SEVENTH FRAMEWORK PROGRAMME

SECURITY, Collaborative Project

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Best Practice Enhancers for Security in Urban Regions

BESECURE

D3.3: GIS-based modelling in support of urban security enhancement

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EXECUTIVE SUMMARY

Objectives

This document presents the report on demonstrating the role of GIS in informing decisions relating to urban security policy

Description of the work

The report focuses on describing how GIS based spatial modelling is relevant and required in the delivery of effective and efficient decisions relating to urban security problems. It focuses on what GIS is, identifying the purpose of using GIS in urban security, understanding the role of visualisations and communicating information, as well as demonstrating the role of GIS in the BESECURE project for enhancing urban security.

Results and conclusions

The report details that GIS is an essential tool in the management, response and prediction of urban security related issues. However, it identifies that GIS must have a purpose and when applied, it must be relative to the problem and intervention that it is trying to support/inform.

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Table of Contents

1. Introduction

1.1. Purpose of Work Package 3

The objectives of work package 3 as described in the Description of Work (DoW) are:

1. to develop process based models and methodological frameworks that inform, structure and guide urban security enhancement
2. to create a user-friendly process model of urban security enhancement for stakeholders
3. to provide software tools which support the security enhancement process
4. to deliver a modular approach for enhancing the urban security process
5. to develop a bespoke decision support system that can be used to inform and enhance the security process, and that will make use of GIS views to visualize relevant information.

1.2. Purpose and Outline of Deliverable 3.3

The purpose of Deliverable 3.3 (D3.3) is to detail the role in which GIS and spatial modelling can play in the enhancement of urban security policy and how such approaches can enable more effective and efficient decisions to be made by urban security practitioners. It does so by first providing context to the role of GIS and spatial modelling in informing decisions and supporting policy, then helping the end user understand what GIS actually is (there is currently no agreed definition in the urban security field), it then discusses the role of visualisation in communicating information to the end user and finishes by presenting an example of how GIS and spatial modelling is being used within the BESECURE project to enhance urban security.

2. Contextual Overview of GIS and Spatial Modelling

In 2004, Longley et al. coined the phrase “Almost everything that happens, happens somewhere. Knowing where something happens is critically important”. In the case of our daily lives, this phrase could not be more relevant and indeed, location has been the foundation of pretty much everything that has happened throughout history. Every day, our lives are characterised by behaviour that is directly related to location – whether it is understanding the route that we commute to work, the retail outlets that we shop in or the reasoning behind the education establishments that our children attend, location is always a consideration. This behaviour is not solely a result of the person’s internal decision making skills, but instead influenced by the decisions of government, retail outlets, banks, sporting stadia, transport infrastructure, police stations, fire stations, fuel stations and other every day services, to locate where they do. These decisions, in the majority, are often driven by location. Large retail outlets do not locate where there is no demand or competition, education establishments (schools, nursery schools etc.) are usually situated where demographics are favourable and residential development occurs where market conditions are positive. As a consequence of location being so important, it is also a component of and consideration in the problems that occur each day.

Urban security decision making and policy support is also directly linked to location. The criminal activity that occurs is usually as a consequence of a number of factors, but location is predominant – burglaries occur where there are vulnerable neighbourhoods, where wealth is high (as high priced goods can be stolen), where accessibility and urban connectivity are both good and bad (good being where it is easy to get in and out of areas by vehicle; bad being local knowledge of an area by a criminal that would prevent police responding and pursuing by car). Other urban security issues are also directly linked to location, such as the manipulation of how an area is designed, where rioting occurs (usually where tension has built up at certain locations and also where there are opportunities for looting), attacks on security forces (knowledge of sight lines are intrinsically linked with location), car crime (where higher priced cars are owned and where there is a lack of a capable guardian – areas where there is no continuous footfall), as well as many other urban security related issues.

As a consequence, urban security decision makers require methodologies that enable a better understanding of the problems, facilitate management of such events and provide an evidence base that allows for the formulation of responses that are proactive in nature (while having the utility to be reactive when needed). These methodologies will only be meaningful when the importance of location is realised. The very starting point of these methodologies should therefore be data – data needs to be captured with a location element (geographic information). This data must be collected, structured, managed, analysed and presented in alignment with the purpose of all of these components and if this is not done, it will be essentially meaningless. The understanding of data needing a purpose is often ignored and in many situations, the purpose is based on the structure of the data and this limits its utility. Instead, data should be collected in a manner consistent with the operational and strategic objectives of the organisation. Decisions can only be informed and consequently made, if organisations know what the problems are, where they are and when they happen – knowing what happens and when it happens are fundamental, but if you do not know where things are happening, the other components are relatively redundant as you cannot prioritize and direct resources to manage and prevent and/or reduce problems.

Once the importance and collection of location based data is realised, the methodology can progress to the next level. At this stage, information systems and more specifically, geographical information systems (as they permit the management, manipulation, analysis and presentation of location based data), will become a core component of the methodology. Within geographical information systems (GIS), the analysis of data can be achieved through the use of spatial modelling approaches which essentially permit the data to be interrogated, modelled and new data generated based on the location element. This allows a greater understanding of the influence of location in the study area.

In the current literature base, most of the research that has been conducted on the role of GIS/spatial modelling in urban security has focused on analysis specific to crime patterns and trends, with particular emphasis on the role of hotspot mapping for understanding localised problems. Whilst most of this research has focused on developing the architecture and modelling specification for crime analysis as well as demonstrating the potentiality of GIS for communicating evidence, there is a relative lack of discussion on how such methodologies can be used to influence decision making and policy support within government and law enforcement. Although this is not the core focus of the work delivered in work package 2 and work package 3 of BESECURE, it is fundamental for the BESECURE project to know the needs of government and law enforcement agencies in order to develop a platform that can be influential in this sphere.

The development of maps to understand crime is not a new phenomenon and dates back a number of centuries. Crime mapping has come and long way since its early beginnings in the 1800s when social scientists such as Adolphe Quetelet and André-Michel Guerry used spatial analysis to explore crime (Paynich and Hill, 2004). Both Quetelet and Guerry mapped French crime statistics with Quetelet mapping crimes against property and people and Guerry the same crime categories but also level of education (Dent, 2000). Their separate analyses revealed that crime was not only unevenly distributed but that it also clustered geographically with other social variables including population density and socio-economic status (Paynich and Hill, 2004). Throughout the 1900s crime maps continued to develop first from pin maps to crime maps generated by computers. Early crime maps generated by large mainframe computers in the 1960s and 1970s were the preserve of large agencies that could afford them; however, their quality was poor and not suitable for law enforcement use. As Paynich and Hill (2004) note it was not until the 1990s that crime maps began to be produced by desktop computers with GIS capabilities following the enhancement of processing speeds, the availability of greater memory and improvement in printer quality.

As Bowers and Hirschfield (2001) explain crime mapping involves “the manipulation and processing of spatially referenced crime data in order for it to be displayed visually in an output that is informative to the user”. Unsurprisingly then there are numerous technologies and techniques that can be used from the most basic such as pin maps depicting the location of offences and victims and chloropleth maps, which use graduated shading in accordance with the scale of the problem to more sophisticated maps such as voronoi polygons that indicate distances between offences and crime ‘contour’ maps (kernal density estimation) utilising GIS software packages. Subsequently, there are many uses for crime mapping including operational policing purposes, the targeting of resources for crime prevention, police investigations, monitoring changes in the distribution of crime over time and in the evaluation of the effectiveness of crime prevention measures (Bowers and Hirschfield, 2001; Chainey and Ratcliffe, 2005). In addition to mapping crime that has already occurred, the statistical capabilities within most GIS packages allow for the modelling of potential crime, for example, an offender’s next target (Paynich and Hill, 2004).

There are a number of concerns that need to be borne in mind with respect to crime mapping. Firstly, the user needs to have certain knowledge to be able to produce maps. This would include familiarity with the programme being used and defining a large number of parameters before processing the data, for example, what constitutes a hotspot? Secondly, the quality of the data is an important consideration, criminologists are well aware that there exists a disparity between levels of officially recorded crime data and instances of crime reported in victimisation surveys such as the Northern Ireland Crime Survey and the Crime Survey of England and Wales (formally known as the British Crime Survey). Thus, official crime data represent only the tip of the iceberg with respect to crime in general and that a dark figure of unreported crime exists. Indeed, research suggests that the ratio between officially recorded crime and incidents reported via victimisation surveys is 1:4 (Newburn, 2013). The quality of official crime data can also be affected by decisions concerning which offences to include, changes in ‘counting rules’ over the years and to police practices, namely the ‘upgrading’ or ‘downgrading’ of certain offences (Newburn, 2013). Moreover, Bowers and Hirschfield (2001) highlight common problems associated with the spatial quality of data including the absence of x and y co-ordinates, the referencing of incidents to the midpoint of streets due to a lack of specific details pertaining to location, duplicate records and the existence of ‘dumping sites’ for entries that the system could not geocode.

Whilst Bowers and Hirschfield (2001: 6) argue that “maps are, therefore, good tools to use as evidence of the presence of phenomenon” they do not explain why crime occurs at a location. GIS can play an important role with respect to urban security and community safety by identifying where crime occurs, predicting where they could occur next and contribute to an understanding of crime distribution through analysis of other variables such as socio-economic factors and demographics.

Given the importance of location in the study of urban security, the BESECURE project has developed most of its functionality in the BESECURE platform based on geographic information. Indeed, the individual platforms developed (Inspirational Platform, Policy Support Platform and the Urban Data Platform) all utilize the location component to some degree in their utility. At its most simplest, the Inspirational Platform and the Policy Support Platform use location as a function of comparison, which allows an area to be selected and saved and analysis then carried out in the Urban Data Platform. The Urban Data Platform (UDP) is the component of the wider BESECURE platform that has a bespoke GIS system that allows spatial data modelling to be carried out and information presented to the end user in the forms of maps, tables and graphics. This will be described in greater detail in later sections.

3. GIS and Spatial Modelling

Organisations are increasingly becoming aware of the vast amount of locational data available to them and are now exploring how best to leverage this (Handa and Vohra, 2012). The principle of a “border-free Europe” has contributed to the development and creation of a spatial data infrastructure that can aid territorial management and ensure the presentation of geospatial data in a standard way through the EU INSPIRE directive (Feltynowski, 2013; Masser, 2007). Geospatial data describe the geographic location of real-world objects along with self-describing attribute information (King and Arnette, 2011). Geographic information consists of two components; a) spatial data that are raw data with a geographic link representing real world entities (Tomlinson, 2007), and b) aspatial data, or attribute data, that describe their characteristics or attributes (Douglas, 2008). Geographic and spatial data are those with a content that includes a location component (Meeks and Dasgupta, 2004). Maps are an integral part of GIS data, both as raw materials and as final products as they are intended to clearly convey geographic information data as abstractions, simplifications, and representations of reality.

In general, geospatial data can be divided into raster and vector formats. A raster consists of a grid of cells that represent quantitative information, such as temperature that are usually derived using sensing technology. Vector data are points, lines and polygons representing location, distance or area in graphical form that are generated from GIS processes using a quality approach. Raster quantitative geospatial data are used to generate maps that help to answer “how much” questions whereas vector data are commonly used in government urban planning and policy making processes answering questions related to “how clearly identifiable” is the information because of its greater qualitative approach (Lwin et al., 2012). Spatial data are the cornerstone of GIS (Harque, 2001) as they provide the information content for the information layers on maps each representing a unique phenomena that can be used to better analyse and understand data held by an organisation (Handa and Vohra, 2012). GIS provide the imagery of spatial data that help to reveal its structure and identify visualisation of concealed relationships and trends. These can enable the combination of data, information and spatial mapping using analysis and modelling tools for decision making (Handa and Vohra, 2012).

The importance of geospatial data has grown in recent years as it has been estimated that nearly 80% of all government information has a spatial reference (Gilfoyle and Thorpe, 2004). In an urban security context, geographical information is used by many departments of government, law enforcement agencies, urban planners, housing authorities and other key stakeholders for the tasks that underpin most of their activities (Zhang, 2012) and decisions (Richards (2006). However, although geographic information depends on these data, the meaning and knowledge resulting from it can only be provided by the decisions of the user and analyst, as computers and software cannot make sense of the data without the expertise of a user (Maantay and Ziegler, 2006).

3.1. What are GIS?

Geographic Information Systems (GIS) is a term that is now widely recognised in most disciplines. Indeed, since their inception in the 1960’s/70’s their uptake has increased dramatically and this has seen GIS turn in to a multi-billion dollar industry globally. It has also seen the focus of their application move steadily away from a land/resource management system to a non-exhaustively applied solution for managing, manipulating, analysing and presenting all kinds of spatially relevant information. Contemporary usage is particularly strong in ecology, demographics, utilities, planning, logistics, quaternary science, defence, retail, asset management and business, yet application within urban security, particularly at the operational level, is still relatively peripheral. This comes despite the fact that location is critical in understanding urban security problems, the premise upon which GIS is based. The BESECURE project seeks to move the debate and evidence forward in order for the application of GIS to become more firmly aligned with decision making in the urban security domain and highlights the opportunities that exist for open source GIS to be integrated in to urban security operational and strategic policy.

Many definitions exist to explain what GIS is or does. Research has discussed GIS as computer-based tools that enable mapping and spatial analysis of the earth's features and events (Handa and Vohra, 2012). Indeed, Zhang et al., (2012) describe GIS as a computer system capable of assembling, storing, manipulating and analysing geographically referenced information. Maantay and Ziegler (2006), state that although it is difficult to find a single definition that encompasses the multiplicity of GIS use, they can be recognised as a decision support system related to geo-referenced applications and by their ability to process information both geographically and logically with a powerful representation of data (Gobani and Ahmadi, 2011). ESRI, a worldwide provider of geographic information systems, define GIS as

> ***"a computer based tool for mapping and analysing things that happen on the earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualisation and geographic analysis benefits offered by maps."***

Harque (2001) provided his views of GIS as analytical and decision–making tools that organise, compare and analyse disparate types of information into one organised system. He claims that they offer an unparalleled power to examine social, economic, and political circumstances. Lwin et al. (2012) support this describing GIS as a powerful tool used to solve spatial problems. Through GIS, geographic information is becoming an organisational asset, integrating seemingly disparate information quickly and visually to facilitate communication, collaboration and decision-making capabilities (Tomlinson, 2007). Gorbani and Ahmadi (2011) identify the five constituent components of any GIS as its hardware, software, application procedure, data base type and the people using it. They also note that the key feature that distinguishes GIS from other information systems are their capacity for integrating geographical data with other sources of information. Pick (2005) contends that geographic information systems can assess spatial data and attribute information to it, analyse it, and then produce outputs with mapping and visual displays. Thus, GIS programmes can be designed to store, manage, display, analyse and report on such data centric information that has a "where" component (Douglas, 2008). In essence, this suggests that GIS is the best technology to understand and solve problems related to place and space (Harque, 2001).

