Urban planning combining soil data and urban structure characteristics in GIS

M.W.A. HOUNJET[1] & D.J.M. NGAN-TILLARD[2]

[1] GeoDelft. (e-mail: m.w.a.hounjet@geodelft.nl)
[2] TUDelft. (e-mail: D.J.M.Ngan-Tillard@citg.tudelft.nl)

Abstract: Dutch people used to build residences on higher and stable locations in the Netherlands. Nowadays, most of these locations are occupied and urban development occurs in areas where soils are weak and heterogeneous. Although planning sites are geologically variable, it is common that planning and construction processes are similar and engineering geological differences between and within sites are ignored. As a result, many municipalities have financial problems due to the fact that differential settlement has damaged roads and sewer systems.

A pilot study for a location near Rotterdam showed that when engineering-geological information is integrated in the planning process, sensitive structures like roads and sewers can be allocated in areas where soil conditions are relatively good. Maintenance costs for sensitive structures decrease considerably.

The study is based on the use of GIS to combine different qualities of soil and characteristics of structures (roads, sewers, parks, industrial areas and houses). For each structure the best engineering geological locations are indicated and this information is used to create an optimal urban planning design.

GeoDelft has used this study to help municipalities in urban planning processes. The municipalities of Almere and Delft are examples.

Almere had three different pre-existing designs for a new urban area. GeoDelft used engineering-geological information to create a design and to indicate which one of the other designs would be most suitable and less expensive. A continuation of the study indicated which different construction methods would be most suitable for different constructions.

The design for the area in Delft was already finished and could not be changed. Therefore, the emphasis of the study was to indicate the differences in soil conditions and construction methods. An insight was obtained into the expense and the period of time for different land parcels. This helps to generate a time schedule and to indicate prices for each parcel.

Résumé: Les Hollandais ont toujours construé leur habitations dans les régions plus élevées et plus seches d'Hollande. À present, la plupart de ces régions est occupé et l'urbanisme se situe dans les régions òu la terre est mou et très hétérogène. Meme si les localisations sont different dans la géologique, le processus d'urbanisme et le processus de construction sont identiques: Les differences geotechniques sont ignoré. De ce fait, beaucoup des municipalités ont des problèmes financiers parce que les routes et le système d'égouts sont abîmé par la consolidation différentielle.

Les rèsultats d'un projet pilote pour une localisation proche de Rotterdam, monteraient que quand des donneés sont usé dans le processus de l'urbanisme, les éléments sensibles (les routes et les égouts) sont placé aux localisations òu la terre est mieux. Les dépenses pour réparer les éléments sensibles sont réduit au maximum.

Cette étude ce base sur l'application de GIS pour combiner les qualités differentes de la terre et les caractéristiques des éléments du quartier (des routes, des jardins publics, des sysèmes d'égouts, des blocs d'habitation, des zones industrielles). Pour chaque élément les meilleurs localisations sont calculé et cette information est utilisé pour créer un plan d'urbanisme optimal.

GeoDelft utilise cette étude pour aider des municipalités dans le processus d'urbanisme. Almere Pampus et Delft Technopolis sont des examples. Il y avait déjà trois plans d'urbanisme pour Almere Pampus. GeoDelft a utilisé des données de la geologie et de la géotechnique pour créer un plan d'urbanisme et pour indiquer quel des autres plans était le meilleur et le plus économique.

Le plan d'urbanisme de Delft Technopolis était definitif. De ce fait, l'étude se concentrait sur les différences des qualités de la terre et les différences des méthodes de construction. Le resultat était de la comprehension des dépenses et de la durée pour construire les parcelles de terrain. Cela avait aider le municipalité de Delft a créer un emploi du temps et a indiquer des prix pour les parcelles.

Keywords: case studies, data visualisation, geodata, geographic information systems, planning,urban geosciences.

INTRODUCTION

VINEX-locations are being established throughout the Netherlands. These new neighbourhoods are required to provide enough houses for new households in the coming decades. The VINEX neighbourhoods are designed and built according to a new way of thinking: sustainable development. Buildings are constructed with recycled material or materials that can be re-used. The design of the neighbourhood can also be used in the future for other purposes than residential quarters.

