GIMA
Geographical Information Management and Applications

Road Hazard Point Acquisition

The Smartphone Way

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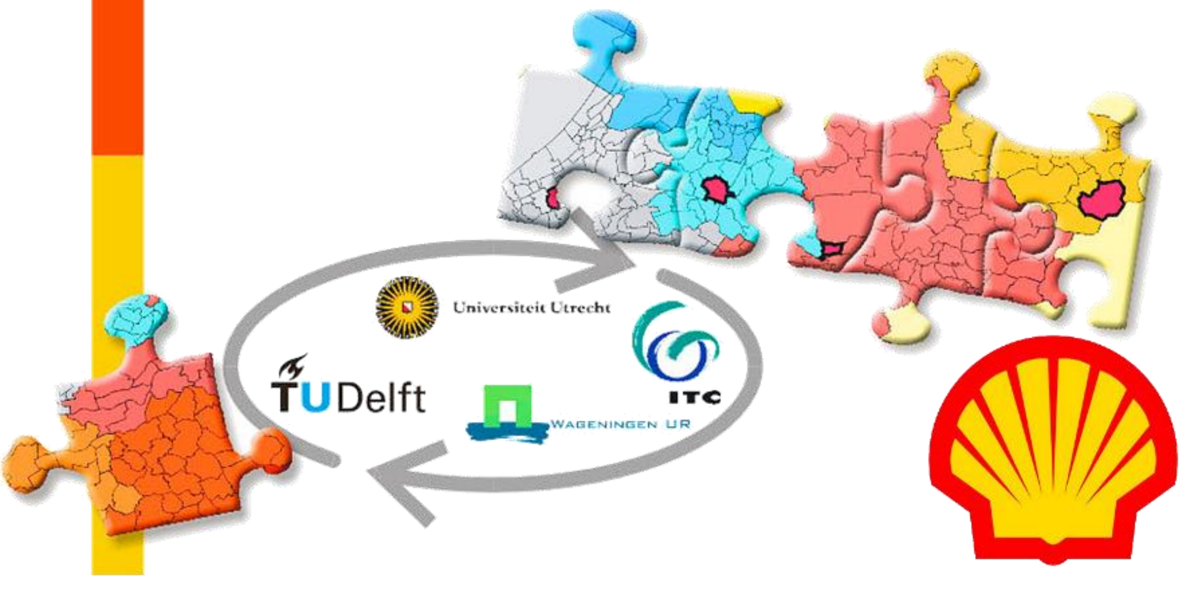

Summary

The goal of this thesis is to research the usability of smartphones for the acquisition of road hazard points as well as research the quality of the reported hazards and see if that matches the requirements. For the purpose of this research a smartphone app was developed on the Android platform that integrates with backend infrastructure developed in the Amazon cloud. Information gathered in the backend is then imported in the Shell standard Geomatics infrastructure for use in journey management. A pilot was conducted in Gabon, Iraq, Oman and the United Arab Emirates, and from this pilot results were gathered.

The hazard acquisition system has received quite some positive feedback from many of the participants of the pilot and other people involved. Use of the Amazon cloud in combination with consumer electronics and standard tools, while able to handle restricted information in an approved way, is considered a great accomplishment.

The app is assessed as easy to use for most users, but there are also lessons to be learned to improve it. Different user groups have different requirements either related to their location or the function they fulfil, resulting in different expectations about the app and its use. None of the desired improvements are expected to be very hard to accomplish, but some of them might require a specialised app for that particular purpose.

Centrally publishing road hazard information with a standard symbology set integrated with Shell's standard legend is seen as a great step forward. Maintenance of the acquired data is however acknowledged as a concern to assure the hazard catalogue contains hazard data of acceptable quality. Field research to determine the positional accuracy of the used smart phones has resulted in a standard deviation of 11 meters, which is expected to be sufficient for how the road hazard data will be used.

The requirement of governance on the quality of the data becomes obvious when looking at the reported hazards by different users at the same location. Validity of reported hazards needs to be assessed and maintained for the data to become and remain valuable for journey management. Roles and responsibilities need to be defined and agreed to accomplish this.

The greatest challenge to overcome to make a solution as designed and built for this PoC is however to get it fully supported and embedded in the organisation. Many different user and interest groups need to have agreement on the way forward. Also getting software development contracts and support agreements with potential infrastructure suppliers in place requires an involved and dedicated person to steer and monitor the progress.

Preface

Shell as my employer and my sponsor for my study has provided me this wonderful opportunity to work on this project. At first it was a struggle to get the scope right with somewhat conflicting interests between the scientific requirements of a dissertation and the requirements to deliver a product. It has been hard work with time conflicts between work-life, study-life and barely a personal life, but I enjoyed every bit of it.
It has been my pleasure to work with many colleagues in Geomatics and other disciplines related to road safety to make this project to the success it has become. The list of people would grow too long to mention everyone I owe some credits for their contribution to this project, but I would like to mention some people in particular. I would like to express my thanks to Lammert Zeylmaker for being my supporter at Shell, and pulling me in the "Geomatics for Road Safety" forum which has been an excellent source of information. Robert Dunfey I thank for his out of the box thinking and assistance setting up the integration of the Amazon and Shell infrastructure. Khadija Aisari many thanks for creating the user guide for the app. Many credits to Roel Nicolai for his patience to get me up to speed with coordinate reference transformations and calculating positional accuracy, it has made me enthusiastic about the topic. Of course I should not forget my professor Arnold Bregt, Arend Ligtenberg and John Stuiver for guiding me in how to get this research started and limit the scope of my proposal.
I hope the results of this research will bring me closer to my graduation for GIMA but also to be beneficial to Shell and road safety as it is my desire to do something in return for this study opportunity.

Best regards,

Jorrit Jorritsma

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Colophon

1 Problem and Context

1.1 Background

In the context of Health, Safety, Security and Environment & Social Performance (HSSE & SP) road safety is one of the main areas of concern as more than half of the injuries and fatalities are caused in road transport (OGP, 2009). The "HSSE & SP Control Framework" (Shell, 2010a) mandates the implementation of a Journey Management Plan (JMP) in high-risk locations. It states the following:

2.4.1 The JMP must include the loading and discharge site (where applicable), authorised route, identification of route Hazards and communication requirements during the Journey.
2.4.2 The Driver must understand the JMP before each Journey.
2.4.3 The Driver must report any change from the plan that occurred during the Journey, and changes must be reviewed to decide whether to update the JMP.

Several Shell companies have adopted, or are in the process to take-up these requirements in their journey management processes. Due to the autonomy of these organizations, different local conditions and lack of centrally guided standards this often results in different implementations.

Several initiatives were undertaken to find innovative solutions to recurring problems with HSSE & SP systems, processes and tools. One of these initiatives, the In-Vehicle Monitoring System (IVMS) was found fit-for-purpose which has resulted in an adoption for most high risk areas (Shell, 2010b). The large IVMS vendors collect the drive event data and send it aggregated on trip level to the Shell Insight Browser system, where it is used to benchmark between Shell companies and individuals (who can achieve awards for good performance). In recent years several small local pathfinder projects were conducted with the potential to grow on their success or to be terminated otherwise. The goal of these projects is to create a global standard with tools, processes and best practices for road hazards data acquisition, maintenance as well as dissemination.

Improving on Journey Management has recently received renewed attention from the "Goal Zero" programme with as ultimate goal to bring the amount of road incidents and fatalities to zero within Shell operations. Amongst other things this has lead to the set-up of a "Geomatics Road Transport Safety" forum, which tries to unite several initiatives in a framework for road safety and learn from each other's experiences. The forum consists of representatives of Geomatics departments from different regions where road safety is high on the agenda, combined with representatives from global Geomatics in Rijswijk in the Netherlands.

This forum is currently focussed on integrating three different areas:

- Cross-country and on-road mobility between HSSE points of interest, like hospitals and fire stations, and any point in the field. These time-cost surface maps consider time, distance and terrain, and are used to assess the nearest point of interest, the fastest route, the time it takes to travel, but also to classify the area in risk zones. An overview of Cross Country Movement map process is presented in figure 1.

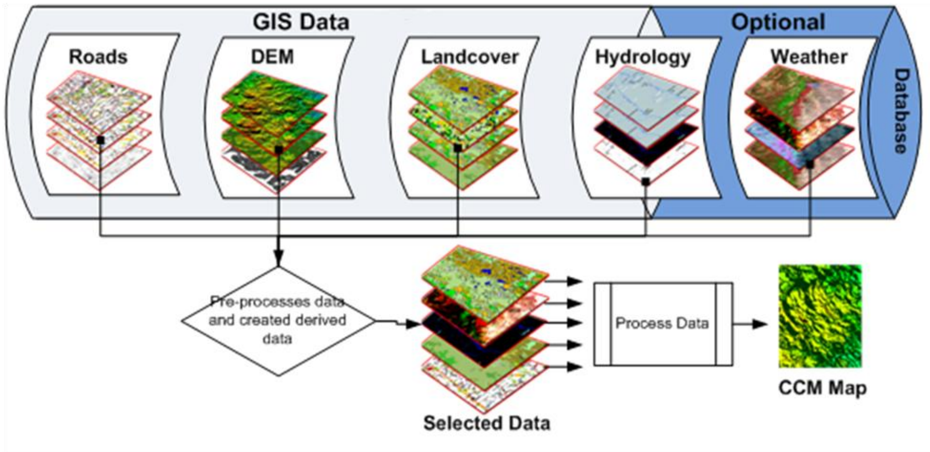

Figure 1: Process of CCM map (Neil & Kolonic, 2011)

- Turn by turn navigation including hazard voice warning based on updated maps. The need for complete road datasets (geometry and attribute) requires merging of off-the-shelf maps with GPS data acquired from IVMS devices or mapping agency. The maps need to be delivered in a variety of formats including for Personal Navigation Devices (PND). Road hazards are collected by geo-info analysis from IVMS data as well as from spatial database queries.
- Road Hazard Point acquisition with smartphones. Currently only limited road hazard information is retrieved from contractors and Joint Venture (JV) partners. Systems are not integrated and formal reporting lines for providing journey feedback do not always exist. By enabling anyone with a general available smartphone to easily capture road hazard information, improvements in the acquisition are expected. The ability to centrally disseminate the captured information to partners is expected to increase the adoption.

The "Geomatics Road Transport Safety" forum initially focuses on ventures in the following regions:

- Iraq
- Jordan
- Kalmykia (Russia)
- Oman
- South-Africa

Journey management is focussed on planning and performing safe journeys. It takes care of planning a journey, monitoring compliance and progress and providing performance feedback to the driver. Several articles describe this plan-do-check-act cycle as the best practice for Journey Management (Al Kurdi et al., 2008; Flanagan & Bashara, 2010; Twilhaar et al., 2000).
In high risk countries drivers working for Shell are required to create a JMP before they undertake a journey. In general the current journey management process can be visualised as shown figure 2. This is following the current international Oil & Gas Producers (OGP) recommendations as stated in (Tate, 2008).

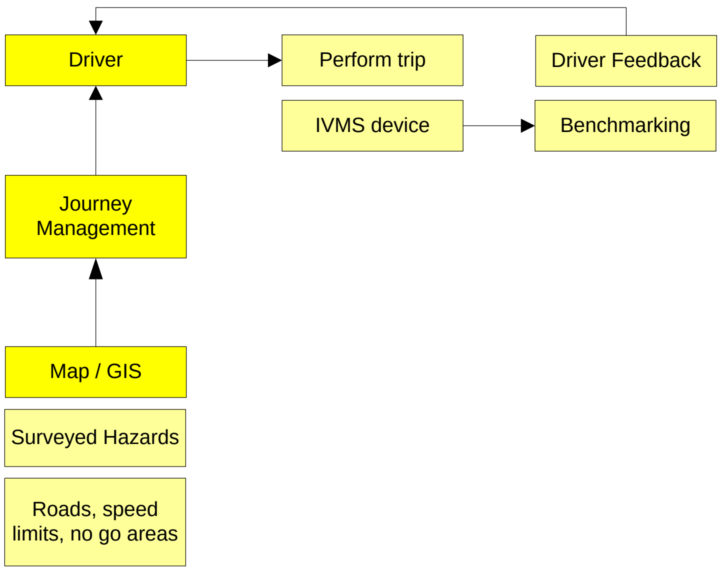

Figure 2: Journey Management process (inspired on (Zeylmaker, 2009)*)*

The articles mentioned all reference to a potential to gather new hazard information from the captured event data, there are however no references found to implementations. Figure 3 shows the situation the "Geomatics Road Transport Safety" forum tries to accomplish. The thick line represents the focus area of this research, and tries to accomplish a driver experience feedback into the system by means crowdsourcing the information from the drivers using smartphones. After embedding the acquired information in existing road hazard information systems (GIS) it is supposed to be used for journey management maps to plan future trips, and also as input for PND's to provide voice warnings to drivers.

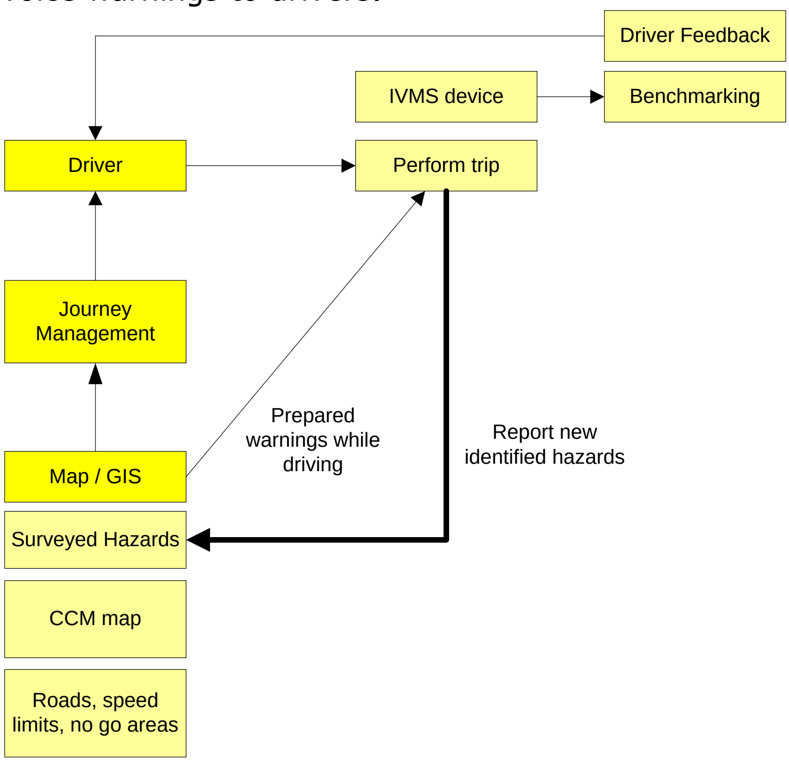

Figure 3: Focus area of this research

1.2 Problem Definition

While there is an enterprise wide desire to use all available information about road hazards as input for journey management to improve road safety, several problems stand in the way to make this happen:

- Different local environmental conditions provide different kind of hazards that need to be treated differently. There is no common information or classification model that can be used across the organisation.
- Different organizational set-ups make a centralized solution difficult; few entities are purely run by Shell staff, while others are JV's comprised of governmental bodies, other oil companies, contractors and suppliers. External parties typically do not have access to the Shell infrastructure. For this reason they cannot have access to road safety information kept in Shell.
- Autonomy of the individual ventures tends to result in different road hazard data models and map presentations. This makes information exchange or re-use of tools and symbology difficult. It also results that staff moving from one venture to the other is not aware of how to use the tools or interpret the local hazard maps. Common tools and infrastructure to support are missing.
- The quality of road hazard information is of high importance for people to rely on the information provided and to achieve general adoption. It is difficult to maintain road hazard information that is up-to-date, accurate and complete. A simple method to collect and maintain road hazard point information is required to improve road safety even in regions without dedicated staff.

1.3 Research Objectives

The goal of this study is to introduce crowdsourcing for the collection of road hazard points making use of smartphones. The smartphone application facilitating this must be easy to use. The data created with the application must be in line with the requirements for road hazard point information. The data shall be easily accessible from within the Shell network as well as to selected external parties and contribute to existing road hazard information systems while maintaining the company's security policies.

To achieve this, the following objectives are formulated:

1. Design a **road hazard classification** model for road hazard point information to be used by all involved parties.
2. Design and build a **Proof of Concept** (PoC) application to capture road hazard points using smartphones that can store and disseminate the information to the required parties in line with the company's security and regulatory policies.
3. Assess the **smartphone app usability** to acquire road hazard points.
4. Assess the **road hazard data quality** for use in journey management maps.

1.4 Scope

In scope of this pilot project are:

- Develop information and classification model for road hazard points.
- Design smartphone application.
- Build the designed mobile application on a smartphone platform.
- Design a security model that matches Shell's security policies.
- Design a web backend to collect the captured hazard points.
- Build the designed web backend accessible by all required parties to access the uploaded hazard points.

- Collect user feedback to assess the quality of the smartphone application as well as the web backend.
- Collect spatial data quality feedback from end users.
- Perform limited field tests to assess some application and information quality aspects.

Out of scope are:

- Provide infrastructure for general road hazard map
- Hazard information export to personal navigation system.
- Data entry for shape features (time to hospital shapes, GSM coverage etc). This will be provided by Shell Geomatics staff.
- Data entry for hazard points acquired from GIS analysis or other sources like IVMS suppliers
- Comparison between on hazards points acquired with the smartphone application and other methods of collection.
- Assess influence of user motivation factors on captured road hazards.

1.5 Thesis Overview

This document will first describe the methods followed to conduct this research. The literature review chapter following the methods looks into prior work on the assessment of crowdsourced geospatial data quality as well as other crowdsourced hazard studies. The four following chapters describe the results of the effort to accomplish the objectives of this research. Because of the amount of information covered by these chapters they are all concluded with a discussion paragraph reflecting on the findings. The road hazard classification chapter gives insight in the decisions made on which hazard classes and categories to use in the application, as well as how these are used. The following chapter, proof of concept, tells about the design and build phase for the application infrastructure built to facilitate this research. The chapter smartphone app usability gives insight in the usability of the app from a regulatory and end-user point of view. The last of the result chapters, road hazard data quality, assesses the quality of the data gathered in the pilot and tries to relate it to the requirements for us in a journey management map. The final chapter contains the conclusions and recommendations coming from this research.

All abbreviations are referenced in the colophon which can be found on one of the first pages of this report after the table of contents.

2 Methods

In this chapter the methods are described to reach the stated objectives for this research. In the following paragraphs is described how the road hazard classification is created, how the PoC is setup and how the usability of the app and the data quality are assessed.

2.1 Road Hazard Classification

The classification of hazards is based on results of prior hazard acquisition pilots and input from the participants from the "Geomatics for Road Safety" forum. The classification needs to be designed and it needs to be decided what classes are required in the application and how they should be applied.

2.1.1 Road Hazard Classes

An attempt is made to distinguish different road hazard classes containing different hazard categories. The internet is searched for good quality and public domain symbols that can be used as hazard category symbology. Where required the artistic capabilities of the author are challenged to create the missing categories. All base images shall be vector based to allow for scaling and generation of different formats from that. As the symbols will likely be used for different applications, different image formats must be provided.

2.1.2 Road Hazard App Classes

Contributors to the "Geomatics for Road Safety" forum are asked to select the hazard classes / categories to be included in the smart phone app. The selected set is applied in the PoC application and used for field tests during the pilot stage of this project.

2.1.3 Risk Classification of Hazards

Hazards represent a risk. Every time a hazard will be entered in the system an assessment of the risk needs to be made on which to decide to include it for journey management or not. A decision will be made on how to incorporate this in PoC application.

2.2 Proof of Concept

Designing and building a PoC road hazard application involves many activities.

2.2.1 Infrastructure Design

To meet the objective to allow all required parties to be able to access the gathered road hazards, a design needs to be created that takes this into account. The design is formed based on the authors inside knowledge of the Shell IT infrastructure and its policies from a practical angle. The forthcoming ideas are reviewed by the "Geomatics for Road Safety" forum as well as subject matter experts, leading to the eventual design.

2.2.2 Road Hazard Application

Designing and building the road hazard application is an iterative process based on feedback from the "Geomatics for Road Safety" forum as well as technological opportunities and limitations. Several components need to be designed and built to allow piloting this PoC, such as a smartphone application to enter the hazards with, but also a database backend accessible by all required parties. Also data exchange needs to be looked into, to allow for easy integration and dissemination in the existing infrastructure.

2.2.3 Geomatics Integration

To facilitate a pilot running with the PoC road hazard application, the information that is gathered needs to be made available to Geomatics for incorporation in existing GIS portals and journey management systems. The test and development environments shared between Geomatics Rijswijk and global Geomatics support are used to implement this without the involvement of too rigid change management processes. The upside of this approach is the possibility to deploy and change software and data models on demand, the downside however is that support is only provided on best endeavours. In the light of this being a PoC, agility is preferred over stability.

2.2.4 Pilot

With the built infrastructure in place and funding from Geomatics global a pilot is run in the countries / regions represented in the "Geomatics for Road Safety" forum. Support to the pilot users is provided by the author on best endeavours, when possible besides his normal work activities. Responsibility for collection of road hazard data is with the operating companies.

2.3 Smartphone App Usability

To test the usability of the road hazard smartphone app a pilot will be performed with participants in different parts of Shell and in different parts of the world. The usability of the road hazard app is assessed on compliance with regulatory requirements, the user friendliness of the app and the usability of the adopted classification.
This is done by collecting feedback from the pilot users by means of a survey as well as general feedback. To limit the scope of this project no formal usability assessment model is followed.

2.3.1 Regulatory Compliance

In order to ship the application and smartphones to different nations the software and hardware needs to comply with the export regulations of the nation of origin but also with the import regulations of the nation it is shipped to. Export of the software and the devices is reviewed by the export compliance office. The regions in scope for the pilot are assessed on their import regulations. Only when the regulatory compliance rules are met participation to the pilot can be granted.

2.3.2 Road Hazard Classes

The usability of the hazard classification and symbology quality will be assessed by a survey requesting for abundant or absent classes as well for the clarity of the symbols used.

The user friendliness of the application is assessed by collecting some metrics on:

1. How much time is needed to train the users of the smartphone application?
2. How many support calls do they make?

Also a qualitative assessment will be done by means of a survey asking for user experiences.

2.3.3 Road Hazard Acquisition Survey

Towards the end of the pilot everyone who has contributed to the pilot either by collecting road hazard data or other input to the project is approached to fill in a questionnaire. This questionnaire focuses on the usability of the smartphone app as well as the symbology and classification of the hazards.

2.3.4 Feedback

All feedback provided by participants as well as observations by the author with regards to the road hazard PoC will be gathered and reviewed. Noteworthy information in relation to this research is captured and described.

2.4 Road Hazard Data Quality

Quality is not a very tangible property, generally described as "fitness for its purpose". In a more formal way spatial information quality can be measured against a specification at the level of spatial object, spatial object type, dataset or dataset series. There is however no such thing as absolute quality. Quality is relative and only becomes meaningful when measured against a specification. Assessment of quality can be done against a number of quality properties; these can be non-quantitative or quantitative. Non quantitative or subjective quality properties provide information about the data. Three quantitative properties are recognised (Coote & Rackham, 2008; ISO, 2005):

- Purpose - why was the data created?
- Usage - what application does the data service?
- Lineage - what has the data been used for, how was it captured, maintained and modified?

Quantitative quality is usually subscribed to five components (ANSI, 1999; Bennat et al., 2007; Coote & Rackham, 2008; Faïz, 1996; ISO, 2005; ISO, 2006):

- Positional accuracy - the accuracy of the position of geographic objects.
- Temporal accuracy - the accuracy of temporal attributes and temporal relationships between features
- Thematic accuracy - the accuracy of attribute values
- Completeness - the excess or absence of objects in a dataset, their attributes and relationships
- Logical consistency - degree of adherence to logical rules of data structure and relationships

To assess the geo-information quality there is a need to determine what the fit-for-use criteria are. This relates to the purpose and the application of the data.

The overall purpose of capturing road hazard point information is to improve on road safety for people working for Shell. The "Geomatics for Road Safety" forum was consulted for these criteria:

- New hazard points can easily be created and uploaded by anyone with a prepared smartphone. This relates to the user friendliness of the applications, how much time is required to create an entry and how much training people need to start using it. Also this is dependent on network connectivity and the applied security model.
- Data can be used in an existing journey management map and adheres to a standard classification for hazard points with related symbology. The classification needs to be consistent, complete and unambiguous for the whole life cycle of road hazard points from collection to presentation.
- The information can be accessed and maintained by a selected group of actors, the access model needs to be in line with the Shell information security model.

- Positional accuracy needs to be in line with the requirements for use on existing journey management maps and navigation devices.
- The captured hazards should be represented with a correct classification. A pre-defined set of classes helps to make this classification syntactically correct, however the semantic correctness is highly dependent on the selections made by the user of the smartphone application. This puts constraints on the easy distinction of the defined classes.

Within the context of this research not all spatial data qualities are considered as important or easily measured. Temporal accuracy is considered good enough if it identifies the date on which the hazard point was collected. This is sufficient to identify an expiry or re-assessment date for that particular hazard. Completeness is highly dependent on the adoption of the smartphone application and the hazard awareness of the user. There is a desire to have an as complete as possible road hazard point data set, but no baseline data available to compare results with. Also logical consistency is due to the simplicity of point features and the strict data entry with a dedicated application not deemed relevant. With regards to the road hazard data the positional accuracy as well as the thematic accuracy of the data is assessed.

Fitness-for-use with regards to road hazard point information also imposes other properties that relate to quality. For instance security, availability and accessibility are such quality properties. Those quality properties can be regarded as inherited from the more general information class (Naumann & Rolker, 2000; Stvilia, 2007). Obviously these properties are also important; accessibility and security are therefore assessed as well.

2.4.1 Accessibility and Security

The road hazard data needs to be accessible to Shell but potentially also to external affiliates. This requirement implies that the data has to be kept outside the Shell network as external parties cannot get access. To accomplish this, an external party will be used to host the data. In order to host externally however, the solution needs to comply with Information Risk Management (IRM) rules. Based on the requirements imposed by IRM an access and security model will be built in the PoC and validated for its quality by assessing the accessibility by the pilot participants. The security design is to be challenged and signed off by Shell's Exploration and Production () EP) IT architect.

2.4.2 Positional Accuracy

The positional quality will be assessed qualitatively by requesting feedback from cartographers who use it for journey management maps or PND's, this feedback will be collected by interview or by survey.

Also some qualitative tests will be performed by:

1. Comparing the positions acquired with the smartphone application with positions acquired with a differential GPS (dGPS) system.
2. Acquiring the location with the smartphone application on prior accurately measured locations.

In both cases the accurately measured points are believed to have an accuracy of better than 10 cm.

2.4.3 Thematic Accuracy

To be able to assess the thematic accuracy road hazard points reported by different users will be compared. A comparison of the chosen classes between the users will be used to assess the clarity and ambiguity of the symbol classes. Potentially some qualitative assessment of completeness can be deducted from these results.