Table 1: Various definitions of the term 'Geographical information systems'

Source	Definition
Dueker, 1979	"A GIS is a special case of information systems where the database consists of

	observations on spatially distributed features, activities or events, which are definable in space as points, lines or areas”
Burrough, 1986	“a powerful set of tools for storing at will, transforming and displaying spatial data from the real world, for a particular set of purposes”
Clarke, 1995	“automated systems for the capture, storage, retrieval, analysis and display of spatial data”
Longley et al., 2001	“a tool for performing operations on geographic data that are too tedious or expensive or inaccurate if performed by hand”
Radke and Hanebuth, 2008	“GIS is a system for input, storage, processing and retrieval of spatial data”
Ren, 1997	“powerful tool for the analysis of spatial data to support development planning and decision making”
Hua et al., 2007	“ a powerful tool to gather, store, process and analyse spatial data”
Wei et al., 2011	“GIS is a powerful platform to store, visualise and fuse data”
Ballas and Clarke, 2000	“GIS, combined with computer modelling techniques, can provide an enhanced environment for analysis, evaluation and decision making in urban and regional planning”
Kistemann et al., 2000	“ A GIS is an organised collection of computer hardware, software, geographical data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information”
Wofford and Thrall, 1997	“A technology tool for the display of geographical information”
McIlhatton et al., 2013	“GIS involves the development and/or utilisation of hardware and software for the collection, collation and governance of data that can be/ or is referenced to a location which can then be analysed, visualised and manipulated to generate further data, provide an evidence base and geographically represent information in an effective, efficient and accountable manner”

Despite the extensive multi-disciplinary utilisation of GIS, it should not be assumed that everyone knows fully what GIS is and/or can do, especially those in urban security that do not come from a geography background. The difficulty in providing a definition to those within the urban security environment is that even within the core GIS discipline, a standardised definition does not exist, with different sectors of the GIS user community adopting and adapting to suit their own requirements. In order to alleviate any ambiguity within the urban security discipline, a definition must be presented that is firmly aligned with the diversity of the urban security discipline. Table 1 highlights the plethora of definitions that exist to explain what GIS is/does and/or can do. Most of these definitions are relatively obscure and do not provide enough information, particularly for urban security, to illustrate the potentiality that utilising such a methodology can provide for those seeking answers from spatially linked questions. Without such clarity, GIS may continue to be lost in translation for those that seek to fully understand how GIS can help this sector. It is therefore an intention of this project to move beyond this ambiguity and present a definition of GIS that is fully aligned with the needs of the urban security profession and that of the traditional GIS thought process. In this context, GIS in the urban security environment could be considered as:

> ***"GIS involves the development and/or utilisation of hardware and software for the collection, collation and governance of data that can be/ or is referenced to a location which can then be analysed, visualised and manipulated to generate further data, provide an evidence base and geographically represent information in an effective, efficient and accountable manner" (McIlhatton et al., 2013)***

3.2. Benefits and Challenges

Goodchild (2009) makes the case that the critical spatial thinking capabilities of GIS should be a central theme in education for a world where information is increasingly seen through geographical filters. These capabilities have enabled the evolution of GIS into a powerful tool used to represent and analyse spatial data that can turn this data into useful information through analysis (Tomlinson, 2007). GIS programmes have been developed to make the computer think it's a map, a new map that is a dynamic entity, designed to assist people in decision making as a GIS map exhibits "intelligence" (Kennedy, 2009). GIS combines mapping with information technology and in so doing, transfers the control of the mapping process from cartographers to the user (Maantay and Ziegler, 2006). Therefore, viewed as a horizontal technology, GIS has wide ranging applications across both the industrial and intellectual landscape (Tomlinson, 2007).

Whilst defining GIS for urban security is important, it is not what is going to sell the concept of using such a methodology to the urban security academy and industry. Indeed with benefits, come challenges. The challenges in the contemporary climate are very much misaligned with those from a decade ago, with most of the inhibiting factors becoming almost redundant through significant changes in technology, software availability and accessibility. Nevertheless, barriers still remain, albeit in a different guise. There is still a large literature base that highlights cost as a difficulty that needs to be overcome (Longley et al., 2001; Elwood, 2006; Kohsaka, 2001; Kidman and Palmer, 2008; Cairns, 1998), however, this is perhaps a stigma that has stuck with the evolution of GIS and IT in general, but needs to be addressed. Whilst cost is always going to be an issue to accountants and those that sign off on IT-based procurement, it is not something that is inhibitive as software and hardware costs have decreased exponentially as increased competition has entered the market. Indeed, there has also been the emergence of the 'Open' GIS environment which is making many GIS packages freely available, many with advanced functionality and others which include 'Open' hardware also. This emergence is helping to revolutionise other industries, particularly those concerned with preparedness, response, reconstruction and recovery in crisis situations, and also facilitating greater exposure in the academic environment. In regards to the uplift in 'Open' GIS in the crisis preparedness, response and recovery sector, there are many similar applications to how GIS could potentially be used in the situational awareness, intelligence and response components of urban security research. Although not entirely similar, the underlying assumptions are the same- to build up a holistic picture of the past and current environment, to analyse and understand where the demand, supply and need may be, and to facilitate proactive and reactive responses in the future based on a robust evidence base.

Despite this, there continues to be relative resistance, both intentional and unintentional. Most of this stems from the notion that outside of the core geography discipline, there is a distinct lack of skills or expertise in the GIS field for specific industry sectors or skills which can be aligned with certain industry perspectives (Montagu, 2001). In this regard, whilst there may be a large number of GIS graduates and post-graduates leaving academia each year globally, most are trained specifically in core GIS techniques and not necessarily how they may relate to industries such as urban security. This in itself is not an issue as a GIS professional should use the 'spatial thinking' that they inherently have to complement the GIS requirements of their job, however, it is very difficult for many organisations to justify bringing in niche expertise, without having transferable skills that can be applied outside of the GIS requirements. This phenomenon is not restricted to the urban security field but is characteristic of the difficulties that many face in the current economic operating environment.

Perhaps the most difficult barrier to overcome is that of data availability, accessibility and quality. Many studies focus on the issues of data in the GIS (John, 1993; Martin and Longley, 1995; Huevelink and Burrough, 2002; Couchelis, 2003) disciplinee, with most focusing on data availability, accessibility, accuracy and quality. It is within these areas that the robustness and credibility of your analysis lies. Thrall (REF), indicated that availability was very much dependant on federal, state, or local governments collecting and disseminating the information, with commercial data vendors also providing a functional data stream. However, the data collected and made available by different tiers of government is entwined in a number of general assumptions. The data collected must be the most reliable and robust available. However, there may be many inconsistencies in the data capture such as comparable scalability across regions, issues relating to data input, as well as the traditional temporal problems associated with data capture (Thrall, 1998).

In an urban security context, organisations must use the operational data that they collect to form a basis of the analysis that they undertake for informing the decision making process. In many cases, this is only occurring to a degree and as a consequence, challenges are faced. In many situations, the data is held in silos. GIS or IT managers are responsible for the storage and management (and sometimes analysis) of the data that they collect. This in itself does not pose a problem as long as the data can be openly shared as a resource across the organisation. However, it is our experience that this is not always the case and as such, the effectiveness and efficiency of decision making is often inhibited. Therefore there needs to be a clear strategy of use of GIS based data within urban security environments.

3.3. GIS for a Purpose

The benefits discussed in previous sections will only be realised when urban security organisations understand that GIS needs a purpose – both operationally and strategically. In this sense, the BESECURE project proffers that such organisations need to clearly set out the role of GIS in their decision making process and adopt only where there is an actual need and where it is likely to enhance effectiveness and efficiency of service delivery. If they do not do this, they are likely to incur significant cost with little benefits, which in turn, will detract from the realisation that GIS is fundamental in decision making in urban security. In order to achieve this, the urban security organisation must clearly identify the role in which

GIS must play in the delivery of the objectives of their corporate and departmental plans. To do this they need to understand what questions they need to answer to ensure they are providing the most optimum level of service delivery to their local community. The BESECURE project has identified through its case study analysis and through analysis of the current literature base that in many cases, organisations are trying to make GIS fit their data, instead of making their data fit GIS – this results in the organisation, in many situations, being unable to maximize the potential of their data. In order to avoid this going forward and to ensure that any potential adopters of the BESECURE platform are not faced with similar challenges, the BESECURE consortium advocate that urban security organisations ask the following key questions prior to any commercial commitment to GIS.

Table 2: Key questions to be answered by urban security organisations prior to commitment to GIS

What questions do you need to answer both operationally and strategically? The following questions can serve as guides for data creation, collection and consideration. 1. What are the main problems affecting my area? 2. Where are these problems occurring? 3. Are there hotspots of problems? 4. When are these problems occurring? (e.g., time of day, day of the week, season) 5. Are there trends over time? 6. What interventions (and where) have gone in to the area in the past? 7. Did these interventions reduce problems or displace them? 8. Are my interventions in the right place?
Can these questions be answered easily without GIS?
Have you carried out a cost benefit analysis of using GIS against potential cost of problems/ interventions?
Do they have the right data to answer the operational and strategic questions needing answered?
Do we have the expertise to carry out the analysis and interpretation required?

In the context of the BESECURE project, the development of the platform has been mindful of the questions that need to be answered by the urban security professionals. The functionality present is based on engagement with urban security stakeholders in case study areas who have demonstrated their needs for the management of urban security issues. This was done through story boarding and use case development of a typical requirement of urban data analysts and decision makers within local government and law enforcement and the interconnections of such work in departmental and corporate strategies. This was captured through workshops with end users in order to understand the functionality required to meet the needs of the decision making process, as well as to gain knowledge of what GIS functionality they would like to enhance their service delivery. This was achieved through the use of a hybrid version of the MoSCoW model (Must-have, Should-have, Could-have, Would-have) used at the workshops with the end users in order to help answer the questions identified through their story boards/use case development sessions. A sample storyboard of a decision making request developed at the workshop with end users is presented below in Table 3.

In order to frame the requirements of the BESECURE Urban Data Platform and the GIS functionalities and features that needed to be developed, the development team of the UDP needed to understand the purpose of such a platform in a crime prevention and management setting. This then allowed for the creation of a common data framework, GIS analysis functionality and information model that is interoperable in any jurisdiction and in most crime prevention and management scenarios. In order to understand the needs of the end user, the BESECURE development team needed to define the purpose of the GIS, the questions that needed to be answered, how they could be answered and how the GIS could support the decision making process from a policy informing perspective. As mentioned previously, this was done through the use of story boards and use case development.

Table 3: Understanding the needs of the end user

Story board	Using GIS to develop an operational strategy for tackling burglary
Context	On the 12th October 2014, local media in Belfast report that an 84 year old woman was injured in a burglary at her house in the Ravenhill area of Belfast. The assailants were armed with a hammer and attacked the woman when she confronted them in her hallway. A sum of money was stolen, as was a collection of antique jewellery. Unfortunately, this report was not an isolated incident, but one of many over the course of the past 3 months. As a consequence of the latest media attention, the local police commander has come under immense pressure from local councillors and community groups across the Belfast area. The police commander for the City has promised that she will launch crime prevention initiatives in areas where there is high vulnerability and enhance police visibility at key times and locations when operational intelligence suggests that there is a risk of such events occurring.
End-user needs	Maria is a crime prevention officer within Belfast City Council and tasked by her management with developing the response to the spate of residential burglaries over the short term. Her responsibilities include understanding, responding to, and mitigating against residential burglary across the city. She has been tasked with liaising with the community policing management for each of the areas of Belfast and understanding where crime prevention initiatives need to be directed and where police visibility need to be enhanced in order to reduce the fear of residential crime. Based on the brief that Maria has been given by her senior management team, she needs to understand a number of things before she can develop her strategy.
Questions that Maria needs to answer as identified at workshop:	• Where are there high levels of residential burglary in Belfast over the course of the past 12 months and do we have a holistic picture of all crime recorded by different agencies? • Maria has been instructed that the majority of victims are in the age range of 60 years old and over. Therefore she needs to answer the question of 'where are there high densities of this age cohort in the City?

	• She needs to match this against high rates of residential burglary • Maria also needs to understand where residential burglary problems may be a problem in the future and have a mechanism to monitor residential burglary in the City and understand when it is potentially becoming a problem • Maria then needs to decide on where she is going to direct her crime prevention initiatives • Maria then needs to draw areas which can be provided to the community policing teams for enhancing police visibility • Maria needs to be able to review this on a monthly basis to ensure that they are directing resources in to the right locations

Based on an understanding of the needs of the end user, the GIS development team were able to identify what functionality the UDP Must Have; Should Have; Could Have and Would Have in ideal circumstances. This was done through answering these questions with functionality/ features using the MoSCoW model. The Must-Have components are the functionality that the UDP must have in order to answer the basic questions of the end user. The Should-Have functionalities are those that the software should have in a final state which would enhance the current analytical capabilities in an easy to use manner. The Could-Have functionalities are what the software could have in order to advance the current state of the art and the Would-Have capabilities of the UDP are those that the end user has identified might be needed in the future. The first stage of identifying the GIS and spatial modelling needs of the end user was done through understanding how the end user needed to develop their information model. Essentially, this meant that the BESECURE GIS development team needed to know how much of an answer the end user needed for each question. The following table illustrates the needs of the end user in relation to answering their core questions. This was used to develop the functionality and features of the final UDP in the BESECURE platform, as presented in section 5.

Table 4: Example of user-needs and meeting these needs through features and functionality of the UDP.

Must-have	Should-have	Could-have	Would-have
Where are there high levels of residential burglary in Belfast over the course of the past 12 months and do we have a holistic picture of all crime recorded by different agencies?			
• **The ability to show spatial trends of different crime types** • **The ability to analyse data over time** • **Disparate data (from other key stakeholders) to how the complete picture of crime**	• The ability to query data • Visualisation of data on map • Data presented in tables/graphs • Easy to work user interface that is simple and requires little training	• Advanced analysis showing correlations • Linkage of crime data to crime prevention pages	• Automatic reporting mechanisms that alert authorities when certain thresholds are met

Where are there high densities of this age cohort in the City?			
• **Data relating to demographics that can be analysed on a spatio-temporal basis** • **Ability to generate clusters/ density maps of different age bands** • **Identification of areas that are 'at risk' based on concentration of certain age bands**	• Choropleth maps showing gradients of population for any available age cohort • Tabular data showing comparisons of areas • Graphics showing trends	• Other influential factors that may impact on crime/ make an area vulnerable (schools, physical interventions, nursing homes, etc)	• Correlations with other variables to derive high risk vulnerable areas based on a range of factors
Understand where residential burglary problems may be a problem in the future and have a mechanism to monitor residential burglary in the City and understand when it is potentially becoming a problem			
• **Forecasting mechanism for identifying when issues are becoming problems** • **Early warning system that can trigger potential interventions** • **Functionality to select any variable and see when it is likely to become a problem** • **Alert mechanism to illustrate when things are reaching problematic stage**	• Graphs (different kinds) illustrating trends • Alert system demonstrating when a threshold has nearly been reached/ has been reached • Query mechanism for different variables	• Be linked to the map spatially so user can have a more localised understanding of problems	• Email alert system set up to inform authorities when issue was reaching threshold
Where do crime prevention initiatives need to be directed and potentially what type of intervention?			
• **Ability to understand where there are hotspots of problems on the ground** • **Ability to understand the impact of putting an intervention in place (i.e. how much crime is likely to fall within a**	• Hotspot/heat map functionality (kernel density) • Place point on the map and draw radius by certain distances • Generate information of only the occurrences that fall within that distance	• Ability to only create a heat maps or hotspot map within the radius created	• Cost benefit calculator showing unit cost of crime against cost of proposed intervention

certain distance of an intervention based on past occurrences)	• Ability to be created based on any crime variable		
Draw options that can be provided to the community policing teams for enhancing police visibility based on hotspots of problems			
• **Functionality to draw polygons/ line/points on map to demonstrate locations for police patrols based on hotspots of problems**	• Polygon creation tool • Line creation tool • Point location tool	• Ability to return all crime/other data within that area/ proximity of line	• Ability to add attribute data
Review on a monthly basis to ensure that they are directing resources in to the right locations			
• **Feature that allows monthly data updates/analysis** • **Ability to pull in data for other partners** • **Spatio-temporal analysis**	• API for crime data and other partner data • Query facility based on time	• Ability to only query/ analyse data based on that time period	• Early warning system that indicates whether data is much different to previous months and what it is likely to be in future

Prior to the development of the UDP, the GIS development team created wireframes of the proposed features/ functionality (not how it would necessarily look) and engaged with end users on this. Essentially, this was to gain feedback on the features and functionality proposed and how these addressed the needs of the end users based on the questions that were identified through the different story boards/ use cases that were developed. This allowed the end user to have an iterative feedback loop with the GIS development team which allowed the software to be developed in alignment with their needs. Figure 1 shows an example wireframe of proposed UDP functionality that resulted from interaction sessions with end-users. More examples of wireframes from the UDP design sessions can be found in the Annex to this report.

