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# IMPLEMENTATION OF GIS BASED MOBILE APP FOR BUILDING ENVIRONMENTAL MANAGEMENT

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**Abstract**: This paper describes the need and solution for building environmental management by using GIS. It offers a brief overview of existing challenges, covers most relevant requirements of an ideal solution and takes the reader through development steps with key decision points. The final result, a mobile GIS-Android application for indoor environmental management, is shown.

**Keywords**: Building environmental management, indoor GIS, EMAS, ArcGIS Android application.

## IMPLEMENTIERUNG EINER GIS-BASIERTEN MOBILEN APP ZUR UNTERSTÜTZUNG DES UMWELTMANAGEMENTS IN GEBÄUDEN

**Zusammenfassung**: Dieser Beitrag befasst sich mit der Notwendigkeit und Lösung von Umweltmanagement in Gebäuden. Alle bestehenden Anforderungen und Lösungen werden mithilfe von Geoinformationssystemen (GIS) realisiert. Zusätzlich werden in diesem Beitrag alle Entwicklungsschritte detailliert beschrieben. Das Resultat ist eine mobile Android-basierte GIS-Applikation für das Gebäude-Umweltmanagement.

**Schlüsselwörter**: Gebäude-Umweltmanagement, Indoor-GIS, ArcGIS Android-Anwendung

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## 1.1 INTRODUCTION AND EMAS BACKGROUND

It's a generally accepted fact that a long-term environmental sustainability is one of the greatest challenges of this time. To mitigate this hazard one of the principal steps is to reduce greenhouse gas emissions. Although we most often hear about cutting manufacturing and transport related emissions, there are other important areas where change is necessary to decrease amounts of greenhouse gas entering atmosphere. One of them being – buildings. According to United Nations Environmental Programme report "Buildings and Climate Change" *"The building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy"* (United Nations Environment Programme 2009).

As a part of tackling this problem European Commission has designed a voluntary environmental management instrument for organizations and industries of all sizes, which is called EMAS (Eco-Management and Audit Scheme). It guides organizations to better environmental performance, subsequently better financial performance and better communication of environmental issues between stakeholders. There are more than 4.500 EMAS registered organizations since its debut at 1993, 1.223 of which are in Germany.

University of Applied Sciences Stuttgart (HFT-Stuttgart) is one of about 400 EMAS registered universities and one of 20 pioneer-universities in Germany in environmental management. HFT-Stuttgart is aspiring to obtain EMAS certificate and to do that there are well defined steps that have to be carried out. Some steps include site assessment and regular audits of environmental aspects, like waste, water, energy. Site assessments and audits are powerful instruments, but at the current form of execution, they are very labor intensive, time consuming, and on top of that, the results are hard to analyze, update and communicate.

### 1.2 CHALLENGES WITH CURRENT SOLUTIONS OF ENVIRONMENTAL BUILDING MANAGEMENT

The main problem with current site assessment solutions is that it is hand-written and mostly supported by generic off-the-shelf software. A general assessment process is following – an inspector walks around the buildings and marks down found issues on printed paper maps. All additional information on the found issues is written down in notes. Later this additional information can be digitized, for example, by entering it into special Excel spreadsheet, as it will be used for analysis. In this case, data can be entered straight into digital storage, if inspector opts for it and is equipped with necessary technology. However, the relationship between spatial location marked on map and data entry is maintained in any given way chosen by inspector – color coding, letter or number coding etc.

Described approach is wide-spread and inherits classic hand-written data problems: it is near impossible to update information on the map, impossible to neatly delete it, with more information it becomes crowded and hard to perceive, it cannot be queried. Paper maps themselves can get lost or damaged, and it's hard to navigate between and in them. In broader aspect, it is also hard to visualize and understand the entire situation as details on the issue are digitized, but actual spatial location is on a paper map. For decision making process it means it is slowed down in the best case. Communicating and reporting site assessment / audit results to involved stakeholders is also a challenge.