3 Literature Review

User generated geospatial data, the proposed solution to provide hazard information into the journey management process, is a relatively new phenomenon that uses the public to collect information that was traditionally collected by formal mapping agencies or professional surveyors. It comes under a number of disguises as Voluntary Geographic Information (VGI), crowdsourcing geospatial data or neogeography. The term crowdsourcing geospatial data are used in this paper as with road hazard data acquired during a trip for work it can be debated whether that is voluntary. Neogeography on the other hand implies more than just data acquisition, with its reference to geography it suggests also activities as data modelling prior to acquisition, data integration and interpretation for use in some application (Heipke, 2010). A large number of crowdsourcing initiatives have emerged over the last years. One of the most prominent examples is likely http://openstreetmap.org, with the goal to create and provide free geographic data to anyone (OpenStreetMap, 2011). There are however also other projects that try to achieve something more in-line with the goal of this research. A very successful project is Ushahidi http://www.ushahidi.com which is an initiative to crowdsource crisis mapping information. It has proven to be a very successful source of information for rescue workers after the 2010 Haiti earthquake and the floods in Pakistan later that same year (Vericat, 2010). Ushahidi offers an open source solution to build an infrastructure to report geoinformation in virtually all current electronic methods available. Also http://www.verbeterdebuurt.nl/ and http://buitenbeter.nl are efforts to improve neighbourhoods in the Netherlands by enabling citizens to report improvement ideas or grievances in their area. Community councils get notifications about these reports for them to assess and action. Both initiatives use smartphones and social media as means of data entry. The mentioned examples follow, as many other projects, the open source strategy. There are however also successful commercial examples like the HD traffic solution of TomTom.

3.1 Crowdsourced Geospatial Data Quality

Crowdsourcing geospatial data has taken a great flight basically due to the wide availability of handheld GPS receivers or GPS enabled smartphones and the possibilities that Web 2.0 technologies offer. Benefits of crowdsourced information are accredited to the low monetary cost of the data, utilization of local geographic expertise, and the suggestion that entries created and validated by large numbers of people are likely to be more accurate than entries created by individuals (Goodchild, 2008). Studies on the quality of OpenStreetMap data acknowledge this suggestion (Ather, 2009; Haklay, 2010). It needs to be said however there are also issues related to user contributed geo information. Equal distribution of quality parameters over the area is more questionable. Less frequently accessed areas will likely be less complete, and some users might be more sloppy than others when geo-tagging a location (Haklay, 2010; Heipke, 2010).

The quality of crowdsourced spatial data is, besides the experience of the contributor, dependent on their motivation. Methods to stimulate creation of good quality content are subscribed to recognition of the contributor but also on the quick availability of their contributions. Means to validate contributions are considered of importance to the quality of the data (Coleman, 2010).

3.2 Crowdsourced Hazard Studies

There are many crowdsourcing initiatives also in research, some of which not very dissimilar to what is pursued with this research. Rice et al. (Rice et al., 2011) describe a methodology to combine existing local cartographic resources combined with user contributed geospatial data to alert visually impaired when navigating through areas with temporary hazards. The addition of user contributed information is regarded of high interest as it leverages on local geographic expertise and offers significant advantages for provisioning real time hazard information. This project offers multiple ways to provide user contributed data, in textual or spoken form and uses specialized geoparse technologies to match entries to locations. Besides the requirement of advanced technologies to map speech to text and match descriptions to locations, this also requires a very well defined space, tagged with names and aliases, in which hazards can be reported.

Another much to this research related project has been conducted by Jeffery Shi (Shi, 2009). His project, a case study of a road hazard reporting system, has resulted in design for a client server set-up to collect and distribute hazards.

The client side exists of a phone that allows users to enter hazards, or generate entries based on accelerometer readings. The server collects these entries combined with regular position updates submitted by the client. Clients in turn get updates on actual hazards within some range dependent on the position and driving direction. Regretfully there are no references to real implementations of this system. The report however gives a nice overview of such systems capabilities.

4 Road Hazard Classification

One of the goals of this research is to present a road hazard classification that can be used across different regions and businesses, and particularly can be used in a road hazard smartphone app. Prior pilot findings are used as a starting point and adjusted to the author's judgement in liaison with members from the "Geomatics for Road Safety" forum.

4.1 Road Hazard Classes

Three classes of road hazard information are recognised, and are matched with common European road sign classes as defined by the Vienna convention on road signs and signals (Economic Commission for Europe, 1968) as warnings, limits and information. Figure 4 shows the general symbol shape and colouring for the three classes.

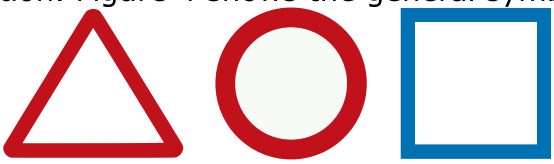

Figure 4: Hazard classes warnings, limits and information

Within the classes different categories of road hazard information were created and selected to depict different hazard types. A complete overview of categories with matching symbols for all three hazard classes can be found in appendix a. All category symbols are derived from public domain Dutch and Belgian traffic signs. All symbols were modified to be usable as small symbols used on a smartphone. Some of the symbols are based on artistic work from the author.

4.2 Road Hazard App Classes

Considering the amount of categories that would be desirable and usable in a smart phone app it was decided within the "Geomatics for Road Safety" forum only to incorporate the categories of the warning class in the smart phone app because these are considered to be the most relevant to report by people travelling. Table 1 gives an overview of the categories used in the phone, and an assessment is made whether the hazard type applies to point, line or area features. Initially all are included in the app; additionally the temporality of the hazards is assessed. It will be for future generations of the app after the pilot to decide which ones are obsolete for its purpose, and possibly to include other hazard categories as well. Some decisions were made to limit the amount of symbols, based on the similarity of the hazard. For the "animal warning" the sheep sign was chosen instead of signs showing camels, kangaroos or cows, as this is considered the most generic one on a global scale. All hazard symbols that can have two directions, like a "roundabout" or "soft verges", for right and left side driving countries, the one for right side driving is chosen as the default. Also for the categories with a direction like "sharp bend" and "winding road", one sign is provided.
All categories used in the road hazard application were made available in the Shell Standard Legend (SSL). This legend is distributed amongst all Geomatics departments globally. The Enhanced Metafile Format (EMF) is the image format used to create the SSL. EMF is just as the Scalable Vector Graphics (SVG) format, the format the symbols are created in, a vector image format. The advantage of vector graphics obviously lies in the scalability of the images without them losing their detail at down-scaling or becoming blurry around the edges when up-scaling. Inkscape (http://inkscape.org/) is used to convert between the 2 image formats as well as ras-

ter based formats such as Portable Network Graphics (PNG) used in a later stage for the smartphone app.

Table 1: Road Hazard warning categories and their use

Description	Category Name	Symbol	Feature Type			Temp.
			Point	Line	Area	
Animal crossing	animalwarning		X	X	X	N
Bad road conditions	badroadsurface		X	X		N
Blackspot	blackspot		X			N
Dangerous point	danger		X			N
Dangerous crossing	dangerouscrossing		X			N
Explosion danger	explosiondanger		X	X	X	Y
Flooding danger	flood		X	X	X	N
Grounding danger	grounding		X			N
Hill top, poor visibility	hilltop		X			N
Landslide danger	landslide		X	X		N
Narrow road	narrowroad		X			N
Crossing pedestrians or school children	pedestrians		X	X	X	N
Poor visibility possible	reducedvisibility			X	X	N
Road works	roadworks		X	X		Y
Roundabout	roundabout		X			N
Overhead cable	overheadcable		X			N
Sand dunes	sanddunes			X	X	N
Road can be slippery	slippery			X		N
Sharp bend	sharpbend		X	X		N
Soft verges	softverges			X		Y
Steep hill	steephill			X		N
Train crossing	traincrossing		X			N
Tunnel	Tunnel		X	X		N
No U-turn beyond this point	uturndanger		X			N
Winding road	windingroad			X		N

4.3 Risk Classification of Hazards

A hazard is a potential source of harm; the risk a hazard exposes is however dependent on the likelihood of occurrence and the potential impact it can cause. This means that to correctly assess hazards for relevance in a journey management map the likelihood and potential impact need to be valued per hazard. As this requires expert knowledge from the person reporting a hazard, it is decided in liaison with the "Geomatics for Road Safety" forum not to include this in the smartphone app. It is believed this would make the app more difficult to operate and rule out a large portion of potential users. To have a hazard reported instead of only with the proper risk values set is considered more important.

4.4 Discussion

For the hazard classes it was decided to largely follow a simplified Dutch road sign classification. Where Dutch road signs distinguish between limit and prohibit classes these are treated as one limit class for this application. The warnings are mostly taken as is with some additions to match warning categories identified in prior pilot projects. The informational class is mostly used as a template for the identified information categories. This approach is believed to result in a clean and consistent set of symbols.

It is decided to only include the warning class of categories as the app is supposed to

be used during field trips and to enable anyone to report on hazardous situations. The informational and limit classes are thought to require more expert knowledge, or to be collected otherwise. The set of categories included in the smartphone app is selected based on prior pilot results from Algeria in 2008, as well as close communications with members of the “Geomatics for Road Safety” forum. The author has noticed however from gathering information from peers that the more input is received on the classification, the more categories seem to be required. For the pilot a relatively small set is chosen over a very extensive one, to allow ease of selection and prevent different categories with the same involved risk type.
The risk classification of a hazard is considered export judgement, which cannot be expected from the occasional hazard reporter, meaning that the hazards reported will likely require post processing to include only hazards above a certain risk threshold to be presented in a road hazard map.

5 Proof of Concept

For the purpose of running a pilot capturing road hazard points using a smartphone, a PoC application stack is created. The application stack is comprised of a smartphone app, an internet backend to store the captured hazards and methods to retrieve these into the Shell Geomatics infrastructure. The following paragraphs describe the design and its components.

5.1 Infrastructure Design

In this pilot to capture road hazards using a smart phone for Shell's journey management a method to report hazards into the Shell network is a requirement. As access to the Shell network over the internet is limited only to Virtual Private Network (VPN) connections, this is not a viable solution for a smartphone implementation. To mitigate this problem intermediate infrastructure is used to store the results on the internet, from which it can be downloaded into the Shell network. At first Google App Engine was chosen as backend to store the records. The use of Google services professionally in Shell is however deemed to result in high contractual costs. For this reason a different service provider was sought and the Amazon Web Services (AWS) were chosen as the internet backend to store the road hazard records. Shell already has contracts with Amazon and using it fits the strategic IT direction Shell is going to. The high-level overview of the infrastructure design can be seen in figure 5.

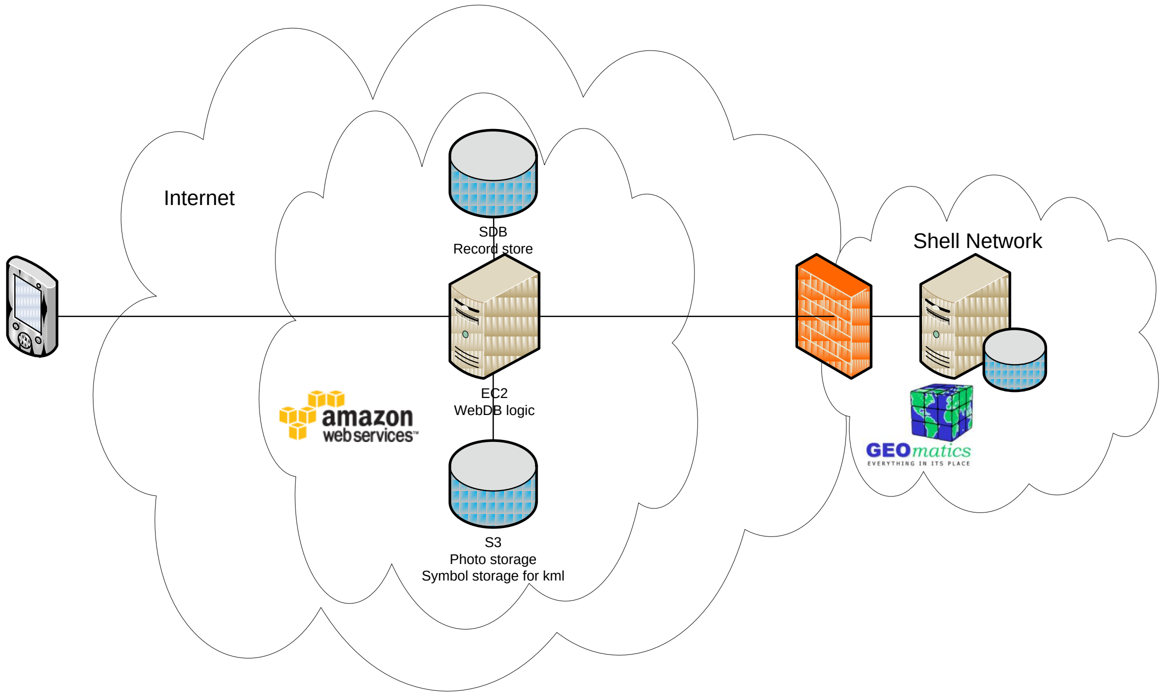

Figure 5: High level infrastructure design

As phone platform Android was chosen for its open and freely available development environment. Besides that Android does not impose an application review process before a new app can be installed on multiple devices, therewith keeping the development / pilot lean. From the Amazon cloud 3 services are used, EC2 (Elastic Cloud Computing) as a server platform, SDB (Simple DB) as a record store, and S3 (Simple Storage Service) as storage for photos that accompany the hazards. The phone used to capture hazards will initially store the points in a local database on the phone itself, and when convenient (access to network) these can be uploaded to the Amazon cloud. The phone communicates with the WebDB Application Programming Interface (API) on an EC2 instance, the WebDB service stores the hazard records in SDB and photos on S3. From the Shell side the records can be downloaded using the Web DB API.

Shell's Information security policies put constraints on the accessibility and use of external infrastructure for storing corporate data. The constraints are dependent on the security classification of the data stored. All information in Shell is classified in 4 categories: public, restricted, confidential, and most confidential. Public information as the word suggest can be shared outside Shell. Restricted information can be shared in Shell and with affiliates. Confidential and most confidential information can only be accessed by a limited or very limited set of people in Shell. As road hazard point information may reveal the locations where Shell does business, this information is classified as restricted. To mitigate this security issue Secure Socket Layer (SSL) certificates are used to allow access to the service. This means that the smartphone app carries such a certificate and is therefore able to upload hazards. Also to access the web DB backend with a script or browser such a certificate is required. All connections to the WebDB without presentation of a valid certificate are denied access. This solution is accepted by the EP IT architect for the purpose of this pilot.

5.2 Road Hazard Application

The whole smart phone application involves, as the infrastructure design shows, more than just the smartphone app. The design and implementation of the components involved and how they integrate is described in the following sub-paragraphs.

5.2.1 Smartphone App

The road hazard capturing smart phone application was designed with simplicity in mind, as it should be quick to use and also usable by less literate people, as drivers a main interest group for this app are usually not highly educated. From discussions with peers in Geomatics and in the "Geomatics for Road Safety" forum it was decided a hazard should be categorised with a direct match to a symbol that can be chosen from a list. Combined with that some form of description has to be provided and where applicable a mitigating action and photo need to be added. These requirements have led to the design of a simple app of which the four screens are shown in figure 6.

Figure 6: Smartphone application screens 1 - 4

The first picture shows the main screen of the application. If there is a GPS fix the

“New Hazard” button can be pressed to go into the “Edit Hazard” screen and enter the hazards details. To be able to save on the phone’s battery the GPS can be turned off and on. The “List Hazards” button shows the hazards which are stored locally in the phone’s database, while the “Sync On-Line” will upload the points in the phones database to the Web DB in the Amazon cloud. The “Edit Hazard” screen (picture 2) can be accessed not only by creating a new hazard, but also by selecting a stored hazard (picture 4). A category must be picked from the “Hazard Categories” screen (picture 3) after pressing the “Category” button. Symbols with description are provided to allow selection of a category. Less literate people and non English speakers are supposed to make a decision based on the symbols. The photo button opens Android’s native camera app and allows taking a photo of the hazard. The hazard description must be entered and if a mitigative action is apparent this can be entered in the relevant field. The “Show On Map” button opens androids native navigation app and positions the requested hazard’s location at the centre of the shown map. Regretfully putting a marker at this point did not seem possible. The “Cancel” button cancels the current hazard registration, whereas the “Delete” deletes it from the local database in case it was already stored with the “Save” button.

During development of the smartphone app a beta version was released to a limited group of users. After feedback some amendments were made to it. The beta version incorporated a user-ID field that could be filled in to be able to identify different users. This field was perceived to be cluttering the screen unnecessarily because most users would not fill it in any way. For this reason the field was removed from the final version. Instead the phone’s IMEI number, a unique identifier every phone has, was added to the data model. The field is filled automatically by the app itself without any required user action. For the same reason it was tried to include the phone number, this however failed to work. Another change that was included in the final release is reporting of 3D coordinates instead of 2D.

The latest source code of the road hazard app can be downloaded from here: http://jorritsma.cc/~jorrit/Android/CaptureRoadHazards_android.zip

5.2.2 Backend Web Database

To centrally store the collected hazards on the internet a service is needed that provides an API to the phone as well as to the back-office to upload / download the information stored. Initially the Google App Engine was considered for this, making use of a modified version of the TinyWebDB service (Wolber & Abelson, 2010). Due to restrictions for commercial use of the App Engine services it was however decided not to use this. Instead AWS were chosen as a platform to build this backend on (Amazon Web Services LLC, 2011). A completely new and extended implementation of TinyWebDB was written to serve as the API between the phone, the records, and the Shell infrastructure. The basic TinyWebDB API implements only a PUT and GET method to store and retrieve key value pairs. The Road Hazard Web DB implementation incorporates some more, specific for storing and retrieving the road hazard records created with the smartphone app, while still compatible with the original specification. For convenience all calls are made accessible via a simple web interface shown in figure 7.

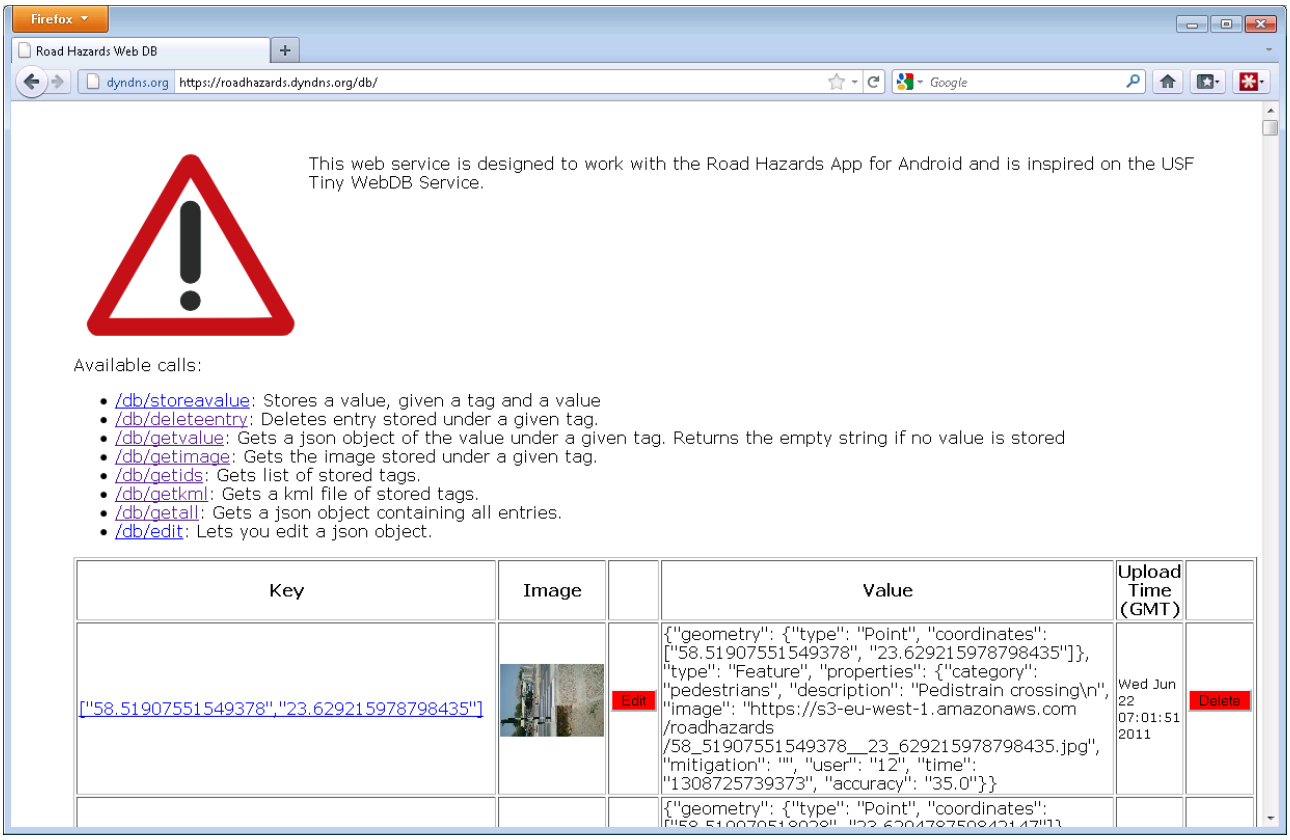

Figure 7: Road Hazards Web DB

The methods implemented are:

- storeavalue
  Stores a new record.
  This method accepts tag and value parameters which contain a key value pair, and stores that entry in SDB, and if the value object, explained in paragraph 5.2.3, contains an image attribute the image will be stored in the S3 roadhazards bucket.
- deleteentry
  Deletes a record entry
  This method accepts a tag parameter with the ID of the to be deleted record. Recursively also the image will be deleted from S3 if referenced in the hazard record.
- getvalue
  Retrieves one record
  The tag parameter provided with the ID of the record will be retrieved, the value will be presented.
- getimage
  Retrieves the mime encoded image referenced in the road hazard record.
  This method uses the tag parameter with the ID of the record of which the image needs to be retrieved.
- getids
  Retrieves all ID’s stored in the record store
  This method accepts no arguments
- getkml
  Generates a KML file containing all stored road hazards.
  No arguments are accepted.

- getall
  Retrieves a json array with all stored record values.
  No arguments are accepted
- edit
  Provides an edit mechanism of already stored records.
  When only provided with a tag parameter with the ID of the record to be edited, a web form is generated in which the record can be modified.
  When however also a value parameter with the record object is provided this record is stored in SDB.

The RoadHazards WebDB service runs on a standard Linux Amazon Machine Image (AMI) with some additional packages added to support the required functionality. These packages are:

python-dtopt
python-paste-deploy
python-tempita
python-webob
python-webtest
python-wsgiproxy
python-simplejson

The source packages were retrieved from the Fedora 15 build repositories and recompiled for this particular platform (Fedora, 2011). The complete source code of the backend scripts and the required configuration files can be found in appendix b.

5.2.3 Data Exchange

Data exchange between the smartphone and the Road Hazards WebDb, or to access of the data, is done via REST calls. Five methods already described in the previous paragraph deal with data exchange. The "getvalue" and "getall" methods return one or all stored records in GEOJSON format. The "storeavalue" method expects a GEOJSON object as input to store as a record. The "getkml" method returns all records in a KML file, whereas the "getimage" method returns a mime encoded image. The following subparagraphs describe the exchange formats and how they are used within the different methods. The GEOJSON format was chosen for data exchange with Shell as this is well supported in most programming languages like Java and Python, but also because it is easily imported into ArcSDE using FME Workbench, a standard tool used in Shell. The KML format was chosen as a format to exchange with external parties due to the wide availability of tools that can work with this format and its open standard (OGC, 2011).

GEOJSON

As said in the introduction the GEOJSON format (Butler et al., 2008) is used to exchange data between the phone and the Road Hazard WebDB backend as well as for downloading records from it. The structure of the GEOJSON object is as per the example in listing 1.

```
{
  "geometry": {
    "type": "Point",
    "coordinates": ["4.39979517", "51.82616671", "45.5"]
  },
  "type": "Feature",
  "properties": {
    "category": "dangerouscrossing",
    "phonenr": "",
    "accuracy": "9.0",
    "description": "poorly visible road from right with right of way",
    "androidver": "10",
    "mitigation": "drive slowly",
    "phonetype": "htc_wwe - Desire HD",
    "time": "1309079538341",
    "imei": "352668045888748",
    "image": "https://s3-eu-west-1.amazonaws.com/roadhazards/4_39979517__51_82616671.jpg",
    "user": ""
  }
}
```

Listing 1: Example GEOJSON entry

The geometry object of the GEOJSON record describes the geometry type of object as well as its coordinates (longitude, latitude, height). The type object defines the type of record stored in the object. The properties are user defined, in this case specific for exchanging road hazard points between the backend and the smartphone app or the retrieval scripts; it thus contains the data model used for road hazard point records, the fields are described in table 2.

Table 2: GEOJSON property attributes

Attribute	Value
category	Hazard category
phonenr	Phone number of reporting phone (not used)
accuracy	Positional accuracy of hazard location
description	User based description input
androidver	The android version of the phone used
mitigation	User based mitigative action input
phonetype	Brand and model of the phone used
time	• storeavalue: Time in seconds since epoch at which hazard was reported • getentry / getall: Time in GMT in human readable format
imei	The IMEI number of the used phone SIM
image	• storeavalue: base64 encoded photo • getentry / getall: URL pointing to the image location on S3
user	User based user ID input (obsolete)

Images

The images are uploaded in base64 format by the Road Hazards smartphone app but are after conversion saved in PNG format in the S3 roadhazards bucket. The bucket itself is made readable only to authorised users (the owner); the images themselves however are publicly downloadable, which makes them accessible only when the exact URL is known. The PNG image format was chosen for its high compression rate and wide support amongst internet browsers and other applications.

KML

The getkml call generates a KML file containing all stored road hazard records according to the OGC KML specifications (OGC, 2011). An example entry is shown in listing 2.

```
<Placemark>
  <name>dangerouscrossing</name>
  <description>
  <![CDATA[
  <li>Acquisition time: Fri Sep  2 13:35:25 2011 GMT</li>
  <li>Description: poorly visible road from right with right of way</li>
  <p><img src="https://s3-eu-west-1.amazonaws.com/roadhazards/4_39979517__51_82616671.jpg" width="200" /></p>
  <li><a href="https://s3-eu-west-1.amazonaws.com/roadhazards/4_39979517__51_82616671.jpg">Download photo</a></li>
  ]]>
  </description>
  <Point>
    <coordinates>4.39979517,51.82616671,45.5</coordinates>
  </Point>
  <styleUrl>#dangerouscrossing</styleUrl>
</Placemark>
```

Listing 2: Example KML entry

The categories referenced in the KML all have a related style to match the hazard symbol when displayed on Google® Maps or other KML capable tool. The images referenced in the KML directly point to the storage location of the image in the S3 roadhazards bucket. An example of a record displayed in Google Maps is shown in figure 8.

