



**The role of Geographical Information System (GIS) in spatial
planning: Integrating Land Use and Transport Planning,
Scotland**

TP53001: Dissertation

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Master of Spatial Planning and Geographical Information System**

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Abstract

Integrated land use and transport systems involve aligning transport infrastructure and services with land uses. The connection between land use and transport systems have been well researched on the influence that one can have on the other. Land use has a big influence and impact on the way transport systems are planned and managed in large cities.

The aim of this study was to investigate the role of geographical information systems (GIS) in spatial planning in Scotland with the focus on integrating land use and transport planning. To achieve the aim of this study, two objectives were covered such as profiling different uses of GIS in integrating transport and land use planning in Scotland; and identifying and evaluating barriers affecting GIS use and opportunities for more effectively integrating transport system and land use in Scotland by using GIS. To achieve these objectives, a mixed methods approach with two inter-related elements was used and this includes documents analysis and questionnaire survey. The results from those two methods were put together for the overall analysis of the level to which GIS is being used in Scotland in integrating land use and transport planning.

The findings have shown that GIS is being used in geospatial analysis; map production; monitoring; integrated land use and transport planning; visualization; data management; data collection; transport network analysis; traffic management; transport accessibility analysis; land use and transport interaction modelling and policy development, assessment and decision making of proposals.

Furthermore, it has been found out that advanced data structure, as an opportunity in using GIS, is the key success in the integration of land use and transport planning. However, after exploring the barriers that affect the utilization of GIS in land use and transport planning, the results are showing that the applications of GIS still confront many barriers, including: lack of awareness; lack of communication; entry cost; lack of required software; insufficient data sources; lacks of computing power; usability; data accessibility and availability are the common barriers encountered in any planning process. Therefore, despite all of these applications of geographic information systems evidenced by this current research, these barriers to the use of GIS show that the potential of GIS as a planning tool is not being fully exploited in the domains of integrating land use and transport planning in Scotland.

Finally, some recommendations have been drawn up for the sake of Scotland strategic development planning process and these include: the interaction of accessibility, transport

and the development strategy should be considered early in the planning process; land allocations should take account of transport opportunities and impacts, relating settlement strategy to the capacity of the transport network and identifying where economic growth or regeneration requires additional transport infrastructure, including transport assessments and travel plans; local plans should express the relationship between development proposals and transport at a local level in accord with the policy contained in the Scottish Planning Policy; due to some barriers from users, GIS training are required to meet demands for different level of users; transportation planners should use integrated land use and transport GIS models to forecast how future travel demand will be affected by land use; transportation agencies should develop mechanisms to engage with local land planning processes as a way to bridge the divides created by divisions of responsibility for transportation and land use. This will be one of the responses that can help to strengthen linkages between transportation and land use.

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Glossary of Terms / List of Abbreviations

Term	Explanation / Meaning / Definition
GIS	Geographical Information System
LATIS	Land-use and Transport Integration in Scotland
LTS	Local Transport Strategy
NTS	National Transport Strategy
RTS	Regional Transport Strategy
SEStran	South East Scotland Transport Partnership
SNAPTA	Spatial Network Analysis of Public Accessibility
TACTRAN	Tayside and Central Scotland Transport Partnership

Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Contents of this proposal should not be produced without the permission of the author and the institution (University of Dundee).

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1 INTRODUCTION

1.1 Background

The development of Geographical Information Systems (GIS) began in the early 1960s and rapidly advanced since the late 1980s. Over the past 50 years, GIS technology has been increasingly introduced to a wide range of sectors. In addition to planning agencies and local governments, many other sectors have been involved, such as social science, transportation, earth science, military, agriculture, environmental protection, etc. The integration of GIS technology in traditional geospatial tasks provides a number of optimal solutions for individuals/groups, e.g. policy developers, decision-makers, managers, researchers, and allows the performance of existing tasks cheaper, faster and more completely better (Hao, et al., 2014).

Integrated land use and transport systems involve aligning transport infrastructure and services with land uses, co-location compatible land uses and higher densities in accessible locations and prioritizing resourcing for public transportation over new road construction and making it central to spatial planning and design at all physical scale (Planning Institute of Australia, 2008). Land use and transportation are inextricably linked. It is often a struggle to understand and respond to this linkage in a way that fulfils natural resource and quality-of-life objectives while fulfilling community economic objectives (ICF Consulting , 2005).

Everything that happens to land use has transportation implications and every transportation action affects land use (Antheneh G, 2007). For example, the relationship between land use and transport decisions can be complex and is influenced by a range of socio-economic factors such as car ownership, housing demand, and income (Ward, et al., 2007).

The connection between land use and transport systems have been well researched on the influence that one can have on the other (Chang, 2006). Land use has a big influence and impact on the way transport systems are planned and managed in large cities. For example, poor infrastructure can result in an increase in traffic accidents, congestions, and poor mobility (Guiliano, 1995). While the importance of integrating land use and transport planning is widely acknowledged, the delivery of integrated approaches remains problematic. A range of barriers to the effective integration continues to hinder successful implementation (Ward, et al., 2007).

The aim of this study is to gather information from literatures, as well as questionnaire responses to identify and update the current application domains of GIS and existing barriers as focal points for the identification of future opportunity and proposal of potential solutions.

Specifically, the Author is to explore and profile the use of geographical information system (GIS) in integrating land use and transport planning in Scotland. To date, GIS has been applied to different transport and land use problems as it is outlined throughout this document.

1.2 Statement of the Problem

While the importance of integrating land use and transport planning is widely acknowledged, the delivery of integrated approaches remains problematic. A range of barriers to the effective integration continues to hinder successful implementation (Ward, et al., 2007). The interaction of accessibility, transport and the development strategy should be considered early in the planning process. Land allocations should take account of transport opportunities and impacts alongside consideration of economic competitiveness (Scottish Executive, 2005b). Despite the widespread availability of geographic information systems (GIS) in local government, there is some evidence that the potential of GIS as a planning tool is not being fully exploited in the domains of land use and transport planning. While obstacles to GIS implementation in local government have been investigated, most of these investigations are either dated or do not focus on planning applications (JAPA, 2010). Therefore, the role of GIS in Scotland in integrating transport and land use planning ought to be fully exploited and more effective so that Scottish government stay on the same level of its cities in terms of planning.

1.3 Justification of the study

We know that GIS can be used and it's been shown that there is a role for it but has Scotland fully exploited that capacity? The multidisciplinary nature of GIS technology leads that the diffusion, appropriation and use of GIS technology are distributed in a variety of subject domains, such as spatial planning, which was regarded as a new technology or approach on traditional task. Due to this characteristic, studies have revealed that the adoptions of GIS technology have not yet fully delivered its potentials or adequately addressed the need of GIS users (Hao, et al., 2014).

There is some evidence that the potential of GIS as a planning tool is not being fully exploited and in general, practitioners are not aware of the full potential of GIS and planning support systems (JAPA, 2010).

Therefore, the aim is to add to the limited literature on the current potential of GIS as a planning tool and barriers hindering its use in public and private planning agencies to help them move beyond using GIS simply for routine tasks of data access and mapmaking. Moreover, it is hoped that the study will contribute to the body of knowledge in building sustainable cities, specifically focusing on the integration of policies on urban transport and land use plans, and it is a partial fulfilment required for MSc. Spatial Planning with GIS.

1.4 Research aim and objectives

The aim of this study is to investigate the role of GIS in spatial planning in Scotland with the focus on land use and transport planning integration.

To achieve the aim of this study, the following objectives are covered:

- To profile different uses of GIS in integrating transport and land use planning in Scotland.
- To identify and to evaluate barriers affecting GIS use and opportunities for more effectively integrating transport system and land use in Scotland by using GIS.

1.5 Research question and assumption

The focus of this study is to explore the role of GIS in transport and land use planning in Scotland. Therefore, the research question is formulated as:

- To what extent can Geographical Information System (GIS) play a role in effective transport and transport integration.

Assumption: Since land use and transport are cross-cutting issues. There is a need of using GIS for the land and transport system planning, which is not yet fully implemented in Scotland (Community & Gouvernement, 2007).

1.6 Dissertation Structure

The dissertation consists of five chapters:

Chapter one is the introduction; chapter two concerns the literature review which includes the land use and transportation, application of GIS in spatial planning, land use and transport planning in Scotland; chapter three deals with the research methodology; chapter four is about findings which includes data collection and data analysis and chapter five which is conclusions and recommendations.

2 LITERATURE REVIEW

2.1 Introduction

Transportation and land use are relentlessly linked. Everything that happens to land use has transportation implications and every transportation action affects land use (Antheneh, 2007). Over the last decade, the integration of land use and transport has gained increasing international attention. In large part; this trend has been a big concern due to the growing environmental and social impacts of road networks and motor vehicle use. These impacts are widely seen as being made worse by a lack of integration between land use and transport planning (Ward, et al., 2007). Different planning sectors can have impact on each other by their: the transport system affects the accessibility of a region, which affects the planning of land-use in that region and the activities that will take place in the region, which in turn will affect mobility and subsequently the further development of the transport system (Jos, et al., 2014).

There are some responses that can help to strengthen linkages between transportation and land use by developing mechanisms that engage with local land planning and the GIS-based analysis results, as discussed in the following sections.

2.2 Link between land-use and transport

Land use and transport are like the human life. Their usage and liveability depend on the residents, goods and materials that can be moved from one location to each location to another (David & Banister, 2007). Recent concerns surrounding the growth of mobility and associated increases in journey length and number of motorized journeys for an increasingly diverse pattern of trips have placed demands on the planning system in terms of the need to consider the land use–transport interaction (Hine, et al., 2000). As land use and transport planning are linked, the cooperation of different planning bodies is required. They have to be a sustainable land use and transport planning at local level which has to be guided by national, regional and European strategy (European Commission, 2014). Transportation planners need to forecast how future travel demand is affected by land use. Similarly, they must be able to estimate how new transportation policies will modify land use in rapidly growing cities with conventional land use and transportation planning practices, this process is typically difficult. The conventional practice focuses on separate visions, scenarios, plans,

policies and projects related to a specific land use or transport issue. The consequences of these scenarios, plans, and policies on land use and transport at the larger level have received little attention (Mohammed, 2014). The design of transportation facilities has a major impact on your community's character. These facilities are the result of land use decisions. Land along the road becomes more accessible. This increased accessibility makes the land more valuable and attractive to developers. As land along the road is developed, traffic volumes and the number of driveways increase. This results in more congestion and a deterioration of the road's capacity to efficiently move people and goods. The reduced efficiency of the road eventually necessitates roadway capacity improvements that may encourage additional development and the start of a new cycle (Daniel & David, 2004). Although transportation and land use are planned in separate contexts, transportation agencies can support easier and faster implementation of transportation projects and avoid the problems the separation inevitably creates by considering the land use impacts of projects earlier and producing initiatives that truly address those impacts. Doing so does not require transportation agencies to abandon the goals of improving mobility and accessibility, but rather to employ new means to achieve those goals (ICF Consulting, 2005).