Previously described problems are common not only with environmental, but with general building management as well. Therefore, there are off-the-shelf software that aid this problem and offer to have digital databases of different sorts for findings. Although it is a step forward, the spatial information is then lost or paper maps still have to be kept as part of process. Plus, it entails a need of software knowledge and appropriate access level for inspector.

The appropriate solution would include both – maps for marking issues and linked database for additional information. Market was searched for a fit, off-the-shelf solution not only for EMAS process specifically, but also for facility management process that supports directly linked spatial information. The search was not successful to find a fitting solution that could be readily deployed in HFT-Stuttgart for described purpose, however, the topic itself proved to be conscious, and the industry is aware of application possibilities as described by Rich & Davis (2010). As a result, it was decided that a tool that is appropriate for EMAS audits and environmental management will be developed at HFT-Stuttgart as a Master Thesis topic (Fridrihsone 2015).

The intended solution fits within GIS and Computer-Aided Facility Management (CAFM) fields. *"CAFM includes the creation and utilization of Information Technology (IT)-based systems in the built environment. A typical CAFM system is defined as a combination of Computer-Aided Design (CAD) and/or relational database software with specific abilities for Facilities Management"* as stated by Watson & Watson (2015). It largely focuses on information about the facilities, and in desired solution graphical part would be interactive maps.

CAFM is a growing industry and is expect to expand over the next years: *"The global facility management market is estimated to grow from USD 27.25 Billion in 2015 to USD 49.44 Billion by 2020, at a Compound Annual Growth Rate (CAGR) of 12.7%"* (marketsandmarkets.com 2015).

## 2 THE REQUIREMENTS FOR A NEW SOLUTION

Once the need was identified, a proper set of solution requirements had to be established. Three base requirements for new solution are:

1) have a comprehensive data model which models interactive floor maps and issue markings (further in text issues) which can be geo-referenced,
2) have a web-service, and
3) have it functioning on a mobile platform.

### 2.1 COMPREHENSIVE DATA MODEL

The data model is essential for successful solution. The data model has to include all the necessary data fields, but it cannot be too clustered to preserve easy usability. Most of data fields must be filled in a semi-automatic manner by having roll-down menus and automatically filled fields.

Some of the fields describe the spatial location of an issue, for example, building number, floor number, and room number. Therefore, floor maps should not only serve as a visual background on which to place a building issue, but also provide information for filling these fields automatically. Which means that issues data fields have to be designed in a way that spatial analysis can be performed on them and maps together.

When designing a comprehensive data model also future enhancements were taken into account, namely automatic floor detection and indoor positioning system. For that purpose, maps should be geo-referenced and store floor height information.

### 2.2 WEB-SERVICE AND CLOUD DATA REPOSITORY

The solution must be available through internet to enable easier data sharing, multi-user access, to allow implementation of different access level privileges and to allow the data usage on mobile devices. By having a data repository stored on cloud and creating a web-service and mobile application that connect to the same data repository, all requirements can be achieved.

Web-service can be accessed through any computer and it would enable a user to work with the current information. Information that must be delivered for a building manager and for EMAS audit report looks substantially different although it has the same source. Without the planned solution, data must be manually parsed, which means somebody has to organize the data in appropriate format and so on, before it can be shared. Possibly even the issues on paper map must be remarked for cleaner look before sharing the information. Yet more, the classified or sensitive data must be hidden. By having a web-service and online data repository, data sharing is made easy by having different access levels that can be controlled by giving the right credentials to parties involved and data parsing can be handled automatically.

Another great benefit of this approach is a multi-user access, which means all data can be accessed simultaneously and updated in real time. All stakeholders see the same, current and correct information.

## 2.3 MOBILE PLATFORM

Using an online data repository service also enables using mobile devices which is very important as the user can collect data while on site without any following post-processing. It significantly decreases the time spent on data collection and increases the correctness. Global trends clearly indicate that mobile devices are here to stay and programming for smartphones and tablets is essentially the same. Therefore, the new solution will be a native mobile application, further in text referred to as EMAS app.

