A Web Accessibility Analysis Service based on the OpenLS Route Service

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SUMMARY

Within the project "A Web SDSS (Spatial Decision Support System) for the automation of the multi criteria model development of a user specific, regionalized housing market analyses in RLP" we develop an Accessibility Analysis Service as a first analysis module. The implementation is using OGC WMS and WFS and in particular the OGC OpenLS Route Service, that was developed in an earlier project. In this paper we discuss the concept and realization of the service, describe its interface and the usage within the project.

1 INTRODUCTION

The objective of the project is to develop a Web-SDSS (Spatial Decision Support System) which automates the multi criteria model building for user specific, regionalized housing market analyses in the German State of Rhineland Palatinate (RLP). We work together with our project partner from the IRP Immobilien-Gesellschaft Rheinland-Pfalz mbH in order to help governmental, economic and administrative decision makers with their assessment and evaluation of the regional and local housing market. We are currently developing a multi functional online analysis- and information system, which exceeds all previous housing market monitoring system capabilities.

Our System needs to meet the following requirements:

- Being able to maintain and aggregate all necessary statistical and spatial information in order to allow the development of the corresponding site-related factors as well as supply and demand indicators
- Highly independent from pre-defined administrative and aggregative levels
- Extensive configuration possibilities to support decision making processes of diverse user needs
- Conducts complex spatial analyses and displays the results automatically and specific for different user-groups in adequate forms (tables, diagrams, maps etc.)
- Freely extendable and able to process data from multiple sources
- Low budget development and transferability to other projects and areas of application

For supporting political and economic decision making a geographic information system (GIS) is used to prepare and analyze relevant data (e.g. economical- and population statistics, building permits, completion of buildings, etc.). This system must be able to manage and aggregate the necessary spatial and statistical information which is needed to develop the respective supply and demand indicators – for instance on a meso level (regional labor market, area of planning, etc.)

In order to go beyond pure map visualization, possibilities have to be provided which ensure complex analyses of relevant parameters. Hence, it is necessary to combine statistical calculations with spatial (geometries, topologies, geostatistics, etc.) analysis functions and to incorporate the free choice of spatial units depending on thematic and spatial characteristics.

The project has the following goals:

- Analysis and characterization of the regional housing market situation in RLP
- Spatial boundaries of housing market segments
- Not solely oriented on community-, state-, or country borders
- The development of the segments on a scientific base
- Prediction of future development of the RLP housing market
- Continuous updates of the regionalized housing market monitoring

The most important outputs from the analyses will be:
- Time comparisons
- Comparisons of housing market segment (e.g. communities with the same settlement structure types)

The aim of the project is the low budget development of a representative SDSS for analysing the housing and real estate market in RLP. This will be achieved by using and extending open source software packages and development of our own tools. This should be transferable to and applicable on other projects. Furthermore, relevant components should be re-usable and conform to the OGC (Open GeoSpatial Consortium) and the W3C (World Wide Web Consortium) standards. Using GIS technology enables spatial analyses and the visualization of the outcomes in form of thematic maps. One significant feature is to obtain maximum independence from pre-defined administrative- and aggregative levels.

Extensive configuration possibilities should allow different user types to perform automated spatial analyses using specified units. This provides a diverse decision making tool (investment decisions, planning schemes, etc.). On the basis of the multi criteria decision model, various relevant statistical and spatial methods will be stored in a configurable database of methods which is set up according to user specified work flows. Also, a report generator is being developed which will prepare the outcomes according to user queries in form of a user friendly assessment report.
First results are incorporated in the Website http://www.rewob.de (fig. 1) that already allows to perform statistical analysis and thematic mapping of a large number of statistical indicators describing the regional structure of the German state Rhineland-Palatinate.
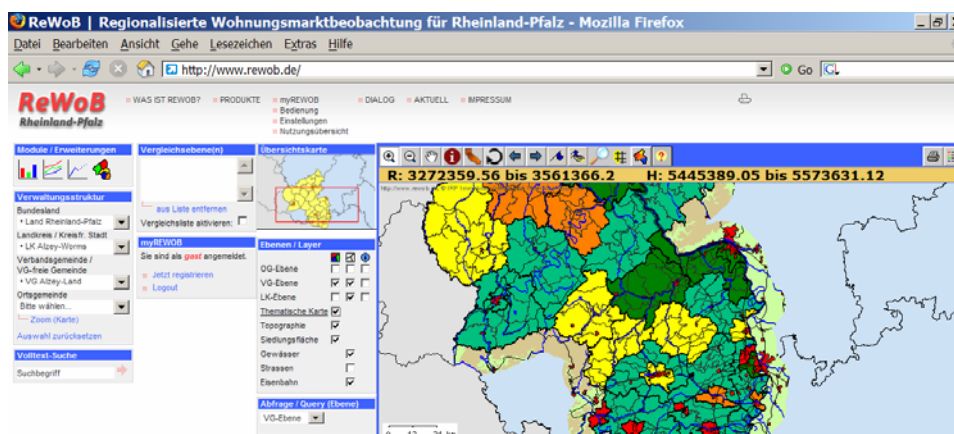

