Developing a methodological geographic information system framework to augment identification of future risk of anomalous dwelling fires

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A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

This research programme was carried out in collaboration with Merseyside Fire and Rescue Service

March 2015

This thesis is dedicated to my family

It wouldn't have been possible without your love and support

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Acknowledgements

I would like to thank my supervisors, Dr. Mark Taylor and Hulya Francis, for their patient guidance, encouragement and advice provided throughout my time as their student. This research would not have been possible without their support and I feel very lucky to have had such a wonderful supervisory team. I would also like to thank Dr Mike Francis who encouraged me to start this research and I am very thankful to him for this.

I would also like to thank all the members of staff at the School of Computing and Mathematics at Liverpool John Moores University. In particular, I would like to thank Prof. Paulo Lisboa and Dr Ian Jarman for their advice and guidance in reference to Chapter Six of this thesis.

I must express my gratitude to colleagues and friends at Merseyside Fire and Rescue Service. I am grateful for the opportunity to have worked with such a fantastic team for a number of years while completing this research. The opportunity to apply this research methodology has been invaluable, and I appreciate the opportunity given through funding from the Local Government Customer Led Transformation Fund and later Merseyside Fire and Rescue Authority. In particular, I would like to express my heartfelt thanks to DCFO Phil Garrigan, AM Myles Platt, SM Mark Jones, Deb Appleton, Paul Terry and the District Prevention teams for their leadership and support, particularly in relation to the application of this research. Completing this work would have been all the more difficult were it not for the support and friendship provided by colleagues at Merseyside Fire and Rescue Service. I would like to thank them all for their help along the way.

I would like to express thanks to my family and friends for their support over the past five years while I was completing this research. My thanks must go to my husband Dave for giving me the motivation to keep going and for believing in me when I doubted myself. Your love and support kept me going and got me through the most challenging points of my research. Finally, thanks to my parents, May and Joe. I am indebted to them for their encouragement throughout my life. They have encouraged me to achieve my dreams and I cannot thank them enough for everything they have done for me.

Abstract

This thesis outlines research completed in partnership between Merseyside Fire and Rescue Service and Liverpool John Moores University. The aim of the research was to investigate ways to develop and implement a bespoke Geographic Information System framework that could be used to identify risk of future anomalous accidental dwelling fires. This thesis outlines the techniques used to develop the framework and its application. In particular, the thesis presents an understanding of accidental dwelling fire causal factors and how data related to these can be incorporated into a model for identifying risk and targeting initiatives relative to the risk. The thesis also investigates two strands of customer insight developed for Merseyside Fire and Rescue Service. These are community profiles, based on a cluster analysis approach, to understand risks present within communities and the vulnerable person index, which identifies individuals most at risk from fire using data shared through information sharing agreements. Nationally recognised risk modelling toolkits, such as the Fire Service Emergency Cover toolkit do not utilise local information or have the ability to identify risk to an individual level. There is a need for this intelligence to be able to proactively target services, such as the Home Fire Safety Check. This paper also discusses some of the key operational and strategic areas that benefit from this information and presents some case studies related to the application of the research.

Published Works

The following publications have resulted from this research:

1. Higgins*, E. Taylor, M., Francis, H., Jones, M., Appleton, D. (2014) The evolution of geographical information systems for fire prevention support, Fire Safety Journal, 69, 117-125

2. Taylor, M., Higgins*, E., Lisboa, P., Arshad, F. (2014) Developing a data sharing framework: a case study, Transforming Government: People, Process and Policy, 8, 1, 151-164

3. Higgins*, E., Taylor, M., Francis, H. (2013) A systemic approach to multi-agency community safety, Systems Research and Behavioural Science, DOI: 10.1002/sres.2248

4. Higgins*, E., Taylor, M., Jones, M., Lisboa, P. J. G. (2013) Understanding Community Fire Risk – A Spatial Model for Targeting Fire Prevention Activities, Fire Safety Journal, 62, 20-29

5. Taylor, M. J., Lisboa, P. J., Kwasnica, V., Higgins*, E. (2012), An exploration of causal factors in unintentional dwelling fires, Risk Management, 14, 109-125

6. Higgins*, E., Taylor, M. (2012), Developing a statistical methodology for improved identification of geographical areas at risk of accidental dwelling fires, in Proceedings of Geographical Information Science Research UK Conference, Lancaster University, Lancaster, UK, 11 – 13 April, 2012

7. Higgins*, E., Taylor, M., Francis, H., (2012) A systemic approach to fire prevention support, Systemic Practice and Action Research, 25, 5, 393-406

8. Taylor, M. J., Higgins*, E., Lisboa, P. J., Francis, M. (2012), Testing geographical information systems: a case study in a fire prevention support system, Journal of Systems and Information Technology, 14, 3, 184-199

9. Taylor, M. J., Higgins*, E., Francis, M., Lisboa, P. J. (2011) Managing unintentional dwelling fire risk, Journal of Risk Research, 14, 10, 1207-1218

* Author's name changed from Emma Higgins to Emma Dean in July 2014

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List of Abbreviations Used

ADF	Accidental Dwelling Fire
AM	Area Manager
ANOVA	Analysis of Variance
ASB	Anti Social Behaviour
CFO	Chief Fire Officer
CFS	Community Fire Safety
COPD	Chronic Obstructive Pulmonary Disease
CSV	Comma Separated Values
CT	Council Tax
CWI	Child Wellbeing Index
DCFO	Deputy Chief Fire Officer
DLA	Disability Living Allowance
FRAM	Fire Risk Assessment Methodology
FSEC	Fire Service Emergency Cover
GIS	Geographic Information System
GMFRS	Greater Manchester Fire and Rescue Service
GP	General Practitioner
HFSC	Home Fire Safety Check
IMD	Indices of Multiple Deprivation
IRMP	Integrated Risk Management Plan
IRS	Incident Recording System
LSOA	Lower Super Output Area
MFRA	Merseyside Fire and Rescue Authority
MFRS	Merseyside Fire and Rescue Service
MLR	Multiple Linear Regression
MSOA	Middle Super Output Area
NHS	National Health Service
OA	Output Area
OiC	Officer in Charge
ONS	Office of National Statistics
OS	Ordnance Survey

PDF	Portable Document Format
POPIN	Promoting Older People's Independence Network
RM1	Risk Management Form 1
SM	Station Manager
SPSS	Statistical Package for the Social Sciences
SQL	Structured Query Language
SSM	Soft Systems Methodology
UML	Unified Modelling Language
VPI	Vulnerable Person Index
VPI	Vulnerable Person Index
WM	Watch Manager

Chapter 1 – Introduction

1.1 Thesis Introduction

Fire and Rescue Services within the United Kingdom attend thousands of incidents every year. The impact of fire to an individual or community can be devastating; therefore, Fire and Rescue Services are continually looking to find ways to target their services and initiatives towards the most vulnerable in order to prevent fires from occurring. Ongoing budgetary constraints within the public sector have resulted in cuts to many services, and Fire and Rescue Services are no exception. Over the coming years, there will be some significant changes with regards to changes of operational resources, such as the availability of fire appliances and the closure of fire stations. For this reason, prevention initiatives have become increasingly important, as they have the potential to stop fires from occurring and reduce risk from fires within communities. One problem with the delivery of prevention initiatives is it is often difficult to know where to target particular resources in relation to risk.

This problem can be addressed through intelligent analysis of relevant data. There is a wealth of information available across the public sector, and this can be successfully used by Fire and Rescue Services to improve the understanding of at risk communities and individuals. The development of a new geographic information systems framework, based on existing methodological techniques, can aid with the identification of accidental dwelling fire risk. This thesis outlines the development of such a framework and its application within a Metropolitan Fire and Rescue Service within the United Kingdom.

1.2 Motivation

All UK Public Sector Services are facing austerity measures because of the global recession, and Fire and Rescue Services face this same concern. In response, Fire and Rescue Services are committed to finding ways to improve the targeting of prevention services to help achieve the required savings whilst still delivering a high quality, value for money service. All Fire and Rescue Services within the United Kingdom report annually on incidents, injuries and deaths [1]. These have been consistently reducing since the introduction of the Home Fire Safety Check in 1999 [2], but there is a real risk that figures could start to increase given reduced resources. Of course, no Fire and Rescue Service would wish to witness this as they have a duty of care to prevent incidents and protect the community.

Many current methodologies available to Fire and Rescue Services simply focus on the association of risk with past incidents and the geographic areas where they occur. Whilst this has helped to reduce accidental dwelling fires, it does not address that the underlying causes of such incidents, namely the lifestyles, circumstances and behaviours of individuals. For this reason, accidental dwelling fires and associated injuries and deaths, are seen to be preventable; often the key to this is putting measures into place that mitigate the risk the occupant presents. Systems and methodologies focused solely on past incidents and geographic areas do not assist in understanding where future accidental dwelling fires may occur, as they do not take into account the risk an individual presents. The outputs from these methodologies are simply illustrating localities where there have been a large proportion of incidents in the past, and users of these outputs associate risk to areas that have seen the highest proportion of incidents. As a result of this, there is an ever increasing need for a new methodology to associate accidental dwelling fire risk with the wider determinants of fire, that is the factors that can increase the likelihood of a fire occurring. Understanding these factors allows for true fire prevention work to happen, as it can identify the root cause of the risk and measures can be put into place to reduce the particular risk present.

The Government in the United Kingdom is increasingly pushing for their Local Government agencies to publish information and data sources in the public domain in order to become more transparent [3]. Many of these freely available, published data sources link to the wider determinants of accidental dwelling fires; therefore, there is an opportunity to link these with the development of this framework. This presents an ideal opportunity in the current climate to focus on the development of a framework that can assist with the identification of accidental dwelling fire risk, whilst utilising information and data sources already available in the public domain.

1.3 Objectives of this Research

There are a number of objectives related to this research. The overall aim is to develop a framework to assist community fire prevention teams within Fire and Rescue Services deliver Home Fire Safety Checks towards those most at risk or most vulnerable. There is a particular focus on the move to associate accidental dwelling fire risk with an individual rather than an area. It is anticipated that this will improve the identification of anomalous accidental dwelling fires occurring in unexpected localities that are not flagged as at risk in current methodologies. It is accepted that there is still a need for an area based approach for assessing risk for strategic purposes; however, this approach should also consider the characteristics of the communities living within them, rather than solely focusing on past incidents. It is anticipated that both the area based and person specific approaches should complement each other for strategic and operational purposes.

This research also aims to develop an understanding of how existing information and data sources can be utilised to develop new products and knowledge within the Fire and Rescue Service community. This is important, as it links in with the Local Government Open Data Strategy [3], but also demonstrates that there is a wealth of information available across the public sector that can be utilised to solve complex problems.

The purpose of the framework is to support a proactive delivery of services based around a methodology modelling accidental dwelling fire causal factors. This is opposed to the current methodologies used which are purely reactive, as they are based on the assumption that areas that have seen a large numbers of accidental dwelling fires in the past will be where future accidental dwelling fires will occur. The following activities contribute to this research:

1) Requirements analysis

Within any large organisation, there are often conflicts related to the requirements of new systems. A potential methodology to understand the conflicts and potential solutions is soft systems methodology (SSM). A SSM analysis will provide a holistic understanding of the needs and expectations of a wide range of system users, therefore allowing for the development of a framework that takes into account all of these needs.

2) Exploration of causal factors

A number of factors can contribute to fire risk. The next stage of this research is to understand what these factors are through an analysis of incidents occurring within the Fire and Rescue Service studied. In particular, this will provide information about the circumstances that may have contributed to the fire, leading to an understanding of whether there are any common factors involved.

3) Statistical modelling

Understanding the causal factors most likely to increase fire risk is not enough to improve targeting of resources. There is a need to apply these findings to understand where risk might occur and build those factors into a predictive model. Multiple linear regression modelling is a mechanism to interpret these factors and provide a meaningful risk assessment based on the combinations of causal factors present. However, the outputs of this activity are often in a format that is difficult to manage and interpret in a fast-paced environment such as a fire and rescue service, therefore there is a need to translate this in a user friendly way. In addition, there is the potential to develop a segmentation model of the population to understand whether there are any common characteristics within small communities that could be associated with accidental dwelling fire risk. This is particularly useful for determining whether there are any additional, indirect, factors contributing to accidental dwelling fire risk. One technique that could be used to complete this is cluster analysis. This type of analysis is useful for identifying similarities within datasets and segmenting appropriately into groups with similar characteristics.

4) Integration of statistical model with GIS

Access to the model needs to be user-friendly, with the appropriate use of graphical user interfaces and maps to illustrate the results. Staff concerned with fire prevention initiatives at the fire and rescue service may not be familiar with the statistical approaches used; therefore, it needs to be integrated with a user-friendly interface to increase its accessibility.

5) Testing and user acceptance of framework

After the development of any framework or system, it is important to test the application to ensure users do not receive any errors. In this example, errors could be costly as they may lead to an incorrect allocation of fire prevention resources. To prevent this from occurring, tests related to data retrieval, statistical modelling and map generation can be completed. To complement this, users will test the 'usability' of the system to ensure it is fit for purpose.

6) Application of framework for fire prevention

As this methodology has been developed for an operational fire and rescue service, the results of this research have been actively used to target resources related to fire prevention. This includes the application of resources for completing Home Fire Safety Checks.

The combination of these six objectives will support improved understanding of why accidental dwelling fires occur, and will support improved targeting of fire safety initiatives.

1.4 Contributions Made to the Field by this Research

The main contribution of this research will be the development of a framework that can be applied by any Fire and Rescue Service to understand accidental dwelling fire risk within their Service boundaries. The framework has been developed with the consideration of the wider determinants of accidental dwelling fire. These factors, in different combinations, are universally agreed as being the main causes of accidental dwelling fires, injuries and fatalities meaning that it can be used and applied by any Fire and Rescue Service, regardless of whether it is a Metropolitan, County or Combined Service.

The development of this framework has taken the Fire and Rescue Services in the United Kingdom on an important journey in relation to the way prevention services are delivered. It should be noted that as a result of this research, the Fire and Rescue Service studied developed a new Prevention Delivery strategy [4] encompassing a person focused approach to understanding risks opposed to solely focusing on past incidents. Many other Fire and Rescue Services are starting to adopt similar approaches for understanding their risks based on the implementation of this research in the Fire and Rescue Service studied. It has been long believed that such an approach should be taken, but there has been a gap in knowledge and skills about how this could be achieved prior to the development of this framework.

The framework has been developed and tested in a real world environment, and every step of the study has involved an operational, Metropolitan Fire and Rescue Service. The Service studied was Merseyside Fire and Rescue Service, based in the North West of England. Merseyside Fire and Rescue Service have since adopted this framework as their primary source of accidental dwelling fire risk identification. Each phase of this study has been documented in the form of publications submitted and published in a wide range of academic journals [5], [6], [7], [8], [9], [10], [11] [12] [13]. The Local Government Association has also recommended the approach as good practice in one of their recent customer led transformation case studies [14].

1.5 Thesis Structure and Organisation

Chapter 1 provides a brief overview of the thesis, including the main aims and objectives, the motivation for the researcher to complete this study and the contribution that this research has made to the field of anomalous accidental dwelling fire risk identification.

Chapter 2 provides an overview of the role of fire and rescue services within the United Kingdom, including their key statutory duties. In particular, this chapter will focus on Merseyside Fire and Rescue Service, where this research was conducted, and outline their structure in terms of prevention delivery services. The chapter will also focus on the risk management methodologies currently available to UK fire and rescue services, assessing whether there is a gap that can be addressed by this research.

Chapter 3 will focus on the methodologies used to develop a framework for assessing future risk of accidental dwelling fires. In particular, this chapter will investigate the qualitative and quantitative methodologies used and how these can be integrated to enhance understanding of accidental dwelling fire risk.

Chapter 4 will provide a more detailed analysis of the qualitative methodologies used. Specifically, this chapter will review how the problem situation was defined for this research and how this was utilised to create the first phases of an accidental dwelling fire risk framework.

Chapter 5 will provide a more detailed analysis of the quantitative methodologies used. In particular, this will focus on understanding which lifestyle and behavioural factors can potentially lead to an accidental dwelling fire. This chapter will also assess the barriers faced related to accessing information and data to inform the modelling process recommended through this research.

Chapter 6 provides an overview of the statistical modelling processes developed to provide an estimate of accidental dwelling fire risk. Previous chapters provide a summary of causal factors that may increase risk of accidental dwelling fire, but do not provide an indication of how significant these factors are, or otherwise. This chapter also investigates how the presence of these causal factors can be modelled to 'predict' anomalous accidental dwelling fire risk, and how they can also be used to create other tools beneficial to Merseyside Fire and Rescue Service.

Chapter 7 investigates the development of a user friendly interface based on the developed statistical models. It was noted at the outset of this research that staff members at Merseyside Fire and Rescue Service had little understanding of more complex statistical techniques. For this reason, the development of an interface that removed all contact with the statistical model was required.

Chapter 8 looks at the testing process used for the GIS framework. There was little available literature that outlined a full process of testing, therefore a GIS testing framework was developed for this research. This framework outlined the testing process required for each element of the framework and a schedule of user acceptance testing.

Chapter 9 outlines some applications of the framework that were completed by Merseyside Fire and Rescue Service after the development of the framework was completed. These applications were the first steps to fully implementing the model into Merseyside Fire and Rescue Service's routine activities.

Finally, Chapter 10 provides a summary of the research completed and its applications. It also suggests some future areas of research that could build on the framework described in this thesis.

1.6 Summary of Introduction

This chapter provides an overview of the structure of the thesis and the aims and objectives of the research. This research was commissioned by Merseyside Fire and Rescue Service as ongoing budgetary constraints within the public sector have resulted in cuts to many services, including to fire and rescue service prevention activities. Accidental dwelling fires have often been associated with a number of causal factors, but there has been little practical research available allowing the fire and rescue service to apply this thinking. The aim of this research is to provide a localised investigation into accidental dwelling fire causal factors and develop a practical framework that can be applied in the operational environment to reduce accidental dwelling fires and associated injuries and fatalities. The following chapters of this thesis will provide a detailed investigation of how this was developed and later applied.

Chapter 2 – Background

2.1 Introduction to the Background

In order to gain an understanding of the development of a geographic information system (GIS) framework to aid with the identification of accidental dwelling fires, it is important to first gain an understanding of the Fire and Rescue Service environment to develop a solution that can truly meet their needs.

This chapter outlines the current environment of Fire and Rescue Services within the United Kingdom, the activities they are involved with related to fire prevention and the methodologies currently used to support this.

This chapter also provides an introduction to Merseyside Fire and Rescue Service and outlines their approach for delivering Home Fire Safety Checks prior to the implementation of this research.

2.2 Fire and Rescue Services within the United Kingdom

There are 63 Fire and Rescue Services in the UK, providing emergency response for over sixty-one million people [15]. Each Fire and Rescue Service is governed by a Fire Authority, made up of elected members, which is responsible for managing the Fire and Rescue Service on behalf of the community. The responsibilities of the Fire Authority are related to budget setting, approving policies, plans and strategies and ensuring resources are in place to deliver an effective service [16]. Many Fire and Rescue Services were known as ‘Brigades’ or simply ‘Fire Services’ prior to the implementation of the Fire and Rescue Services Act (2004) [17], which recognised the wider role Fire and Rescue Services played within the community. The Fire and Rescue Services Act (2004) outlines a number of core functions that is required of every Fire and Rescue Service [17]. These core functions are:

- Fire Safety
- Fire Fighting
- Road Traffic Accidents
- Emergencies

The Act states that Fire and Rescue Services have a duty of care to prevent fires, and other incidents from occurring; protecting the community from incidents; and responding to incidents should they occur. The scope of this research is concerned solely with the fire safety element, and in particular a smaller subset of that, which is around accidental dwelling fire prevention. The legislation of the Fire and Rescue Services Act (2004) outlines that there is a statutory duty for every Fire and Rescue Service to make provisions to promote fire safety within their local area. A particular focus of this is around preventing fires and escaping property [17]. Although the Act does not outline how this should be delivered, many Fire and Rescue Services within the United Kingdom have adopted the Home Fire Safety Check, or Home Fire Risk Assessment methodology [2]. This, as the title suggests, is focussed primarily on home safety and ways to prevent fires from occurring within the property. The Home Fire Safety Check was developed in response to the increased likelihood of having a fire or suffering from a related injury or fatality in the home [18], [19], [20]. The Home Fire Safety Check involves visiting homes to complete an assessment of risks present, and providing fire safety advice. Since its introduction in 1999 [2], the number of accidental dwelling fire incidents in the United Kingdom has decreased by 32% in the 10 years from 1999 until 2009 [21].

2.2.1 Merseyside and its Fire and Rescue Service

Merseyside is a metropolitan county in the north west of England, which spans the River Mersey and includes the metropolitan boroughs of Knowsley, Liverpool, Sefton, St Helens and Wirral. The county of Merseyside has boundaries with West Lancashire in the north and Cheshire in the south. The boroughs of Sefton, Liverpool and Wirral are coastal communities are bounded by the Mersey Estuary and Irish Sea. The land use within Merseyside is very diverse, and it contains a mix of high density urban areas, semi-rural and rural locations. Liverpool is the largest urban area within Merseyside; however, there are large urban areas within each of the boroughs. Each borough has a different set of demographics, which in turn presents different risks for Merseyside Fire and Rescue Service. For example, Sefton and Wirral have pockets of very deprived communities and also pockets of the wealthiest communities in the country and Liverpool has a very dense population base with a varying mix of deprivation.

At the 2011 Census, Merseyside had a population of approximately 1.4 million [22] residents but this is changing over time. Between 2001 and 2011 the overall population has increased by 1% (13,400 people in real terms) but the Asian/Asian British ethnic group has seen an 82.6% increase between 2001 and 2011 [22]. As is the case in many areas in the UK, Merseyside has an increasing ageing population, with older age groups increasing in numbers (age groups over 75 years) and the younger age groups (5-9, 10-14 and 15-19 age groups) reducing in numbers from 2001 to 2011 [23]. For some boroughs, the ageing population brings some significant challenges. In Sefton, the increasing ageing population is coupled with a declining working aged population. In particular, this means there will be a growing dependency of an increasing older population on a reducing working age population in the borough. This may impact on the need for certain services for residents in the area.