Throughout the Netherlands, similar 'sustainable' neighbourhoods are being built, regardless of the subsoil conditions. Municipalities that have to deal with worse soil conditions, for instance in the western part of the Netherlands, adopt standard lay-outs for their new quarters. They spend fortunes on maintaining their roads and sewers that keep on settling. The inhabitants of these neighbourhoods also have to cope with considerable inconvenience as well: the recurrence of road repairs, the continuing settlement of their gardens and driveways and the nuisance associated with damage to the sewage network; flooding, smell and health hazard.

When the subsoil conditions of a new site are taken into account, worse and better locations can be pointed out and used in the planning process. Different types of development within a neighbourhood (residential quarters, business quarters, infrastructure and recreational areas) have different sensitivities to poor ground conditions. When an area with good ground conditions is allocated to a very sensitive development, construction and, particularly, maintenance costs can be minimised.

In this paper, the added value of integrating subsurface information in the planning of VINEX-locations is demonstrated, using 2 sites: Almere Pampus and Delft Technopolis. A stepped strategy, developed to design new neighbourhoods based on ground engineering performance, is described and applied to these sites. Savings made on the maintenance costs of road and sewers are quantified and shown to be substantial for Almere Pampus. The municipality of Delft used the information for ongoing discussions with the architect.

METHODOLOGY

The methodology for implementing geotechnical information into the planning process is based on the fact that different development types that are built within a VINEX-location have different sensitivities to the quality of the subsoil. This is related to the construction method (see Table 1). These sensitivities indicate the need for certain development types to be built on appropriate locations. These appropriate locations can be different for each development type and depend on the combination of subsoil properties: depth to foundation layer, thickness of weak Holocene soils (and therefore settlement and differential settlement), depth to groundwater level, etc (see Table 2). To combine these properties, a GIS is used.

Table 1. Development types and construction methods

Residential Quarters	Above ground	High-rise Low-rise Gardens	Piles Piles Embankment
Business Quarters	Subterranean	Car park	Excavation
	Commercial area	High-rise Low-rise Parking space	Piles Piles Embankment
	Industrial area	High-rise Low-rise Heavy equipment Parking space	Piles Piles Piles/embankment Embankment
Infrastructure	Above ground	Roads Tram/metro bridge	Embankment Piles
	Subterranean	Viaducts	Excavation/Boring
Utilities	Subterranean	Sewers Cables + pipelines	Excavation No dig/excavation
Recreation/sports	Aboveground	Public gardens Sports fields	Embankment/excavation Embankment
	Water	Open water Ditches	Excavation Excavation

Table 2. Construction methods and their sensitivity to geological, geotechnical and hydrological aspects.

		Sensitivity		
		Piles	**Embankment**	**Excavation**
Geology	Foundation layer	++	+	+
	Stratigraphy	+	++	++
Geotechnics	Shear strength	+	+	++
	Settlement	-	++	+
	Diff. Settlement	-	++	+
Hydrology	Groundwater level	-	+	++
	Groundwater flow	-	-	+
	Exc.p.w. pressure	-	-	++
	Peak storage	-	+	-
	Heat storage	-	-	-
	Fresh-salt contact	+	-	+

++very sensitive + sensitive - not sensitive

The results of these combinations are maps for each development type which indicate different grades from good to bad and the most suitable location for each development type. These maps can be combined in a certain way to create an urban design. The creation of this design is based on the rule that certain development types have a priority in the choice of locations within the site. For example, Table 3 shows how maintenance costs increase when roads and sewers are built on or in poor soil conditions.

Table 3. Indication of maintenance cost increase when building on or in certain soil conditions.

Soil conditions	Roads	Sewers
Sand	100 %	100%
Loam	138 %	117%
Clay	200 %	137%
Peat	238 %	300%
Peat > 12 m thickness	325 %	467%

In the following paragraphs the methodology and its use in each municipality is explained.

ALMERE PAMPUS

The municipality of Almere is planning on building a new neighbourhood of 800 ha (Figure 1). Three architects had already assessed the area and produced three different urban designs. The municipality of Almere wanted to determine the influence of the subsoil on the sustainability of their new neighbourhood and asked for an evaluation of the three existing designs and for a new design solely based on subsoil information.

Figure 1. Project area of Almere Pampus.