Figure 1: Screenshot from REWOB Online.

2 THE ACCESSIBILITY ANALYSIS SERVICE (AAS)

A first analysis service we have developed, that performs a typical GIS analysis needed for the given scenario is the calculation of accessibility of regions from a given location. At the moment we have defined and implemented a simple prototype of a first Accessibility Analysis Service (AAS). The accessibility analysis determines a region (as polygon) that can be reached from a given location within a specified time (or distance).

But the response of the service is not only the region that can be accessed as polygon, but it can also return a list of locations (e.g. cities or POIs), that are within this calculated area, as well as a map and other information. We will present this below when discussing the request and response parameters of our implementation.

2.1 ACCESSIBILITY ANALYSIS

Accessibility analysis is a subject with a long history of GI research (e.g. Juliao 1998, Miller 1999, De Jong et al. 2001), or even earlier interaction modelling (e.g. Wilson 1971). A range of definitions, as well as more or less complex models are available. In our first scenario we do not need a complex model of accessibility in the sense of the potential for interaction, but do only want to know what areas can be reached within a given time or distance. So for the sake of the needs within our project we have so far a much simplified notion of accessibility. It is similar to the tool called "Find Service Area" (see Zipf & Röther 2000 for an example of their usage for individualized tour proposals) from the "Network Analyst" extension of ESRI ArcGIS. "Service areas" in that sense are polygon regions that include all accessible streets around one or several locations (e.g. certain facilities) within the specified impedance.

2.2 AN IMPLEMENTATION OF THE AAS

In order to perform the analysis, several data sets are needed, including detailed street networks for routing with additional attributes such as street type or travelling times.

Name:	edgeid	streetname	oneway	streettyp	the_geom
Datentyp:	Integer	String	String	Integer	Geometry
Value:	28	Am Stollenbach	TF	1	MULTILINESTRING(…)

Table 1: Table structure for network graph.

oneway preference		
ft = from > to , digitalization direction	TF = To > From , again the digitalization direction	" " = both directions

A first implementation of the AAS was realized by using our implementation of the OpenLS specification, in particular the Route Service (Neis 2006) as basis. This implementation is currently extended to support further OpenLS Core Services. The Route Service has already been extended towards an Emergency Route Service – ERS (Weiser et al 2006), an 3D Route Service, as well as an 3D Emergency Route Service (Neis et al 2007). The Emergency Route Service (ERS) is used within the project OK-GIS (http://www.ok-gis.de), the 3D Route Service (3D-RS) is used within the project Heidelberg-3D developing a spatial data infrastructure for 3D city models (3D-SDI) (Schilling et al 2007, Nonn and Zipf (submitted), http://www-gdi-3d.de).

2.3 OPENLS – THE OPEN LOCATION SERVICES

OpenLS is the short form for Open Location Services or OpenGIS Location Services. Since 2000 this OGC initiative has been developing implementation specifications (interfaces and protocols) for standardizing services that are relevant for Location Based services (LBS). The OpenLS service framework consists at the moment of five core services (OpenLS 2000):

- The *Directory Service* is a network-accessible service that provides access to an online directory (e.g., Yellow Pages) to find the location of a specific or nearest place, product or service.
- The *Gateway Service* is a network-accessible service that fetches the position of a known mobile terminal from the network; this interface is modelled after the Mobile Location Protocol (MLP), Standard Location Immediate Service.
- The *Location Utility Service* provides a Geocoder/Reverse Geocoder; the Geocoder transforms a description of a location, such as a place name, street address or postal code, into a normalized description of the location with a Point geometry usually placed using Cartesian coordinates, often latitude and longitude.
- The *Presentation (Map Portrayal) Service* portrays a map made up of a base map derived from any geospatial data and a set of Abstract Data Types as overlays.
- The *Route Service* determines travel routes and navigation information according to diverse criteria.

