a easy way due to the statistic and cartographic functions of GIS

A further aspect for an overall construction progress report is the use of aerial photographs of satellite images, which will show the growing of the project at certain time intervals. The accuracy difference (ground resolution) between satellite images and aerial photographs is one factor for the decision which kind will be established on site. When further processing of the data is required e.g. for volume calculations the aerial photographs will be used. In pure documentations for the construction progress of heavy construction sites satellite images can be taken into account. The frequency of satellites passing the same location can be determined and images can be ordered from satellite image providers. Satellite images cover large areas. A cost comparison between both methods has to done after the decision of further usage of the data as described above. Map server technology enables both types of images to be stored and reflect certain stages of a construction site by easy overlay techniques.

8.3.3 Quality Assurance – Quality Management

Quality control represents increasingly important concerns for project managers of an infrastructure project. Defects or failures in constructed facilities can result in very large costs. Even with minor defects, reconstruction may be required and facility operations impaired. Increased costs and delays from the time schedule are the result. Generally a major demand for all participants is to ensure that their job is done right the first time and that no deviations occur on the construction process.

The most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of ensuring conformance to the original design and planning decisions. Exceptions to the rule of conformance as the primary focus of quality control can occur due to unforeseen circumstances, incorrect design decisions, changes desired by the owner of the facility and current site conditions for example soil conditions. These rule breakers give occasion for re-design with all the attendant objectives and constraints.

Inspectors and quality assurance personnel will be involved in a project to represent a variety of different organisations. Each of the parties directly concerned with the project may have their own quality inspectors, including the owner, the architect and the various constructor firms. In addition to on-site inspections, samples of materials will commonly be tested by the laboratory to ensure compliance. Also involved are a group of inspectors, who ensure the compliance with regulatory requirements.

In addition to the various organizational bodies involved in the quality control, issues of quality control arise in virtually all the functional areas of construction activities. Ensuring accurate and useful information is an important part of maintaining quality performance. Other aspects of quality control include document control, procurement, field inspection and testing, and final checkout of the facility.

Quality control in construction typically involves ensuring compliance with minimum standards of material and workmanship in order to ensure the performance to the facility according to the design. These minimum standards are contained in the specifications. For purpose of insurance compliance, random samples and statistical methods are commonly used as the basis for accepting or rejecting work completed and batches of material. The field inspections will be highlighted in this section because of its geo spatial related information (see figure 8.3.3a form for field density inspection).

HOCHTIEF CONSTRUCTION AG	FIELD DENSITY TEST - QRLAB04

CONTRACTOR / SUBCONTRACTOR:		PROJECT:	
AXIS / AREA:	BUILDING / SITE:		TIME:
DATE:	ELEV.:	EAST:	NORTH:
LABORATORY:	OPRATOR:		REG./TEST No.:
MATERIAL SOURCE:			
REQ. / TARGET DENSITY:		LAYER No.:	

EQUIPMENT CALIBRATION					
DATE:					
TIME:					
STANDARD COUNTS - MS:					
STANDARD COUNTS - DS:					

STATION	TEST NO.	BS/DT DEPTH (cm)	READINGS			PROCTOR		COMPACTION		AIR VOIDS %
			WD (kg/m³)	DD (kg/m³)	MC (kg/m³)	DD (kg/m³)	MC (kg/m³)	REQUIRED %	ACTUAL %	

Figure 8.3.3a Field density inspection - location determined by spatial information

The geo spatial reference of the inspection will be determined by the survey department or by the inspectors by the use of simple survey equipment. By using a map server based system to collect the inspection data and in order to represent the place the inspection has been carried out in order to show the compliance with the specifications requirements for certain areas on the project site. The table character of the inspections test and their results is ideal for memorizing the data in a GIS environment. Statistical functions can help to visualise the results of several inspections in adjacent areas and serve the representation of the analysis on the map server. The demand for a document control system can be served in this way as well.

8.4 Monitoring - Controlling - Presentation

The aspects for monitoring have been described in the previous sections for the reason of better understanding of the time related activities and the process control on a construction site. Controlling the analysis of the monitoring reports which will have an influence to the budget, accountancy and the decisions the site project management has to be undertaken in order to fulfil their leading tasks. Leading a construction site means to know the current situation combined with knowledge about the financial resources of the project.

Presentation is a task for the site management. The way information is presented to the client and to the public will change in the future. The transparency of the construction workflow can be easily gained with implementation of new intranet - internet technology (Map Server – Model Server).

8.5 Project management on construction sites

Project management - a definition:

“Tapscott and Caston (1992, In Huxhold & Levinsohn, 1995) state that four shifts influence the state of businesses;

- *a shift towards a more volatile world*
- *the transformation of markets and national economies*
- *a shift towards dynamic enterprise*
- *a shift towards open, user centred network computing*

These factors of change are the driving forces that affect the project management process throughout every level of the organisation. A technology system may be well designed, planned and scheduled carefully and executed with the utmost care, but if the people have not been involved at every possible stage then the project may easily fail. Managing any level of change must include training, task familiarity, good communication procedures, and operational support during the projects total life cycle, i.e., design and development phases, and not just on implementation. Organisational issues need to be assessed for changes in office practice, task procedures, and allowing time for change-over training and acceptance learning curves. Three things will definitely be affected by the change process, knowledge, skill and attitude (Cleland, 1995). These personal attributes apply to all aspects of working practice. Here these attributes are related to project management, although they apply to any member of any project team……” [FISHER1999]

In terms of methodologies, the selection is virtually at first, but some methodologies only deal with particular aspects of a projects lifecycle, and therefore can only be used at definite stages in the process. This may amplify the management overheads of running two or more methods side by side. This is where a good deal of knowledge is required about the various methodologies, knowing what to apply and when. Knowledge is gained by experience and learning, but training is often a sideline to daily operations, which results in a false economy of resources, increased operational costs and a possibility of failing to succeed.

Matching the right methodology to the project has to be done by evaluating the various techniques available. Among the methodologies are those that only assess the technical framework of the project. These are useful for the engineering of the software and application, but may not cover the organisational features.

It is important for the construction company to realize that, although an accurate base map database is most desirable and its pursuit should not be forgotten, it must not wait to take advantage of GIS potential until a mapping database is available. Although direct engineering street and site design cannot be had without accurate mapping, there is a multitude of engineering functions, particularly in the operation and maintenance of the constructed facilities that could make excellent use of GIS and FM applications. This in itself would justify the building of the engineering database. When properly designed, a database sharing the resources of the various departments of a construction site could produce operational savings that could be used to eventually create the base mapping to the desired engineering accuracy.

The merging of GIS and Civil Engineering technologies is a result of developers looking down the road in an effort to provide the end-user a truly unified database serving multiple disciplines. The growing popularity und use of GIS will inevitably result in the integration of GIS and other technologies in the coming years. Additionally, once the overall system has been implemented and track records of sounds become available, the system can be expanded to incorporate decision making techniques to assist the community in its budgeting, planning and optimized use of its funds.

Using database technology as necessary for the implementation of the site management system is of use to the various departments of the overall technical departments, as well as to various commercial services as well as for the client. Under a judicious shared resource cost sharing plan, the initial implementation and the maintenance of the database can be recovered quickly, and in the long run provide overall company wide economic savings.

Project management relies upon good management practice but has the overall goal of project completion in terms of the project objectives as its prime objective. The implementation of the GIS techniques mentioned in this thesis are aimed at making improvements in management practice and hence increasing the effectiveness of projects. The successful implementation of the GIS technique will support the project management in the tasks of reacting to monitoring reports, steering the necessary processes, initiate the actions for acceleration and represent the decisions internally and externally to the public.

Statistic functions, which are part of any GIS software, will enable the project management to get an overview about the current situation of the project and its sub projects. Cartographic functions will help the project management to visualise the statistics. Running analyses will support the project management to get new findings in order to make better forecasting for the next future. All in all this will result in improved project management procedures integrating discreet business functions to enhance the effectiveness of decision making.

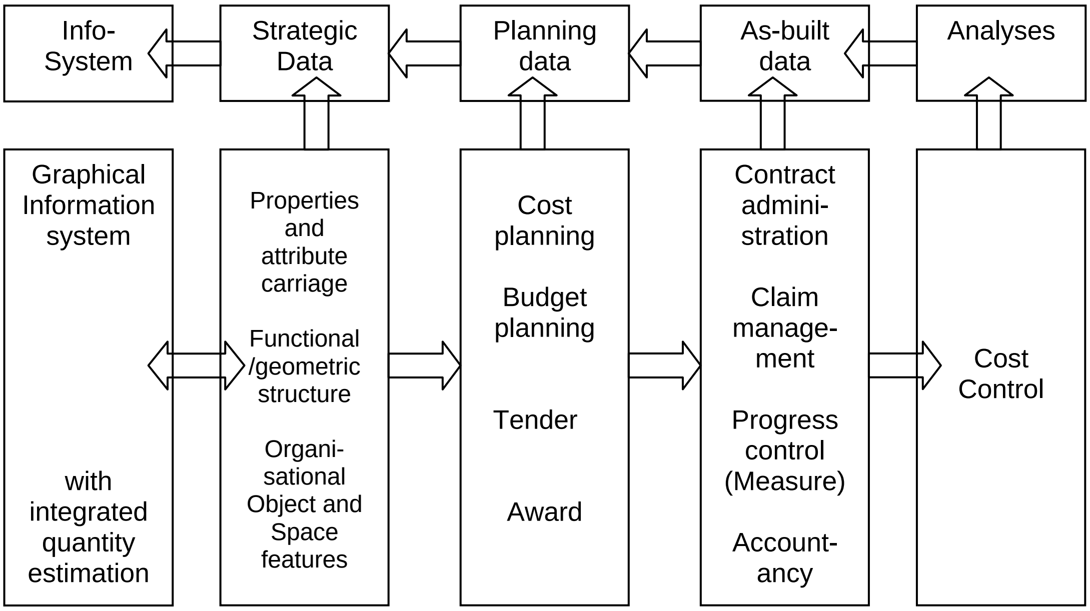


Figure 8.5a Integrated information and decision management [GREINER, chapter 12]

8.6 End of construction

When the objective of the infrastructure project is reached the termination of all construction activities is initiated. Although the main construction time and period has stopped there are some duties, which have to be fulfilled:

- The temporary facilities have to be removed in order to create obstacles for the following operation of the new facility.
- The as-built documents have to be prepared, tightened for handing over to the client.
- The maintenance group of the construction company has to be established for repairing and maintain the facility for the warranty period.
- All acceptance protocols should be registered and claims from the client have to be listed, in order to refit the listed items.
- Claims from the construction company against the client have to be collected and discussed internally and at the end with the client.
- A backup-system of the documents has to be created.
- Etc.