Improved integration of land use and transportation planning can reduce the need for highway expansion and maintain the quality of our communities. Three cost-effective strategies useful for integrating land use with transportation are: nodal development/zoning; livable walkable communities and access management. Nodal development/zoning concentrates development (to encourage walking or bicycle use so that land between nodes can be used for low density, low traffic land uses. Liveable walkable communities are municipalities that provide facilities to promote walking, bicycling, services, and activities that promote a healthier lifestyle. Access management is the ability to control the number and location of access points to a property (Strafford Regional Planning Commission, 2003).

Thus, to adequately assess and evaluate the long-term impacts of investment and policies affecting land use on transport and vice versa, a more robust methodology is needed for deriving accessibility indices as the feedback mechanism of the land use-transport link. However, accessibility, the key concept that links land-use with transportation is quite difficult and complex to theorize and operationalize in any meaningful and acceptable way (Acheampong & Elisabete, 2015).

2.3 Role of land-use and transport integration

The integration of land-use and transport planning is indispensable to achieving sustainable communities and sustainable travel patterns. The way land is developed including the mix of uses, the location and the design will determine the length of journeys necessary to undertake everyday activities and the modes of transport most likely to be used to undertake those journeys. Planning policy, when implemented concurrently and consistently with transport planning, can be used to reduce dependency on private cars, encourage active travel and grow the public transport network (SPT, 2014). Land use planning and transport planning have key roles in shaping our cities and in delivering social, economic and environmental sustainability. The successful delivery of these outcomes requires strong integration of a land use and transport planning (Michael, 2015). GIS is rapidly being developed and applied in a no-limit list of applications. Planning in general, and transportation in particular, have greatly benefited from some very effective and efficient technology. Some of the specific transportation applications of GIS include road design, highway mapping, and analysis of accident data and traffic volumes. Since activities are based on a network of roads and projects, GIS plays a revolutionary role in illustrating and manipulating the analysis of results (Mezyad, 2001). Spatial planning can have an integrating role in the ways it can bring together places and people by visioning their future and helping to manage the public and private sector contributions to place making in a new way.

Since cities grow with or without planning, meeting the resource requirements of a growing population requires land-use change in one way or another in order to satisfy the need for food, space, infrastructure development and service provision. As a matter of fact, with every change in land use of an area, which could be in terms of intensity and/or type of use, there is a corresponding change in the flow of people and goods to and from the site. Similarly, with every change in flows of people, vehicles and goods along routes adjacent to a site, there is a corresponding change in accessibility to the site and its attractiveness to the present use, or for some other potential use (Antheneh, 2007). The main role that can be from GIS is that data collected and stored in GIS for one purpose can be easily made available to a number of application in land use and transport integration. The land use and transport decisions contribute significantly to shaping urban environments. Reflecting this, integration of land use planning and transport planning is increasingly being acknowledged as an important component of creating sustainable cities. The relationship between land use and transport

comprises a significant element of theories promoting more sustainable urban forms (Peter & Jeffrey, 1999). Integrating land use planning and transport planning is increasingly being acknowledged as an important element of creating sustainable cities.

The goal of a local planning process for land use and transportation is to build consensus around a community vision for future land use supported by transportation improvements, based on analysis that captures the interactions between land use and transportation. It can then serve as a point of departure for efforts to revise local comprehensive plans and regional transportation plans (ICF Consulting , 2005). Transport and land use are critical elements of sustainable development given high emphasis in most development programs and policies since they are pervasively integrated to improving the urban environment and the lives of those living in it (Mary, 1983).

Moreover, in the world of increasing concern for the ecosystem, the impact of the transport system on the environment has been given a considerable attention. This is mainly because developing infrastructure for a motorized transportation system takes vast amounts of land, intrudes into natural habitats and permanently alters the landscape of an area. But the concept of sustainable transportation promotes a balance of the economic as well as social benefits of transportation with equal consideration to the environment. A well-organized transportation system can enhance the economic efficiency of urban centres and the result could be synergetic when integrated with land use strategies that result in reduced transport demand (Dagnachew, 2007). In order to capitalize on this new motivation within planning, the term spatial planning is useful in both expressing a shift beyond a traditional idea of land-use planning and describing many aspects of planning practices that provide proactive possibilities for the management of change, including policymaking, policy integration, community participation, agency stockholding, and development management (Mark & and Stephen, 2009).

Therefore, the integrated land use and transportation planning can assist in delivering a sustainable city by providing equitable and accessible urban transport and lower greenhouse gas production. Achieving a travel mode shift away from a single occupant, auto-dependency and reducing the need to travel requires a shift to more intensive and mixed-use land uses that are physically accessible to local services, social facilities, shops, jobs and to other metropolitan locations via walking, cycling and mass transit (Planning Institute, 2008).

2.4 Barriers to land use and transport integration

While the importance of integrating land use and transport planning is widely acknowledged, the delivery of integrated approaches remains problematic. Issues of transport system bring a challenge not only for data processing, but also data analysis and long term planning. The new technologies cannot be good in deep into every step of planning. Since land use and transportation can be compared as two systems, and then we should combine them in one system by the use of GIS technology and make more application of GIS in the field of land use and transport integration and if the amount of data in transportation system when it became a lot the analysis of data is difficult (Miller & D.Storm, 1996). A range of barriers to the effective integration continues to hinder successful implementation. Barriers to integration of land use and transport planning have been the subject of several research initiatives internationally. The common barriers are grouped into seven main categories (Ward, et al., 2007):

- Legal and institutional barriers, including lack of powers or divided responsibilities for implementing land use or other policy instruments;
- Financial barriers, including budget restrictions on total expenditure for implementing a strategy or limitations on the flexibility with which revenue instruments can be used to acquire land or invest in public transport infrastructure;
- Political and cultural barriers, including public or pressure group opposition to certain policy instruments such as road pricing or land use regulations;
- Practical and technological barriers, including lack of tools, methods and/or skills needed to move from transport engineering solutions toward the design and delivery of integrated land use and transport strategies;
- Barriers created by organizational conflicts or complexity. Barriers to integration may occur due to conflicts or a lack of cooperation between organizations involved in planning. Conflicts or lack of cooperation may arise from differences in objectives or responsibilities or disputes regarding cross-territory issues;
- Barriers created by plan conflict or complexity. Barriers to integration can be created where land use and transport plans provide conflicting objectives, policies, and implementation mechanisms. It can be concluded that the greater the number of different plans, the greater the potential for lack of coordination or conflict between plans. A proliferation of plans can also create the potential for barriers as a result of the complexity of planning arrangements;

- Barriers created by professional conflicts. Direct conflicts between land use planning and transport planning professionals or departments create another barrier to integration. This type of conflict may arise where there are separate departments or separate plans (e.g., land use plan and transport plan) pursuing separate objectives or directives. As a result, there is a lack of shared goals and common interests among land use planners and transport planners that hinder integration.

They are also some barriers that limit spatial planning from being more effective. One of the most important of these is the difficulty of ensuring that Chief Executives and Executive members in Local Authorities and leading politicians in Regional Assemblies recognise the key role that spatial planning has in shaping and delivering tomorrow's places. Another major barrier lies in planners' understanding of the role of spatial planning within the wider and rapidly changing public sector landscape (Community & Government, 2007).

One of the responses that can help to strengthen linkages between transportation and land use is that transportation agencies develop mechanisms to engage with local land planning processes as a way to bridge the divides created by divisions of responsibility for transportation and land use. The goal of engaging in land planning is to create a vision for land use in which transportation plays an integral role, ensuring that transportation projects have the effects that local community's desire and so are supported by the communities they serve (ICF Consulting , 2005). The degree of accessibility has a positive impact in land use patterns. For long time they have been theories and model in the study of land use and transportation and most research which has been done found that most model 'are static, partial equilibrium'. Effects of transportation can also be significant. Direct and indirect land use barriers can result from transport, direct are from the amount and location of land used from transport and the indirect arise from transport decisions which affect land accessibility (Litman, 2007).

2.5 Application of GIS in land use and transportation planning

Planners use geographic information systems (GIS) and other technical tools to visualize and land use and transportation connections. Specific software to develop and analyse scenario alternatives, specific projects, or regional assets and vulnerabilities are available to assist planners with spatial planning. State, regional, and local agencies, as well as non-profit organizations, have undertaken database development, mapping, and analysis of land use, community, and environmental features using geographic information systems. These databases and analysis tools provide information that can help minimize land use,

community, and environmental impacts when locating new transportation facilities (Shenandoah Mountain Geographic, 2003). A GIS can be conceptualized as a series of layers of information (e.g. population, road networks, land uses, shopping Centre location) with each observation in each layer tied to specific points and areas on the earth's surface via specific coordinate system see figure 8. As GIS involve analysis, which cut through the relevant information layers, and analyses the relationship between phenomena co-located in space. The methodology and technology of GIS allows the different patterns to be visualized in many ways (Eva, 2007). During this period, planners have been aggressive adopters and adapters, and strong advocates for local governments deploying GIS. GIS technology is currently converging with several other technologies to provide new levels of accessibility and functionality. As GIS use becomes more widespread, planners make up less of the market. As GIS technology has become complex, they have been an important new class of practitioners called the GIS profession which is concentrated on the technology and its uses rather than a particular application of the technology, such as planning (Harris, 1989).

Transportation has always been one of the most important domains of GIS application. While GIS is not spread as office software products, it has been used by planning bodies and consultants. Maps have always played a major role in planning, and today digital maps provide an unlimited range of map views. The last decade of the twentieth century brought a rapid evolution in all forms of computing and in the evolution of GIS, culminating in the widespread availability of GIS software that is powerful, and runs on inexpensive desktop computers and servers (Howard, 2004).