Figure 8: Example of hazards in Google Maps®

5.3 Geomatics Integration

In order to use the road hazards captured for journey management processes the information needs to be imported on a regular basis and made accessible to the user communities. The central repository for spatial data in Shell is ESRI® ArcSDE, in which the information needs to be imported for use in the Geomatics services and applications. The service components used are ESRI® ArcSDE as spatial database, ESRI® ArcGIS Server with map and feature services. SAFE® FME Server, combined with some scripts to facilitate the integration, is used to import the GEOJSON objects into ArcSDE. On the user side the information can be used with ESRI® ArcGIS Desktop or by consuming services with a browser from ArcGIS Server. Figure 9 gives an overview of how that all fits together. The process works as follows. At scheduled intervals (when least people are working in the whole organisation) the ArcGIS Server RoadHazard service is stopped to release any locks on the database. Thereafter a script on the ArcSDE server downloads the road hazards in GEOJSON and KML format. The GEOJSON file is stored in a location where the FME server can access it, while the KML file is stored under the document root of the web server. After download is complete the same script requests the FME server to run the conversion job. This job truncates the existing table in ArcSDE and loads new the new data in the table. Again at a scheduled interval, some minutes after the start of this process the ArcGIS Server Road-

Hazard service is started again.

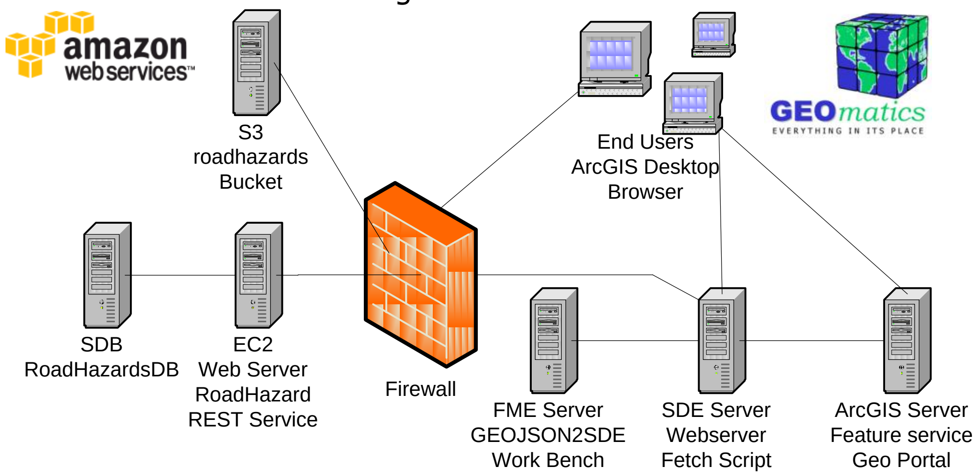

Figure 9: Integration of road hazard point data in the Geomatics infrastructure

The road hazard point information stored in ArcSDE can be accessed directly using ArcGIS desktop software, or can be accessed using map or feature services serviced from ArcGIS server. The feature service can be accessed with ArcGIS desktop but is also published in map portal and can be found using a search service, see figure 10.

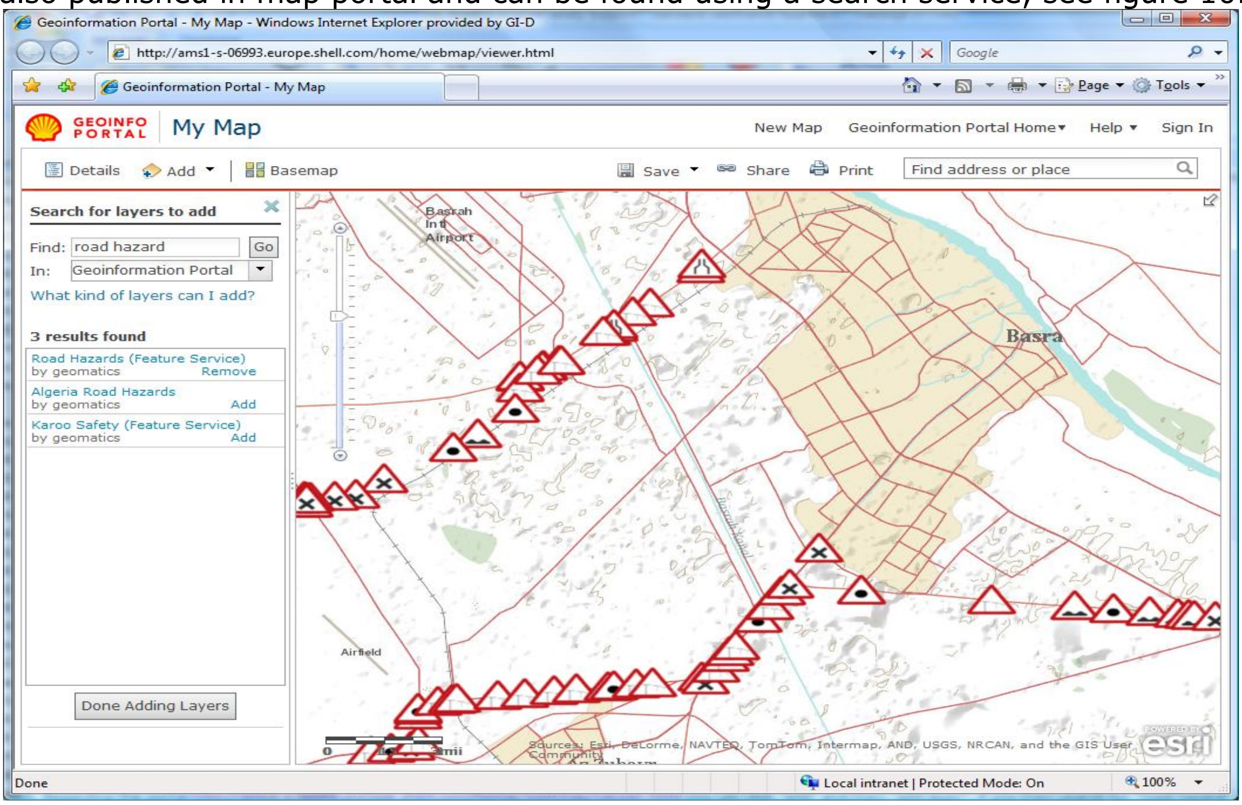

Figure 10: Geoinformation Portal

5.4 Pilot

After building and testing the infrastructure a pilot was run to validate the usability of a smart phone app to capture road hazards and to determine the feasibility of having one centralised infrastructure and standard classification.

Centrally 5 phones were procured to ship to participants or to hand out to people going on a survey trip. The phones were provided together with a normal and a car charger, no car mount brackets were provided to avoid the use of the phone functions while driving. Besides these 5 phones the app is also installed on personal and on in the regions locally procured phones.

One of the goals of the forum is to integrate the different focus areas. To be able to include captured road hazards in a PND is one of those desires. By assigning standard mitigating actions to the available hazard categories this could be piloted using Garmin devices. It was assessed that the options for mitigating actions is very limited and therefore a one to one match with the categories was made. This eliminates the need to have text to speech functionality on the free form mitigating actions field, and makes that process a lot less complex.
Consistent use of symbology for the captured hazards is assured by integrating the warning class of hazards in the SSL; therewith making it available globally and to all Shell geomatics users and applications.
The road hazard app was used to perform Logistics Infrastructure Risk Assessment studies (LIRA) which involves a field study and risk assessment of all hazards in the area. A dedicated team inventories the area and integrates that information in a logistics map used for transport and journey planning purposes. The app was extensively used as one of the sources for input to create those maps. An example of a logistics map can be seen in figure 11.

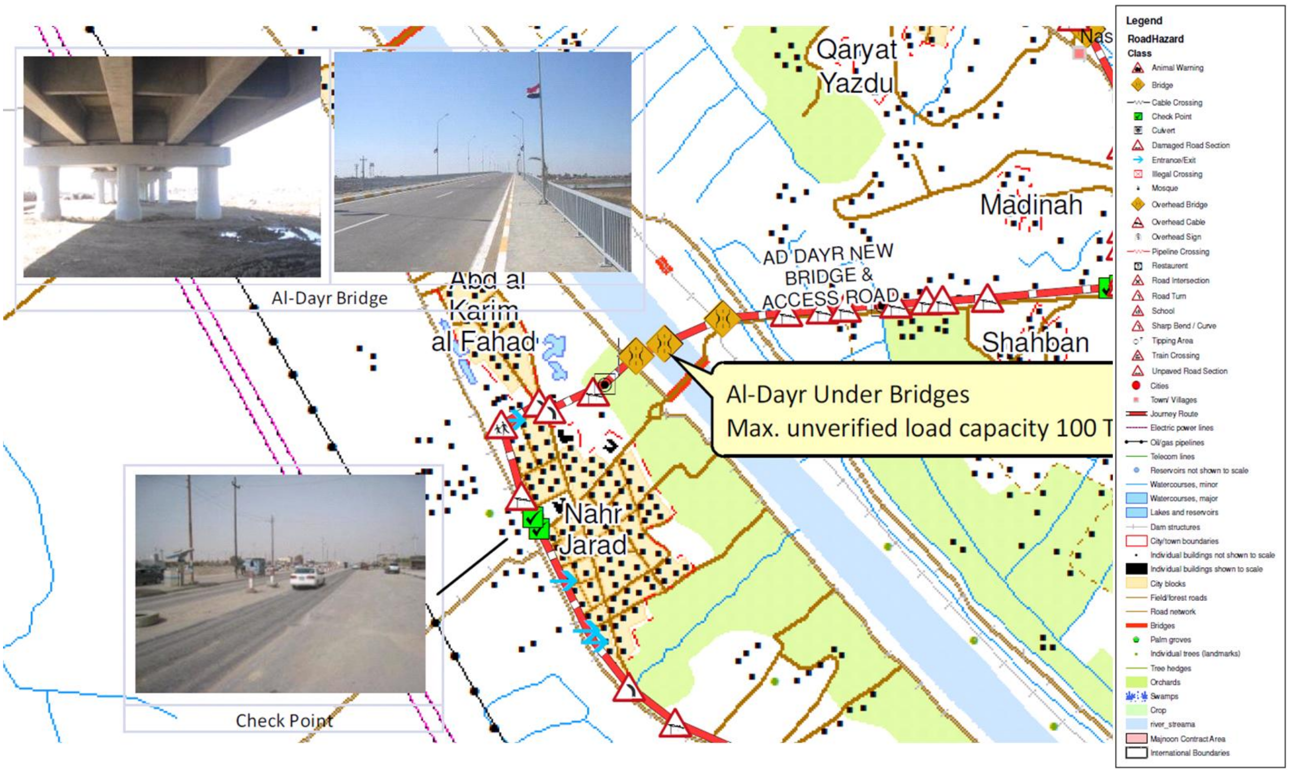

Figure 11: Snippet from Logistics map

At the start of the pilot there was a big requirement in being able to distribute the hazard information across all different regions. Automating the data retrieval from the WebDB backend and processing it into a central ArcSDE repository from which it is accessible via a feature service from ArcGIS server solved this issue. Serving the gathered road hazards via a feature service and updating the contents on a daily bases has much simplified the way the different ventures can access up-to-date data. This is acknowledged as a well appreciated feature, to enable direct use of the data or import it in for the regions local infrastructure. The data distribution had a couple of disruptions, none however related to the implementation, but all due to the use of

test and development environments. The problem with these environments is that support is only provided on best endeavours and change management is not strictly enforced what can result in unexpected malfunctioning.
Also the KML output format provided by the road hazard WebDB backend is made available as a layer in the Geomatics web portal and can be mashed with other information available in the portal. The KML file is, contrary to the daily refresh of the SDE database, updated every 15 minutes and thus provides near real-time information. References to the images and the symbology still point to their original location in the Amazon cloud. No tests with external partners was performed, it is however believed that sending a KML file to affiliates would provide them with sufficient information to use the road hazard points for their journey management.
One concern remained about the maintenance of the data; who will check the data for its validity. For the author this appeared to be an impossible task without knowledge of local circumstances. During the pilot there was no-one with that responsibility but it is regarded as a major requirement to make a central hazard repository a valuable and trustworthy asset. The common perception is that this would be a responsibility for the journey manager to take care of the information in his / her area. To bring this pilot to an operational state these roles need to be assigned.

The choice to first deploy a beta version to a limited group of users before deploying the final version to a bigger audience has resulted in having 2 versions of the app with slightly different data models in use. Not everyone could be persuaded to update the phone to the final version, resulting in a mix of data entries in the database. The import mechanism making use of FME workbench could however be easily adjusted to include the new fields while still compatible with the old format. This shows a support channel is required able to push out updates instead of relying on the action of the users. Publishing the app in the Android Market would offer this functionality. For this PoC however this was not desired in order to keep the user base limited to selected people.

During the pilot the centrally distributed phones were all provided with a Dutch SIM card. Roaming costs for voice and data traffic can be significant, especially when travelling outside of the European Union. Although all pilot users were instructed to use the phone wisely and use WIFI connections where possible to do data uploads, the phones log records showed however this is not always taken for granted. Continuation of this project requires that SIM's are procured locally in the country of use or data access via the mobile network provider disabled to allow WIFI network access only.
Another cost aspect is the potential savings made recording hazards in this fashion can deliver compared to the current used methods. Besides the benefits for being able to centrally manage road hazard points in a standardised way, real savings can likely be made when it could replace the current IVMS systems, therewith fulfilling multiple purposes. Most smartphones are equipped with a compass, accelerometer, gravity sensor and GPS, which can also be found in most IVMS systems, it would therefore be perfectly possible to use smartphones for this purpose.

5.5 Discussion

The infrastructure design makes use of a third party, AWS, to host the back-end infrastructure in the cloud. This is accepted as this is a paid service without any restrictions (within reasonable limits) on what it is used for. Besides that is Amazon a cloud service provider Shell already does business with. The only difference is with the preferred way of running the service is that in the pilot the public cloud is used on behalf of the author, while for Shell operations this would need to be migrated to the virtual private cloud. The virtual private cloud offers more security features to shield off services from the public domain. Migration to this is however something that needs more investigation if this pilot is continued after this project.

The authentication currently implemented using a public key infrastructure is based on the certificate authority hosted by the author lacking any form of trust from the well established certificate authorities or browser vendors. For the purpose of this pilot this is accepted. A production implementation making use of a similar authentication mechanism however should make use of the Shell certificate authority or alternatively one of the well established ones like Thawte or Verisign.

The external implementation of the WebDB ensures no third party access is granted to the Shell network while the road hazard information can still be accessed by selected parties by providing them with a private key that can be revoked when required.

The road hazard application is comprised of the road hazard smartphone app and the WebDB backend. The chosen smartphone platform, Android, is currently alien to Shell as the supported smartphone platform in Shell is Blackberry. Android was chosen for the ease of development and distribution of a test application amongst a relatively large group of people. With the current developments in the mobile area however it is expected the preference for Blackberry will become a more agnostic one and not focussed on one platform. This will mean however that the current implementation of the road hazard app needs to be made available to multiple mobile platforms, or a build once, run anywhere solution must be found.

The WebDB backend application implements some methods to transfer data between the phone and the back-end and allows data retrieval from authorised users. The chosen data exchange formats GEOJSON and KML fit the current requirements as GEOJSON easily imports in FME, which is a standard tool used in Shell. The KML can be easily shared with external parties and can also be used as layer in web portal applications.

The current implementation of the import of the GEOJSON data in the SDE repositories likely needs improvement for future implementations. The information is currently only updated once a day, for which the content of the table is erased before the entire content from the WebDB is loaded again. An incremental solution is preferred, this would also allow for more frequent updates without causing an outage on the availability of the data. Offering the layer as web features is highly appreciated as this is a light protocol that can be served from a central location without the many bandwidth and latency issues as a standard SDE connection has. This removes the requirement of database replication and is considered the way forward.

The PoC integration with Geomatics runs entirely on test and development hardware and therefore has no official form of support. Future implementations would need to have an end to end supported infrastructure to be a reliable service.

6 Smartphone App Usability

One of the goals is to validate the smartphone app for its usability. The validation was performed by running a pilot with it, collecting real road hazards and embedding the information in the Geomatics infrastructure to make it available. Initial user tests with a small group of beta users showed the requirement of a user guide to get new users started; this guide can be found in appendix c (Aisari, 2011). Only one pilot user received a demo of the road hazard app of about 15 minutes to enable him to do survey work. In total there were 2 support issues. One was related to the wrong expectation the app would also show earlier gathered hazards, the other to a malfunctioning phone. This suggests the app itself is easy to operate and does not require much training.

6.1 Regulatory Compliance

Initially 5 countries were in scope to contribute to the pilot. Due to potential import / export compliancy issues with some of these countries not all could participate.
Based on information from another pilot project, deploying push-mail to BlackBerry phones, Jordan and Russia were deemed to be off limits for using the road hazard smartphone app. The reason for this is that both countries do not allow strong encryption on data streams. The implemented authentication method to access the WebDB backend and thus the information exchange with the phone is based on that.
In liaison with the export compliance department also the export of the app from the Netherlands to the countries in scope was assessed. As the code for the app is fully developed in the Netherlands, US export regulations do not apply, which are considered the strictest regarding the export of software with encryption functions. Because of this only the European and Netherlands export laws apply, which have no restrictions regarding cryptography to the countries in scope of the pilot.
Acquiring exemptions from Jordan and Russia to allow use of the app was considered too much effort for the scope of this project.
Import and export regulations regarding the smartphones is not deemed relevant as these can be locally procured in the countries involved in the pilot, it is therewith assumed that the hardware vendors gathered all required permits.
The regions visited with the android phone for the pilot are at the time of writing:

- United Arab Emirates
- Gabon
- Iraq
- Oman
- Qatar

6.2 Road Hazard Classes

During the pilot it has become apparent from feedback from four users that the list of provided hazard categories is too extensive and should be adjusted to local needs. In relation to this is missing hazard categories, for instance having a camel as a hazard is a much desired category as local users in the Middle East will not likely associate sheep with camels. Making adjustments to the app that it can receive different hazard classes with customised categories could solve these issues. This should however be centrally managed to maintain compatibility of the data model between the different communities.
Too late in the development cycle to implement it, registration of begin and end points of hazards was requested. The idea was that this would allow for capturing line type hazards if it would be combined with post-processing on road network information,

and so being able to identify road segments for which the hazard applies. This would in principle leave the idea of capturing road hazard points although still reported as such. It was considered too much of a design change in the application to implement it at the stage the app already was. The data model however could be easily adjusted to cater for this by adding some additional columns to the table. The data exchange format, GEOJSON, is relatively loosely defined and can thus be easily extended to facilitate additional information without breaking the data import functions. Changing the data model during the pilot has proven this can be done and having two versions in use does not have to interfere with the processes when done cautiously.
Another request also not related to road hazard points is to capture GSM signal to map areas where mobile phones have network and where not. This requires a different or additional data model however, as this provides more or less continuous data.

6.3 Road Hazard Acquisition Survey

To get feedback on the road hazard smartphone app pilot, a survey is conducted among anyone that has been directly involved with the project group. A cascade to peers that have contributed is requested from all people addressed to also involve people outside the "Geomatics for Road Safety" forum. In total 35 people were approached to fill in the survey, it is unknown what part of this reached group actually used the smartphone app. The survey is split into different subjects and respondents are guided to the questions relevant to them. The survey is provided in two forms, an on-line version which can be filled in interactively, and a printed version that is to be returned with internal mail. The printed survey can be found in appendix d. The online version is created with mod_survey (Palmius, 2011); the survey code used for mod_survey can be found in appendix e.
The survey is split in different topics. First some personal background is asked and thereafter questions about the symbology and classification. Depending on the use of the smartphone app questions about its use are asked. After that some more general questions about thematic content and positional accuracy requirements are requested. An overview of the questions is shown in table 3.

Table 3: Survey questions

General
1. What is your age
2. What is your primary location
3. What is your relation to this pilot project

Symbology
4. Which of the following classes are not useful and should be removed?
5. Which symbols are not clear and should be graphically improved?
6. Are there any missing hazard symbols / classes?
7. Please leave any remarks with regards to the warning symbology and classes.
8. The Road Hazard application now only contains warning type hazards; do you think informational classes should also be included?
9. Which of the following informational classes should be included?
10. Are there any informational classes missing?
11. Please leave any remarks with regards to the informational symbology and classes.
12. The road hazard application now only contains warning type hazards; do you think limit classes should also be included?
13. Which of the following limit categories should be included?
14. Are there any limit classes missing?
15. Please leave any remarks with regards to the limits symbology and classes.

Road hazard smart phone app
16. Have you used the smart phone with the Road Hazard application to capture hazards?
17. Had you already used a smart phone with touch screen before this pilot?
18. Do you have a smart phone with touch screen yourself?
19. How do you consider your level of English?
20. Are you used to a keyboard with Latin characters (US American)?
21. Did you find it easy to enter text in the free form text fields?
22. What do you think of the usability of the road hazard application?
23. On average how long did it take for the phone to get a GPS signal?
24. How many hazards did you capture with the Road Hazard application?
25. Would you prefer this Road Hazard application over the old way of capturing road hazards?

Thematic
26. Do you think the description field provides useful information for journey management?
27. Should the description field be mandatory
28. Do you think the mitigating action field provides useful information for journey management?
29. Would it be better to make mitigating action categories tailored to the hazard class it belongs to so they can be chosen from a pick list?
30. Should providing a mitigating action be mandatory?

Accuracy requirements
31. What accuracy is needed to capture road hazards?
32. What is you reason for choosing the above accuracy?

General
33. If you have any additional comments on this pilot, you can leave them in the box below.

All responses were done in the on-line survey. No paper copies were returned.
Due to a bug in the online survey code, question 9 “Which of the following informational classes should be included” cannot be assessed.

6.3.1 Respondent Population

The survey has resulted in 18 responses which is just over 50% of the amount of directly approached people. The age, primary location and role distribution of the respondent population are shown in figures 12 and 13.

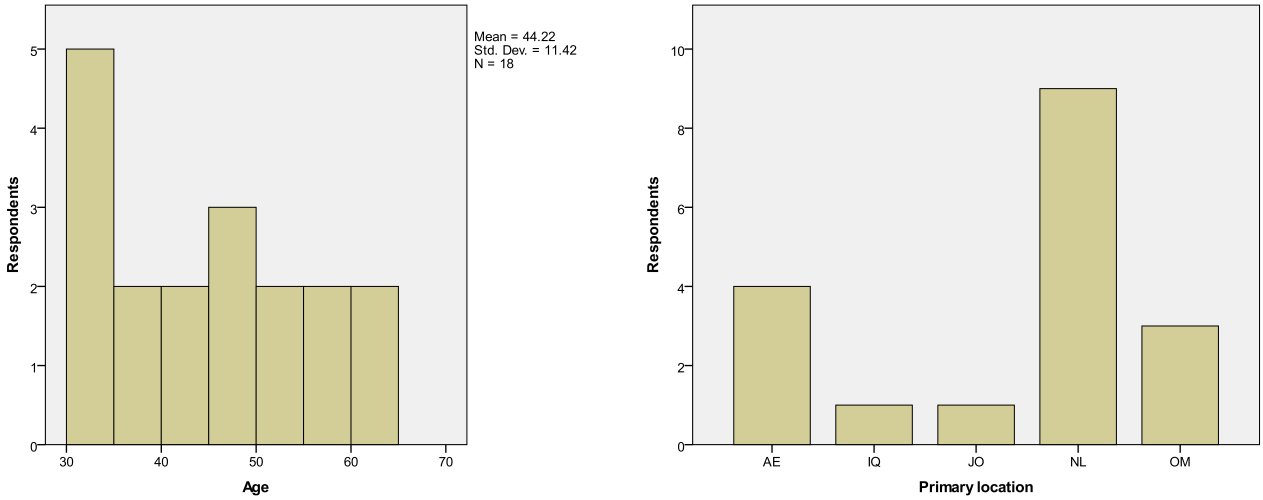

Figure 12: Age and primary location of total survey population

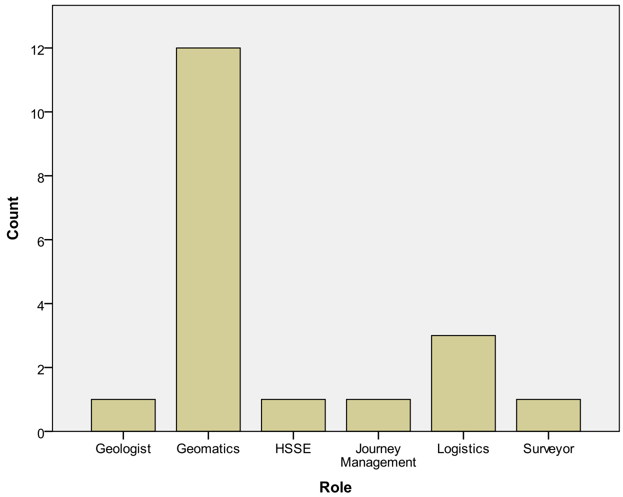

Figure 13: Respondent's role in the organisation

Twelve respondents reported to be working in a Geomatics role, one of them also as a surveyor. No drivers filled in the survey; from an HSSE perspective this can be considered a good thing, as phones are not allowed to be used while driving. The population is very small and can therefore not be used for quantitative statistics. The information gathered is thus used descriptively. The reason for the high representation of Geomatics people is likely because of their close involvement with this project.

6.3.2 Symbology and Classification

Warning Class

The respondents were asked to assess the used danger symbols for their usefulness and for their clarity. The aggregated results are shown in table 4.

Table 4: Remove or improve danger symbols results.

Description	Symbol	Remove	Improve
Animal crossing		3	
Bad road conditions		1	1
Blackspot		3	2
Dangerous crossing		1	
Dangerous point			
Explosion danger		6	
Flooding danger		3	1
Grounding danger		1	1
Hill top, poor visibility		1	
Landslide danger		3	
Narrow road			
Overhead cable		1	
Crossing pedestrians or school children		1	
Poor visibility possible			3
Road works		1	
Roundabout			
Sand dunes		1	4
Sharp bend		1	
Road can be slippery		1	
Soft verges		1	
Steep hill		2	
Train crossing		1	1
Tunnel		1	
No U-turn beyond this point		4	1
Winding road		2	
Flag hazard for removal		1	1

Looking at the information there does not seem to be a clear consensus between all respondents what should be necessary or not. "Explosion danger" and "No U-turn beyond this point" indicate these are abundant in the app. Two respondents, one from Geomatics and one from logistics think many of the classes are not required. "Poor visibility" and "Sand dunes" seem to require some visual improvements.
In the free form "Missing classes" question an aggregation of the following additional symbols can be made:

- Axle load limits
- Bridge crossing with Axle load limits
- Clean toilets
- Clinic
- Coffee shop
- Culvert
- Graded road ahead
- Hospital

- National border customs / immigration check point
- Other danger
- Overhead bridge
- Overhead cable
- Overhead pipelines
- Petrol stations
- Police check point
- Populated area
- Restaurant
- Safe parking
- Safe parking overnight
- Shell bases
- Shopping
- Stream / Wadi crossing

In the remarks the following points come forward:

- Symbols need to be selectable; types of hazards are very location specific.
- List of symbols too long, a sub-set should be selectable.
- Hazard symbols should allow for off road driving, therefore the "Flooding" symbol is better changed to "Flooding / Wadi".
- Points need to be available in the SSL.
- Limit number of symbols to ease the matching to voice warnings, or group them to match certain warnings.