There are four dominating mobile operating systems (OS) – Android, iOS, Windows Phone and BlackBerry OS. Android operating system is chosen for development of EMAS app due to its dominating worldwide market share (idc.com 2015) and the fact that it is open source.

## 2.4 A TYPICAL DAY OF ENVIRONMENTAL SITE INSPECTOR USING EMAS APP

An inspector gets to work, check his errands of the day and grabs his tablet to head out for building assessment. He logs in the app with given credentials and easily navigates to the floor he is on. A floor map opens and he finds his location. In the next few minutes an inspector finds an issue – a window is left open and cannot be closed as it is broken. The inspector drops a new issue on a map at the correct location. Right after an issue is spatially recorded a list of fields open. Some fields are already filled – his name, the date issue was found, building, floor and room number. He adds that problem's aspect is energy from a roll-down menu. After adding aspect, other fields subsequently offer roll-downs with energy related issues. For extra information, he takes a picture of the broken window, clicks *Save* and moves forward with his inspection.

In few minutes, he is in a bathroom and sees on his tablet screen that there is a leak reported earlier. However, he sees no leak anymore, which means it has been fixed. He removes the leak issue from the map and continues his site assessment.

In the meantime, environmental manager at her office prepares for a meeting with her supervisor to discuss overall condition of a building. She logs in online service and exports all issue records to print out just as a handout. During the meeting, she logs in the same web-service and goes from floor to floor showing the situation and performing necessary filters, like displaying only high priority issues. After few series of analysis, it is clear to everybody that there are many energy related issues, they occur often and most of them are in the basement. The decision is easy to make and it is well informed.

While meeting was taking place, the site inspector went back at his office and moved on to other duties of his work. No post-processing was necessary as everything was handled on site and involved stakeholders can access the newest information from their own workstations.

## 3 SOLUTION'S TECHNICAL FRAMEWORK

Analysis of the need and requirements clearly indicate that this is a rather regular GIS task that have to be tailored for indoors and specific data management needs. An abundance of choice is presented among commercial GIS desktop software and freely available ones. Desktop GIS software is necessary to create the underlying data model, but the entire scope of work requires a number of other services and, preferably, of-the-shelf solutions.

After researching possibilities offered by the market, the conclusion was made that Esri offers the most comprehensive GIS software and services that can be mutually integrated and streamlined. For the EMAS app desktop software (ArcMap and ArcCatalog) will be used to prepare data model and to publish it in ArcGIS Online. ArcGIS Online is the central online platform that will host all data. Besides creating, managing and sharing spatial data online, ArcGIS Online also offers analytical functions. The relatively easy interface of ArcGIS Online and limitation in functionalities will help non-GIS specialists to work with this product in a web-browser, which is a web-service part of the desired outcome.

Esri's ArcGIS Runtime SDK enables utilization of ArcGIS Online content and functionalities. With ArcGIS Runtime SDK for Android it is possible to develop the native EMAS app which will communicate with content published in ArcGIS Online.

## 4 DATA MODEL

The data model consists of properties and design requirements for entire content. It is created by taking into account the requirements from environmental management specialists and also considers possible future advancements. Data model is composed of two parts – building floor maps and issue feature class template. For floor maps it includes a set of shapefiles for different parts of floor plans, workflows to prepare these shapefiles, symbolization and