With the end of construction massive data is available for further use and its information content is high. The primary further use of the data will be the facility management of the new infrastructure during the operation period. Other construction company internal aspects for the further use of the data are the keeping of records of the build facilities and the challenges within them. The advantage for the construction company here is the recording of problems faced and solved with regard to the geo-referenced special conditions of infrastructure building sites, which can be used and transformed for other similar construction sites. The backup of the documents (historical – site progress) is important for claims, which might occur. The estimation can adjust their forecast to the actual final costs of the project and its items. The system for the estimation of unit rates and the monitoring of construction process can be approved and adapted to other projects or completely rejected.

9.0 Handing over phase and maintenance – Facility management.

The financial investment in infrastructure projects is enormous. A considerable part of the investment is occupied by projects like highways, railways, harbours and airports. The increasing cost pressure and the international competition enforcing a critical assessment of this cost item. More weight is put on the immobile infrastructure building due to its strategic potential of economic success. In the past the emphasis was focused on new construction of infrastructure buildings, while the expenditures of the maintenance of the infrastructure building were comparatively low. This situation has changed in the last years so that today cost involved between the new construction and the maintenance is near to 60% to 40% [GREINER, page 251].

As interpretation of the above mentioned description a need can be seen - the importance of a sustainable data collection and administration of information which is relevant for the maintenance period of the infrastructure facility. This will lead to a new business industry the facility management. The definition of facility management is given in [GREINER, page 251-257]:

“Facility management is the holistic, strategic frame for coordinated programs in order to continuously provide for buildings, their systems and capacities, functional capability, and the adjustment to the ever organizational necessity changes. Hereby a high qualified use and a sustainable value of the building will be achieved.” (Translated Hesterkamp)

The activities for facility management are widely diverse. The resulting tasks from the above statement are (selection):

- Technical building management
  Including new constructions, reconstructions and maintenance
- Commercial building management
  Including operative and strategic Controlling, contract administration
- Management of spaces
  Including real estate management, environmental management
- Enhanced Services
  Including information technology infrastructure, telecommunications

One major aspect management of the facilities apart from the inventory list is the knowledge of the location. To reach the target of economic success with infrastructure facility management it is indispensable to form a central database with spatial reference. The focus here in on the spatial databases for heavy construction sites with large extensions and not the building related facility management although a great amount of overlapping exists.

After the construction activities the infrastructure project building will be handed over to the client. The official handing over ceremony is one part that demonstrates to the public the successful conclusion of the project. Within the handing over period the as-built documents will be prepared and combined with descriptions for maintenance of the placed facilities. One part of these documents is an inventory list of the built-in parts, where the location of the parts traditionally is captured in sketches, drawings and maps. The conversion of this information in digital format is one step in the direction of an integrated solution. A strict observance of standards right from the beginning of an infrastructure project - evaluation of existing and design of new information as well as the storage of information in well structured databases - is a better step.

New technologies of distributed databases with spatial reference (Map Server / Model Server) establish a tool which can be used sustainable throughout the infrastructure project phases. It enables the participants of an infrastructure project to store their workflow relevant and refined data to the system, which can be commonly used by a great number of persons, who need the information for their tasks. An information chain is created from the start to the end with the effect of reducing time and money for information distribution. More information about facility management especially Computer Aided Facility Management (CAFM) can be found in [SCHÜRLE].

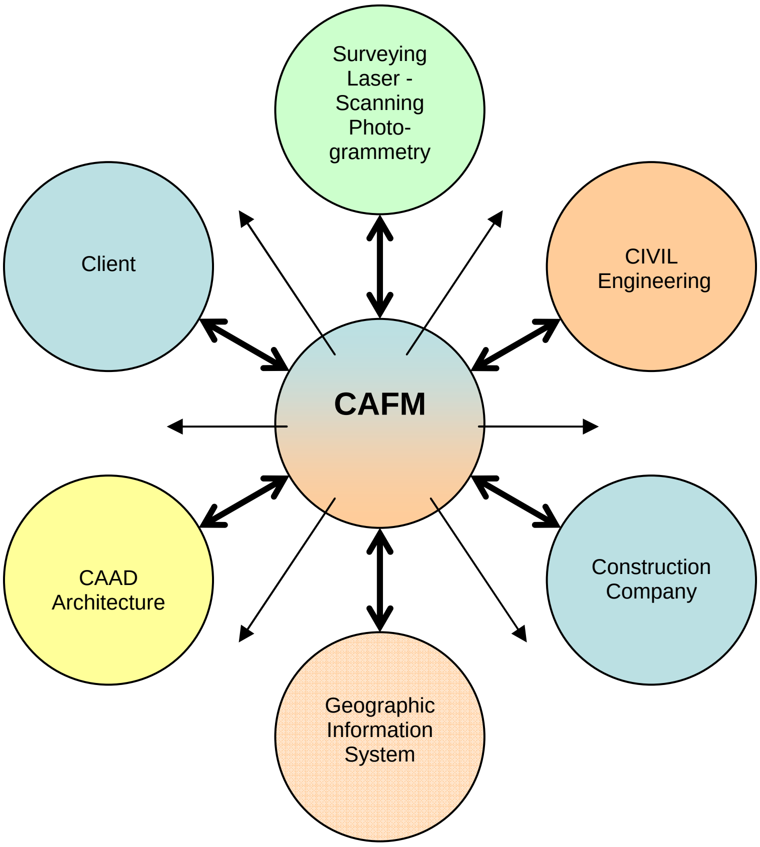


Figure 9.0a Computer aided facility management (CAFM) and interfaces ([SCHÜRLE], changed)

10.0 New Form: Pre Construction – Construction

A new form of partnership between client and contractor will enter the construction business industry. The main topic of this new form of partnership is an early participation of the construction company within the design process of the project, because here is the best time to control the cost of a project (see figure 10.0a). Huge construction companies (like HOCHTIEF Construction AG) which have several business groups in their port folio, that range from project developers to the facility management have experienced staff to support all kind of tasks from the initiation of a project until the use and will assist the deconstruction if required. All groups will be contacted and will give their qualified input to bridge all the periods of the infrastructure project lifecycle. The main target items of this new form are:

- Promoting close collaboration in the spirit of partnership at an early stage in construction projects.

- Complex projects, building refurbishment and upgrading are demanding challenges for all project participants since the new form will produce significant time and cost advantages.
- The Client will profit from the professional knowledge of the construction company right from the start of the planning phase.
- The potential cost savings will identified early on in a project.
- Risks will be identified in the planning phase before the impact the execution of a project.
- The project specifications will be defined in cooperation with the client during the pre-construction phase.

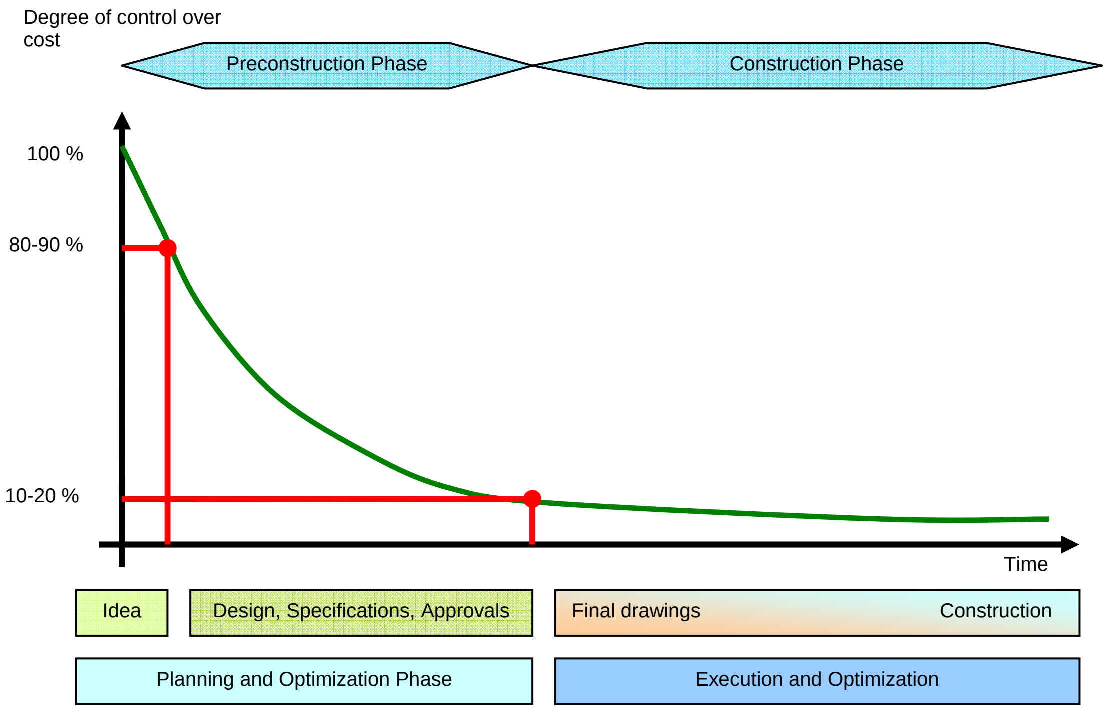


Figure 10.0a New form of partnership [PREFAIR] HOCHTIEF CONSTRUCTION AG

The beginning of the planning process, when the schematic and design development phases occur, is the best time to control costs. Up to 80 to 90 percent of the project costs can be influenced at the beginning of the preconstruction phase. Once the planning process is finished, the degree of control over cost will drop to around 10 to 20 percent. As the project planning is progressing further, opportunities to create savings opting for alternatives will decrease.

The idea behind the concept is to assist the client until a certain stage of the project. The transition point is given at the end of pre-construction period. The client will have to decide at this point in the project either to be accompanied by the construction company or proceed based on previously defined and mutually agreed terms in the project with another construction company.

The use of GIS can support the tasks during pre-construction phase and construction phase because it provides a homogenous platform for collection and dissemination of the project relevant information, which will be involved during the feasibility studies, the design, detailed quantity estimation, detailed design modelling and the construction process.

11.0 Data stream line of core data and WEB - GIS as glue

Infrastructure projects are very expensive investments and the engineering and constructed assets have long life cycles. Typically these cycles include planning - engineering – bidding and letting – construction – maintenance and operation phases.
Networks of companies are involved in the specification, design, material procurement, construction, operation as well as renovation and decommissioning of buildings, manufacturing facilities, industrial process plants, infrastructure and other build assets either public or private.

Several huge infrastructure assets could be undergoing any number – or all – of these phases at the same time, with a diversity of reconstruction and enhancement projects being worked on simultaneously.