What can be deducted from this is that not all desired symbols are included to report hazard information on one side, but on the other the current list is regarded as overkill for the locations it is used. Not all respondents have made the distinction between hazards that should go in the warning class and potential other classes. Also some symbols are reported not available while they in fact are, or were intended to be used in that way. As an example the desired "Other danger" could be reported by the general "Dangerous point". This makes apparent that a consensus about the meaning and use of the symbols between all participants should be accomplished. This would however require better information sharing and training. The same counts for the availability of the symbols in the SSL, in which they are, this should be better shared in the user community. Users of the infrastructure should be fully aware on how to use it.

Although expected no obvious relation between missing categories and role of the respondent becomes apparent from the responses.

Informational Class

Eleven out of the eighteen respondents think informational classes should also be included in the Road Hazard app. Regretfully their responses got lost due to a bug in the survey code. The fact that a majority thinks this type of information should be included justifies some additional thought on this topic.

From the responses on the missing symbols and remarks two additional categories are mentioned:

- ATM machines
- Rest points for intermediate stops

It is suggested twice that the app could be made more generic, to also report on different points of interest for other types of surveying and application.

Limit Class

Fourteen of the respondents think limit classes should also be included the results are shown in table 5.

Table 5: Limit classes for inclusion

Description	Symbol	Include
Maximum height		12
Maximum speed		12
Maximum weight		12
Maximum width		12
No entry		7
No entry from this side		8
No entry for trucks		8
No overtaking		7
No overtaking by trucks		6

Most of the respondents think the signs for maxima should be included, also the other signs show a high score. The amount of respondents of the opinion that limit classes should be included in the app justifies including functionality in the app to cater for this. Two additional categories are mentioned:

- Axle weight limits
- No entry for pedestrians

Two remarks come from respondents from logistics. One, to add a functionality to mark a limit as verified, seems a very important one as many of the limits likely require expert judgement.

The other comment suggests limiting the app to real hazards and not indicated by regular road signs.

6.3.3 User Friendliness Smartphone App

Nine of eighteen respondents have used the smartphone road hazard app. It is regretful only users that have collected a handful of hazards were reached by this survey. The people doing most of the fieldwork have apparently not been reached.

Based on the assumption that younger people are earlier adopters of new technology like smart phones, a relation is sought between age, adoption of smartphones and the usability of the app. As there is only one respondent that has used a smartphone with touch screen before but does not have a smart phone him or her-self, only the relation between familiarity with the device and the app's usability are assessed. Figures 14, 15 and 16 show these relations.

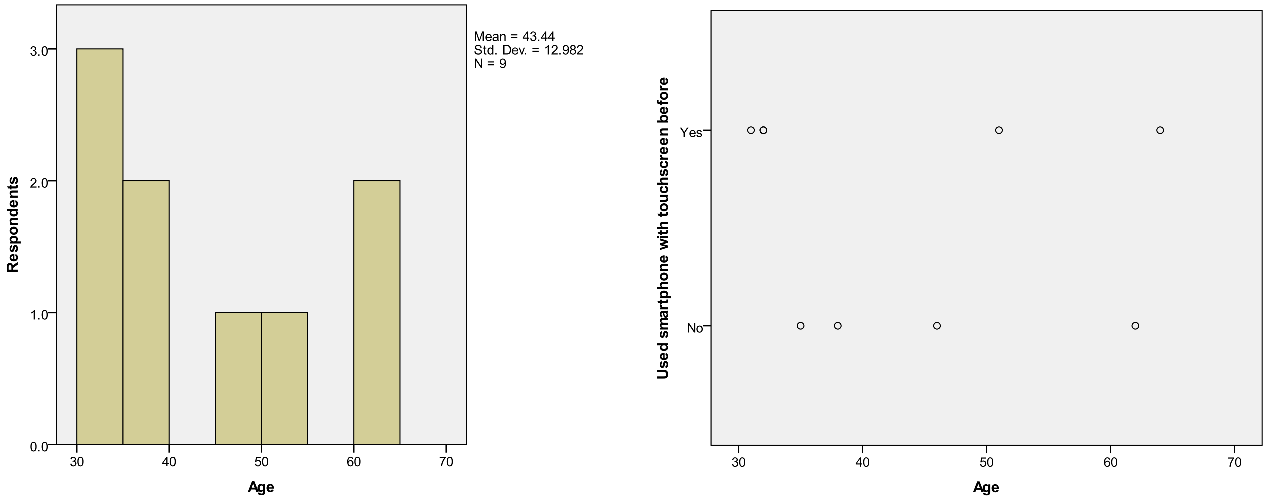

Figure 14: Age distribution and familiarity with smartphones

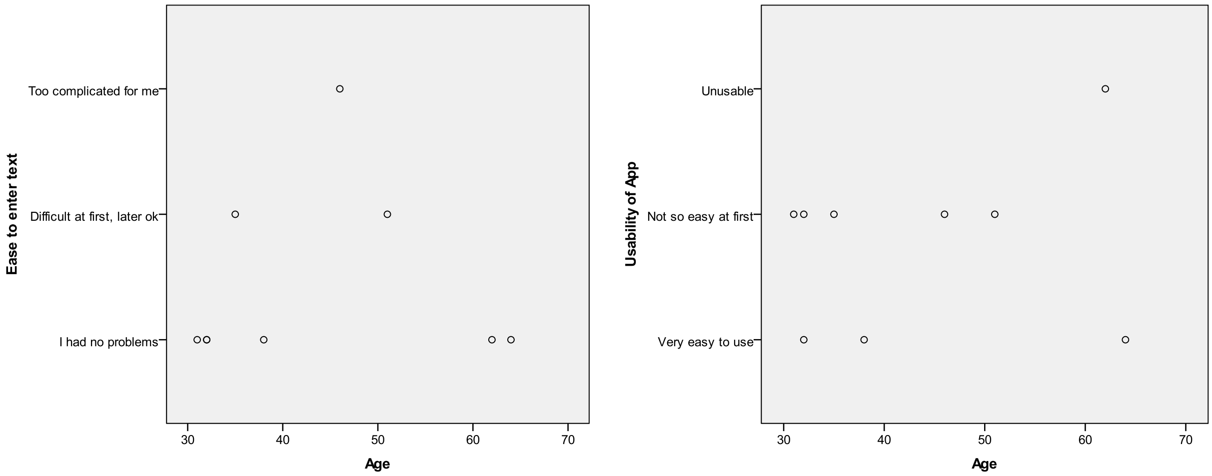

Figure 15: Age related to usability of app

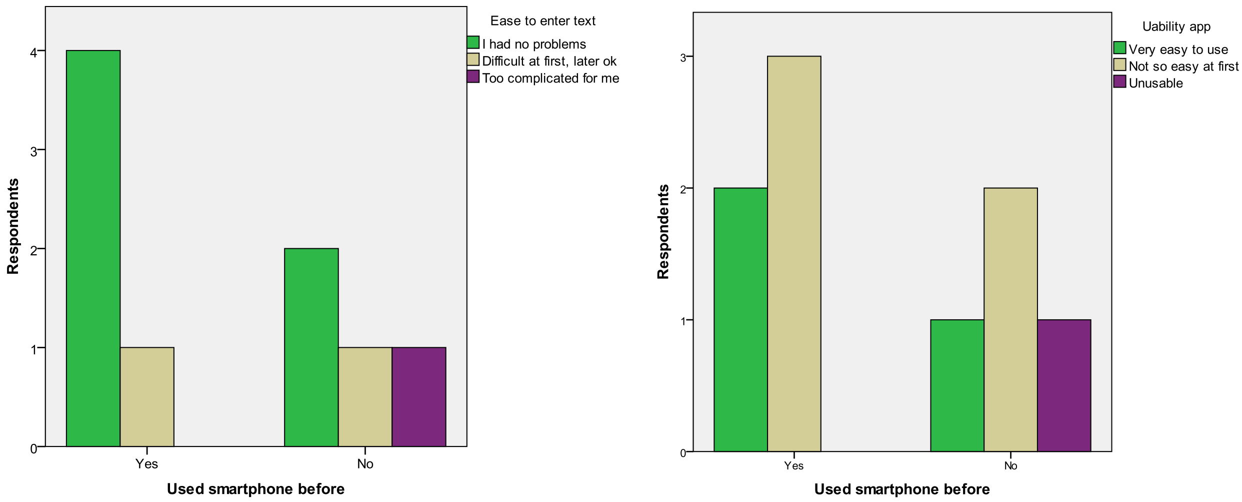

Figure 16: Ease to enter text or use the app related to familiarity with smartphone

There seems to be no direct relation between age or prior experience with smartphones with touch screen and the ease to enter text information or use the app. In general most respondents find it easy from the beginning or after some experimenting. To be able to draw conclusions on the relations depicted above, the population should be bigger than the current achieved one.

One important aspect of the app is to have accurate location information. It takes some time to get a reliable reading from the GPS device when it is initiated. When the GPS is not used for a longer period of time, or it travelled for a long distance in-between usage sessions, the GPS almanac transmitted by GPS satellites but also stored on the phone can be outdated. This causes additional time to get a fix. The respondents were asked how long on average it took to get a usable GPS signal. The results are shown in figure 17.

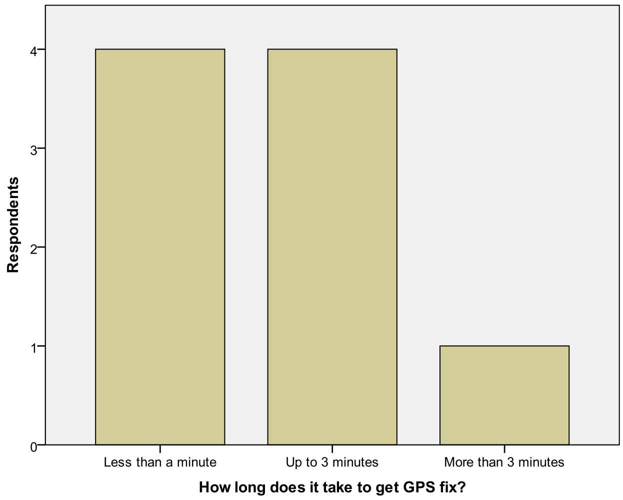

Figure 17: Time to get GPS fix

Most of the participants have experienced delays in the GPS fix from less than a minute up to 3 minutes, with one respondent having to wait more than that. It is regretful the surveyors capturing many hazards did not participate in the survey; their feedback would have added some real field experience.

On the question whether using the Road Hazard app is preferred over currently used methods of gathering road hazard information, everyone agrees this is the way forward. Most of the respondents see a requirement for improvement however, as can be seen in figure 18.

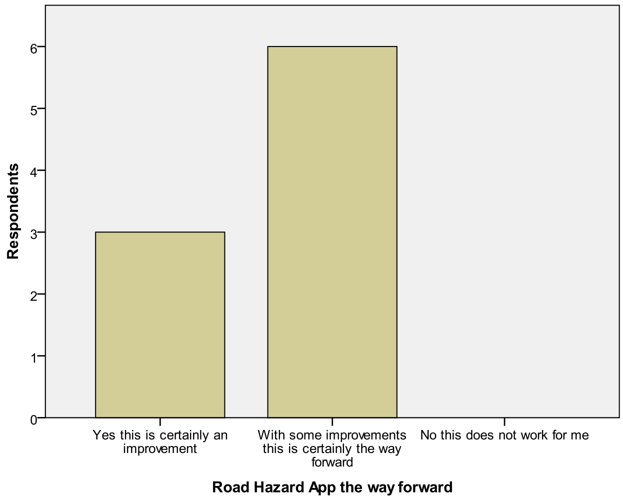

Figure 18: Road Hazard app to be used in future

6.3.4 Thematic Accuracy

In the section of the survey about thematic accuracy one respondent noted in a comment field that it was impossible to answer the questions about thematic accuracy and positional accuracy. These responses were removed from the results.

All respondents but one think the description field is useful to provide information regarding the reported hazard. Nine of seventeen respondents think the field should be mandatory.
Thirteen of all respondents assessed the mitigating action field is useful to describe a hazard and only four people think this field should be mandatory.
Seven respondents are of the opinion a pick list for mitigating actions related to the hazard category chosen should be provided in the app to report mitigating actions. Three persons think the current implementation of a free form field should be implemented, while six people suggest both options should be provided.
There appears to be preference to keep both the description and mitigating action field. Whether they should be mandatory cannot be decided from the results on the description field; however there is a preference for the mitigating action field not to enforce it. There is equal preference to keep the mitigating action field as free form or combined with a pick list.

6.3.5 Positional Accuracy

In the section about positional accuracy the respondents were asked to provide their accuracy requirements and why they think it should be as they indicate. Figure 19 shows the responses for positional accuracy requirements.

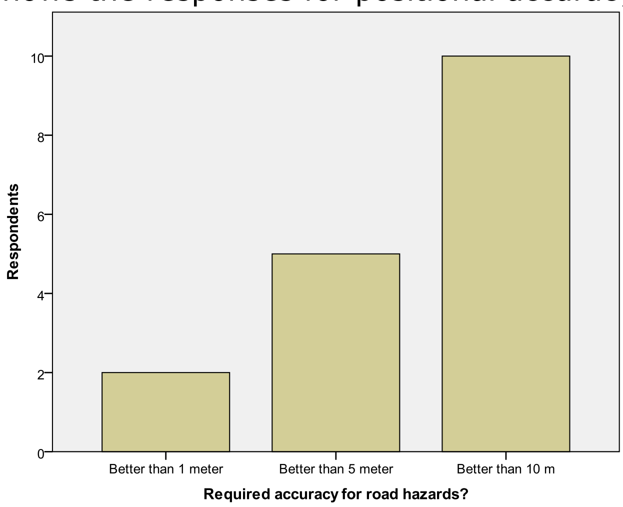

Figure 19: Required positional accuracy for Road Hazards

There is a notable preference for an accuracy of better than 10 meters. Most reasons for the last two classes relate to the fact that warnings need to be provided well before the hazard while driving, and therefore 5 or 10 meters don't matter. Other comments are that the scale of usage will not be more accurate than 10 meters.
One reason given for opting for an accuracy of 5 meters or better is that it would be possible to distinguish hazards at close proximity.
The two respondents opting for a high accuracy of better than 1 meter argue this is required as the accuracy of PND's need to be added for navigating and thus multiplying the inaccuracy; better accuracy is better data.

6.3.6 General feedback

In the last general remark field there are many acknowledgements this project has resulted to a nice piece of work which looks very promising. Integrating mobile devices in the Shell Geomatics infrastructure making use of cloud services and existing services is noted as a great achievement.
There are however notes about improvements that would be required to make this a

success in operation.
Acceptance by the different user communities as well as working out the internal processes is noted as a point that will require additional effort.
The expenses of roaming costs and the requirement for a short guide on how to use the phone when abroad are noted as a concern. This will especially be of importance to get guidance and rules around when this way of working makes it into operations exceeding the limited scope of this pilot.
Optimisation of the screen layout to fit on the screen of the device is suggested. To achieve this some redesign is required, if it can be accomplished for all different form factors of phones around is however doubtful.
The desire to keep the GPS polling for data all the time is also here noted as an improvement to speed up the acquisition time. In the same context also dropping the necessity to fill in the description field is mentioned.
The desire to find a mechanism to select which hazard categories are available on the phone by choosing an area of application is suggested as an improvement.
Difficulty of using the phone in bright sunlight is mentioned as an issue, as well as the difficulty to enter text, especially from a moving vehicle. Also operation from a vehicle with security restrictions is regarded difficult.
Clean-up of the phone before handing it out to the next user is regarded as a requirement. This will in an operational situation likely be less of an issue if people use their dedicated phone.
As a final note it is mentioned this system should be kept simple to avoid it will not be used for its complexity. Use of the information relies on the professionalism of the driver.

6.4 Feedback

During the pilot the author has received many comments and recommendations either verbally or in written form. This paragraph tries to capture most of these when considered relevant to this research.
In general the app and the workflow making use of consumer electronics are much appreciated; there is however also some side notes to be made.
One of the complaints about using the app on smartphones is that the keyboard is too small to key in information while in a moving vehicle. One of the suggestions is to try the app as well on Android tablets which would make everything bigger and therefore easier to operate.
As mentioned in paragraph 5.4 the app was used to do LIRA field work, which is a different use case as was initially foreseen. The app was intended to enable anyone with a prepared smartphone to report road hazard points. For the purpose of LIRA studies a different workflow applies, what would require a somewhat modified application and work process. The main remark from the LIRA surveyors was that while on the road, the prime thing they want to do is make georeferenced photos and post process the information later while in the office. The app currently requires selection of a category and entering a description, this is considered to slow down their work process. A simple point and click application with the same backend as currently used is proposed, complemented with tools to post process the captured information. This might require a different version of the app specifically focused on speed and gathering georeferenced photos. It would also require a more sophisticated backend to easily complement the data later. Android smartphones by default, provided that the GPS module is on, make georeferenced photos and store that information in the Exchangeable Image File Format (EXIF) header of the saved image file. Due to a resizing action of the photos taken with the app, intended to reduce network traffic and therewith mobile data

costs, the EXIF information is lost. Obviously for a point and click application this needs to be fixed.
Most users find it an annoyance that the app needs to re-initiate the GPS every time the main screen is entered. It typically takes 10 to 20 seconds to get a GPS fix and even a bit longer to reach an acceptable accuracy of around 10 meters. The way Android applications work requires that every screen of an application needs to express its intention to use a particular hardware element. Hardware elements not referenced by an intent are suspended by the Android operating system to save on energy and therewith extend battery life. This means for instance that to keep the GPS module on while using the application, every screen must express this intent. During the build phase it was considered a good thing that once a position is captured the GPS turns off to save on the phone's battery.
Bright sunlight conditions have proven to be problematic while the information on the screen is simply not visible. Possibly future generations of smartphones solve this with higher brightness and contrast ratios in their screens.
An often heard remark was that the app and infrastructure would also be perfect for other types of surveying work; it would then however require a configurable category set. This can be considered as an improvement for future versions.
During the pilot support for other devices than Androids was requested several times. To be able to support people with different types of smartphones, the app needs to be ported to the main smartphone operating system platforms.
Many of the photos taken with the app ended up having a wrong orientation. It appears not all smartphones treat rotation of the photos in relation to the gravity sensor in the same way. The application was written with a HTC Desire HD smartphone as test model. With this phone and Android version 2.3, the camera app is 'aware' of the orientation of the phone and rotates photos in line with the orientation of the gravity sensor. Other phones and Android versions however treat this differently resulting in wrongly oriented photos ending up in the database. For future releases of the software this needs to be solved to avoid unnecessary post-processing of the photos.

6.5 Discussion

For an application like the road hazard smartphone app in combination with its backend import and export controls need to be considered. Export controls caused no issues to distribute the application form the Netherlands to the other nations the app is used in. Import restrictions were however deemed to limit import of the app to some countries for the strong encryption used on its data streams. Several solutions can be considered. One of them is to acquire import exemptions from the countries into which the app needs to be imported. From experience it is however known that this can be a lengthy process. Other options are to remove the encryption and use less secure methods of data transfer or only do encryption on the authentication between phone and WebDB. This is something that needs to be looked into deeper when the pilot will be extended into a production solution. Likely experience from other mobile applications can be leveraged in this area.
From the survey and feedback it becomes apparent that there is a demand for more hazard categories to be able to capture all the different types of hazards around, while also being able to limit the amount of categories shown. It should be tailored to local requirements. Provided hazard classes and categories have to be customisable to limit the amount of hazards shown to the user. At the same time additional categories and potentially even classes should be added to the centrally maintained one to make sure the set is complete for all locations and purposes while maintaining one classification

and symbology.
It is thought the app has potential to fulfil more purposes for surveying. Modification that it can be used to capture other types of survey information, capture GSM coverage or even replace currently used IVMS systems are considered desired extensions and potential cost savers.
Some ambiguity exists in what category should be used for what hazard. To make sure all users of the app have the same understanding for the same kind of hazards and their meaning, this has to be documented and training provided.
For hazards that need expert judgement it is suggested to provide a method to mark hazards as validated. This would also be a great feature to mark hazards as validated for inclusion in a journey management map based on the risk they expose. The requirements for a road hazard acquisition app are not the same for all user groups. Possibly it would require different versions to cater for the different needs, for instance one for professional surveyors and one for the occasional reporter. How to cater for these different requirements in the app and data model needs to be given some additional thought.
In general the app was perceived as easy to use after gaining some experience. With the limited responses no relation between age or prior experience with smartphones as used in the pilot and the usability of the app was found. With some adjustments to the app the acquisition of road hazards using a smartphone app is unanimously considered as the preferred way forward over the current work processes. One respondent found the app not suitable for their work however, suggesting that there are different requirements for using the app and this should thus be better investigated.
Improving on the performance to get and hold a GPS fix is suggested as an improvement for future generations of the app, it is now considered to take too long.
There is a preference to drop the necessity for filling in the description and mitigating action fields in the app, possibly providing a pick list of mitigating actions related to the selected hazard type by means of a pull down list. A classification model between hazards and mitigating actions needs to be looked into more carefully instead of assuming a one to one relation.
On the scale of which road hazard information is used the general perception is that a positional accuracy of better than 10 meters is sufficient.
Having an automated method for gathering and the ability to access the data globally is regarded as great functionality. However roles and responsibilities, but also tooling, for maintaining and validating the data needs to be set-up.
A support structure for maintaining the software on the phones needs to be accomplished to be able to push updates therewith limiting version conflicts.
To limit roaming costs SIM cards have to be procured in the country of use, or data access via the mobile provider disabled to allow WIFI network access only.
Finally GPS speed, compatibility with more devices, and interface improvements are required before the app can make it in operation.

7 Road Hazard Data Quality

To assess the usability of the data for use in journey management maps, three qualities are researched. The first paragraph assesses the access to the data. This is the first requirement for the data to be of any quality. Security is discussed in the same paragraph as it can have several implications on the accessibility of the data. Positional accuracy is assessed in the second paragraph. It can be argued that this information can be retrieved from prior research on the accuracy of consumer GPS devices; it is however decided to validate this in a real field test, using the devices, software and infrastructure used for the purpose of this research to include any errors that might be introduced in the system. In the last paragraph the thematic accuracy is assessed.

7.1 Accessibility and Security

Accessibility to the road hazard data by Shell and partner companies was a requirement. No affiliated companies were involved in the pilot; it is however believed that by delivering KML files with references to publicly accessible symbols and photos this would provide sufficient information.

The data stored in the Amazon WebDB backend is categorised as restricted information and as such needs to be protected from public access. Only access by Shell staff and affiliates is granted for this information security level. To restrict access public key cryptography is used requiring clients to connect with a certified client key. The application design implementing this method for restricting access is accepted by the EP IT architect as a sufficient precaution.

For national security reasons however some countries have governmental requirements about cryptography in software. Some countries do not allow for the use of strong encryption as used in the road hazard app to communicate with its backend. Based on experience of a different pilot was decided to leave Jordan and Russia out of the pilot scope. This means the appointed testers in those countries could not have access to the app, nor to the data from the Amazon backend. The remaining countries did not have this barrier.

To allow use of a road hazard app with a similar method for its communication, import exceptions need to be acquired from the counties with these limitations.

All participants of the "Geomatics for Road Safety" forum were provided with the client key, for installation in their browser, to gain access to the WebDB backend.

7.2 Positional Accuracy

To determine the positional accuracy of the road hazard smartphone application, multiple samples were taken at well known locations, hereafter referred to as the reference points. Two approaches were followed. The first method was done by doing measurements in the field simultaneously with the smartphone app and a dGPS. The second by measuring reference points provided by the Dutch cadastre. The following paragraphs describe the reference points and the procedure followed to compare these with the smartphone findings.

7.2.1 Reference Points

The reference points provided by the Nederlandse Aardgas Maatschappij (NAM) are measured with dGPS. The horizontal coordinate reference system used is RD_New, while the vertical coordinate reference system used is NAP. To convert the coordinates to ETRS89 the program RDNAPTRANS 2008 (provided by the Dutch cadastre) is used

(Kadaster, 2009). The points provided are listed in table 6.

Table 6: Reference points provided by the NAM

Grid_Northing (RD_NEW)	Grid_Easting (RD_NEW)	H (m) (NAP)	Name	Lat (ETRS89)	Lon (ETRS89)	h (m)
578307.959	257058.631	0.095	080200A	53° 10' 54.1768"	6° 54' 49.9291"	40.8765
589475.414	257409.677	-1.34	080200B	53° 16' 55.0726"	6° 55' 21.6452"	39.2411
589482.848	257290.895	-0.979	080200C	53° 16' 55.3949"	6° 55' 15.2446"	39.6019
520152.354	249467.375	10.415	080300A	52° 39' 38.2627"	6° 47' 00.6757"	52.662
591708.698	254938.464	-0.481	080400A	53° 18' 08.9764"	6° 53' 10.8136"	40.0627
578130.818	258735.234	-0.113	081200A	53° 10' 47.2902"	6° 56' 19.9787"	40.6732
578124.957	258747.194	-0.472	081600A	53° 10' 47.0924"	6° 56' 20.6157"	40.3143

Another set of reference points are as courtesy provided by the Dutch cadastre. These points are in the ETRS89 horizontal and vertical coordinate reference system. Their values can be found in table 7.

Table 7: Reference points provided by the Dutch cadastre

Lat (ETRS89)	Lon (ETRS89)	h (m)	Name
51° 51' 18.1205"	4° 20' 20.8464"	49.08	370354
51° 53' 53.8637"	4° 28' 0.9684"	46.94	370531
51° 50' 52.1092"	4° 28' 11.6344"	45.17	370360
51° 43' 55.6109"	4° 31' 59.1545"	45.38	430316
51° 49' 10.1770"	4° 29' 45.6944"	46.94	370353

7.2.2 Sample Acquisition

The test samples are acquired by two different persons also using different reference samples. The set provided by the NAM are surveyed by one of NAM’s employees doing soil subsidence monitoring fieldwork. These points are only measured once. The set provided by the Dutch cadastre is sampled by the author using three different phones and taking two samples per phone at an interval of around 10 minutes. This was once repeated with two weeks in between the sampling sessions. This was done to somewhat mitigate bias from atmospheric conditions on the GPS results.