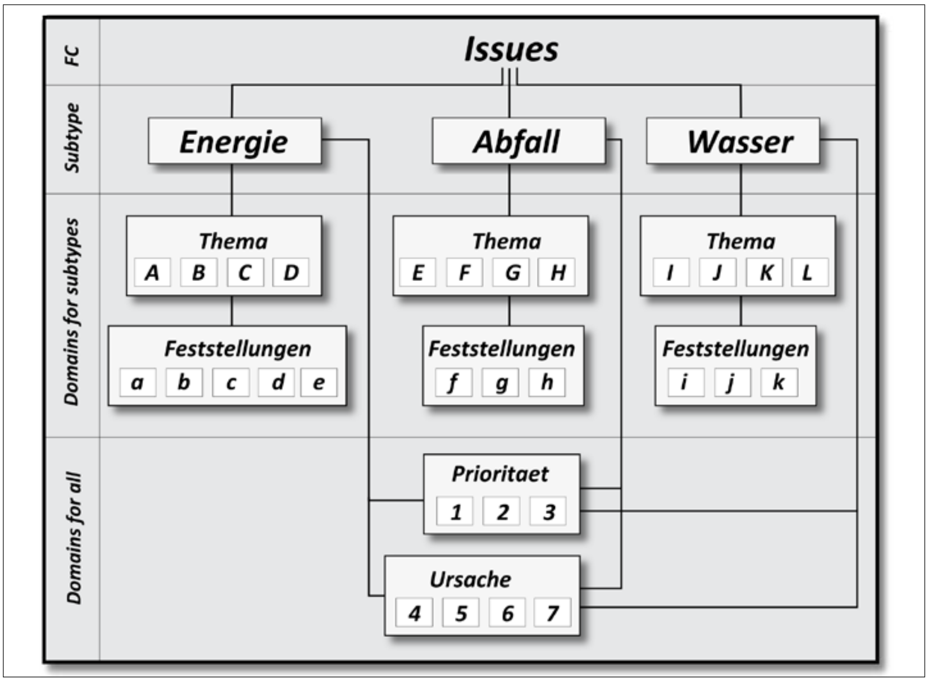


*Figure 1: Illustration of how issues subtypes and domains are linked*

publishing requirements. For issue feature class it includes empty feature class with set-up fields and properties, symbolization and publishing requirements.

### 4.1 BUILDING FLOOR PLANS

Building floor maps have to be created for each floor, therefore, workflows must be established to ensure similar data is represented in the same way. Moreover, having well-established and fast workflows allow applying this solution for any building anywhere.

For this case study input data of building floor maps is in DXF format. DXF files must be manually pre-processed in AutoCAD to ensure rooms have closed polygon outlines. Then data is imported into ArcMap to derive necessary shapefiles. A following set of shapefiles is necessary to create building floor web-maps for every floor:

- *BauX_YYY_Rooms* – polygon features;
- *BauX_YYY_Floor* – polygon features;
- *BauX_YYY_Lines* – line features.

Each of listed shapefiles has its role. *BauX_YYY_Rooms* stores a meaningful attribute table, *BauX_YYY_Floor* provides background and has an attribute table that will become important in future when floor detection and indoor positioning system will be incorporated. *BauX_YYY_Lines* serves as a visual enhancement and helps a user to navigate in the building as doors and windows are shown in this map layer.

By implementing a meaningful attribute table for *BauX_YYY_Rooms* following advantages arise:

- Possibility to perform spatial relationship queries with *Issues*;
- Possibility to automatically populate *Issues* attribute table with field values regarding location (building, floor, room number);
- Possibility to integrate automatic floor detection in future (has a field with room height);
- Greater facility maintenance possibilities by having more content delivered to the user.

Since *BauX_YYY_Rooms* shapefile for each floor has to be prepared in the same way, a customized tool was created with Python script. This tool deletes unwanted fields, creates new fields with specified properties and populates fields with user given values. If an input DXF file has annotations with room numbers, by spatial join between *BauX_YYY_Rooms* and annotation points it is possible to populate room number field automatically.

| Layer Name | Sublayers | Layer Type | Reused | Notes |
|---|---|---|---|---|
| Visualized on top | | | | |
| *Issues* | – | Feature | Yes | Filters set by floor |
| *BauX_YYY_Lines* | – | Feature | No | |
| *BauX_YYY_Rooms* | – | Feature | No | |
| *BauX_YYY_Floor* | – | Feature | No | |
| *HFT_Background* | Building footprints and streets | Tiled | Yes | |
| Visualized on bottom | | | | |

*Table 1: Layers of a floor webmap*

By following designed workflows and using the new Python tool, it became possible to prepare all three floor map shapefiles and publish them in ArcGIS Online in approximately 30 minutes.