There are some areas of affluence, for example in West Wirral and north Sefton, but large areas of Merseyside fall within the highest ratings of social deprivation nationally [24]. There are large pockets of deprivation with high levels of social exclusion and crime. The UK Indices of Multiple Deprivation 2010 [24] indicate that 40 per cent of the wards in Merseyside are ranked in the top 5 per cent of the most deprived wards in England. In addition, all the local authorities in Merseyside are within the top 20 per cent of the most income-deprived in England.

Merseyside Fire and Rescue Authority (MFRA) is a local authority created by the Local Government Act 1985. It is made up of elected representatives appointed by the constituent local authorities. Merseyside Fire and Rescue Service (MFRS) has the operational responsibility for providing emergency response service for fires and other incidents (e.g. road traffic accidents) and fire prevention and protection services across the county. Approximately 1,600 staff members are employed at a number of administrative centres and at 26 Community Fire Stations and a Water Rescue station.

Prevention services within Merseyside Fire and Rescue Service are delivered across five districts[1] by a team of District Prevention Managers, Fire Prevention Advocates and volunteers. Home Fire Safety Checks are also delivered by operational crews based at each of the 26 stations. The District Prevention teams are specially trained to deal with the most vulnerable members of the community and to understand and identify a broad range of risks within the home. The role of the District Prevention team is to provide a holistic approach to fire safety, and refer or signpost an occupant onto other local authority departments, such as housing or benefits, should it be necessary.

Since the introduction of the Home Fire Safety Check in 1999, there has been a strong focus towards providing preventative initiatives to residents of the Merseyside communities. For a number of years, Merseyside Fire and Rescue Service had a target of completing 100,000 Home Fire Safety Checks

[1] The five districts are Knowsley, Liverpool, Sefton, St Helens and Wirral.

annually, the highest of any fire and rescue service in the United Kingdom [25]. Because of the extensive fire prevention work completed, the Authority was awarded “Excellent” status for its performance, one of very few Fire Authorities to be awarded such an achievement [26]. However, a change in Government in 2010 resulted in all UK public sector services facing austerity measures, and Merseyside Fire and Rescue Service was no exception. Between the period 2011/12 and 2012/13, Merseyside Fire and Rescue Service were required to save approximately £9million from their budget, with approximately £2.5million related to the reduction in back office costs, including the delivery of prevention services [27]. This further drove the need for the development of a system that could be used to target services and initiatives more effectively towards Merseyside communities.

2.2.2 Analysis of Accidental Dwelling Fire Incidents

Between April 2011 and March 2012, there were over 220,000 incidents reported and attended by fire and rescue services within the United Kingdom, and of these approximately 16% (35,000 incidents) were accidental dwelling fires[2]. Although accidental dwelling fires only contribute to about a sixth of incidents attended by fire and rescue services, these incidents have the potential to be more deadly than other types of incident. Approximately 60% of fire related deaths in 2011/12 were as a result of an accidental dwelling fire [15]. The number of accidental dwelling fire incidents

[2] The definition of an accidental dwelling fire from the Department of Communities and Local Government is “a fire in the home that was not started intentionally. This also includes fires where the cause was unknown or not specified”.

has reduced significantly since the introduction of the Home Fire Safety Check. In 1998, the year prior to the introduction of the Home Fire Safety Check, there was 57,700 accidental dwelling fires and 656 related fatalities [28]. This means there has been a reduction of accidental dwelling fires by almost 40% and fatalities by over 53% nationally. It is widely accepted that Home Fire Safety Check delivery has had an impact on the reduction of accidental dwelling fire incidents and fatalities. An evaluation study by Nottinghamshire Fire and Rescue Services suggests that these reductions could be related to changing behaviours as a result of the information delivered as part of the Home Fire Safety Check [29]. Whilst this is positive, these figures do not illustrate whether the reductions in accidental dwelling fires are occurring uniformly across different segments of the community. In particular, one issue reported by Merseyside Fire and Rescue Service is that a significant proportion of accidental dwelling fires were occurring in 'out of context' locations [30] and not spread equally across the community or within areas traditional modelling identified as high risk. Within Merseyside, the number of accidental dwelling fire related fatalities has decreased by 54 percent between since 1999 [30]. However approximately 33% of accidental dwelling fire fatalities in the period between April 2012 and March 2013 occurred in 'out of context' locations [31]. This means that approximately one third of fatalities are occurring in areas where current systems and methodologies identify as 'low risk'. Findings from Merseyside Fire and Rescue Service also suggest that risk of accidental dwelling fire increases with age, and all of the fatalities occurring in the ‘out of context’ locations involved an individual aged over 50 [31].

While there has been a significant reduction in accidental dwelling fires over the past 15 years, the rate of reduction appears to have slowed somewhat. Between 1999 and 2005, there was an overall reduction in accidental dwelling fires by approximately 30%. However, the rate of reduction in incidents has significantly slowed, with the overall reduction in incidents between 2006 and 2009 being approximately 12%. During the financial years 2010/11 and 2011/12, the numbers of accidental dwelling fires within Merseyside have been very similar [32]. This is illustrated in Figure 1.

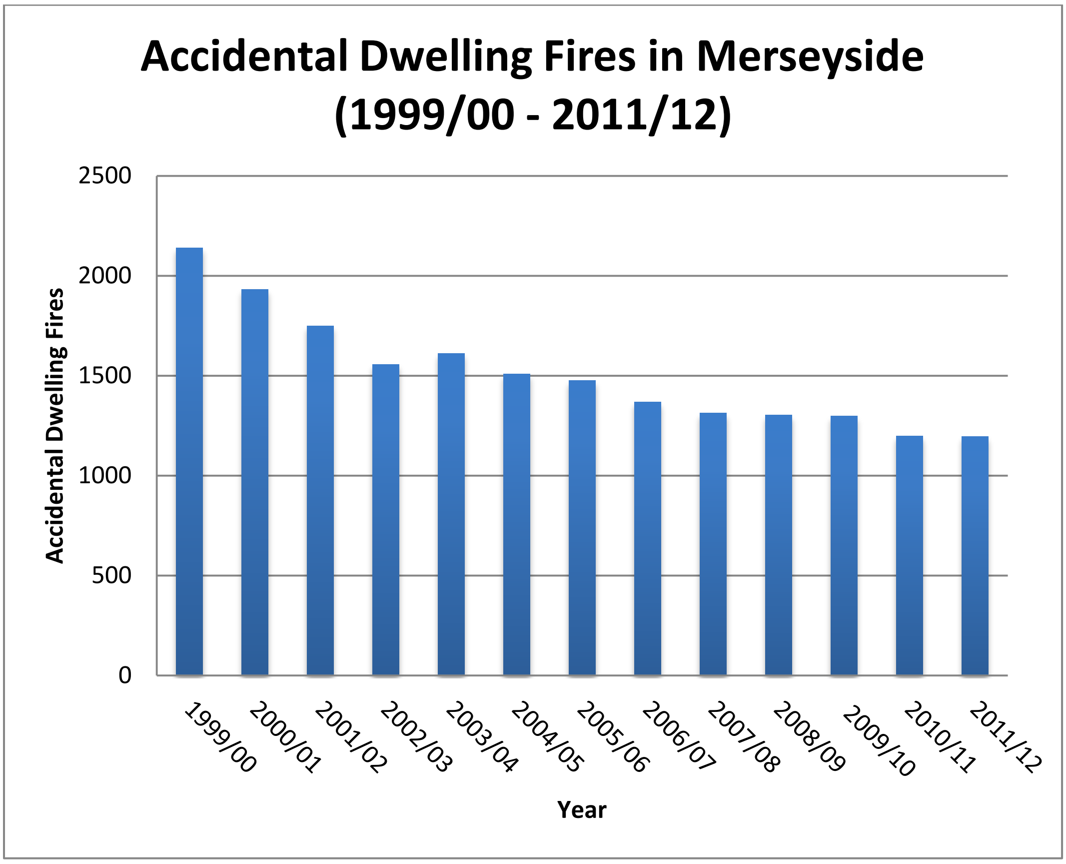

Figure 1 - Accidental dwelling fires in Merseyside between 01/04/1999 and 31/03/2012

2.3 The Home Fire Safety Check in Merseyside

Merseyside Fire and Rescue Service have been delivering the Home Fire Safety Check since 1999. Between the period 1999 and 2010, the Service completed approximately 650,000 Home Fire Safety Checks and fitted over 1,000,000 free smoke alarms to the residents within Merseyside [14]. Initially, Home Fire Safety Check delivery was supported by central Government grants [33]. These have since ended due to budget cuts across all Government departments [14]. Prior to the budgetary constraints, Merseyside Fire and Rescue Service set a target of completing approximately

100,000 Home Fire Safety Checks annually [25]. This was no longer sustainable when the grants ended. A new appliance based strategy has since been put into place, with most appliances[3] being set a target of completing 40 Home Fire Safety Checks per month. This equates to approximately 50,000 Home Fire Safety Checks across the County annually [4].

Merseyside Fire and Rescue Service has a call centre, based at their Service Headquarters, that is responsible for booking Home Fire Safety Checks with members of the public. Operational Crews at each station will have access to a calendar of booked Home Fire Safety Checks to be completed on their tour of duty[4]. The Crews will visit the property and engage with the occupant, looking for potential fire risks and hazards and providing advice. Smoke alarms will be fitted if necessary. When completing the visit, the Crew will complete a Home Fire Safety Check form, which documents information about the occupant such as their age, number of occupants in the property or whether the occupant has any disabilities. The Crew can also record whether there are any fire risks or hazards present. Based on the answers given, the occupant will be rated as having a high, medium or low accidental dwelling fire risk at the end of the assessment. The risk rating will be reassessed following the crew providing advice and fitting smoke alarms, if necessary. The final risk rating will determine when the Home Fire Safety Check will be next reviewed. Those who are rated as low risk will be revisited in 5 years;

[3] 'Appliance based targets' equates to what each Watch must complete on a monthly basis. There are 4 Watches – Blue Watch, Green Watch, Red Watch and White Watch.
[4] A tour of duty equates to the shift pattern each Watch completes. In Merseyside, as at August 2013, these are typically 2 consecutive day shifts followed by 2 consecutive night shift followed by four rest days.

those who are rated as medium risk will be reviewed in 2 years and those who are rated as high risk will receive a referral to the District Prevention teams for further intervention.

If considered necessary, the visiting Crew can make a referral to the District Prevention Team should they believe that the risk from fire within the property is beyond that they professionally feel to be acceptable after completing the check. An example may be an individual with hearing problems who needs a special deaf alarm instead of a standard audible alarm. Any information gathered during the Home Fire Safety Check is stored on a Customer Relationship Management system within Merseyside Fire and Rescue Service called Goldmine [34]. The Goldmine system allows users to interrogate the information held for performance management or equality and diversity analysis, but also provides Operational Crews within information about occupants in properties when attending incidents.

Figure 2 illustrates the process used by Merseyside Fire and Rescue Service for organising their prevention delivery service.

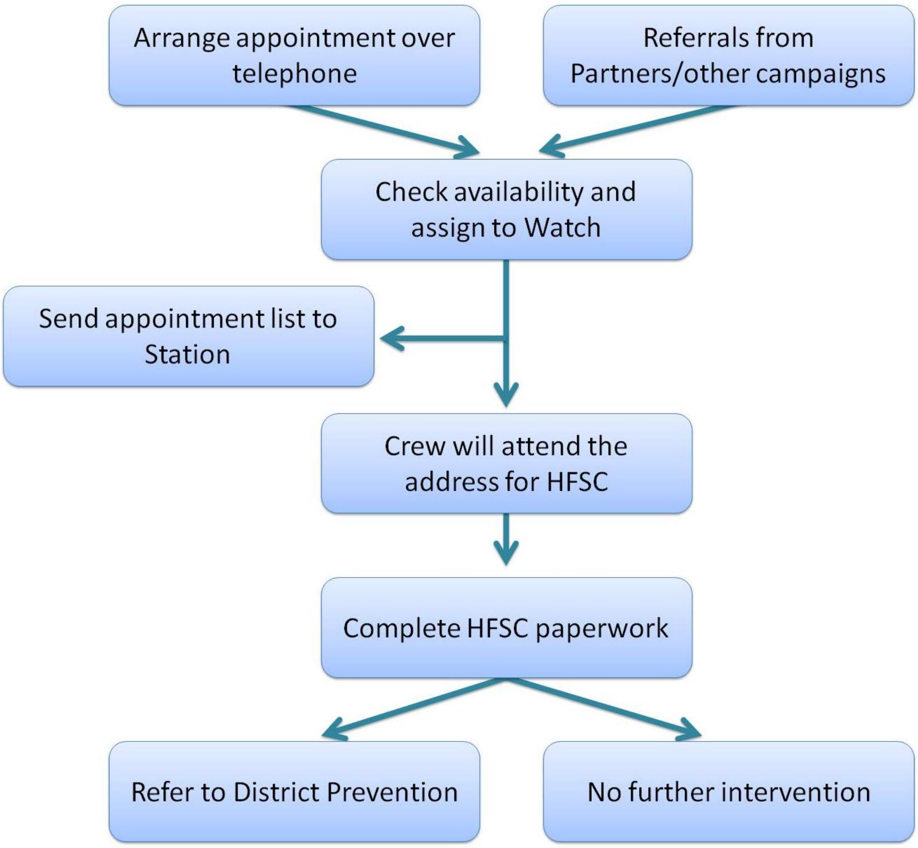

Figure 2 - Flow chart illustrating the Home Fire Safety Check process adopted by Merseyside Fire and Rescue Service

2.4 Geographical Information Systems

Geographic Information Systems (GIS) are commonly utilised within Fire and Rescue Services and often support their risk management methodologies. Church [35] argued that the field of GIS has evolved into a mature research and application area involving a number of academic fields including geography, computer science and land-use planning. The advantage of GIS when compared to other tools is that it can display results graphically, which is beneficial for any analysis involving geographic or spatial information. This often cannot be achieved using other types of information system. An example of where this is beneficial is understanding where clusters of fire incidents occur or the location of station boundaries. Although this information can be presented by other information systems in the form of reports, often the visual representation is of value as it allows the user to make links and associations between the phenomenon and a geographic location. GIS have been used in fire and rescue services for many years to perform basic spatial tasks such as mapping incidents and boundaries, but it has been somewhat limited in its use. GIS are often the basis for a number of risk management methodologies that are available to the Fire and Rescue Service because of the visual nature of the outputs.

2.5 Risk Management Methodologies

The risk management methodologies that are currently available are typically based on a reactive model investigating fires that have occurred within an area previously, rather than a proactive understanding of what contributes to fire risk. Risk models adopted by UK fire and rescue services as part of their Integrated Risk Management Planning (IRMP) activities [36] typically concentrate on an analysis of previous fire incidents, combined with indices of multiple deprivation [24]. Fire and Rescue Services have a statutory duty to produce an IRMP annually, and a key element of this is risk mapping. Within Merseyside, a methodology was developed called Fire Risk Assessment Methodology (FRAM) [37], which looked at data about incidents that posed the greatest life risk to the public. FRAM involved the interrogation of six datasets:

- Dwelling Fires (deliberate and accidental).
- All incidents where injuries have occurred.
- Incidents where there has been a recorded fire death.
- Special Service Calls (i.e. any request for service for an activity other than fire fighting) involving a risk to life.
- Any fire in non domestic premises which has been the result of a deliberate act
- Indices of Multiple Deprivation.

Data on each of these factors is gathered for Lower Super Output Area (LSOA) within Merseyside [38] and a weighting factor applied. The weighting factor is based on professional judgement and relates to the life risk of a particular incident to the public e.g. the greater the life risk, the more heavily a particular factor is weighted. This is then ranked and split into three groups; high, medium and low risk. Within Merseyside, this was the chosen methodology for targeting Home Fire Safety Checks prior to the implementation of the research presented in this thesis. An element of the FRAM tool focuses on accidental dwelling fires; however, the methodology also has a focus on other types of incident that could potentially lead to areas being identified as high risk. An example might be within Liverpool City Centre – areas might be identified as high risk because of fires in non domestic premises rather than fires within dwellings.

Another risk map created by Greater Manchester Fire and Rescue Service (GMFRS) follows a similar approach. This methodology originally focused on a matrix of rates of dwelling fires, dwelling fire casualties, fires in commercial and public buildings and fires posing risk of major loss of life in commercial and other buildings [39]. A recent update of this methodology ensured this information was displayed to Lower Super Output Area level and incorporated the Indices of Multiple Deprivation [40]. This map segments risk into four categories; very high, high, medium and low. Finally, Lancashire Fire and Rescue Service's risk map also focuses on a relationship between fires in commercial properties and dwellings, casualties and the Indices of Multiple deprivation [41].

The Fire Services Emergency Cover (FSEC) toolkit is another model of fire risk used by some UK fire and rescue services [42]. The model was developed by the Department for Communities and Local Government however its use is not mandatory [43]. The FSEC model is based on four modules that include dwelling risk, special service risk, other buildings risk and major incident risk. The dwelling risk module is related to accidental dwelling fire risk. This module utilises data available from previous dwelling fire incidents, and also takes into account the time it would take to travel to an incident based on where a fire appliance is located. The basis of the risk assessments performed by FSEC is a relationship between response time and fatality rates for each incident type. The main outputs of the FSEC dwelling fire risk module are a predicted number of deaths per year, the predicted annual death rate per resident and predicted costs for responding to an incident for a given area [44].

Both the IRMP risk models/maps and the FSEC model are based on the occurrence of previous incidents within a locality. The opportunity explored through this research is to ascertain whether a more predictive model, based on an understanding of the demographic influences that cause fires, can be an improved way of measuring risk. There are a number of previous research studies investigating the use of predictive modelling for forest fires, [45], [46], [47] however, there appears to be little research that has examined predictive risk modelling approaches for accidental dwelling fires and related fatalities [48]. Previous studies related to accidental dwelling fires have identified significant causal factors in these incidents and related fatalities [49], [50], [51], [52]. This was largely from a reactive viewpoint, rather than from a pro-active viewpoint of modelling geographical areas that are at a higher risk of accidental dwelling fires for the purposes of target hardening of fire prevention activities.

2.6 Understanding the Wider Determinants of Accidental Dwelling Fires

Researchers in various countries around the world have identified there are a number of determinants of fire, or causal factors, that can increase ones risk of an accidental dwelling fire. Leth et al [53] in a study of fatal accidental dwelling fires in the Copenhagen, Denmark, identified combinations of factors such as smoking with alcohol misuse or disability as significant factors associated with fatal fires. This was because the smoking materials[5] acted as a source of ignition and the alcohol misuse or disability could impair or prevent the occupant escaping safely. Similarly, another study by Jordan et al [54] in Eastern Scotland in the UK identified smoking, alcohol misuse, and social deprivation as significant factors in accidental dwelling fire incidents. Social deprivation is commonly linked with accidental dwelling fire incidents in current modelling [42] as it is often linked with poor quality housing or inappropriate heating methods, which could lead to a fire incident.

Chien and Wu [52] identified a range of casual factors including the age of residents, housing type, fire location, and ignition source involved in accidental dwelling fires and associated fire fatalities in Taipei in Taiwan. In particular, this study identified that older residents were at particular risk of these types of incident. Similarly, Barillo and Goode [49] highlighted resident age and smoking as significant factors in accidental dwelling fire fatalities in the American state of New Jersey. In particular, this study found that children and the elderly were most vulnerable. This is related to the effect smoke inhalation and burns would have on a particularly young or elderly resident. The Baux Score for burns suggests that if the percentage burns plus the burns victims' age exceeds 130, then it is unlikely that the victim will survive [55].

Mulvaney [56] found that fire fatalities were most commonly caused by smokers' materials in a study of fatal and non-fatal fire injuries in England between 1995 and 2004. This is echoed by fire statistics from the UK

[5] Smoking material are classified as cigarettes, cigars, tobacco, cigarette lighters and matches

Department for Communities and Local Government in 2011, which identified that approximately 35% of accidental dwelling fire fatalities were caused by the careless use and improper extinguishing of smoking materials [1], which could act as a source of fire ignition. Holborn et al [51] in a study of fatal accidental dwelling fires in London in the UK identified a number of causal factors, such as smoking, alcohol misuse, elderly residents, disability, illness, living alone, social deprivation and not having a smoke alarm fitted as causal factors in accidental dwelling fire fatalities. Stevenson and Lee [57] echoed this, and stated the importance of smoke alarms being present in residential dwellings as a key factor in reducing fatality rates. This supports the delivery of Home Fire Safety Checks, especially as an occupant is 50% more likely to die in a fire where there is no working smoke alarm [58]. A smoke alarm is the most effective way to alert an occupant to a fire, especially when the occupant is sleeping. However, smoke alarm ownership is typically lower in disadvantaged neighbourhoods and among families living in privately rented accommodation, where there is little regulation of landlords regarding fire safety. Merrall [59] in a study in Greater Manchester in the UK found that dwelling fires had a strong correlation with levels of socio-economic deprivation, however this study included deliberate as well as accidental dwelling fire incidents. Duncanson et al [60] also found a high level of correlation between accidental dwelling fires and socio-economic deprivation in a study in New Zealand.

The UK Department for Communities and Local Government analysis of fire and rescue service performance and outcomes with reference to population socio-demographics [61] found that socio-economic deprivation, living alone, elderly residents and lone parents with dependent children were significant causal factors in dwelling fires at the UK national level. However, the Department did not complete a similar analysis at the local level for each fire and rescue service to see if there were any local differences.