7.2.3 Coordinate Transformations

Consumer GPS devices like the ones used in smartphones provide on average a theoretic horizontal accuracy of ≤ 7.8 m (Department of Defense & GPS Navstar, 2008). For most practical purposes it is safe to assume ETRS89 and WGS84 are the same (Kadaster, 2011) as the frame shift is in the order of half a meter. To determine the positional accuracy the author however attempts to rule out reference frame changes and tectonic plate movements, which would introduce a common bias to all point coordinates. Both sets of reference points are provided or converted to the European Terrestrial Reference System 1989 (ETRS89) coordinate reference system according to the standards of the Dutch cadastre. ETRS89 is fixed to the stable part of the Eurasian continental plate and consistent with the International Terrestrial Reference Frame (ITRF) at the epoch 1989.0 (EPSG::4937) (OGP, 2011b). Currently in the Netherlands the ITRF at epoch 2000.0 realisation of WGS84 is in use as a reference for ETRS89 (Kadaster, 2011). ITRF is the datum realisation of the International Terrestrial Reference System (ITRS) and because of the better quality the WGS84 datum now effectively takes its definition from ITRS (Ordnance Survey, 2010). Therefore to be able to accurately compare GPS coordinates with ETRS89 coordinates it is necessary to transform the GPS coordinates from ITRF89.0 to ITRF2000.0 to correct for the frame shift, as in January 1989 ETRS89 and WGS84 are both identical to ITRF89.0. Besides the ITRF datum shift also the movement of the Eurasian plate needs to be accounted for. As the ETRS89 moves with at a speed of about 2.5 cm a year the GPS coordinates need to be corrected for this as well. See figure 20 for the tectonic plate movement of the Eurasian plate for the Netherlands.

Figure 20: Tectonic plate movement Netherlands (source (Jet Propulsion Laboratory, 2011)*)*

ITRF89.0 to ITRF2000.0 Transformation

The WGS 84 ellipsoid is in practical terms identical to the GRS 1980 ellipsoid (National Imagery and Mapping Agency, 2000); the relevant parameters of this ellipsoid to be able to calculate the positional accuracy are listed in table 8.

Table 8: Parameters WGS84 ellipsoid

Parameter	Value
a	6378137.0 m
1/f	298.257223563

The transformation parameters are obtained from the European Petroleum Survey Group (EPSG) website (OGP, 2011b) as listed in table 9. As this transformation is from ITRF89 at epoch 1988.0 to ITRF 2000.0 the parameters need to be corrected with one year to start at epoch 1989.0, this is done with the transformation rates provided with the EPSG record.

Table 9: Coordinate Transformation ITRF89 to ITRF2000 (EPSG::45911)

Parameter Name	Parameter value	Unit of measure	Sign Reversible
X-axis translation	-0.0297	metre	Yes
Y-axis translation	-0.0475	metre	Yes
Z-axis translation	0.0739	metre	Yes
X-axis rotation	0	arc-second	Yes
Y-axis rotation	0	arc-second	Yes
Z-axis rotation	0.00018	arc-second	Yes
Scale difference	-0.00585	parts per million	Yes

The transformation is done using a Helmert transformation using equation 1 (OGP, 2011a).

Equation 1: Helmert transformation

$$\begin{pmatrix} X_T \\ Y_T \\ Z_T \end{pmatrix} = M \begin{pmatrix} 1 & -R_Z & +R_Y \\ +R_Z & 1 & -R_X \\ -R_Y & +R_X & 1 \end{pmatrix} \begin{pmatrix} X_S \\ Y_S \\ Z_S \end{pmatrix} + \begin{pmatrix} dX \\ dY \\ dZ \end{pmatrix}$$

Where:

$$M = 1 + dS\ 10^6$$

Written out, this results in three formulas to resolve X, Y and Z for the target coordinate system.

$$X_T = M\ (X_S - R_Z\ Y_S + R_Y\ Z_S) + dX$$
$$Y_T = M\ (R_Z\ X_S + Y_S - R_X\ Z_S) + dY$$
$$Z_T = M\ (-R_Y\ X_S + R_X\ Y_S + Z_S) + dZ$$

The Helmert transformation requires that the geographic coordinates are transferred to geocentric coordinates. To do these calculations the ellipsoid's radius of curvature in the prime vertical for the location in question is needed. As this parameter as well as the radius of curvature in the meridian is needed later on for the distance calculations, the equations are given first.(National Imagery and Mapping Agency, 2000)

Equation 2: Radius of curvature in the meridian

$$\rho = R_M = \frac{a(1 - e^2)}{(1 - e^2 sin^2\varphi)^{3/2}}$$

Equation 3: Radius of curvature in prime vertical

$$\nu = R_N = \frac{a}{\sqrt{(1 - e^2\ sin^2\varphi)}}$$

In the above 2 equations the first eccentricity *e* is required this can be calculated with the formula below:

Equation 4: First eccentricity

$$e^2 = 2f - f^2$$

[1] At epoch 1988.0. Rates dX=0.0000 m/yr, dY=0.0006 m/yr, dZ=0.0014 m/yr, rX=rY=0.0"/yr, rZ=-0.00002"/yr, dS=-0.00001 ppm/yr.

As the reference points are in cartesian degrees and the Helmert equation requires positions to be in geocentric coordinates, a transformation from cartesian to geocentric coordinates has to be performed. This and the reverse can be done with the equations below (OGP, 2011a).

Equation 5: Geographic to Geocentric coordinates conversion

$$X = (\nu + h)\, cos\varphi\, cos\lambda$$

$$Y = (\nu + h)\, cos\varphi\, sin\lambda$$

$$Z = [(1 - e^2)\, \nu + h]\, sin\varphi$$

Equation 6: Geocentric to Geographic coordinates conversion

$$\varphi = atan\left(\frac{Z + \varepsilon\, b\, sin^3 q}{p - e^2\, \mathrm{a}\, cos^3 q}\right)$$

$$\lambda = atan\frac{Y}{X}$$

$$h = \frac{p}{cos\varphi} - \nu$$

Where

$$\varepsilon = \frac{e^2}{1 - e^2}$$

$$b = a(1 - f)$$

$$p = \sqrt{X^2 + Y^2}$$

$$q = atan\frac{Z\, a}{p\, b}$$

As the points in this experiment are very near (should be identical) to each other the radii of curvature of the reference point are used to calculate the distance between the X_S, X_T and Y_S, Y_T, obviating the need to calculate the mean radius of curvature, which could however be calculated as per the formula below (Weisstein, 2011).

Equation 7: Mean radius of curvature

$$\bar{R} = \sqrt{R_N * R_M}$$

The resulting distance vector between the reference and sample point is calculated using Pythagoras theorem, therewith assuming a flat surface instead of an arc. As the distance between the points is very small at the scale of things, any errors are negligible.

Tectonic Plate Movement Correction

As a final step the GPS coordinates need to be corrected for the tectonic movement of the Eurasian tectonic plate. The parameters are taken from the Jet Propulsion website (Jet Propulsion Laboratory, 2011). As tectonic plate movement is very constant (Ordnance Survey, 2010) the WGS84 coordinates can be easily corrected to current ETRS89 coordinates by multiplying the amount of years, between the creation of ETRS89 frame and the date of sample acquisition, with the yearly movement, and adding or subtracting that from the coordinates found. To calculate this, the values for Delft, a permanent monitoring station to determine the relations between the ITRS realisations, are used, see figure 21.

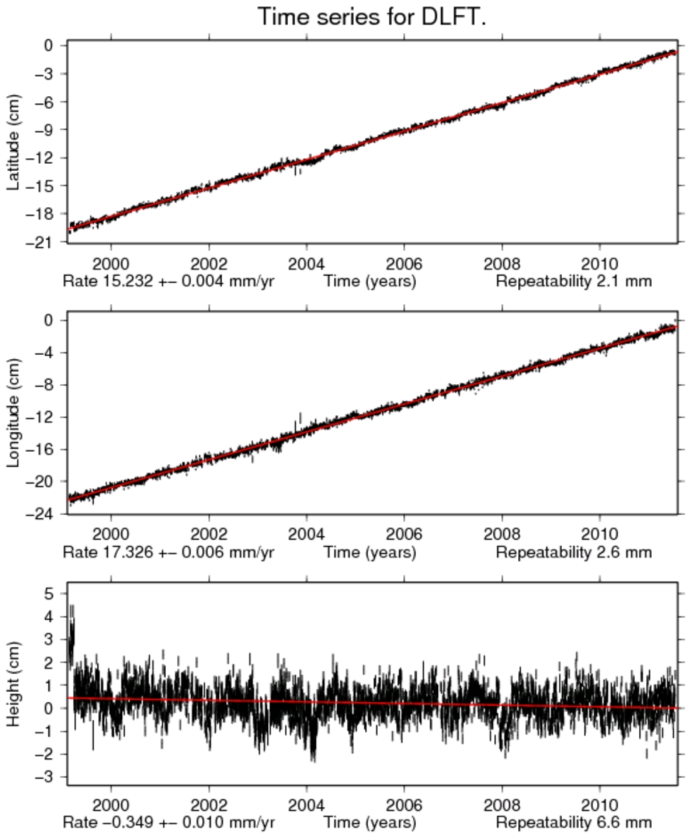

Figure 21: Eurasian tectonic plate movement parameters for Delft (source: (Ordnance Survey, 2010)*)*

7.2.4 Positional Accuracy Results

The sampling measurements with their correction for WGS84 frame and tectonic plate movement are displayed in appendix f. The first 6 entries shown in the appendix are ignored due to the low accuracy reported by the phone. Experience shows that with a little bit of patience, it is easily possible to have the phone report an accuracy of within 10 meters. The accuracy results based on the other entries are shown in table 10. Due to the lack of clarity of the transformation methods offered by ESRI and SAFE software, the calculations are done in Excel instead.

Table 10: Positional accuracy

	Syst. error X (m)	Spread X (m)	RMSE X (m)	Syst. error Y (m)	Spread Y (m)	RMSE Y (m)	Syst. error Z (m)	Spread Z (m)	RMSE Z (m)	Mean vector error (m)	RMSE vector (m)
No correction	0.19	-6.27 - +10.49	± 3.07	0.72	-4.83 - +11.22	± 3.31	-0.53	-13.06 - +13.44	± 5.22	± 3.61	± 11.17
After correction	0.38	-608 - +10.68	± 3.09	0.78	-4.77 - +11.30	± 3.25	-0.52	-13.06 - +13.44	± 5.22	± 3.61	± 11.50

Contrary to the expectations the positional accuracy results have not improved correcting for the frame shift of ETRS89 from WGS84 and the movement of the Eurasian tectonic plate. It was expected the correction would result in a reduction of the systemic errors.

7.3 Thematic Accuracy

Based on the tremendous road hazard acquisition work done by two surveyors working in Iraq it is possible to do some analysis on the thematic accuracy in their results. An assessment of proximity in relation to the chosen hazard categories is performed on their gathered data. Some samples are looked into more closely.

7.3.1 Proximity Statistics

To create statistics about the proximity of captured hazard points and their likelihood an ArcGIS model and an arcpy script were created to calculate the distances between all points and to and to provide information of the amount of identically and differently assessed points in their vicinity. The model and arcpy script are shown in appendix g. To calculate the distance between points the average radius of curvature for the WGS84 ellipsoid is used. The results about the equality and non-equality are shown in figure 22 and 23; the count results were divided by 2 as complementary points are referenced twice by the count.py script.

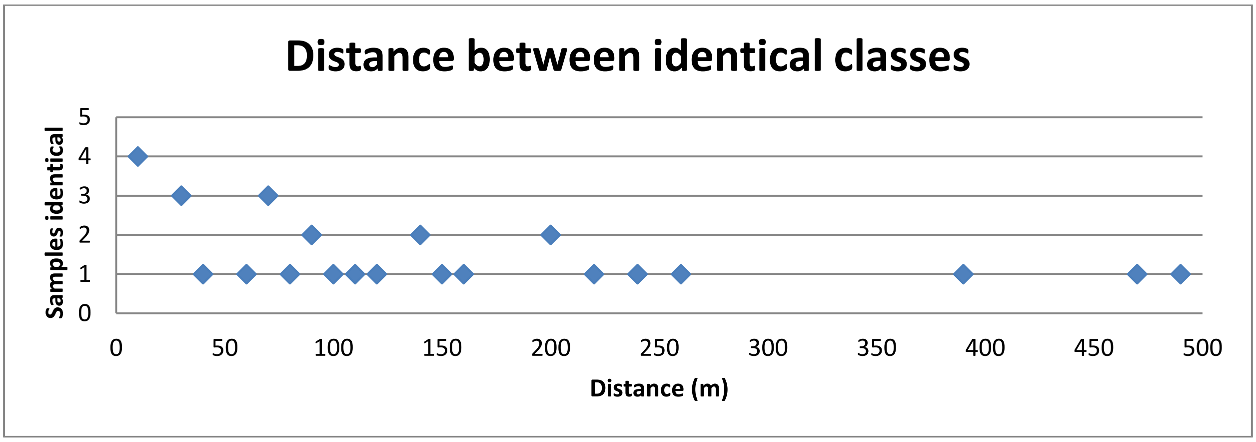

Figure 22: Distance between identical classes

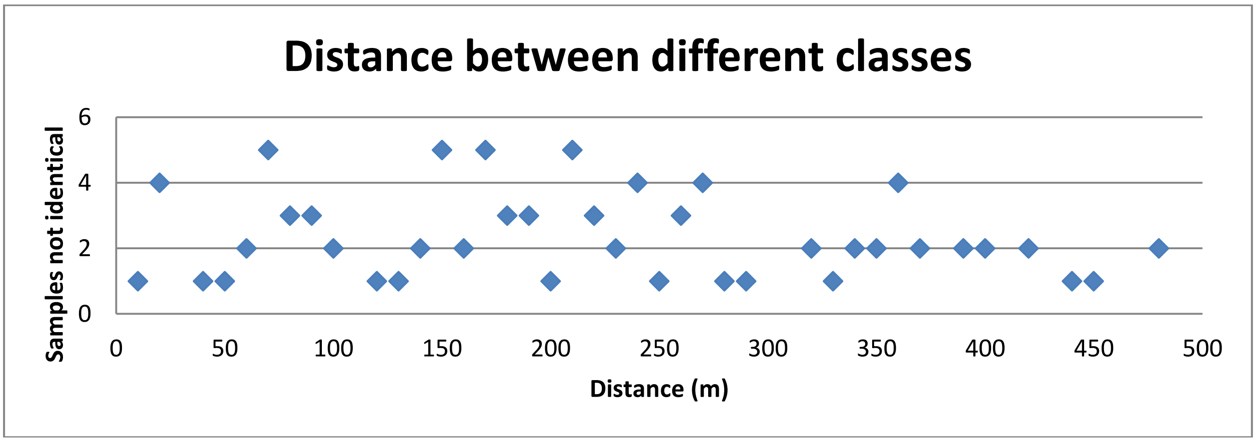

Figure 23: Distance between different classes

In the first graph a trend is visible; the nearer points are the more likely it is that they are given the same category. The second graph does not show any trend like that. This suggests that points at close proximity are assessed twice by different people. It is also still possible that points at close proximity are assessed as different categories, but resemble the same hazard. The following paragraph will pick out a couple of examples and look in to the details.

7.3.2 Classification Quality

Some of the points found at close proximity of another are reviewed in this paragraph, high resolution imagery of the area is used as a backdrop. In figure 24 two hazards located very closely together are shown, both report an overhead cable over the road. Having more sources reporting the same thing is considered a good validation for the correctness of the data. It is however not desired to have redundant information in the database.

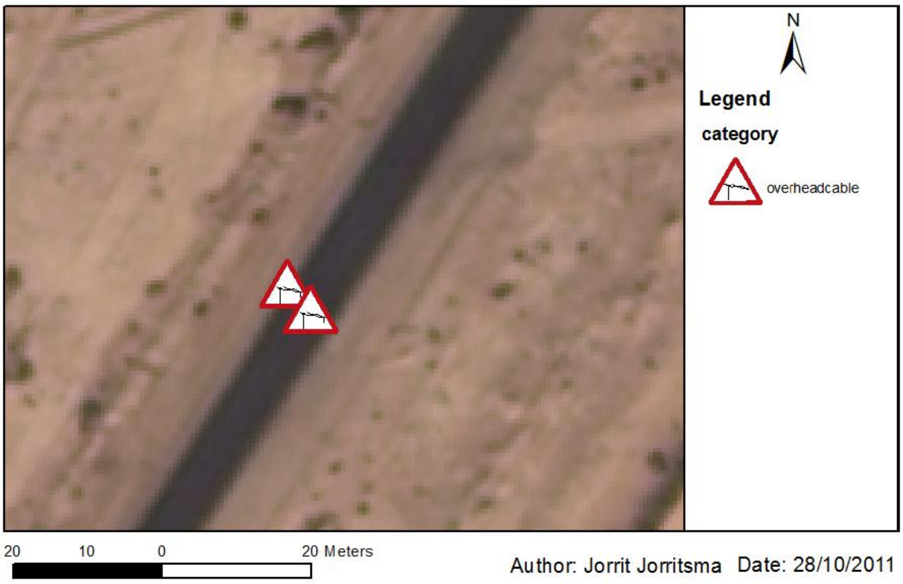

Figure 24: Two overhead cable reports describing the same location

Figure 25 also shows identically assessed points at close proximity of each other, this time categorised as dangerous crossings. The description however state in both occasions it is an entrance to a facility, therefore the validity of the categories can be doubted, likely a symbol for some kind of facility was required.

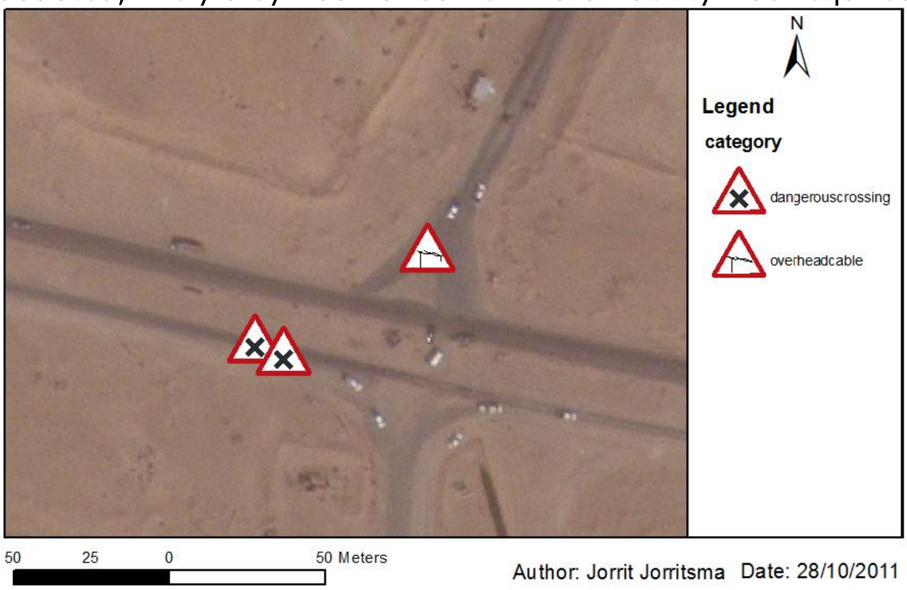

Figure 25: Two dangerous point reports describing the same location

Figure 26 shows two different hazards at close distance of each other, assessed differently though. In this case they represent a check point and an overhead cable as can be seen in figure 27, which is the photo attached to the reported "dangerous crossing". The fact that the "dangerous crossing" category was chosen to report a check point confirms informational categories should be added to the app.

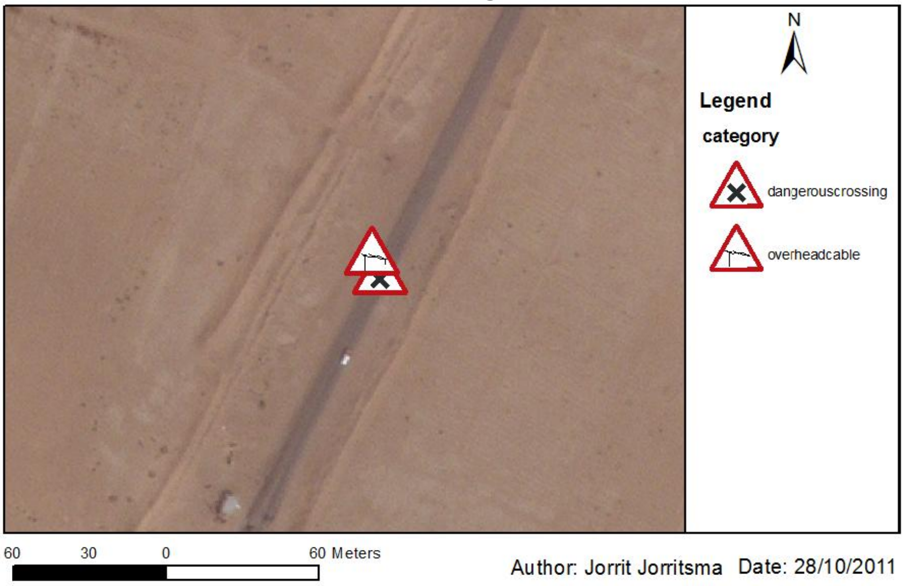

Figure 26: Two hazards at close proximity

Figure 27: Attached photo belonging to dangerous crossing hazard

The last example, figure 28, shows a check point reported twice, but with different symbols chosen to report it. Again here the required category could not be chosen, but there is also ambiguity about what "other" category should be chosen instead. It could in this case well be that there are indeed 2 check points but next to each other. It seems in this case better to report it as one to avoid an overload of warnings, provided that warnings to be provided are given well in advance.

Figure 28: Two check points categorized differently

The author is of the opinion that to correctly determine the validity of road hazards often local knowledge of the area is required. High resolution imagery like available in this case certainly helps, but in many occasions still lacks the required detail to make a proper assessment.

Despite having sufficient people with local knowledge able to access the WebDB backend, limited active maintenance on the road hazards was done on the gathered points.

7.4 Discussion

Comparing the results of the different positional sample sets, taken by different people, show differences in accuracy results reported by the phone, suggesting that the GSM module should be always on to allow for faster and better GPS fixes. This is in line with the pilot feedback and findings from the survey. Surveyors are likely inclined to get as many points possible captured in a day that having to wait for a proper GPS fix is seen as a burden.

With a probability of 68 % (1 σ) the points measured with a smart phone are within about 11 meters accuracy, provided the points are measured accurately. It can be argued whether correction of the GPS coordinates found require coordinate transformation to compare the samples with ETRS89 reference points. No improvement was found, it appears there is another factor the cause of a systemic error, or the sample set was still too small to do proper validation. Depending on the location and the coordinate reference systems used this should however be re-assessed on a case by case basis.

For use of these points for car navigation purposes however a greater probability would be required to receive a warning in time in all cases using a value of 3 σ raises the probability above 99.7 %. 3 σ is the value currently used for existing road hazard mapping efforts (feedback from “Geomatics for Road Safety” forum members). It needs to be noted that PND’s use similar GPS receivers and thus the resulting number should be multiplied by two plus some safety margin to allow the driver to react.

The accomplished accuracy is perceived to be sufficient for car navigation purposes, however if the road hazard information would be used for pedestrians or cyclists a higher accuracy of the hazard locations but also the navigation device would be required in order not to warn 30 to 60 meters in advance.

Quality control of the thematic values is required to filter out duplicates but also validation of the hazard classification is needed. By experience of the author trying to assess the validity of some of the points proved to be difficult without having local knowledge of the area and means to contact the person who reported the hazard, as the samples show the current classification symbols are not sufficient for the information that needs to be captured.
It also is apparent that a good set of rules on which category to use for what hazard should be used. This requires proper documentation, communication and training.

8 Conclusions and Recommendations

The goal of this study, to introduce crowdsourcing for the collection of road hazard points using of smartphones is successfully piloted. In line with the findings of Jeffery Shi in his road hazard reporting system (Shi, 2009), the crowd can be very well used to collect road hazard information for journey management. As shown in this pilot also within a corporate environment. Overall the perception of the pilot users was that the smartphone application built for this purpose is easy to operate. The data created with the road hazard smartphone app is largely appreciated as usable for journey management maps, and is also considered easily accessible from within Shell or can be easily shared with external parties respecting Shell's security policies.
Looking deeper into the objectives however there are some more side notes to be made:

1. **Design a road hazard classification model for road hazard point information to be used by all involved parties.**

A classification model was created comprised of 3 classes, warnings, limits and information. Based on experience of prior pilot findings and feedback from the "Geomatics for Road Safety" forum it was decided only to include the warning class hazard categories for the purpose of the pilot. These categories have been used by all involved parties to capture and map the found hazards.
Use of the European road signs as a basis for the classifications has greatly helped the author to make most of the symbols, only categories not used in Europe or that could not be found in the required SVG format had to be created by the author itself.
Inclusion of the related symbology in the SSL ensured everyone uses the same classification and symbology for the road hazard points captured with the road hazard smartphone app. Storing the symbols in the Amazon cloud and referencing them in the KML export format of the WebDB also ensures consistent representation to external parties or services consuming KML. This does however not mean that the classification is flawless. In general the warning class is considered incomplete, it should allow categories more focussed on the different local requirements Shell does business in. From the total set it should be possible to select the categories required for local needs.
From the survey can be concluded that also the limit and informational classes should be included. Also for these two classes extra categories are proposed to complement them, suggesting they are not yet complete as well.

2. **Design and build a PoC application to capture road hazard points using smartphones that can store and disseminate the information to the required parties in line with the company's security and regulatory policies.**

The designed and built infrastructure to support running a pilot on a PoC road hazard acquisition application has proven to be useful for road hazard surveying. All involved parties, except those that could not participate due to regulatory compliance issues, were able to use the road hazard smartphone app to collect and store the road hazard point information. The provided infrastructure to disseminate the data importing the information from the WebDB backend in ArcSDE and serving it as web features has enabled even remote locations to consume the data and use it for their local needs. The implemented design was accepted from a security perspective taking the information classification and protective measures of using public key encryption into account.

3. Assess the smartphone app usability to acquire road hazard points.

In 2 countries the road hazard smartphone app was supposed to be tested in, import restrictions on software containing cryptography were deemed to disallow use of the app, rendering it useless in these locations.
Besides bureaucratic limitations on the usability of the app, the usability is also very much dependent on the user requirements. Feedback from logistics surveyors tells the current implementation of the app is not working for them as it misses the speed of just making georeferenced photos. Other users however state this greatly improves their way of working to collect road hazards. All users involved in the pilot testing acknowledge however this method of acquiring road hazards is the way forward.
From the feedback gathered it can be said that the smartphone app is simple to use, not requiring a lot of training to get started.
The amount of hazard categories is considered too limited and too extensive at the same time. Too limited for missing desired categories and too extensive for the abundance of categories that will never be used in the location the app is used in, therewith cluttering the screen too much. A centrally managed set of symbols containing all globally used hazard categories has to be created. From this a locally used subset can be chosen to ensure the same symbol is used for the same type of hazard globally while reducing the amount of categories provided in the smartphone app.