Since all the activities in everyday life are based on network land use and transport integration with the use of GIS play an important role in the analysis of land use and transport planning for manipulating better results for a better future and as the technology evolve GIS has become a powerful tool for maintaining and updating land use and transportation sector with the aid key maps. The role of GIS gives a quick and easy method in terms of monitoring network and has the ability to of producing coloured maps to provide a visual for analysing different features (Mezyad, 2001). To date, GIS has been applied to different transport problems, such as short path analysis, vehicle routing, trip investigation, road navigation, dynamic routing, accident analysis, intelligent transport system. Mostly the application of GIS in land use and transportation integration is seen in data creation, for instance land use, zoning and in development (Hao, et al., 2014). GIS was used for combining different maps of land uses and for analysing the land use change where all the characteristics were put into

a GIS database, in land use approach, GIS has been frequently used as land evaluator to have land mapping units (Malczewski, 2004).

Furthermore, planners can use GIS and analysis tools for a variety of land use and transportation purposes. Among other uses, these analysis tools can help identify and disseminate information about potential development sites; estimate trip generation and distribution; explore accessibility for people with disabilities; and analyse household costs based on location to transit and services. For example, the Southern California Association of Governments (SCAG) developed CA Land Opportunities Tracking System, (CALots) a web-based information portal and mapping platform designed to support and promote transit oriented development. CALots aims to help assess and maximize the potential for infill development in strategic development opportunity areas identified in SCAG's regional growth and land use vision. These areas include existing or projected employment centres and transportation (particularly transit) infrastructure, such as light rail, heavy rail, and commuter rail stations (U.S Department for Transportation, 2015). GIS integrate spatial and attribute data to create powerful database and mapping system; they are designed to work with location-based system, and are therefore an attractive choice for land use and transport planning sectors.

Data management in GIS is based on database technology, and it has the powerful data storage, query, retrieval and inquiries and etc. The main expression of GIS is visualization expression. During the process of researches on interaction of land use and transportation, the analysis result can be expressed through various means such as maps, video, animation and virtual reality technology. The relationship between them is glance and let observer can easily understand what they mean. GIS also has the model database management and model building function. So the transportation forecasting model, land use forecasting model, integrated model of land use and transportation can be expanded into the GIS model database, and then user can do its jobs in GIS directly. Using GIS for integrated relationship between land use and transportation need not only make the best of various GIS technology, but also integrates urban land use and transportation system into GIS and form an independent platform. It will not only have GIS data management, expression and spatial analysis functions, but also have the interaction analysis function of urban land use and transport system, especially special prediction model (Peng, 2007).

GIS is utilized to model existing facilities/utilities along with the topography of the given

region. The integration of transport models has become more prominent in the analysis of transport systems, and GIS data enables the integration of modelling for both planning and operations (Samat, 2006; Dueker, 2008). For example, the rural traffic shed model is a method for allocating development permits based on the capacity of the roadway system. It is most applicable where there is a general flow of traffic towards an urban centre. The method requires dividing a rural area into "traffic sheds" based on land served by various collectors and arterials. Trip generation rates associated with various land uses are applied to estimate traffic volumes and compare future volumes to roadway capacity with a given amount of development. The method includes a market-based system for phasing development concurrent with roadway improvements (Lane & Stephen, 1999).

Similarly, Space Syntax is a GIS-based modelling technique used to identify urban locations that have a potential to increase pedestrian use, based on location of pedestrian-oriented land uses and other facilities. The method uses available or readily obtainable data such as: Census data, street networks, major trip generators, and pedestrian count samples to predict pedestrian volumes. For example, the City of Oakland applied the Space Syntax model to identify locations with a high pedestrian demand and a low supply of facilities, based on data on population, employment, trip generators, and pedestrian facilities (Raford; Noah & David, 2003). The GIS-based analysis results, such as field value, the scale value, and cell counts, provide a clear picture of which area is sufficient and safe for locating a particular type of road construction. Depending upon the relative importance of spatial aspects, a GIS-based methodology can be developed and demonstrated through a case study to locate a safe site that satisfies various spatial safety aspects. The location of a road construction with respect to the topography will cause minimum disturbance to the natural profile of an area; reduce cut/fill, developmental and constructional cost, and environmental damage; and ensure construction safety. This practice improves coherence among various spatial safety aspects of existing and proposed facilities/utilities (Satish & Bansal, 2016).

GIS can both model transportation networks, and integrate the association of network characteristics directly into a database. In this regard, finding the fast routes for the delivery of fresh vegetables takes into account different parameters as its impedance. The GIS Network analyst tool is used to solve the distribution problem. This tool helps the decision-makers determine the best routes among all of the existing road networks for transportation

and delivery services (Abousaeidi, et al., 2015). Also, the methodology has been developed to identify bus links between urban centres and newly developed urban expansion areas using GIS by considering reduction of route overlapping. A traffic analysis zone based analysis was undertaken to identify the demand responsive bus routes, which maximize population coverage, minimize travel time, and reduce duplicating routes (Vimal, Gahlot & Parida, 2012).

In terms of the principles of sustainable development, land use planning often requires the compromise between economic development and environmental conservation while advocating social justice. The economic, social and environmental processes involved in the land use planning are inherently spatial. GIS has the capabilities to produce, store, analyse and visualize spatial data and holds great potentials to deal with land management issues. Land use planning, like any other spatial decision problems, typically involves a large set of feasible alternatives and multiple, conflicting and incommensurate evaluation criteria (Sylla, et al., 2012). For that, GIS can easily provide an overall profile of land uses and open space surrounding the environmental amenity of interest in terms of their spatial distributions (Norzailawati, et al., 2015).

It sometimes seems inevitable that human and natural factors can cause landscape changes. However, knowledge of land use and land cover can be important in national plans if used to reverse deteriorating environmental quality trend. There is an increasing need for standardized land use and land cover information especially in critical areas of environmental concern like urban extension (Arzu, et al., 2012, (Diyana & Puziah, 2015). In short, concerning land use planning, GIS has been used mostly in mapping of features showing street layout, different roads network and land use in one particular area, nowadays GIS is used for recording and mapping the distribution of land uses; monitoring and updating land use changes; and planning and predicting land use changes. GIS plays a successful important role in the integration of land use and transport planning as GIS help to integrate the spatial data from a zone from people discussion and the model is linked with a GIS for the input of type of data and results. The main tool for land use and transport planning is currently GIS which has a strong capacity in data integration and analysis and visualization this is well documented in the Scottish documents.

2.4.1 Tools used in Transportation Planning Software

According to Caliper (2016), TransCAD is the first and only Geographic Information System (GIS) designed specifically for use by transportation professionals to store, display, manage, and analyse transportation data. TransCAD combines GIS and transportation modelling capabilities in a single integrated platform, providing capabilities that are unmatched by any other package. TransCAD can be used for all modes of transportation, at any scale or level of detail. TransCAD provides:

- A powerful GIS engine with special extensions for transportation;
- Mapping, visualization, and analysis tools designed for transportation applications;
- Application modules for routing, travel demand forecasting, public transit, logistics, site location, and territory management

TransCAD is the only software package that fully integrates GIS with demand modelling and logistics functionality. This makes it possible for models to be much more accurate and efficient. For example, network distances and travel times are based on the actual shape of the road network and a correct representation of highway interchanges. Also, with networks, you can specify complex road attributes such as truck exclusions, delays at intersections, one-way streets, and construction zones.

TransCAD extends the traditional GIS data model to include transportation data objects such as transportation networks, matrices, routes systems and linear-referencing. These extensions make TransCAD the best data management and analysis tool for working with transportation data. You can use the GIS functions to prepare, visualize, analyse, and present your work, and use the application modules to solve routing, logistics, and other transportation problems with greater ease and efficiency than with any other product. Networks and matrices can be of virtually unlimited size.

Networks:

Transportation networks are specialized data structures that govern flow over a network. Networks are stored in a highly-efficient way, enabling TransCAD to solve routing problems very quickly. Networks can include detailed characteristics such as:

- Turn delays or restrictions;

- Overpasses, underpasses, and one-way links;
- Intersection and junction attributes;
- Intermodal or interline terminals, transfer points, and delay functions;
- Transit access, egress, and walk transfer links.

Matrices:

Matrices hold data such as distance, travel times, and origin-destination flows that are essential for many transportation applications. TransCAD provides functions for creating and manipulating matrices, and tools for spatial analysis and advanced visualization of matrix data. This combination lets you see and understand transportation flows and network characteristics in new and different ways.

Routes & Route Systems:

Routes indicate paths taken by trucks, rail, cars, buses, or individuals travelling from place to place. TransCAD includes tools to create, display, edit, and manipulate routes, and unique display technology for mapping routes in a clear and compelling fashion. You can organize a set of related routes into a single route system layer, and include route attributes, stop locations, and vehicle schedules.

Linear Referencing:

TransCAD allows you to identify the location of transportation features as a distance from a fixed point along a route. TransCAD can display and analyse these data sets without conversion, and includes dynamic segmentation functions to merge and analyse multiple linear-referenced data sets. This makes TransCAD a natural choice for:

- Facility infrastructure and operations data;
- Accident locations;
- Pavement or rail condition ratings;
- Traffic flows and transit ridership data;
- Facility alignments;
- Capital project data

2.4.2 Land Use Scenario Development and Scenario Planning Tool

According to FHWA (2015), state and regional agencies and non-profit groups sometimes use workshop settings to tap the knowledge of local officials, staff, and the general public to develop future land use scenarios for a region, corridor, or community. Planners can use this information to guide planning activities. Increasingly, GIS tools are being used for this process, in addition to or instead of printed maps.

Some software applications allow planners to adjust multiple variables to analyse different land use and transportation scenarios. Such programs can be used to create maps or 3-D imagery of proposed plans or scenarios to better illustrate and visualize impacts. Different programs offer a range of analyses, including simple mapping and visualization functions. The following examples illustrate some useful software tools for scenario planning.