### 4.2 *ISSUES* FEATURE CLASS TEMPLATE

*Issues* point feature class template (further in text – *Issues*) is created once in ArcCatalog, published via ArcMap and then used as a database for all environmental building issues. *Issues* attribute table is created in a way that ensures easy usage, maximum error-proofness, reviewability and good organization. It is mainly achieved by creating subtypes, domains, linked-domains, defaults and setting appropriate properties on fields.

All environmental issues are divided in six subcategories-aspects (energy, waste, water, emissions, soil and safety/risk). There are different pre-defined themes for each subcategory, and each of theme has different pre-defined findings. When a certain aspect, implemented as a subtype, is chosen by a user, all subsequent choices also automatically change. For example, energy aspects can only have energy related themes and findings. User cannot make a mistake of having energy aspect and water themes or findings. Illustration

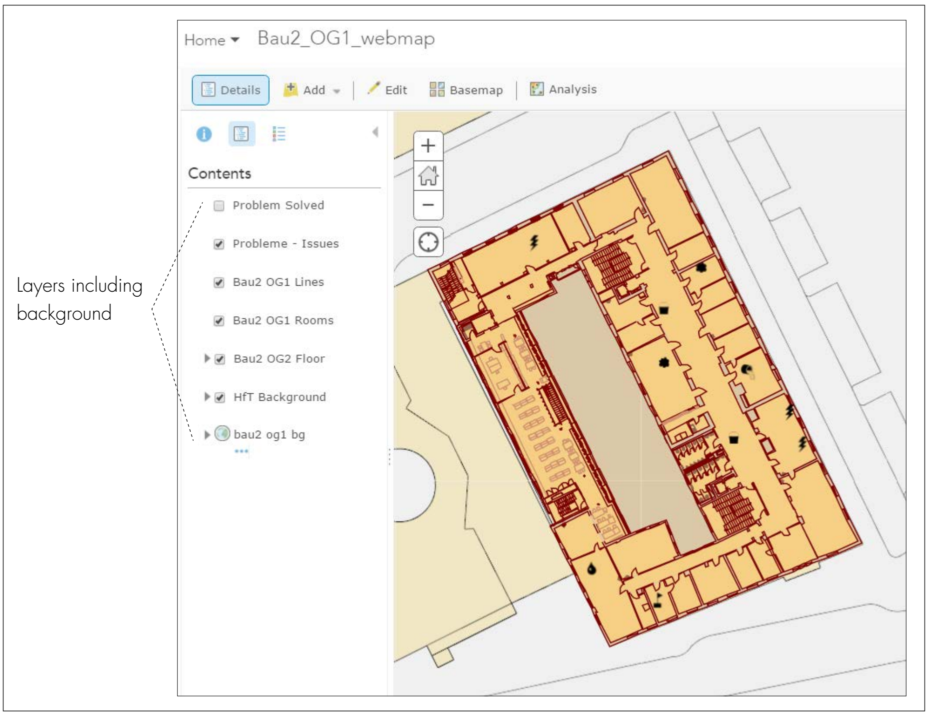


*Figure 2: A composed floor webmap that is visible to a user. Clicking on rooms (light brown) and issues (black markings) initiates further options.*