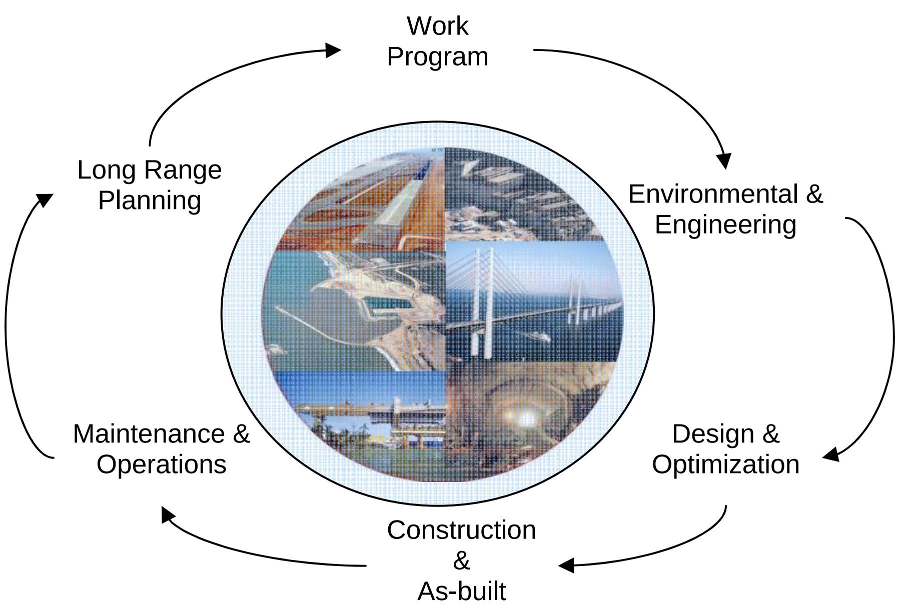


Figure 11.0a Infrastructure life cycle [MONNIER, changed]

In today’s construction there is no clear marking out of discrete steps as shown in the figure 11.0a. While construction phase design and engineering will be underway, reacting on conditions in the field. Modifications and additional design will be initiated during the operation of the infrastructure. These circumstances of constant and simultaneous change have to be taken into account by the solution of the information technology. Historical GIS software is basically a stand alone function, which is either not entitled to take changes in other areas of the project or be incorporated on an ongoing basis in the other information technology in the project. The process required to manage the construction of infrastructure facilities across extended geographical areas is on the other end of this business model spectrum. It is a challenge to move and exchange the information to and on the internet.

Management of large infrastructure projects include the complex factors and constrains [MONNIER].

- Very high cost project
- Liability risks at every step
- Very long duration
- Multiple participants
- Extensive and strict regulations to comply with (from environmental to bid letting)
- Massive amount of data, recorded and stored in many disparate forms (from index cards to digital imagery)
- Accuracy required in the smallest details of this information
- Overlay of front-office (geo-engineering, project management), and back office (enterprise and ERP) processes
- Politics (both the “good” democratic process as well as the inevitable internal politics within large public and private organizations)

There are clear and simple project objectives which are valid generally. These reduce costs – shorten time – lower liabilities. An example for this statement is to catch errors early in the project design phase instead of realizing them during construction phase. A demand of these requirements will bring the right information to the right person at the right time. The need for a comprehensive, sophisticated engineering information management system is obvious, but it did not exist until now. Some solutions are at the moment growing on the internet. It is recognized that the complexity of the current business networks is one of the major hurdles for engineering information management. They are maintained as well as possible with mail, telephone calls, faxes, e-mail messages, and travel and overnight shipments. The internet seems to be the appropriate upgrade for all these disconnected means of communication and information management.

12.0 Conclusion of thesis

Geographic information systems (GIS) have become a prevalent method of analysis in civil engineering. Flexible GIS models that manipulate, compile, process spatial data above or below the earth's surface have provided a powerful tool in civil engineering applications. CAD systems which are traditionally the favourite tool for civil engineering purposes and GIS which is used for massive data collection and analysis are beginning to be merged. The integrated advantages of both tools will speed up a host of processes in civil engineering due to the homogenous data integration and access as well as the better information based decisions. Some details, especially the use of three dimensional features produced by architectural and engineering programs (multipachtes, solids, design object with attributes) and their three dimensional analysis methods have to be refined as well as the vice versa loading and access of attributed GIS features in CAD.

The knowledge of both tools is advantageous and the choice which to use for each situation in infrastructure project phases is a matter of education and will be a task for the universities, academic institutions (governments) and the private business. The master thesis has highlighted by some small examples the advantages of the use of GIS for a few civil projects. Unfortunately the use of GIS during construction phase and the later facility managing could not be proved on a current project because of the short research period, but some ideas and experiences gained during the construction of an airport were used to show up the opportunities. These investigations might be executed in some extra studies treating the topic of GIS integration in infrastructure construction phases with the focus on detailed workflows during infrastructure project realisation.

With today's information technology, construction planning and engineering processes already include several sophisticated software solutions. Currently obtainable systems include GIS and planning, imaging (satellite and aerial), surveying, scanning, and raster conversion, AM/FM, civil engineering, network engineering and others. A new way of interdisciplinary work can be entitled "geo-engineering", which combine the grouped technologies to serve large infrastructure projects.

Unfortunately it is recognised that geospatial data (geo spatial base data, geological data, etc) is currently not as accessible as pronounced. The reason for these circumstances might be explained as the interoperable access and distribution through the internet of detailed geospatial data is just set up. It could also be realized that an easy loading or transferring of features – models between CAD and GIS wasn't as simple as thought. The objects of CAD and especially their set of attributes were not transferred in an easy way. Special applications had to be used to transfer the data with intelligence. For an integrated system is should be easy for the user to load features into any system without losing information. The combination of OGC and IFC standard is the right way for an integrated solution. In the future more geospatial data will be placed on platforms like Map servers or 3D model servers with the ability of geospatial information selection and extraction. The set up of information in the infrastructure projects phases (pre qualification to handing over as-built documents) will reduce cost for the client and the contractor. It will be a paradigm change in the kind of work for the construction industry with the opportunity of saving time and resources (see Appendix D for a list of advantages of GIS in project phases).

13.0 Future - outlook

With new satellite sensors, which have increased resolutions and accuracy the remote sensing will play a role in the evaluation of data for civil projects [BAMLER] [EADS2004]. There will be an opportunity to evaluate information for rural and not easily reachable areas of the world. Their data analysis and interpretation will find the base for better assessment for investment in the initiation phase of civil projects. During the design and construction phase these new technologies and the kind of storing, administering and condensing the information on information server will be helpful for the project implementation and observation. A cascaded server system with clear tasks and holding information in specific level of detail (terrain in the vicinity of the project, detailed terrain within the projects boundaries and buildings with all utilities inside and outside) can help to serve the amount of data. The project management can observe, monitor, control and lead the project's progress by better based information based decisions enabled through the support of internet based information systems (WMS, WebGIS, and Statistic on the Web) which enable easy access and collection of project relevant data. Through an agreed frame of access all projects stakeholders are able to fulfil their tasks for information delivery in order to satisfy the client's expectation. At the end of construction works a consistent data pool is created, which can be used for the maintenance and facility management of the civil infrastructure project. The deconstruction can be assisted by using the model for removal of critical materials and parts.

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[TURTON]: Turton, D.; Jonas, D.; (2003); Airborne Laser Scanning – Cost effective spatial data; on: Map Asia Conference, Kuala Lumpur, Malaysia, 2003.

[UNIGIS04]: Unigis Module 04; Geo-Database Management; Chapter 12, Fundamentals of GeoDBMS; University of Salzburg.

[VAN DER MERWE, S. E.]: van der Merwe, S., E. (1997): Spatial Modelling and Decision Support for new Linear Developments.

[VENEZIANO]: Veneziano, David; Souleyrette, Reginald; Hallmark, Sauna; Evaluation of LIDAR for Highway planning, Location and design; Pecora 15 /Land Satellite Information IV/ISPRS Commission I/FIEOS 2002 Conference Proceedings

[WEISUN]: Sun, Wei; Hasell, M.,Jo.: Exploring a GIS Prototype to Improve the Management of the Architectural Design, Engineering and Construction Building Project Process, University of Florida, http://gis.esri.com/library/userconf/proc02/pap0212/p0212.htm

[WMS1.1.1]: Open Geospatial Consortium: Web Map Service Implementation Specification, Version 1.1.1, OpenGIS Project Document 01-068r3, 2002

[WMS1.3.0]: Open Geospatial Consortium: Web Map Service Implementation Specification, Version 1.3.0, OpenGIS Project Document 04-024, 2004

Glossary:

The renouncement for a glossary for GIS specific terms is declared by the very well organized and public accessible glossaries on the internet. To announce only a few:

ESRI Support Centre: GIS – Dictionary:
http://support.esri.com/index.cfm?fa=knowlegdebase.gisDictionary.gateway

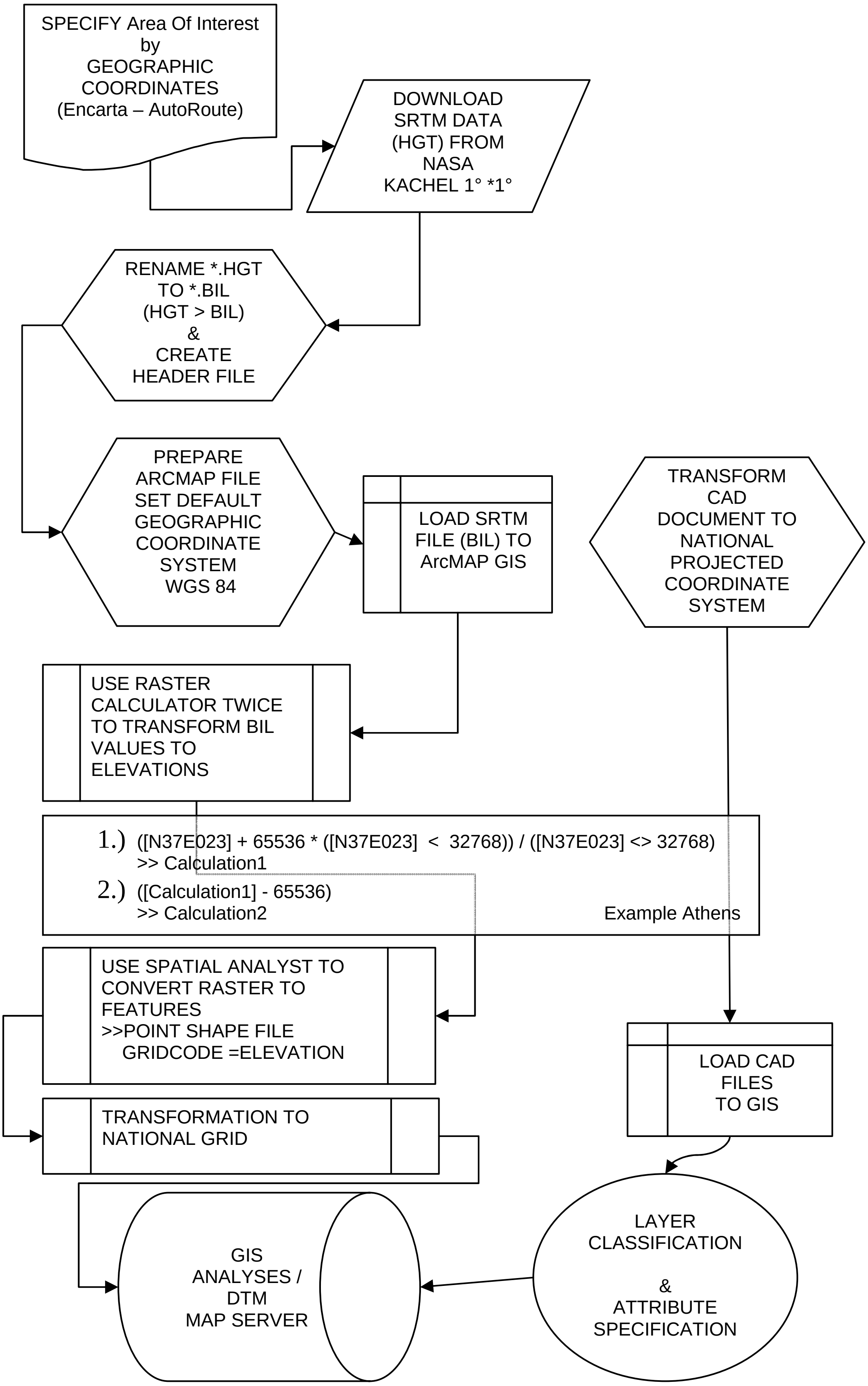
University of California, Berkley: Dictionary of Abbreviations and Acronyms:
Http://www.lib.berkeley.edu/EART/abbrev.html