The app as used in the pilot is generally assessed as easy to use from the beginning or after a bit of practice. Some improvements were however suggested to improve the user experience.
Free text fields are difficult to fill in, especially from within a moving vehicle.
Uploading the hazards from the phone into the backend infrastructure has not led to any problems. This shows that the communication protocol used is robust, but also that the implemented security model does not hinder usage.
Usability proves to be a not so tangible property; it is very dependent on the use case as well as personal preference. With the successful road hazard point acquisition surveys done in Iraq delivering many usable points and the positive feedback received via the representatives in the "Geomatics for Road Safety" forum the author is of the opinion the app and backend were fit for its purpose.

4. Assess the road hazard data quality for use in journey management maps.

The countries that were assessed to have import restrictions on software with strong encryption could not participate in the road hazard acquisition pilot using the smartphone app. This is considered as no quality at all. In countries where this was of no concern the data proven to be well accessible and usable for their local purpose using the data access channels provided to them by the project.
The positional accuracy was empirically determined in field tests and found to have standard deviation of about 11 meters. This means that with a probability of 99.7% (3 σ) all points are within 33 meters of its reading. For navigation purposes this is considered as sufficiently accurate as warnings need to be given well in advance when in a moving vehicle.
Thematic accuracy has shown to be a difficult topic. Different surveyors classify hazards differently. Maintenance proves to be something that needs to be done by local staff, familiar with the surroundings. Governance on roles and responsibility on the maintenance of the data is required to maintain good quality.

Recommendations

Although the PoC is largely considered a success, there is still a long way to go before a road hazard application as built can be consumed as a service, for which there seems to be some appetite in Shell. The main point of concern is the requirement for governance on the data and the processes. Centrally the standards need to be set and maintained while being accepted by the different potential user communities. Appreciation of the added value of such an application will be required from all parties to get their buy-in and support. In the regions where the data is collected, roles and responsibilities need to be defined to appoint people responsible for the quality and maintenance of the data as well as to maintain the smartphones and the road hazard app that runs on them. Common understanding from the users on the classification of hazards is required to ensure hazards with the same risk are labelled in the same way. This will require the definition of well documented standards for the classification, as well as proper training for the users on how to apply these. Support on the infrastructure is required for this to become operational, Shell's Technical IT Infrastructure supplier need to accept the infrastructure as theirs to support. Contractual negotiations and a service on-boarding project will be required to define what is included in the service, what service levels will be provided and what the responsibilities of the service provider are. A partner needs to be found for the further development of the smartphone app and its backend. This partner should be chosen for its capabilities in delivering smartphone applications for multiple platforms like Android, IOS and Windows Mobile, but also for the support it can deliver in case of problems with the software. To get all these requirements in place to make the road hazard acquisition with smartphones available as a service, someone familiar with the matter and a passion for it will need to drive this. Building a service around road hazard acquisition using smartphones should preferably be managed as a project.

Usability as a quality depends largely on the user requirements and how these are met. The road hazard app has shown to be usable for some applications but too restricted for others. Modifying the app in such a way that it is possible to deploy different classification classes with selectable categories will greatly improve selection of hazards but also open up potential other use cases for surveying work. Additional research is required to investigate if a modified app, with customisable classes can cater for the requirements of different business use cases. It is expected that this will enlarge the applicability of the app and thus reduce development and maintenance costs over maintaining different apps for different purposes. It is however unknown if the additional complexity required in the app and infrastructure to facilitate this additional functionality indeed results in cost savings and if the acceptance level of the app would remain the same as with the currently tested one.
An even further extension of the app could potentially reap bigger benefits then the one piloted in this project. The ability to capture line segments as hazards or for limit information, or coverage of GSM signal should be considered. Ultimately a replacement tool for the used IVMS systems should be considered. Most smartphones have all the required sensors to perform this task.

Governance on the data quality needs to be established. Not only roles and responsibilities will be required, also means to identify reported hazards as validated need to be created. Several implementations are possible, either by including a field in the data model that flags a hazard as validated or by having a split off database for validated hazards. This needs to be given additional thought to allow also for different user experience levels. A means for an occasional reporter of a hazard that would require validation and a means for an experienced surveyor that would immediately qualify as a validated hazard are desired. Either solution will need post processing tools to manage the hazard points. Potentially topological decision rules, based on already available geo-information, can be made to allow for automated flagging of hazards with a dubious category. This is not looked into during this research and requires further study to see if this can add value.

The for the purpose of this pilot adopted security model, using client side certificates for authentication was accepted by the EP IT architect. This solution has however resulted in some issues with software import restrictions for some countries. To resolve these kinds of issues with the software some additional research is required to come to a globally workable and architecturally accepted solution. The virtual private cloud offers more security features to shield off services from the public domain, its use as a detached infrastructure from Shell that can be accessed by selected third parties needs to be investigated. Other projects using smartphones in Shell are likely dealing with the same kind of issues. It is recommended to see if there are lessons learned in those projects that can be applied for road hazard acquisition app.

The current WebDB backend and the implementation of the hazard import function are not based on standards or of the shelf products. The decision to move away from the Google App Engine resulted in the rewriting the TinyWebDB API to make it available on a different hosting platform. This likely has implications for future support; some additional research is required to decide on the proper online data record storage mechanism.

Also importing the hazard points into Shell's Geomatics infrastructure needs additional study, currently whole table contents is dropped daily and reloaded from the on-line WebDB. This does for instance not allow for internal modification of the data as it gets overwritten daily. An incremental method can mitigate this and can also offer a more frequently updated version of the road hazard data in the Geomatics infrastructure.

Despite the great care taken to make simple symbols, there are still quite a few that require visual improvement. Centrally guiding the build-up of high quality symbology set that matches a classification model is expected to greatly improve standardisation and global usability for road hazard management. It is advised to also look closely in to the relation between hazard categories and their mitigating action to see if there really is a one to one relation, this would drop the requirement to report the mitigating action. When this is not the case and some form mitigating action of classification is required, the mitigating actions could be chosen from a pull down list instead of using free form text.

The positional accuracy that is achieved using smartphones for reporting road hazards is sufficient for car navigation if the uncertainty is taken into account and warnings are given well in advance. For navigation purposes that need a more detailed map, more accurate means to acquire location information need to be considered.
Maintaining and quick acquiry of a GPS fix in the smartphone app is something that needs more research in how this can be improved while balancing between GPS fix and energy consumption of the smartphone.

Crowdsourcing geo-information for road hazard acquisition within a corporate environment shows potential. Likely it can also leverage from public domain contributions, how these contributions should be validated and how corporate information can be shielded off from the public when required is something that needs more study. Potentially a third party offering this as a service could be considered.

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Appendix A Symbology and Classification

Warning Class

Category	Symbol
Animal crossing	
Bad road conditions	
Blackspot	
Dangerous crossing	
Dangerous point	
Explosion danger	
Flooding danger	
Grounding danger	
Hill top, poor visibility	
Landslide danger	
Narrow road	
Overhead cable	
Crossing pedestrians or school children	
Poor visibility possible	
Road works	
Roundabout	
Sand dunes	
Sharp bend	
Road can be slippery	
Soft verges	
Steep hill	
Train crossing	
Tunnel	
No U-turn beyond this point	
Winding road	
Flag hazard for removal	

Information Class

Category	Symbol
Airport	
Ambulance station	
Check point	
Cafe	
Fire station	
Heliport	
Hospital	
Landmark	
No GSM signal	
Overnight accommodation	
Overnight accommodation and restaurant	
Parking place	
Petrol station	
Police station	
Non hospital medical facility	
Restaurant	
SOS communication point	
Town / habitat	

Limits Class

Category	Symbol
Maximum height	
Maximum speed	
Maximum weight	
Maximum width	
No entry	
No entry from this side	
No entry for trucks	
No overtaking	
No overtaking by trucks	

Appendix B Road Hazard Web DB Code

Apache configuration

/etc/httpd/conf.d/wsgi.conf

```
LoadModule wsgi_module modules/mod_wsgi.so
WSGIScriptAlias /db /etc/httpd/webdb/webdb.wsgi
WSGIPythonPath "/etc/httpd/webdb"
```

/etc/httpd/conf.d/ssl.conf

```
LoadModule ssl_module modules/mod_ssl.so
Listen 443
SSLPassPhraseDialog  builtin
SSLSessionCache         shmcb:/var/cache/mod_ssl/scache(512000)
SSLSessionCacheTimeout  300
SSLMutex default
SSLRandomSeed startup file:/dev/urandom  256
SSLRandomSeed connect builtin
SSLCryptoDevice builtin
<VirtualHost _default_:443>
DocumentRoot "/var/www/html"
ServerName roadhazards.dyndns.org:443
ErrorLog logs/ssl_error_log
TransferLog logs/ssl_access_log
LogLevel warn
SSLEngine on
SSLProtocol all -SSLv2
SSLCipherSuite ALL:!ADH:!EXPORT:!SSLv2:RC4+RSA:+HIGH:+MEDIUM:+LOW
SSLCertificateFile /etc/pki/tls/certs/roadhazards.dyndns.org-key.pem
SSLCACertificateFile /etc/pki/tls/certs/ca.jorritsma.cc-cacert.pem
SSLVerifyClient require
SSLVerifyDepth  1
<Location />
SSLRequire (    %{SSL_CIPHER} !~ m/^(EXP|NULL)/ \
        and %{SSL_CLIENT_S_DN_O} eq "roadhazardsdb" )
</Location>
<Files ~ "\.(cgi|shtml|phtml|php3?)$">
    SSLOptions +StdEnvVars
</Files>
<Directory "/var/www/cgi-bin">
    SSLOptions +StdEnvVars
</Directory>
SetEnvIf User-Agent ".*MSIE.*" \
         nokeepalive ssl-unclean-shutdown \
         downgrade-1.0 force-response-1.0
CustomLog logs/ssl_request_log \
          "%t %h %{SSL_PROTOCOL}x %{SSL_CIPHER}x \"%r\" %b"
</VirtualHost>
```

Python sources

/etc/httpd/webdb/webdbconfig.py

```
ID = "<Replace Me>"
KEY = "<Replace Me>"
DOMAIN = 'RoadHazards'
BUCKET = 'roadhazards' # needs to be lowercase
S3URL = 'https://s3-eu-west-1.amazonaws.com/roadhazards/'
KMLTEMPL = '/var/www/html/templates/kml.tmpl'
```

/etc/httpd/webdb/webdb.wsgi

```
#!/usr/bin/env python
# RoadHazard WebDB
# http://jorritsma.cc
#
# Copyright (C) 2011 Jorrit Jorritsma (jsj@xs4all.nl)
#
# This is free software; you can redistribute and/or modify it under
# the terms of the GNU Lesser General Public License as published
# by the Free Software Foundation.
# See the http://www.gnu.org/licenses/gpl-3.0.html for the license.

# vim: set tabstop=4 ai paste expandtab:

from webob import Request, Response
from boto.s3.key import Key
import os
import sys
import time
import base64
import boto
import pprint
import simplejson as json
from Cheetah.Template import Template
import urllib

### Credentials to connect to AWS SDB
# Keep secret!
from webdbconfig import *
```

```
### defaultRedir
def defaultRedir(start_response):
    status = '301 Moved Permanently'
    response_headers = [('Location', '/db/')]
    start_response(status, response_headers)
    return []

def errorPage(start_response):
    status = "501 Not Implemented"
    output = "501 Not Implemented\nYou tried to load invalid content."
    response_headers = [('Content-Type', 'text/plain'),
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]

### connectDB
def connectDB():
    conn = boto.connect_sdb(ID,KEY)
    try:
        domain = conn.get_domain(DOMAIN)
    except:
        domain = conn.create_domain(DOMAIN)
    return domain

def connectS3():
    connS3 = boto.connect_s3(ID,KEY)
    try:
        bucket = connS3.get_bucket(BUCKET)
    except:
        bucket = connS3.create_bucket(BUCKET)
    return bucket

def myMethods(req):
    sname = req.script_name
    out = '''
    <p>Available calls:\n
    <ul>
    <li><a href="%s/storeavalue">%s/storeavalue</a>: Stores a value, given a tag and a value</li>
    <li><a href="%s/deleteentry">%s/deleteentry</a>: Deletes entry stored under a given tag.</li>
    <li><a href="%s/getvalue">%s/getvalue</a>: Gets a json object of the value under a given tag.  Returns the
empty string if no value is stored</li>
    <li><a href="%s/getimage">%s/getimage</a>: Gets the image stored under a given tag.</li>
    <li><a href="%s/getids">%s/getids</a>: Gets list of stored tags.</li>
    <li><a href="%s/getkml">%s/getkml</a>: Gets a kml file of stored tags.</li>
    <li><a href="%s/getall">%s/getall</a>: Gets a json object containing all entries.</li>
    <li><a href="%s/edit">%s/edit</a>: Lets you edit a json object.</li>
    </ul>''' % (sname, sname, sname, sname, sname, sname, sname, sname, sname, sname, sname, sname, sname, sname,
sname, sname)
    return out

### editValue
def editValue(req, start_response):
    params = req.str_params
    if len(params) == 0:
        output = '''
            <html><body>
            <form action="%s/edit" method="post"
                    enctype=application/x-www-form-urlencoded>
                <p>Key<input type="text" name="tag" /></p>
                <input type="submit" value="Edit value">
            </form></body></html>\n''' % (req.script_name)
        status = '200 OK'
        response_headers = [('Content-Type', 'text/html'),
                            ('Content-Length', str(len(output)))]
        start_response(status, response_headers)
        return [output]
    else:
        try:
            value = params['value']
        except:
            # ah we have an edit request
            domain = connectDB()
            tag = params['tag']
            tag = urllib.unquote(tag)
            entry = domain.get_item(tag)
            if entry:
                output = '''
                    <html><body>
                    <form action="%s/edit" method="post"
                            enctype=application/x-www-form-urlencoded>
                        <p>Key : %s</p><input type="hidden" name="tag" value="%s">
                        <p>Value</p><p><textarea name="value" cols=80 rows=6>%s</textarea></p>
                        <input type="submit" value="Submit value">
                    </form></body></html>\n''' % (req.script_name, urllib.unquote(params['tag']),
urllib.quote(params['tag']), str(entry['value']))
                status = '200 OK'
                response_headers = [('Content-Type', 'text/html'),
                                    ('Content-Length', str(len(output)))]
                start_response(status, response_headers)
                return [output]
            else:
                return defaultRedir(start_response)
        else:
            # submit results
            # let's first try if what we are presented is still valid json if not... bummer
            #print >> sys.stderr, "Here...."
            try:
                jvalue = json.loads(value)
            except:
                return errorPage(start_response)
```

```
            domain = connectDB()
            item = domain.get_item(urllib.unquote(urllib.unquote(params['tag'])))
            #print >> sys.stderr, "Item :" + params['tag']
            item['value'] = json.dumps(jvalue)
            item.save()

            return defaultRedir(start_response)


### getValue
def getValue(req, start_response):
    params = req.str_params
    if len(params) == 0:
        output = '''
            <html><body>
            <form action="%s/getvalue" method="post"
                    enctype=application/x-www-form-urlencoded>
                <p>Key<input type="text" name="tag" /></p>
                <input type="submit" value="Get value">
            </form></body></html>\n''' % (req.script_name)
        status = '200 OK'
        response_headers = [('Content-Type', 'text/html'),
                            ('Content-Length', str(len(output)))]
        start_response(status, response_headers)
        return [output]
    else:
        domain = connectDB()
        entry = domain.get_item(params['tag'])
        if entry:
            #output = str(entry['value'])
            #mytime = time.asctime(time.gmtime(int(jvalue['properties']['time']) / 1000)) + " GMT"
            jvalue = json.loads(entry['value'])
            jvalue['properties']['time'] = time.asctime(time.gmtime(int(jvalue['properties']['time']) / 1000)) + "
GMT"
            output = json.dumps(jvalue)
            status = '200 OK'
            response_headers = [('Content-Disposition', 'attachment; filename=SingleRoadHazard.json'),
                                ('Content-Type', 'application/json'),
                                ('Content-Length', str(len(output)))]
            start_response(status, response_headers)
            return [output]
        else:
            return defaultRedir(start_response)


### storeAValue
def storeAValue(req, start_response):
    # get the GET and POST parameters
    params = req.str_params
    if len(params) == 0:
        output = '''
            <html><body>
            <form action="%s/storeavalue" method="post"
                    enctype=application/x-www-form-urlencoded>
                <p>Key<input type="text" name="tag" /></p>
                <p>Value<input type="text" name="value" /></p>
                <input type="submit" value="Store a value">
            </form></body></html>\n''' % (req.script_name)
        status = '200 OK'
        response_headers = [('Content-Type', 'text/html'),
                            ('Content-Length', str(len(output)))]
        start_response(status, response_headers)
        return [output]
    else:
        # roadhazards specific images are larger than 1024 bytes, which is max
        # for sdb, so let's split that off to S3
        epoc = time.time()
        domain = connectDB()
        bucket = connectS3()

        try:
            value = params['value']
        except:
            return errorPage(start_response)

        # let's check if the values provided were real json objects
        # if not let's redirect to the main page
        try:
            jvalue = json.loads(value)
        except:
            return errorPage(start_response)

        if len(jvalue['properties']['image']) > 0:
            image = base64.b64decode(jvalue['properties']['image'])
            longitude = jvalue['geometry']['coordinates'][0]
            latitude = jvalue['geometry']['coordinates'][1]
            filename = longitude + "__" + latitude
            filename = filename.replace('.', '_') + '.jpg'
            k = Key(bucket)
            k.key = filename
            k.set_contents_from_string(image)
            k.make_public()
            jvalue['properties']['image'] = S3URL + filename
        # save modified json object
        item = domain.new_item(params['tag'])
        item['ctime'] = epoc
        item['value'] = json.dumps(jvalue)
        item.save()
        return defaultRedir(start_response)
```

```
### deleteEntry
def deleteEntry(req, start_response):
    params = req.str_params
    if len(params) == 0:
        output = '''
            <html><body>
            <form action="%s/deleteentry" method="post"
                    enctype=application/x-www-form-urlencoded>
                <p>Key<input type="text" name="tag" /></p>
                <input type="submit" value="Delete entry">
            </form></body></html>\n''' % (req.script_name)
        status = '200 OK'
        response_headers = [('Content-Type', 'text/html'),
                            ('Content-Length', str(len(output)))]
        start_response(status, response_headers)
        return [output]
    else:
        domain = connectDB()
        try:
            tag = params['tag']
            tag = urllib.unquote(tag)
            entry = domain.get_item((tag))
            value = entry['value']
        except:
            return defaultRedir(start_response)
        try:
            jvalue = json.loads(value)
            if len(jvalue['properties']['image']) > 0:
                longitude = jvalue['geometry']['coordinates'][0]
                latitude = jvalue['geometry']['coordinates'][1]
                filename = longitude + "__" + latitude
                filename = filename.replace('.', '_') + '.jpg'

            bucket = connectS3()
            k = Key(bucket)
            k.key = filename
            bucket.delete_key(k)
        except:
            pass

        entry = domain.delete_attributes(tag)
        return defaultRedir(start_response)

### getImage
def getImage(req, start_response):
    params = req.str_params
    if len(params) == 0:
        output = '''
            <html><body>
            <form action="%s/getimage" method="post"
                    enctype=application/x-www-form-urlencoded>
                <p>Key<input type="text" name="tag" /></p>
                <input type="submit" value="Get image">
            </form></body></html>\n''' % (req.script_name)
        status = '200 OK'
        response_headers = [('Content-Type', 'text/html'),
                            ('Content-Length', str(len(output)))]
        start_response(status, response_headers)
        return [output]
    else:
        domain = connectDB()
        tag = params['tag']
        tag = urllib.unquote(tag)
        entry = domain.get_item(tag)
        if entry:
            value = entry['value']
        else:
            #print >> sys.stderr, "hmm in else..."
            return defaultRedir(start_response)

        jvalue = json.loads(value)
        if len(jvalue['properties']['image']) > 0:
            output = '''
                <html><body>
                    <img src="%s" />
                </body></html>\n''' % (str(jvalue['properties']['image']))
            status = '200 OK'
            response_headers = [('Content-Type', 'text/html'),
                                ('Content-Length', str(len(output)))]
            start_response(status, response_headers)
            return [output]
        else:
            return defaultRedir(start_response)


### getIds
def getIds(req, start_response):
    domain = connectDB()
    entries = domain.select("SELECT * FROM `" + DOMAIN + "`")
    myArray = []
    for entry in entries:
        jentry = json.loads(entry.name)
        #myArray.append(entry.name)
        myArray.append(jentry)
    output = json.dumps(myArray)
    status = '200 OK'
    response_headers = [('Content-Type', 'text/plain'),
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]
```

```
### getKml
def getKml(req, start_response):
    domain = connectDB()
    entries = domain.select("SELECT * FROM `" + DOMAIN + "`")

    hazards = ""
    #print >> sys.stderr, "Just before for loop"
    for entry in entries:
        #print >> sys.stderr, "In for loop"
        value = entry['value']
        try:
            jvalue = json.loads(value)
        except:
            #print >> sys.stderr, "hmmm in except json.load"
            continue
        jproperties = jvalue['properties']

        if jproperties.has_key('category') :
            stylename = jproperties['category']
        else:
            #print >> sys.stderr, "hmmm in except category"
            continue

        if jproperties.has_key('description') :
            description = jproperties['description']
        else:
            #print >> sys.stderr, "hmmm in except description"
            continue

        if jproperties.has_key('time') :
            mytime = time.asctime(time.gmtime(int(jvalue['properties']['time']) / 1000)) + " GMT"
        else:
            continue

        if jvalue.has_key('geometry') :
            longitude = jvalue['geometry']['coordinates'][0]
            latitude = jvalue['geometry']['coordinates'][1]
        else:
            #print >> sys.stderr, "hmmm in except geometry"
            continue

        message = '''<![CDATA[\n          <li>Acquisition time: %s</li>\n          <li>Description: %s</li>\n''' %
(mytime, description)

        if jproperties.has_key('mitigation') and len(jvalue['properties']['mitigation']) > 0:
            message = '''%s          <li>Mitigation: %s</li>\n''' % (message, jvalue['properties']['mitigation'])


        if len(jvalue['properties']['image']) > 0:
            message = '''%s          <p><img src="%s" width="200" /></p>\n<li><a href="%s">Download
photo</a></li>''' % (message, jvalue['properties']['image'], jvalue['properties']['image'])

        message = message + '\n        ]]>'
        #print >> sys.stderr, "Message: " + message


        hazard = '''
    <Placemark>
      <name>%s</name>
      <description>
        %s
      </description>
      <Point>
        <coordinates>%s,%s,0</coordinates>
      </Point>
      <styleUrl>#%s</styleUrl>
    </Placemark>''' % (stylename, message, longitude, latitude, stylename)
        hazards = hazards + hazard

    #self.response.out.write(hazards)
    hazard_values = {
        'hazards': hazards
    }

    output = str(Template(file = KMLTEMPL, searchList = [hazard_values]))

    status = '200 OK'
    response_headers = [('Content-Disposition', 'attachment; filename=RoadHazards.kml'),
                        ('Content-Type', 'application/vnd.google-earth.kml+xml'),
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]

### getAll
def getAll(req, start_response):
    domain = connectDB()
    entries = domain.select("SELECT * FROM `" + DOMAIN + "`")
    myArray = []
    for entry in entries:
        jvalue = json.loads(entry['value'])

        jvalue['properties']['time'] = time.asctime(time.gmtime(int(jvalue['properties']['time']) / 1000)) + "
GMT"

        myArray.append(jvalue)
    output = json.dumps(myArray)
    status = '200 OK'
    response_headers = [('Content-Disposition', 'attachment; filename=AllRoadHazards.json'),
                        ('Content-Type', 'application/json'),
```

```
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]

### myEnv
# for debugging purposes only
def myEnv (req, start_response):
    pp = pprint.PrettyPrinter(indent=4,depth=6)
    output = "WSGI Environment\n" + pp.pformat(req.environ.items())
    output = output + "\nPython path:\n" + pp.pformat(sys.path)
    status = '200 OK'
    response_headers = [('Content-Type', 'text/plain'),
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]

### mainPage
#def mainPage(environ, start_response):
def mainPage(req, start_response):
    domain = connectDB()
    output = '''
<html>
    <head>
        <style type="text/css">
            body {margin-left: 5% ; margin-right: 5%; margin-top: 0.5in;
            font-family: verdana, arial,"trebuchet ms", helvetica, sans-serif;}
            ul {list-style: disc;}
        </style>
        <title>Road Hazards Web DB</title>
    </head>
    <body>
    <table border=0>
        <tr valign="top">
            <td><image src="/images/icon.png" width="200" hspace="10"></td>
            <td>
                <p>
                    This web service is designed to work with the Road Hazards App
                    for Android and is inspired on the USF Tiny WebDB Service.
                </p>
            </td>
        </tr>
    </table>''' + myMethods(req)

    output = output + '''
    <p><table border=1>
        <tr>
            <th>Key</th>
            <th>Image</th>
            <th> </th>
            <th>Value</th>
            <th>Upload Time (GMT)</th>
            <th> </th>
        </tr>'''
    entries = domain.select("SELECT * FROM `" + DOMAIN + "`")
    for e in entries:
        value = e['value']
        jvalue = json.loads(value)
        if len(jvalue['properties']['image']) > 0:
            imageform = '''
                <form action="%s/getimage" method="post" enctype=application/x-www-form-urlencoded>
                <input type="hidden" name="tag" value="%s">
                <input type="image" src="%s" width="100"></form>''' % (req.script_name, str(urllib.quote(e.name)),
jvalue['properties']['image'])
        else:
            imageform = " "
        #print >> sys.stderr, "So far so ...." + imageform

        output = output + '''
        <tr>
            <td><a href="http://maps.google.com/maps?q=%s,%s" target="_blank">%s</a></td> <!-- key -->
            <td>
                %s <!-- image form -->
            </td>
            <td><form action="%s/edit" method="post" enctype=application/x-www-form-urlencoded>
                <input type="hidden" name="tag" value="%s">
                <input type="submit" style="background-color: red" value="Edit"></form>
            </td>
            <td>%s</td> <!-- value -->
            <td><font size="-1">%s</font></td> <!-- ctime -->
            <td>
                <form action="%s/deleteentry" method="post" enctype=application/x-www-form-urlencoded>
                <input type="hidden" name="tag" value="%s">
                <input type="submit" style="background-color: red" value="Delete"></form>
        </tr>''' %
(str(jvalue['geometry']['coordinates'][1]),str(jvalue['geometry']['coordinates'][0]),str(e.name),
                    str(imageform),
                    req.script_name, str(urllib.quote(e.name)),
                    str(e['value']),
                    str(time.asctime(time.gmtime(float(e['ctime'])))),
                    req.script_name, str(urllib.quote(e.name)))
    output = output + '</table>'
    status = '200 OK'
    response_headers = [('Content-Type', 'text/html'),
                        ('Content-Length', str(len(output)))]
    start_response(status, response_headers)
    return [output]

### application
# This is what is called by apache handler
```

```
def application(environ, start_response):
    req = Request(environ)

    caller = req.path_info
    #print >> sys.stderr, "Caller: " + caller
    # The URL's responding with the calls to be made
    options = {
        "/getvalue"    : getValue,
        "/storeavalue" : storeAValue,
        "/deleteentry" : deleteEntry,
        "/getimage"    : getImage,
        "/getids"      : getIds,
        "/getkml"      : getKml,
        "/getall"      : getAll,
        "/environ"     : myEnv,
        "/edit"        : editValue
    }

    if options.has_key(caller):
        # dynamically calle pre-defined function
        #return options[caller](environ, start_response)
        return options[caller](req, start_response)
    else:
        #return mainPage(environ, start_response)
        return mainPage(req, start_response)
```