Envision Tomorrow

Envision Tomorrow is an easy-to-use, analytical decision making tool for municipalities, regional governments, and private organizations to test and refine transportation plans, produce small-area concept plans, and build scenarios. This software then processes the scenario and evaluates the development's impact on several factors, including land use, housing, sustainability, transportation, carbon emissions, and economic conditions. For example, the City of Waco, Texas, used the Envision Tomorrow software to evaluate different land use scenarios for the metro area. The outputs of the model helped the city determine potential phasing options for increasing density in the central city, and identifying the costs and benefits of implementing a Bus Rapid Transit system.

INDEX

INDEX is a planning support software tool used to model land use/ transportation scenarios. INDEX is a GIS software extension that helps stakeholders create, implement, and achieve plans informed by indicator measurements to gauge planning actions. The software also includes a new "Cool Spots" module, which planners can use to estimate greenhouse gas emissions from buildings and transportation.

CommunityViz

CommunityViz is a GIS software package that allows users to create and manipulate a virtual representation of a town and explore different land use scenarios. It is used to develop and compare alternative future land use scenarios and their impacts on the transportation system.

PLACE3S

The PLACE3S model is a GIS-based analytical tool to support community land use and transportation planning. Using GIS for integrated relationship between land use and transportation need not only make the best of various GIS technology, but also integrates urban land use and transportation system into GIS and form an independent platform. It will not only have GIS data management, expression and spatial analysis functions, but also have the interaction analysis function of urban land use and transport system, especially special prediction model (Peng, 2007).

2.5 Barriers to GIS applications in land use and transport planning

Planners in both land use and transport planning face a multitude of barriers in using GIS in their everyday work. According to those planners, the most significant of these barriers relate to training and understanding the technology, which encompasses not just a lack of training necessary to learn how to do a GIS function but also insufficient knowledge of what the technologies can offer. Barriers related to funding, data, software, staffing, and organizational coordination follow training-related barriers for planners (JOE, 2013). In the ideal GIS environment all information from all departments should be available to all users. But the need for data protection cuts across the approach. In terms of local government this usually seems to mean an application which uses large numbers of maps the Land Terrier or Planning Applications rather than an application that involves lengthy geographical analysis (Martin & Simon, 2007). In fact, the multidisciplinary nature of GIS technology leads that the diffusion, appropriation and use of GIS technology are distributed in a variety of subject domains (e.g. land use planning, transport planning etc), which was regarded as a new technology or approach on traditional task. Due to this characteristic, studies have revealed that the adoptions of GIS technology have not yet fully delivered its potentials or adequately addressed the need of GIS users (Hao, et al., 2014).

Furthermore, communities across the world are undergoing rapid changes in land use, demographic, socioeconomic and infrastructure conditions. Identification, visualization,

monitoring and evaluation of these changes and trends can be enhanced using GIS and online data and mapping technologies. GIS and related technologies can also be used to inform and assess land development projects. It is not clear, however, that organizations use GIS effectively for land redevelopment initiatives even when software, hardware, training, data and access to GIS services are all in place. There seems to be a general disconnect between ease of access to data repositories and GIS applications and effective use of the technology for planning and development (Esnard, 2008). A rapidly expanding technology base is transforming GIS, but this change is shaped by demand for particular functionalities, initially by planners and other professional users, but increasingly by a much wider group of users. Some notable planning scholars even argue that GIS has distracted planners from developing more important and useful methods (Drummond & Steven P. French FAICP, 2008)

As the matter of the fact, it has been attempted to investigate the direct or indirect barriers which affect the adoption rate of GIS from early stage to now. Up to present, the existing barriers found for effective use of GIS were classified into two classifications: organisational and technical barriers; the organisational barriers are generally referred to department factors, such as lack of staff (e.g. constraints by size of the team or funding), lack of purpose or mission to promote GIS application, lack of collaborators and networking, etc.; the technical barriers often include lack of context, insufficient software and tools, lack of reliable data, lack of technical knowledge (Hao, et al., 2014). In the early of 1990s they have been a remarkable change in public agencies of planning practice. Today planners have access to more user-friendly GIS software, and internet-based geospatial service that have helped alleviate many technical challenges related to hardware and software maintenance. However, many barriers remain, including the training or understanding of technology, funding, support for GIS, staff availability, data, hardware, and other organization in order to keep up with technology (Tang & Waters, 2005).

According to Hao et al (2014), these two classes of barriers affecting the use of GIS in land use and transport planning are more clearly illustrated by using two examples of fields in which GIS are applied. Those include Government and Transportation sectors. GIS has been utilised in major governmental sectors such as land management, coastal condition monitoring, environment protection, surveying, etc. There were a number of researchers who have started to examine the barriers of GIS implementation in local governments. These studies primarily identified three types of main barriers for government staffs, including: lack of programs/software for desired application; lack of awareness of available tools and lack of national initiatives (Mark & and Stephen, 2009).

Similarly, in the past some studies revealed that transport modelers are used to coding up abstract road networks and managing transportation data non-spatially. Many transportation planners are unfamiliar with GIS data management and tools. Therefore, at that time the barriers to GIS utilization are likely to be technical, referred to lack of awareness. Other barriers identified included insufficient tools and data required by many transportation applications. In transportation sector the barriers for implementing GIS application are summarized and include: unawareness the benefits of GIS; lack of good communication between transport engineers and GIS engineers; insufficient data and lack of knowledge in understanding GIS methods. In short, the Transportation sectors are restricted by technical factors in applying GIS such as lack of tools and expertise (Drummond & Steven P. French FAICP, 2008). Planning has always been known as the organization of space. An integrated part of land use and transport planning is the collection, manipulating, and analyzing spatial data. For planners in order to make and assess development options, GIS is needed to provide many of the necessary operation. However, there is a need to be in GIS area of planning process instead of the planning process. GIS deals with the spatial aspect of planning, but any integrating planning GIS must be must be modified for the planners (Petit & Pullar, 1999)

In overall, after exploring the barriers that affect the utilization of GIS in land use and transport planning, the results are showing that the applications of GIS still confront many barriers, including: lack of awareness; lack of communication; entry cost; lack of required software; insufficient data sources; lacks of computing power and usability.

2.6 Land use and transport planning in Scotland

Land use planning has a key role in supporting the achievement of the Scottish Ministers' economic, environmental and social objectives. Integration of land use and transport planning can play a positive role in supporting the Scottish Executive's transport delivery agenda. For the transport network to most effectively support the economy, land use planning should assist in reducing the need to travel; in creating the right conditions for greater use of sustainable transport modes; and in avoiding or mitigating adverse environmental impacts. The interaction of accessibility, transport and the development strategy should be considered early in the planning process. Land allocations should take account of transport opportunities and impacts alongside consideration of economic competitiveness (Scottish Executive, 2005b).

The achievement of good spatial accessibility and equity in the distribution of urban services is one of the supreme goals for urban planners. With Scottish Government backing, the City

of Edinburgh Council (CEC), for instance, constructed a tram network to cater for the future needs of Scotland's capital city by providing an integrated transport solution using trams and buses. Spatial Network Analysis of Public Transport Accessibility (SNAPTA) which is a GIS-based accessibility model has been developed to measure the accessibility by public transport to different urban services and activities. GIS has been used to visualize the different types of datasets in map form portraying space-time accessibility to services and identifying the hotspots of unequal access (Karou & Hull, 2014).

The planning system at both a national and local level aims to address competing demands for resources and land, and achieve a balanced and sustainable outcome. The National Planning Framework for Scotland sets out a guide to improving connectivity and promoting sustainable land use and transport patterns, across Scotland until 2025. Planning and transport are intrinsically linked, and planning decisions are capable of influencing demand for transport whilst promoting accessibility and sustainable travel. The Structure Plan and Local Plan will together seek to promote a land use framework supporting the National Planning Framework for Scotland. This will aim to promote land use, which reduces the need to travel, creates the right conditions for greater use of sustainable modes and restricts adverse environmental impacts. Land allocations should take account of transport opportunities and impacts, relating settlement strategy to the capacity of the transport network and identifying where economic growth or regeneration requires additional transport infrastructure, including transport assessments and travel plans (Stirling Council, 2006).

Land-Use and Transport Integration in Scotland (LATIS) is one of Transport Scotland's principal tools in ensuring that transport investment is well focused and integrated with the wider policy environment (Hugh et al., 2009). GIS has shown the capability to produce more detailed data of build environment and spatially putting it together to information on travel behaviour at the household level. Poor data and techniques are still being used, the question remain the degree of connection and direction between cause and effect (Susan, 2005).

Therefore, the main purpose of integrating land-use and transport is to reduce travel demand including numbers of trips, travel time, travel distance and to encourage people shifting from private vehicle ownership to green modes including walking, cycling and bus by improving accessibility to job site and other public services as well as to encourage healthy environment for living (Government, 2012). Eventually, one focus of Scottish Planning Policy (SPP)¹⁷ is to achieve better and earlier integration between transport and land use planning at national, regional and local level (Scottish Executive, 2005a) and this section focuses on the

implication of geographical information system (GIS) in land use and transport planning at those levels in Scotland.

2.6.1 Local strategic development plan

The process of preparing a local plan relates the existing land use development pattern to the capacity of the transport network, and appraises the pattern of new land allocations in relation to transport opportunities and constraints. The location of significant travel-generating uses is critical to the number and length of trips. Planning authorities locates such developments in places well served by public transport, especially town centres and other key locations. In such locations, higher density development is appropriate to maximise the role of public transport. Local plans should express the relationship between development proposals and transport at a local level in accord with the policy contained in the Scottish Planning Policy (Scottish Executive, 2005b).

In this local strategic plan, for instance Stirling Council has a clear vision of the type of area it wants to be: a better, more caring, place to live, work or visit. The Council's Corporate Plan describes its strategic aims of local democracy and participation: social inclusion; sustainability and promotion of quality services. Together these form the basis of the Council's strategies and policies. The Local Transport Strategy aims to support these by coordinating land use and transport at all levels. The development strategic objectives of the local transport strategy (LTS) are to:

- Widen travel choices by creating conditions to encourage more sustainable travel;
- Reducing the need to travel through integration of land-use and transport;
- Ensure that the existing transport network is adequately maintained and managed;
- Plan accordingly to address safety and accessibility issues within communities, acknowledging the diverse urban and rural nature of the area.