The previous studies of causal factors in accidental dwelling fire and related fatalities described in this section were conducted within different cities and regions across the world, and were conducted over different lengths of time and different periods. However, the studies investigated concluded that there are certain factors that can increase an individual's risk of fire. Some of the studies attempted to analyse a wide range of factors associated with accidental dwelling fires and fatalities, and to identify the most significant (for example, [51]), which is a useful starting point to understand causal factors that may be prominent within Merseyside.

The fire risk within a geographical area or an individual dwelling can fluctuate depending on changes in causal factors. For example, smoking, binge drinking, living alone, and disability are all factors associated with an increase in the risk of a dwelling fire. Over time, there will be changes in the smoking and binge-drinking patterns due to changing attitudes or public health campaigns, there will be changes in household occupancy, and the percentage of elderly residents; all these can affect the fire risk levels within different areas within a geographical area. This demonstrates that fire risk is dynamic; therefore, any system or tool developed with these causal factors in mind need to reflect this.

2.7 Summary of Background

The aim of this chapter is to gain an understanding of the Fire and Rescue Service environment and some challenges faced. The Fire and Rescue Service has a statutory duty to provide elements of community fire prevention, and given current budgetary constraints, it is becoming ever more important to do this effectively.

An analysis of historic incidents and fatalities illustrates that fire prevention has placed a role in changing behaviours of the community, which has resulted in the number of accidental dwelling fires and fire deaths decreasing quite significantly. However, this effect is starting to slow, meaning that Fire and Rescue Services need to view how they target these initiatives in order to return the greatest impact.

Reviewing current methodologies available shows that there is no methodology or framework in place to support the prediction of where accidental dwelling fire risk may occur in the future. It is well documented that there are a number of causal factors that can increase ones risk from fire, however this has yet to be embedded into a framework to support its use. Some steps have been made by a number of Fire and Rescue Services, including Merseyside, Greater Manchester and Lancashire, which include deprivation as a key measure in forecasting future accidental dwelling fire risk. A review of current literature demonstrates that deprivation is not the only indicator of accidental dwelling fire risk, and focusing only on deprivation and historic incidents could potentially skew representations of where future risk may occur. The causal factors of accidental dwelling fire risk are not only limited to deprived areas, but individuals with these characteristics could be found anywhere in the country. In the case of Merseyside, approximately a third of accidental dwelling fire deaths occurred in localities which were not deprived, suggesting there is a need to move away from solely associating accidental dwelling fire risk with deprivation and previous incidents, to associating it with the causal factors that are proven to increase risk of accidental dwelling fires.

Chapter 3 – Developing a Methodological Framework

3.1 Introduction to Developing a Methodological Framework

The aim of this chapter is to identify appropriate methodologies that can be utilised when developing the accidental dwelling fire risk identification framework. In order to develop such a framework, it is important to understand the processes involved within each component part that contributes to the overall framework. There are a number of components that need to be considered when developing such a framework, such as:

- Understanding the user's requirements
- Developing a methodology to assess risk levels
- Incorporating the risk model into a Geographic Information System (GIS)
- Ensuring the framework is fit for purpose

This research utilises current methodologies that are commonly used across a variety of different disciplines; however, the development of this framework brings together these methodologies for a novel application.

The research methodologies broadly fall into three distinct groups; qualitative research to understand the user requirements and the problem domain, quantitative research to take the concept and develop it to a point where it can be used and GIS development and testing to ensure the developed products are user friendly, robust and appropriate for operational use.

Having gained an understanding of the component parts of the framework, the next step is to review how each of these link together. A combination of qualitative research interviews [62] and Checkland's Soft Systems Methodology (SSM) [63] will be utilised to underpin the requirements of the user of the developed framework. Assessing the needs of the user can be a very complex activity as there are a number of different stakeholders in this study, each with differing needs and expectations. SSM can be a very useful tool for assessing what these needs are and the transformation required to achieve it, but it cannot assist with how this will be delivered in the real world. As a result, there is a need for additional quantitative methodologies to be employed.

After completing the SSM analysis, a quantitative approach will be adopted to understand what factors influence accidental dwelling fire risk within Merseyside. A number of statistical modelling techniques will be developed to assist with achieving an overall understanding of risk. Initially, an exploratory analysis will be completed using data from Merseyside Fire and Rescue Service to assess whether the fire causal factors identified through existing research have a bearing on the occurrence accidental dwelling fires within the County. A number of different statistical analyses will be investigated to provide a representation of accidental dwelling fire risk. These are:

- Correlation analysis
- Multiple linear regression

- Logistic regression
- Cluster analysis
- Factor analysis

For this study, correlation analysis was identified as a technique to understand the relationship between the identified accidental dwelling fire causal factors and incidence of fire. A correlation analysis will be completed using the number of historical fire incidents within an area as the dependent variable and the provenance of the identified causal factors as the independent variables. Although correlation does not imply causation, it does provide an indication as to whether there is any relationship between the causal factors identified and the number of accidental dwelling fires within a given area.

The regression analysis was identified as a method that could model the identified accidental dwelling fire causal factors into an expression of accidental dwelling fire risk. This analysis would utilise the variables identified in the correlation analysis that have a positive relationship with the number of accidental dwelling fires within an area. The regression analysis outputs in this research are suitable for integrating with a GIS. The output of the regression analysis is a series of coefficients that can be multiplied with the prevalence of each causal factor. This is a simple expression that can be embedded easily into the GIS programming code. The outputs from the regression modelling can be associated with a geographical area, which means they can be visually displayed on a map. For this research, the multiple linear regression and logistic regression modelling were selected to provide a comparison. It was important to understand the most effective way to model the data to provide the optimum solution. Both modelling processes were utilised to ensure this could be achieved.

The cluster analysis was selected to be able to provide a more enhanced understanding of communities at a very small geography. The regression analysis provided an understanding of accidental dwelling fire risk. The cluster analysis was utilised to enhance this by provide deep and detailed insight into communities, in particular socio-demographics, behaviours and lifestyles that may be indirectly linked with increased risk from fire. The aim of the cluster analysis was to segment the population of Merseyside into a smaller number of groups that could then be used to deliver services based on the characteristics of each particular group. The outputs of this analysis can be easily embedded into a GIS because it is completed on the geographic footprint of Output Areas [23], which means the outputs can be linked with a geographic area and then be displayed visually on a map.

Factor analysis was identified as a means of data reduction, which can be used to understand the variables within the cluster analysis that have the largest impact on the overall model. Although the outputs of this analysis would not be embedded into the GIS, it was important to know which variables influenced the modelling process the most so the efforts could be made to ensure this data is collected on a regular basis.

As GIS is a familiar tool for Fire and Rescue Service staff, it is important that it is utilised for the interface between the statistical risk models and the user. An important aspect of the GIS is that it is user friendly and simple to navigate. Ensuring that the GIS is fit for purpose is also crucial. As the framework will be used to assist with resource allocation and prevention service delivery, it is important that the outputs are reliable and can be trusted by the Fire and Rescue Service staff users. A thorough GIS testing framework will be put into place to ensure that this is achieved.

3.2 Soft Systems Methodology for Requirements Analysis

Qualitative methods were utilised in the first phase of developing the framework in order to understand some of the more social aspects of the framework development. This was an important phase to ensure that stakeholders involved had the opportunity to express their needs and for the research to deliver a tool to meet their expectations. The qualitative method used was the Soft Systems Methodology process.

Soft Systems Methodology, or SSM, was developed by Checkland in 1966 as a systemic approach for understanding complex problems and situations. The SSM approach is holistic, allowing for consideration of the whole environment when completing the analysis. The methodology is often best utilised when dealing with 'softer problems' involving human, social and cultural elements, which can often be very complex. The different analyses completed as part of the SSM process focuses on the relationships and interactions between different stakeholders and how these relationships and interactions help to achieve a common goal or purpose.

The main reason SSM was chosen for this research is because of the many different stakeholders involved. It would have been difficult to organise the views and expectations of the different stakeholders using ‘hard’ methodologies, which assume that there is a well defined problem with one, optimum solution. In the case of this research, it was difficult to understand the exact nature of the problem domain from the outset, and the best way to deliver a solution to meet the needs of many different stakeholders. Soft Systems Methodology allowed for a greater understanding of each stakeholder, and how they would interact with the final framework.

The SSM process is based on a seven stage model called the Lancaster Model. The Lancaster Model [64] aims to move through the process of describing an unstructured or undefined problem situation to designing an optimum human activity system that can be utilised to improve or change the problem situation.

Stage 1 involved understanding that the problem situation is complex or poorly defined. At this particular stage, the problem situation is not expressed, but merely the general area of interest is expressed, for example, Fire and Rescue Service prevention service delivery. This provides a starting point for further analysis, and the scope of the problem domain can be narrowed to identify the exact issue or concern the user is attempting to address through the methodology.

As part of this process, it is proposed that a number of staff members should be interviewed to gain a better understanding of the problem situation. Sofaer [65] identifies that the use of qualitative methods, such as interviewing, are beneficial for understanding how complex processes can be implemented, therefore improve the way services are delivered. Generally, there are three types of interview that can be conducted, and the approach chosen depends on the overall purpose of the research being undertaken. At either end of the spectrum, there are structured and unstructured interviews. A structured process typically involves a questionnaire type approach, where the questions are rigid and the interviewees are expected to provide a reply which falls into a pre-defined response category. An unstructured interview is the opposite. Generally there is no structure and the interviewer will allow the interview to flow based on the conversations [66]. In the middle of the spectrum is the semi-structured interview. This approach uses a series of pre-determined questions as prompts, which can be used to start a conversation around a particular topic [62]. This approach allows the interviewer to get the most out of the interview by directing the conversation, but allows the interviewee to provide some context and reasoning to their responses. This approach was utilised for this research as it gave the opportunity to explore the needs of the stakeholders, while ensuring the conversations remained relevant to the research.

There were a number of key stakeholders identified for interview. These stakeholders included:

- Chief Fire Officer
- Deputy Chief Fire Officer
- Area Manager, Prevention and Protection
- Watch Manager, Home Fire Safety
- Corporate Systems Support Manager.

Each of these stakeholders were interviewed individually. Each interview lasted approximately 45 minutes and notes were taken to capture the key points. The key points were then translated into the SSM rich picture, which is described below.

This nature of the problem situation is investigated within Stage 2 of the process. This is addressed through the development of a rich picture, which attempts to express the problem domain in a visual manner. The rich picture takes into consideration the wider domain, such as the people, processes, interactions, relationships and environment which may impact on the problem situation. The rich picture is the output of the second stage of the model and looks at the real world that affects and influences the problem domain.

Stage 3 of the process involves the creation of a root definition and is the first step in moving from the real world situation to finding a solution to the problem domain. The purpose of the root definition is to pin down exactly what the problem definition is, and the activities or transformations required to solve the problem. The first step of this is the creation of 'holons', which are relevant perspectives that can describe the real world activities. These different perspectives are drawn out from the rich picture and presented as a series of statements. A number of perspectives, or holons, may be identified, however the key perspectives that most closely meet the desired needs are selected and analysed more closely through a CATWOE analysis. The CATWOE analysis identifies the required transformation and the other key elements of the system. The CATWOE analysis is detailed below:

C (Customers) = who are the beneficiaries/victims of the transformation?

A (Actors) = who is responsible for completing the transformation?

T (Transformation) = the conversion of an input to an output

W (World View) = a particular world view that means the transformation is needed

O (Owner) = who has the authority to abolish/change the transformation?

E (Environment) = what external constraints are taken as a given?

From the CATWOE analysis, it is possible to identify a statement for the relevant system, which takes the following form:

A system to do X, by Y to achieve Z within the constraints of P (where P are environmental constraints)

This statement forms the root definition. The processes in stage 3 are iterative, in that they may be completed numerous times before achieving the optimum assessment of the problem situation.

Stage 4 involves the development of a conceptual model. Taking the root definition, CATWOE analysis and holons, the core activities of the system can be identified. The conceptual model is also very highly visual, and the interactions between each core activity within the model can be identified. Again, this process may be iterative and completed numerous times until the optimum solution is identified.

Stage 5 involves a comparison of the conceptual model with the real world. This may be achieved through discussions or trying to structure the real world using the same structure as the conceptual model. This will provide the opportunity to assess whether there is anything missing from the conceptual model that is required for it to work in the real world.

Stage 6 involves developing desirable and feasible changes. At this point, the analyst will assess whether the interventions identified are actually feasible and achievable. This stage often involves revisiting the previous stages and undertaking the analyses from different perspectives, ensuring that the optimum solution is presented.

Finally, stage 7 involves action to improve the situation. While the SSM seven stage model may identify what the problem domain is and the activities needed to improve it, it does not involve actually completing these activities. At this point, the SSM process may start a new cycle, or the project or activity will move into the development stage. In the case of this research, this will be the quantitative statistical analyses.

3.3 Quantitative Methodologies

The outputs from the SSM model will guide the direction of this study. The next stage is selecting methodologies to ensure the transformation suggested can be completed.

For this research, five statistical approaches were utilised, which are:

- Correlation analysis
- Multiple linear regression
- Logistic regression
- Cluster analysis
- Factor analysis

In combination, these analyses will contribute to the overall development of the system by producing the risk model for accidental dwelling fire risk and an understanding of risks and needs at a local level.

3.3.1 Correlation Analysis

A correlation is a measure of the relationship between one or more variables [67]. The result of the correlation analysis is a coefficient that varies between -1 and +1. A value close to 1 signifies a strong relationship between the two variables. A correlation coefficient close to -1 shows that there is a strong negative correlation and a coefficient close to +1 shows that there is a strong positive correlation. In this research, a Pearson's correlation [67] was used as this determines how two variables are related to each other, but does not depend on the unit of measurement used for each variable. This is beneficial for this research as the causal factors used have differing units of measurement.

In this research, the purpose of the correlation analysis is to assess the association between the identified causal factors and the rate of accidental dwelling fires occurring within a local area. It is important to note that correlation analysis shows that there is an association or relationship between variables; however it does not imply causation. This is the first step in understanding whether the presence of a particular causal factor has an impact on accidental dwelling fires, and if so, the magnitude of that impact. The correlation coefficients will be assessed for each causal factor to understand the strength of the relationship. The significance of the relationship will also be measured to understand whether the relationship between the factors is genuine or occurred by chance. The statistical significance of a correlation analysis is measured using the p-value [68]. In this analysis, the p-value is tested to the 0.05 level, in other words, that there is a 95% probability that the results occurred because of a genuine relationship between the variables.

3.3.2 Multiple Linear Regression

The process of multiple linear regression (MLR) is defined as the relationship between one dependent variable and a number of independent, or explanatory variables [69]. The model can be denoted as follows:

$$Y = ß_0 + ß_1X_1 + ß_2X_2 + \ldots + ß_nX_n$$

where y represents the dependent variable, $ß_0$, $ß_1$, $ß_2$ and $ß_n$ are the coefficients of the independent variables and X_1, X_2 and X_n are the independent variables [69]. It is the goal of a MLR model to take a number of random data variables and look for the relationship between them. The overall output of the model is a straight line that best approximates all of the data points. The results of this are the coefficients as described in the equation above. MLR is often optimised by 'least squares', which means the model minimises the sum of squares of the differences between the actual and predicted values for each observation in the sample.

In this research, the MLR methodology was used to model the identified causal factors, resulting in an expression of accidental dwelling fire risk. Only casual factors that were identified to have a significant correlation with historic incidents of accidental dwelling fires were selected for this modelling to ensure that the resulting model was robust and reliable. The resulting R^2 value is a representation of how robust the model is for understanding accidental dwelling fire risk [70]. The multiple linear regression analysis was completed using SPSS statistical software package [71] utilising the 'multiple linear regression analysis' tool.

The multiple linear regression analysis is proposed as a methodology that can be used to assess the relationship between accidental dwelling fires and the identified causal factors, therefore expressing an equation that describes accidental dwelling fire risk within a local area. The MLR model expresses the level of risk within a given area based on the causal factors present.

3.3.3 Logistic Regression

The logistic regression approach differs from the MLR model as it is used for predicting the outcome of a dependent variable with a limited number of values, e.g. binary variables such as '1' or '0' or 'yes' or 'no'. Similar to the MLR model, this model can take into account the relationship a dependent variable has with a number of independent variables, however it differs as the output of this type of modelling is an estimate of the probability of an event occurring [72]. In this research, it could be used to estimate the probability of a fire occurring.

The logistic regression approach was presented as an alternative to the MLR model. It was selected to understand whether it would be beneficial to model accidental dwelling fires based on the likelihood they would occur, as opposed to level of risk identified within an area, as presented with the MLR model. In this research, an assessment will be made as to which approach is most appropriate for describing the relationship between accidental dwelling fires and causal factors. The logistic regression analysis was completed using SPSS statistical software package [71] utilising the 'logistic regression analysis' tool.

3.3.4 Cluster Analysis

Cluster analysis involves grouping a set of data so that data points within each group are broadly similar to each other and broadly different to the other groups. There are many algorithms that can be used for a cluster analysis; however, the k-means clustering approach was used for this research. The purpose of the k-means cluster analysis is to segment the whole data set into a smaller number, or k clusters [73]. This is completed by identifying particular structures within the datasets, which may suggest particular patterns and trends. The algorithm then segments the data into a smaller, predetermined number of groups. The k-means clustering approach is beneficial in that it allows the analyst to determine the number of clusters, and the algorithm will best fit the data to this request [74]. This allowed the operational requirements for Merseyside Fire and Rescue Service to be considered when running this modelling process.

The reliability of cluster analysis can be checked by using 'Cramer's V' statistic. Cramer's V is used to test for association between variables, and in this example to test for association between each of the cluster groups. Cramer's V statistic ranges from 0 to +1, where 0 represents no association and +1 represents a perfect relationship [75]. For this analysis, the optimum solution would have a Cramer's V statistic value close to 0, as this would represent that the clusters identified are different from each other. The cluster analysis was completed using SPSS statistical software package [71] utilising the 'k-means cluster analysis' tool.

3.3.5 Factor Analysis

Factor analysis is a data reduction method [76], which can be used to understand the variance between the datasets used for the cluster analysis with smaller number of variables. Factor analysis for data reduction works by removing variables that are highly correlated, as this could be adverse to the analysis. It then finds another variable that is uncorrelated, but accounts for as much variance as possible. The variables that are remaining in the analysis, or the extracted variables, are used to determine how much variance they explain within a model. Variance is a measure of how much the data observations are spread out across the variable. If the extracted variables explain a large proportion of the variance, then they represent the model and the variables well [77].

Understanding this would mean the process could be completed in the future even if fewer datasets were available, a key consideration given that public sector budgets are reducing. Factor analysis can be used to identify a small number of variables that explain most of the variance that is observed in a much larger number of variables. The factor analysis was completed using SPSS statistical software package [71] utilising the 'factor analysis' tool.

3.4 GIS Development

After completing the qualitative and quantitative analyses, the next stage of the methodological framework is incorporating the results into a tool that is user friendly for the staff at Merseyside Fire and Rescue Service. An important consideration needs to be given to the reliability and robustness of results. While it is important that staff members are satisfied and familiar with how the tool operates, they also need assurances that the statistical modelling approach is delivering the correct results.

In order to create a toolkit that met the needs of the user, the requirements of the GIS outputs were documented using the Unified Modelling Language. The Unified Modelling Language (UML) object-oriented design approach [78], [79] was utilised as a methodology to document the queries requested by staff members at Merseyside Fire and Rescue Service. The UML process was advantageous as it provided a visual representation of how different elements of the GIS interact. Staff at Merseyside Fire and Rescue Service requested a number of queries that they would like the GIS to perform, which inluded the automatic calculation of risk estimates for each area, and a corresponding risk map to be generated, the ability to map each identified causal factor and the ability to generate reports listing properties within high risk localities. Following the principles of UML, a class diagram was created to illustrate the datasets used within the GIS, and the actions that would be completed in each part of the system to perform these queries. The aim of the class diagram is to illustrate the static structure of the system being developed [80] The class diagram also illustrates the associations present between each of the classifiers [78]. In additon to this, 'use case' diagrams were developed, which illustrates the users interaction with the developed system. In particular, this shows the actors, or people involved, the activities and the actors relationships with the activity.

In order to ensure that the developed GIS product aligned with corporate systems, the GIS package MapInfo [81] was utilised. Within MapInfo, there is a development platform called MapBasic [82] that can be used to develop bespoke tools and functions within MapInfo. The MapBasic platform is based on the BASIC [83] programming language.

The statistical models developed as part of this research were embedded into the MapBasic code, which ensured the user did not need to interact with a process they were not familiar with. In addition, a number of additional layers could be added or removed, such as Ordnance Survey raster mapping (in particular the 1:50,000 scale Landranger [84] map and the 1:25,000 scale Explorer [85] map), ward, district and fire station boundaries and fire station locations.

The bespoke tools developed were added to the standard menu and toolbar within Merseyside Fire and Rescue Service's MapInfo package, which loaded each time the software was launched. The tools allowed the user to create maps and query the data without needed to understand the statistics behind the results.

3.5 GIS Testing Model

As with any testing process for information systems, GIS testing involved a number of different stages. These included unit testing, component testing, system testing, performance testing and user testing [86], [87]. Until this research, there was no documented framework developed for testing a GIS.

Although research was published on testing different components, there did not appear to be a framework in place which looked at the whole approach. As part of this research, a journal paper was published outlining the framework testing process utilised [9].

Bryce and Colbourn [88] commented that software testing can often be an expensive and lengthy activity. Often the testing process can be costly and the lack of funds towards the end of the project often means that the testing process sometimes does not receive the attention it requires. In this research, the testing process was seen to be vital, especially as the GIS framework would be used to allocate resources in relation to reducing accidental dwelling fires.

The testing of geographical information systems has common features with the testing of other types of information systems. To test a GIS, there is a requirement to test a number of aspects involving unit, component, system and user acceptance. In addition to this, there is also a requirement to test the mathematical and statistical models, accuracy of spatial analysis, and the map-based presentation of outputs. This implies that different approaches to testing are required to test a GIS.