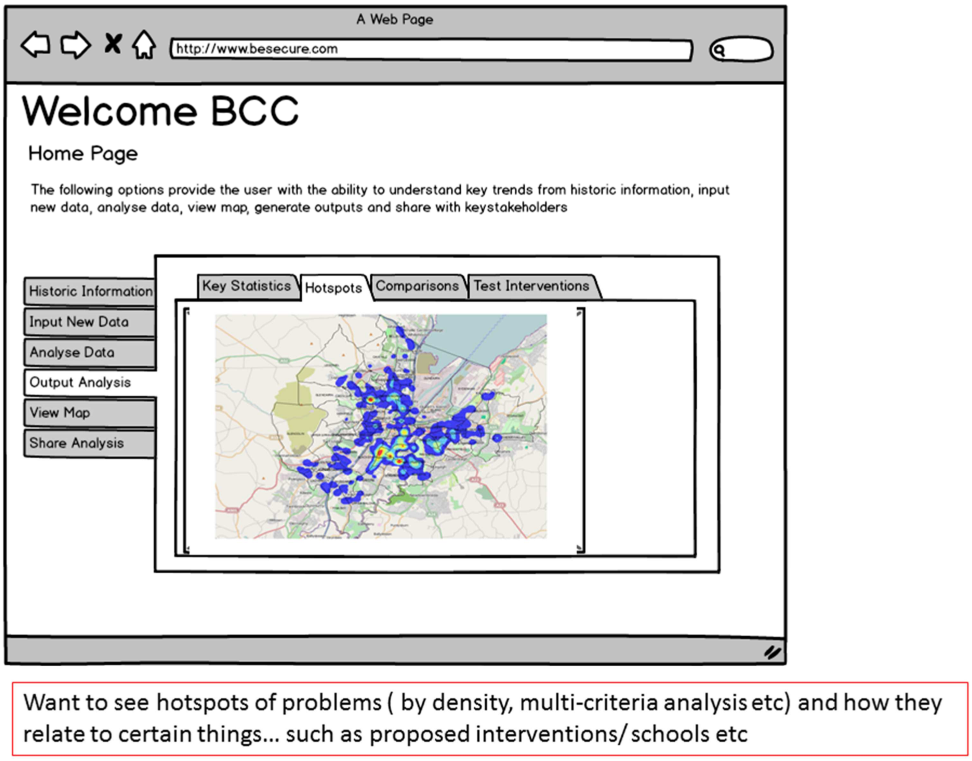

Figure 1: Example wireframe of proposed UDP functionality, as developed in end-users requirement sessions.

After engagement with the end users took place, a number of features were described as not being needed (by end user) and therefore these were omitted from the final version of the GIS development of the UDP. These features were Google Streetview[1] (because of the costly licence fee required); Cost Benefit calculator (as finance systems do not tie in with other databases and appraisals are carried out separately/ independently). Therefore, the development of the final version of the UDP was based on the remaining features/ functionalities identified in partnership with the end users.

[1] http://www.google.com/maps/about/behind-the-scenes/streetview/

4. Visualisation and Communication

4.1. Communicating Information

In GIS, one of the main aims is to provide accurate and meaningful information to the end user in the form of a map. Essentially, this is the representation and communication of the analysed data in a layout that should be useful and understandable. The information can come in many different forms ranging from point based information, thematic maps as well as the communication of information by tables and graphs (Maantay and Ziegler, 2006). Data visualisation can be understood in two ways. Visalingham (1994) states that it is 'the use of computer technology for exploring data' and second that it is the use of 'computer graphics for acquiring a deeper understanding of data'. In GIS, maps are rich sources of qualitative and quantitative data and GIS, through its functionality, allows the user to understand that data in many different ways (data manipulation, graphical understanding, summary statistics analysis, classify and in cases re-classify the data, display statistical movement in the data, examine its temporality). This make GIS a powerful tool for communicating information to the end user. This information, however, must be the right information and easily understood by the lay person.

There are many kinds of data representation possible through the modelling of spatial data in a GIS ranging from advanced visualisation such as approaches like geographically weighted regression and kernel density analysis, through to, simple graphical and tabular displays. In many cases, the user will not have advanced knowledge of statistics and therefore they need the information presented to them in the simplest, yet meaningful, way. If they do not have this, it will result in a less meaningful interpretation, which in turn, results in a less-informed evidence base as the user does not fully understand the information that they are trying to communicate. In urban security, the user may be tasked with making decisions that impact upon millions of people. Indeed, they may also be tasked with spending millions of pounds of public funds on resources, physical and community based interventions, special projects and other related things, therefore, the information that must present and communicate needs to be easy to understand, easy to interpret and easy to communicate to non-GIS specialists. The user must get the visualisation of the analysed data right in order for it to be communicated in an effective and efficient manner.

There are many types of approaches to data visualisation in a GIS that are possible and available to the user. However, not all will be relevant or meaningful in representing certain information. For example, there is no point including a graph detailing information for 100 different administrative areas. Instead, this information would be easier to communicate through approaches such as thematic mapping or summary statistics. The following presents the types of GIS based visualisation available to the urban security end user. These visualisation types were taken to the end user to understand how they wanted the information presented back to themselves. Most of the engagement that took place on this matter illustrated that the end user wanted a simple visualisation of the information in order to enable accurate and meaningful interpretation. The following visualisation types were presented to the end user and feedback obtained.

4.1.1. Maps

Base Maps. Base maps are fundamental in enabling the user to understand the area in which the information relates, if the user does not have a scalable base map, then communication of information can be inhibited (especially where there is a need for accuracy in data) as spatial awareness is critical in GIS informed decision making. In the context of the UDP, the end user detailed that an open source base map would be suitable in order to reduce the data costs of the organisation- the base map selected was OpenStreetMap [2]as no commercial licence costs were applicable and it was the industry standard free and open source base map. It was generally agreed that where there was a need for specific base maps that the functionality should allow these to be included/ layered in the UDP. This was agreed and the ability provided in the code of the UDP to do this.

Figure 2: Example of a 1:1250 scale Base Map (allows user to work at greater resolutions of data)

Thematic Maps. Thematic maps are very useful in displaying information across geographic areas. Essentially, this allows the user to quickly be able to draw comparisons between areas and understand where 'hotspots' of certain issues may exist. In the context of the UDP, end user consultation suggested that choropleth maps were the most suitable mapping type for communicating information about different geographies. This feature has been incorporated in to the UDP. Examples of thematic maps are presented below.

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[2] https://www.openstreetmap.org/

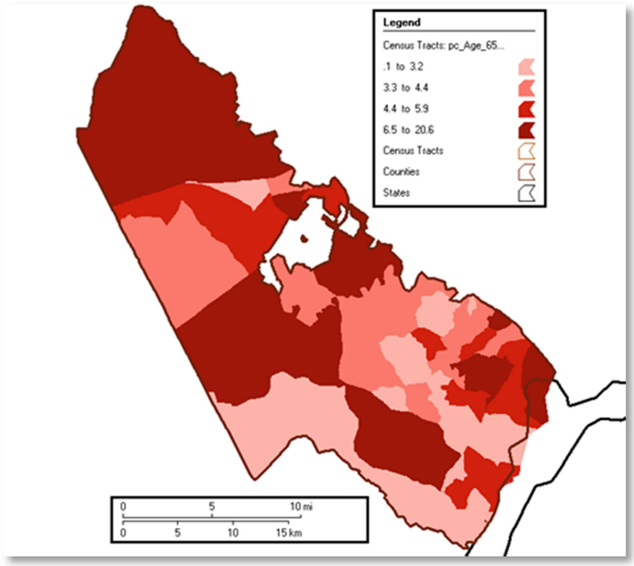


Figure 3: Thematic Map showing population by age at the census tract level

Figure 4: Thematic Map showing data by categories (in this case based on county names)

4.1.2. Graphs

There are different types of graphs available to urban security end users.

Bar Chart (Basic). Bar charts can enable greater understanding of trends in variables spatially. They can be used to present information for numerous variables for any particular geographic area. In the case presented below, time of day analysis is presented for each of the crime hotspots showing peak hours of crime in those areas. These can be used to understand where you need to locate resources and when. It was generally accepted that Bar Charts, pie charts and line charts were the most appropriate manner in which to communicate information to the end users as they were relatively easy to interpret trends from. These visualisation types were therefore incorporated in to the final version of the UDP.

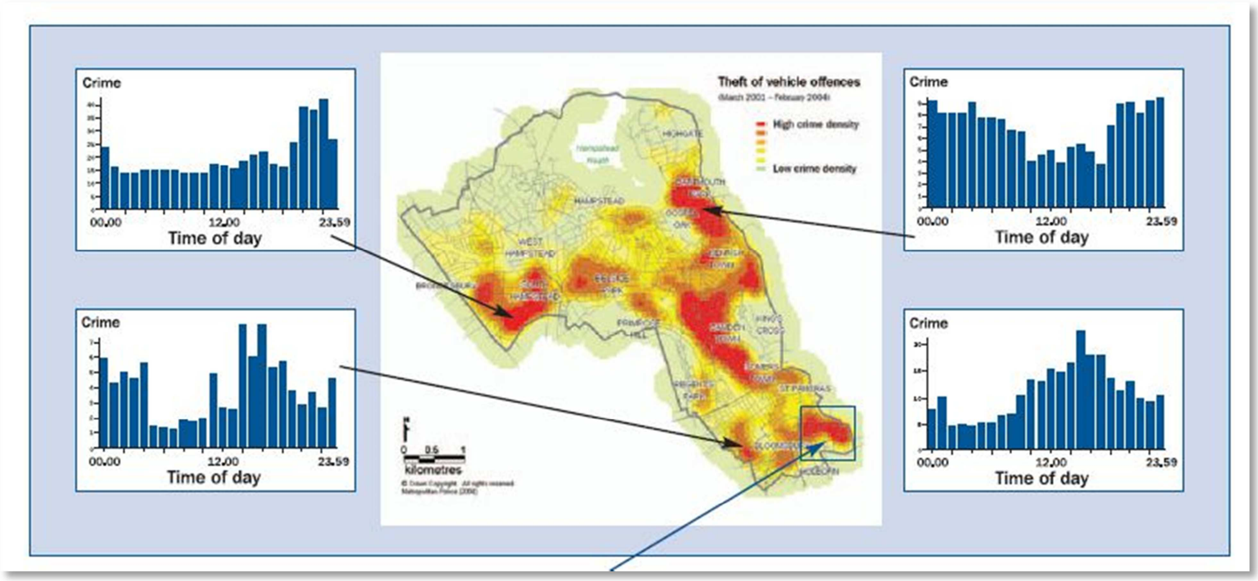


Figure 5: Typical example of the use of bar graphs

The bar charts can also be visualised on the map, however, this starts to add complexity to the map and you need to be careful not to detract from what the map is telling you.

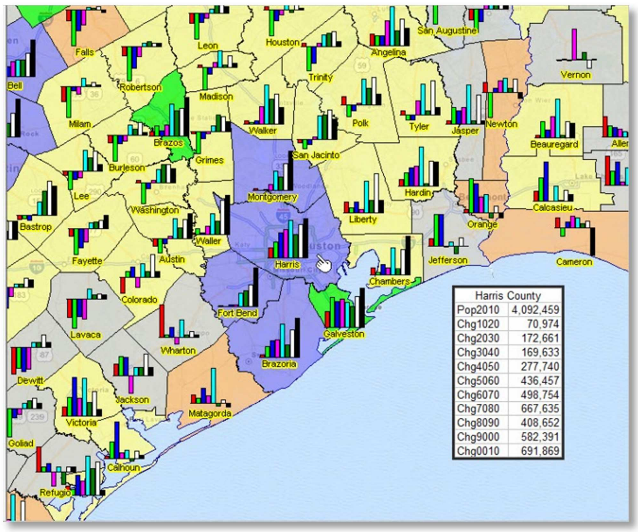


Figure 6: Example of a complex bar graph chart

Pie Charts. Pie charts can be used to represent proportionality in data for specific areas (in this case, showing the breakdown in types of police officer available for any administrative area). Research suggests (Maantay and Ziegler, 2006) that if using pie charts, they should not be placed at angles or in 3D format due to difficulties in interpretation of such visualisations.

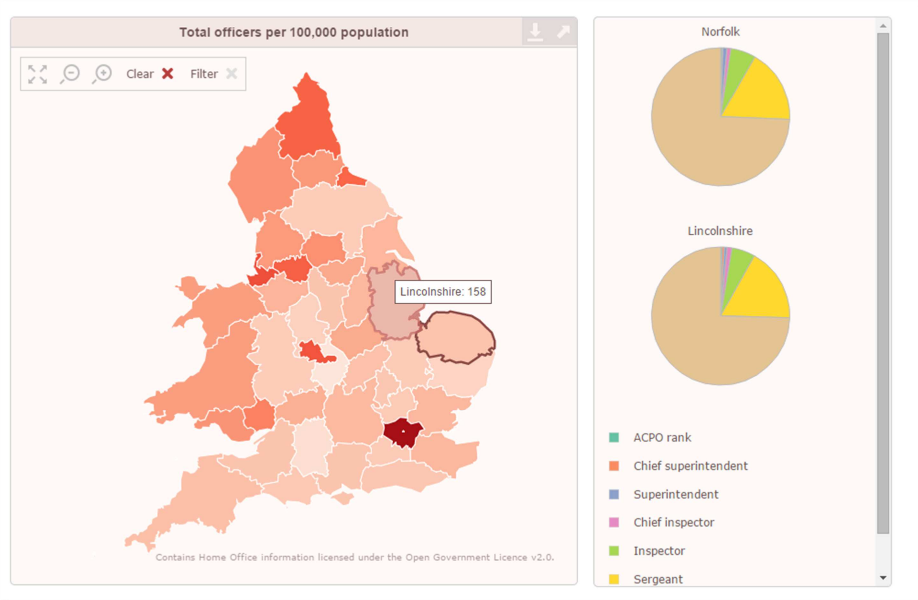


Figure 7: Typical example of the use of pie charts

Line Graphs. The use of line graphs is extensive in communicating trends in normalised data. They can be used to draw comparisons or communicate forecasts of 'what might happen' to the user. The line graph below is communicating forecasts of unemployment beyond the actual data available. The end users suggested that the most appropriate manner in which to present the early warning system information was through the use of line graphs as they were able to follow the trend line more easily than with other charting methods. The provision was made in the early warning system component of the platform that the user could select between bar, scatter and line graphs.

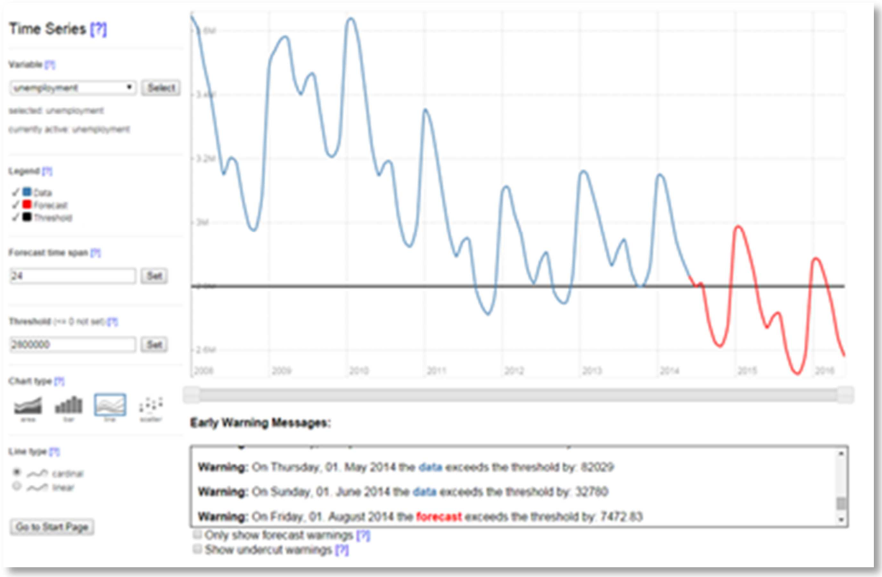


Figure 8: Typical example of a line graph.
Screenshot taken from the BESECURE Early Warning System prototype.