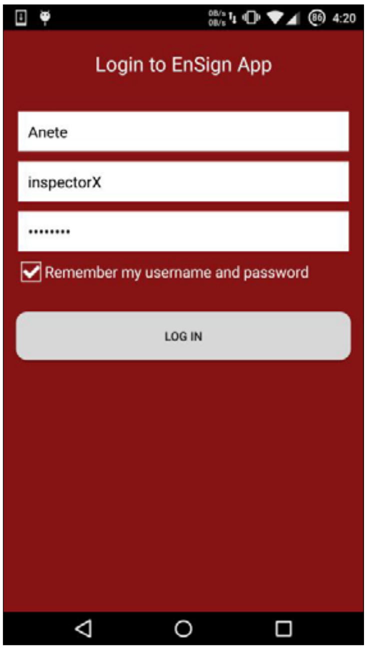


*Figure 3: Login screen*


*Figure 4: Home screen*


*Figure 5: Floor map with a few reported issues*

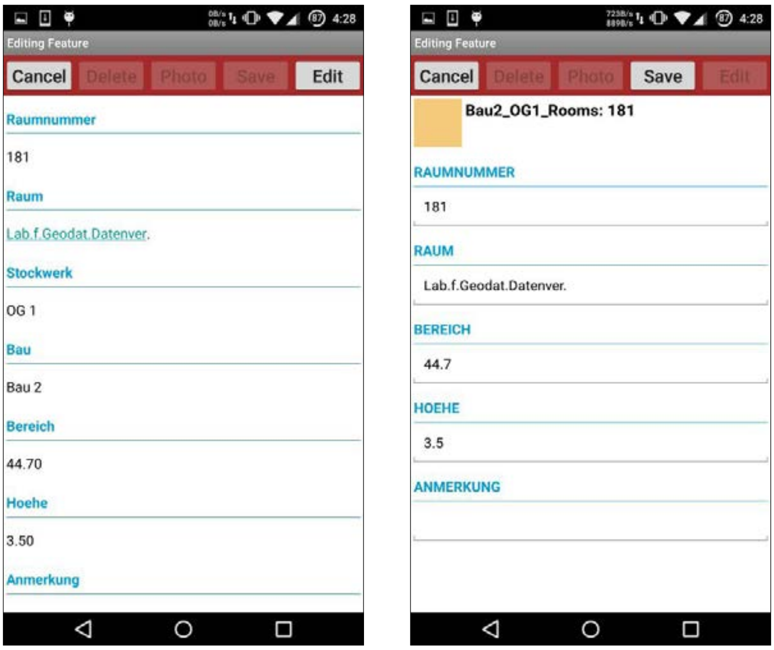


*Figure 6: Room information pop-ups for viewing (left) and editing (right)*

on how described subtypes and domains are used is given in Figure 1.

This data model substantially decreases possibility of human error and speeds up the work with the application. Some fields have default values chosen based on statistical analysis of Environmental Management department. It furthers the benefits of this data model.

### 4.3 A FINISHED WEBMAP

Once the actual data have been prepared according to the data model and published, the next step is to process it in ArcGIS Online before data can be used by the end-user. Processing consists of creating a webmap from layers and setting the right configurations for each. List of webmap layers is shown in Table 1.

Setting filters is a crucial configuration to make sure webmap displays the correct situation. As mentioned before all records are stored in one *Issues* feature class, however, each floor has different *Issues* associated with it and only those must be visible and editable on a given floor, not all. *Filter* must be applied to aid this problem. Figure 2 shows a composed floor webmap.

At this point end-user can already use ArcGIS Online or Collector app to handle environmental management.

## 5 DEVELOPMENT OF THE EMAS APP

### 5.1 A NEED FOR A CUSTOM APP

Once content has been set up and configured in ArcGIS Online, end-user can use it via web-browser. There is an existing Esri application called Collector that can tap into user's ArcGIS Online content and be used in the field. Also Collector can be used at this point and it already offers a number of well-developed core functionalities that will be also available in the EMAS app, the customized developed app has major following advantages, like:

- Querying possibilities can be realized;
- Field auto-fills can be realized;
- Fields can be suppressed for editing;
- UI suitable for multi-floor building environment;
- Labels can be added;
- Removed issues can be stored for historical analysis;
- Usage modes can be implemented;
- Automatic indoor positioning solution can be incorporated;
- Automatic floor detection can be incorporated;
- It can be adapted to other needs of buildings management;