KML Template

/var/www/html/templates/kml.tmpl

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
  <Document>
    <Style id="animalwarning">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_animalwarning.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="badroadsurface">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_badroadsurface.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="blackspot">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_blackspot.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="dangerouscrossing">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_dangerouscrossing.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="danger">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_danger.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="deletehazard">
      <IconStyle>
        <Icon>
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="explosiondanger">
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        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_explosiondanger.png</href>
        </Icon>
      </IconStyle>
    </Style>
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      </IconStyle>
    </Style>
    <Style id="grounding">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_grounding.png</href>
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      </IconStyle>
    </Style>
```

```
    <Style id="hilltop">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_hilltop.png</href>
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      </IconStyle>
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    <Style id="landslide">
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          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_landslide.png</href>
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      </IconStyle>
    </Style>
    <Style id="narrowroad">
      <IconStyle>
        <Icon>
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        </Icon>
      </IconStyle>
    </Style>
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        <Icon>
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="pedestrians">
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        </Icon>
      </IconStyle>
    </Style>
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="roundabout">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_roundabout.png</href>
        </Icon>
      </IconStyle>
    </Style>
    <Style id="sanddunes">
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        <Icon>
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        </Icon>
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    </Style>
    <Style id="sharpbend">
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="slippery">
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      </IconStyle>
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        </Icon>
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="traincrossing">
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="tunnel">
      <IconStyle>
```

```
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          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_tunnel.png</href>
        </Icon>
      </IconStyle>
    </Style>
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        </Icon>
      </IconStyle>
    </Style>
    <Style id="windingroad">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/ic_windingroad.png</href>
        </Icon>
      </IconStyle>
    </Style>
$hazards
  </Document>
</kml>
```
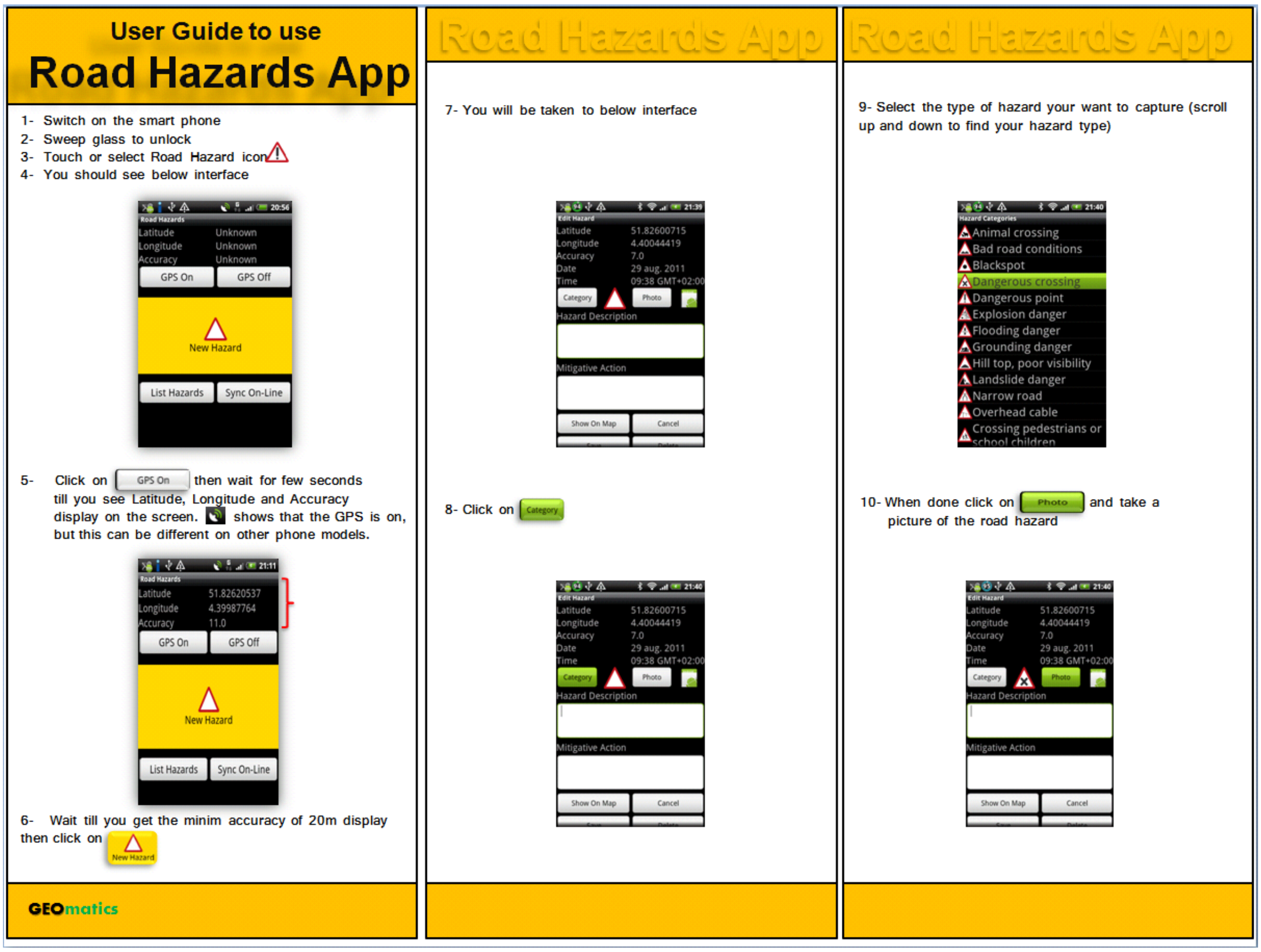

gen_templ.sh

```
#!/bin/bash

# Copyright (C) 2011 Jorrit Jorritsma (jsj@xs4all.nl)
#
# This is free software; you can redistribute and/or modify it under
# the terms of the GNU General Public License as published
# by the Free Software Foundation.
# See the http://www.gnu.org/licenses/gpl-3.0.html for the license.

echo "<?xml version=\"1.0\" encoding=\"UTF-8\"?>
<kml xmlns=\"http://www.opengis.net/kml/2.2\">
  <Document>"

for i in `ls ../markers/` ; do
  stylename=`echo $i | sed 's/.png$//' | sed 's/^ic_//'`

  echo "    <Style id=\"$stylename\">
      <IconStyle>
        <Icon>
          <href>https://s3-eu-west-1.amazonaws.com/roadhazards/markers/$i</href>
        </Icon>
      </IconStyle>
    </Style>"
done
echo '$hazards'
echo "  </Document>
</kml>"
```

Appendix C Road Hazard App Instructions

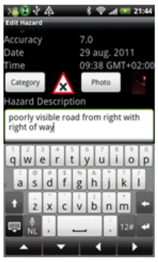


Road Hazards App

11- Back in the hazard entry interface type (Using touch key board):

- Hazard Description
- Mitigative action

The keyboard appears when a text field is touched Use [keyboard icon] to hide the keyboard again.

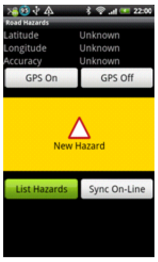


12- After typing you need to save your record and to do so click on [Save]

GEOmatics

Road Hazards App

13- Before proceeding to the next Road Hazard check if your recorded road hazard has been saved by click on [List Hazards]



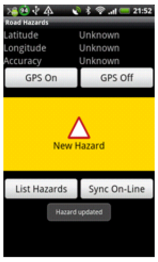
You should see your recorded details as below. Selecting it brings you back to the hazard input screen where corrections can be made if needed.

Road Hazards App

At the end of the day you will need to synchronize your new records to the database. To do so you need GSM coverage or have WIFI connectivity (preferred).

14- Click on [Sync On-Line]

You should see the message "All hazards uploaded successfully"



DONE

Appendix D Road Hazard Pilot survey - Printed

Welcome to this survey about the Road Hazard collection smartphone application and its collected data.

This survey can also be done online at the following location:
http://jorritsma.cc/~jorrit/survey/general1.survey

If you prefer to fill it in on paper, please print out this document in colour, fill it in and send it to (preferably with internal mail):

Shell International Exploration and Production BV
Jorrit Jorritsma
RIJKES UR 3.44C

Postbus 60
2280 AB Rijswijk
Netherlands

This survey is anonymous and all information entered will be treaded confidentially.

First some general questions about yourself and your involvement with the pilot project are asked. The choices made on the involvement will present you with the relevant questions.

Yourself

What is your age?

[ ]

1. What is your primary location (2 letter country code)?

[ ]

Your involvement

2. What is your relation to this pilot project? (check all that apply).

☐ Driver

☐ Surveyor

☐ Journey Management

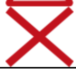
☐ Geomatics

☐ Other

[ ]

Hazard symbology and classification

3. Which of the following classes are not useful and should be removed?

Category	Symbol	Remove
Animal crossing		☐
Bad road conditions		☐
Blackspot		☐
Dangerous crossing		☐
Dangerous point		☐
Explosion danger		☐
Flooding danger		☐
Grounding danger		☐
Hill top, poor visibility		☐
Landslide danger		☐
Narrow road		☐
Overhead cable		☐
Crossing pedestrians or school children		☐
Poor visibility possible		☐
Road works		☐
Roundabout		☐
Sand dunes		☐
Sharp bend		☐
Road can be slippery		☐
Soft verges		☐
Steep hill		☐
Train crossing		☐
Tunnel		☐
No U-turn beyond this point		☐
Winding road		☐
Flag hazard for removal		☐

Hazard symbology and classification (continued)

4. Which symbols are not clear and should be graphically improved?

Category	Symbol	Improve
Animal crossing		☐
Bad road conditions		☐
Blackspot		☐
Dangerous crossing		☐
Dangerous point		☐
Explosion danger		☐
Flooding danger		☐
Grounding danger		☐
Hill top, poor visibility		☐
Landslide danger		☐
Narrow road		☐
Overhead cable		☐
Crossing pedestrians or school children		☐
Poor visibility possible		☐
Road works		☐
Roundabout		☐
Sand dunes		☐
Sharp bend		☐
Road can be slippery		☐
Soft verges		☐
Steep hill		☐
Train crossing		☐
Tunnel		☐
No U-turn beyond this point		☐
Winding road		☐
Flag hazard for removal		☐

Hazard symbology and classification (continued)

5. Are there any missing hazard symbols / classes? (optional)

6. Please leave any remarks with regards to the warning symbology and classes (optional)

7. The Road Hazard application now only contains warning type hazards; do you think informational classes should also be included (e.g. hospital, checkpoint, parking place, etc.)?

   ☐ Yes

   ☐ No

If you answered the last question with **no**, you can **continue with question 12**

Hazard symbology and classification (continued)

8. Which of the following informational categories should be included?

Category	Symbol	Include
Airport		☐
Ambulance station		☐
Check point		☐
Cafe		☐
Fire station		☐
Heliport		☐
Hospital		☐
Landmark		☐
No GSM signal		☐
Overnight accommodation		☐
Overnight accommodation and restaurant		☐
Parking place		☐
Petrol station		☐
Police station		☐
Non hospital medical facility		☐
Restaurant		☐
SOS communication point		☐
Town / habitat		☐

Hazard symbology and classification (continued)

9. Are there any informational classes missing? (optional)

10. Please leave any remarks with regards to the informational symbology and classes (optional).

Hazard symbology and classification (continued)

---

11. The Road Hazard application now only contains warning type hazards; do you think limit classes should also be included (e.g. maximum speed, maximum weight, etc.)?

   ☐ Yes

   ☐ No

If you answered the last question with **no**, you can continue **with question 16**

---

12. Which of the following limit categories should be included?

Category	Symbol	Include
Maximum height		☐
Maximum speed		☐
Maximum weight		☐
Maximum width		☐
No entry		☐
No entry from this side		☐
No entry for trucks		☐
No overtaking		☐
No overtaking by trucks		☐

13. Are there any limit classes missing? (optional)

Hazard symbology and classification (continued)

Please leave any remarks with regards to the limits symbology and classes (optional)

Road hazard smartphone app

14. Have you used the smartphone with the Road Hazard application to capture hazards?
    - ☐ Yes
    - ☐ No

If you answered the last question with **no**, you can continue **with question 26**

15. Had you already used a smartphone with touch screen before this pilot?
    - ☐ Yes
    - ☐ No

    Do you have a smartphone with touch screen yourself?
    - ☐ Yes
    - ☐ No
16. How do you consider your level of English?
    - ☐ Fluent
    - ☐ Good
    - ☐ Reasonable
    - ☐ Not so good
17. Are you used to a keyboard with Latin characters (US American)?
    - ☐ Yes this is my normal kind of keyboard
    - ☐ Yes but normally I use another kind of keyboard
    - ☐ No but I can manage
    - ☐ No I need help to enter text

Road hazard smartphone app (continued)

18. Did you find it easy to enter text in the free form text fields?
    - ☐ I had no problems
    - ☐ Difficult at first, later OK
    - ☐ Too complicated for me
19. What do you think of the usability of the Road Hazard application?
    - ☐ Very easy to use
    - ☐ Not so easy at first but after some use that improved
    - ☐ Unusable

    On average how long did it take for the phone to get a GPS signal?
    - ☐ Less than a minute
    - ☐ up to 3 minutes
    - ☐ more than 3 minutes
20. How many hazards did you capture with the Road Hazard application?
    - ☐ 1 to 5
    - ☐ 6 to 10
    - ☐ More than 10
21. Would you prefer this Road Hazard application over the old way of capturing hazards?
    - ☐ Yes this is certainly an improvement
    - ☐ With some improvements this is the way forward
    - ☐ No this does not work for me

Thematic - Hazard description and mitigating action

22. Do you think the description field provides useful information for journey management?

    ☐ Yes

    ☐ No

23. Should the description field be mandatory?

    ☐ Yes

    ☐ No

24. Do you think the mitigating action field provides useful information for journey management?

    ☐ Yes

    ☐ No

25. Would it be better to make mitigating action categories tailored to the hazard class it belongs to so they can be chosen from a pick list?
    Two examples:
    If a "sharp bend" is chosen as hazard class the mitigating action would be limited to options like:
    - Slow down to 15 km an hour
    - Slow down to 30 km an hour
    - Slow down to 50 km an hour

But if a "steep hill" is chosen the mitigating action would be limited to options like:

- Take this hill in second gear maximum
- Take this hill in third gear maximum

(Chose one)

☐ Yes this should be implemented

☐ No the free form text field should be used

☐ A pick list should be implemented but an optional text field should be there as well

26. Should providing a mitigating action be mandatory?

    ☐ Yes

    ☐ No

Accuracy requirements

27. What accuracy is needed to capture road hazards?
    - ☐ Better than 1 meter
    - ☐ Better than 5 meter
    - ☐ Better than 10 meter
28. What is your reason for choosing the above accuracy?

29. If you have any additional comments on this pilot, you can leave them in the box below.

You have come to the end of this survey, thank you for filling it in and sending the results to me.

Best Regards,

Jorrit Jorritsma

Appendix E Road Hazard Pilot Survey - Online

general1.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Survey on Road Acquisition Pilot - General">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h1&gt;Road hazard collection using a smart phone application survey&lt;/h1&gt;
&lt;p&gt;&lt;i&gt;&lt;b&gt;
Welcome to this survey about the Road Hazard collection smart phone application and its collected data.
&lt;br /&gt;

This survey can also be conducted on paper, if you wish to do so you can download it
&lt;a href="http://jorritsma.cc/~jorrit/survey/survey.pdf"&gt;here&lt;/a&gt;
&lt;br /&gt;
This survey is anonymous and all information entered will be treaded confientially.
&lt;br /&gt;
First some general questions about yourself and your involvement with the pilot project are asked. The choices
made on the involvement will present you with the relevant questions.
&lt;/b&gt;&lt;/i&gt;&lt;br /&gt;&lt;br /&gt;&lt;/p&gt;
&lt;hr /&gt;

&lt;h2&gt;Some questions about yourself&lt;/h2&gt;

  </CUSTOM>

  <TEXT NAME="q01" CAPTION="What is your age?" NUMERICAL="yes" MINVAL="10" MAXVAL="99" MUSTANSWER="yes" MAXLEN="2"
/>

  <TEXT NAME="q02" CAPTION="What is your primary location? (2 character country code)" MUSTANSWER="yes" MAXLEN="2"
/>

  <CUSTOM ESCAPED="yes">
  &lt;hr /&gt;
&lt;p&gt;&lt;i&gt;&lt;b&gt;
Your involvement
&lt;/b&gt;&lt;/i&gt;&lt;br /&gt;&lt;br /&gt;&lt;/p&gt;

  </CUSTOM>

  <CHOICE NAME="q03" CAPTION="What is your relationship to this project? (check all that apply)" MULTI="yes"
MUSTANSWER="yes" OTHERFIELD="Other">
    <CHOICEELEMENT CAPTION="Driver" VALUE="1" />
    <CHOICEELEMENT CAPTION="Surveyor" VALUE="2" />
    <CHOICEELEMENT CAPTION="Journey Management" VALUE="3" />
    <CHOICEELEMENT CAPTION="Geomatics" VALUE="4" />
  </CHOICE>

  <ROUTE CONTINUE="symbology1.survey" />
</SURVEY>
```

symbology1.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Hazard symbology and classification">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes"
VARIABLES="q04_0,q04_1,q04_2,q04_3,q04_4,q04_5,q04_6,q04_7,q04_8,q04_9,q04_10,q04_11,q04_12,q04_13,q04_14,q04_15,q
04_16,q04_17,q04_18,q04_19,q04_20,q04_21,q04_22,q04_23,q04_24,q04_25">
  &lt;h2&gt;Hazard symbology and classification&lt;/h2&gt;


&lt;div class="component MATRIX"&gt;
    &lt;div class="caption captionMATRIX"&gt;
        Which of the following classes are not useful and should be removed?
    &lt;/div&gt;
    &lt;table class="element elementMATRIX" border="0" cellspacing="2" cellpadding="2"&gt;
        &lt;tr&gt;&lt;th
align="left"&gt;Category&lt;/th&gt;&lt;th&gt;Symbol&lt;/th&gt;&lt;th&gt;Remove&lt;/th&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Animal crossing&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/AnimalWarning.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_0" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Bad road conditions&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/BadRoadSurface.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_1" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Blackspot&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/BlackSpot.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_2"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
```

```
        &lt;tr&gt;&lt;td&gt;Dangerous crossing&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/DangerousCrossing.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_3" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Dangerous point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Danger.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_4"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Explosion danger&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/ExplosionDanger.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_5" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
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SRC="images/Warnings/Flood.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_6"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
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SRC="images/Warnings/Grounding.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_7"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Hill top, poor visibility&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/HillTop.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_8"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Landslide danger&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Landslide.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_9"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Narrow road&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/NarrowRoad.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_10" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Overhead cable&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/OverheadCable.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_11" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Crossing pedestrians or school children&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Pedestrians.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_12" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Poor visibility possible&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/ReducedVisibility.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_13" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Road works&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/RoadWorks.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_14"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Roundabout&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Roundabout.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_15" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Sand dunes&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SandDunes.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_16"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Sharp bend&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SharpBend.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_17"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Road can be slippery&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Slippery.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_18"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Soft verges&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SoftVerges.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_19" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Steep hill&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SteepHill.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_20"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Train crossing&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/TrainCrossing.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_21" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Tunnel&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Tunnel.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q04_22"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No U-turn beyond this point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/UturnDanger.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_23" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Winding road&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/WindingRoad.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_24" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Flag hazard for removal&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/deletehazard.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q04_25" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
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&lt;/div&gt;
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  </CUSTOM>

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align="left"&gt;Category&lt;/th&gt;&lt;th&gt;Symbol&lt;/th&gt;&lt;th&gt;Improve&lt;/th&gt;&lt;/tr&gt;
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name="q05_0" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Bad road conditions&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/BadRoadSurface.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_1" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Blackspot&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/BlackSpot.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_2"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Dangerous crossing&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/DangerousCrossing.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_3" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Dangerous point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Danger.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_4"
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        &lt;tr&gt;&lt;td&gt;Explosion danger&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
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name="q05_5" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Flooding danger&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Flood.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_6"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
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SRC="images/Warnings/Grounding.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_7"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Hill top, poor visibility&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/HillTop.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_8"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Landslide danger&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Landslide.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_9"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Narrow road&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/NarrowRoad.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_10" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Overhead cable&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/OverheadCable.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_11" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Crossing pedestrians or school children&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Pedestrians.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_12" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Poor visibility possible&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/ReducedVisibility.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_13" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Road works&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/RoadWorks.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_14"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Roundabout&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Roundabout.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_15" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Sand dunes&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SandDunes.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_16"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Sharp bend&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SharpBend.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_17"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Road can be slippery&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Slippery.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_18"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Soft verges&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SoftVerges.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_19" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Steep hill&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/SteepHill.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_20"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Train crossing&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/TrainCrossing.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_21" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Tunnel&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/Tunnel.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_22"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No U-turn beyond this point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/UturnDanger.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_23" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Winding road&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/WindingRoad.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_24" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Flag hazard for removal&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Warnings/deletehazard.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_25" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
    &lt;/table&gt;
&lt;/div&gt;
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  </CUSTOM>

  <MEMO NAME="q06" CAPTION="Are there any missing hazard symbols / classes? (optional)" />

  <MEMO NAME="q07" CAPTION="Please leave and remarks with regards to the waring symbology and classes (optional)"
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  <ROUTE CONTINUE="symbology2.survey" />
</SURVEY>
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symbology2.survey

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<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Hazard symbology and classification (continued)">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h2&gt;Hazard symbology and classification (continued)&lt;/h2&gt;
  </CUSTOM>

  <CHOICE NAME="q08" CAPTION="The road hazard application now only contains warning type hazards; do you think
informational classes should also be included? (e.g. hospital, checkpoint, parking place, etc.)?"
MUSTANSWER="yes">
```

```
    <CHOICEELEMENT CAPTION="Yes" VALUE="0" />
    <CHOICEELEMENT CAPTION="No" VALUE="1" />
  </CHOICE>

  <CASEROUTE DEFAULT="symbology3.survey" SWITCH="q08">
    <CASE VALUE="1" CONTINUE="symbology4.survey" />
  </CASEROUTE>
</SURVEY>
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symbology3.survey

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<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Hazard symbology and classification (continued)">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes"
VARIABLES="q09_0,q09_1,q09_2,q09_3,q09_4,q09_5,q09_6,q09_7,q09_8,q09_9,q09_10,q09_11,q09_12,q09_13,q09_14,q09_15,q
09_16,q09_17">
  &lt;h2&gt;Hazard symbology and classification (continued)&lt;/h2&gt;

&lt;div class="component MATRIX"&gt;
    &lt;div class="caption captionMATRIX"&gt;
        Which of the following informational classes should be included?
    &lt;/div&gt;
    &lt;table class="element elementMATRIX" border="0" cellspacing="2" cellpadding="2"&gt;
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align="left"&gt;Category&lt;/th&gt;&lt;th&gt;Symbol&lt;/th&gt;&lt;th&gt;Include&lt;/th&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Airport&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/AirPort.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_0"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Ambulance station&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Ambulance.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_1" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Check point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/CheckPoint.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_2" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Cafe&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Coffee.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_3"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Fire station&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Firetruck.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_4" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Heli port&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/HeliPort.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_5" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Hospital&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Hospital.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_6" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Landmark&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Landmark.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_7" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No GSM signal&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/NoGSM.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_8"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Overnight accommodation&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/OvernightRest.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_9" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Overnight accommodation and restaurant&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/OvernightRest_Restaurant.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input
type="checkbox" name="q05_10" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Parking place&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Parking.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_11" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Petrol station&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/PetrolStation.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_12" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Police station&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/PoliceStation.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_13" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Non hospital medical facility&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/RedCrossRedHalfMoon.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_14" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Restaurant&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Restaurant.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q05_15" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;SOS communication point&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/SOS.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_16"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Town / habitat&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Information/Town.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q05_17"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
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&lt;/div&gt;
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  </CUSTOM>

  <MEMO NAME="q10" CAPTION="Are there any missing information symbols / classes? (optional)" />
```

```
  <MEMO NAME="q11" CAPTION="Please leave any remarks with regards to the informational symbology and classes
(optional)." />

  <ROUTE CONTINUE="symbology4.survey" />
</SURVEY>
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symbology4.survey

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<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
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"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Hazard symbology and classification (continued)">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h2&gt;Hazard symbology and classification (continued)&lt;/h2&gt;
  </CUSTOM>

  <CHOICE NAME="q12" CAPTION="The road hazard application now only contains warning type hazars; do you think
limit classes should also be included (e.g. maximum speed, maximum weight, etc.)?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes" VALUE="0" />
    <CHOICEELEMENT CAPTION="No" VALUE="1" />
  </CHOICE>

  <CASEROUTE DEFAULT="symbology5.survey" SWITCH="q12">
    <CASE VALUE="1" CONTINUE="app1.survey" />
  </CASEROUTE>
</SURVEY>
```

symbology5.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Hazard symbology and classification (continued)">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes" VARIABLES="q13_0,q13_1,q13_2,q13_3,q13_4,q13_5,q13_6,q13_7,q13_8">
  &lt;h2&gt;Hazard symbology and classification (continued)&lt;/h2&gt;


&lt;div class="component MATRIX"&gt;
    &lt;div class="caption captionMATRIX"&gt;
        Which of the following limit classes should be included?
    &lt;/div&gt;
    &lt;table class="element elementMATRIX" border="0" cellspacing="2" cellpadding="2"&gt;
        &lt;tr&gt;&lt;th
align="left"&gt;Category&lt;/th&gt;&lt;th&gt;Symbol&lt;/th&gt;&lt;th&gt;Include&lt;/th&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Maximum height&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/MaxHeight20.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_0"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Maximum speed&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/MaxSpeed50.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_1"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Maximum weight&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/MaxWeight10.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_2"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;Maximum width&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/MaxWidth25.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_3"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No entry&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/NoEntry.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_4"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No entry from this side&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/NoEntryThisWay.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q13_5" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No entry for trucks&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/NoEntryTrucks.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q13_6" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No overtaking&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/NoOvertaking.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox" name="q13_7"
value=1&gt;&lt;/td&gt;&lt;/tr&gt;
        &lt;tr&gt;&lt;td&gt;No overtaking by trucks&lt;/td&gt;&lt;td align="center"&gt;&lt;IMG
SRC="images/Limits/NoOvertakingTruck.png"&gt;&lt;/td&gt;&lt;td align="center"&gt;&lt;input type="checkbox"
name="q13_8" value=1&gt;&lt;/td&gt;&lt;/tr&gt;
    &lt;/table&gt;
&lt;/div&gt;
&lt;div class="componentspc"&gt;&lt;/div&gt;

  </CUSTOM>

  <MEMO NAME="q14" CAPTION="Are there any limit classes missing? (optional)" />

  <MEMO NAME="q15" CAPTION="Please leave any remarks with regards to the limits symbology and classes (optional)."
/>
```

```
  <ROUTE CONTINUE="app1.survey" />
</SURVEY>
```

app1.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Road Hazard Android application">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h2&gt;Road Hazard Android application&lt;/h2&gt;
  </CUSTOM>