Land*info*, Worldwide Mapping LLC:
Http://www.landinfo.com/resources_dictionaryAD.htm

University of Rostock: Geo informatics – Service: Wörterbuch
Http://www.geoinformatik.uni-rostock.de/lexikon.asp

University Of Edinburgh: Association of Geographic Information
Http://www.geo.ed.ac.uk/agidict/welcome.html

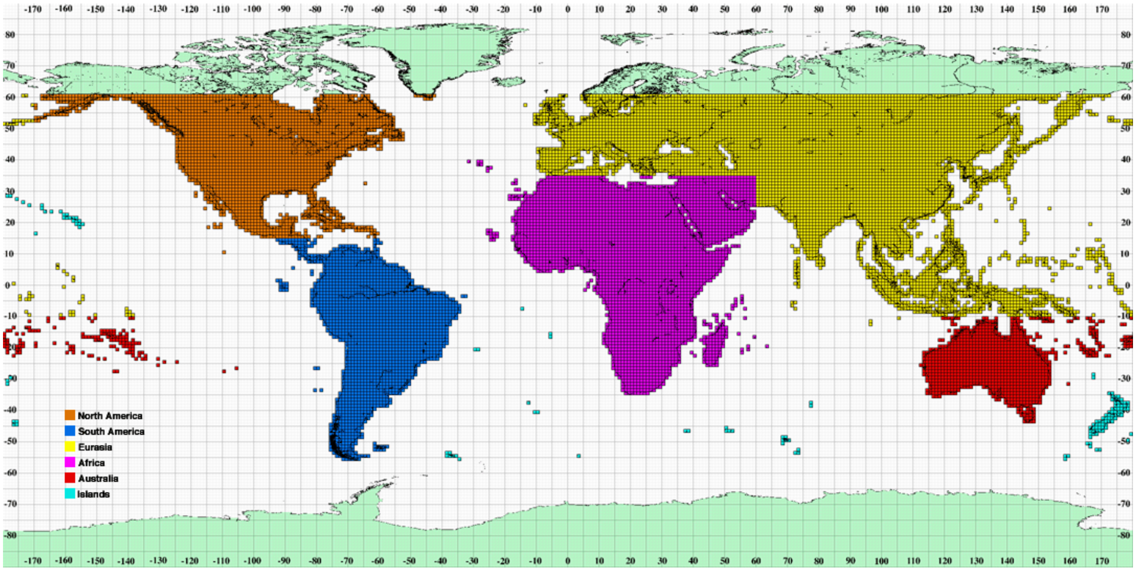
Appendix A
Preparation of SRTM data (NASA) and integration in Design Model



Appendix B
(Example: Area of New International Airport of Athens)

Determination of the geographical coordinates of the site.
(AutoRoute, Google Earth, EarthSat)

Determination of the Continent of location (continent_def) on
FTP://e0mss21u.ecs.nasa.gov/srtm/continent_def.gif)



Download file *.hgt.zip File (here N37E023.hgt.zip) from NASA web site
FTP://e0mss21u.ecs.nasa.gov/srtm/Eurasia

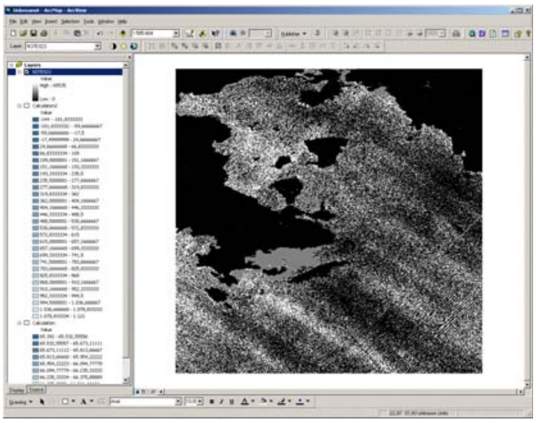
Unzip and rename the file to *.BIL
N37E023.hgt -> N37E023.BIL

Create Header file N37E023.hdr

```
BYTEORDER      M
LAYOUT         BIL
NROWS          1201
NCOLS          1201
NBANDS         1
NBITS          16
BANDROWBYTES   2402
TOTALROWBYTES  2402
BANDGAPBYTES   0
NODATA         -32768
ULXMAP         23,00
ULYMAP         38,00                    Latitude + 1
XDIM           0,000833333333333
YDIM           0,000833333333333
```

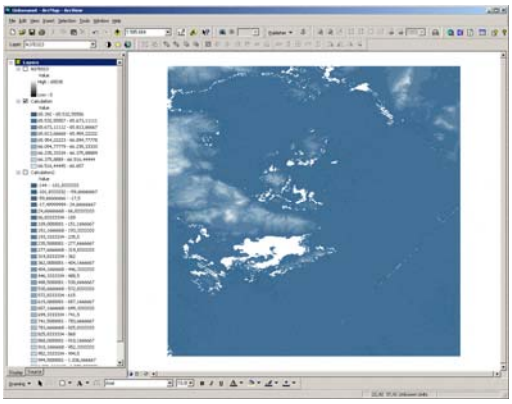
Appendix B (Example: Area of New International Airport of Athens)

Load BIL to ArcMAP
Here N37E023.BIL
Rename layer in ArcMAP to N37E023

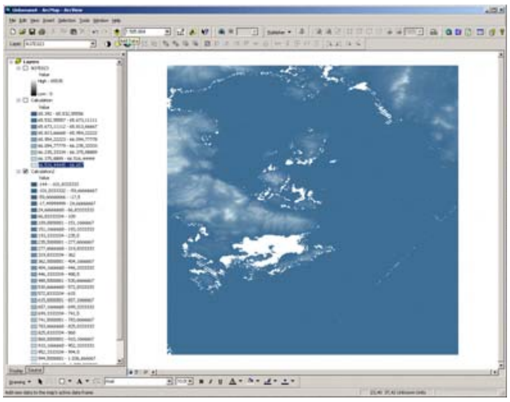


Use Raster Calculation 2 times for Conversion to elevation

A) ([N37E023] + 65536 * ([N37E023] < 32768)) / ([N37E023] <> 32768)
The resulting raster layer is named **Calculation**
B) ([**Calculation**] - 65536)

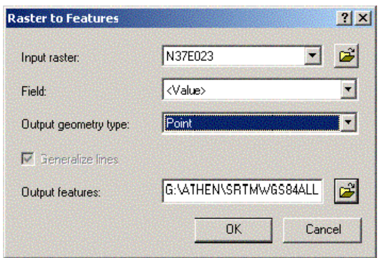


Result A



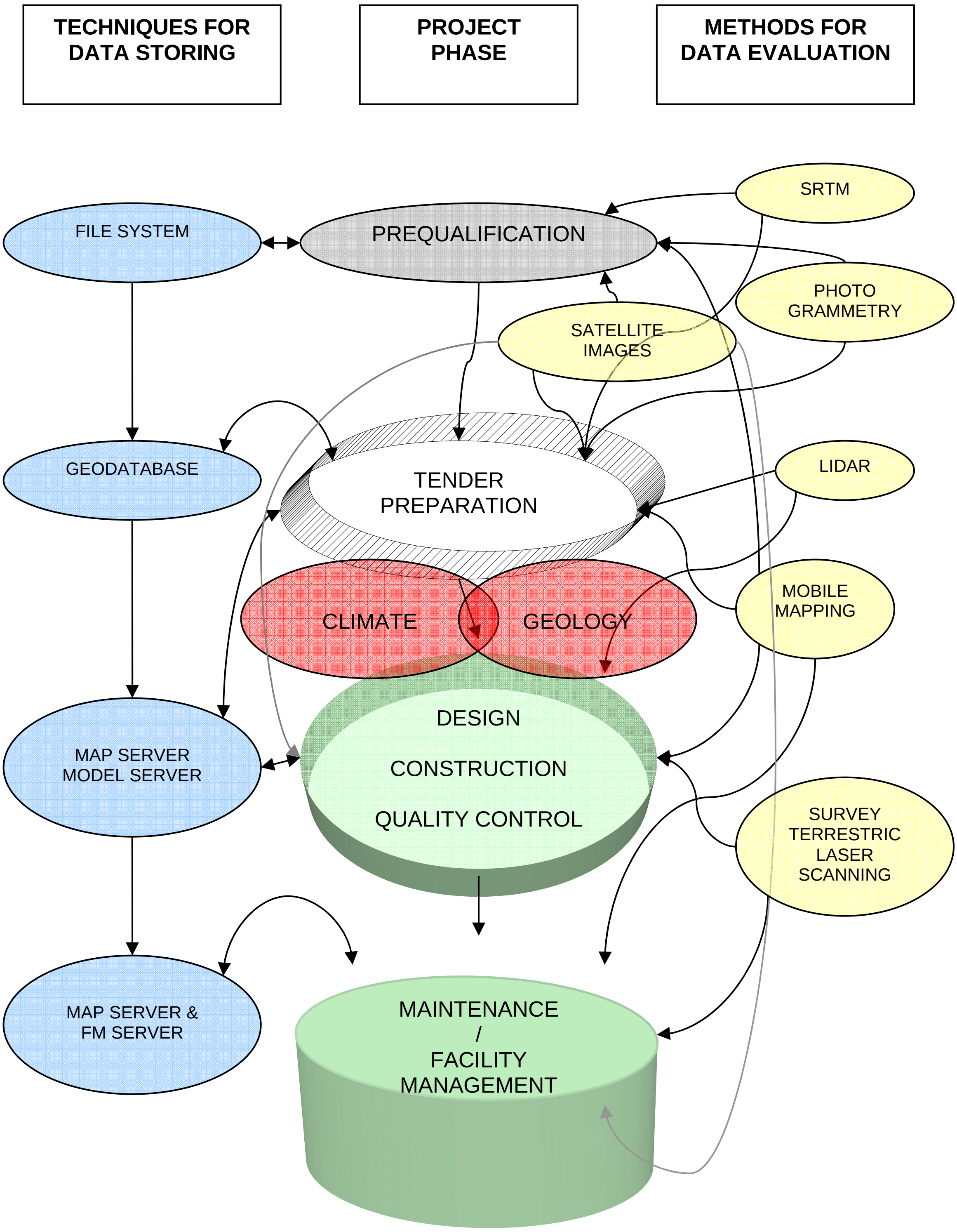
Result B

Use Conversion Raster to Features to generate Point shape file with elevations
Field Value for source of elevation