These objectives form the basis of the individual transport strategies for the City, the National Park and the Smaller Towns and Villages and illustrate the links between transport and other policies such as development and land-use planning, social inclusion, economic development, environment and safety. Also, the LTS objectives have been drawn up mindful of the longer-term vision and aims for land use planning and transport in Stirling to maintain and improve the quality of life. Stirling Council believes that putting these objectives at the heart of its Local Transport Strategy will deliver real quality of life improvements to the people in Stirlingshire (Stirling Council, 2006).

Similarly, the Local Development Plan for Dundee contains the spatial strategy that will guide future development up to 2024 and shows which land is being allocated to meet the City's development needs and where new development should and should not happen. The Plan contains policies and proposals covering the principal land use issues in the City and will provide the context in which decisions on planning applications will be made. In the preparation of the Dundee Local Development Plan, vision and principles have been developed into a land use planning strategy to guide the future development of the City up to 2024(Dundee City Council, 2014).

GIS, as a good tool in spatial planning, can be used in transport and land use planning. This section concerns about how GIS has been applied in planning at local level in Scotland. For example, in Aberdeen which has seen many forms of public transport.

Also GIS has been used for traffic management. For example, the project of Berryden Corridor Scheme in Aberdeen, as shown on the figure 1, was about a variety of traffic management and road improvement measures with the overall objective to ease City Centre traffic congestion and support the delivery of the City Centre regeneration project (Aberdeen City Council, 2015).

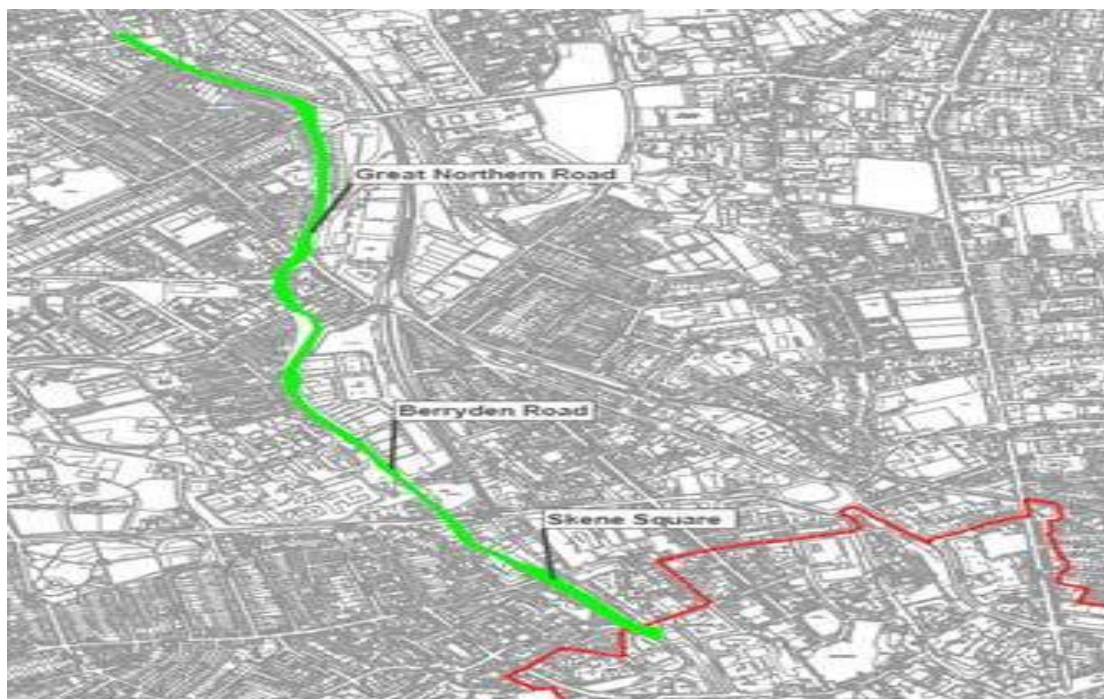


Figure 1: Berryden Corridor (Aberdeen, 2015)

2.6.2 Regional strategic development plan

Through extensive consultation the Scottish Executive has recognized the importance and real benefits of building upon and strengthening the existing voluntary regional partnerships. “Scotland’s Transport Future” details proposals for reform and the creation of statutory regional transport partnerships which seek to capture the best of both regional and local planning and delivery. The aim of the partnerships is to identify, develop, implement and monitor matters of “mutual transport interest”. The regional transport plans (RTP’s) were granted full powers in to improve regional transport through (Stirling Council, 2006):

- Provision of a more strategic approach to planning and delivery;
- Building on existing joint working relationships;
- Working in partnership with the national transport agency; and
- Bringing together local authorities and principal stakeholders.

The Tayside and Central Scotland Transport Partnership (TACTRAN) was established on 1 December 2005 as one of seven statutory Regional Transport Partnerships across Scotland. Transport (Scotland) Act 2005 places a duty on Regional Transport Partnerships to develop a Regional Transport Strategy (RTS), which sets out a vision and objectives for meeting the transport needs of people and businesses throughout their region. TACTRAN has developed this first RTS for the region, covering the Angus, Dundee City, Perth and Kinross and Stirling Council areas. TACTRAN’s vision is to deliver: “a transport system shaped by engagement with its citizens, which helps deliver prosperity and connects communities across the region and beyond, which is socially inclusive and environmentally sustainable and which promotes the health and well-being of all” (TACTRAN, 2008).

In this planning GIS has been used in different ways such as mapping; visualization and transport network analysis. For instance, figure 2, GIS has been used to produce the map of TACTRAN region and also to visualize the constituents of the region.

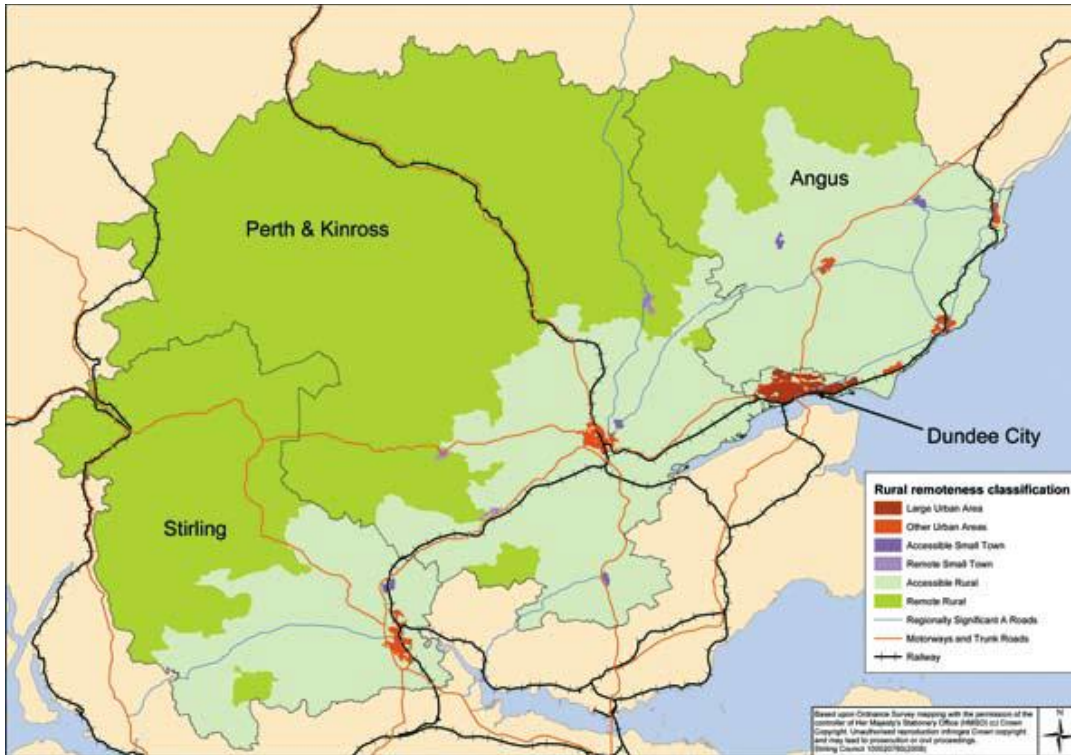


Figure 2: Urban and rural areas of the Tactran region (TACTRAN, 2008)

Similarly, GIS has been used for regional transport network analysis. The TACTRAN region includes a number of Scotland’s key transport routes and corridors, making it a central hub in the national transport network. These routes link the region to its neighbors, provide for journeys which pass through the region and also provide internal connections between our main cities and towns. Figure 2 shows how GIS has been applied in transport network analysis.

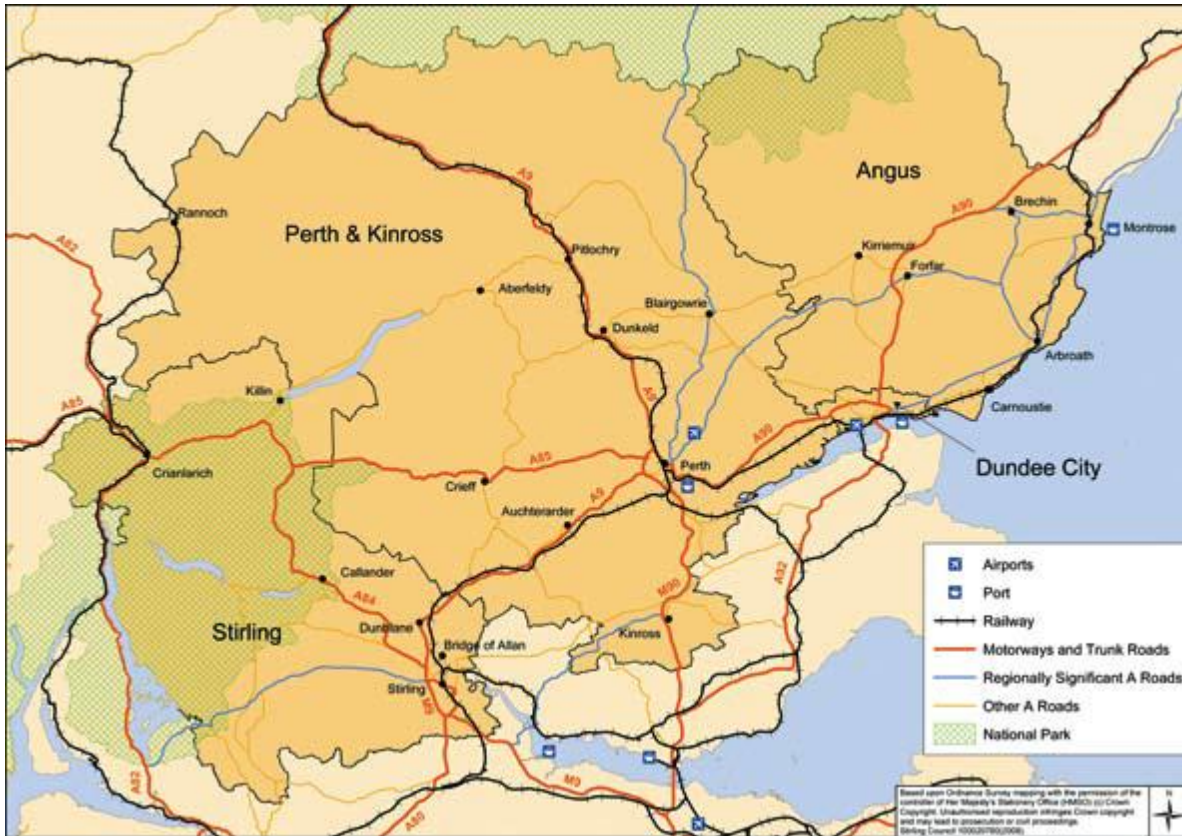


Figure 3: Tactran Transport Network (TACTRAN, 2008)