Scatter plots. Scatter plots are used to display the relationship between two variables such as unemployment and crime. They allow a trend line to be drawn to characterize the relationship between the variables. An upward sloping trend from left to right usually indicates a positive relationship, a sloping trend from right to left indicate a negative relationship.

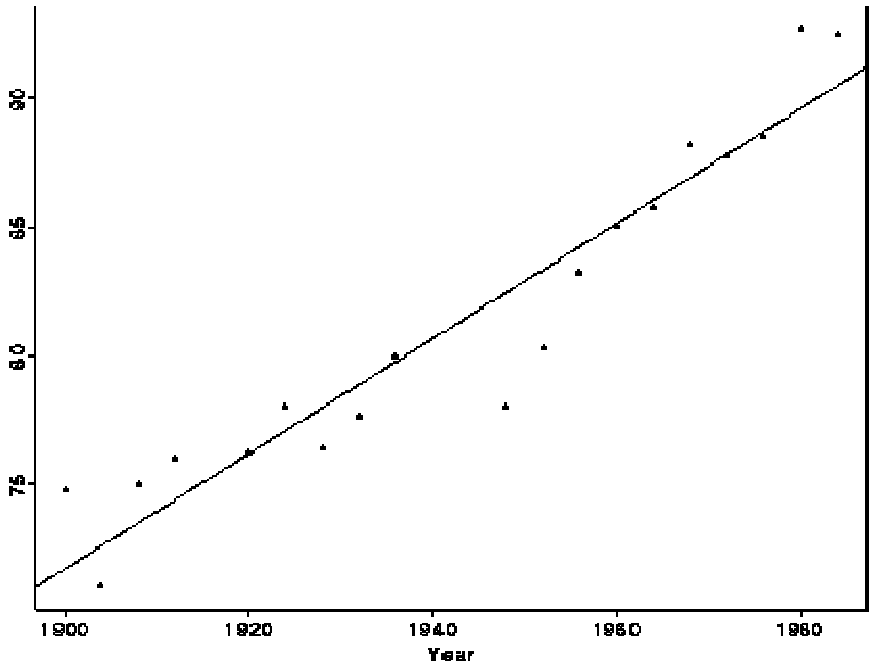


Figure 9: Typical scatter plot graph example

Histograms. Histograms are used in GIS to illustrate data values on an x axis and frequencies of values on the y axis. They provide information about the distribution of the data. The user can immediately see how many values are in each classification.

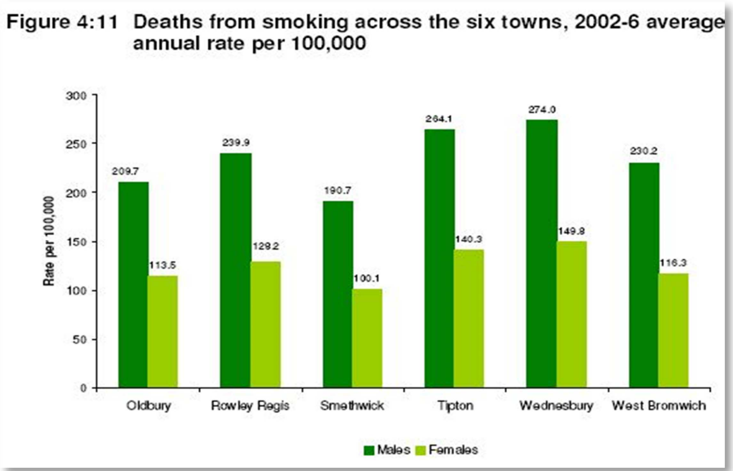


Figure 10: Example of the use of histograms

Heat Maps. Heat Maps are used to present point based density across geography. They essentially show where clustering is occurring in the area under investigation. They are particularly useful at providing an understanding of hotspots of crime in areas. In the BESECURE UDP, heat maps are enabled to understand local concentrations of crime.

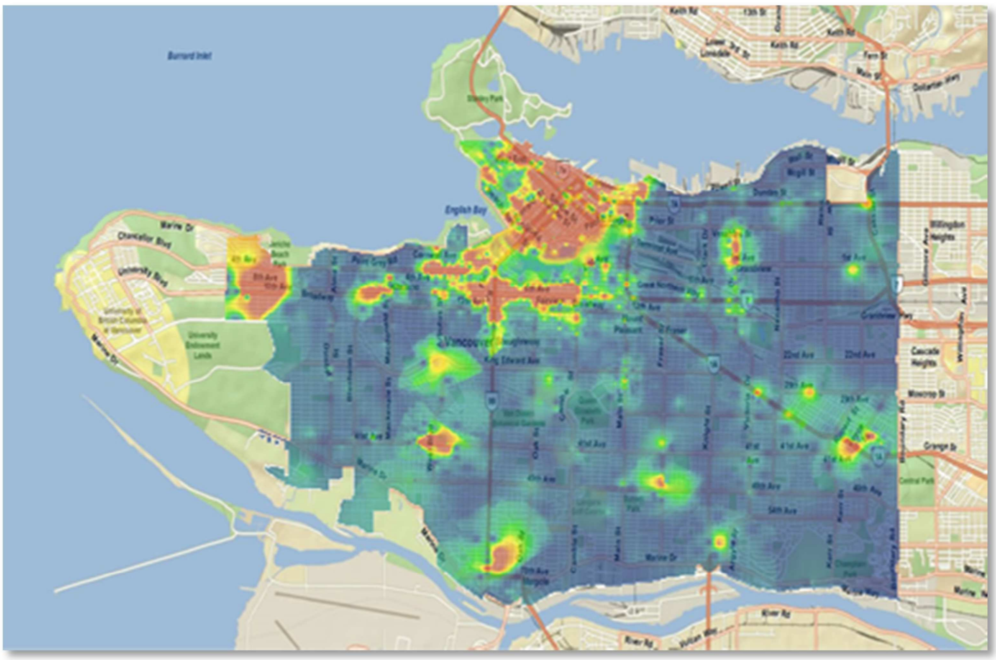


Figure 11: An example of a heat map displaying particular hotspot in an urban area

End users identified that these heat maps needed to also be available within the radial select feature and also in the polygon creation feature in order to understand even more localised trends. This functionality is available within the UDP.

4.2. Benefits and Challenges

There are many benefits and challenges that exist in relation to the types of visualisations that you should use for communicating GIS based information in urban security and these were identified by the end users. These include:

Benefits

- Can present the end user with a visual understanding of problematic areas through the use of hotspot mapping. Hot spot mapping (depending on the cell size/search radius) can illustrate on the ground (base map) where the problems lie – as long as the data is available at localised levels (such as <X,Y> coordinates).
- User can understand spatio-temporal trends associated with GIS information by the use of thematic mapping and bar charts/ histograms. Such approaches enable the user to present multiple data sets related to location which the user can easily interpret.
- User can make forecasts and present visually using line graphs. This is particularly useful when you need to allocate resources going forward and you need to provide evidence of where is likely to need them. Many urban security professionals (based on case study consultation) do not have forecasting abilities.
- In many cases simple tabular data is easy to interpret especially when the data is showing ranges or normalised values and not simple counts. This helps the user to have a greater understanding of what the information is telling them which makes it easier for them to communicate to other.

Challenges

- User needs to design the information that they want on the graph and in many cases, they simply do not know.
- User needs to select a colour scheme, which again can make communication difficult. Indeed, it is very easy to be misled by the colour scheme used (i.e. reds and blues – in many cases, people would use red to represent high levels and blue to represent low levels. If you flip these colours, people may automatically assume that red still means high and blue means low when in actual fact, that is incorrect).
- The visualisation needs to be relevant to the information that you are trying to communicate. There is no point visualizing information through a heat map if you have very few data points behind it. This will only mislead the audience and make them think that there is lots of values behind it

5. GIS-Based Modelling in Practice: The BESECURE Approach to Urban Security Enhancement

5.1. Data to Information to Knowledge

In the BESECURE platform, GIS capabilities are included in the 'Urban Data Platform' (UDP) component of the architecture. The end user of the BESECURE platform must be familiar with the "data to information to knowledge to action to outcome" model (Figure 12) that the project consortium has adopted in relation to the operationalisation of the GIS structure in the UDP. They must be mindful that GIS provides the functionality to help them understand and fulfil the data-information-knowledge components and that that the results of these phases must then be used to inform their interpretation of the situation. The actions that they take will not be provided through the BESECURE GIS or other connected components, but instead based on their professional judgment when they have all the necessary evidence, including knowledge of what has and has not worked in similar situations in different jurisdictions. The data-information-knowledge process is fulfilled through the following steps in the GIS components of the BESECURE platform.

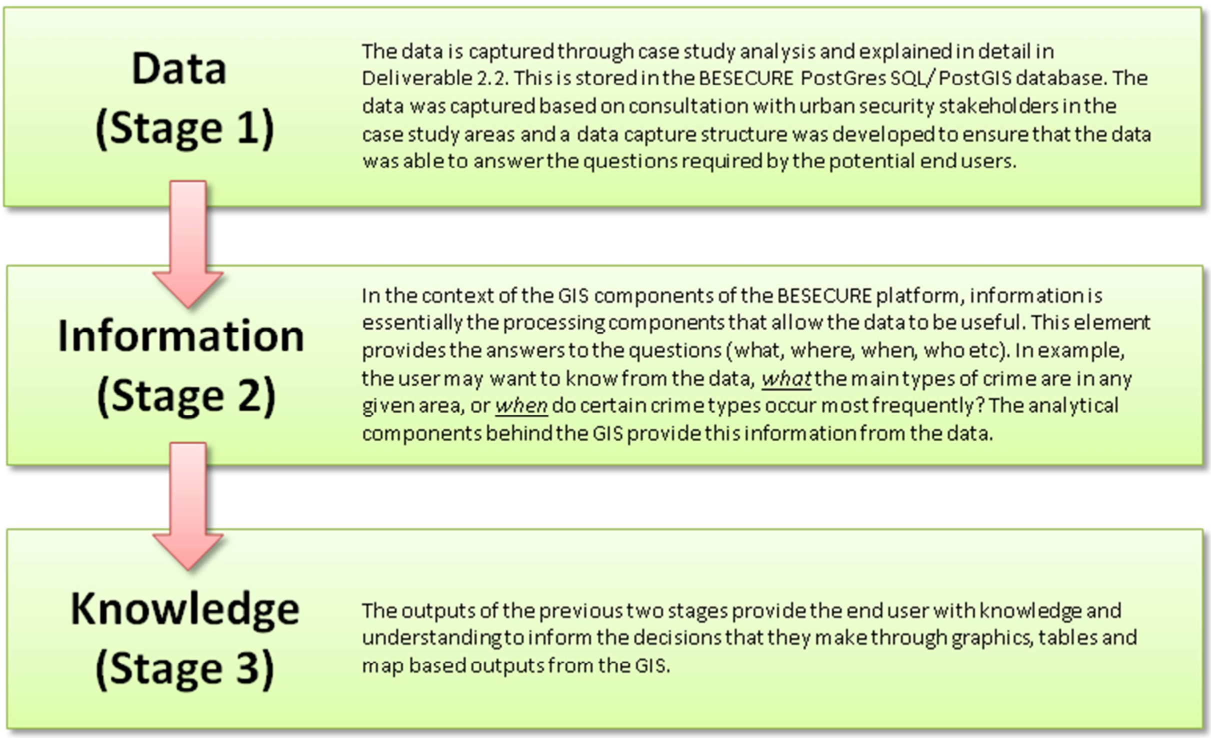


Figure 12: The data-information-knowledge process in the GIS component of the BESECURE platform

5.1.1. Stage 1: GIS Data and the UDP of the BESECURE Platform

The data that will be in the UDP of the BESECURE platform will depend on the area in which is under investigation by the end user. The platform is based on a common data framework that allows the same functionality for any urban area as long as the data is collected/ structured in a common format consistent with the BESECURE data framework. Based on the end user engagement that occurred, the following sections demonstrate the functionality that is included in the UDP in order to meet the needs identified by the end user.

Requirements as identified by the end-user

Engagement with the end user community demonstrated that there was a need to have a common data framework that would be relevant in any jurisdiction. They believed that if the platform was to have any impact within the urban security world that it needed to be based on an open environment that was not spatially restricted and could include spatial data relevant for any geographic area. Indeed, consultation detailed that any GIS development within the UDP also needed to provide the user with the ability to be able to view, create and interrogate data at different geographic scales (administrative areas) and as a consequence, the analysis that would be undertaken would need to be enabled for point and polygon based data.

Another requirement on the data side of the end user was the need to be able to overlay other spatial data on top of other data. This was to understand the relationship between different factors and to provide greater situational awareness to those tasked with supporting decisions. Further dialogue illustrated that currently, it was very difficult for decision makers to have the bigger picture of urban security issues in their area. Indeed, they discussed that most of the understanding that they have on issues collected by other stakeholders did not have any time series attached and was usually the status quo, therefore any platform that would be developed within the UDP needed to be mindful of this and include time series data, that was based on disparate data sources and which could be queried. They stressed that these querying facilities must be easy to user, not require expertise guidance and include some sort of wizard approach that essentially 'held their hand' in analysis.

Functionality and intention of UDP

When the needs of the end user were identified, the GIS development team worked with the end user community to design the functionality of the GIS based components of the UDP. The functions and features agreed upon were done using the MoSCoW model identified in section 3 of this report and were proposed and agreed with the end user engaged. The GIS development team proposed that in order to meet the data needs of the end user, the following features/ functionalities would be most suitable in achieving the agreed needs.

Need/Requirement	Features/ Functionality
1. Open Environment that is not spatially restricted	• UDP will use open source web mapping base data API namely, OpenStreetMap (http://api.openstreetmap.org/) • Database functions allow for own base data to be included where required (such as large scale data, orthophotography etc). This enhances utility of platform
2. Spatial data for any area	• The database will be spatially enabled using PostGIS/Openlayers • There will be functionality in the back end to re-project/

	translate data in to the correct coordinate system automatically based on SRID
3. View/edit/analyse data at different geographic scales (administrative units)	• There will be zoom in/out, pan and select functions included • Code will be developed to automatically analyse data for selected geographic areas and return to end user (i.e if the user selects a polygon and the variable that they want to analyse, only the data within that spatial extent selected will be returned) • There will be function to select different geographic scales (administrative units such as wards, local government districts, metropolitan areas etc.)
4. Point and Polygon data inclusion	• UDP will be able to display point/ line and polygon feature classes • User will be able to create new point/ line and polygon features and save in to database for use in the future
5. Need to Overlay data	• Layer display functions will be provided that enable user to overlay different point/line and polygon data
6. Ability to bring in data from other sources	• API calls will be permitted to pull in data from disparate sources • Data can be called in from different databases therefore not restricted to single database analysis or needing to have all data stored in central database directories
7. Wizard approach for end user	• Step by step wizard will be provided to guide user through the generation of information related to the different descriptors needed • This will be simple and understandable and will necessitate the user to select the data that they want to analyse
8. Information presented when geographic areas are selected	• The user will be able to select polygon and point data and display their attributes through pop out dialog boxes and in tables so that know the data that they have selected

Implementation and features of the UDP

Once the functionality/features were aligned with the end user needs and agreed with the end user community, the GIS development team developed the data model of the UDP and the user interface that would be within the final GIS component of the UDP. This was taken to the end user and agreed that it was suitable and included all the features that was necessary for enhancing security policy in their area. The functionality and features agreed were implemented in to the UDP in the following manner. A map window was created displaying the OpenStreetMap base mapping data which allows the user to provide data for multiple areas (in the example provided, the user can select the geography that they wish to understand, such as Northern Ireland, London or Poznan). The user can then select the geographic scale that they wish to understand also through a simple drop down menu based on the spatial data that they have within their database (such as Ward, LGD, Metropolitan Area). User has ability to overlay data using a layers tab. The user selects which layers that they wish to display (or turn off) and can have multiple layers displayed with the ability to change layer opacity. A simple step-wise wizard has been developed to guide the user through the selection and analysis of their data. This once again has been simplified at the front end (to avoid complex querying that a user might have to do if having to write the scripts themselves to do similar tasks in other software) to allow efficient analysis to be undertaken and aid in the understanding of the methodology used by the end user when supporting/informing decisions. The user has the functionality to use the mouse cursor to select the data that they wish to understand and click on that data. The interface then returns the data (through both a pop-out window for point data and in tabular format for polygon and point data. This includes data that has been pulled in through the API functionality created. The following annotated screenshots illustrate how the functionality agreed has been implemented within the UDP.