*Figure 7:* *Pop-up for adding information on a new issue*

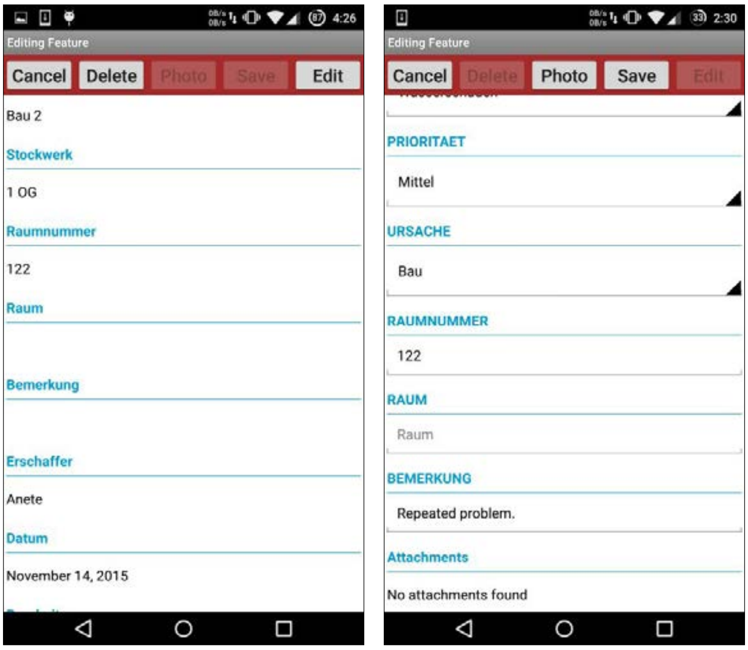


*Figure 8:* *Issue information pop-ups for viewing (left) and editing (right). Some fields are disabled for editing.*

- The EMAS app can be turned into a commercial product.

## 5.2 DEVELOPMENT TOOLS

Esri offers a software development kit for developing new applications. Other tools and software for programming Android ArcGIS applications are well established:

- JDK™ (Java SE Development Kit);
- Android Development Tools (ADT) plug-in;
- Eclipse Integrated Development Environment or Android Studio.

ArcGIS Runtime SDK enables utilization of ArcGIS Online content and functionalities. It allows to *"build native mapping apps for Android devices. Integrate a wide range of mapping and GIS tasks online or offline, including editing, […], and data visualization"* (Developers.arcgis.com 2014).

All data used in the application is hosted on ArcGIS Server and managed from ArcGIS Online. By using the REST URLs provided in ArcGIS Online, data is fed into EMAS app, making the programming independent from possible changes in webmaps. Configurations also form a part of REST URL specification. For example, filter set on *Issues* will be displayed in EMAS app. If settings are changed in ArcGIS Online, application will receive these changes through REST URL next time the content is loaded. By using this solution, the programming effort is relatively easier, code is lighter, and the application's code isn't affected by changes in data content.

## 6 RESULTS

The EMAS app was developed and deployed for beta tests. Figure 3 shows a login screen where users' given name in the first field is used for automatic work tracking. Credentials determine access level and available functionalities, for example, credentials that are linked to administrator mode allow deleting all issues and exporting the issue report by emailing it. Figure 4 shows home screen where a user can choose a building on campus to start work with.

There is a floor map with a few reported issues shown in Figure 5. Floor-floor navigation is conveniently handled by a scroll-tab on top. With a single swipe a user can open other floor maps. For easy floor-to-building navigation there is a drawer on left side of the screen. It opens a choice for buildings, duplicating functionalities of home screen. A user's click on a floor map opens a pop-up with room information for viewing or editing (see Figure 6). Viewing and editing functionality is also dependent on entered credentials; not everybody is supposed to access and manipulate this sensitive information. Since rooms have an absolutely static nature, not all fields can be edited as shown in Figure 6.