The following information was available for the study (Figure 2):

- Depth to the Pleistocene sand layer;
- Thickness of the weak Holocene soil layers
- Foundation depth for light buildings
- Settlement indication for load of 1 m of sand
- The good/bad soil map of TNO-NITG

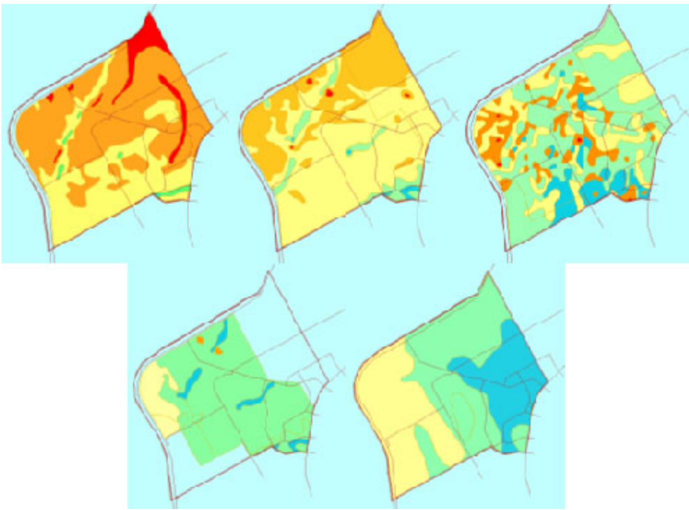

Figure 2. Mapped information on the subsoil of Almere Pampus.

This subsoil information is used to establish a list with the preferred conditions of the subsoil for each neighbourhood function. These conditions are combined in GIS for each function to create maps which indicate the most suitable location. Figure 3 shows the suitability maps for residences, infrastructure and parks and water. The red coloured locations are the worst locations for a certain function. Blue colours represent the best locations. The centre map represents the suitability map for infrastructure. As can be seen from the differences in green and blue areas in comparison with the first map (for residences), infrastructure is more sensitive to worse soil conditions than buildings on piles. Therefore, the suitable location for infrastructure is much smaller.

Figure 3. Suitability maps for residence, infrastructure and parks and water.

In the next step the suitability maps are combined by taking into account the sensitivity of each function, in order to create a neighbourhoud design (Figure 4). Red colours represent the residences, grey is main infrastructure, green areas are parks and blue is water. Figure 3 shows that the best locations for residences and infrastructure are in the South part of the building area. Unfortunately this area is now a park and should remain intact as much as possible. Therefore, green and blue connections are created from the remaining park, South of the area, to the most suitable locations for parks and water in the new neighbourhood.

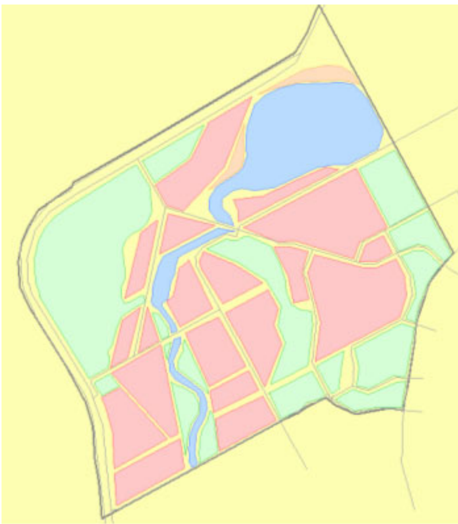

Figure 4. Neighbourhood design for Almere Pampus. The design is based on suitability of the subsoil for certain neighbourhood functions.

The other three designs for Almere Pampus are very different from the design based on the soil conditions and from each other (Figure 5). These four designs are compared to each other in terms of the “good” hectares that are used for each function (Figure 6a and b), with a calculation for maintenance costs and the amount of sand needed to prepare the soil for building.