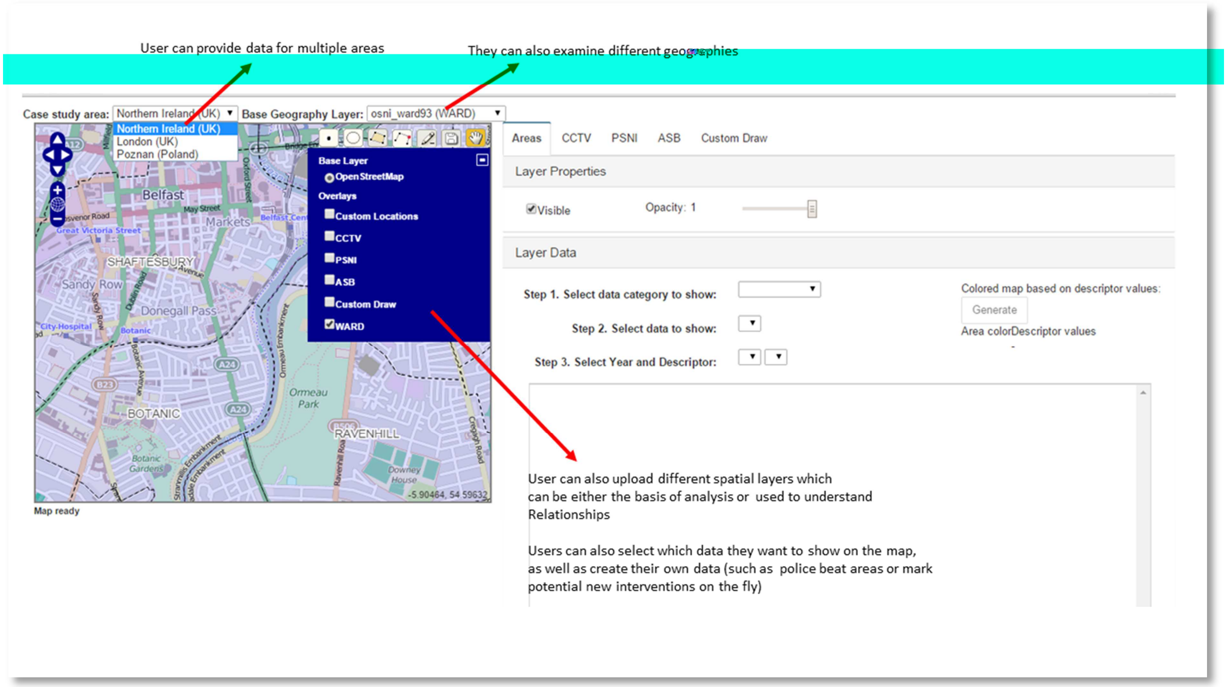


Figure 13: Annotated screenshot of implemented UDP functionalities

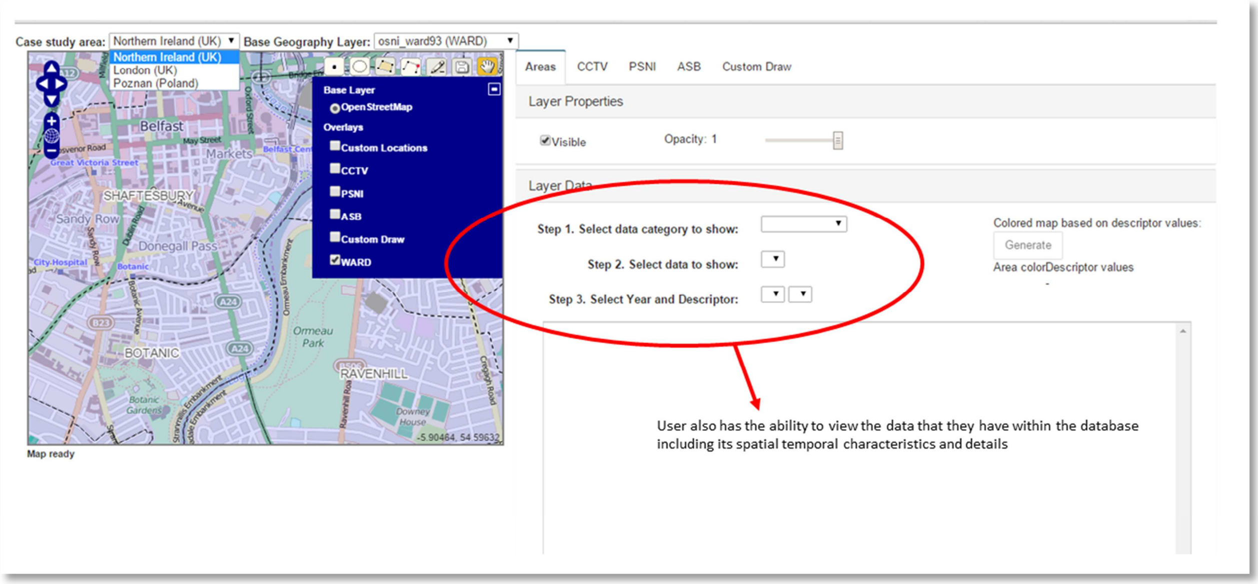


Figure 14: Annotated screenshot of implemented UDP functionalities

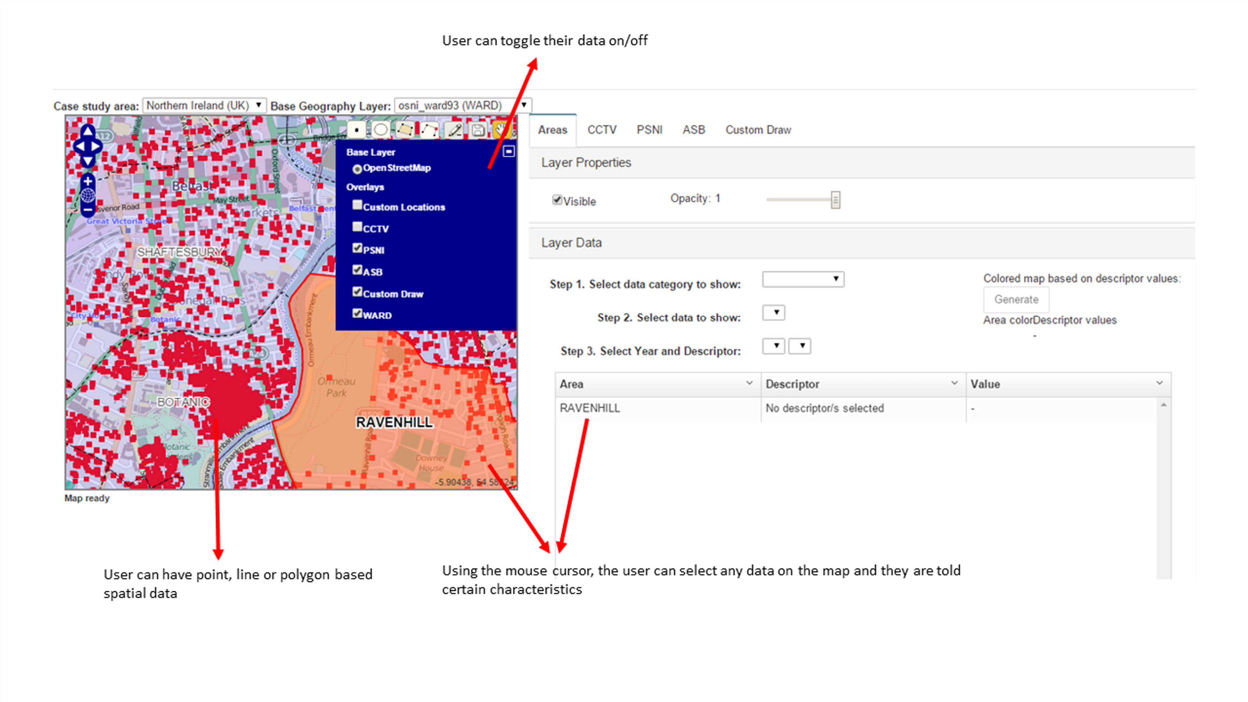


Figure 15: Annotated screenshot of implemented UDP functionalities

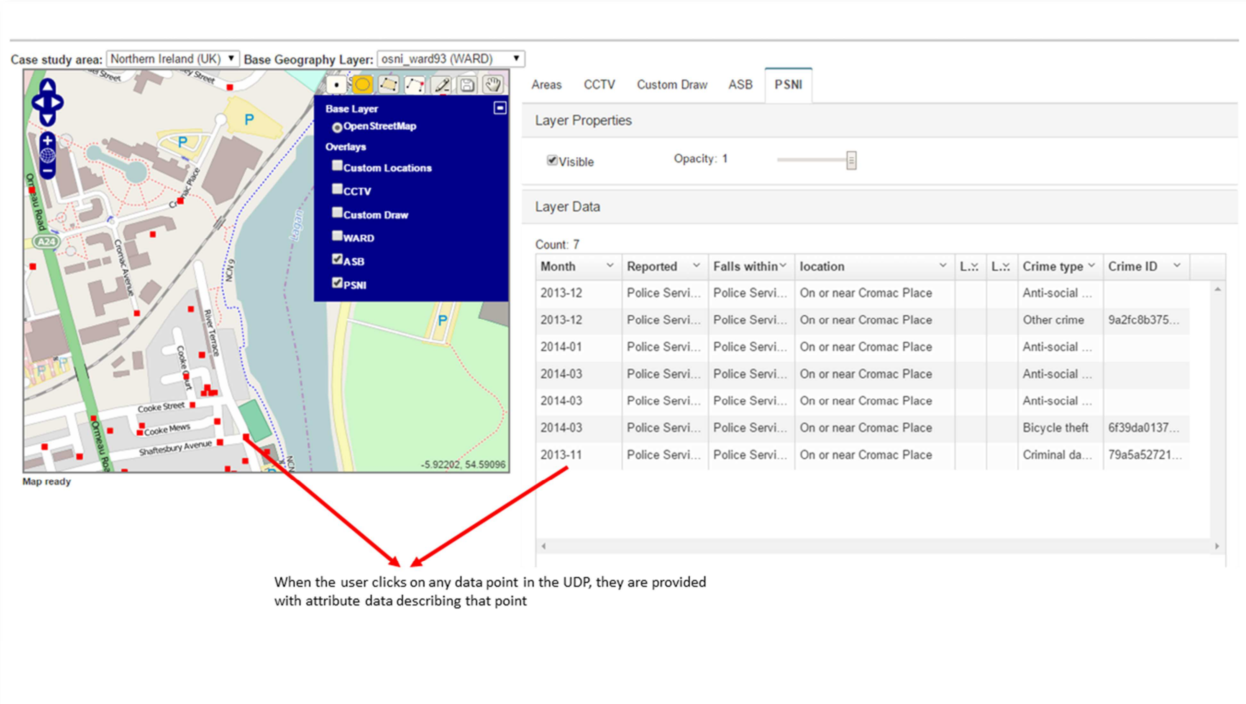


Figure 16: Annotated screenshot of implemented UDP functionalities

5.1.2. Stage 2: GIS Information and the UDP of the BESECURE Platform

The functionality and spatial modelling capabilities of the UDP enable the user to interrogate their data in alignment with the main questions that they need to answer (as identified previously). In this instance, the information model of the UDP enables the user to undertake both simple and advanced analysis which essentially facilitates the answering of the 'what, where, when and who' questions that the end user will be faced with in relation to understanding urban security issues. The features have been developed in line with the current state of the art in GIS for urban security and are based on an open source platform that allows for the addition of new features as and when they might be required. These GIS features have also been developed with the user in mind to enable them to make the GIS fit their data and not the data fitting their GIS.

In addition, the information that the modelling of the data provides has been developed in line with current thinking in the visualisation domain in that it provides easy to interpret information through interactive tables, graphs and maps. Consultation with end users in the urban security environment during the case study analysis indicated that they would need simple to use functionality (so that the user did not need to be an expert), visualisations must be in line with answering the questions that they need to answer and information must be presented in simple to understand tables and charts.

Requirements as identified by the end-user

As was done in Stage 1 end user engagement was used to agree on the information model required to enhance urban security decision making. This was again carried out in an iterative manner with end user needs identified and matched with features/ functionalities using the MoSCoW approach. The end user engagement highlighted that any GIS component of the UDP must be able to provide trend analysis (through choropleth or thematic mapping). These trends should be modelled spatially, temporally and categorically and the user should be provided with graphics, map based output and tables. Indeed, the user community asserted that they should be able to conduct custom area creation and analyse only the information that falls within that area. This is to enable the user to understand potential implications of resource allocation and whether they are directing such resources in to the right locations. Additionally, the user would be able to create as many custom areas as they like and save these areas in to the database for use in future analysis in an ideal situation. This would allow the user to understand if the interventions/ resources that they have put in place are working over-time and to delineate new areas in the future to understand if approaches are working or not

Other discussions highlighted that the user needs to be able to interrogate data at different geographic scales. Essentially they should be able to select the geographic scale at which they want their analysis to be conducted and the GIS only carries out analysis at this level. This is to provide the user with information at different administrative units (wards, postcodes, local government districts, municipalities etc.) rather than interrogating the entire spatial extent. In current software offerings, this was considered onerous on the side of the user and therefore must be simplistic. The end user group stipulated that there must be a radial select function that allows the user to interrogate the data at different radial distances. This is to allow the user to select any point on the map and create a buffer (or multiple buffers) around that point and only the information within that buffer will be returned to them.

The user group would also like to be able to dynamically change this distance through a simple to use slider or + and – buttons (the buffer and the slider/ distance change buttons should be labelled in meters) and the GIS automatically updates the numbers based on the distance. This allows users to understand how much crime is likely to fall within distances of proposed interventions. This buffer should be based on point and lines. This information is returned to the user through tabular output detailing the total numbers of records that fall within that point and also a breakdown of the information characteristics (based on the attributes of the data). Indeed, it was highlighted that this could be done through some sort of custom area custom area creation function that allows the user to draw their own areas on the map which can then be saved to the BESECURE database. The users should therefore be able to delineate their own area using the mouse cursor (they can create multiple areas) instead of being restricted to specific geographic scales. Additionally, the end users indicated that the understanding of hotspots would be essential to their analysts in the targeting of hotspots in their areas. In current provision, this again is difficult to understand and many felt that they did not have the expertise to conduct such analysis as proprietary software provision requires in-depth training. Therefore, the UDP should include a simple to use heat map function that allows the user to understand hotspots of point based data.

Finally, the end users specified that the UDP should include some sort of Early Warning System that allows the user to understand when certain issues might become a problem in the future (and when), as well as providing the user with an understanding of risk associated with certain objectives based on dynamic thresholds set by the user. This should be permitted through time series analysis that provides forecasts for any of the data (as long as spatio-temporal attributes are present over a certain length of time). The results that are generated should be in a very simple interface/ dialog box that shows exactly when issues may become problems in the future and alert the user to this.

Functionality and intention of the UDP

In order to meet the needs of the end users in the development of the information model, the GIS development team again went utilised a MoSCoW approach to align platform functionality and features with needs. These were agreed through an iterative process and the results of which are presented below. In utilising this approach, it ensured that the GIS components of the UDP were meeting the needs of the end user and enhancing the decision making process.