Transform to the National Coordinate System

Appendix C
Techniques for data storage – project phases – spatial data evaluation



Appendix D

Table of advantages using GIS technology in infrastructure project phases (Relevance for project stage)

Advantages	Pre-Qualification	Tender-Preparation	Design and Construction	Facility Management
Location of construction site worldwide (latitude, longitude) and in the certain nation (E,N)	X	X	X	X
Environment in the vicinity of the project (Cities, Roads, Ports, Airports, Water-resources, Quarries)	X	X	X	X
Climate and weather conditions	X	X		
Integration of Raster and Vector (CAD) based information	X	X	X	
Impact of the project to the environment	X			
Impact of the environment to the project	X			
Socio demographic data resource	X	X		
Integration of detailed design data, consolidation of data, Information pool,		X	X	X
First estimation of cost	X			
Alternatives for project implementation	X	X		
Support of decision making process	X	X	X	
Structure of data / Database, Integration of tables; spreadsheets; text files		X	X	X
Support of construction workflow (Planning, Procurement, Engineering, etc		X	X	
Overlay of different information sources	X	X		
Homogeneous environment for information presentation and dissemination	X	X	X	X
Support of Estimation		X	X	

Support of construction operation			X	X
Risk management, reduction of risks (technical and financial) because of entire integration and organisation of information	X	X	X	
Knowledge base for further constructions and tender preparations	X	X	X	X
Access for multiple users, worldwide internet, intranet		X	X	X
Better communications platform between actors - Interactions are possible	X			
Transparent information management for the client, and subcontractors			X	X
Interoperability (OGC – IFC), Easier communication of interfaces, buildings – civil		X	X	X
Monitoring the status of the project – statistics and graphical view for the status		X	X	
Compare As-Built with design			X	
Information platform for maintenance period			X	X
Collection of As-Built data during construction - As-Built model, Geo spatial referenced knowledge base for construction and claim management			X	X
Facility for operation due to changes forced by the market			X	X
Basis information for managing facilities				X
Basis for advertisement and tendering of similar infrastructure projects	X	X	X	X
Reduction of redundant information, central storage	X	X	X	X
Observation of impact of the construction to the environment			X	X
Management tool		X	X	X
Holistic view of the project	X	X	X	X