In order to test the GIS predictive modelling, a number of geographic areas were selected at random [89]. The calculations performed by the GIS were compared with the same calculations performed manually to see if they correspond [90], [91]. Selecting an area for testing should be random as this provides an unbiased sample of geographic locations to test a predictive model and its accuracy [90], [92]. This was achieved by selecting number areas from Microsoft Excel spreadsheet listing areas in Merseyside.

Boone et al [93] and Heywood et al [94] stated that an important aspect of testing the validity of the data used in geographical information systems is in relation to testing for count, attribute and positional errors. There is a concern that errors with data inputted into the modelling process would lead to incorrect results. This would occur even if the integrity of the statistical model was correct. Another important feature of a successful GIS framework model would be the accuracy and correctness of the spatial data collected and displayed. Mutluoglu and Ceylan [95] commented on this particular feature. Errors in spatial accuracy may result in incorrect placement of points, lines or polygons, which in turn would result in errors when analysing this with other sources of spatial information. Heywood et al [94] commented that there are few robust methodologies published on modelling of errors in spatial data. Of those methodologies that are available, many typically focus on the effects of positional errors.

Bonazountas et al [45] stated that there is a need to verify the program code within a geographical information system to ensure that any map layers generated as a result are accurate. In particular, a random sample should be tested comparing actual results with results generated by the programme code. Jolly et al [96] commented on the need to test geographical information systems at different levels of map resolutions to ensure that sliver polygons and misplaced points do not appear at a large scale. De Man and Van den

Toorn [97] and Li and Qi [98] commented in their respective research that a vital part of GIS testing is user acceptance testing to ensure that stakeholders have a framework that meets expectations. In relation to this, Soh et al [99] stated that the human computer interface design aspects of geographical information systems is also important to consider and that it is considered acceptable by users.

Haynes et al [100] commented that overall the accuracy and robustness of geographical information systems might receive little attention in some organisations as they are often accepted as being correct with little interrogation. De Mers [101] echoed this concern in their research and stated that stated that many GIS models are accepted as fact. De Mers [101] also advocated that in order verify a GIS model, users and developers should question whether the data used in the model accurately represent the conditions. An example of this may be whether the model factors have been combined correctly to represent the proper factor interactions (i.e. whether the correct factors are used for the condition to be modelled); and whether the final solution is acceptable and useful for the users to make informed decisions.

3.6 Summary of Developing a Methodological Framework

This chapter has outlined the methodologies which have been utilised in this research. In particular, the methodologies broadly fall into one of three categories:

- Qualitative research, which has been used to understand the user requirements, needs and expectations. This will be used as a building block for developing the GIS framework;
- Quantitative research, which takes the findings from the qualitative research and applied some 'hard' statistical techniques. This results in a model of accidental dwelling fire risk;
- GIS development and testing, which focused on ensuring that the framework developed is user friendly, robust and reliable so users can trust the outputs

It is important to note that the framework developed as part of this research does not look to develop new, untested methodologies, but take existing methodologies and apply them to a new area of research. The framework methodology has been developed in such a way that it could be easily replicated by anyone else wishing to take the same approach. This is particularly true of the GIS testing framework. When carrying out this research, it was realised that this type of methodology did not exist and current literature only referenced certain elements of GIS testing. The framework developed as part of this research looked at these elements, bringing them together to form a new approach. This is true of all the research presented in this thesis.

Chapter 4 – Problem Definition and Solution

4.1 Introduction to Problem Definition and Solution

The aim of this chapter is to discuss the results of the qualitative research methods used in this study to help identify the problem domain, user requirements, needs and expectations. As outlined in the previous chapter, the method of qualitative research utilised was Soft Systems Methodology.

The purpose of the Soft Systems Methodology process was to explore the problem domain in greater detail, to get a deep understanding of what this framework is trying to achieve. It also provided an opportunity to put the feedback from the staff interviews into perspective, especially in areas where they were differing views of the requirements of the framework. There were a number of key outputs from this qualitative research process. These included:

- Rich picture illustrating the problem domain and the wider environment in which it sits
- Root definition that describes what the framework should aim to achieve
- CATWOE analysis outlining the key opportunities and constraints of the framework
- Conceptual model, which illustrates where this framework will sit in the real world environment.

As part of the Soft Systems Methodology process, staff interviews were conducted to give the key stakeholders involved an opportunity to discuss the problem domain from their perspective. The messages gleaned from these interviews were analysed further as during the development of the rich picture.

It is important to develop each of these outputs and gain a fuller understanding of the softer, social concerns and issues prior to the development of any quantitative models.

4.2 Defining the Problem Using Soft Systems Methodology

The seven stage Lancaster model [63] was utilised as a process for understanding the gap between current methodologies used within the fire and rescue service and the optimum solution of more effective delivery of services. In this research, the seven stage model was amalgamated into a four stage model for simplicity. This also meant that fire and service staff needed to input into the development of this part of the research less frequently, which was beneficial as their time was often limited.

The original seven stage model was grouped into four stages as follows:

- Defining the situation: This grouped stages one and two of the Lancaster model. The final output was the developed rich picture
- Developing a definition: This relates to stage 3 of the original model
- Developing a conceptual model: This relates to stage 4 of the original model

- Actioning the model: This grouped stages 5 to 7 of the original model and involves moving the conceptual model to the real world.

Each of these phases will be described in turn in the following sections.

4.2.1 Defining the Situation

Following the simplified four stage model approach, the initial stage was to define the problem situation for this research. The first part of this stage was to conduct staff interviews with principal stakeholders to gain an understanding of the issues that this research should be addressing

4.2.1.1 Staff Interviews

The interview process chosen was semi-structured and interviews were held on a one-to-one basis in the interviewee's office. Interviews were initially conducted with five members of staff who had an interest in the framework. Those interviewed included:

- Chief Fire Officer of Merseyside Fire and Rescue Service
- Deputy Chief Fire Officer of Merseyside Fire and Rescue Service
- Area Manager for Prevention and Protection
- Watch Manager for Home Fire Safety
- Corporate Systems Support Manager

Each interview involved the same four questions. The discussions within each of the interviews varied based on the interviewee's particular area of interest or expertise. The four questions asked were:

- What are your thoughts on the current methodologies used to understand accidental dwelling fire risk in Merseyside?
- What do you feel would be the ideal way to measure accidental dwelling fire risk?
- How would you want an accidental dwelling fire risk model to be delivered (e.g. any particular tools or format that you would prefer to use)?
- What information would you like to get from a new methodology for understanding accidental dwelling fire risk?

The staff interviewed could be split into three categories based on their role within the organisation, and this is broadly reflected in the responses given to each of the questions. In particular:

- The Chief Fire Office and Deputy Chief Fire Officer were interested in the development of this framework, as they wanted to ensure they were targeting resources and delivering services based on risk present within the community in a time of reducing budgets. In particular, they were keen to ensure that any new methodology developed could stand to scrutiny by the Fire Authority. It was important to these staff members that Merseyside Fire and Rescue Service delivered their statutory duties in the most efficient means, whilst being mindful of the best interests of the communities they serve.

- The Area Manager for Prevention and Protection and the Watch Manager for Home Fire Safety were interested in the development of this framework from an operational perspective. They were keen to ensure that the services offered to the community were reflective of their needs and are delivered in the correct locations. It was discussed that current methodologies do not truly represent the needs of the local communities. Another restriction of current methodologies concerns the fact that they do not reflect the needs of the individual. This was very important to these staff members, as they wanted to ensure they could offer an targeted, individualised service. The way the information was presented was also important. Maps were important for a strategic overview, which could be displayed in fire station offices or in reports. However, it was also important to have the information available in a format that would be easy for fire crews and district prevention teams to utilise. It was suggested that a list of high risk properties or individuals would be beneficial in assisting with the delivery of services.
- The corporate systems support manager had different views on the development of this framework. Whilst interested in the overall goal of delivering services, the corporate systems support manager was keen to ensure that the GIS framework would be simple to use for staff members in the team. There was a particular concern about the proposed statistical modelling, especially as the team did not have experience of this. This staff member was keen for any developed

product to be compatible with current systems that the staff had experience using, and also to ensure that any costs incurred were to be kept to a minimum.

The interviews with staff members were very valuable, as they provided an insight into the current situation at Merseyside Fire and Rescue Service and the anticipated final outcomes of the framework. Although the interviews provided a useful starting point, there was a requirement for further analysis to be completed through the Soft Systems Methodology process. This would help define the problem situation. The responses from the interviews were used further within the development of a rich picture.

From the staff interviews, each colleague identified that the overall aim was to reduce the numbers of accidental dwelling fires and contribute towards the organisational mission of 'Safer, Stronger Communities; Safe, Effective Fire-fighters'. There were differing views on how to achieve this, which appeared to be related to the job function that staff member held within the organisation. For example, the corporate systems support manager's views were around how such a framework could be developed and supported, whereas the Watch Manager for Home Fire Safety was interested in how this framework could help target services. Although the views of each staff group differed, they were all of equal importance for gauging the requirements of the framework.

In addition to the first cohort of staff interviews that were conducted, it was realised through the Soft Systems Methodology process that further information gathering sessions were required, in particular with the staff members who would be using the outputs of the framework on the ground to deliver services. To achieve this, an interpretivist approach involving a series of informal sessions with fire fighters was conducted. These interviews were completed in a focus group environment. This method was selected to maximise the time available as fire-fighters work in crews of four or five team members. Fire-fighters can be called to an emergency incident at any time; therefore holding one to one interviews was not practical. It wasn't possible to meet with every crew at every station; therefore, five crews were visited based on their availability at the point when this part of the research was being completed. The aim of these sessions was to identify, at an operational level, why a new methodology was required and what it would help to achieve. For these sessions, discussions were focussed around the following three topics:

- How do you currently target your initiatives?
- In your professional opinion, where do you feel you should target your initiatives?
- Do you think the tools you currently have help you to target your initiatives?

Much like the original cohort of interviews, these sessions were scheduled to last for approximately 45 minutes, allowing a discussion of 15 minutes per topic.

In general, the interpretivist view of fire prevention was very similar for all those crew members interviewed. The common themes included:

- Current delivery of fire prevention initiatives were focussed to the most deprived locations
- Delivery of fire prevention initiatives should be focused to those most vulnerable, such as older people. Typically, older people may have additional concerns such as ill health or poor mobility

Crews made the following comments regarding the current tools available:

- General feeling that the same places are being targeted, yet fires are still occurring elsewhere. There is a feeling that fire prevention should be more targeted towards an individual and their circumstances as opposed to the area where they live
- General feeling that resources are targeted towards areas that have seen the greatest number of fire incidents. These are not always the same places where serious injuries or fire fatalities are occurring.

Conducting these interviews teased out a number of themes, which generally supported the findings from the original cohort of staff interviews. In particular, it was recognised by every staff member interviewed that there was a need to move away from the current risk methodologies to deliver more successful prevention campaigns. The perceptions and opinions of staff have been embedded through many years delivering fire prevention initiatives, and there was a great sense that change was required to continue delivering a quality service with fewer resources.

The additional interviews were significant as they provided an insight into what fire-fighters believed were potential fire causal factors based on their professional experience. These findings broadly supported what was identified as part of the literature review, and would be explored in further detail as part of the statistical analysis to understand the significance of these causal factors in relation to accidental dwelling fires.

Utilising the principals of Soft Systems Methodology, a rich picture was created that encompassed the views of each staff group with an interest in fire prevention. This approach was beneficial as it included all of the differing views of each stakeholder group. The rich picture identified mechanisms for examining causal factors in accidental dwelling fires. It also encouraged a multiple perspective approach to the identification of causal factors associated with accidental dwelling fires.

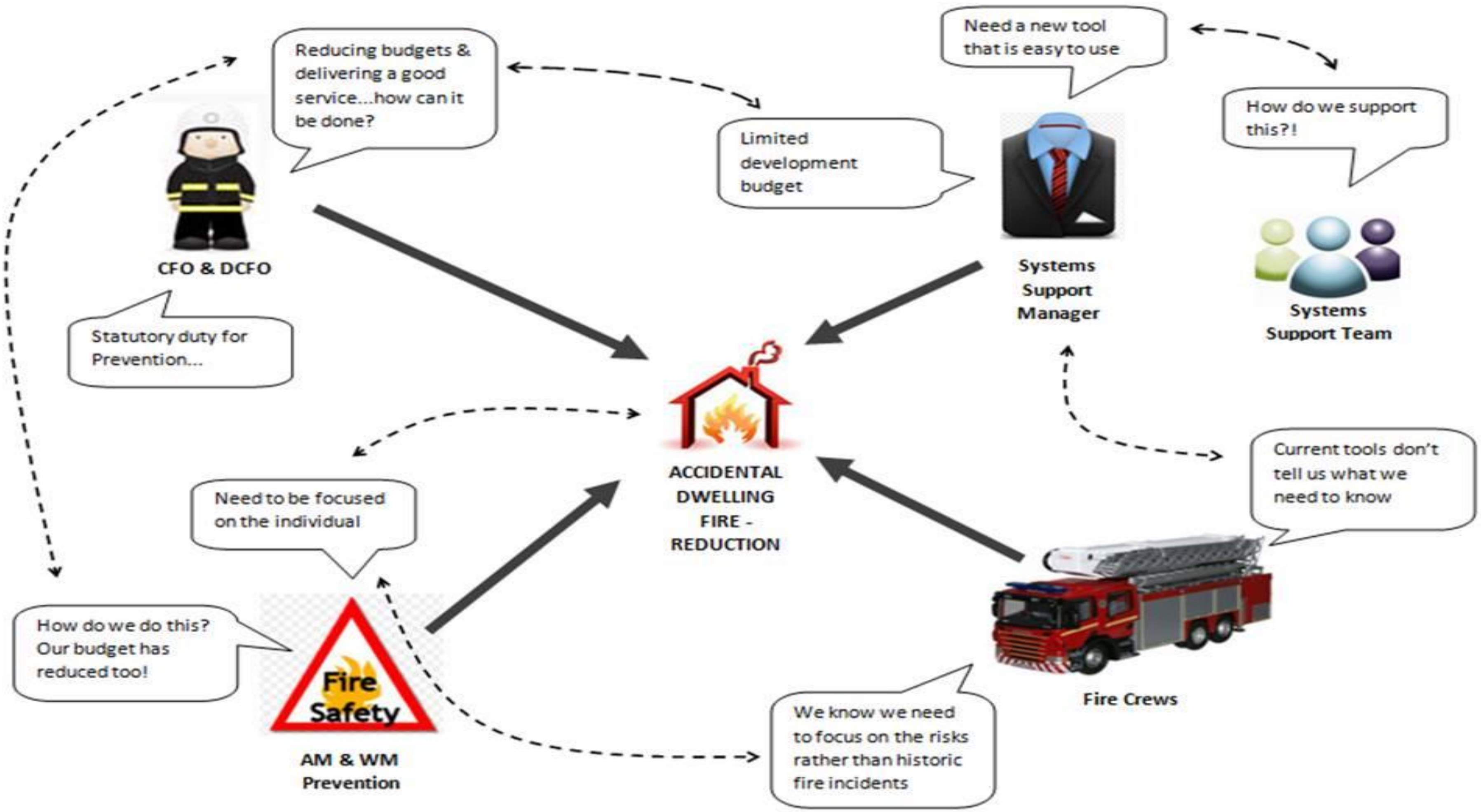

Figure 3 - Rich picture for accidental dwelling fire prevention framework

Figure 3 illustrates the rich picture developed for fire prevention. This captures, in a simple manner, the multiple perspectives of different staff groups with an interest in the framework. It also illustrates how each staff member contributes to the overall goal of reducing accidental dwelling fires and their problems or concerns. This method is beneficial to the framework as the result is an improved understanding of the problem domain, and it is possible to start to realise how the situation can be improved.

4.2.2 Developing a Definition

Once the factors relevant to fire prevention had been identified through the rich picture, it was then necessary to refine and prioritise those factors. It was identified that a key issue was related to the way fire prevention initiatives were targeted towards a community, whereas fire risk was very personal and could fluctuate greatly within a community. Through the discussions and subsequent development of the rich picture, it was identified that targeting interventions towards an individual or community based on the risks present was the key priority to be achieved via this framework. This improved method of targeting has the potential to reduce accidental dwelling fires by ensuring that initiatives are delivered proportionate to risk. It also has the potential to help achieve the required monetary savings in two ways; first by potentially reducing the number of incidents that Merseyside Fire and Rescue Service would need to attend and secondly by delivering preventative initiatives primarily to those individuals who require them most.

The first stage of defining this was through the development of a root definition. The root definition for the fire prevention system examined and described the factors involved, as shown in Figure 4.

Root Definition for a Fire Prevention GIS Framework
A framework for providing information for activities associated with increasing awareness of fire risks and reducing fire risks by analysis of causal factor data to achieve a reduction in fire incidents within the constraints of the data available for analysis.

Figure 4 - Root definition for fire prevention GIS framework

Using the root definition as guidance, a more detailed understanding of fire prevention activities and accidental dwelling fire causal factors was identified using a CATWOE analysis. The CATWOE analysis ensures that the preposition outlined in the root definition is robust and rigorous. The CATWOE analysis for fire prevention is outlined in Figure 5.

CATWOE for a Fire Prevention GIS Framework	
Client	Fire and rescue service
Actors	Fire and rescue service strategy & performance team staff, community fire prevention staff, fire and operational crews
Transformation	Reducing accidental dwelling fires and related injuries and fatalities through improved information relating to accidental dwelling fire risk
Weltanschauung (World View)	More targeted fire prevention activities can reduce accidental dwelling fires and related injuries and fatalities
Owners	Fire and rescue service
Environment	Different levels of accidental dwelling fire risk exist amongst different areas within the region. Causal factor data will be required from a variety of external sources and data sharing agreements may need to be developed.

Figure 5 - CATWOE analysis for a fire prevention GIS framework

The root definition and the CATWOE analysis provide some structure to the problem domain, and start to identify how this framework can be developed. In particular, the CATWOE analysis is beneficial in identifying who will be involved from this point forward in developing the framework. Those staff members who will be particularly heavily involved include the Strategy and Performance team (which includes the Corporate Systems Support Manager and their team) and those members of staff involved with delivering prevention services. Although the views of other staff members were vital for developing the rich picture, many of the senior members of staff would not be involved in actually using the framework, therefore from this point it was important to involve those stakeholders who would be using the developed tools as part of their daily work routine. Another important area identified by the CATWOE analysis was that there is the potential need for data sharing agreements to access some datasets. One key theme identified by the rich picture was the need to identify *individuals* most at risk from fire as well as communities. Information about individuals is not freely published online, although the data can often be accessed to larger geographical areas. It was important to identify that data sharing agreements may be required at an early stage of the research as they can often be lengthy and time consuming processes. Finally, the CATWOE identified that Merseyside Fire and Rescue Service were to the be the final owners of this framework, therefore implying that part of this research would involve knowledge transfer from academic research to the operational environment. In time, this should help bridge the gap that was identified at the outset about using information and data to proactively understand risk.

4.2.3 Developing the Conceptual Model

The next step in the simplified four stage process was the development of a conceptual model, illustrated in Figure 6. The aim of the conceptual model is define a process that will be followed for the rest of this research. The final output is similar to a flow chart, outlining key steps that need to be taken in order to achieve the overall goal.

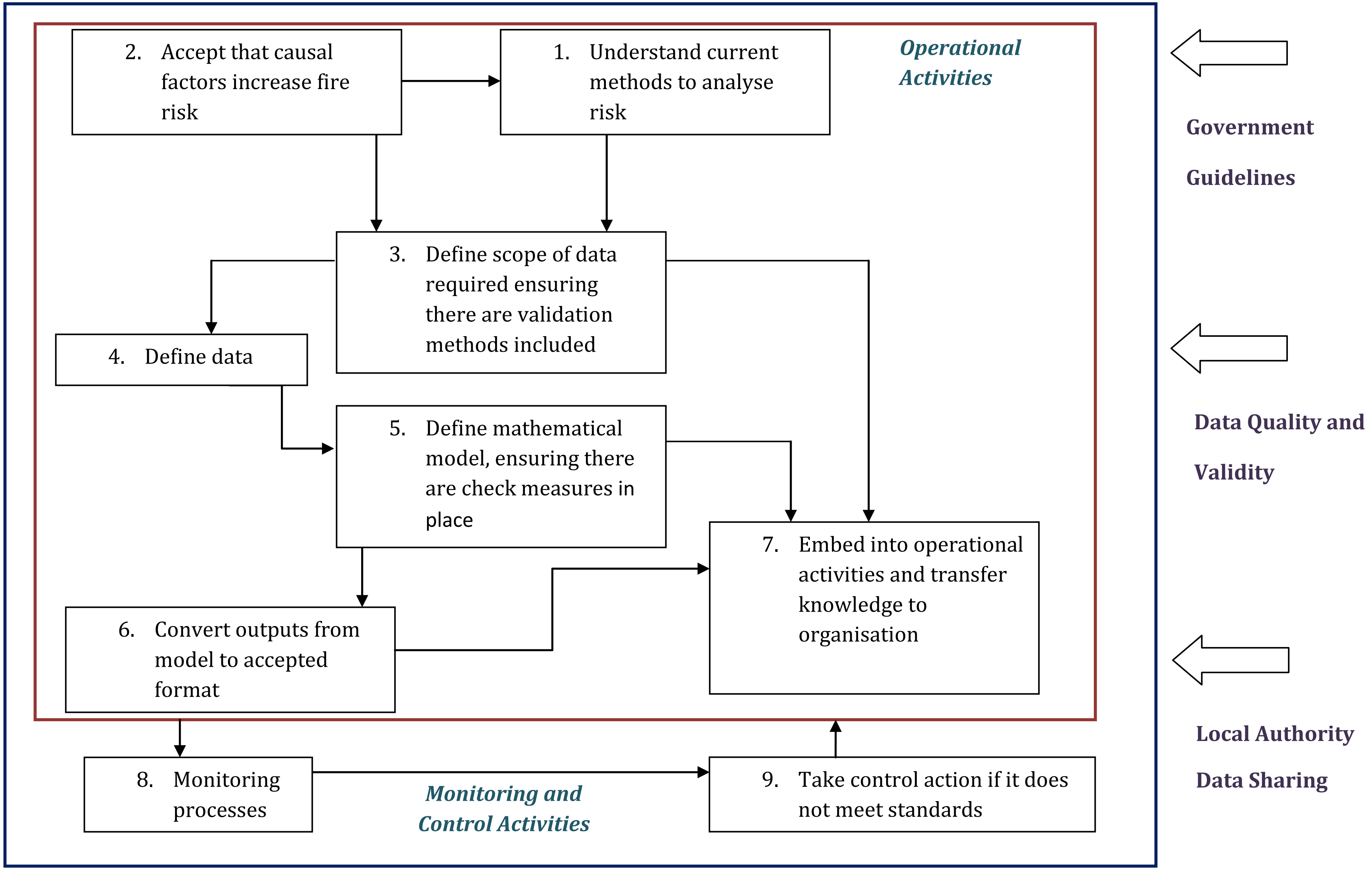

Figure 6 - Conceptual model for fire prevention GIS framework

Within the conceptual model for the accidental dwelling fire risk identification framework, there were a number of steps proposed to achieve the overall goal. These included:

- Accepting that accidental dwelling fire risk is related to causal factors. This was evidenced through the literature review outlined in Chapter 2
- Understanding current risk modelling methodologies and identifying the gap. This was achieved through the qualitative research
- Define what data is required and how this will be modelled statistically
- Take the outputs from the statistical model and convert them to a format that is acceptable for staff at Merseyside Fire and Rescue Service
- Embed the model by transferring knowledge and skills

In addition to these processes, there will be a monitoring process that will take place throughout the research, which will involve taking controlling action, if necessary. This was to be achieved by a regular project group involving stakeholders and ensured that the research remained on track to achieving the required goals. Finally, there are a number of external sources that may impact on the progression and success of the research that cannot be controlled. These include Government guidelines, agreements to sharing data and data quality. Although these factors cannot be controlled, it is important to be aware of them and monitor how they may impact on the research.