SEStran (South East Scotland Transport Partnership) is one of seven Regional Transport Partnerships (RTP's) in Scotland set up by the Transport (Scotland) Act 2005. SEStran contains eight constituent council areas – City of Edinburgh, Clackmannanshire, East Lothian, Falkirk, Fife, Midlothian, Scottish Borders and West Lothian (SEStran, 2008). As for TACTRAN, SEStran in its strategic transport planning, GIS has been used in many different ways.

Firstly, it was used for producing map and visualization as it can have shown on the figure 3, showing the overview map of the SEStran area, Secondly, GIS has been used for transport network visualization and analysis. The two figures below show SEStran area road and rail networks respectively. Thirdly, GIS at regional level has been used for public transport accessibility analysis as show in figure 4.

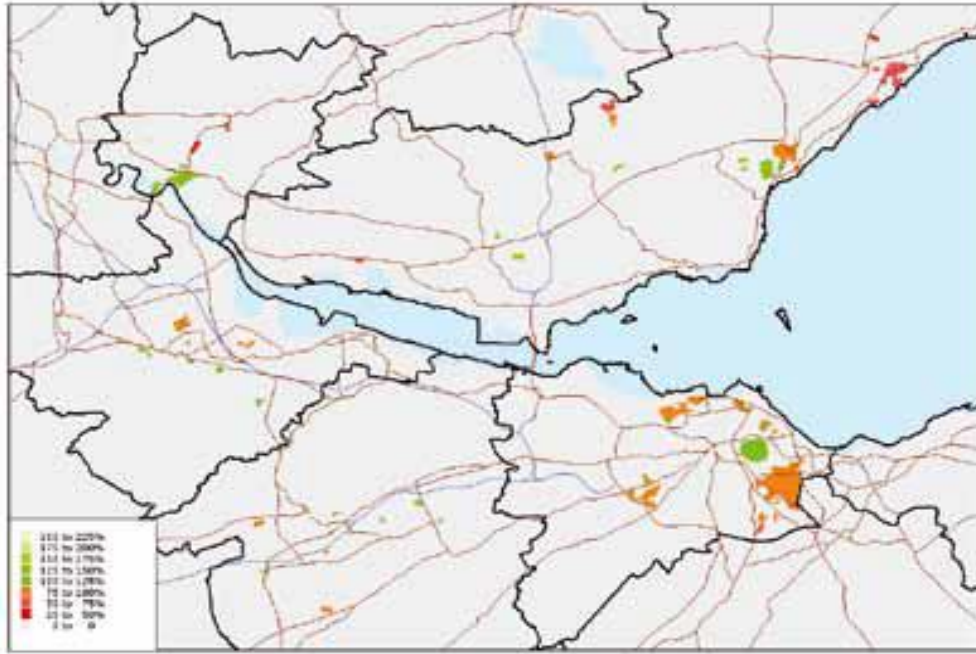


Figure 4: Access to jobs (Source: SEStran, 2008)

Each of the areas highlighted in color in the figure 4 is classed as deprived. The access to employment measure for each of these data zones is then compared to the average access to employment measure for its relevant local authority, and mapped as a percentage. Any deprived data zone with a score of less than 100% has a worse than average access to employment for that local authority area – shown as shades of red above. Data zones with better than average access to employment are shown in shades of green. Therefore, GIS can help to analyze the accessibility of the geographical area for detailed examination of the bus services available from these areas and suggest modifications to routes to improve access to employment in the areas (SEStran, 2008)

2.6.3 National strategic development plan

Transport Scotland, the executive agency for transport in Scotland established in early 2006 is mandated to deliver the National Transport Strategy (NTS) for Scotland. The NTS expands upon the Executive’s aims and aspirations set out in Scotland’s Transport Future, and provides the context for the activities of regional transport partnerships and local authorities. Concerning the planning policy context, the Scottish Planning Policy (SPP) 17, which is planning for transport, provides policy guidance and supports the Scottish Executive’s transport vision through the integration of land use, economic development, environmental

issues and transport planning. SPP17 identifies that the planning system is a key mechanism for integration through:

- Considering population and land use changes; reducing the need to travel, promoting road safety and safety on public transport; facilitating public transport movement;
- Provision of high quality public transport access, in order to encourage modal shift away from the car towards more sustainable modes (Stirling Council, 2006).

A number of Scottish transport GIS models already exist. These range from strategic models covering large areas to relatively small but detailed single junction simulation models. The Transport Model for Scotland (TMfS) is a strategic level model now available for use by local authorities. It is related to the TELMOS model which uses an economic land use model input, covers the whole of Scotland and contains planning data from all planning authorities. The intermediate level of models is the more detailed transport assignment models, such as the Saturn type model. At the most detailed level are the micro simulation models, for example PARAMICS.

Modelling is usually undertaken by transport planners in policy development and assessment of proposals. Modelling assists in decision making by basing projections on quantitative data and it can be used for different types of assessment, for example mode choice, trip generation and land use interactions. Joint transport and land use models are being developed which dynamically represent the interaction between transport changes and land use patterns rather than simply requiring land use data as a manual model input. These models are very useful in strategic land use planning. In simple terms they use modelled transport outcomes to generate elements of future year land use planning data (Scottish Executive, 2005a).

The capability exists in Scotland to make more effective use of data and to use it to make better informed decisions. The development of models is explored and Geographic Information System (GIS) tools to enable assessments of land use/management change. For example, the regional pilot projects in Aberdeenshire and the Scottish Borders have demonstrated the value of ecosystem services data, and the power of utilising that data in GIS mapping tools to inform decision making. Other organisations and groups have similarly made good use of the range of data now available. The availability of data is accompanied by improved tools for its use and recognises the exploratory work that has been undertaken by a range of groups to develop and use GIS tools. The Scottish Government takes a lead by exploring the practicality of developing methods and methodologies to assist in the assessment of land use benefits and opportunities at a more local level. The explorations of

the development of an online national mapping tool which reduce the burden locally set out a national data baseline and encourage consistency across Scotland (Scottish Government, 2016).

At national level GIS has been used to produce map and visualization of different modes of transport in Scotland such as road, rail, air and ferry (Scottish Executive, 2006).

The figure 5 below shows the strategic transport corridors in Scotland in which GIS has been used to identify and analyze urban network, strategic transport nodes and national transport corridors (Transport Scotland ,2009).



Figure 5: Strategic transport corridors in Scotland (Transport Scotland, 2009)

3 RESEARCH METHODOLOGY

This study to collect the data it will use qualitative method which deal with questionnaire survey in order to understand the potential role of GIS based on the perceptives of planners in the sector of land use and transport planning to give insights on how they apply GIS, what they think of the barriers, opportunities and what solution should be put in the future usage the targeted people are planners; and a review of documents analysis.

3.1 Research area

Scotland is a country that is part of the United Kingdom and covers the northern third of the island of Great Britain. It shares a border with England to the south and is otherwise surrounded by the Atlantic Ocean, with the North Sea to the east and the North Channel and the Irish Sea to the southwest. Edinburgh, the country's capital and second-largest city, and Glasgow, Scotland's largest city was once one of the world's leading industrial cities and now lies at the centre of the Greater Glasgow conurbation. The total area of Scotland is 78,772 km² (30,414 sq mi). The population of Scotland at the 2001 Census was 5,062,011. This rose to 5,295,400, the highest ever, at the 2011 Census.

Scotland has five main international airports (Glasgow, Edinburgh, Aberdeen, Prestwick, and Inverness), which together serve 150 international destinations with a wide variety of scheduled and chartered flights. The Scottish motorways and major trunk roads are managed by Transport Scotland. The remainder of the road network is managed by the Scottish local authorities in each of their areas.

The Scottish motorways and major trunk roads are managed by Transport Scotland. The remainder of the road network is managed by the Scottish local authorities in each of their areas. There were 55,768 kilometres of public road in Scotland in 2011. Trunk road network accounted for 6% of the total, non-trunk road represented 13% of the total and minor roads remained with 81% of roads (Government, 2012). Network Rail Infrastructure Limited owns and operates the fixed infrastructure assets of the railway system in Scotland, while the Scottish Government retains overall responsibility for rail strategy and funding in Scotland. Scotland's rail network has around 340 railway stations and 3,000 kilometres (1,900 mi) of

the track. Over 62 million passenger journeys are made each year (Government of Scotland, 2012).

3.2 Research data collection method

The research comprised a mixed methods approach with two inter-related elements:

1. Document analysis
2. A questionnaire survey

Details of each of these are listed below. The feedback and analysis of the different aspects is combined in the subsequent chapter.