Need/Requirement	Features/ Functionality
9. Trend Analysis	• Choropleth map generation function that user can dynamically update with legend display in a graduated colour scale using natural breaks in data • Tabular display of trends for different spatial scales providing summary statistics
10. Heat Map/ Hotspot function	• Kernel density based heat map tool that allows the user to derive raster based heatmaps for point based data • User can alter the bandwidth of the search criteria/cell size for identification of densities • User can change opacity of heat map • User can change radius size and intensity of heatmap display
11. Early Warning System	• User can create trend lines of time-series data • User can forecast data (to understand what the future might look like in relation to certain issues) • User can set their own thresholds in relation to crime rates which are then used to act as an early warning system on the graphs • User will have a dialog box detailing when thresholds have been reached/ or are close to being reached in relation to issues such as crime rates • User can present data in different graphic formats (scatter plot, line graph and bar chart)
12. Custom Area Creation and Analysis	• User will have function to digitise their own area and multiple areas (if needed) • User will be able to save these areas in to the default database

	and access in future if needed • When the area has been digitised, the modelling framework will only analyse the data that falls within the custom area(s) created and return this information in the form of graphics, tables and map displays
13. Radial distance function	• User will be able to delineate a specific radius around any point on the map • User will be able to increase/decrease the size of this radius • Modelling framework will only return information within that radius to end user through graphics, tables and map displays
14. Tabular/Graphic Display	• The user will be able to toggle between graphs and tables of the analysed information to aid in the understanding of complex data analysis that may involve large datasets
15. Dynamic Query and Update	• The use will be able to filter information/data based on different criteria, as well as search for specific time periods • UDP will automatically update the results presented back to the end user with little interaction from the user

Implementation and features of the UDP

Once the features/ functionalities were agreed with the end user, the GIS development team of the UDP created the components of the agreed specification. Indeed, the first component developed was that of the heat map which is simple to generate and requires the user to tick a box to indicate if they wish to create a heat map of the data. The user can then alter the size of the density search as well as the bandwidth. The second function developed was the Early Warning System. The user now has the ability to be alerted when data is reaching predefined thresholds as well as understand when issues may start to become problems in the future through forecasts. The next need met was that of the custom area creation and radial distance function. In the platform, the user now has the ability to delineate their own areas, save these to the database and return only the information within these areas. The radial select function allows the user to set/edit the radius size and generate a radius around any point on the map. Again, only the information within the radius is returned to the end user. The other functions/features identified above were also developed. The following screenshots show these features implemented in the UDP.

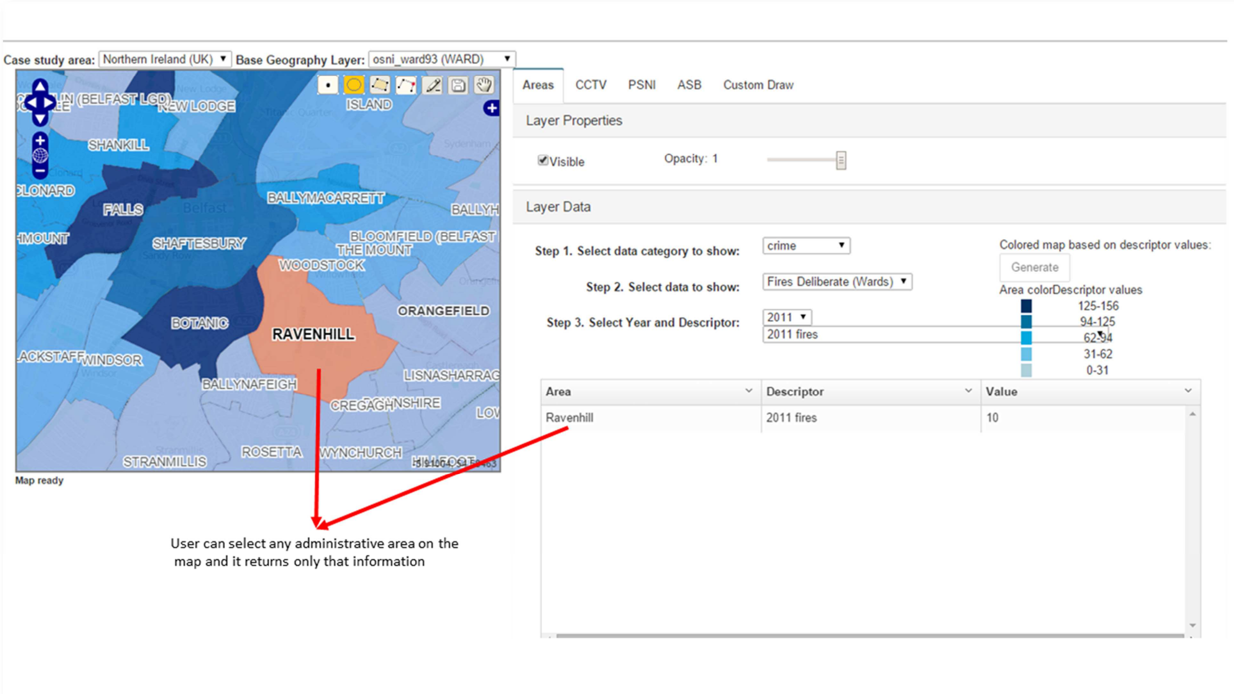


Figure 17: Annotated screenshot of implemented UDP functionalities

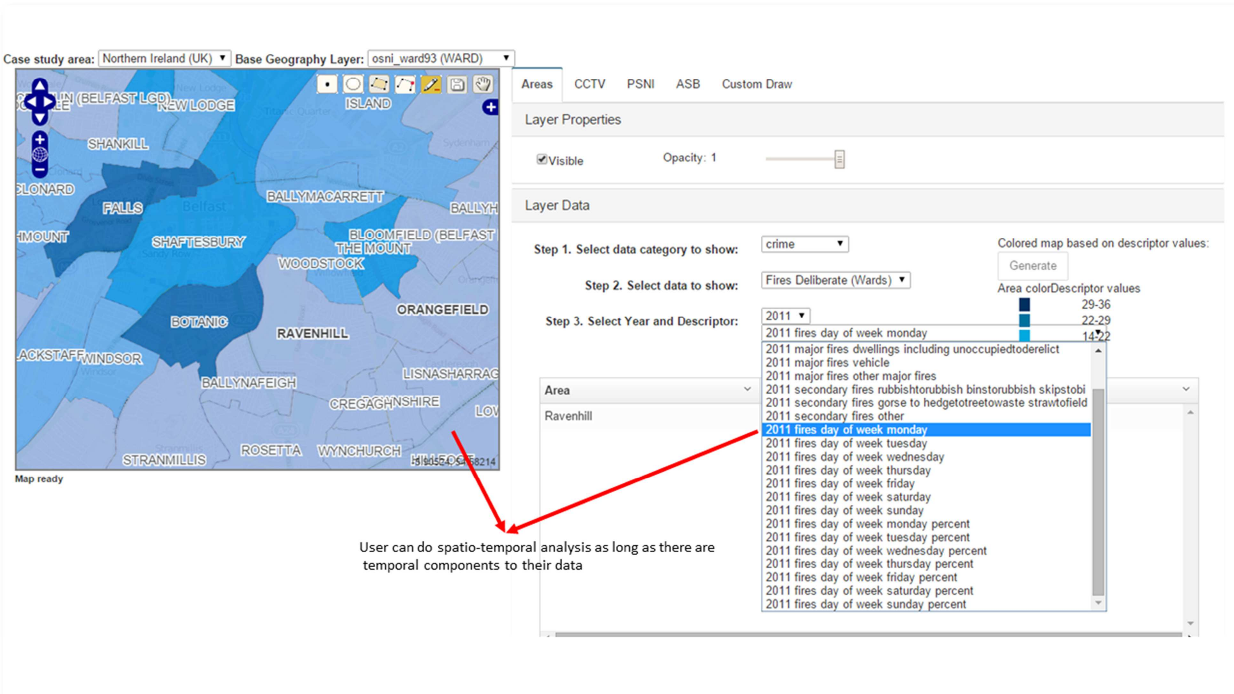


Figure 18: Annotated screenshot of implemented UDP functionalities

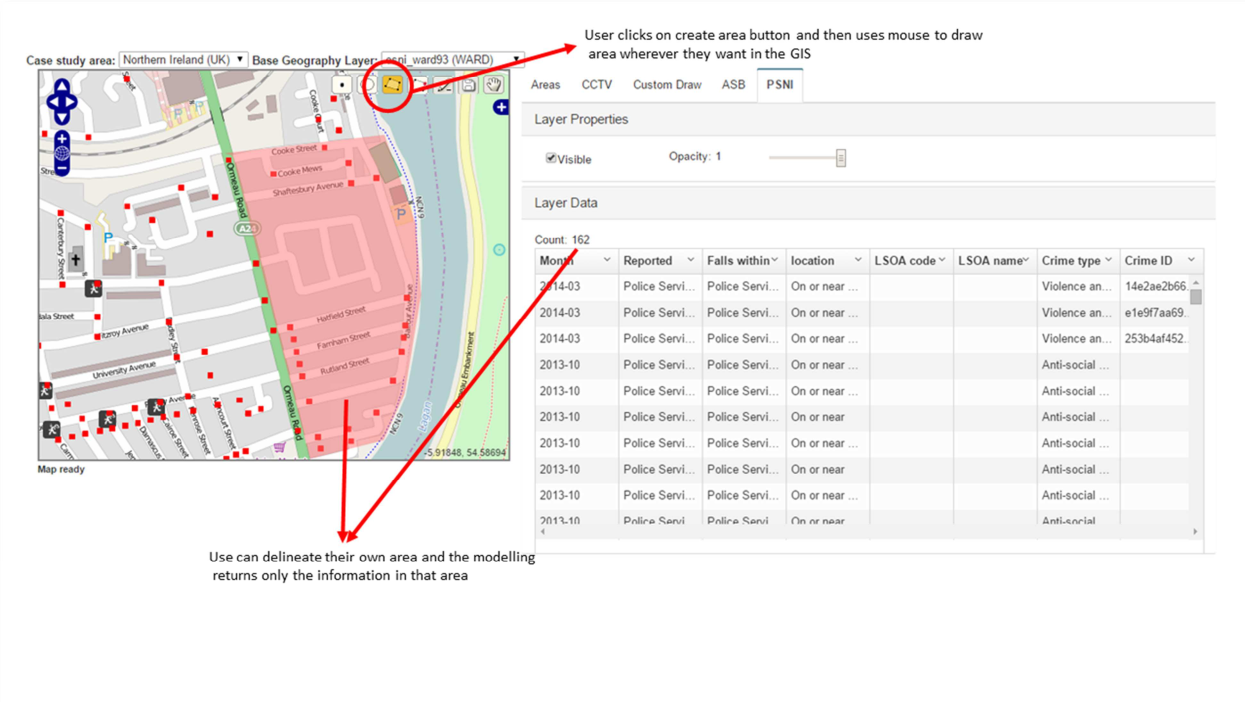


Figure 19: Annotated screenshot of implemented UDP functionalities

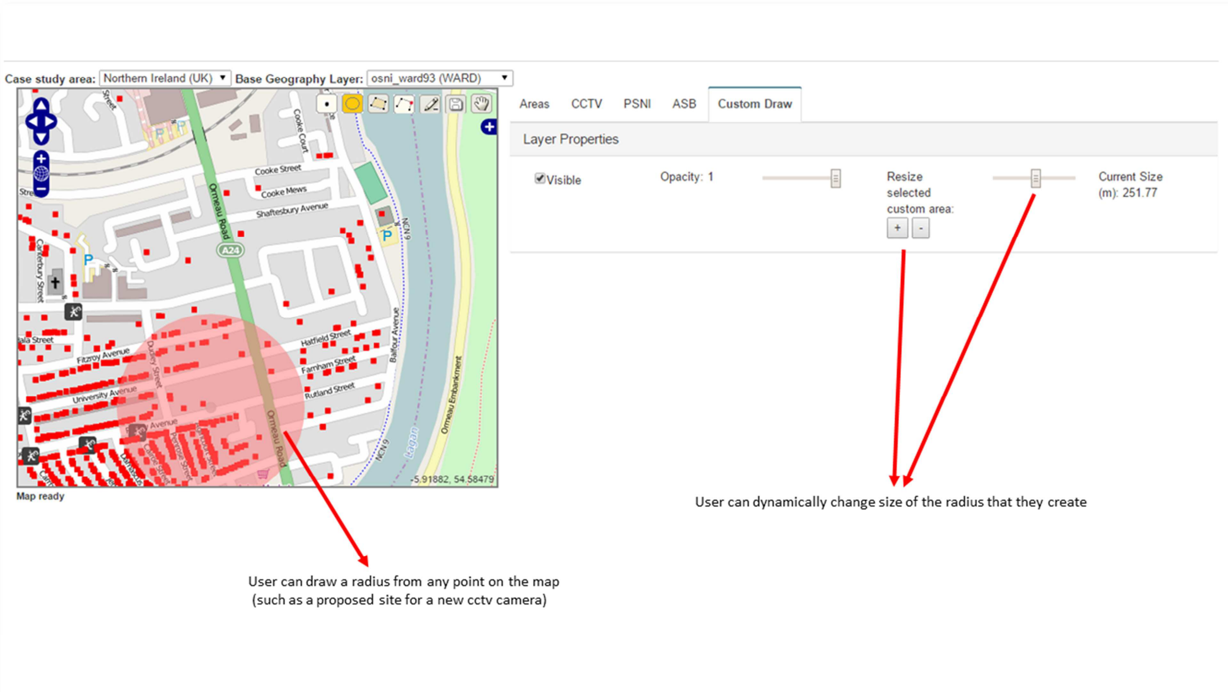


Figure 20: Annotated screenshot of implemented UDP functionalities

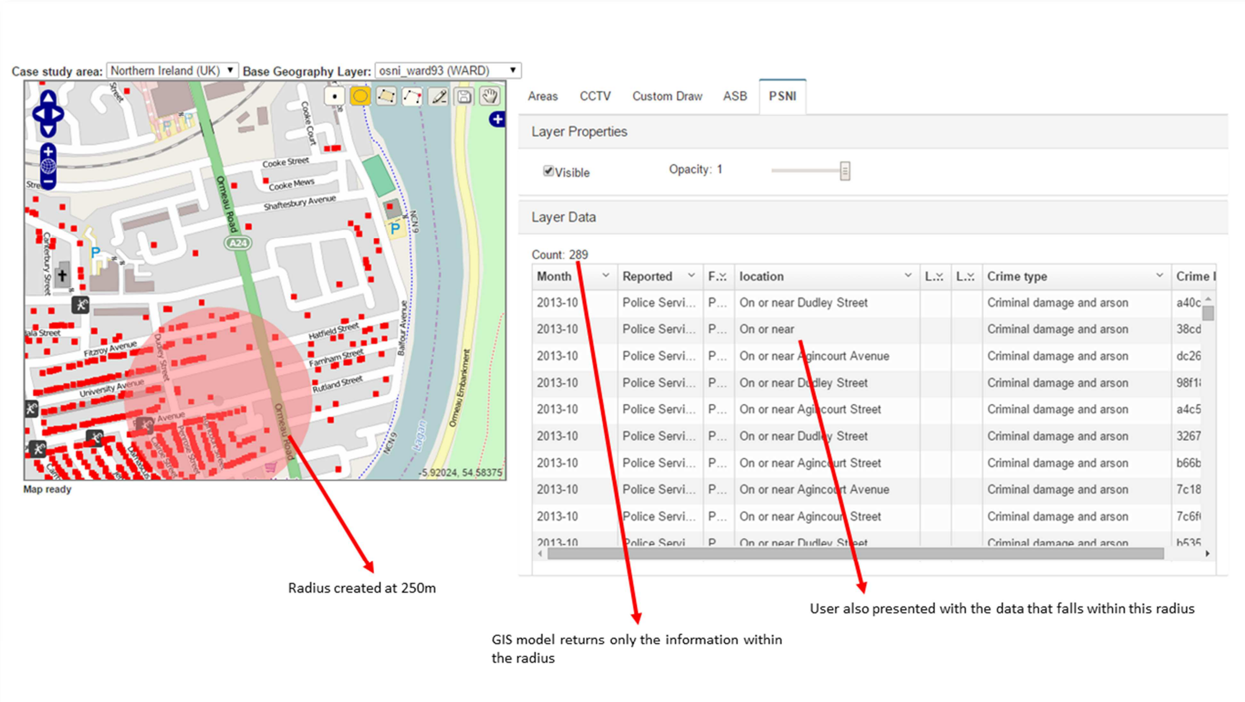


Figure 21: Annotated screenshot of implemented UDP functionalities

Figure 22: Annotated screenshot of implemented UDP functionalities

5.1.3. Stage 3: GIS knowledge and the UDP of the BESECURE Platform

In order for the urban security professional to be able to use the understanding that they have received from the GIS information in informing decisions and supporting policy, they must structure their evidence in a manner that is consistent with the objectives of the decisions that they want to inform and the policies in which they want to support. They must use the information to present a story that clearly indicates their findings and is easy to follow by the user. This must be based on the best available information, it must be up to date and meaningful, without that, it is meaningless and the knowledge in which the end user has developed will be limited. In the context of the decision making process, the wider BESECURE platform provides the mechanism in which policy makers can inform and support the decisions that they make. In this vein however, it must be remembered that the UDP and more specifically the wider BESECURE platform, do not automate decisions, but instead act in a semi-automatic manner as the interpretation of approaches and outcomes must be on the end user side. In essence, they can use the BESECURE platform in its full capacity (Data to Information to Knowledge to Action to Outcome) to build up their evidence base for deciding the best course of action in particular areas, but they must use their professional judgement in allocating resources, deciding on interventions and their associated impacts. The BESECURE platform is not designed to remove the end user in decisions but instead empower them with the right information at the right time.