4.2.4 Actioning the Model

The semi-structured interviews and subsequent Soft Systems Methodology analysis helped to identify the problem situation. It was identified that the solution to the problem situation would be a framework that focused on understanding the accidental dwelling fire causal factors and provided a model of risk related to this. In addition, the outputs of such a model need to be easy to understand and interpret for the user. The conceptual model was presented to senior officers within Merseyside Fire and Rescue Service for approval and to understand whether what was being proposed would be practical in their environment. The products developed as part of the Soft Systems Methodology were approved by Merseyside Fire and Rescue Service staff to move onto further development.

While the Soft Systems Methodology was beneficial for understanding the problem domain, it did not actually provide the technical solution which was required. This involved moving the research from its current qualitative model to the real world using quantitative research methods. The staff interviews provided some interesting thinking to kick-start the process, for example operational staff professional knowledge about accidental dwelling fire risk factors, however the Soft Systems Methodology analysis did not provide any indication on how significant or valid any of these thoughts were. This would be achieved through the statistical analysis.

4.3 Summary of Problem Definition and Solution

This chapter presents the findings of the qualitative research completed as part of this study. In particular, two approaches were used, which were semi structured interviews and the application of Soft Systems Methodology. It was identified through the Soft Systems Methodology process that further interviews were required, therefore some additional time was spent on this activity and involved the operational staff who would eventually utilise this tool. The findings from the interviews were beneficial in ensuring the developed framework was relevant to those who would be utilising it on a daily basis.

The Soft Systems Methodology process explored the problem domain in greater detail and allowed for an improved understanding of what the application of this framework was looking to achieve. There were a number of outputs from this process, including the rich picture, root definition, CATWOE analysis and the conceptual model. Each of these products is a tool to ensure the needs and expectations of the end user are maintained throughout the research process.

As discussed in this chapter, the completion of the Soft Systems Methodology process does not provide a full understanding of the causal factors that should be focused on or the significance of these, but rather an understanding of what the overall framework should be aiming to achieve. To better understand what causal factors are involved and how they influence on accidental dwelling fire risk, some further quantitative analysis is required, which is discussed in the following chapter.

Chapter 5 – Exploring Accidental Dwelling Fire Causal Factors

5.1 Introduction to Exploring Accidental Dwelling Fire Causal Factors

The requirements analysis identified that there was an appetite for an accidental dwelling fire framework to improve fire prevention through identification and modelling of fire causal factors. However, one of the main challenges when attempting to model accidental dwelling fire risk is to be able to identify all the relevant causal factors and gather data relating to them. Previous research [49], [50], [51], [52], [57] had identified smoking, alcohol misuse, physical and/or mental disability, age (particularly those aged over 65), housing type, socio-economic deprivation, lack of working smoke alarm and living alone as the most common causal factors associated with accidental dwelling fires and related fatalities. Although these studies were completed to different geographies (i.e. cities, regions and countries) in different locations around the world, it demonstrates that there are common characteristics in the occurrence of accidental dwelling fires. This could potentially be incorporated into a predictive model.

One of the key issues in accessing data is related to its availability to the required geography. Often, there are datasets available about the identified causal factors, but often not to the required granularity. This issue is further exacerbated if the data is gathered via survey information. Often it is not appropriate to make this type of information available to smaller geographies. There are often issues related to the timeliness of data, meaning that only out of date information is available, which could impact on the reliability of any modelling completed. Finally, there are also barriers related to accessing personal information, which is required to achieve the person-specific risk identification required by Merseyside Fire and Rescue Service. This chapter will explore how these barriers have been overcome for this research.

5.2 Exploration of Factors

Following the initial literature review on accidental dwelling fire causal factors, a more in-depth analysis was completed for Merseyside to understand whether there were any similarities in the factors identified. The literature review focused on different geographical areas across the world; therefore, it was important to understand what the local factors were for Merseyside before assessing whether it would be feasible to collect information about each variable. To complete this, an analysis of accidental dwelling fires occurring in Merseyside was studied.

The analysis looked at fire incidents occurring in the period between 1st April 2010 and 31st March 2013. In this period, there were 3,531 recorded accidental dwelling fires, 372 injuries in accidental dwelling fires and 24 fatalities in accidental dwelling fires. This information was exported from the Incident Recording System, or IRS [102], which is a national system used by fire and rescue services for recording and reporting on all incidents attended by the fire and rescue service. The IRS has a series of mandatory questions that must be completed by the Officer in Charge (OiC) at each incident before the incident log can be closed. The OiC is responsible for collating this information at the time of the incident. Responses to many of the questions can be obtained easily by asking the occupant (or a relative or friend should the occupant not be able to respond themselves) or through a fire investigation. However, some questions can be more difficult to answer accurately than others. An example of this could be whether there was impairment due to the influence of drugs or alcohol. Unless the occupant suffered an injury and was hospitalised or became a fatality, it would be difficult for the OiC to know for certain whether this was a contributing factor. In this case, the OiC would have to use his or her own professional judgement and investigation to help answer this question. Similarly, it may be possible to obtain answers to questions through the fire investigation. For example, if the main source of fire ignition was a cigarette, then the OiC could assume that one of the occupants was a smoker and may be discarding smoking materials in a careless manner.

There are a vast number of questions asked in IRS [103], and many are not of relevance to this research. However, the questions interrogated that were relevant are as follows:

- **Question 5.8 – Was there any alarm system present?**

  This will provide information as to whether there was a working smoke alarm present within the property

- **Question 8.3 – Caused by?**

  This provides an indication of who caused the fire (e.g. child, adult etc). This question also provides an indication of age, in particular those residents aged over 65.

- **Question 8.4 – What was the source of ignition?**

  This provides an indication of the fire cause, in particular if it was caused by smoking materials or careless use of other items

- **Question 8.15 – What was the Household Occupancy Type at the time of incident?**

  This provides information about whether the household comprised of a lone occupant, family, couple, etc.

- **Question 8.16 – Human factors contributing to fire**

  This provides information about whether the occupant had a disability, was confined to bed or a chair or had any other type of immobility that could prevent escape

- **Question 8.17 – Was impairment due to drugs or alcohol a contributory factor in the fire?**

  This will provide information if the occupant was intoxicated by drugs or alcohol at the time of the fire. As mentioned, this may be subjective, as it will depend on the OiC's judgement. Depending on the circumstances of the fire, a fire investigation report, hospital notes or a Coroner's report will provide more firm evidence as to whether this was the case.

Information gathered through these questions provided an insight into what lifestyle factors were typically involved in accidental dwelling fire incidents, and whether any of these factors could later be used to predict future risk of accidental dwelling fires.

When the IRS information was analysed, it was discovered that:

- Fifty-three percent of accidental dwelling fire fatalities involved an individual aged over 65. Of these, approximately 60% were aged over 80. There were no fire fatalities involving a resident aged under 25;
- Forty percent of fire fatalities involved a resident with adult social care needs, signifying that a disability may be present;
- Sixty percent of fatalities involved a resident who was a lone occupant;
- Thirty-six percent of fatalities involved a resident who had the assistance of a carer, again suggesting that a disability or mental health concern was present;
- Thirty-three percent of fires that resulted in a fatality were in properties where there was no working smoke alarm;
- Fifty percent of fires that resulted in a fatality were caused by careless use of smoking materials.
- Thirty-three percent of fires that resulted in a fatality involved an individual who was intoxicated by alcohol.

- Thirty-nine percent of fires that resulted in a fatality involved an individual who was under the influence of drugs (either prescribed or illegal substances)
- Finally, it was identified that approximately 30% of fatalities involved an individual with one or more of the identified causal factors present.

This broadly supported the findings of the literature research, suggesting that these causal factors were also of importance for Merseyside. In addition, the literature research also identified two additional causal factors that may be of importance for the development of a risk model. These are lone parents and deprivation. The London Fire Brigade (LFB) reported that three percent of fatal fires in London in the period 1996-2000 were due to unattended children playing with fire [51]. Unfortunately, children who come from single parent families are more likely to become a victim of fire. There is the concern that a lone parent may be less able to escape a fire with a dependent child or children. In the same study, the LFB found a correlation between accidental dwelling fires and social deprivation, both at borough level and ward level. Research shows that children from the most deprived areas were sixteen times more likely to die in an accidental fire than those from the least deprived areas [104]. Other fire and rescue authorities, not only in the UK, but also in the USA, Australia and Japan, to name but a few, have also suggested this factor. Merseyside Fire and Rescue Service research also indicated that any individual is four time more likely to have an accidental dwelling fire if they live in a more deprived locality [32].

The following factors therefore were identified as potential fire causal factors for the Merseyside Fire and Rescue Service fire prevention framework:

- Disability;
- Lone occupant;
- Lone parent;
- Mental health issues;
- No working smoke alarm;
- Over 65;
- Smoker;
- Social deprivation;
- Substance misuse (i.e. alcohol misuse, drug misuse).

This aspect of the research identified what the potential causal factors were, however in order to identify the significance, or otherwise of these factors, data needed to be collected for each of the identified variables for the Merseyside area. Gathering this information would allow for a through statistical analysis to be completed, allowing a proper assessment of whether any of these factors could be used to model future risk of accidental dwelling fires, in particular those fires occurring in typically out of context locations.

5.3 Accessing datasets for accidental dwelling fire modelling

Although a necessary part of this research, a limiting factor when creating the risk model was being able to obtain information relating to the causal factors. It was identified at an early stage that Merseyside Fire and Rescue Service would not be the owner of many of the required datasets. In addition, some of the required datasets were simply not available and there were no agencies or organisations within the local area that collected the required information. An example of this related to housing data, where up to date data for housing type [52] was not readily available for Merseyside unless an extensive data capture exercise was completed. This was not a viable option for Merseyside Fire and Rescue Service given limited resources. The most reliable source of address information in the United Kingdom is the National Land and Property Gazetteer [105], however this does not provide information about specific types of property [106]. There are some resources available that provide estimates of property type, however, these typically are based on Census data and quickly become out of date [107]. Another limitation of many available data sources is related to the granularity of data available. For example, datasets such as alcohol misuse [108] was only available to Middle Super Output Area (MSOA) [109] because of reliability issues. As the dataset was based on survey information, it would not be appropriate to publish it to geographies smaller than MSOA as it could give misleading or inaccurate results. It is also possible that publishing to a smaller geography could lead to a person being identified from the dataset, which is against the legislation set out in the Data Protection Act 1998 [110]. Many health datasets follow this same survey based format, and it can be very difficult to access more granular datasets unless data sharing agreements are in place to support this.

An additional barrier was related to the timeliness of the datasets available. This study was dependant on external datasets to inform the statistical model, therefore, there were issues concerning how often each dataset was updated and published. For example, certain datasets could be refreshed on a daily basis, some on a monthly basis, some on a quarterly basis and others less frequently. Although this did not pose a problem with the mechanisms of the statistical analysis, it did mean that the model's accuracy could be reduced and patterns in causal factor relationships missed because all datasets were not all looking at the same snapshot in time.

5.3.1 Accessing personal and confidential information

For many datasets, the most accurate source of information is from person identifiable datasets held by external agencies. This is particularly true of health datasets such as substance misuse or mental ill health. Within the health environment, the Caldicott Guardian is responsible for protecting patent data, and it is ultimately their decision whether information should be shared with a third party [111]. The Caldicott review, published in April 2013 [112], outlines clear guidelines for sharing data, in particular health related data. The guidance suggests that the organisation seeking the data should try to gain consent from the individual wherever possible, and that reasons for requesting the data should be clearly justified. The Data Protection Act [110] allows for sharing of sensitive information between organisations. Principle 2 of the Data Protection Act [113] outlines that data can be shared providing there is a legitimate reason for doing so, for example to protect the individual's vital interests (i.e. in cases of life or death) or for administering justice. [114]. This principle of the data protection act was applied for the purposes of this research. In many cases, this was an acceptable legal gateway for sharing information, for example sharing data between housing providers or local councils and the fire and rescue service. The exception to this was related to health datasets.

Sharing of health datasets is bound by an additional set of regulations as it involves confidential information such as information about health conditions [115]. When sharing confidential data, the common law duty of confidentiality applies [115]. In order for the National Health Service to share confidential information, the organisation requesting the information must apply for the common law duty of confidentiality to be lifted for the purposes of their research under Section 251 of the National Health Service Act 2006 [116]. This can be done if the research aims to improve patient care or is in the public interest to share. When this research was conducted, there were five Primary Care Trusts[6] within Merseyside, and each of these trusts had a different view on whether sharing personal information would be in the best

[6] From April 2013, Primary Care Trusts in England and Wales were replaced by Clinical Commissioning Groups
http://www.legislation.gov.uk/ukpga/2012/7/contents/enacted/data.htm

interests of the individual. For this research, specific information about health conditions was not requested, but a list of names, addresses and contact details was requested with an indication of whether the individual had any of the identified causal factors present. Although sharing information did not breech the Data Protection Act or the Common Law Duty of Confidentiality, some organisations were reluctant to share. This is likely to be related to the fact the interpretation of the guidelines is very subjective, and those responsible for making the decision are likely to interpret the aims and objectives of the research in different ways.

A number of external agencies were approached with a request to share information about individuals who presented the identified risk factors. As mentioned above, confidential information was not requested, but contact information about an individual with a known risk factor was requested. Contact was made with the following organisations across Merseyside:

- Registered social landlords/housing providers
- Adult social care services
- Revenue and benefits teams
- Primary care trusts (now called Clinical Commissioning Groups)

Dataset	Information Received	Frequency of Update
Adult Social Care	Name, address, postcode and telephone number of individuals known to adult social care services	Monthly
Registered Social Landlords	Name, address, postcode and telephone number of residents living in a property owned by a registered social landlord. Where available, additional filters were added e.g. known to be a smoker, living alone.	Quarterly
Revenue and Benefits	Name, address, postcode and telephone number of residents who either live alone, are over 65 or are a lone parent and claiming housing or council tax benefit	Monthly
'Exeter' information (from Primary Care Trusts)	Name, address, postcode and telephone number of residents aged over 65 and registered with a GP	Monthly
Air Liquide	Addresses of properties were the resident uses oxygen for medical purposes	Ad-Hoc (updated as new properties are known)
MF&RS risk data	Name, address, postcode and telephone number of residents who have been identified to have risks present after a visit by MFRS	Ad-Hoc (updated as new properties are known)

Table 1 – Data Merseyside Fire and Rescue Service collect about vulnerable individuals

Table 1 outlines the data sources consulted and used within this research. Given the barriers, the data sharing process was largely successful, with Merseyside Fire and Rescue Service setting up a number of data sharing agreements with external agencies and gaining access to over 20,000 records about people potentially at risk from accidental dwelling fire [11]. However, not every organisation approached was willing to share. As discussed, this may be related to the subjective nature of the guidance available or their understanding of the purpose of this research. In addition, Merseyside Fire and Rescue Service were required to review their data sharing agreements with National Health Service organisations following the disbanding of the Primary Care Trusts and formation of Clinical Commissioning Groups in April 2013. However, this would provide the opportunity to see whether other datasets could be accessed, such as mental ill-health or substance misuse. At the time of writing this thesis, the review of data sharing agreements with these organisations was still ongoing.

In order to ensure data remained secure, information transfers were completed using a tool called AVCO AnyComms [117]. This tool allowed for an automated and secure process of transferring data from one organisation to another. The transfer was also encrypted to ensure that it could not be accessed by an unauthorised person.

5.3.2 Accessing other datasets

Although good progress was made accessing personal datasets, it was recognised that it would be a lengthy process. Despite accessing a number of datasets around the causal factors, some gaps still remained. However, there were some nationally available datasets published to the local level that were beneficial for this analysis and related to the identified causal factors. The datasets consulted were:

- Data about people with mental health concerns was collected by the UK Department for Work and Pensions [118]. This information was published on a quarterly basis and published to Lower Super Output Area (LSOA) [109] geography. This dataset was based on individuals who were flagged on the Incapacity Benefits[7] database because of a mental health condition.
- Data about residents claiming incapacity benefits was collected by the UK Department for Work and Pensions [118]. This information was published on a quarterly basis to LSOA. The dataset is based on all individuals claiming incapacity benefits because of a limiting long-term illness or disability.
- Data about residents living alone was published by the UK Department for Work and Pensions [118]. This information was based on lone residents claiming a support allowance. The information was published to LSOA geography and updated quarterly.
- The Indices of Multiple Deprivation dataset is published to LSOA geography by the Department for Communities and Local Government. This dataset is published every three years.
- Residents claiming disability living allowance benefit was collected by the UK Department for Work and Pensions [118]. This information was published on a quarterly basis and published to LSOA geography. This dataset was based on all claimants of this particular benefit.

[7] Incapacity benefit is now known as Employment Support Allowance.

- Information about binge drinking was collected from each of the five Primary Care Trusts within Merseyside. This provided a percentage estimate of binge drinking within each Middle Super Output Area (MSOA) [109] within Merseyside. This information was collected from binge drinking surveys completed independently for each Primary Care Trust within Merseyside.
- Information about lone parents was collected from the Her Majesties' Revenue and Customs [119] Tax Credits database. This data is published annually to the LSOA geography. This database was based on individuals claiming Tax Credits who were flagged as a lone parent.
- Information about properties without a smoke alarm fitted by Merseyside Fire and Rescue Service was collected from Home Fire Safety Check information. This information was aggregated from property level to LSOA geography to align with the other datasets. The information was refreshed quarterly, again to align with many of the other datasets.
- Information about smoking was collected from Merseyside Fire and Rescue Service Home Fire Safety Check data. Until recently, Merseyside Fire and Rescue Service had a target of visiting over 100,000 properties annually [25]. This means the information available from this source was more comprehensive that what was available from other sources, such as the Primary Care Trust. This information was aggregated from property level to LSOA geography to

align with the other datasets. The information was refreshed quarterly, again to align with many of the other datasets.

- Information about residents with a severe disability was collected from the UK Department for Work and Pensions [118]. The dataset is concerning those individuals aged over 60 with a limiting long-term illness or disability. This information is available to LSOA level and is updated on a quarterly basis.
- Information about elderly residents was collected from the UK Department for Work and Pensions [118]. The dataset is concerned with residents aged over 65 claiming a state pension. This information is published to LSOA level and is updated on a quarterly basis.

It was accepted that there would be barriers to accessing data. In the ideal world, data would be accessed directly from source and aggregated up to the required geography. In this research, the barriers were accepted, as there were no alternative data sources available within Merseyside for this type of analysis. It is possible that the framework could have been enhanced with the addition of other data sources that link with accidental dwelling fire, however access to other data sources would only have been available if a large scale data capture exercise was completed, which was outside the scope of this research.

5.4 Summary of Exploring Accidental Dwelling Fire Causal Factors

The exploratory data analysis approach was utilised in order to attempt to build a comprehensive risk model, based upon the data available. There were a number of barriers present, such as the availability of information to the required geography and timeliness of data releases. The barriers were accepted, as there was no alternative way to access the information unless an extensive data collection exercise was completed. This was outside the scope of this research and was not viable for Merseyside Fire and Rescue Service.

Where possible, data was sought from its primary location. In these cases, data sharing agreements were required in order to access the personal information. This was the optimum solution as it provided opportunities for Merseyside Fire and Rescue Service to use this information to target specific individuals they may feel are at risk, and also allowed for aggregation of the information to larger geographies to use for community based targeting. Although accessing information this way was broadly successful, it was identified that there were still some gaps in the data. This was particularly true of the health related datasets. In addition, a number of data sharing agreements required review following large scale restructuring within the National Health Service. The structural changes resulted in the data flows and legal gateways changing within the National Health Service.