Currently a 6th OpenLS core service – the *Tracking Service* is being specified by OGC and ISO TC211.

Based on our implementation of the OpenLS Route Service a first simple accessibility analysis corresponding to a service area calculation has been realized. This will be presented in the following sections. An overview of the services used can be seen in fig. 2:
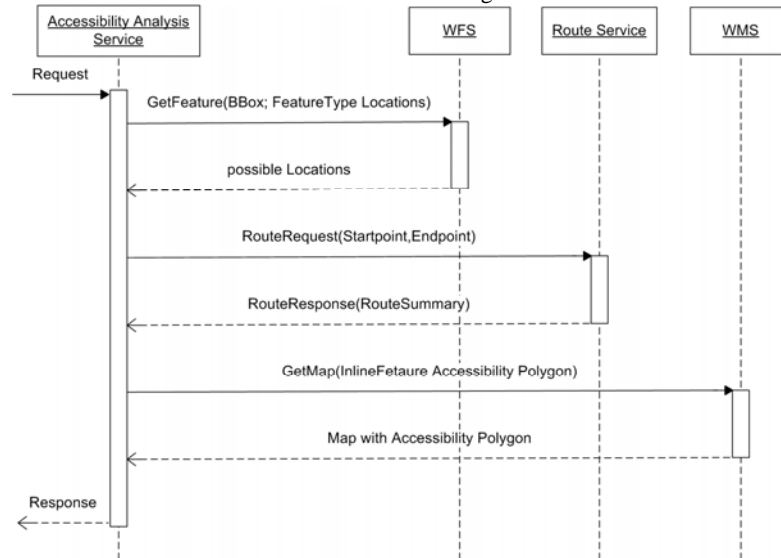

Figure 2: UML Sequence diagram: usage of OGC & OpenLS services within the realized AAS.

The Route Service is mainly used to calculate the shortest or fasted route between the location for which the accessibility region shall be calculated and all the locations within that region. All matching locations can be returned as a list together with time and metric distances from the start location. This is necessary, so that this list of "accessible locations" can be used in further steps of an analysis within the REWOB system.

2.4 ARCHITECTURE OF THE AAS IMPLEMENTATION

The implemented AAS is a Java servlet running on the Tomcat Server (for architecture see fig. 3). It can be accessed exclusively through HTTP-POST and XML. The request and response are modelled as XML schema as explained later. The service can generate maps of the result using an SLD-WMS.
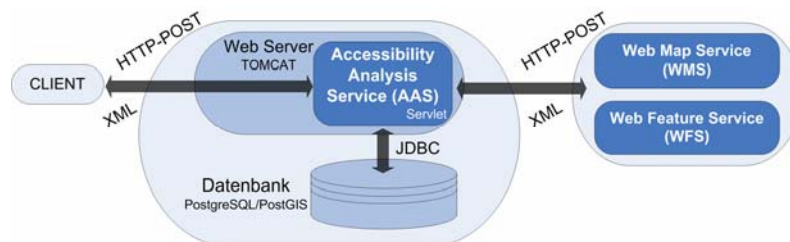

Figure 3: Accessibility Analysis Service Architecture.

The street network that is used for the graph is stored in a PostGIS database. It can be loaded from Shape-Files. The graph is generated when the servlet is initiating. In order to calculate the travel time

as impedance we use the Dijkstra-Shortest-Path-Algorithm (Dijkstra 1959). Also our AAS implementation can be configured through a XML-based configuration file, which among others includes the parameters for accessing the database.

Due to the performance the OpenLS Route Service was used internally in our implementation. But in addition, it would be possible to include an external OpenLS Route Service.