Appendix E
Example on Map-Server technology (New Athens International Airport)

```
#
# Start of map file
#
NAME ATHEN
STATUS ON
SIZE 600 600
EXTENT  486900 4193000 500000 4205911
#EXTENT  4193000 486900 4205911 500000
UNITS METERS
SHAPEPATH "c:\ms4w\data\athen\"
IMAGECOLOR 255 255 255

PROJECTION
  "init=epsg:2100"
END

FONTSET "c:/ms4w/data/athen/fonts/fonts.list"
SYMBOLSET "c:/ms4w/data/athen/symbol.sym"
#

#
# Start of web interface definition (including WMS enabling metadata)
#
WEB
  IMAGEPATH "c:\tmp\"
  IMAGEURL "/tmp"
  METADATA
    WMS_TITLE "Athen"
    WMS_ABSTRACT "Athen"
    WMS_FEES "none"
    WMS_FEATURE_INFO_MIME_TYPE "text/html"
    WMS_ONLINERESOURCE "http://htcdeess01c058.hochtief.org/cgi-bin/athenserv?"
    WMS_SRS "EPSG:2100"

   END
END

QUERYMAP
  SIZE 600 200
  STATUS ON
  STYLE HILITE
  COLOR 255 0 0
END

OUTPUTFORMAT
  NAME png
  DRIVER "GD/PNG"
  MIMETYPE "image/png"
  IMAGEMODE RGB
  EXTENSION "png"
END

#
# Start of reference map
#
REFERENCE
  IMAGE graphics/reference.gif
  EXTENT  486900 4193000 500000 4205911
  #EXTENT 4193000 486900 4205911 500000
```

```
  SIZE 120 120
  STATUS ON
  COLOR -1 -1 -1
  OUTLINECOLOR 255 0 0
END

#
# Start of legend
#
LEGEND
   STATUS ON
   KEYSIZE 40 20
   KEYSPACING 10 10
   IMAGECOLOR 255 255 255
   LABEL
      COLOR 0 0 0
      TYPE BITMAP
      SIZE MEDIUM
   END
END

#
# Start of scalebar
#
SCALEBAR
  IMAGECOLOR 255 255 255
  LABEL
    COLOR 255 255 255
    SIZE tiny
  END
  STYLE 1
  SIZE 80 2
  COLOR 255 255 255
  UNITS MILES
  INTERVALS 1
  TRANSPARENT TRUE
  STATUS TRUE
END


#
# Start of layer definitions
#

LAYER
   DEBUG ON
   DUMP TRUE
   NAME "Satellite"
   DATA "C:/ms4w/data/athen/shape/rectifyahensair2005.tif"
   #DATA "E:/projekte/iran/satellite/n30-e048_lr.tif"
   TYPE RASTER
   OFFSITE 255 255 255
   STATUS ON
   TRANSPARENCY 50
   PROJECTION
     "init=epsg:2100"
   END
   METADATA
      WMS_TITLE "Satellite"
      WMS_ABSTRACT "Satellite"
      WMS_SRS "EPSG:2100"
   END
END
```

```
LAYER
  DEBUG ON
  DUMP TRUE
  NAME "DigitalTerrainDesign"
  DATA "C:/ms4w/data/athen/shape/athensfin_08.tif"
  #DATA "E:/projekte/iran/satellite/n30-e048_lr.tif"
  TYPE RASTER
  OFFSITE 255 255 255
  STATUS ON
  TRANSPARENCY 50
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "DTM-DESIGN"
    WMS_ABSTRACT "DTM-DESIGN"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "DigitalTerrainOGL"
  DATA "C:/ms4w/data/athen/shape/athensOGL_08.tif"
  #DATA "E:/projekte/iran/satellite/n30-e048_lr.tif"
  TYPE RASTER
  OFFSITE 255 255 255
  STATUS ON
  TRANSPARENCY 60
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "DTM-OGL"
    WMS_ABSTRACT "DTM-OGL"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "GoogleSat_Design"
  DATA "C:/ms4w/data/athen/shape/rectifyathenairportgoogle_03.tif"
  TYPE RASTER
  OFFSITE 255 255 255
  STATUS ON
  TRANSPARENCY 60
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "GoogleSat_Design"
    WMS_ABSTRACT "GoogleSat_Design"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "DesignSlopes_deg"
  DATA "C:/ms4w/data/athen/shape/airtindeslope.tif"
```

```
  TYPE RASTER
  OFFSITE 255 255 255
  STATUS ON
  TRANSPARENCY 40
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "DesignSlopes_deg"
    WMS_ABSTRACT "DesignSlopes_deg"
    WMS_SRS "EPSG:2100"
  END
END


LAYER
  DEBUG ON
  DUMP TRUE
  NAME "building"
  DATA "c:/ms4w/data/athen/shape/airbuilding.shp"
  TYPE LINE
  STATUS ON
  CLASS
    NAME "Design-Building"
    COLOR 230 150 100
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Design-Building"
    WMS_ABSTRACT "Design-Building"
    WMS_SRS "EPSG:2100"
  END
END


LAYER
 NAME "OGL_AthensPl"
 #GROUP "Vector"
 DATA "c:/ms4w/data/athen/shape/OGL_AthensPl.shp"
 STATUS on
 TYPE Polygon
 TRANSPARENCY 51
 TOLERANCE 7
 TOLERANCEUNITS pixels

 METADATA
  WMS_SRS  "epsg:2100"
  WMS_TITLE "Original Ground Poly"
  WMS_GROUP_TITLE "Vector"
  WMS_FEATURE_INFO_MIME_TYPE "text/html"
 END #METADATA

 PROJECTION
  "init=epsg:2100"
 END

 CLASSITEM "Layer"

 CLASS
  NAME "22504"
  EXPRESSION ("Layer" eq "22504")
```

```
  STYLE
   COLOR 90 191 237
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

 CLASS
  NAME "23003"
  EXPRESSION ("Layer" eq "23003")

  STYLE
   COLOR 128 84 96
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

 CLASS
  NAME "23103"
  EXPRESSION ("Layer" eq "23103")

  STYLE
   COLOR 108 245 117
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

 CLASS
  NAME "23523"
  EXPRESSION ("Layer" eq "23523")

  STYLE
   COLOR 240 160 91
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

 CLASS
  NAME "23563"
  EXPRESSION ("Layer" eq "23563")

  STYLE
   COLOR 93 148 100
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

 CLASS
  NAME "23610"
  EXPRESSION ("Layer" eq "23610")

  STYLE
   COLOR 183 81 189
   OUTLINECOLOR 110 110 110
  END #STYLE
 END #CLASS

END #LAYER



LAYER
   DEBUG ON
   DUMP TRUE
   NAME "lines"
```

```
  DATA "c:/ms4w/data/athen/shape/airlnegsa.shp"
  TYPE LINE
  STATUS ON
   CLASS
    NAME "Design-Breaklines"
    COLOR 0 0 0
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Design-Breaklines"
    WMS_ABSTRACT "Design-Breaklines"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "Points"
  DATA "c:/ms4w/data/athen/shape/airpteg82.shp"
  TYPE POINT
  STATUS ON
  CLASS
    NAME "Design-Points"
    SYMBOL "kreis"
    SIZE 5
    COLOR 0 0 255
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Design-Points"
    WMS_ABSTRACT "Design-Points"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "obuilding"
  DATA "c:/ms4w/data/athen/shape/ogl_athenspl.shp"
  TYPE LINE
  STATUS ON
  CLASS
    NAME "Ogl-Building"
    COLOR 150 150 150
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Ogl-Building"
    WMS_ABSTRACT "Ogl-Building"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
```

```
  NAME "olines"
  DATA "c:/ms4w/data/athen/shape/ogl_athensln.shp"
  TYPE LINE
  STATUS ON
   CLASS
    NAME "Ogl-Breaklines"
    COLOR 255 0 0
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Ogl-Breaklines"
    WMS_ABSTRACT "Ogl-Breaklines"
    WMS_SRS "EPSG:2100"
  END
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "SRTM-points_Elev"
  #DATA "c:/ms4w/data/athen/shape/ogl_athenspt1.shp"
  DATA "c:/ms4w/data/athen/shape/srtm_in_Airport.shp"
  #DATA "c:/ms4w/data/athen/shape/ogl_athenspt1.shp"
  TYPE POINT
  STATUS ON
  LABELITEM "GRID_CODE"
  CLASS
    NAME "SRTM-points_Elev"
    SYMBOL "kreis"
    SIZE 3
    COLOR 255 0 255
      LABEL
        SIZE MEDIUM
        TYPE BITMAP
        COLOR 255 50 255
        POSITION UR
      END
  END

  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "SRTM-Points_Elev"
    WMS_ABSTRACT "SRTM-Points_Elev"
    WMS_SRS "EPSG:2100"
  END
  TOLERANCE 5
  TEMPLATE "SRTM_code.html"
  HEADER "SRTM_header.html"
  FOOTER "SRTM_footer.html"
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "srtmpoints"
  DATA "c:/ms4w/data/athen/shape/srtm_in_Airport.shp"
  TYPE POINT
  STATUS ON
  CLASSITEM "GRID_CODE"
  CLASS
```

```
    EXPRESSION "81"
    NAME "SRTM-Points rot"
    SYMBOL "kreis"
    SIZE 5
    COLOR 255 0 0
  END
  CLASS
    EXPRESSION "84"
    NAME "SRTM-Points blau"
    SYMBOL "kreis"
    SIZE 5
    COLOR 0 0 255
  END
  CLASS
    EXPRESSION /./
    NAME "Rest"
    SYMBOL "kreis"
    SIZE 5
    COLOR 0 0 0
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "SRTM-Points"
    WMS_ABSTRACT "SRTM-Points"
    WMS_SRS "EPSG:2100"
  END
  TOLERANCE 5
  TEMPLATE "SRTM_code.html"
  HEADER "SRTM_header.html"
  FOOTER "SRTM_footer.html"
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "Original_points"
  DATA "c:/ms4w/data/athen/shape/ogl_pt.shp"
  TYPE POINT
  STATUS ON
  LABELITEM "ELEVATION"
  CLASS
    NAME "OGL95-Points"
    SYMBOL "kreis"
    SIZE 2
    COLOR 255 0 255
    LABEL
      SIZE MEDIUM
      TYPE BITMAP
      COLOR 255 50 255
      POSITION UR
    END
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Ogl95-Points"
    WMS_ABSTRACT "Ogl95-Points"
    WMS_SRS "EPSG:2100"
  END
  TOLERANCE 5
  TEMPLATE "hoehen.html"
```

```
  HEADER "hoehen_header.html"
  FOOTER "hoehen_footer.html"
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "Utility_points"
  DATA "c:/ms4w/data/athen/shape/Example6Pt_Egsa_ano.shp"
  TYPE POINT
  STATUS ON
  LABELITEM "PKT_NR"
  CLASS
    NAME "MANHOLE"
    SYMBOL "kreis"
    SIZE 12
    COLOR 255 0 255
    LABEL
      SIZE MEDIUM
      TYPE BITMAP
      COLOR 255 50 255
      POSITION UR
    END
  END
  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Utility-Points"
    WMS_ABSTRACT "Utility-Points"
    WMS_SRS "EPSG:2100"
  END
  TOLERANCE 5
  TEMPLATE "UTIL_code.html"
  HEADER "UITL_header.html"
  FOOTER "UITL_footer.html"
END

LAYER
  DEBUG ON
  DUMP TRUE
  NAME "Utility_LINES"
  DATA "c:/ms4w/data/athen/shape/Example6Ln_Egsa.shp"
  TYPE LINE
  STATUS ON
  CLASSITEM "LAYER"
  CLASS
      EXPRESSION "1"
      NAME "Keine Zuordung"
      COLOR 255 0 0
    END
    CLASS
      EXPRESSION "23403"
      NAME "Culvert Watersystem"
      COLOR 0 0 255
    END
    CLASS
      EXPRESSION "23814"
      NAME "Fire Fighting SL"
      COLOR 0 250 155
    END
    CLASS
      EXPRESSION "23864"
      NAME "Protable Water SL"
```

```
  COLOR 50 60 155
END
CLASS
  EXPRESSION "23914"
  NAME "Culvert Watersystem"
  COLOR 0 60 255
END
CLASS
  EXPRESSION "24000"
  NAME "Sewer System MH R"
  COLOR 0 20 155
END
CLASS
  EXPRESSION "24054"
  NAME "Sewer System SL"
  COLOR 150 60 155
END
CLASS
  EXPRESSION "24084"
  NAME "Well Water SL"
  COLOR 150 0 0
END
    CLASS
      EXPRESSION "24100"
      NAME "StormWater MH R"
      COLOR 70 70 50
    END
    CLASS
      EXPRESSION "24110"
      NAME "StormWater MH S"
      COLOR 10 60 55
    END
    CLASS
      EXPRESSION "24113"
      NAME "Sand-Level"
      COLOR 0 20 155
    END
    CLASS
      EXPRESSION "24173"
      NAME "Storm Water ToP"
      COLOR 150 60 155
END
CLASS
          EXPRESSION "24193"
          NAME "Cable Duct ToP"
          COLOR 150 0 25
        END
        CLASS
          EXPRESSION "24350"
          NAME "Cable Duct"
          COLOR 200 70 225
        END
        CLASS
          EXPRESSION "24360"
          NAME "LAMP"
          COLOR 180 60 55
        END
        CLASS
          EXPRESSION "24383"
          NAME "Cable Duct MH R"
          COLOR 200 20 155
        END
        CLASS
          EXPRESSION "24600"
```

```
              NAME "Telephon Line"
              COLOR 150 150 155
    END
    CLASS
      EXPRESSION /./
      NAME "Rest"
      COLOR 0 0 0
  END

  PROJECTION
   "init=epsg:2100"
  END
  METADATA
    WMS_TITLE "Utility-LINES"
    WMS_ABSTRACT "Utility-LINES"
    WMS_SRS "EPSG:2100"
  END

END

LAYER
 DEBUG ON
 DUMP TRUE
 NAME "AirLnE82"
 TEMPLATE "AirLnE82_query.html"
 #GROUP "Vector_Info"
 DATA "C:/ms4w/data/Athen/shape/AirLnE82.shp"
 STATUS on
 TYPE Line
 TRANSPARENCY 50
 TOLERANCE 7
 TOLERANCEUNITS pixels

 METADATA
  WMS_SRS  "epsg:2100"
  WMS_TITLE "DesignLinesP"
  #WMS_GROUP_TITLE "Vector_Info"
  WMS_FEATURE_INFO_MIME_TYPE "text/html"
 END #METADATA

 PROJECTION
  "init=epsg:2100"
 END

 LABELITEM "Elevation"
 CLASSITEM "Layer"

 CLASS
  NAME "12000"
  EXPRESSION ("Layer" eq "12000")

  STYLE
   SYMBOL "kreis" #AirLnE82-0-0
   SIZE 2
   COLOR 63 158 68
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
```

```
END #CLASS

CLASS
 NAME "12110"
 EXPRESSION ("LAYER" eq "12110")

 STYLE
  SYMBOL AirLnE82-1-0
  SIZE 1
  COLOR 136 247 236
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12120"
 EXPRESSION ("LAYER" eq "12120")

 STYLE
  SYMBOL AirLnE82-2-0
  SIZE 1
  COLOR 205 131 242
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12200"
 EXPRESSION ("LAYER" eq "12200")

 STYLE
  SYMBOL AirLnE82-3-0
  SIZE 1
  COLOR 168 106 171
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12210"
 EXPRESSION ("LAYER" eq "12210")

 STYLE
```

```
  SYMBOL AirLnE82-4-0
  SIZE 1
  COLOR 194 125 72
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12510"
 EXPRESSION ("LAYER" eq "12510")

 STYLE
  SYMBOL AirLnE82-5-0
  SIZE 1
  COLOR 118 56 143
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12520"
 EXPRESSION ("LAYER" eq "12520")

 STYLE
  SYMBOL AirLnE82-6-0
  SIZE 1
  COLOR 178 160 250
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "12540"
 EXPRESSION ("LAYER" eq "12540")

 STYLE
  SYMBOL AirLnE82-7-0
  SIZE 1
  COLOR 156 232 121
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
```

```
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

 CLASS
  NAME "12610"
  EXPRESSION ("LAYER" eq "12610")

  STYLE
   SYMBOL AirLnE82-8-0
   SIZE 1
   COLOR 128 66 54
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

 CLASS
  NAME "12620"
  EXPRESSION ("LAYER" eq "12620")

  STYLE
   SYMBOL AirLnE82-9-0
   SIZE 1
   COLOR 200 204 94
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

 CLASS
  NAME "12630"
  EXPRESSION ("LAYER" eq "12630")

  STYLE
   SYMBOL AirLnE82-10-0
   SIZE 1
   COLOR 75 204 172
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS
```

```
CLASS
 NAME "12640"
 EXPRESSION ("LAYER" eq "12640")

 STYLE
  SYMBOL AirLnE82-11-0
  SIZE 1
  COLOR 154 196 130
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "13100"
 EXPRESSION ("LAYER" eq "13100")

 STYLE
  SYMBOL AirLnE82-12-0
  SIZE 1
  COLOR 227 79 89
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "13710"
 EXPRESSION ("LAYER" eq "13710")

 STYLE
  SYMBOL AirLnE82-13-0
  SIZE 1
  COLOR 91 179 212
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "13770"
 EXPRESSION ("LAYER" eq "13770")

 STYLE
  SYMBOL AirLnE82-14-0
  SIZE 1
```