Figure 7 shows a pop-up for entering information on a newly added issue. An issue itself can be added by long-pressing on a map at the desired location, the pop-up then will open automatically. A little, black triangle on the right side indicates that there is a roll-down choice for the field as designed in data model. Statistically correct defaults are already set for each aspect, location-based fields are auto filled based on special query and user's name and date are also automatically entered in the field and not allowed to be edited by a user. The latter fields are not visible in Figure 7.

Figure 8 shows what happens when a user clicks on an existing issue. A pop-up window opens showing all field information. Difference between this and pop-up, that shows when adding a new issue, is function buttons on top and the fact that all fields are visible for viewing. When *Edit* is clicked, some fields disappear as information in them is not supposed to be edited and some are again auto-filled (editors name, date).

Function buttons on top of pop-up are enabled / disabled depending on what can be done at a given moment. *Delete* button's functionalities depend on entered credentials. A regular user can only delete his own features in a certain time limit after he has added it. In administrator mode there are no restrictions for the delete button.

For decision makers to understand the entire situation of a building and follow the changes over time, track of every issue, fixed or existing, is important. To aid this need, a user is presented with a choice when deleting – to delete issue permanently (if, for example, issue was a false entry) or to mark it as solved (see Figure 9). In latter case an issue is removed from the map, but written in another feature class preserving its spatial location. The deleted issue feature class is available in ArcGIS Online.

There are other functionalities and details in the application that ease inspector's work with it and ensure data correctness. It is a field app first and mostly. While developing EMAS app it was important to keep in mind that people using this application are not familiar with GIS. Therefore, all functionalities are designed to allow for everybody to use EMAS app with no previous GIS experience.

For data analysis a user has to use ArcGIS Online. At this stage, most that could be done is providing written manual for stakeholders of how to handle most important operations in ArcGIS Online with regard to environmental management.

## 7 CONCLUSION

EMAS app was firstly developed with limited functionalities as part of a Master's Thesis. However, since it was designed to aid a real problem and real data was used for the data model, the app has been further developed by Anete Fridrihsone and Bishoy Gerges at HFT-Stuttgart.

The described technologies are rather streamlined, therefore the data model and app development are two key parts that needed attention. Understanding the core problem that had to be solved while leveraging existing, of-the-shelf technologies was the driving force behind the data model. App development was largely carried out by keeping in mind problems that raise in current environmental data collection processes.

Further enhancements will be mostly targeted on providing analysis tools in the EMAS app. For example, filters for field values and queries. By adding simple-to-use analysis tools, more non-GIS specialists will be able to benefit from possibilities offered by standard GIS solutions and it will also decrease the need of using ArcGIS Online.

Among other future enhancements there is crowd sourcing, incorporation of indoor positioning system and development of automatic floor detection, as well as possibility to make this solution Esri-independent. Taking the entire solution off the Esri's services, by creating a new web-service and Esri independent application, is the next goal.

In this solution the focus is on environmental management by EMAS, but with simple data changes of point feature class template, the solution can be applied to other problems in indoor management that have not been solved with GIS approaches so far. This work contributes to bringing GIS further indoors and applying many well-known outdoor solutions to indoor problems.

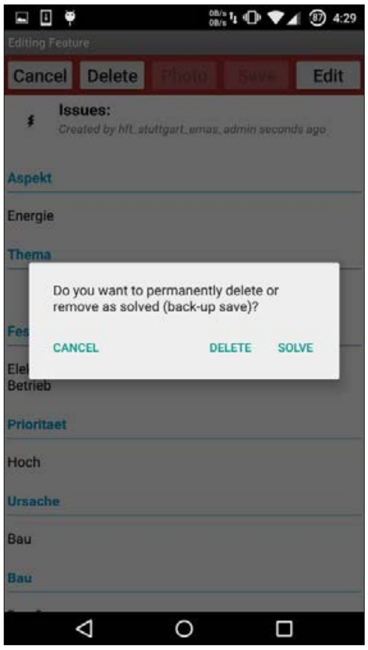


*Figure 9: A user is presented with a choice when deleting an issue – to delete it permanently or remove as solved*

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