2.5 COMPUTATION OF THE ACCESSIBILITY AREA

The accessibility area is computed by the creation and intersection of an elevation model. First a 3D-point cloud is rendered. Each 3D-point thereby receives the 2D-position coordinate of the location (place/city). The time value, in which the location of the starting point can be reached, is additionally assigned to each 3D-point as elevation information. This 3D-point cloud is afterwards meshed by the use of the delaunay triangulation and thus generates an elevation model. The lowest point in the area is the position wherefrom the accessibility area is to be determined. It is set to the "height" of zero. The other points correspondingly receive larger elevation information depending on the driving distance from the starting point. The land model can thus be conceived as a kind of funnel or hopper.
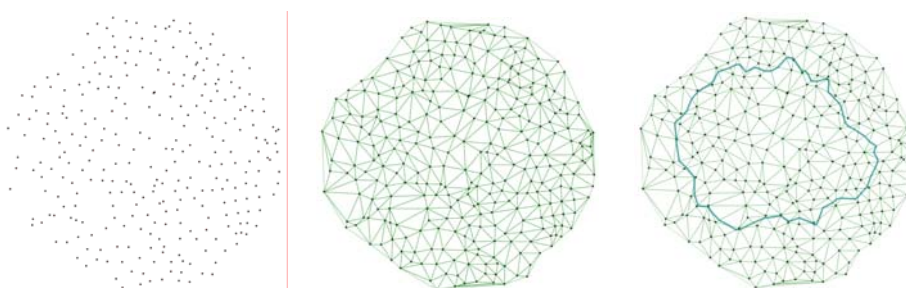

Figure 4: a.) point cloud b.) mesh point cloud c.) contour (polygon) in land model.

The so generated land model can afterwards be used to determine contours. Thereby a kind of slice through the model is calculated. This resulting contour corresponds to the area, which can be reached in the given time from the starting point. The accuracy of this computation can be improved if the nodes of the network graph are included in the point cloud. But thereby the additionally needed computation expenditure should not be disregarded, which is needed to mesh the denser point cluster.

2.6 AAS REQUEST AND RESPONSE

The requests and responses are modelled similar to the OpenLS XML schemas, which include the requests and responses for the OpenLS core services.

2.6.1 DetermineAccessibilityRequest

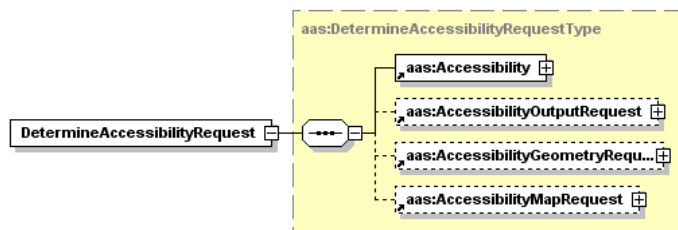The DetermineAccessibilityRequest-element is the main element of a request to an AAS (fig. 5).

Figure 5: Schema of the DetermineAccessibilityRequest-Element.

It includes the element Accessibility, which contains the preferences (AccessibilityPreference) for the request as well as the location (LocationPoint) of which the accessibility should be calculated. The preferences basically tell if time or metric distances should be used for the calculation. Several units of measurements based on the OGC UOM can be used for representing the distances. There is quite a number of further ML elements and data types, but the focus here is only set on the most important ones. A detailed documentation is available as internal project paper.

AccessibilityOutputRequest

The AccessibilityOutputRequest (fig. 6) defines what information to return in the output list.

- Name   - if true, return the name of the location.
- Time   - if true, return the time in which the location can be reached
- Distance   - if true, return the distance in which the location can be reached
- DistanceUnit   - specifies the unit for measuring distance
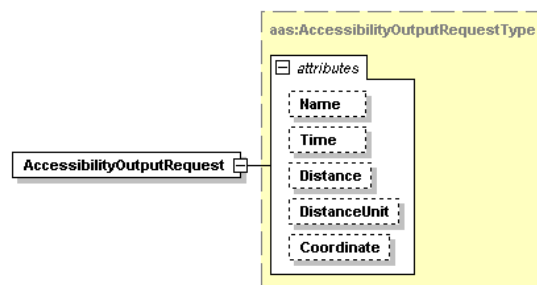- Coordinate   - if true, return the coordinate of the location

Figure 6: Schema of the AccessibilityOutputRequest-Element.

The coordinate in the response parameter AccessibilityOutputList is a sequence of gml:Point that specify the coordinates of the locations that can be reached within the given time or distance.