It was identified through this part of the research that the optimum geography to use for mapping this information would be the Lower Super Output Area. Most of the datasets available from online sources were available to this geography and were updated on a regular basis. It was also simple to aggregate personal information to this geography to feed into the statistical modelling process. With a population of approximately 1,500 residents, a Lower Super Output Area would not be a useful geography for identifying individuals at risk, but would provide a good strategic overview for understanding pockets of risk across the County, which was one of the requests made by Merseyside Fire and Rescue Service.

Chapter 6 – Accidental Dwelling Fire Modelling

6.1 Introduction to Accidental Dwelling Fire Modelling

As discussed in the previous chapters, the interpretivist approach based upon soft systems methodology was utilised to provide an overview of fire prevention activities and assisted with defining the problem domain. An understanding of accidental dwelling fire causal factors relevant for Merseyside was gained through the exploratory data analysis. However, neither of these approaches explained the significance of the causal factors and how useful they would be for identifying future fire risk. For example, an identified causal factor may be very significant and useful for identifying risk, or the opposite could be true. To determine this, a positivist approach [120] was used to determine those causal factors where measureable data could be collected. A number of statistical analyses were proposed to understand the relationships between the data and accidental dwelling fire risk. These analyses include:

- Correlation analysis
- Multiple Linear Regression
- Logistic Regression
- Cluster Analysis
- Factor Analysis

Each of these techniques will be used to understand the relationships between the datasets, and the outputs will be used to support further development of the GIS framework. The aim of this chapter is to explore the statistical techniques used and present the findings from this part of the research study.

6.2 Correlation analysis

The first element of the statistical analysis for developing a model of accidental dwelling fire risk was to complete a correlation analysis with all of the identified variables. The aim of the correlation analysis was to understand whether any of the identified causal factor variables displayed a relationship with accidental dwelling fires that had previously occurred.

To achieve this, a Microsoft Excel spreadsheet was created listing each Lower Super Output Area [121] and the corresponding number of fire incidents and information about each causal factor. This was opened within the software package SPSS, and the correlations between each variable was analysed.

Within SPSS, the bivariate correlation option was selected, which optimised the 'Pearson Correlation' [122]. The Pearson correlation is a method used to determine the linear relationship between two variables. In this example, the method would be looking to determine the linear relationship between accidental fire incidents and each causal factor. The result of this analysis is a Pearson correlation coefficient, which is between -1 and 1. A coefficient value of 1 shows that there is a perfect, positive linear relationship between both variables, a coefficient value of -1 shows that there is a perfect negative linear relationship between both variables and a coefficient value of 0 shows that there is no relationship between both variables.

		ADF
ADF	Pearson Correlation	1
	Sig. (2-tailed)	
	N	905
Binge Drinking	Pearson Correlation	.412**
	Sig. (2-tailed)	0
	N	905
DLA	Pearson Correlation	.482**
	Sig. (2-tailed)	0
	N	905
Elderly	Pearson Correlation	.229**
	Sig. (2-tailed)	0
	N	905
IMD	Pearson Correlation	.535**
	Sig. (2-tailed)	0
	N	905
Incapacity	Pearson Correlation	.596**
	Sig. (2-tailed)	0
	N	905
Lone Parent	Pearson Correlation	.396**
	Sig. (2-tailed)	0
	N	905
Mental Health	Pearson Correlation	.623**
	Sig. (2-tailed)	0
	N	905
No Alarm	Pearson Correlation	.315**
	Sig. (2-tailed)	0
	N	905
Single	Pearson Correlation	.593**
	Sig. (2-tailed)	0
	N	905
Smokers	Pearson Correlation	.528**
	Sig. (2-tailed)	0
	N	905

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2 - Output from correlation analysis investigating relationship between causal fires and accidental dwelling fire incidents

Table 2 shows the output from the SPSS correlation analysis and lists the correlations coefficients between accidental dwelling fires and each identified causal factor. The following conclusions about the correlations were made:

- All of the causal factor variables had a positive correlation with the number of accidental dwelling fire incidents. This suggests that as accidental dwelling fires increase, the value of the causal factor also increases.
- None of the causal factors were strongly correlated with numbers of accidental dwelling fires (i.e. Pearson correlation value greater than 0.7 [123]).
- The majority of causal factors displayed a moderate correlation with the number of accidental dwelling fires (i.e. between 0.3 and 0.6). The causal factors for residents aged over 65, lone parents and properties with no smoke alarm displayed a weak correlation with the number of accidental dwelling fires (i.e. between 0.1 and 0.3).

The result of the correlation analysis broadly reflected what was expected following the literature review and analysis of Merseyside Fire and Rescue Service incidents. However, the strength of some correlations was less than expected. This is particularly true of the causal factor about elderly residents. Some reasons why the strength of this correlation is less than expected may be related to the relatively small number of accidental dwelling fires or small presence of the causal factor within some Lower Super Output Areas.

Although there were over 3,000 accidental dwelling fires during the period studied, when this was broken down to Lower Super Output Area level, the numbers in some localities were very small – in fact, some localities experienced no accidental dwelling fires during the period studied. However, it was a necessary part of the research to split the data by Lower Super Output Area to understand whether causal factor data can be used to provide an indication of future fire risk at a local level.

As each of the causal factors demonstrated a positive correlation with the number of accidental dwelling fires, they were all selected to be used within the multiple linear regression modelling stage. This process would incorporate a level of filtering, which would ensure only the most appropriate causal factors were selected.

6.3 Multiple Linear Regression

Following the correlation analysis, an all-subsets linear regression model [124] was developed to create the model of accidental dwelling fire risk for Merseyside. For this modelling, it was identified that the number of accidental dwelling fires would be the dependant variable, and each of the identified causal factors would act as independent variables. This analysis was completed to the Lower Super Output Area geography. It was decided that numbers of accidental dwelling fires would be used rather than accidental dwelling fires rates (e.g. rate per 100,000 population) as the structure of Lower Super Output Areas means that they have a consistent population with each area. The population within a Lower Super Output Area is approximately 1,500 residents [121].

There is an assumption with multiple linear regression that each variable is normally distributed. Before commencing with the multiple linear regression analysis, the normality of each variable was tested to ensure it was fit to be included. This was achieved by creating normal probability plots for each variable. The normal probability plots can be found in Appendix A. The normal probability plots showed that the causal factor variables did not show a perfect normal distribution, but their distributions would be acceptable for this analysis. In addition to this, the multivariate normality of the set of predictor variables was tested using bivariate scatterplots and coefficients. A normal probability plot of the standardised residuals was used to test for a linear relationship. The model showed a reasonably constant variability of the variables.

A number of outputs were generated from the multiple linear regression analysis. One was the ANOVA (Analysis of Variance) table (Table 3). This is used to test for significant differences between means. The ANOVA analysis was beneficial as it could test the statistical significance between a number of groups. The 'F' score provides an indication of the fit of the model to the data. From the table below, it was identified that the F test was highly significant (i.e. significance less than 0.01), therefore, the model fits the data well.

ANOVA						
Model		Sum of Squares	Df	Mean Square	F	Sig.
4	Regression	48697.21	7	6956.7	147.1	0
	Residual	42425.26	897	47.297		
	Total	91122.47	904			

Table 3 - ANOVA results from the multiple linear regression modelling

The developed multiple linear regression model is illustrated in Table 4. In the final model, a number of causal factors were excluded as they did not contribute to the overall predictability of the model. The casual factors that were selected were:

- Disability Living Allowance claimants
- Elderly residents
- Indices of Multiple Deprivation
- Lone parents
- No working smoke alarm in the property
- Lone occupants
- Smokers

The Unstandardized Coefficients provide factors that can be applied to each variable to create a score of accidental dwelling fire risk for an area. The results of this analysis were significant to the 0.01 level, which suggests there is a 1% probability that the solution occurred by chance.

	Unstandardized Coefficients	Std. Error	Standardized Coefficients	t	Sig
(Constant)	-7.536	1.366		-5.52	0
DLA	-0.054	0.009	-0.311	-6.01	0
Elderly	0.009	0.003	0.091	3.007	0
IMD	0.069	0.03	0.15	2.314	0.02
Lone Parent	-0.265	0.028	-0.518	-9.64	0
No Alarm	0.025	0.002	0.352	12.98	0
Single	0.133	0.017	0.663	7.642	0
Smokers	0.082	0.008	0.62	10.7	0

Table 4 - Coefficients generated from the multiple linear regression model

The correlation between the model and the number of accidental dwelling fires was 0.73, which shows a strong, positive correlation. The R^2 value, or the coefficient of determination, was calculated from this to determine how well the developed model could explain future accidental dwelling fire risk. The R^2 value was 0.53, which suggests that this model could explain approximately 53% of future accidental dwelling fire risk.

6.4 Logistic Regression

In order to provide a comparison, a logistic regression analysis was completed to understand whether this alternative approach yielded a more accurate set of results. For the logistic regression, the Lower Super Output Area data needed to be split into two groups; those with a high number of accidental dwelling fires and those with a low number of accidental dwelling fires. Areas with a high number of accidental dwelling fires were taken to be localities experiencing nine or more. Areas with a low number of accidental dwelling fires had fewer than 9 fires. This was identified using the median value, but also broadly aligned with an operational definition of high rates of accidental dwelling fires. Similar to the multiple linear regression model, the analysis involved a number of iterations. Again, similar to the multiple linear regression model, a number of causal factors were excluded from the analysis as they did not contribute to the effectiveness of the overall model. The causal factors used within the logistic regression analysis were:

- Disability Living Allowance claimants
- Elderly residents
- Indices of Multiple Deprivation
- Lone Parents
- Individuals with a mental ill health concern
- Properties with no working smoke alarm
- Lone occupants
- Smokers

The Coefficients identified in Table 5 provide factors that can be applied to each variable to create a score of accidental dwelling fire risk for an area. The results of this analysis were significant to the 0.05 level, which suggests there is a 5% likelihood that the solution occurred by chance.

		Coefficients	S.E.	Sig.
Step 3a	DLA	-0.021	0.004	0
	Elderly	0.004	0.001	0
	IMD	0.039	0.013	0.002
	Lone Parent	-0.05	0.016	0.001
	Mental Health	0.03	0.012	0.017
	No Alarm	0.006	0.001	0
	Single	0.03	0.012	0.011
	Smokers	0.021	0.004	0
	Constant	-6.345	0.668	0

Table 5 - Coefficients generated from the logistic regression model

The correlation between the model and the number of accidental dwelling fires was 0.66, which shows a moderate, positive correlation. The R^2 value, or the coefficient of determination, was calculated from this to determine how well the developed model could explain future accidental dwelling fire risk. The R^2 value was 0.44, which suggests that this model could explain approximately 44% of future accidental dwelling fire risk.

6.5 Comparison of the regression models

Two models of regression were completed to gain an understanding of which would be most effective for predicting future risk from fire. The multiple linear regression approach was selected as a means to predict levels of risk within a community, whereas the logistic regression approach was used to assess the probability of a fire actually occurring. Both methods appeared to show a good correlation with the numbers of accidental dwelling fires witnessed within an area, and both methods appeared to fit the data well.

The multiple linear regression model had an R^2 value of 0.53, which suggests the model developed can replicate actual outcomes in approximately 53% of cases. This was better when compared with the logistic regression approach, which could only replicate actual outcomes in 44% of cases. This suggests that the multiple linear regression approach was the optimum solution for understanding future risk of accidental dwelling fire. In addition, this solution was favoured by staff members at Merseyside Fire and Rescue Service, who commented that they would find a model that could show risk levels would be more beneficial that a model looking at the probability of a fire occurring within a particular locality.

The developed multiple linear regression model was compared with the existing model used to understand accidental dwelling fire risk within Merseyside. The current FRAM [37] tool utilised within Merseyside had an R^2 value of 0.16 when analysed with occurrences of accidental dwelling fires [125]. This shows that the newly developed multiple linear regression model may be more useful for identifying future risk of accidental dwelling fire than the current FRAM tool. This is likely related to the fact FRAM looks at risk from other types of fires in addition to accidental dwelling fires. The multiple linear regression model focused solely of understanding future accidental dwelling fire risk.

6.6 Cluster Analysis

In addition to the multiple linear regression model, it was proposed that a segmentation model may be beneficial as it could be used to better understand the needs of the community. The cluster analysis approach was developed following the implementation of the multiple linear regression as it was identified as a way to understand some of the wider factors that may contribute to accidental dwelling fire risk.

To complete the segmentation task, it was outlined that a cluster analysis would be completed using the statistical software package SPSS. The particular technique adopted was '*k-means clustering'.* This approach involves grouping together a number of data variables into a specified, or k, number of clusters. The aim of this process is to segment the data variables into a cluster with the nearest mean value. Thus, the result of this process is a number of clusters that have similar characteristics. The process is iterative, which means the algorithm will adjust the cluster centres to best fit the data, therefore giving clusters that most accurately reflect the distribution of data points.

Many of the datasets used for the cluster analysis were identified through the original data collection exercise for creating the multiple linear regression model. These datasets may have been excluded from the multiple linear regression model because they were not in an appropriate format, for example binary datasets or datasets with a very small range of values. In addition, some additional survey information from the British Household Panel Survey [126] was made available after the completion of the multiple linear regression modelling process and it was identified that it could be used within the cluster analysis. A full list of the variables utilised can be found in Appendix A.

To ensure that the variables identified were suitable for analysis, a data testing exercise was completed. Similar to the multiple linear regression model, each dataset needed to be normally distributed to be completed within this analysis. This resulted in identifying 49 aggregated datasets for analysis. The following factors were investigated using Q-Q plots to examine the distributions of the variables in the datasets:

- The standard deviation is a measure of dispersion around the mean. A low standard deviation value indicates that most values are found close to the mean. A high standard deviation value indicates that there is greater dispersion, and values are spread out over a larger range of values. When a dataset is normally distributed, approximately 68% of values can be found within one standard deviation of the mean, and approximately 99% of values can be found within 3 standard deviations from the mean. Ideally, this should be the case for datasets used in this analysis.
- The skewness is a measure of symmetry within the data. A normal distribution has a skewness of 0. A skewness value greater than twice the standard deviation for that dataset is considered to have a departure from symmetry

- The kurtosis is a measure of how a dataset clusters around a central point. For a normal distribution, the kurtosis value is 0. This changes as the distribution departs from symmetry.

Before the cluster analysis commenced, it was important to identify the number of clusters centres to be generated by the analysis. It was identified through other customer insight projects and other market segment tools [127], [128], [129] that an appropriate number of clusters would be between 5 and 15 clusters. For example, Experian's Mosaic has 15 groups and a number of sub-groups [127], and ONS Area Classification has 7 groups and a number of subgroups [129]. The proposed number of clusters appeared to give the optimum balance between detailed insight and easy to manage and update profiles.

Within the k-means clustering option, the following options were selected.

- The method chosen was *'iterate and classify'*. This ensured that the clustering analysis applied the iterative algorithm to identify the most appropriate cluster centres.
- Maximum number of iterations was set to 100. This ensured that the algorithm was not limited by a small number of iterations. The process would stop once the optimum cluster centres was achieved or when the algorithm reached the maximum number of iterations

After running the analysis for between 5 and 15 clusters, boxplots were created to check the '*cluster membership*' against the '*distance from cluster centre*'. The resultant graphs would allow for identification of outliers, in particular significant outliers, which may affect the reliability of the clusters. The clustering with fewest significant outliers would be identified as being the most appropriate solution for the data. A final test would be to check the 95% confidence levels for distance from cluster centres. The purpose of this analysis is to identify the reliability of the estimate made in the cluster analysis. The range of the confidence intervals should be narrow as this will indicate that there is less uncertainty within the estimates.

After running the initial analysis in SPSS, it was apparent that the variables would need to be standardised in some way. This resulted in the variables with large distance calculations (i.e. large distance from the mean of the cluster) to dominate the analysis, while other variables with smaller distances were effectively ignored. To standardise the variables, a transformation was applied which converted the mean of each variable to zero and the standard deviation of each variable to 1. This transformation would reduce the issues related to varying distance sizes from the mean.

The transformation used is shown below and is called the z-score transformation:

$$\frac{(x - \text{Mean}\ (x_n))}{\text{Stdev}\ (x_n)}$$

Where ‘x’ is equal to the individual observation in the variable, ‘Mean x_n’ is equal to the mean of all data observations within the variable and ‘Stdev x_n’ is equal to the standard deviation of all data observations within the variable.

However, after additional analysis, it became apparent that the methodology needed to be reviewed further. Some of the data needed be omitted from the cluster analysis as it would have a negative impact on the results. Data obtained from survey information was omitted, as was binary data and data with a small range of values (i.e. fire fatality data). This is because the small number of unique values within the observations could cause problems when clustering. In addition, the correlations were checked between the remaining variables. Pairs of variables with very high correlations were not included within the analysis as it will effectively result in variables being ‘double counted’ i.e. pairs of variables explaining each other. The final solution included 20 variables within the analysis to give a number of unique clusters. The variables not included within the analysis could be later matched back against each cluster. This could be achieved as the cluster analysis would produce uniquely defined segments for each geographical area. The 20 variables used within the cluster analysis were:

- Persons Life Expectancy
- All age groups (0 – 15; 16 – 24; 25 – 49; 50 – 64; 65+)
- Emergency Admissions to Hospital
- Fuel Poverty
- Crime

- Child Benefit Recipients
- Housing in Poor Condition
- Department for Adult Social Care Claimants
- Revenue and Benefit Claimants
- Social Landlord Owned Properties
- % of residents claiming other income benefits
- Health deprivation score
- % claiming severe disablement allowance
- Pension Claimants (ages 60-69; 70-74; 75-79; 80+)

Following the cluster analysis, an analysis of Cramer's V statistic was completed. This method was used as it is a way of calculating correlations in tables with more than 2 rows and columns and where the number of rows and columns is unequal [130]. In this example, there were over 4,000 output areas and it was anticipated that there would be between five and 10 cluster centres. The Cramer V analysis was utilised to understand the optimum number of cluster centres for the cluster analysis. The Cramer V analysis showed that the optimum number of clusters for this analysis would be 7. This is highlighted in Figure 7.

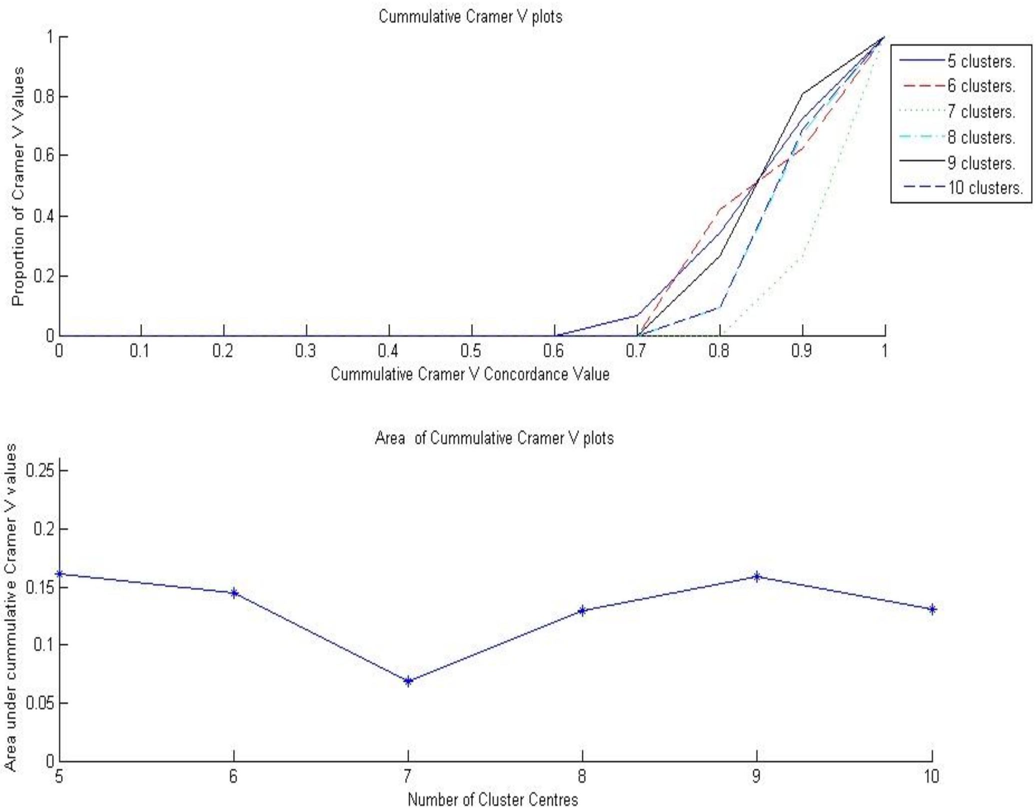

Figure 7 - Cramer V plots illustrating optimum number of cluster centres

The second diagram in Figure 7 illustrates that 7 is the optimum solution as the area under cumulative Cramer V values is the least. However, there is a need to ensure that this would provide the optimum solution operationally. When the 7 cluster solution was mapped using MapInfo GIS, it became apparent that it did not provide the level of segmentation and detail required for Merseyside Fire and Rescue Service. The 7 cluster solution broadly segmented the population to ward level, which would not take into account the differences that are present at the very local level. The diagrams suggest that a 10 cluster solution may also be appropriate. The 10 cluster solution also appears to be appropriate statistically and when mapped in the GIS provide a solution that takes into account differences present at the local level.