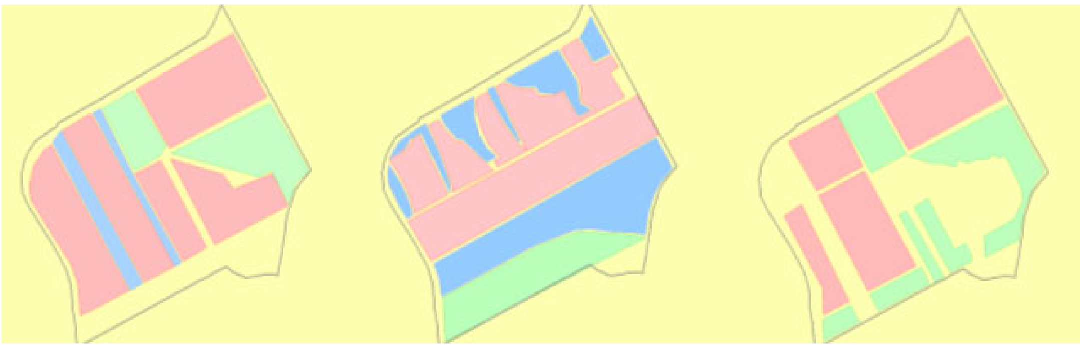

Figure 5. The three designs for Almere Pampus made by architects.

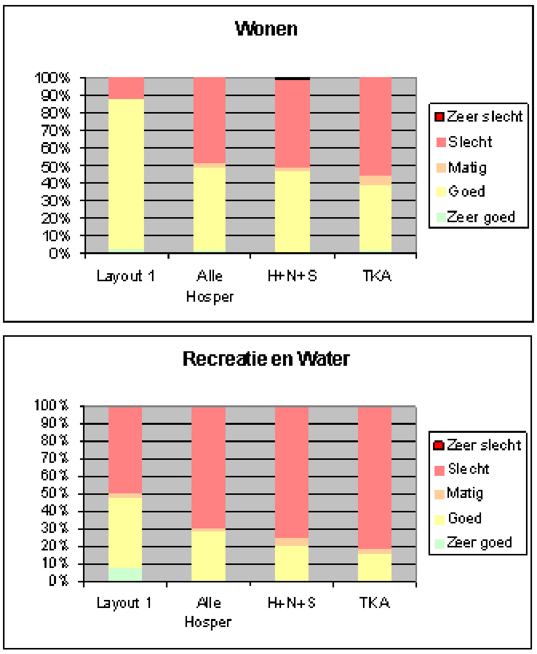

Figure 6. Green and yellow colours represent the percentage of the development type residences (a), and parks and water (b), situated on suitable soil conditions. The first column presents the results for the design based on soil conditions.

As can be seen in Figures 6a and b, it is clear that higher percentages of the residences and parks and water development types from the three designs by architects are situated on unsuitable soil conditions (the red columns) when compared to the first column (results for the design based on soil conditions).

When roads are constructed on soils that are prone to settlement, more sand is needed to create stable road constructions. When the four designs are compared to each other in the amount of sand needed to make sure that the building area is ready to be built on, it is calculated that the design based on soil conditions needs 1000 m^3 of sand less per ha than the other three designs.

Furthermore, maintenance costs are calculated. The fourth design was most similar to the design based on soil conditions. When maintenance costs are calculated for a period of 50 years, the fourth design is 20% more expensive than the design created in this study.

The municipality of Almere was interested in the design based on soil conditions, and a similar study will be performed for this area to find out where the ideal locations for water storage will be. After this, it can be implemented in the design as described.

DELFT TECHNOPOLIS

For the area in the municipality of Delft, Technopolis, there was no flexibility left in the design for the area. Figure 7 shows the design for the area of 100 ha. Blue colours are new parcels. Grey ones are parcels that are already built upon in the last 30 years. Although the municipality couldn't change the design, nevertheless suitability maps were calculated for the study of Technopolis (figure 8).

The municipality of Delft found themselves in certain situations where these maps were indeed very useful and where they regretted not to have them in an earlier phase of the development of Technopolis. The architect had some very good ideas for the area, but sometimes these ideas were situated in locations where soil conditions were so poor, that building costs and time would be high and would result in geotechnical instabilities.

One example is a pond between the two main roads. Where this pond was planned, the roads would be 2 m above the natural water level. However the architect's drawings showed a water level almost at the same level as the road surface. It was designed this way to enable people to see water when driving their cars. This would be impossible with the natural water level and therefore it was decided to build a concrete tank in which the water level would be artificially raised.

Fortunately, the municipality of Delft was able to explain to the architect that the soil underneath the location of the concrete tank was poor and would cause significant geotechnical problems for construction and maintenance. Moreover, the closed tank, would not contribute to the water storage needed for the whole area, thus requiring. the creation of another pond elsewhere to make up for this. Finally, the municipality and the architect came to an agreement that instead of raising the water level artificially in this local pond, a fountain be constructed. Therefore, motorists would still be able to see water.