AccessibilityGeometryRequest

The content of the AccessibilityGeometryRequest-element is specific (fig. 7). Two elements are possible: PolygonPreference or LineStringPreference. That means that the requested geometry could be the accessibility area(s) as a gml:polygon or the relevant line strings of the street network.
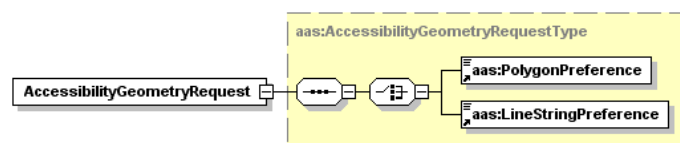

Figure 7: Schema of the AccessibilityGeometryRequest-Element.

AccessibilityMapRequest

A characteristic of the AccessibilityMapRequest-element (fig. 8) is that the desired representational form of the accessibility area can be selected. The most important attribute is thereby AccessibilityMapPreference. Three options are possible: DetailedPolygon, ConvexPolygon and StreetsBuffer (for more information see ch. "2.5 Result Accessibility Area").

Optional attributes are: width, height, format, BGColor, transparent and in addition a boundingbox of the requested map (BBoxContent).
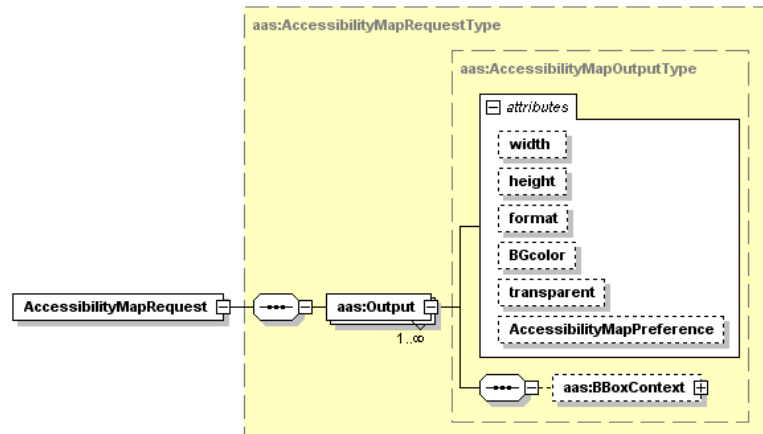
Figure 8: Schema of the AccessibilityMapRequest-Element.

As it can be seen in the schema of the AccessibilityMapRequest-element (fig. 8), either one or more maps can be requested.

2.6.2 AccessibilityResponse

The element AccessibilityResponse (fig. 9) includes several elements that fine-tune the response of the service. They tell what kind of information should be returned by the service. When they are included within the request they determine if such kind of information should be provided. The elements are then filled with the corresponding values that have been calculated and returned within the response.
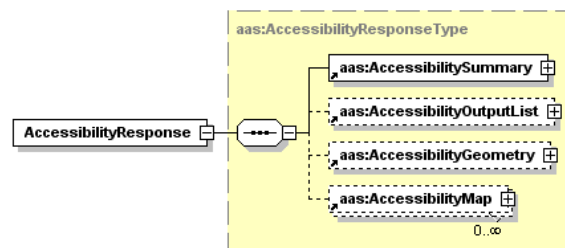

Figure 9: Schema of the AccessibilityResponse-Element.

- AccessibilitySummary – contains overall information about the accessibility analysis, (e.g. number of locations in the accessibility area and bounding box)
- AccessibilityOutputList – information about the locations within the accessibility area (e.g. Name, Distance and Time).
- AccessibilityOutputGeometry – geometry of accessibility area as gml:polygon or the relevant streets as gml:linestring.
- AccessibilityMap – one or more maps with the plotted accessibility area or concerned streets.