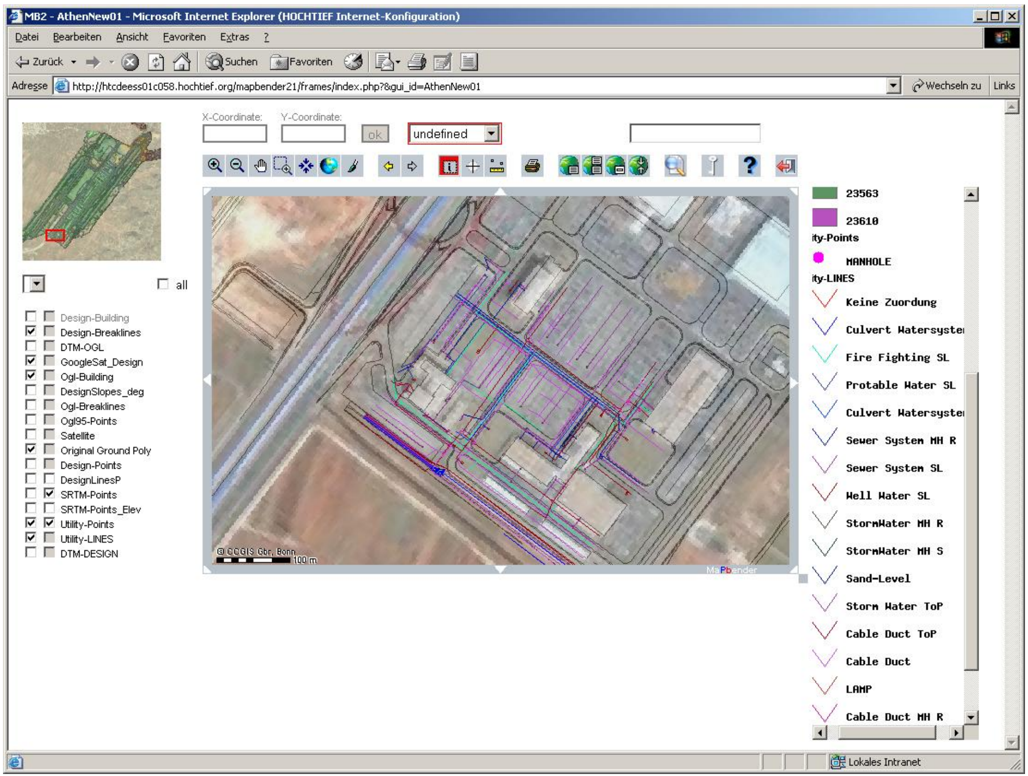
```
  COLOR 89 85 128
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "13780"
 EXPRESSION ("LAYER" eq "13780")

 STYLE
  SYMBOL AirLnE82-15-0
  SIZE 1
  COLOR 140 88 245
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14010"
 EXPRESSION ("LAYER" eq "14010")

 STYLE
  SYMBOL AirLnE82-16-0
  SIZE 1
  COLOR 240 181 153
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14420"
 EXPRESSION ("LAYER" eq "14420")

 STYLE
  SYMBOL AirLnE82-17-0
  SIZE 1
  COLOR 156 61 97
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
```

```
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14510"
 EXPRESSION ("LAYER" eq "14510")

 STYLE
  SYMBOL AirLnE82-18-0
  SIZE 1
  COLOR 87 128 130
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14520"
 EXPRESSION ("LAYER" eq "14520")

 STYLE
  SYMBOL AirLnE82-19-0
  SIZE 1
  COLOR 245 93 235
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14530"
 EXPRESSION ("LAYER" eq "14530")

 STYLE
  SYMBOL AirLnE82-20-0
  SIZE 1
  COLOR 128 124 60
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "14730"
```

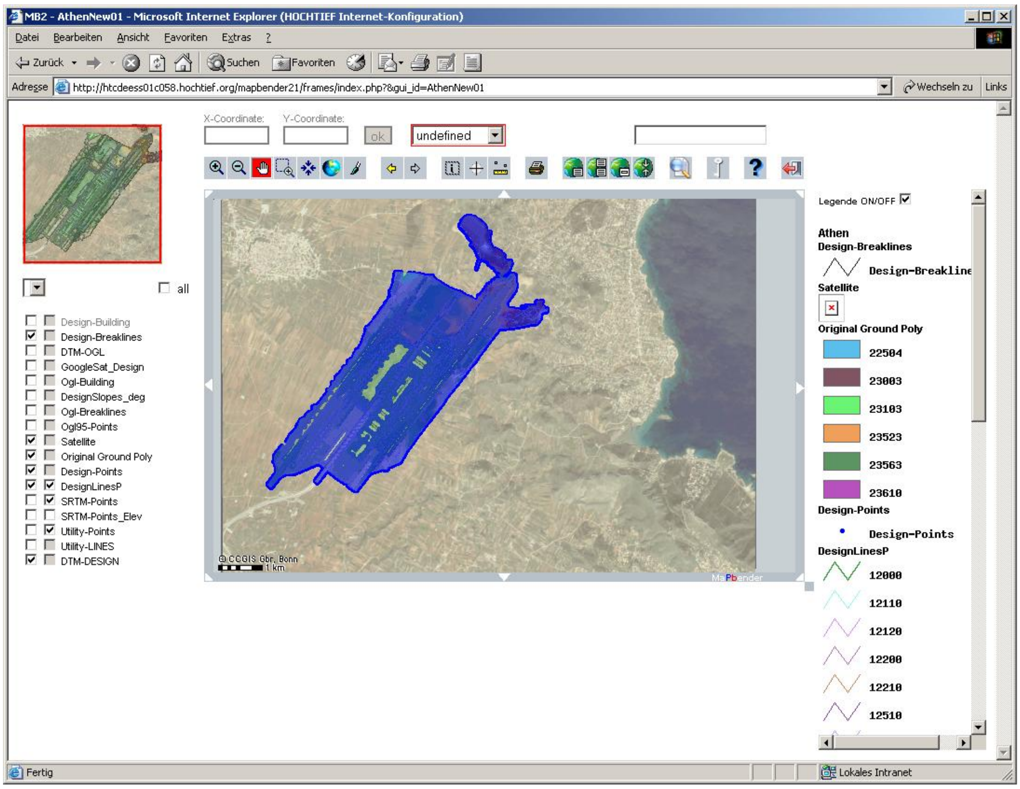
```
 EXPRESSION ("LAYER" eq "14730")

 STYLE
  SYMBOL AirLnE82-21-0
  SIZE 1
  COLOR 143 170 227
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "22000"
 EXPRESSION ("LAYER" eq "22000")

 STYLE
  SYMBOL AirLnE82-22-0
  SIZE 1
  COLOR 64 70 179
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "23523"
 EXPRESSION ("LAYER" eq "23523")

 STYLE
  SYMBOL AirLnE82-23-0
  SIZE 1
  COLOR 94 242 166
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "23563"
 EXPRESSION ("LAYER" eq "23563")

 STYLE
  SYMBOL AirLnE82-24-0
  SIZE 1
  COLOR 207 74 165
 END #STYLE
```

```
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "25000"
 EXPRESSION ("LAYER" eq "25000")

 STYLE
  SYMBOL AirLnE82-25-0
  SIZE 1
  COLOR 90 133 232
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "32100"
 EXPRESSION ("LAYER" eq "32100")

 STYLE
  SYMBOL AirLnE82-26-0
  SIZE 1
  COLOR 173 116 134
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
 END #LABEL
END #CLASS

CLASS
 NAME "32170"
 EXPRESSION ("LAYER" eq "32170")

 STYLE
  SYMBOL AirLnE82-27-0
  SIZE 1
  COLOR 73 135 96
 END #STYLE
 LABEL
  TYPE BITMAP
  SIZE tiny
  COLOR 0 0 0
  POSITION CR
  ANGLE 0
  OFFSET 0 0
```

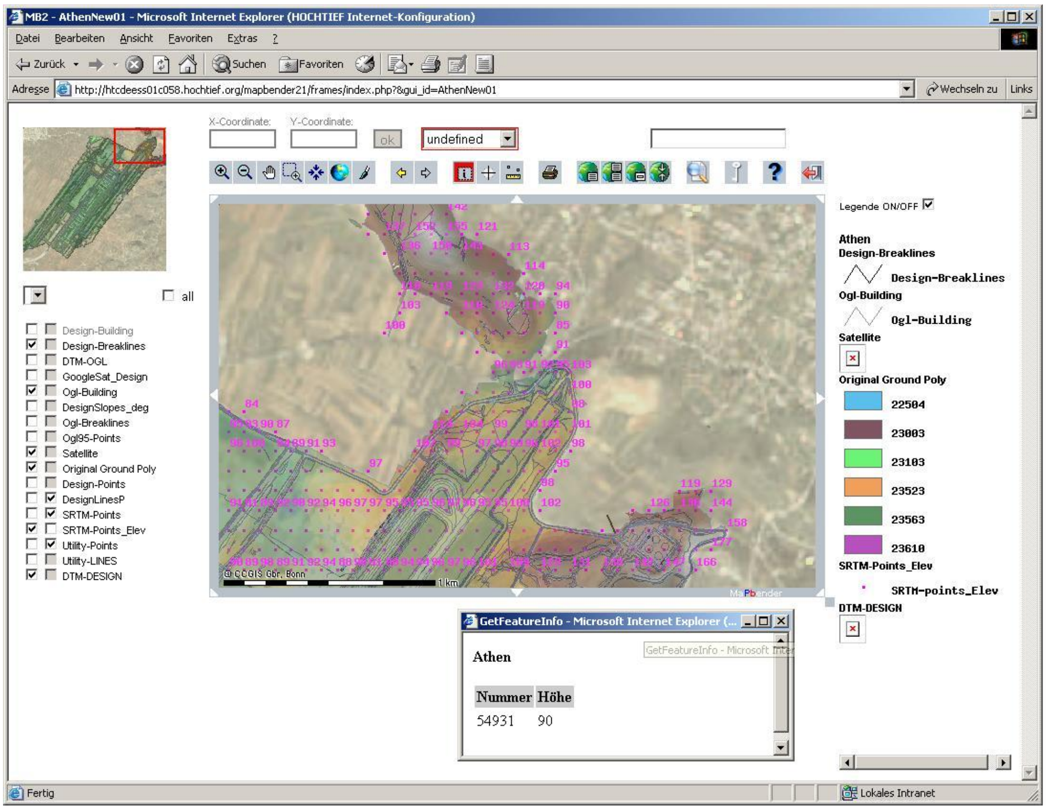
```
  END #LABEL
 END #CLASS

 CLASS
  NAME "32500"
  EXPRESSION ("LAYER" eq "32500")

  STYLE
   SYMBOL AirLnE82-28-0
   SIZE 1
   COLOR 245 137 187
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

 CLASS
  NAME "32670"
  EXPRESSION ("LAYER" eq "32670")

  STYLE
   SYMBOL AirLnE82-29-0
   SIZE 1
   COLOR 145 118 96
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

 CLASS
  NAME "AF_SCHWARZ"
  EXPRESSION ("LAYER" eq "AF_SCHWARZ")

  STYLE
   SYMBOL AirLnE82-30-0
   SIZE 1
   COLOR 117 250 87
  END #STYLE
  LABEL
   TYPE BITMAP
   SIZE tiny
   COLOR 0 0 0
   POSITION CR
   ANGLE 0
   OFFSET 0 0
  END #LABEL
 END #CLASS

END #LAYER

END # Map File
```



Satellite Image, various utility systems on New Athens International Airport (selection)



Satellite Image, 220000 Design points for Airfield, Runway, Taxiway as well as untouched areas



STRM Point Layer, Satellite Image and Result of Inquiry

Appendix F

Assessment of capacity for dam construction site
(Example from Caterpillar Performance Handbook; edition 32; German version)
(Caterpillar Inc., Peoria, Illinois, USA; October2001)

Beispiel

Ein Unternehmer will die folgenden Maschinen bei Dammbauarbeiten einsetzen. Zu ermitteln sind die geschätzte Produktionsleistung und die Kosten pro fm³.