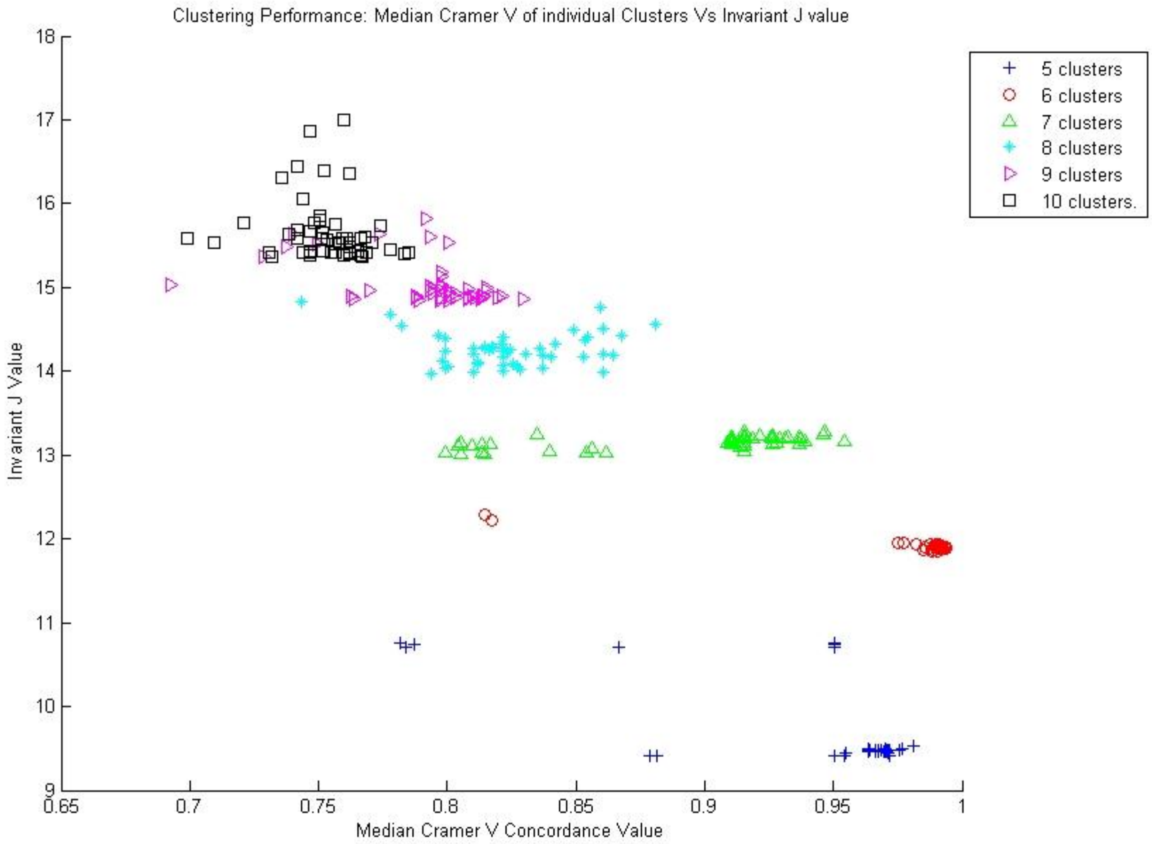

Figure 8 - Chart of cluster centre performance

The chart in Figure 8 also supports the recommendation of a 7 or 10 cluster solution. This can be identified by the dispersion of observations in the chart. The 7 and 10 cluster solution appear to be more closely clustered when compared to the other solutions.

As the cluster analysis was performed using 20 variables only, the variables not included within the analysis could be profiled against each cluster. This allows for detailed profiles or pen portraits for each of the 10 identified clusters for operational use. The ten developed community profiles are as follows:

- Group 1 - Wealthy over 50 population living in semi-rural locations (12.5% of areas in Merseyside)
- Group 2 - Older retirees (4.8% of areas in Merseyside)
- Group 3 - Middle income residents living in privately owned properties (17.3% of areas in Merseyside)
- Group 4 - Average income older residents (11.9% of areas in Merseyside)
- Group 5 - Students living in city centre locations (1.8% of areas in Merseyside)
- Group 6 - Young families (11.6% of areas in Merseyside)
- Group 7 - Young families with high benefit need (16.7% of areas in Merseyside)
- Group 8 - Residents living in social housing with high need for benefits (6.3% of areas in Merseyside)
- Group 9 - Transient population living in poor quality housing (3.6% of areas in Merseyside)
- Group 10 - Younger, urban population living in high levels of deprivation (13.7% of areas in Merseyside)

The pen portrait summaries can be found in Appendix B.

6.7 Factor Analysis

Factor analysis is a methodology that can be used to understand the underlying patterns within data variables. In this example, factor analysis will be used for data reduction (i.e. to understand which variables play the most important part in developing each segment). Factor analysis for data reduction works by removing variables that are highly correlated, as this could be adverse to the analysis. It then finds another variable that is uncorrelated, but accounts for as much variance as possible. Linearity within the data can present problems and can lead to misreading results.

The variables that are remaining in the analysis, or the extracted variables, are used to determine how much variance they explain within a model. Variance is a measure of how much the data observations are spread out across the variable. If the extracted variables explain a large proportion of the variance, then they represent the model and the variables well.

In the cluster analysis completed for this research, 20 variables were identified and used for the analysis. The aim of this analysis is to identify which of these variables are most influential.

The factor analysis was completed using SPSS software, and it was specifically used for data reduction purposes.

Variable	Initial	Extraction
Persons Life expectancy at birth	1	0.637
%Aged 0 – 15	1	0.831
%Aged 16 – 24	1	0.76
%Aged 25 – 49	1	0.586
%Aged 50 – 64	1	0.638
%Aged 65 – Plus	1	0.858
Health Deprivation & Disability Score	1	0.807
Emergency Admissions to Hospital	1	0.579
Crime	1	0.146
%Fuel Poverty	1	0.701
%All Child Benefit recipients	1	0.811
%Severe Disablement Allowance	1	0.22
Housing In Poor Condition	1	0.633
%Pension Claimants Under 70	1	0.882
%Pension Claimants 70 – 74	1	0.638
%Pension Claimants 75 – 79	1	0.564
%Pension Claimants 80+	1	0.837
Adult Social Care Users	1	0.644
Council Tax Benefit Claimants	1	0.379
Renting: Social Landlord	1	0.567

Extraction Method: Principal Component Analysis.

Table 6- Communalities variables output from SPSS showing the variance accounted for by each variable

Table 6 illustrates the 'Communalities' output from SPSS. This table outlines the amount of variance that is accounted for in each variable by the extracted variables (Column 3). The amount of variance explained is high for most of the variables, which the exception of Crime, Severe Disablement Allowance and Revenue and Benefit Claimants. The higher values indicate that the extracted variables represent the other variables well. It is likely that the three variables with low values exist because the counts of data observations within each geographical area for these variables are quite small. This makes it difficult for the other variables to account for its variance.

There are a total of 20 variables used in the cluster analysis, and cumulatively these explain 100% of the variance within the analysis. However, the factor analysis shows that 6 variables can be used to explain approximately 65% of the variance – i.e. the addition of another 14 variables only contributes to identifying an additional 35% of the variance. This suggests that if there were constraints of data collection in the future, a model could be maintained with fewer variables. The 6 variables identified as having the most significant contribution to accounting for the variance are outlined in Table 7.

Component	Variable
1	Combined Health Deprivation
2	Pension Claimants aged 80+
3	Residents aged 0-15
4	Revenue and Benefits Claimants
5	Residents aged 50 – 64
6	DASS claimants

Table 7 - Table showing most significant variables in cluster analysis

Table 7 illustrates the 6 variables that were extracted and that had the most significant impact of the cumulative variance explained. This suggests that, if necessary, the model could be maintained in the future by focusing on these six variables. Although this would not provide the same level of detail, it does mean that if there were cuts to the availability of certain datasets, then Merseyside Fire and Rescue Service could still update and maintain their cluster analysis model.

6.8 Summary of Accidental Dwelling Fire Modelling

This chapter outlines the positivist approaches used to understand the relevance and significance of causal factors identified as part of the interpretivist approach outlined in previous chapters. This statistical analyses outlined in this chapter allowed for an improved understanding of how the presence of each causal factor was linked, or otherwise, with accidental dwelling fire risk.

A number of statistical analyses were proposed to understand the relationships between the data and accidental dwelling fire risk. These analyses include:

- Correlation analysis
- Multiple Linear Regression
- Logistic Regression
- Cluster Analysis
- Factor Analysis

The correlation analysis showed that all of the causal factors identified as part of the exploratory data analysis had a positive correlation with accidental dwelling fires. However, some of the causal factors showed a stronger correlation that others, and this was not necessary anticipated from the outset of the analysis. Each of the causal factors selected showed a relationship that meant it could be used for further analysis for this study.

Two types of regression modelling were utilised. These were multiple linear regression and logistic regression. Both types of modelling were run to ensure the most effective model was selected. Both techniques modelled the data well, however, the multiple linear regression model was selected as it was able to fit the data better and produce results in a format that would be most useful for Merseyside Fire and Rescue Service. The multiple linear regression model was able to 'predict' areas most at risk from accidental dwelling fires in approximately 53% of areas. This is improved on the previous modelling method used by Merseyside Fire and Rescue Service that could correctly predict in 16% of areas.

The cluster analysis was used to assist with the development of the segmentation model, which could be utilised to better understand the needs of the community. The segmentation model was developed using a k-means cluster analysis, and the resulting model produced 10 distinct clusters. This could then be developed into pen profiles describing the characteristics, risks, needs and behaviours specific to each cluster group.

Finally, a factor analysis was completed to understand which variables explained the greatest amount of variance within the model. This analysis was beneficial as it allowed for an understanding of which variables should be focused on for data collection in the future should there be limitation on what can be accessed. This analysis found that six variables explained for approximately 65% of the variance within the model, with the remaining 14 variables accounting for an additional 35% of the variance.

Each of these analyses can be combined and used towards the overall development of the framework. The methodology behind this is explained in the following chapters.

Chapter 7– Integrating the Statistical Model

7.1 Introduction to Integrating the Statistical Model

Although the developed statistical models are useful for identifying risk, they cannot be fully utilised by the user until embedded into a user friendly interface for graphical representation and manipulation. In this research, GIS was the interface between the user and the statistical models. GIS was selected as it was a tool that Merseyside Fire and Rescue Service staff were familiar with and it also allowed for appropriate display of geographical information.

It was important at this stage to ensure that any GIS development was completed using software compatible with the corporate GIS used within Merseyside Fire and Rescue Service. A key aim of this research was to utilise existing resources, including both data and software. The GIS used at Merseyside Fire and Rescue Service is MapInfo [81]. MapInfo has a development function called MapBasic [131], which was used to create the bespoke functionality described in this research.

7.2 Overview of the tools - MapInfo and MapBasic

MapInfo, produced and distributed by Pitney Bowes, is common GIS software that is often used within the public sector. MapInfo has been the corporate GIS within Merseyside Fire and Rescue Service since 2009, when it was procured to replace a number of different GIS packages. The advantage of MapInfo for Merseyside Fire and Rescue Service is it combines a number of different mapping functions within the same suite of software, meaning it was easier for staff within the Service to combine different GIS queries or outputs and utilise the same information sources a number of different times. A key advantage for the fire and rescue service was the ability to create hotspot maps, which are maps illustrating localities where there are high numbers, or hotspots, of a particular phenomenon. It was possible to achieve this functionality in addition to basic mapping requirements within MapInfo.

There is also the functionality within MapInfo to create bespoke tools that are not provided within the standard software suite. This is achieved through an add-on called MapBasic. MapBasic utilises the programming language Basic [83], and allows users to create tools based on their own requirements. Some examples could be tools to create specific map views or edit toolbars to suit the needs of the user. The availability of such a resource enabled the development of bespoke toolbars and menus for this research, allowing the users to interact with the statistical model through the GIS interface.

7.3 Understanding the User's Needs

The outputs of the Soft Systems Methodology analysis provided an understanding of the user's expectations of the bespoke GIS. The staff members who participated indicated what they expected the GIS framework to deliver. In order to create a toolkit that met those needs, the requirements were documented using the Unified Modelling Language.

The Unified Modelling Language (UML) object-oriented design approach [78], [79] was used to design a GIS that was able to perform a number of queries that were requested by Merseyside Fire and Rescue Service staff. The UML approach was beneficial in this research as it provided a visual and graphical representation of the system to be developed and the interaction between each element of the GIS framework. The UML modelling approach utilises a number of different diagrams to explain systems, however, in this research only the Class Diagram was utilised. The Class Diagram is useful as it describes the structure of the system to be developed and each of the actions that will take place, for example, the name of the action, what data is involved and what activities will be completed. The class diagram describes the structure of the system as it shows how each of the desired actions is linked together.

The UML class diagrams for this research included a number of spatial queries that were required by the user. These queries included the number of properties within a station area that were due a Home Fire Safety Check and the characteristics of the communities to be visited. Figure 9 illustrates a class diagram that was developed to understand the requirements for the accidental dwelling fire risk tool. The class diagram shows the desired task and the data and processes required to complete the task.

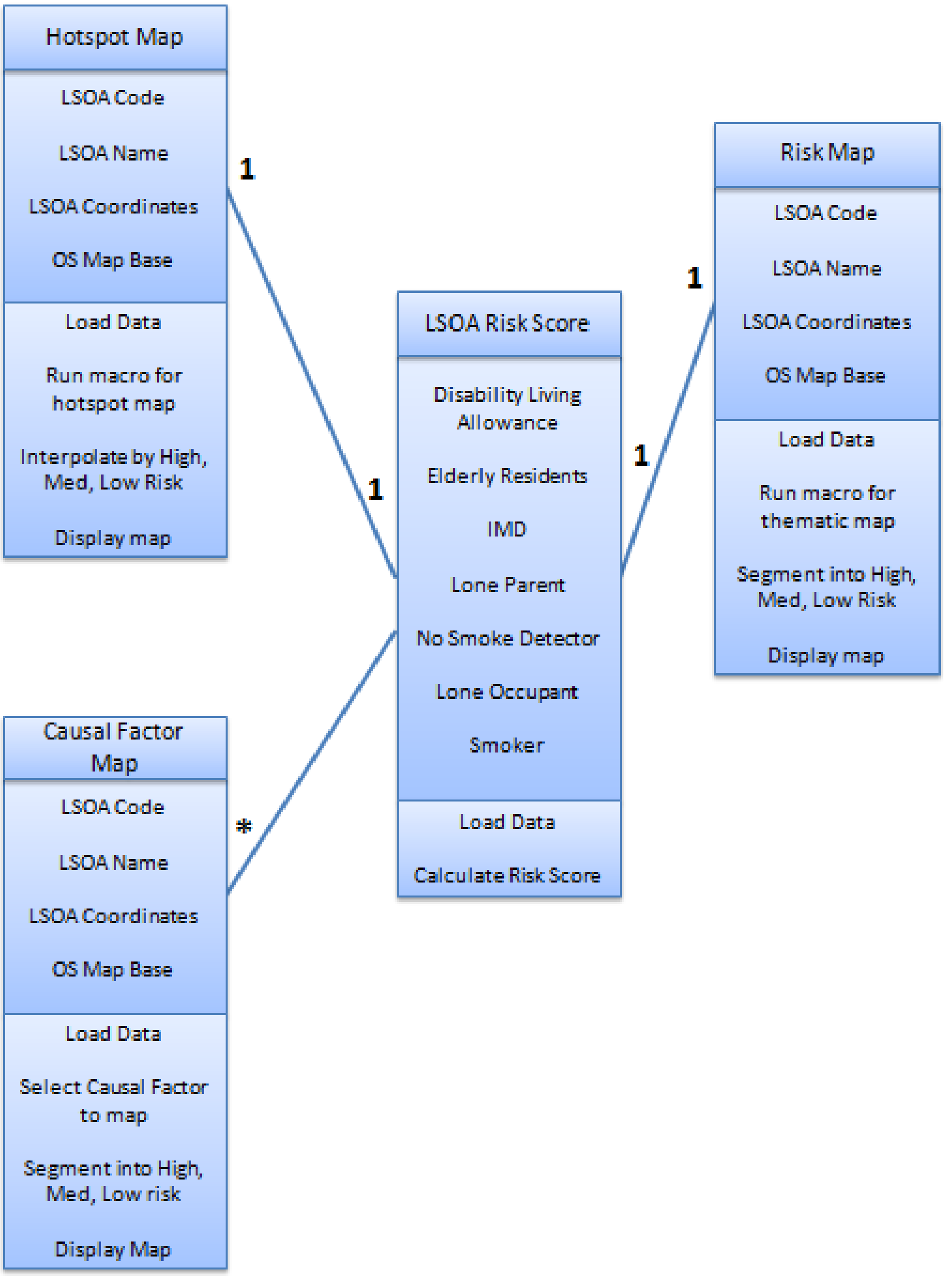

Figure 9- Unified Modelling Language class diagram illustrating the requirements of the Fire Prevention Support system

The class diagram above illustrates the different activities that the user requires the system to perform for modelling accidental dwelling fire risk. This includes calculating a risk score for each LSOA within the Merseyside area and creating a thematic map using this information. The system users also require further interrogation of the data, which involves the creation of causal factor maps and hotspot maps. This allows the user to present the same information in a number of different formats depending on their audience. The UML diagram in Figure 9 shows the relationship the user will have with the model. It was anticipated that the user will be able to create one risk map and one hotspot map from the calculated risk score. However the user will be able to create many risk maps using data about the causal factors that contribute to the overall risk score.

The second class diagram was focusing on the Customer Insight element of the modelling. Again, the user requires a number of activities to be completed by this part of the tool. This includes an understanding of person specific risk within Merseyside and the display of a customer segmentation model, providing a more holistic view of accidental dwelling fire risk.

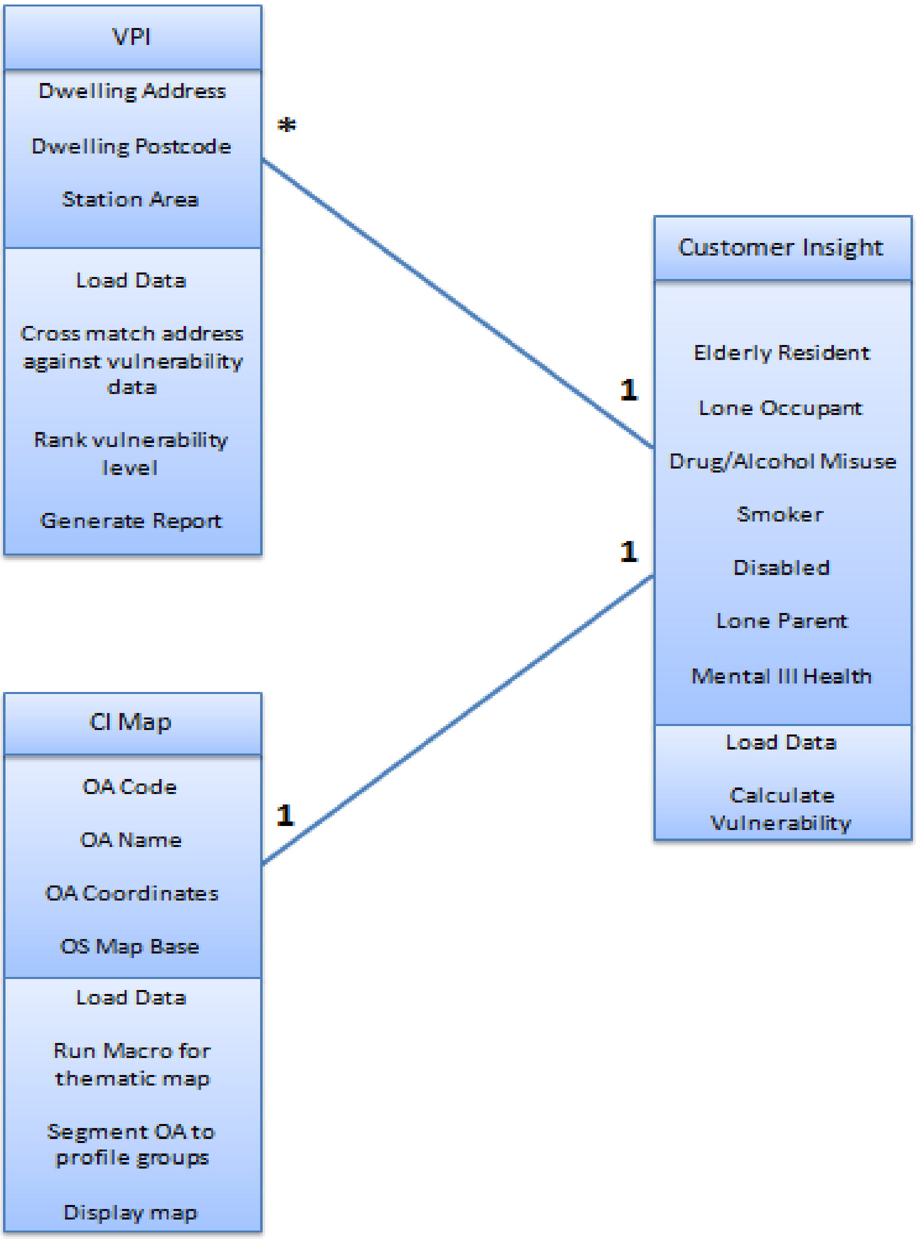

Figure 10 - Unified Modelling Language class diagram illustrating the Customer Insight element of the framework

The UML class diagram in Figure 10 illustrates the actions that are required for the customer insight element of the tool to function. In particular, the UML diagram illustrates that a number of datasets will be loaded to calculate the vulnerability score. This is then cross matched with addresses within

Merseyside that have never received a Home Fire Safety Check, or require a follow up visit. The tool will then rank the properties based on the vulnerability score and then export the information to be picked up by operational crews or fire safety advocates. Users of the tool will be able to create many risk maps from the data loaded (i.e. one for each fire station). The second element of the activity involves creating a map based on the k-means clustering approach. The tool will segment Output Areas based on the cluster it has been assigned to and colour the Output Areas accordingly.

The UML process was helpful as it assisted with understanding the user's expectations the tools to be developed. After understanding the requirements of the system, bespoke applications were written for each of the desired functions, thus resulting in a toolbar that provided the functionality to create maps, status reports and reports of properties to be visited based on the data collected. The toolbar also allowed the user to interrogate the community risk maps, for example, to understand what risks were present within their station area and what types of incident were occurring within their locality. It also provided the functionality to run a 'status reports' that looked at properties that were due to receive a Home Fire Safety Check. These visits could be prioritised based on the risk factors that were present within each station area.