2.6.3 EXAMPLE OF AAS REQUEST

AAS Request with time as AccessibilityPreference and one coordinate as LocationPoint:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<aas:AAS version="1.0" xmlns:aas="http://www.geoinform.fh-mainz.de/aas"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.geoinform.fh-mainz.de/aas AccessibilityService.xsd">
 <aas:RequestHeader srsName="31467" clientName="UserXY" clientPassword="PasswdXY"/>
 <aas:Request methodName="AccessibilityRequest" requestID="123456789" version="1.0">
    <aas:DetermineAccessibilityRequest>
       <aas:Accessibility>
          <aas:AccessibilityPreference>
              <aas:Time Duration="PT0H04M00S"></aas:Time>
          </aas:AccessibilityPreference>
          <aas:LocationPoint>
            <aas:Position>
                <gml:Point xmlns:gml="http://www.opengis.net/gml" srsName="EPSG:31467">
                   <gml:pos>3433000.00 5794000.00</gml:pos>
                </gml:Point>
            </aas:Position>
          </aas:LocationPoint>
       </aas:Accessibility>
       <aas:AccessibilityOutputRequest Coordinate="true" Distance="true"
                 DistanceUnit="KM" Name="true" Time="true"/>
       <aas:AccessibilityGeometryRequest>
          <aas:PolygonPreference>Detailed</aas:PolygonPreference>
       </aas:AccessibilityGeometryRequest>
       <aas:AccessibilityMapRequest>
          <aas:Output format="png" height="600" width="600"
                 AccessibilityMapPreference="DetailedPolygon"></aas:Output>
       </aas:AccessibilityMapRequest>
    </aas:DetermineAccessibilityRequest>
 </aas:Request>
</aas:AAS>
```

2.6.4 EXAMPLE OF AAS RESPONSE (SHORTENED)
This is a condensed example of the XML file returns by the AAS as response.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<aas:AAS xmlns:aas="http://www.geoinform.fh-mainz.de/aas"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gml="http://www.opengis.net/gml" version="1.0"
xsi:schemaLocation="http://www.geoinform.fh-mainz.de/aas AccessibilityService.xsd">
 <aas:ResponseHeader xsi:type="aas:ResponseHeaderType"/>
 <aas:Response xsi:type="aas:ResponseType" requestID="123456789" version="1.0">
  <aas:AccessibilityResponse xsi:type="aas:AccessibilityResponseType">
   <aas:AccessibilitySummary>
     <aas:NumberOfLocations>75</aas:NumberOfLocations>
     <aas:BoundingBox srsName="EPSG:31467">
       <gml:pos>3430855.40 5792334.38</gml:pos>
       <gml:pos>3435026.90 5795998.54</gml:pos>
```

```xml
      </aas:BoundingBox>
    </aas:AccessibilitySummary>
    <aas:AccessibilityOutputList>
     <aas:AccessibilityOutput ID="21" Name="Parkplatz" Time="PT3M58S" Distance="2.34">
      <gml:Point srsName="EPSG:31467">
       <gml:pos>3432236.77 5795593.63</gml:pos>
      </gml:Point>
     </aas:AccessibilityOutput>
     <aas:AccessibilityOutput ID="33" Name="Markuskirche" Time="PT3M24S" Distance="1.93">
      <gml:Point srsName="EPSG:31467">
       <gml:pos>3433029.05 5795737.15</gml:pos>
      </gml:Point>
     </aas:AccessibilityOutput>
....
     <aas:AccessibilityOutput ID="274" Name="Parkplatz" Time="PT2M46S" Distance="1.65">
      <gml:Point srsName="EPSG:31467">
       <gml:pos>3434019.00 5793188.00</gml:pos>
      </gml:Point>
     </aas:AccessibilityOutput>
    </aas:AccessibilityOutputList>
    <aas:AccessibilityGeometry>
     <gml:Polygon srsName="EPSG:31467">
      <gml:exterior>
       <gml:LinearRing xsi:type="gml:LinearRingType">
        <gml:pos>3431638.54 5795551.83</gml:pos>
        <gml:pos>3431855.39 5795626.14</gml:pos>
....
        <gml:pos>3431608.05 5795538.86</gml:pos>
        <gml:pos>3431638.54 5795551.83</gml:pos>
       </gml:LinearRing>
      </gml:exterior>
     </gml:Polygon>
    </aas:AccessibilityGeometry>
    <aas:AccessibilityMap description="MapNumber: 1 - DetailedPolygon">
     <aas:Map>
      <aas:Content format="png" height="600" width="600">
       <aas:URL>http://webmap.geoinform.fh-mainz.de/aas/maps/1175065986589.png</aas:URL>
      </aas:Content>
      <aas:BBoxContext srsName="EPSG:31467">
       <gml:pos>3430646.82 5791872.14</gml:pos>
       <gml:pos>3435235.47 5796460.78</gml:pos>
      </aas:BBoxContext>
     </aas:Map>
    </aas:AccessibilityMap>
   </aas:AccessibilityResponse>
  </aas:Response>
</aas:AAS>
```
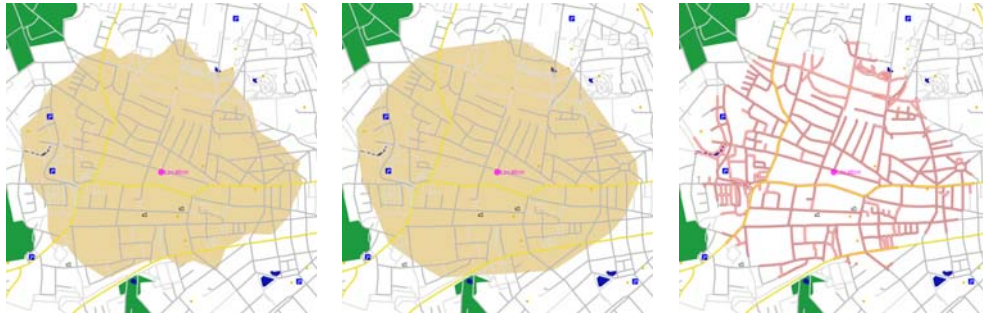
2.7 Result Accessibility Area