3.2.1 Research method 1: Document Analysis

An analysis of the main features of each of the strategic development plans produced in Scotland was undertaken and those documents are five in number and listed below:

1. City centre master plan and delivery programme
2. Getting the best from our land. A Land Use Strategy for Scotland 2016 – 2021
3. Planning for transport: Planning advice note⁷⁵
4. SEStran regional transport strategy 2008-2023
5. TACTRAN regional transport strategy 2008-2023

3.2.2 Research method 2: Questionnaire survey

As an initial quantitative approach, the online questionnaire was designed to be accessible to as wide a range of respondents as possible who had previously interacted with the strategic development planning process. The type of questionnaire was a closed-ended where the questions limit the answers to the respondents to respond options provided on the questionnaires. Based on the survey objectives of the study, I chose participants that are able to effectively represent an institution, an organization and a company. I started by setting a date for creating of questions, then revised the questionnaire before submission. A list of land use and transport planning divisions (private, public, government. Local authorities) was searched through the internet direct to the website of institutions and organizations. Institutions and government of Scotland local authorities have been contacted through mails and phone calls to obtain agreements to administer the questionnaire to people in the area of transportation and land use planning. For that, 55 questionnaires were electronically sent via Bristol online in mid-June 2016. Since the current study is about “role of GIS in spatial

planning: land use and transport planning integration in Scotland”, questionnaires were sent to people who have anything to do with land use and/or transport planning in Scotland and these include Heads of Planning; Planning Officers; GIS Analysts and Senior Planners. With the Bristol online survey, the respondents were able to answer the questionnaire by mean of choosing and inputting their answers while connected to the internet. Then the response was automatically stored in a survey database.

The questionnaire design was structured according to this current research topic and two essential parts covering the study objectives are: the use of GIS in transportation and land use planning and challenges and opportunities of using GIS in transportation and land use planning. The following four questions were to be answered under these two parts (see sample in appendix I) and were purposefully designed to cover a broad range of topics in a bid to uncover relevant issues relating to the potential role of GIS based on the perceptive of planners in the sector of land use and transport planning to give insights on how they apply GIS, what they think of the barriers, opportunities and what solution should be put in the future usage the targeted people are planners:

1. Which type of work have you used GIS for?
2. What are the barriers or challenges do you have in using GIS in integrating transport and land use planning?
3. What opportunities can increase more effective application of GIS in integrating transport and land use planning?
4. To what extent is your GIS system and capacity used?

Questionnaires have been distributed in the sector of land use and transport planning in private and public institutions in Scotland with a number of 55 people to respond to the questions.

The study investigates the role of GIS in spatial planning in Scotland. The method used in the study to obtain person to respond the questionnaire was random from the internet by choosing from different department to represent the entire institution or organization.

A list of land use and transport planning divisions (private, public, government, and local authorities) was searched through the internet direct to the website of institutions and organizations. Institutions and government of Scotland local authorities have been contacted through mails and phone calls to obtain agreements to administer the questionnaire to people in the area of transportation and land use planning.

The respondents in this study will be coming from the department of land use planning and transport planning in Scotland. I chose land use and transport planners experts as respondents in this study because they are the relevant persons in the study especially head of planning and the senior planners.

3.3 Analytical approach

The research analytical framework is based on results of comparative analysis of the use of GIS in integrating land use and transport planning. According to the results obtained from both questionnaire survey and document analysis and knowing all about what GIS can do in spatial planning (especially in land use and transport), this will help to see whether GIS is fully explored or not in Scotland.

4 RESEARCH FINDINGS AND DISCUSSION

4.1 Questionnaire survey

As mentioned in the previous section, questionnaires have been distributed in the sector of land use and transport planning in two categories of institutions, that is, public institutions and private institutions in Scotland for people to respond to the questions. For 55 questionnaires sent out, 40 questionnaires were returned filled and the response rate is 72.7 per cent. The 15 questionnaires were returned incomplete due to that the respondents were late to provide their answers on time. The non-response rate is 27.3 per cent.

Considering the 40 questionnaires returned back complete, the distribution of responses between institutions were as follows: in public institutions (local authorities and city councils), there are 28 responses out of 40 responses in total and this represents 70 per cent of response rate; in private institutions, there are 12 responses out of 40 responses in total and this represents 30 per cent of response rate.

These responses were provided by people from different positions within the two categories of institutions as stated above. These include Heads of Planning; GIS Analyst; Senior Planners and Planning Officers. According to the 40 responses, the distributions among those four different positions were as follows: there are 9 responses from Heads of Planning representing 22.5 per cent; 11 responses from GIS Analyst representing 27.5 per cent; 18 responses from Senior Planning representing 45 per cent and 2 responses from Planning Officers representing 5 per cent. For a certain number of questions asked, the table below summarises responses that have been collected:

Table 1: Responses from questionnaire survey

NO	Questionnaire sections	Public Institutions	Private Institutions
1	The role of the institution in spatial planning.	Conservation; Development planning; Master plan; Urban design; Other (utilities planning & maintenance)	Conservation; Development planning; Master plan; Urban design and Other (landscape planning & EIA)
2	The role of GIS in spatial planning	Geospatial analysis; Map production; Visualization; Planning; Other (Public works, maintenance & asset management)	Geospatial analysis; Map production; Visualization; Monitoring; Planning and Other (data collection & management)
3	Level of staff qualification.	Bachelor	Bachelor; Master's and PhD
4	Barriers/challenges in using GIS to integrate land use and transport planning	Inadequate budgets; Data cost; Data access/availability; GIS expertise and Software	Inadequate budgets; Data cost; Data access/availability; GIS expertise; Policy.
5	Opportunities to increase effective application of GIS in land use and transport planning	Advances in data structure; Greater integration of land use and transport planning and Effective decision making.	Advances in data structure; Less time-consuming; Integration; Data management; Development monitoring; Effective decision making; Spatial analysis and Land use/transport strategic planning.

The research has revealed that the role of all institutions in spatial planning is mostly in the development planning and master plan where GIS is applied in planning; map production; geospatial analysis; urban design; visualization; monitoring; data collection; data management; and other (public works; maintenance and asset management). Furthermore, it has been found out that advanced data structure, as an opportunity in using GIS, is the key

success in the integration of land use and transport planning while technology; data cost; data accessibility and availability are the common barriers encountered in any planning process.

4.2 Documents analysis

The achievement of good spatial accessibility and equity in the distribution of urban services is one of the supreme goals for urban planners. Spatial Network Analysis of Public Transport Accessibility (SNAPTA) which is a GIS-based accessibility model has been developed to measure the accessibility by public transport to different urban services and activities (Karou & Hull, 2014). This section summarizes the findings from review of different documents about how GIS has been used in Scotland, especially in the sector of land use and transport planning. GIS, as a good tool in spatial planning, the current research has revealed that it has been used for transport and land use planning at local, regional and national levels. Through the following documents, some GIS applications in Scotland are listed:

In the document “City centre master plan and delivery programme” (Aberdeen City Council, 2015), it has been found that GIS has been used for map production, the urban rail network analysis and traffic management.

In “Getting the best from our land: A Land Use Strategy for Scotland 2016 – 2021” (Scottish Government, 2006), it has been shown that GIS has been used for assessments of land use/management change and decision making.

The analysis of the document “Planning for transport: Planning advice note⁷⁵” (Scottish Executive, 2005a) has revealed that GIS has been used for land use and transport interaction modelling; policy development, assessment and decision making of proposals.

In “SEStran regional transport strategy 2008-2023” (SEStran, 2008), regionally GIS has been used for map production, visualization, transport network analysis and public transport accessibility analysis.

In the document “Strategic transport projects review” (Transport Scotland, 2009), GIS has been applied in urban network identification and analysis.

Lastly, in “TACTRAN regional transport strategy 2008-2023” (TACTRAN, 2008), the role of GIS has been found in map production; visualization and transport network analysis.

In short, at all levels and in all documents, GIS has been used for map production; transport network analysis; traffic management; visualization; transport accessibility analysis; land use and transport interaction modelling; policy development, assessment and decision making of proposals. These results are presented in the table below:

Table 2: Document analysis results

N0	GIS Applications in Scotland
1	Assessment and decision making of proposals
2	Land use and transport interaction modelling
3	Map production
4	Policy development
5	Traffic management
6	Transport accessibility analysis
7	Transport network analysis
8	Visualization

In summary, putting together findings from questionnaires and documents analysis about the application of GIS in integrating land use and transport planning in Scotland, it has been found out that GIS is being used in geospatial analysis; map production; monitoring; integrated land use and transport planning; visualization; data management; data collection; transport network analysis; traffic management; transport accessibility analysis; land use and transport interaction modelling and policy development, assessment and decision making of proposals. The table 3 presents the profile of GIS use in integrating land use and transport planning in Scotland:

Table 3: GIS profiling for its use in Scotland

N0	GIS Applications
1	Assessment and decision making of proposals
2	Land use and transport interaction modelling
3	Map production
4	Policy development
5	Traffic management
6	Transport accessibility analysis
7	Transport network analysis
8	Visualization
9	Geospatial analysis
10	Monitoring
11	Data collection
12	Data management
13	Urban design
14	Other (public works, maintenance and asset management)

Despite all of these applications of geographic information systems (GIS) evidenced by this current research, these barriers to the use of GIS show that the potential of GIS as a planning tool is not being fully exploited in the domains of integrating land use and transport planning in Scotland

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Land use and transport integration is one of the principal tools in ensuring that transport investment is well focused and integrated with the wider policy environment. The economic, social and environmental processes involved in the land use planning are inherently spatial.

While the importance of integrating land use and transport planning is widely acknowledged, the delivery of integrated approaches remains problematic. A range of barriers to the effective integration continues to hinder successful implementation and these include legal; institutional; organisational; cultural; technological; professional and financial barriers. The interaction of accessibility, transport and the development strategy should be considered early in the planning process. Land allocations should take account of transport opportunities and impacts alongside consideration of economic competitiveness.

Planners use geographic information systems and other technical tools to visualize and analyze land use and transportation connections. Specific software to develop and analyze scenario alternatives, specific projects, or regional assets and vulnerabilities are available to assist planners with spatial planning. State, regional, and local agencies, as well as non-profit organizations, have undertaken database development, mapping, and analysis of land use, community, and environmental features using geographic information systems. These databases and analysis tools provide information that can help minimize land use, community, and environmental impacts when locating new transportation facilities.

Despite the widespread availability of GIS in local government, there is some evidence that the potential of GIS as a planning tool is not being exploited in the domains of land use and transport planning integration.

In this study, findings from questionnaires and documents analysis about the application of GIS in land use and transport planning in Scotland have shown that GIS is being used in geospatial analysis; map production; monitoring; integrated land use and transport planning; visualization; data management; data collection; transport network analysis; traffic management; transport accessibility analysis; land use and transport interaction modelling and policy development, assessment and decision making of proposals.