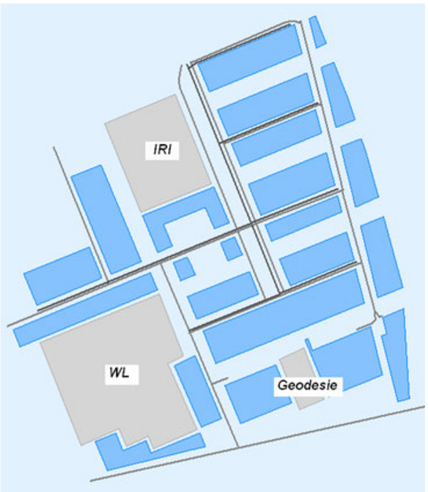

Figure 7. Urban design for Delft Technopolis.

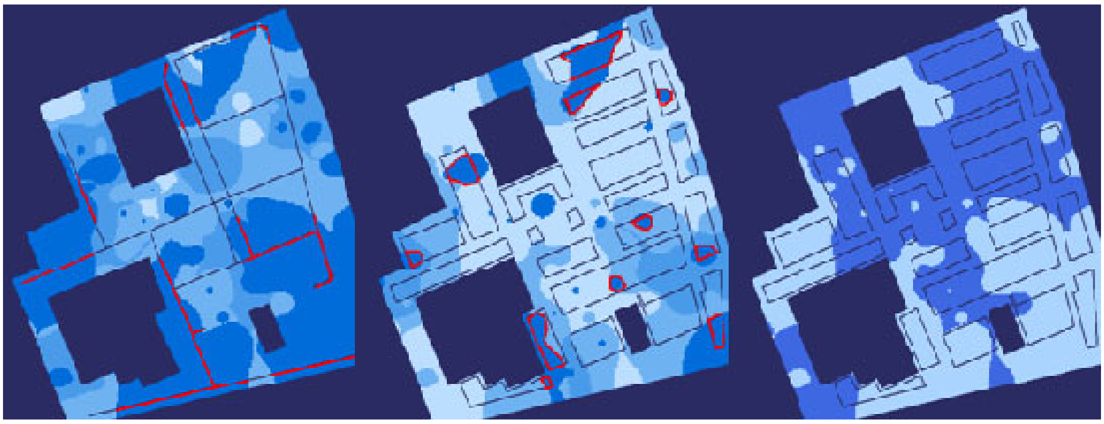

Figure 8. Suitability maps for Delft Technopolis. a) Infrastructure, b) Offices, c) Parks and Water. In red problem areas are indicated.

CONCLUSIONS

The methodology of using soil conditions in urban planning is quite simple and appealing. It must be noted that architects have to take into account more issues than just geotechnics and that geotechnics are just a small part in the creation of an urban area. However, the consequences of ignoring this information can be disastrous when a municipality has to deal with endless maintenance costs for roads and sewers, because in the Netherlands they are mostly situated areas with thick layers of peat instead of more stable sandy areas. Therefore it is helpful for architects use this kind of information in an early phase of a project and decide for themselves if they would like to create just a pretty looking urban area, or one that is sustainable as well. Thus the inhabitants are not confronted with sinking gardens, continuous roadwork maintenance and clogged sewers.

Even in a phase where the design is already defined and the planning of the area draws to an end, it can still be useful to look at the subsoil to see whether the development plan can be optimized and to make final adjustments to the plan that could have a significant impact on budgets.

Corresponding author: Miss M.W.A. Hounjet, GeoDelft, Stieltjesweg 2, Delft, Zuid-Holland, 2600 AB, Netherlands. Tel: +31 152693691. Email: m.w.a.hounjet@geodelft.nl.

REFERENCES

CROW. Beheerkosten weginfrastructuur, CROW publicatie 145, 2001.
SLUIJS, J.F., e.a. Zicht op onderhoud in woonwijken, RBOI, Rotterdam, januari 1987.
TNO-NITG, Grondkaart van de gemeente Almere, personal advice.
WEERTS H.J.T. Geology of the Nesselande area: Facies distribution and lithology of the Late Weichselian and Holocene deposit. TNO-report NITG 01-205-A, Utrecht 2000.