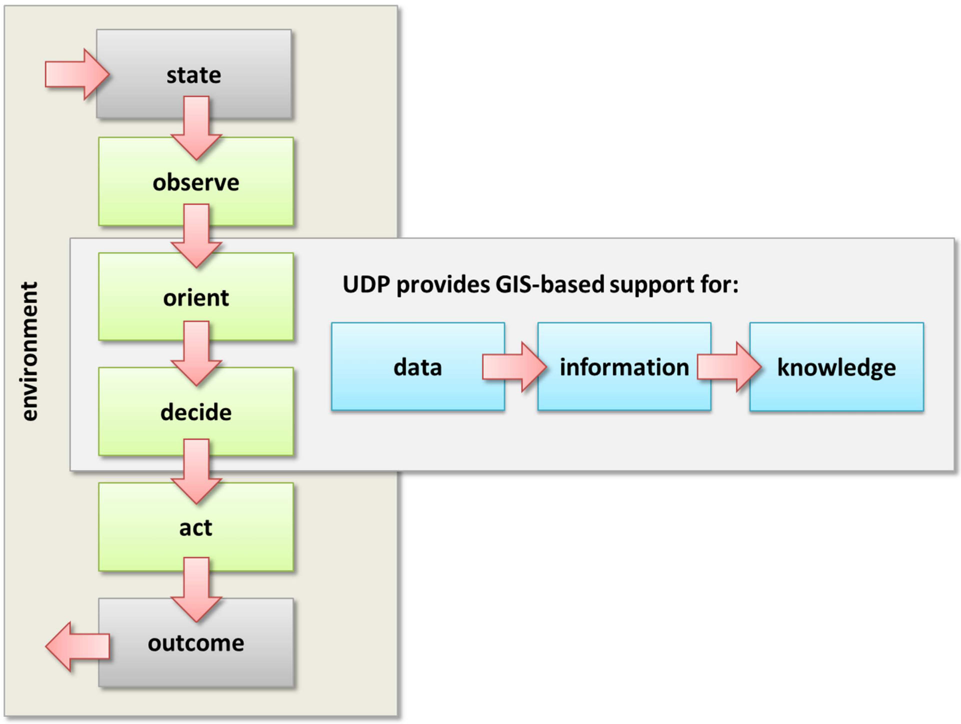


Figure 23: The position of the UDP in a typical decision making cycle

In the bigger picture of the decision making process, the UDP is central in both the generation of information for informing decisions and also enabling decisions to be evaluated. These fit at either end of the decision making spectrum utilised in the development of the BESECURE platform.

The UDP provides the end user with better knowledge through each of the steps of this process and as a consequence provides the ability to be more effective and efficient in the communication of information, the presentation of the evidence base used and the understanding of where interventions have or have not worked in areas. Knowledge in the BESECURE platform is derived from each of the developed platforms (UDP, IP and PSP). Indeed, the knowledge put forward by the UDP is essential in the utility of the IP and PSP in that it plays a fundamental role in demonstrating what the key issues are (and where) in an urban context. The user can then utilise the information gained from the UDP to understand what the key issues are; once these are identified, the user can then go to the IP and understand what other areas have similar issues as well as a clear knowledge of what has or has not worked in those areas. They can then use the knowledge gained from the UDP and IP to inform the development of the PSP – the component which the end user can use to support decisions. This is how the wider BESECURE platform can use the knowledge gained from the UDP to provide a full decision making service.

Of course, the UDP can also be used in isolation in that enhanced situational awareness can be gained through the structured information obtained through presenting the data in an easy to understand manner. Indeed, in its simplest function, the UDP provides the end user with knowledge of the data that is available to them in a centralised repository rather than in disparate sources, thus allowing for a more holistic approach to developing the information that will be enhance the knowledge of the end user. They can use this knowledge to inform actions (e.g. where interventions need to be deployed (physical and human), where resources need to be allocated, what monitoring actions need to be instated?) and ultimately go back to the UDP in the future to understand the effects of interventions that were implemented (has the intervention caused displacement? has the intervention achieved its objectives?).

6. Enhancing Urban Security Decision Making with GIS

In the context of the development of the UDP, it was found that end user engagement is essential in defining the functional specification required to enhance urban security decision making. Consultation was needed to ensure that the development process enabled a product that fitted the needs of the urban security industry and was simple to use and easy to understand. Urban security is complex, challenging and can impact on a significant number of people. Due to this, security issues can have serious cascading effects in that most things are influenced by feeling of safety, perception of areas and reporting through different media channels. This therefore requires partnership working between many different statutory agencies such as local authorities, central government, police, housing providers, health providers, national crime agencies and others. Given the extensive partnership working and the complexity involved, there needs to be well informed joined-up approaches developed to manage, respond to and prevent urban security issues having major impacts.

Leading on from this, it is important to have regular monitoring and management of issues and approaches, to keep these under review and to develop new and innovative approaches where needed in order to maximize the potentiality of the local economy, the urban vitality and the overall attractiveness of an area. In order to deliver this, there must be a mechanism for each partner to see the ‘bigger picture’ and to have the same information (where possible) available. Where this is not available, decision making and policy support will be potentially inhibited. GIS, and as exemplar the BESECURE platform, facilitates this bigger picture understanding in the urban security environment. This is achieved by providing the end user with the ‘right information at the right time’. Indeed, GIS has the ability to turn data in to information. This ability allows the user to understand trends relating to the issues, the impact that certain approaches may have had in the past (such as displacement) and the areas where problems are most defined.

The information that GIS can provide urban security professionals can come in a number of different forms. These all relate to values associated with location, which turn the data in to spatial information. Spatial information describes the ‘where’ question in decision making and links this to the ‘what’, ‘when’ and ‘who’ answers. GIS provides urban security decision making with the ability to structure analysis based on different geographic scales, thus allowing the user to understand how their area compares with others, to understand localised issues within bigger geographies and to how contiguous areas inter-connect with their area of interest. It allows users to share information between each other and disseminate in an easy to understand manner. Urban security decision making and policy support is contingent on joined up approaches so that there is no duplication of effort, cost and intervention. This can be easily avoided, if a common operating picture is available. The BESECURE platform provides this.

Furthermore, GIS allows the end user to make spatial forecasts of the data which can act as an early warning system for understanding the potentiality of problems occurring in the future. Indeed, it also allows the end user to set thresholds for different variables (such as crime rates) and when these thresholds are reached/ broken, hotspots are created to show which areas are most susceptible to these problems. A further benefit is that it allows near real time (there will always be a lag) information to be analysed which in turn enables more timely decisions to be made. Indeed, it also enables the analysis of spatio-temporal data to provide information showing issues based on type, location and temporality. This allows the user to understand the demand within their system (based on issues) and to act as a mechanism for justifying resources and capital and recurrent spent.

7. References

Ballas, D., Clarke, G.P. (2000), GIS and microsimulation for local labour market policy analysis. Computers, Environment and Urban Systems, 24, 305-330.

Bowers, K. and Hirschfield, A. (2001) Introduction. In A. Hirschfield and K. Bowers (eds.) *Mapping and Analysing Crime Data* (pp1- 8). Taylor & Francis: London

Burrough, P.A. (1986), Principles of Geographic Information Systems for Land Resource Assessment. Monographs on Soil and Resources Survey No. 12, Oxford Science Publications, New York.

Burrough, P.A. (1986), Principles of Geographic Information Systems for Land Resource Assessment. Monographs on Soil and Resources Survey No. 12, Oxford Science Publications, New York.

Cairns, S. (1998), Promises and problems: Using GIS to analyse shopping travel. Journal of Transport Geography, 6(4):273–284.

Chainey, S. and Ratcliffe, J. (2005) *GIS and Crime Mapping*. Wiley: Chichester.

Clarke, K.C. (1995), Analytical and Computer Cartography. Edited by K. C. Clarke. 2nd ed. Prentice Hall Series in Geographic Information Science. Upper Saddle River, NJ: Prentice Hall.

Dent, B.D. (2000) Brief History of Crime Mapping. In L.S. Turnbull, E.H. Hendrix and B.D. Dent (eds.) Atlas of Crime: Mapping the Criminal Landscape (pp. 1-21). Oryx Press: Phoenix, AZ.

Douglas, B. (2008), Selecting a GIS, in Achieving Business Success with GIS, John Wiley & Sons, Ltd, Chichester, UK.

Dueker, K.J. (1979), Land resources information systems: a review of fifteen years' experience. GeoProcessing 1 (2):105-128

Elwood, S. (2006), Critical Issues in Participatory GIS: Deconstructions, Reconstructions, and New Research Directions. Transactions in GIS, 10: 693–708.

Feltynowski M. (2013), The Use Of Geographical Information Systems In The Urban Communes Of Łódź Metropolitan Area Management Research And Practice Vol. 5 (1) pp: 5-13.

Gilfoyle, I., Thorpe, P. (2004), Geographic Information Management in Local Government. London, CRC Press.

Goodchild, M.F. (2009), Geographic information systems and science: today and tomorrow. Annals of GIS 15(1): 3–9. [483]

Haque, A. (2001), GIS, Public Service, and the Issue of Democratic Governance. Public Administration Review, 61: 259–265.

Heuvelink, G.B.A., Burrough, P.A. (2002), Developments in statistical approaches to spatial uncertainty and its propagation, International Journal of Geographical Information Science, 16:2, pp. 111-113.

Kennedy, M. (2009), Introducing Geographic Information Systems with ArcGIS -- A Workbook Approach to Learning GIS, Second Edition, published by John Wiley and Sons, 612 pp.

Kidman, G., Palmer, G. (2006), GIS: The Technology is There but the Teaching is Yet to Catch Up, International Research in Geographical and Environmental Education, 15:3, 289-296.

King, M. A., Arnette, A. N. (2011), Integrating Geographic Information Systems in Business School Curriculum: An Initial Example. Decision Sciences Journal of Innovative Education, 9: 325–347.

Kistemann, T., Dangendorf, F., Krizek, L., Sahl, H.G., Engelhart, S., Exner, M. (2000), GIS supported investigation of a nosocomial Salmonella outbreak. International Journal of Hygiene and Environmental Health; 203: 117–26.

Kohsaka, H. (2001), Applications of GIS to urban planning and management: Problems facing Japanese local governments. GeoJournal 52: 271-280.

Longley, P., Goodchild, M.D., Rhind, D. (2001), Geographic Information Systems and Science, Wiley.

Longley, P.A., Goodchild, M.F., Maguire, D.J., Rhind, D.W. (eds.) (2004), Geographical Information Systems: Principles, Techniques, Management and Applications (Abridged edition). Hoboken, NJ: Wiley.

Lwin, K.K., Estoque, R.C., Murayama, Y. (2012), Data Collection, Processing and Applications for Geospatial Analysis. In: Murayama, Y., Ed., Progress in Geospatial Analysis, Springer, Tokyo.

Maantay, J., Ziegler, J. (2006), GIS for the Urban Environment. Redlands, CA, ESRI Press. 620 pp.

Martin, D.J, Longley, P.A. (1995), Data sources and their geographical integration. In P. Longley, G Clarke (eds.) GIS for Business and Service Planning. New York, John Wiley, pp. 15-32.

Masser, I. (2007), A Doubly Weighted Approach to Urban Data Disaggregation in GIS: A Case Study of Wuhan, China. Transactions in GIS. 11:197-211.

McIlhatton, D., McCord, M., Haran, M. Davis, P. (2013), Geographical Information Systems and the Importance of Location: Integrating Property and Place for Better Informed Decision Making. In: A Primer on Property Tax: Administration and Policy. (Eds: McCluskey, William, J., Cornia, G.C. and Walters, L.C.), Wiley-Blackwell, pp. 339-357.

Meeks, W.L., Dasgupta, S., (2004), Geospatial information utility: an estimation of the relevance of geospatial information users, Decision Support Systems 38: 47-63.

Newburn, T. (2013) *Criminology.* Routledge: London.

Paynich, R. and Hill, B. (2004) *Fundamentals of Crime Mapping*. Jones and Bartlett: Sudbaury, MA.

Pick, J.B., Azari, R. (2011), A Global Model of Utilisation of Technology based on Governmental, Social, Economic, and Business Investment Factors. Journal of Management Information Systems, 28(1):51-85.

Radke, S.L., Hanebuth, E. (2008), GIS Tutorial for Homeland Security. ESRI Press. Redlands, California.

Ren, F. (1997), A training model for GIS application in land resource allocation. ISPRS Journal of Photogrammetry and Remote Sensing. Volume 52, Issue 6, December 1997, Pages 261–265.

Richards, J.A. (2006), Remote Sensing Digital Image Analysis: An Introduction, 4th Edition. Springer-Verlag. Berlin.

Thrall, I.G. (1998), GIS Applications in Real Estate and Related Industries. Journal of Housing Research, Volume 9, Issue 1. pp. 33-60.

Tomlinson, R. (2007), Thinking about GIS: Geographic Information System Planning for Managers. ESRI Press. Redlands, California.

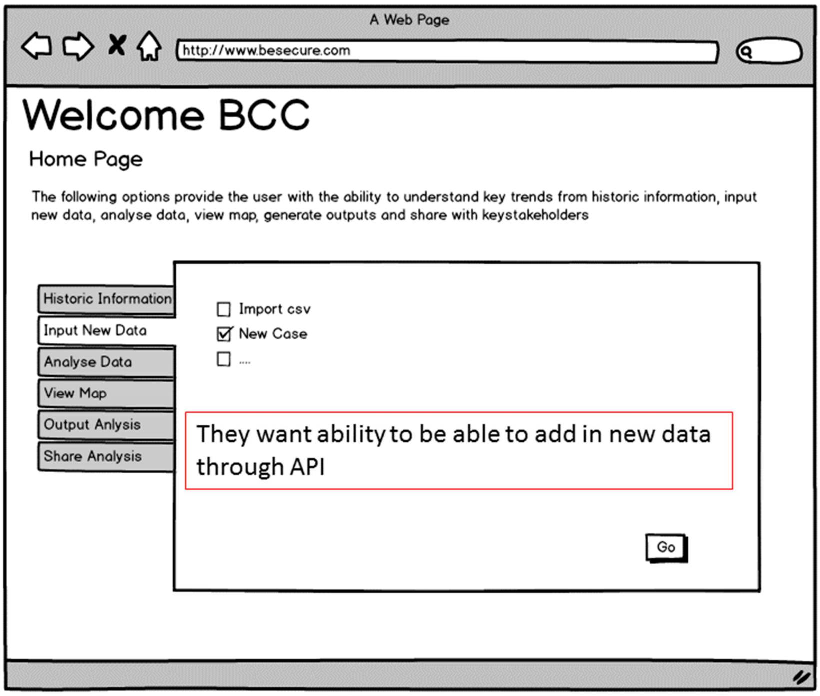
Wei, L, Qian, Q., Wang Z.Q., Glass G.E., Song S.X., Zhang W.Y., Li X.J., Yang, H., Wang, X.J., Fang, L.Q, Cao, W.C. (2011), Using geographic information system-based ecologic niche models to forecast the risk of hantavirus infection in Shandong Province, China. Am. J. Trop. Med. Hyg. 84(3): 497-503.