  <CHOICE NAME="q16" CAPTION="Have you used the smart phone with the road hazard application to capture hazards?"
MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes" VALUE="0" />
    <CHOICEELEMENT CAPTION="No" VALUE="1" />
  </CHOICE>

  <CASEROUTE DEFAULT="app2.survey" SWITCH="q16">
    <CASE VALUE="1" CONTINUE="thematic1.survey" />
  </CASEROUTE>
</SURVEY>
```

app2.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Road Hazard Android application (continued)">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h2&gt;Road Hazard Android application (continued)&lt;/h2&gt;


  </CUSTOM>

  <CHOICE NAME="q17" CAPTION="Had you already used a smart phone with touch screen before this pilot?"
MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes" VALUE="0" />
    <CHOICEELEMENT CAPTION="No" VALUE="1" />
  </CHOICE>

  <CHOICE NAME="q18" CAPTION="Do you have a smart phone with touch screen yourself?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes" VALUE="0" />
    <CHOICEELEMENT CAPTION="No" VALUE="1" />
  </CHOICE>

  <CHOICE NAME="q19" CAPTION="How good do you consider your english?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Fluent" VALUE="1" />
    <CHOICEELEMENT CAPTION="Good" VALUE="2" />
    <CHOICEELEMENT CAPTION="Reasonable" VALUE="3" />
    <CHOICEELEMENT CAPTION="Not so good" VALUE="4" />
  </CHOICE>

  <CHOICE NAME="q20" CAPTION="Are you used to keyboard with Latin characters (US American)?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes this is my normal kind of keyboard" VALUE="1" />
    <CHOICEELEMENT CAPTION="Yes but I normally use another kind of keyboard" VALUE="2" />
    <CHOICEELEMENT CAPTION="No but I can manage" VALUE="3" />
    <CHOICEELEMENT CAPTION="No I need help to enter text" VALUE="4" />
  </CHOICE>

  <CHOICE NAME="q21" CAPTION="Did you find it easey to enter text in the free form text fields?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="I had no problems" VALUE="1" />
    <CHOICEELEMENT CAPTION="Difficult at first, later ok" VALUE="2" />
    <CHOICEELEMENT CAPTION="Too complicated for me" VALUE="3" />
  </CHOICE>

  <CHOICE NAME="q22" CAPTION="What do you think of the usability of the road hazard application?"
MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Very easy to use" VALUE="1" />
    <CHOICEELEMENT CAPTION="Not so easy at first but after some use that improved" VALUE="2" />
    <CHOICEELEMENT CAPTION="Unusable" VALUE="3" />
  </CHOICE>

  <CHOICE NAME="q23" CAPTION="On average how long did it take for the phone to get a GPS signal?"
MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Less than a minute" VALUE="1" />
    <CHOICEELEMENT CAPTION="Up to 3 minutes" VALUE="2" />
    <CHOICEELEMENT CAPTION="More than 3 minutes" VALUE="3" />
  </CHOICE>
```

```
  <CHOICE NAME="q24" CAPTION="How many hazards did you capture with the road hazard application?"
MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="1 to 5" VALUE="1" />
    <CHOICEELEMENT CAPTION="6 to 10" VALUE="2" />
    <CHOICEELEMENT CAPTION="More than 10" VALUE="3" />
  </CHOICE>

  <CHOICE NAME="q25" CAPTION="Would you prefer this Road Hazard application over the old way of capturing
hazards?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Yes this is certainly an improvement" VALUE="1" />
    <CHOICEELEMENT CAPTION="With some improvements this is certainly the way forward" VALUE="2" />
    <CHOICEELEMENT CAPTION="No this does not work for me" VALUE="3" />
  </CHOICE>

  <ROUTE CONTINUE="thematic1.survey" />
</SURVEY>
```

Accuracy1.survey

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE SURVEY PUBLIC "-//Joel Palmius//DTD Survey markup definition//EN"
"http://www.modsurvey.org/mod_survey/survey-3.2.5.dtd">
<SURVEY TITLE="Acquisition Requirements">
  <SECURITY>
    <ANSWER LEVEL="open" />
    <DATA LEVEL="open" />
    <FLUSH LEVEL="closed" />
    <SOURCE LEVEL="closed" />
    <DEBUG LEVEL="closed" />
  </SECURITY>

  <CUSTOM ESCAPED="yes">
  &lt;h2&gt;Accuracy requirements&lt;/h2&gt;
  </CUSTOM>

  <CHOICE NAME="q31" CAPTION="What accuracy is needed to capture road hazards?" MUSTANSWER="yes">
    <CHOICEELEMENT CAPTION="Better than 1 meter" VALUE="1" />
    <CHOICEELEMENT CAPTION="Better than 5 meter" VALUE="2" />
    <CHOICEELEMENT CAPTION="Better than 10 m" VALUE="3" />
  </CHOICE>

  <MEMO NAME="q32" CAPTION="What is your reason for choosing the above accuracy?" />

  <MEMO NAME="q33" CAPTION="If you have any additional comments on this pilot, you can leave them in the box
below." />

  <CUSTOM ESCAPED="yes">
  You have come to the end of this survey, please press submit to save your entries.&lt;br/&gt;
&lt;br/&gt;
Thanks for time filling it in!&lt;br/&gt;
&lt;br/&gt;
Best Regards,&lt;br/&gt;
&lt;br/&gt;
Jorrit Jorritsma
  </CUSTOM>

  <SEQUENCE SELFINCLUDE="yes">
    <FILE FILENAME="general1.survey" />
    <FILE FILENAME="symbology1.survey" />
    <FILE FILENAME="symbology2.survey" />
    <FILE FILENAME="symbology3.survey" />
    <FILE FILENAME="symbology4.survey" />
    <FILE FILENAME="symbology5.survey" />
    <FILE FILENAME="app1.survey" />
    <FILE FILENAME="app2.survey" />
    <FILE FILENAME="thematic1.survey" />
    <FILE FILENAME="Accuracy1.survey" />
  </SEQUENCE>
</SURVEY>
```

Appendix F Raw survey results

srvkey	q01	q02	q03	q06	q07	q08
20110922_143051_16514	32	AE	4	Pipeline Crossing Cable Crossing Overhead Road Sign Overhead Bridge Bridge Populated Area Culvert Bad Road Condition Police Check Point		0
20110922_145442_16516	35	AE	4	Other danger, for anything else There are always "site" specific items to add (and it is impossible to cover anything.	How do these symbols relate to the Shell standard legengd? Are they the same integrated or non-existing?	0
20110922_145922_16516	32	AE	4	Pipeline Crossing, Cable Crossing,		0
20110924_074525_5497	40	OM	4		In PDO we would love to see the possibility of limiting the number of symbols. With each symbol you have to think that in the end it will be translated to a message that will be read out loud if you are driving there an in car navigation unit.	1
20110925_133939_18468	62	NL	777,!Logistics	Overhead pipelines(gas, oil, water. chemicals).Bridge crossing, load limits in force Conduit pipe crossing Axle load limits in force Police check point National border customs /immigration check point Hospital Shopping area Prone to flash f	Add in good +signs Petrol stations Safe parking overnight Safe parking day time Clean toilets Resturent /coffee shop Clinic Shell bases	0
20110928_101328_6279	51	AE	2,4	Jorrit, the symbols need to be selectable, so in the Iraq case there is only the need for about 10 symbols i.e. we don't have steep hills here		0
20111007_110235_29039	57	NL	777,!Group HSSE	Dust is afrequently occuring cause of poor visibility, should we have a separate dust sign?	I think it would be best to copy international (European)signs where available (if notr done already).	1
20111011_055342_23298	32	OM	4	Entering suburban area, watch your speed		1
20111011_062904_23303	46	IQ	4	culvert, bridge (with weight option), check point		0
20111011_081003_486	64	NL	3			0
20111011_083940_23302	46	NL	777,!Logistics Manager	nil	nil	0
20111011_084057_23303	31	NL	4	I'm sure there are, but its pretty comprehensive coverage at the moment.		0
20111017_160404_18005	41	NL	4			1
20111017_160235_18009	46	NL	4	No comments	N/A	0
20111017_190226_18005	54	NL	4	Would be good if a sub-set of symbols could be downloaded per country (removeing those that are no relevant)	Suggest to relate a hazard warning (voice warning) to symblo groups - ie slow down - caution ...	0
20111018_065338_10679	30	JO	777,!Geologist	Stream / Wadi Crossing (for offroad driving)	On a large scale map they may be difficult to differentiate.	1
20111018_140920_18005	38	OM	4	The symbol for the flooding class should be as Flooding/Wadi crossing And a symbol of Graded road a head to be added		1
20111019_095401_18012	59	NL	777,!Global Log. Disc. Lead		Suggest to limit the number of warnings to avoid overkill.	1

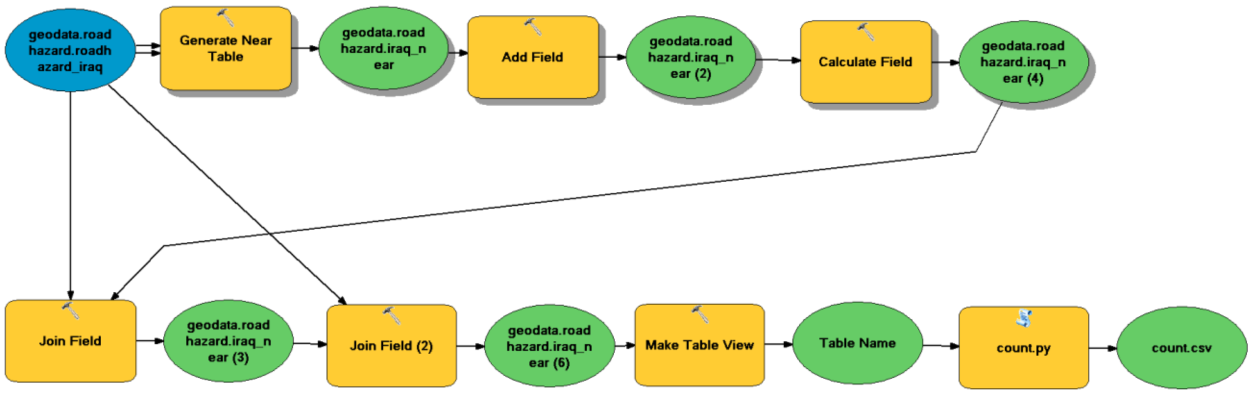
srvkey	q10	q11	q12	q13_0	q13_1	q13_2	q13_3	q13_4	q13_5	q13_6	q13_7	q13_8
20110922_143051_16514			0	1	1	1	1	-1	-1	-1	-1	-1
20110922_145442_16516	no		0	-1	-1	1	1	-1	1	-1	-1	-1
20110922_145922_16516			0	1	1	1	1	1	1	1	-1	-1
20110924_074525_5497	999	999	1	999	999	999	999	999	999	999	999	999
20110925_133939_18468	ATM machines		0	1	1	1	1	1	1	1	1	1
20110928_101328_6279			0	1	1	1	1	1	1	1	1	1
20111007_110235_29039	999	999	0	1	1	1	1	1	1	1	1	1
20111011_055342_23298	999	999	0	1	-1	-1	-1	-1	-1	1	-1	-1
20111011_062904_23303			0	1	1	1	1	-1	-1	-1	1	-1
20111011_081003_486			0	1	1	1	1	1	1	1	1	1
20111011_083940_23302	nil	nil	0	1	1	1	1	1	1	1	1	1
20111011_084057_23303	The app should capture hazards intrinsiclly, it shouldn't be the sole purpose.		0	1	1	1	1	-1	-1	-1	-1	-1
20111017_160404_18005	999	999	0	1	1	1	1	-1	-1	-1	-1	-1
20111017_160235_18009	No comments	N/A	0	1	1	1	1	1	1	1	1	1
20111017_190226_18005	Rest point (pre-designated intermediate stop on long journeys)	when a generic design is made many other applications are possible: eg Pipelines, Valve, Cathodic Protection, T-piece, Cable crossing, etc Geology, Outcrop types	1	999	999	999	999	999	999	999	999	999
20111018_065338_10679	999	999	1	999	999	999	999	999	999	999	999	999
20111018_140920_18005	999	999	1	999	999	999	999	999	999	999	999	999
20111019_095401_18012	999	999	0	-1	1	-1	-1	-1	-1	-1	-1	-1

srvkey	q14	q15	q16	q17	q18	q19	q20	q21	q22
20110922_143051_16514			1	999	999	999	999	999	999
20110922_145442_16516			0	1	0	1	1	2	2
20110922_145922_16516			0	0	1	1	1	1	2
20110924_074525_5497	999	999	1	999	999	999	999	999	999
20110925_133939_18468	Axle weight limits		0	1	1	1	1	1	3
20110928_101328_6279			0	0	0	1	1	2	2
20111007_110235_29039	No entry for pedestrians		1	999	999	999	999	999	999
20111011_055342_23298			0	0	0	1	1	1	1
20111011_062904_23303			0	1	1	1	1	3	2
20111011_081003_486			0	0	0	2	1	1	1
20111011_083940_23302		Note that limits may be subjective : include functionality to add symbol that shows that data is to be confirmed i.e. "TBC" or similar	1	999	999	999	999	999	999
20111011_084057_23303			0	0	0	1	1	1	2
20111017_160404_18005			1	999	999	999	999	999	999
20111017_160235_18009	No comments	N/A	1	999	999	999	999	999	999
20111017_190226_18005	999	9							
20111018_065338_10679	999	999	1	999	999	999	999	999	999
20111018_140920_18005	999	999	0	1	1	2	1	1	1
20111019_095401_18012		Warnings shall be limited to real hazards that are not indicated by regular warning signs.	1	999	999	999	999	999	999

srvkey	q23	q24	q25	q26	q27	q28	q29	q30	q31	q32	q33
20110922_143051_16514	999	999	999	0	1	0	2	1	3	Captured coordinates will be verified against satellite imagery and other available data sets. Another thing is that 10m for moving vehicle is not long distance.	
20110922_145442_16516	2	1	2	0	0	0	2	1	3	when driving most important isto watch the road (rest should be used as indication	
20110922_145922_16516	2	1	2	0	1	1	1	1	3		Jorrit,It is a really good ap to begin with. If you 1. bring all the buttons in a single page instead of dropdown. 2. Remove the mandotory part of description 3. Fix the issue with GPS fix It will become a great ap Cheers Jaydeep
20110924_074525_5497	999	999	999	0	1	0	3	0	3	10 m is sufficient if you are approaching a road hazard while driving a car	well done, keep it up.
20110925_133939_18468	1	1	2	0	0	0	1	1	3	Warnings need to be given at larger distance to warn dirvers in time.	Filling in information on the tiny screen is very difficult in a moving vehicle, slowing down the acquisition work.
20110928_101328_6279	1	3	2	0	1	1	3	1	2	there may be several events in close proximity	
20111007_110235_29039	999	999	999	0	0	0	1	0	1	Please note that I dis not use the tool but still got these questions. I have given the top answer in each case. Please ignore.	
20111011_055342_23298	2	1	1	0	1	1	3	1	2	Because the navigation device will be set to give a warning at big distance (i.e. 50 or 100m)	the users at each OU should be given the freedom to submit their own hazards list and then can load it by choosing their area when they first install the app.
20111011_062904_23303	1	3	2	0	1	0	1	1	3	difficult to operate from moving vehicle with security restrictions	model of phone is important. screen difficult to read in bright sunlight. adding text is slow
20111011_081003_486	2	2	1	0	0	0	1	0	2	To be identified more than 200 meter ahead	
20111011_083940_23302	999	999	999	0	0	0	3	1	3	Scale of useage is not accurate to less than 10m	Good luck - will pick up a phone on the next trip
20111011_084057_23303	3	1	2	0	0	1	3	1	3	you need more than 10 m to respond to a hazard	very promising application.
20111017_160404_18005	999	999	999	0	0	0	3	1	2	reasonable distance for vehicle moving speed	
20111017_160235_18009	999	999	999	0	0	0	1	0	2	As we use accuracy of mobile phone GPS, it can't be more accurate than 5-10 meters.	Instruction prior passing the phone to users should be created on the small paper. Because people can use the phone for private tel calls. The roaming system is expensive!Also, each user should clean up all private pictures or sms messages before r
20111017_190226_18005	999	999	999	1	1	1	1	1	3	That's good enough considering normal speeds of travel	The combination of the App + Cloud and FME download is a great achievement. Gaining user acceptance and working out intenal processes will require additional efforts. Technology is proven. Thanks a lot for this great achievement
20111018_065338_10679	999	999	999	1	1	1	1	1	1	If the plan involves integrating this data into GPS devices (PND) then the this accuracy should be used as the 2ndary accuracy of the PND will multiply any positional erros.	
20111018_140920_18005	1	1	1	0	0	0	1	0	1	better acuracy better data plus we need to use this data on Garmin	
20111019_095401_18012	999	999	999	0	1	0	2	1	3		Also rely on the professionalism of the driver and avoid a too complex system which they will not use.

Appendix G Calculate Thematic Proximity

ArcGIS model:



Arcpy count script:

```
# ---------------------------------------------------------------------------
# count.py
# Created on: 2011-09-21 12:25:35.00000
#   (generated by ArcGIS/ModelBuilder)
# Description:
# ---------------------------------------------------------------------------

# Import arcpy module
import arcpy

InTable         = arcpy.GetParameterAsText(0)
ExportFile      = arcpy.GetParameterAsText(1)
DistanceColumn  = arcpy.GetParameterAsText(2)
InField         = arcpy.GetParameterAsText(3)
NearField       = arcpy.GetParameterAsText(4)
SearchDist      = arcpy.GetParameterAsText(5)
IntervalDist    = arcpy.GetParameterAsText(6)


# Local variables:
f = open(ExportFile, 'w')
counter = 0

# Process: Get Count

while counter <= int(SearchDist):
    OutTable = "t1%d" % (counter)
    #print OutTable

    SQL = "%s >= %d AND %s < %d and %s = %s" % (DistanceColumn, counter, DistanceColumn, counter + 
int(IntervalDist), InField, NearField)
    #print SQL
    arcpy.MakeTableView_management(InTable, OutTable, SQL, "", "")
    equalcount = arcpy.GetCount_management(OutTable)

    OutTable2 = "t2%d" % (counter)
    #print OutTable2
    SQL2 = "%s >= %d AND %s < %d and %s <> %s" % (DistanceColumn, counter, DistanceColumn, counter + 
int(IntervalDist), InField, NearField)
    #print SQL2
    arcpy.MakeTableView_management(InTable, OutTable2, SQL2, "", "")
    nonequalcount = arcpy.GetCount_management(OutTable2)
    #print equalcount, nonequalcount
    outstring = "%d,%d,%s,%s\n" % (counter, counter+10, equalcount, nonequalcount)
    f.write(outstring)
    counter += 10
```

Appendix H Positional Accuracy Samples

Samples					References			Disposition without corrections			Disposition with corrections		
Name	**Λ (WGS84)**	**Φ (WGS84)**	**h (m)**	**Accuracy (m)**	**Λ (ETRS89)**	**Φ (ETRS89)**	**h (m)**	**dx (m)**	**dy (m)**	**dz (m)**	**dx (m)**	**dy (m)**	**dz (m)**
080200b	6.922727153	53.28196155	31.7	46	6.922679306	53.28196464	39.24	-5.34	0.34	7.54	-5.12	0.42	7.55
020800c	6.920914818	53.28204675	38.8	44	6.920901361	53.28205417	39.60	-1.50	0.83	0.80	-1.30	0.89	0.81
080300a	6.783557972	52.66059996	60.6	46	6.783521111	52.66062856	52.66	-4.11	3.18	-7.94	-3.90	3.23	-7.94
080400a	6.88641767	53.3025807	39.3	24	6.886337167	53.30249347	40.06	-8.98	-9.71	0.76	-8.77	-9.64	0.77
081200a	6.938895257	53.17981	45	32	6.938883056	53.17980286	40.67	-1.36	-0.79	-4.33	-1.14	-0.74	-4.32
081600a	6.939087119	53.17972048	43.5	42	6.93906	53.17974789	40.31	-3.03	3.05	-3.19	-2.81	3.13	-3.18
rd370354	4.33914261	51.85502519	56.8	7	4.339124	51.85503347	49.08	-2.08	0.92	-7.72	-1.90	1.00	-7.72
rd370354	4.339110777	51.85505087	60.8	10	4.339124	51.85503347	49.08	1.48	-1.94	-11.72	1.66	-1.88	-11.72
rd370354	4.339142041	51.85503209	49.4	8	4.339124	51.85503347	49.08	-2.01	0.15	-0.32	-1.81	0.22	-0.32
rd370354	4.33912008	51.85502158	44.1	3	4.339124	51.85503347	49.08	0.44	1.32	4.98	0.64	1.40	4.98
rd370354	4.33915394	51.85505321	47.3	2	4.339124	51.85503347	49.08	-3.34	-2.20	1.78	-3.14	-2.12	1.78
rd370354	4.339111447	51.85506105	53	3	4.339124	51.85503347	49.08	1.40	-3.07	-3.92	1.60	-2.99	-3.92
rd370354	4.339100718	51.8550396	47	2	4.339124	51.85503347	49.08	2.60	-0.68	2.08	2.78	-0.61	2.08
rd370354	4.3391498	51.85501879	46	8	4.339124	51.85503347	49.08	-2.88	1.63	3.08	-2.68	1.71	3.08
rd370531	4.46689616	51.89821779	33.5	4	4.466935667	51.89829547	46.94	4.41	8.64	13.44	4.61	8.70	13.44
rd370531	4.466929184	51.89828007	45.7	10	4.466935667	51.89829547	46.94	0.72	1.71	1.24	0.92	1.78	1.24
rd370531	4.4669405	51.89829227	43.5	6	4.466935667	51.89829547	46.94	-0.54	0.36	3.44	-0.35	0.42	3.44
rd370531	4.46692249	51.89829474	60	2	4.466935667	51.89829547	46.94	1.47	0.08	-13.06	1.66	0.14	-13.06
rd370531	4.46695339	51.89829317	54.4	2	4.466935667	51.89829547	46.94	-1.98	0.26	-7.46	-1.78	0.32	-7.46
rd370531	4.466929436	51.89830899	48	2	4.466935667	51.89829547	46.94	0.70	-1.50	-1.06	0.89	-1.44	-1.06
rd370531	4.466966987	51.8982929	43	2	4.466935667	51.89829547	46.94	-3.49	0.29	3.94	-3.30	0.35	3.94
rd370531	4.46692852	51.8981946	54.7	7	4.466935667	51.89829547	46.94	0.80	11.22	-7.76	0.98	11.30	-7.76
rd370360	4.46988984	51.84781054	43.4	10	4.469898444	51.84780811	45.17	0.96	-0.27	1.77	1.14	-0.22	1.77
rd370360	4.469914651	51.84781926	45.1	10	4.469898444	51.84780811	45.17	-1.81	-1.24	0.07	-1.62	-1.18	0.07
rd370360	4.469906688	51.8477869	42	2	4.469898444	51.84780811	45.17	-0.92	2.36	3.17	-0.72	2.44	3.17
rd370360	4.469901323	51.8477869	42	2	4.469898444	51.84780811	45.17	-0.32	2.36	3.17	-0.13	2.44	3.17
rd370360	4.46993464	51.84775393	38.7	3	4.469898444	51.84780811	45.17	-4.04	6.03	6.47	-3.85	6.09	6.47
rd370360	4.46989541	51.84781247	45.5	2	4.469898444	51.84780811	45.17	0.34	-0.48	-0.33	0.52	-0.43	-0.33
rd370360	4.46989807	51.84783522	48.7	3	4.469898444	51.84780811	45.17	0.04	-3.02	-3.53	0.24	-2.94	-3.53
rd370360	4.46987036	51.84783403	44.9	3	4.469898444	51.84780811	45.17	3.13	-2.88	0.27	3.34	-2.81	0.27
rd430316	4.53307364	51.73215754	51	5	4.533098472	51.73211414	45.38	2.77	-4.83	-5.62	2.97	-4.77	-5.62
rd430316	4.53311427	51.7321553	50.2	5	4.533098472	51.73211414	45.38	-1.76	-4.58	-4.82	-1.56	-4.52	-4.82
rd430316	4.533107495	51.73211697	48	4	4.533098472	51.73211414	45.38	-1.01	-0.32	-2.62	-0.81	-0.26	-2.62
rd430316	4.533122834	51.73212552	50.8	8	4.533098472	51.73211414	45.38	-2.72	-1.27	-5.42	-2.52	-1.22	-5.42
rd430316	4.533115625	51.73210859	41	3	4.533098472	51.73211414	45.38	-1.91	0.62	4.38	-1.71	0.67	4.38
rd430316	4.53315465	51.73213047	43.6	4	4.533098472	51.73211414	45.38	-6.27	-1.82	1.78	-6.08	-1.74	1.78
rd430316	4.53308679	51.73210197	40.3	3	4.533098472	51.73211414	45.38	1.30	1.35	5.08	1.48	1.41	5.08
rd430316	4.533088803	51.73210859	41	2	4.533098472	51.73211414	45.38	1.08	0.62	4.38	1.26	0.67	4.38
rd370353	4.49597023	51.81946921	48.6	2	4.496026222	51.81949361	46.94	6.25	2.71	-1.66	6.43	2.77	-1.66
rd370353	4.49593214	51.8194685	51.1	3	4.496026222	51.81949361	46.94	10.49	2.79	-4.16	10.68	2.87	-4.16
rd370353	4.496032828	51.81949731	47.1	6	4.496026222	51.81949361	46.94	-0.74	-0.41	-0.16	-0.54	-0.35	-0.16
rd370353	4.496023944	51.81951483	52.9	4	4.496026222	51.81949361	46.94	0.25	-2.36	-5.96	0.45	-2.29	-5.96
rd370353	4.496031404	51.81944668	45	3	4.496026222	51.81949361	46.94	-0.58	5.22	1.94	-0.38	5.28	1.94
rd370353	4.496042132	51.81947351	44	3	4.496026222	51.81949361	46.94	-1.77	2.24	2.94	-1.59	2.31	2.94
rd370353	4.49596275	51.81945163	52.4	4	4.496026222	51.81949361	46.94	7.08	4.67	-5.46	7.27	4.72	-5.46
rd370353	4.49602611	51.81945753	44.6	4	4.496026222	51.81949361	46.94	0.01	4.01	2.34	0.21	4.07	2.34

Appendix I Geomatics Conference Poster