Maschinen:
11 Schürfzüge 631E
2 Kettendozer D9N mit Schubschild
2 Motorgrader 12G
1 Verdichter 825C mit Stampffußwalzen

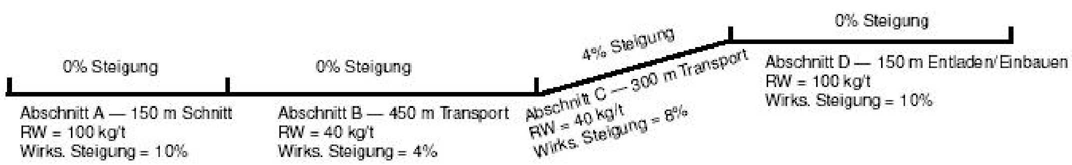
Material:
Beschreibung — Sandiger Ton; feuchtes, natürlich gewachsenes Material
Raumgewicht — 1770 kg/fm³
Ladefaktor — 0,80
Schrumpffaktor — 0,85
Bodenschlusskoeffizient — 0,50
Höhe über NN — 2300 m

Baustellenanlage — Transport und Rückfahrt

1. Schätzen der Schürfkübellast:
Geschätzte Ladung (lm³) × LF × Raumgewicht = Schürfkübellast
24 lm³ × 0,80 × 1770 kg/fm³ = 34 000 kg Last

2. Gewicht der Maschine:
Leergewicht — 40 000 kg oder 40 t
Gewicht der Ladung — 34 000 kg oder 34 t
Insgesamt (BGF) — 74 000 kg oder 74 t

3. Berechnen der nutzbaren Zugkraft (Begrenzung durch Bodenschluss):
Beladen: (Gewicht auf Antriebsrädern: 54% des BGF)
Bodenschlusskoeffizient × Gewicht auf Antriebsrädern = 0,50 × 74 000 kg × 54% = 19 980 kg (196 kN)
Leer: (Gewicht auf Antriebsrädern: 69% des BGF)
Bodenschlusskoeffizient × Gewicht auf Antriebsrädern = 0,50 × 40 000 kg × 69% = 13 800 kg (135 kN)



Gesamte wirksame Steigung = RW (%) ± SW (%)
Abschnitt A: Ges. wirks. Steigung = 10% + 0% = 10%
Abschnitt B: Ges. wirks. Steigung = 4% + 0% = 4%
Abschnitt C: Ges. wirks. Steigung = 4% + 4% = 8%
Abschnitt D: Ges. wirks. Steigung = 10% + 0% = 10%

4. Höhenbedingter Leistungsabfall:
Die bei 2300 m Höhe verfügbare Leistung ist in der entsprechenden Tabelle im Abschnitt "Tabellen" zu ermitteln.

631E — 100%	12G — 85%
D9N — 100%	825C — 94%

Gegebenenfalls sind Anpassungen vorzunehmen:

Zeit zum Laden — bestimmt von D9N bei 100% Motorleistung, keine Änderung.

Zeit zum Fahren, Manövrieren und Verteilen — 631E, keine Änderung.

5. Gegenüberstellung von Gesamtwiderstand und nutzbarer Zugkraft beim Transport:

Steigungswiderstand —
SW = 10 kg/t × t × Prozentzahl der Steigung
Abschnitt C: 10 kg/t × 74 t × 4 (% Steigung) = 2960 kg

Rollwiderstand —
RW = RW-Faktor (kg/t) × BGF (t)
Abschnitt A: 100 kg/t × 74 t = 7400 kg
Abschnitt B: 40 kg/t × 74 t = 2960 kg
Abschnitt C: 40 kg/t × 74 t = 2960 kg
Abschnitt D: 100 kg/t × 74 t = 7400 kg

Gesamtwiderstand —
GW = RW + SW
Abschnitt A: 7400 kg + 0 = 7400 kg
Abschnitt B: 2960 kg + 0 = 2960 kg
Abschnitt C: 2960 kg + 2960 kg = 5920 kg
Abschnitt D: 7400 kg + 0 = 7400 kg

Vergleichen Sie die nutzbare Kraft mit der zum Bewegen des 631E (maximal) erforderlichen Kraft.

Nutzbare Kraft: 196 kN = 19 980 kg beladen
Erforderliche Kraft: 73 kN = 7400 kg max. Gesamtwiderstand

Die Fahrzeit für den Transport ist anhand des Fahrzeitdiagramms für den 631E (beladen) zu schätzen; die Fahrzeit richtet sich nach Streckenlänge und Gesamtwiderstand.

Fahrzeit (aus dem Diagramm)
Abschnitt A: 0,60 min
Abschnitt B: 1,00 min
Abschnitt C: 1,20 min
Abschnitt D: 0,60 min
3,40 min

ANMERKUNG: Dies ist nur eine Schätzung; bei ihr *werden Beschleunigungs- und Bremszeiten nicht erfasst,* daher ist sie nicht so genau wie die Ergebnisse einer Computerberechnung.

6. Gegenüberstellung von Gesamtwiderstand und nutzbarer Zugkraft bei der Rückfahrt:

Gefälleschub —
GS = 10 kg/t × BGF (t) × Prozentzahl des Gefälles
Abschnitt C: 10 kg/t × 40 t × 4 (% Gefälle) = 1600 kg

Rollwiderstand —
RW = RW-Faktor × BGF
Abschnitt D: 100 kg/t × 40 t = 4000 kg
Abschnitt C: 40 kg/t × 40 t = 1600 kg
Abschnitt B: 40 kg/t × 40 t = 1600 kg
Abschnitt A: 100 kg/t × 40 t = 4000 kg

Gesamtwiderstand —
GW = RW – GS
Abschnitt D: 4000 kg – 0 = 4000 kg
Abschnitt C: 1600 kg – 1600 kg = 0
Abschnitt B: 1600 kg – 0 = 1600 kg
Abschnitt A: 4000 kg – 0 = 4000 kg

Vergleichen Sie die nutzbare Kraft mit der zum Bewegen des 631E maximal erforderlichen Kraft.

Nutzbare Kraft: 135 kN = 13 800 kg leer
Benötigte Kraft: 39 kN = 4000 kg

Die Fahrzeit für die Rückfahrt ist dem Fahrzeitdiagramm für den 631E (leer) zu entnehmen.

Fahrzeit (aus dem Diagramm)
Abschnitt A: 0,40 min
Abschnitt B: 0,55 min
Abschnitt C: 0,80 min
Abschnitt D: 0,40 min
2,15 min

7. Schätzen der Arbeitstaktzeit:

Fahrzeit insgesamt (Transport plus Rückfahrt)	= 5,55 min
Höhenanpassung: 100% × 5,55 min	= 5,55 min
Ladezeit	= 0,7 min
Zeit zum Manövrieren und Entladen	= 0,7 min
Gesamte Arbeitstaktzeit	= 6,95 min

8. Überprüfung der Kombination von Schubeinheit und Schürfzug:

Die Arbeitstaktzeit der Schubmaschine besteht aus der Zeit zum Laden, Andocken, Zurückfahren und Manövrieren. Wenn keine tatsächlichen Einsatzdaten vorhanden sind, können die folgenden Angaben verwendet werden.

Zeit zum Andocken	= 0,10 min
Rückfahrzeit	= 40% der Ladezeit
Manövrierzeit	= 0,15 min
Arbeitstaktzeit der Schubeinheit	= 140% der Ladezeit + 0,25 min
Arbeitstaktzeit der Schubeinheit	= 140% von 0,7 min + 0,25 min = 0,98 + 0,25 = 1,23 min

Wenn die Arbeitstaktzeit des Schürfzugs durch die Arbeitstaktzeit der Schubeinheit dividiert wird, ergibt dies die Anzahl der Schürfzüge, die von jeder Schubeinheit geschoben werden können.

$$\frac{6{,}95 \text{ min}}{1{,}23 \text{ min}} = 5{,}65$$

Jede Schubeinheit ist in der Lage, während der Arbeitstaktzeit des Schürfzugs etwas mehr als fünf eigene Arbeitstakte durchzuführen. Daher können zwei Schubeinheiten für elf Schürfkübel eingesetzt werden.

9. Schätzen der Leistung:

Arbeitstakte/h	= 60 min ÷ gesamte Arbeitstaktzeit = 60 min/h ÷ 6,95 min/Takt = 8,6 Takte/h
Geschätzte Ladung	= Kapazität gehäuft × LF = 24 lm³ × 0,80 = 19,2 fm³
Leistung der Einheit pro Stunde	= Geschätzte Ladung × Takte/h = 19,2 fm³/Takt × 8,6 Takte/h = 165 fm³/h
Angepasste Leistung	= Nutzungsfaktor × Leistung pro Stunde = 0,83 (50 min/h) × 165 fm³ = 137 fm³/h
Leistung der Flotte pro Stunde	= Leistung der Einheit × Anzahl der Einheiten = 137 fm³/h × 11 Einheiten = 1507 fm³/h)

10. Schätzen der Verdichtung:

Erforderliche Verdichtungsleistung = SF × Leistung der Flotte pro Std.
= 0,85 × 1507 fm³/h
= 1280 verdichtete m³/h

Verdichtungskapazität (bei den folgenden Voraussetzungen):

Verdichtungsbreite 2,26 m	(B)
Durchschnittliche Verdichtergeschwindigkeit 9,6 km/h	(G)
Verdichtete Schichtdicke 18 cm	(S)
Anzahl der benötigen Übergänge 3	(A)

Leistung des 825C =

$$\text{Verdichtete m}^3\text{/h} = \frac{B \times G \times S \times 10 \text{ (Umrechnungsfaktor)}}{A} = \frac{2{,}26 \times 9{,}6 \times 18 \times 10}{3} = 1302$$

Wenn eine Verdichtungsleistung von 1280 m³/h gefordert wird, ist der Verdichter 825C die geeignete Ergänzung der Flotte. Jede Änderung der Einsatzbedingungen, durch die die Leistung der Flotte erhöht wird, würde diese Eignung jedoch in Frage stellen.

11. Schätzen der Gesamtkosten pro Stunde:

631E	$65,00/h ×	11 Einheiten	= $ 715,00
D9N	$75,00/h ×	2 Einheiten	= $ 150,00
12G	$15,00/h ×	2 Einheiten	= $ 30,00
825C	$40,00/h ×	1 Einheit	= $ 40,00
Fahrer	$20,00/h ×	16 Personen	= $ 320,00
Vorhalte- und Betriebskosten insgesamt pro Stunde			$1255,00

12. Kalkulation:

$$\text{Kosten pro fm}^3 = \frac{\text{Gesamtkosten/h}}{\text{Leistung/h}} = \frac{\$1255/\text{h}}{1507 \text{ fm}^3/\text{h}} = \$0{,}83/\text{fm}^3$$

ANMERKUNG: Durch Berechnungen zum tkm/h-Wert der Schürfzugreifen muss festgestellt werden, ob sie unter diesen Bedingungen gefahrlos arbeiten können.

13. Weitere Überlegungen:

Wenn andere Maschinen wie Aufreißer, Wasserwagen, Scheibeneggen für einen Einsatz benötigt werden, müssen auch diese in die Kostenberechnung einbezogen werden.