Furthermore, it has been found out that advanced data structure, as an opportunity in using GIS, is the key success in the integration of land use and transport planning. However, after exploring the barriers that affect the utilization of GIS in land use and transport planning, the

results are showing that the applications of GIS still confront many barriers, including: lack of awareness; lack of communication; entry cost; lack of required software; insufficient data sources; lacks of computing power; usability; data accessibility and availability are the common barriers encountered in any planning process.

Therefore, despite all of these applications of geographic information systems (GIS) evidenced by this current research, these barriers to the use of GIS show that the potential of GIS as a planning tool is not being fully exploited in the domains of integrating land use and transport planning in Scotland

5.2 Recommendations

Since the role of GIS in integrating land use and transport planning can play a positive role in supporting the Scottish Executive's transport delivery agenda, the Author has drawn up the following recommendations:

- The interaction of accessibility, transport and the development strategy should be considered early in the planning process;
- Land allocations should take account of transport opportunities and impacts, relating settlement strategy to the capacity of the transport network and identifying where economic growth or regeneration requires additional transport infrastructure, including transport assessments and travel plans;
- Local plans should express the relationship between development proposals and transport at a local level in accord with the policy contained in the Scottish Planning Policy
- Due to some barriers from users, GIS training are required to meet demands for different level of users;
- Transportation planners should use integrated land use and transport GIS models to forecast how future travel demand will be affected by land use;
- Transportation agencies should develop mechanisms to engage with local land planning processes as a way to bridge the divides created by divisions of responsibility for transportation and land use. This will be one of the responses that can help to strengthen linkages between transportation and land use;
- More funds and training should be put in place as part of capacity building for new and advanced GIS technology applied in integrating land use and transport planning.

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7 APPENDIX

Appendix I: Questionnaire

Part 1. Background Information

1. What type of institution/organization/company are you affiliated to?
 - a. Public
 - b. Private
 - c. NGO
 - d. Research
 - e. Other:

2. What is the role of your institution/ organization/ company in spatial planning?
 - a. Conservation
 - b. Development planning
 - c. Master Plan
 - d. Urban design
 - e. Other

3. Please specify the number of years that you have used GIS?
 - a. 0-5
 - b. 6-10
 - c. 11-15
 - d. 16-20
 - e. 21+

Part 2. The use of GIS in transportation and land use planning

4. Which type of work have you used GIS for?
 - a. Geospatial analysis
 - b. Map production
 - c. Visualization
 - d. Monitoring
 - e. Planning
 - f. Other:

5. Do you have a department that deals with GIS?
 - a. No
 - b. Yes
 - c. If yes, which departments?
6. What is the highest level of GIS qualification in your institution/organization/company?
 - a. Bachelor
 - b. High national diploma
 - c. Master's
 - d. PhD
 - e. Other:
7. How much money have you spent on GIS technology the last five years?
 - a. Less than 10,000
 - b. Between 10,000 and 20,000
 - c. Between 20,000 – 50,000
 - d. Between 50,000 and 100,000
 - e. Between 100,000 and 300,000
 - f. Beyond 300,000
 - g. Other:
8. Do you often carry out your own GIS or contract the work out to consultants?
 - a. We do most GIS work in-house
 - b. We contract most work to consultants
9. To what level of satisfaction do you have with current **GIS hardware** in your institution/ organization/company?
 - a. Very Dissatisfied
 - b. Dissatisfied
 - c. Neither dissatisfied nor satisfied
 - d. Satisfied
 - e. Very Satisfied
10. To what level of satisfaction do you have with your current **GIS software** in your institution/organization/ company?
 - a. Very Dissatisfied
 - b. Dissatisfied
 - c. Neither dissatisfied nor satisfied

- d. Satisfied
- e. Very satisfied
- f. Neither nor Dissatisfied

Part 3. Challenges and Opportunities of using GIS in transportation and land use planning

11. What are the barriers or challenges do you have in using GIS in integrating transport and land use planning? Select what applies.
 - a. Inadequate budgets
 - b. Data costs
 - c. Data access and availability
 - d. GIS expertise
 - e. Policy
 - f. Technology
 - g. Software
 - h. Other:
12. What opportunities can increase more effective application of GIS in integrating transport and land use planning? Select what applies.
 - a. Advances in data structure
 - b. Greater integration of land use planning and transport
 - c. Data management
 - d. Effective decision making
 - e. Other:
13. How are your GIS outputs put to use?
 - a. Distributed free of charge to others who want it
 - b. Distributed free to other agencies for non-commercial purpose
 - c. For purchase by those who want it
 - d. Restricted to internal agency use only
14. To what extent is your GIS system and capacity used?
 - a. It is over-used
 - b. It is neither over-used nor under-used
 - c. It is under-used
15. What type of planning documents is your data used for?
 - a. EIA (Environmental Impact Assessment)

- b. Planning documents
- c. Public communication
- d. Visualization
- e. Other

Thank you for your participation

APPENDIX II: The United Kingdom Spatial Planning Framework

The national spatial framework proposal put forward in the ESDP consists of two types of linkages: vertical and horizontal links. Vertical links are intended to integrate different spatial tiers upward to the transnational level as well as to the lower regional and local levels. The horizontal links are to coordinate inter-sector issues within the national spatial hierarchy. As explained in the EU Compendium of Spatial Planning Systems and Policies Report (Nadin et al., 1997: 24), spatial planning encompasses elements of national and transnational planning, regional policy, regional planning and detailed land-use planning. National spatial planning includes the broad development frameworks or perspectives prepared at the national level to guide spatial development patterns and lower-tier spatial plans. Due to the confusion associated with the usage of ‘nation’, it is important to clarify the terminology used in this report. Roberts (2000a: 7) provides a very clear and well-founded differentiation between ‘nation state’ and ‘territory’ to describe different spatial levels in the UK. The term ‘nation state’ is used to refer to the United Kingdom which is a member state in the European Union, and is thus an appropriate spatial unit for the implementation of a NSPF. However, different constituent units (i.e. England, Northern Ireland, Scotland and Wales) in the UK can also have their own agenda of developing a territorial spatial framework. The term ‘territory’ is used to describe ‘a spatial level below that of the nation state, be it of the Celtic nations or a region of England’. The terms ‘nation state’ and ‘territory’ are, therefore, used in this report to distinguish the different spatial levels in the UK. When examining the six topic papers commissioned by the RTPI, a consensus emerges among the authors over the importance of having a UK-SPF that provides an integrative framework for horizontal and vertical linkages. The authors highlight five key elements about the nature and purpose of a UK-SPF:

- to understand the spatial context and trends of policy sectors
- to anticipate spatial consequence of sectoral policy
- to establish national principles to guide lower spatial scales
- to collect information on a consistent and frequent basis
- to have a broader framework to cover issues beyond land-use planning.

However, opinion is more divided over the ultimate standing of a UK-SPF in the existing spatial hierarchy of the UK planning system.

Existing planning and development framework

Bearing in mind the focus on ‘national’ and ‘spatial’ dimensions as suggested by a NSPF, a brief appraisal of existing UK planning and development frameworks Table was made to find out whether issues with strong spatial impacts are currently adequately addressed. The assessment in Table shows that the spatial coordination of land-use and other sectoral development activities tends to occur at the lower tiers of the spatial hierarchy which happens at or below the regional level.

Table 3.1: Nature of planning and development policy frameworks in the UK

<i>Spatial level</i>	<i>Planning and development policy framework</i>	<i>Spatial dimension</i>	<i>Sectoral dimension</i>
National level	National Planning Guidance and Government Circulars Planning Policy Guidance (England) National Planning Policy Guidelines (Scotland) Planning Guidance Wales (Wales) Other National Sectoral Strategies	Generally weak	Strong
		Generally weak	Strong
Regional level (for England)	Regional Planning Guidance	Should be strong	Strong
	Regional Economic Strategy	Varies, but generally weak	Strong
	Other Regional Sectoral Strategy e.g. housing, transport	Varies	Strong
Sub-regional and local level	Development Plans	Strong	Strong
	Other Sub-Regional and Local Sectoral Strategy e.g. transport, economic development, coastal, landscape	Varies	Strong

Source: Baker and Wong, 2000.

Table 4. Nature of Planning and development policy framework in the UK

General planning and development policies set out in Planning Policy Guidance for England (PPGs) and, to a lesser extent, National Planning Policy Guidelines for Scotland (NPPGs) and Planning Policy Guidance for Wales (PGWs) are generally non-spatial frameworks (Baker, 1998; Roberts, 1996). They aim to set out general policies to be translated by local and regional actors into local and regional policies and initiatives. Other national sectoral policy frameworks such as the National Transport Strategy focus largely on the distribution of that particular sector, rather than the interaction between different policy sectors and their spatial impacts.

Appendix III. GIS for urban and Regional Planning

Planners require solutions that address day-to-day work needs while also fostering the ability to effectively predict and respond to chronic urban problems and future market fluctuation. The success of planners in combating chronic urban problems is largely determined by their ability to utilize effective tools and planning support systems that allow them to make informed decisions based on actionable intelligence. Today, planners utilize GIS around the world in a variety of applications. GIS tools can provide the necessary planning platform for visualization, modeling, analysis, and collaboration. GIS spatial planning support tools have an important advantage changing the valuation criteria to visually illustrate and depict the implications of different spatial decisions and alternatives is convenient. The capabilities needed for decision making readily available in a single system make GIS a great tool for integrating in planning processes (Matt, 2011).

Singapore Masters Land use planning using GIS

Singapore faces immense challenges in its land-use planning that stem from the fact that almost five million people live and work within a land area of 710 square kilometers (274 square miles). That's why Urban Redevelopment Authority (URA), Singapore's national land use planning agency, relies on GIS to find new ways to minimize development constraints. The result of the URA's GIS-based planning can be seen in two key plans, the concept plan and the master plan both of which provide a comprehensive, forward-looking, integrated framework for sustainable development. The master plan is a land-use plan that guides Singapore's development 10 to 15 years into the future. It is reviewed every five years and translates the broad, long-term strategies of the concept plan into detailed plans to guide development. Like the concept plan, the master plan is produced collaboratively among many government agencies in Singapore (Matt, 2011).