The computation of the accessibility area is done through contour computation. The results can be shown in a map and/or returned as geometry. If street geometry is needed, then an intersection between the accessibility polygon and the network graph takes place. If a

convex is demanded, then the accessibility polygon from the contour computation is used as a base to compute a convex cover. The following illustrations show the different variants, with which the accessibility area in a map can be represented.

Figure 10: Examples of 3 result maps with different procedures for the representation of the accessibility-area a.) contour computation, b.) convex covering, c.) buffered street geometry.

3 DISCUSSION AND OUTLOOK

Accessibility analysis is a typical example of a GIS analysis. Therefore we decided at this point that a specialized service may be a sensible decision. It may act as a starting point or framework for further extensions providing more general, specialized or sophisticated types of accessibility analysis. Of course we are aware that it is also a possible candidate for realization using a Web Processing Service (WPS)(Kiehle 2006). But the WPS specification seems at the moment very much general purpose.
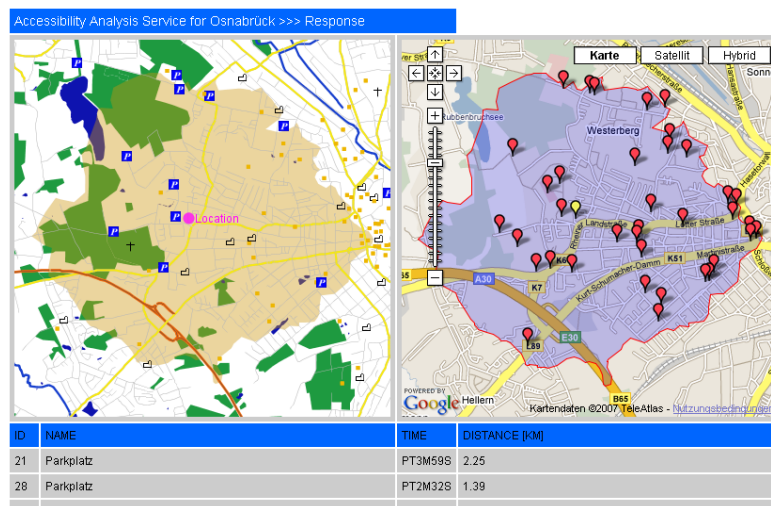
Figure 11: Test User Interface with results formatted into a web page and Google Maps, showing the 5 minutes accessibility region from a Point in Osnabrück (Germany) calculated by our AAS.

Figure 11 shows a screenshot from the web based prototype user interface for the AAS. The resulting XML document has been transformed into HTML and with JavaScript and the API draw in Google Maps.

The next steps within the project are to think about the interface of a more general AAS. This might include the possibility to specify:
- multiple points at the same time
- multiple distances resulting in multiple distances at the same time.

This was even already partially implemented, but the discussion among the project partners and users resulted in the presented approach opting for a very simple version, as this is easier to use and fulfills the purposes within the project the best way.

Currently the service is being integrated within the REWOB system and will then be available to real users. Then actual geographic analyses will be performed regarding the housing market in Rhineland-Palatinate. As explained earlier there is much room for incorporating more sophisticated algorithms in future versions of the AAS.

AKNOWLEDGEMENTS

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