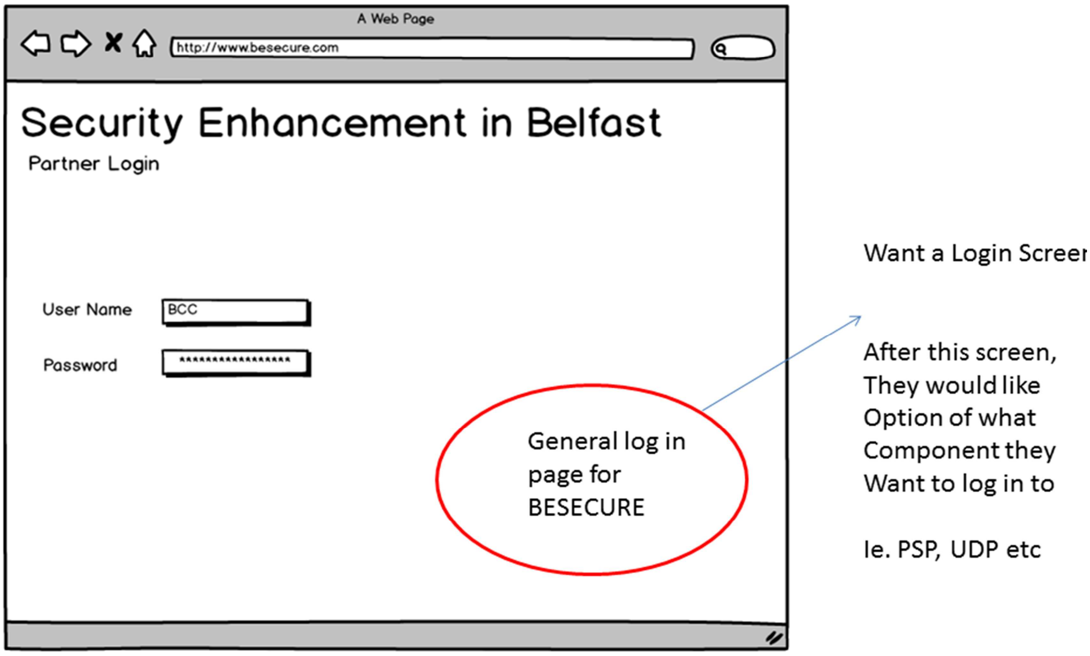
Wofford, L.E., Thrall, I.G. (1997), Real Estate Problem Solving and Geographical Information Systems: A Stage Model of Reasoning. Journal of Real Estate Literature. (5), pp. 177-201.

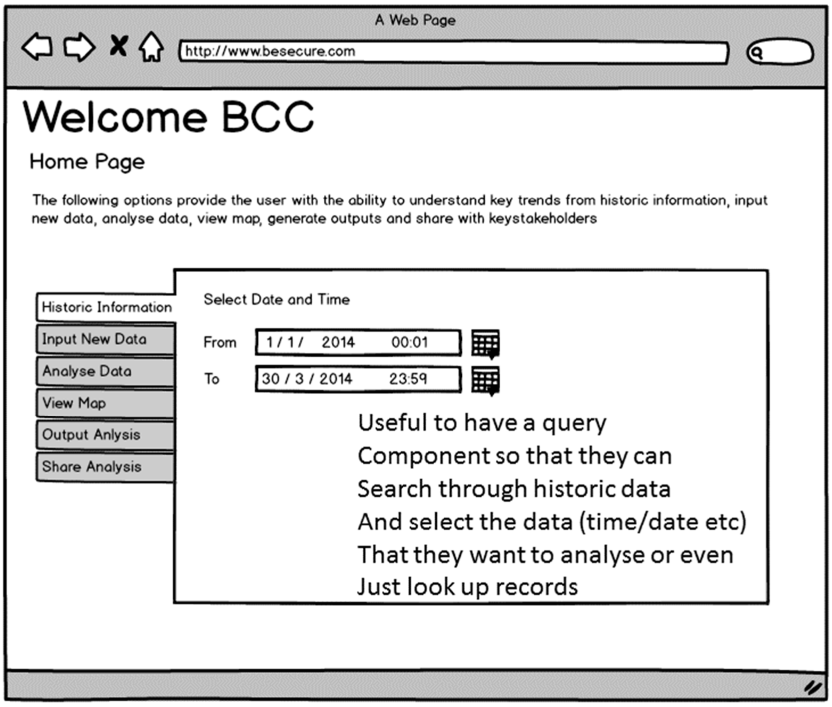
Zhang, H., Suresh, G., Qiu, Y. (2012), Issues in the aggregation and spatial analysis of neighborhood crime. Annals of GIS, 18(3): 173-183.

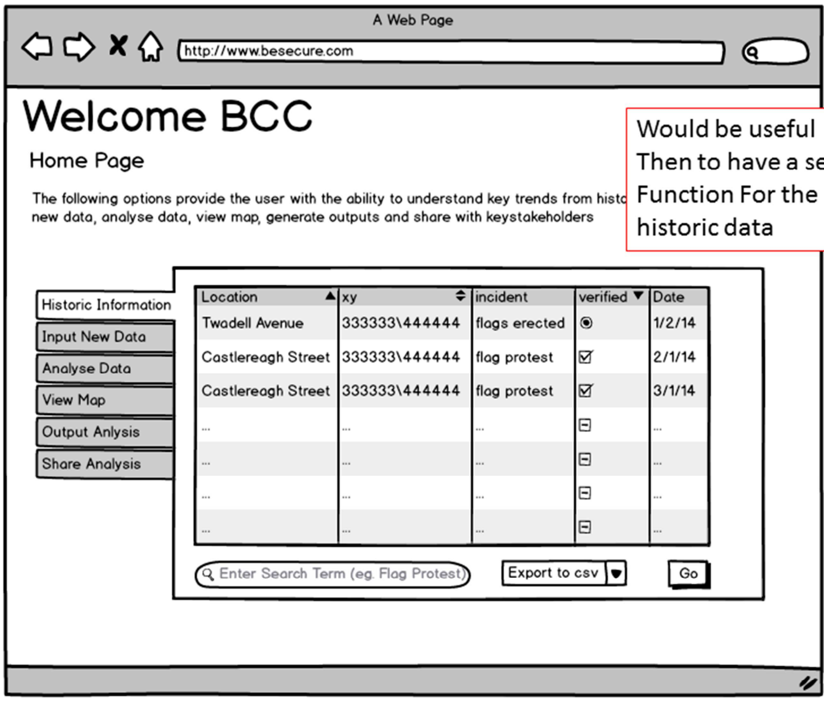
Annex: Wireframe examples from UDP design sessions

The figures in the following pages are results from UDP requirements and design sessions with end-users. The wireframes represent desired functionalities from the end-users perspective and became the foundation for the design of the UDP within the BESECURE platform.

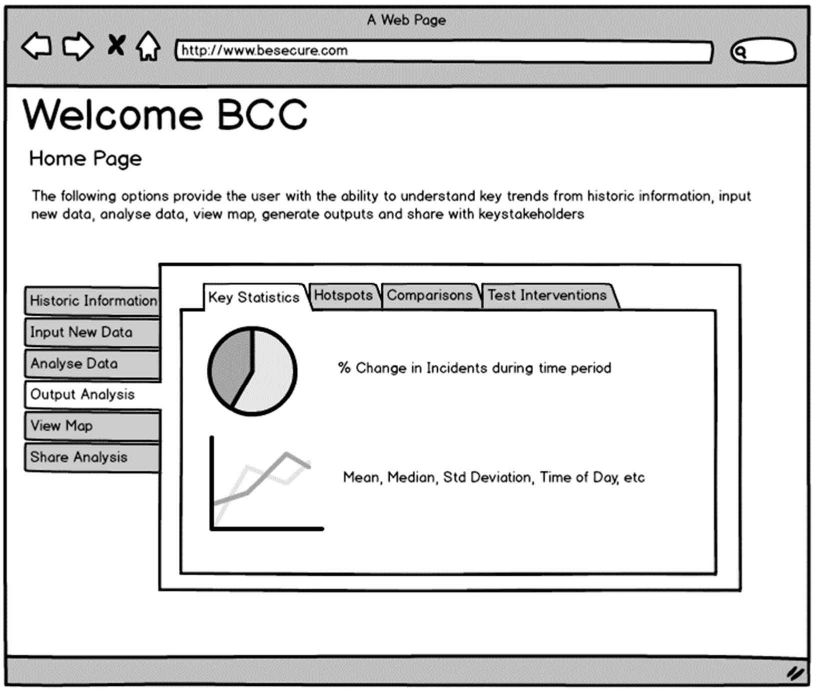



A Web Page
http://www.besecure.com
Security Enhancement in Belfast
Partner Login
User Name
BCC
Password
General log in page for BESECURE
Want a Login Screen
After this screen, They would like Option of what Component they Want to log in to
Ie. PSP, UDP etc

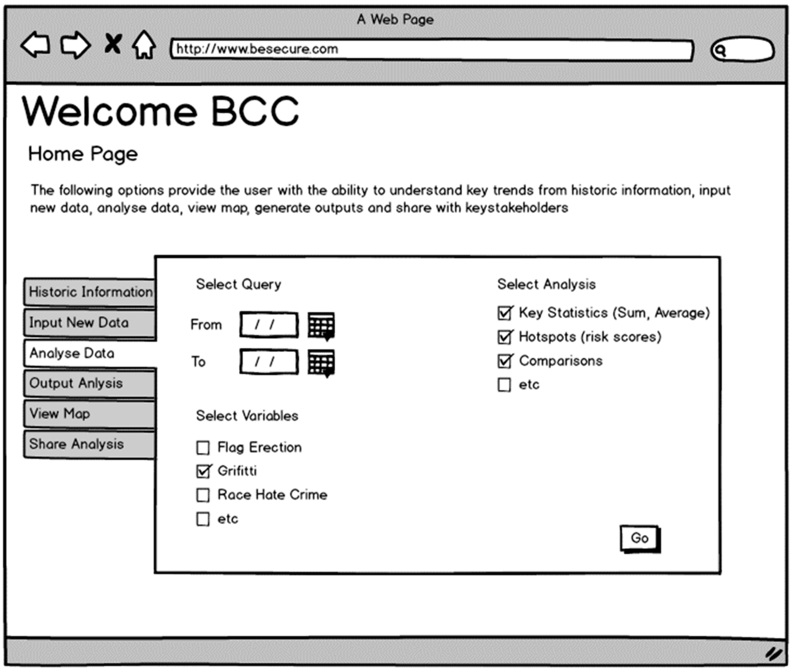

A Web Page
http://www.besecure.com
Welcome BCC
Home Page
The following options provide the user with the ability to understand key trends from historic information, input new data, analyse data, view map, generate outputs and share with keystakeholders
Historic Information
Input New Data
Analyse Data
View Map
Output Anlysis
Share Analysis
Select Date and Time
From
1 / 1 / 2014 00:01
To
30 / 3 / 2014 23:59
Useful to have a query Component so that they can Search through historic data And select the data (time/date etc) That they want to analyse or even Just look up records



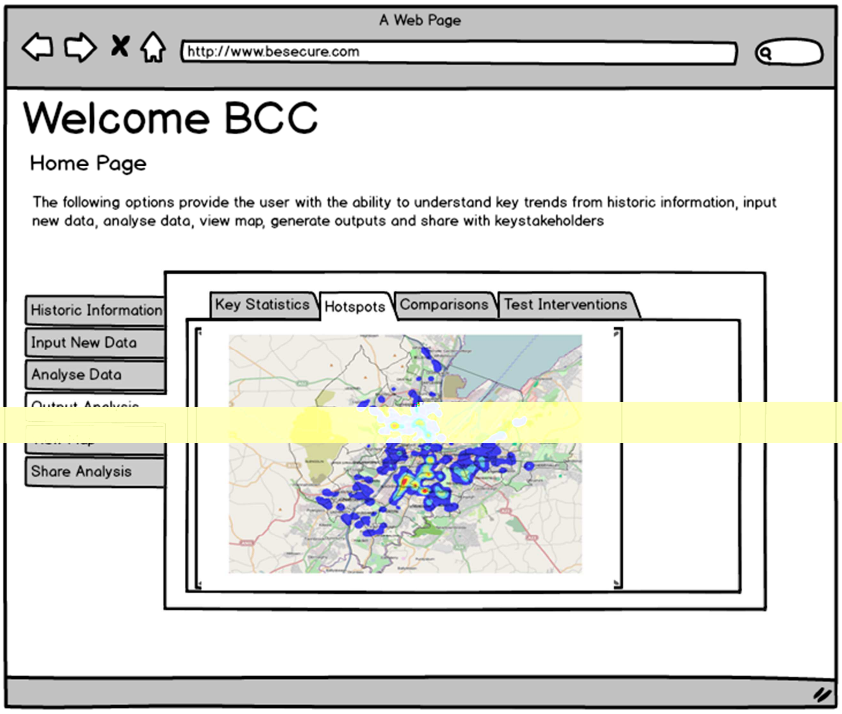
Would be useful Then to have a search Function For the historic data



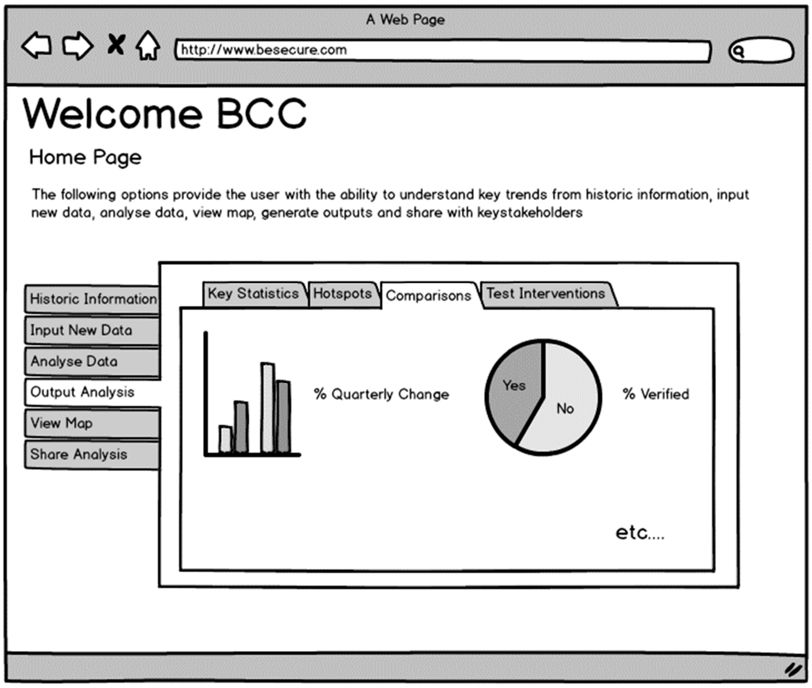
Want a key statistics summary for their area of interest and how it compares over time and against different areas



Should have an analyse data function which allows for different analysis Types (by time, variables, analysis types, areas etc)



Want to see hotspots of problems (by density, multi-criteria analysis etc) and how they relate to certain things… such as proposed interventions/ schools etc



Want ability to measure performance if possible

Want to be able to add in different layers such as population and analyse crime etc by density/ Deprived areas/proximity to facilities such as CCTV/ Police Stations/ Parks etc etc

Want to be able to define own areas and radius to only capture crime/issues
Within that area (as well as be able to select geography (such as ward from dropdown menu)