The developed toolbar allowed for a number of bespoke functions requested by users. This included creating the Community Risk Map, creating individual maps of each of the causal factors, creating a hotspot map, creating a customer insight map and generating reports of vulnerable properties to be visited. Each of these functions will be described in turn in the following sections.

7.4 Accidental Dwelling Fire Risk Modelling Toolbar

The accidental dwelling fire risk modelling toolbar consisted of a number of different tools and functions based on the requirements of staff members at Merseyside Fire and Rescue Service. The toolbar was created using MapBasic. Within the software, there is the option to amend buttons and toolbars of create new ones. For this research, a new toolbar and corresponding menu was created to allow staff to use the developed tools. This involved creating tools for the following functions:

- Creating the Community Risk map
- Creating maps of causal factors
- Creating a hotspot map of accidental dwelling fire risk
- Function to export information to a CSV text file
- Function to refresh the server that was used to hold risk data
- Creating the Customer Insight map (and also function to select a particular group to map individually)
- Function to open the pen portrait documentation directly from MapInfo
- Creating a report of vulnerable individuals

- Finally, function to close all open maps (to prevent corruption of the databases)

```
Sub CreateMenus

OnError goto ErrorTrap

Create Menu "&Risk Identification" as
	"Create &Risk Map" Helpmsg "Create Risk Map"
		Calling Risk_Map,

	"(&Causal Factors Maps" Helpmsg "Causal Factors Maps"
		calling Causal_Factors,

	"(Create &Hotspot Map" Helpmsg "Create Hotspot Map"
		calling Hotspot,

	"(-",
	"(&Export..." Helpmsg "Export..."
		Calling Export,

	"(&Goldmine Server Refresh" Helpmsg "Goldmine Server Refresh"
		Calling Server_refresh,

	"(-",
	"Customer Insight Profiles" Helpmsg "Customer Insight Profiles"
		Calling Customer_Insight,

	"Select Customer Insight Profile to Map" Helpmsg "Query"
		Calling Query,

	"Open Documentation for Profile Group..." Helpmsg "Documentation for
Profiles"
		Calling Documents,

	"Vulnerable Person Report" Helpmsg "Vulnerable Person Report"
		Calling Vulnerable,

	"(-",
	"(Close &All" Helpmsg "CloseAll"
		Calling CloseAll,
```

Figure 11 - MapBasic programming code describing the bespoke toolbar to be inserted into MapInfo

Within MapBasic, there are a number of functions that can be utilised to improve the usability of the interface. This is illustrated in Figure 11. Flow control can be added using the open bracket symbol before the name of the command, for example "(&Causal Factors Maps" would result in the macro for casual factor maps to be unavailable until the user followed the correct process to enable the command. This was particularly useful in this research as the user needed to first create the community risk map before performing commands such as 'creating causal factor maps' and 'creating hotspot maps'. This is because the correct information needed to be available for the macros to query. If flow control was not added, then the user may experience a number of error messages. Options for the different commands are enabled once a user completes a series of other commands in the correct order. For example, causal factor maps will become enabled once the Community Risk map has been created.

Other functionality that was included to improve accessibility was the addition of hotkeys and user help. Hotkeys are a keyboard shortcut, and were created in the code by including an ampersand before the letter to be used for the hotkey. For example '&Risk Map'. In this example, the letter 'R' would become the hotkey used for creating the risk map. The command 'helpmsg' allows for the inclusion of a short statement outlining what the macro would perform when the user hovered their mouse cursor over the tool. The inclusion of some of these items ensured that it would make the toolkit as user friendly as possible, and brought the toolkit up to a similar standard of the other MapInfo tools that were available as part of the standard package.

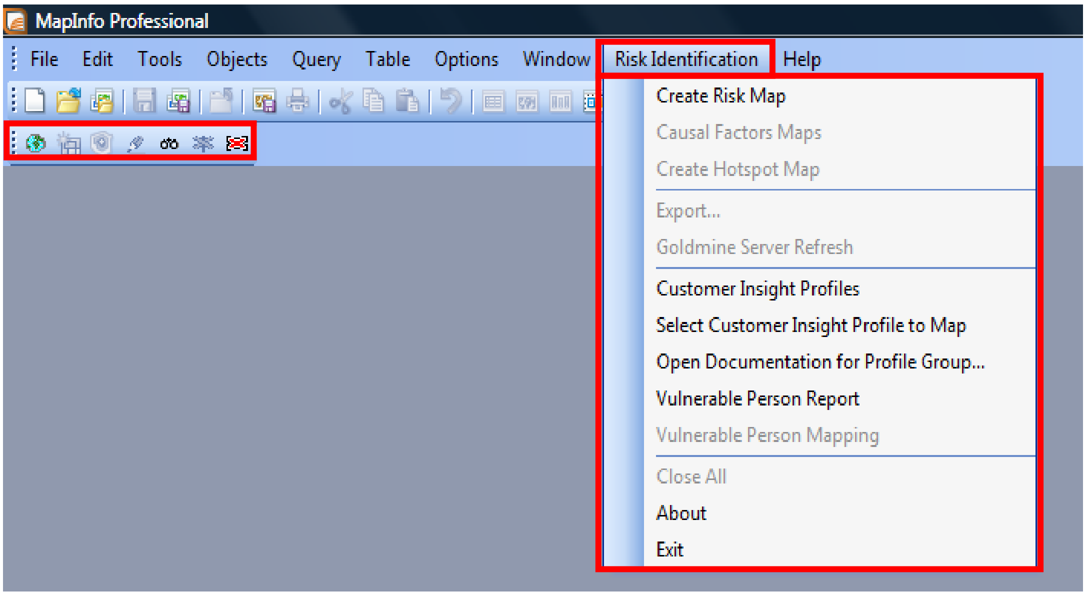

Figure 12 - Illustration of bespoke toolbar inserted into MapInfo

The image in Figure 12 shows the additional menu bar and toolbar buttons that were created in MapInfo as part of this research. The menu bar illustrates the flow control that was added. Items that are not yet available for the user to select are 'greyed out'. In addition, the functions of the toolbar were logically grouped, for example macros relating to the creation and interrogation of the Community Risk map were group together, as were macros related to the Customer Insight elements. Again, this was included to enhance the flow control within the tool.

A number of the tools involved replicating existing MapInfo functions, but brought them into the same place to make the tool user friendly. The tools that were based on existing functionality included 'Close All' and 'Exit'. Some of the tools only involved calling on another programme to open, for example the command to open documentation for the customer insight profile groups. The following sections will focus of the bespoke commands that were developed for Merseyside Fire and Rescue Service based on the research completed.

7.4.1 Community Risk Map

This function of the GIS was developed to display the risk scores generated by the statistical model as a map of Merseyside. The developed macros contained instructions to take the risk score of each LSOA and match it with the LSOA boundaries on the map. Once this had been linked together, each LSOA was classified as being high, medium or low risk based on the risk score generated from the risk model. At the time of developing the risk model, Merseyside Fire and Rescue Service had a target of visiting 100,000 properties annually to deliver Home Fire Safety Checks[8]. The classification of risk bands were related to the number of resources available and the number of Home Fire Safety Checks delivered annually. It was important to relate the risk bands to what could be reasonably achieved in one year, and how many homes could be reasonably visited. The banding that represents this evaluation of risk is:

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[8] *Figure from MFRS Service Plan 2010/11 – Local Performance Indicators 4 & 5*

- Low risk – the 42.5 percentile and below of LSOA, ranked by risk score
- Medium risk – Between the 42.5 percentile and the 85 percentile of LSOA, ranked by risk score
- High risk – the 85 percentile and above of LSOA, ranked by risk score.

Areas designated as low risk represent areas where there is a small likelihood of fire and the outcomes are likely to be less severe. Areas designated as medium risk area areas where hazards have already been identified and are being addressed to ensure they are as low as reasonably practicable. High-risk areas identify those areas where prevention should be focused until risk has been reduced to a medium level.

The developed macros instructed the GIS to open the database that held each dataset and run the risk score calculation each time the function was selected. The GIS user could update the source database whenever new information sources were available, meaning that the risk calculation was always based on the most up to date information. The resulting risk map was more dynamic than other maps available, as it was based on information sources that changed on a regular basis, and the developed macros had the ability to include the most up-to-date information within the calculations. After opening the source database, the macro then instructed the GIS to calculate the risk score for each geography using the coefficients that were the output from the linear regression modelling analysis. This involved multiplying the causal factor value for each Lower Super Output Area with its coefficient and summing all the values as shown in Figure 13. The total of these values was the overall risk score for the geography.

Risk_Score = (-7.54 + (DLA * -0.054) + (IMD * 0.069) + (Elderly * 0.009) + (Lone_Parent * -0.265) + (No_Alarm * 0.025) + (Single * 0.133) + (Smokers * 0.082))

Figure 13 - Formula used to calculate accidental dwelling fire risk score

The next step for creating the risk map was to split geographies based on the 'high', 'medium', and 'low' risk scoring methodology. Keeping with the visual representation of previous risk maps within the fire and rescue service, high risk areas were coloured red; medium risk areas were coloured yellow; and low risk areas were coloured green. This traffic light system was familiar amongst staff, therefore kept to help with the transition to using the new risk map.

Figure 14 shows an example of the generated community risk map for Merseyside. This methodology has assigned the following proportions risk across Merseyside:

- High risk = 128 LSOAs
- Medium risk = 371 LSOAs
- Low risk = 406 LSOAs

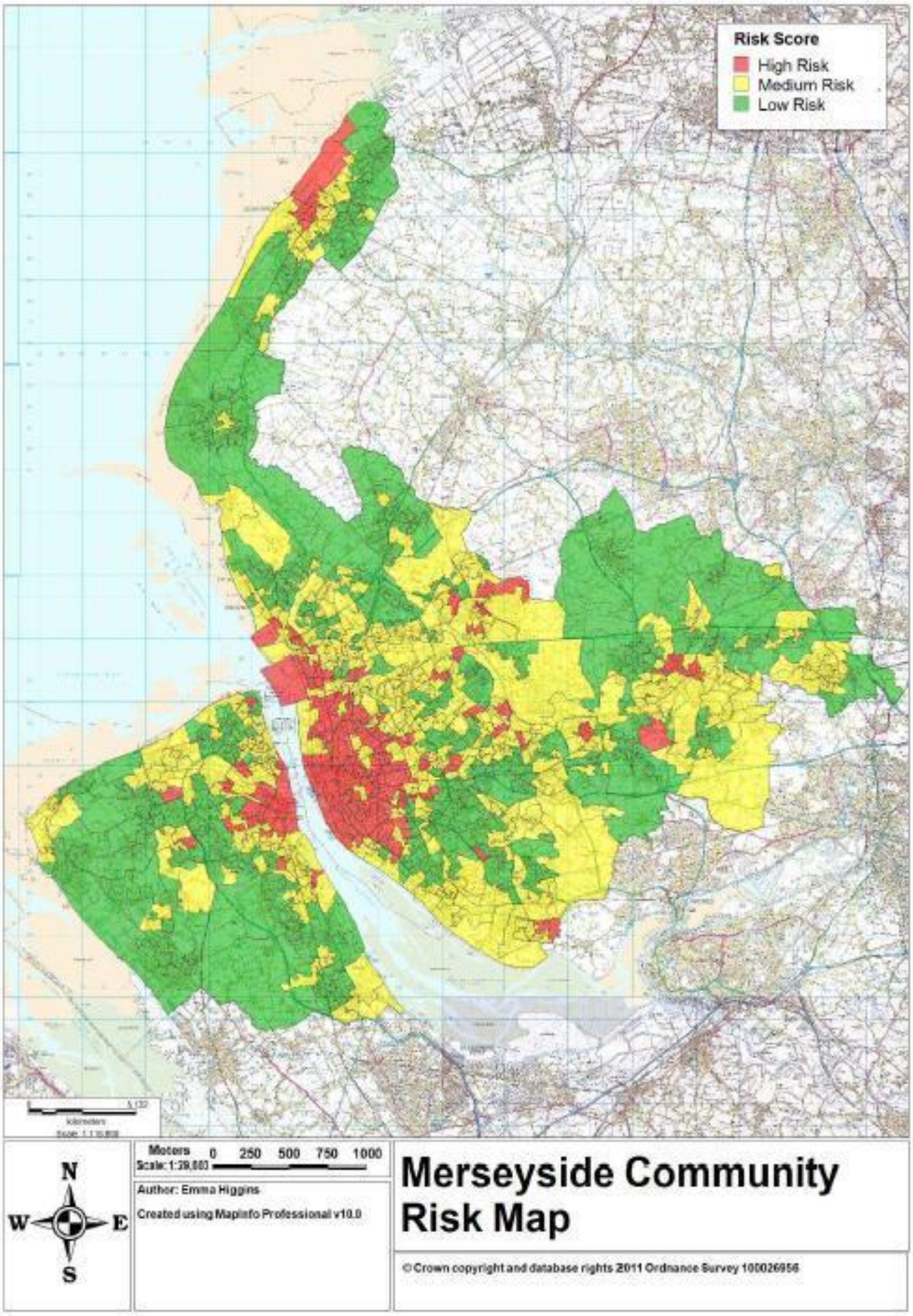

Figure 14 - Map illustrating the developed Community Risk Map for Merseyside **[8]**

This risk map shows clusters of high risk localities around Liverpool City Centre, Bootle, Birkenhead and Southport. There are also smaller clusters of high risk localities elsewhere within the County. This map provides Senior Officers with a visual representation of fire risk based on demographic factors. This map is beneficial from a strategic perspective as it provides an overview of risk that is easy to understand and can be directly related back to particular geographies within the County.

7.4.2 Causal Factor Mapping

This function of the GIS was developed to allow users to interrogate and map each of the causal factors that contribute to the community risk map. The functionality was important to enhance the understanding of fire causal factors in Merseyside and support targeting of preventative initiatives towards particular risk groups. Similar to the community risk map, the developed macros contained instructions to take the values for each causal factor in each LSOA and match it with the LSOA boundaries on the map. Once this had been linked together, each LSOA was classified as being high, medium or low risk based on the values for each causal factor. This was calculated using tertiles of high, medium or low risk as there was no other meaningful way to rank this information. Again, the macros instructed the GIS to open the source database each time the function was requested, ensuring that the most up to date information sources were used within the analysis.

A bespoke wizard was developed allowing the user to select which causal factor they would like to map. This then automatically runs the macro to create the map and display it on the screen.

7.4.3 Hotspot Mapping

This approach is similar to creating the community risk map, however, a hotspot map shows how risk is distributed without the constraints of boundaries. This is useful to understand, especially where LSOAs of high risk are located next to LSOAs of low risk.

In this example, a hotspot map looks at a spatial clustering of risk. The centres of the hotspots relate to the population centres within Merseyside, therefore this approach takes into account where there are clusters of the population to associate with risk. This approach is beneficial as it helps prevention teams understand the location of risk relative to the population. Although LSOAs are roughly equal in population, they do vary in physical size, therefore the hotspot map is of particular importance with larger sized LSOAs. This also makes it easier for the user to compare the accidental dwelling fire mapping with other data sources, for example locations of deliberate fires or location of resources in relation to the risk present. Although Merseyside is a predominately urban county, there are some rural pockets, especially in parts of the Wirral and St Helens districts. In these circumstances, knowing where there is a hotspot of risk is important, and this may not be presented as well visually in the community risk map

7.4.4 Customer Insight Maps

The k-means clustering analysis completed as part of the statistical analysis for this research resulted in each output area[9] within Merseyside being assigned a cluster group. This information is then used to create a map of the clusters or segments. This allows the user to understand the spatial relationships between clusters. This mapping is particularly useful for understanding whether certain types of incidents are more or less likely to occur within a particular group. Knowing this is useful for Merseyside Fire and Rescue Service staff as it assists with targeting specific resources towards particular areas. The Community Risk Map was useful for a strategic overview of accidental dwelling fire risk, however the Customer Insight map provided a bit more detail in terms of the data included and was also presented at a more granular geography.

Within MapBasic, bespoke programming code was written to create a map of the customer insight segments and colouring each output area according to the cluster grouping they were assigned during the statistical analysis. An example of this mapping is presented in Figure 15. The code in MapBasic joins the geographic output area files with the outputs from the statistical model. The code points to a column within the statistical model that provides information about the cluster group for that particular output area.

[9] Smallest Census geography consisting of approximately 125 households

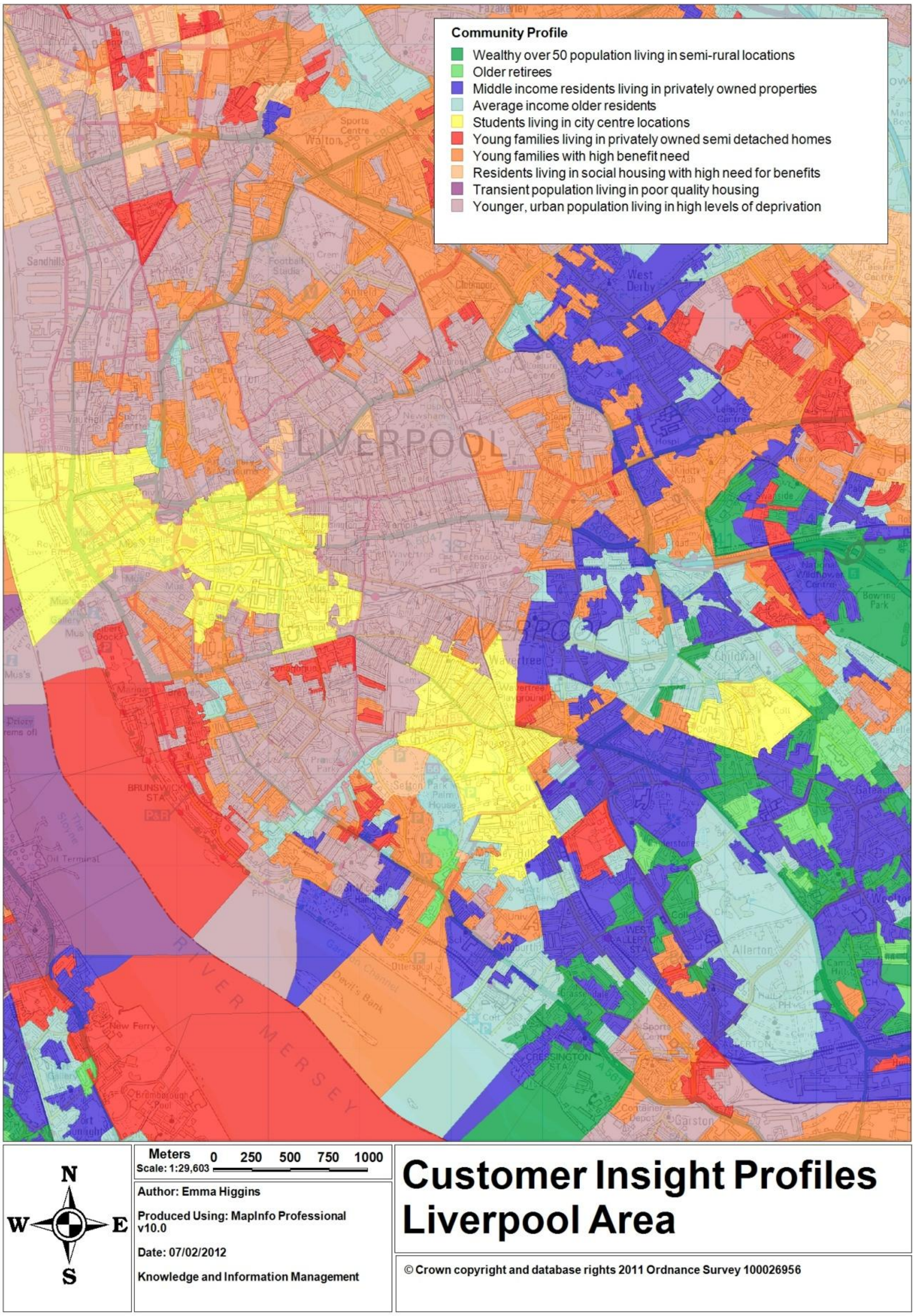

Figure 15 - Map illustrating the developed Customer Insight segmentation, focussed on the Liverpool area **[11]**

7.4.5 Vulnerable Person Index Reports

This functionality involved the creation of Crystal Reports [132] that included a list of addresses for operational crews to visit. This was a requirement for the tactical use of the framework for the actual delivery of services. This risk-based approach to prioritising visits ensured that operational crews were focusing their time, efforts and resources toward high risk or vulnerable individuals.

The creation of these Vulnerable Person Index reports allowed operational crews to target actual addresses based on risk. This was achieved through MapBasic by requesting the GIS to access the 'Goldmine[10]' database and retrieve information stored about vulnerable individuals. Goldmine is the central storage point for information shared by partners about vulnerable individuals. This means that the MapBasic macro only needs to point to one location to retrieve the information. After the information is retrieved, the macro then counts the number of times an address is listed on the database and allocates it a 'priority'. The Priority rankings are as follows:

- 4 or more risk factors at an address = Priority 1
- 3 risk factors at an address = Priority 2
- 2 risk factors at an address = Priority 3
- 1 risk factor at an address = Priority 4

[10] Goldmine is the corporate Customer Relationship Management database used by Merseyside Fire and Rescue Service and stores all information about Home Fire Safety Check engagement with members of the public

To overcome issues related to data protection, the database manager will overwrite and replace shared information when a partner sends new information. This ensures that Merseyside Fire and Rescue Service do not store information for longer than necessary, and ensures that Merseyside Fire and Rescue Service have an up to date list of potentially vulnerable individuals. It also means that Merseyside Fire and Rescue Service are not sending resources to properties where circumstances have changed (e.g. new occupants or deceased occupants), which could result in wasted time and effort of staff involved.

Once addresses are cross matched with vulnerability information, the data is exported to a PDF file, which can then be used by Merseyside Fire and Rescue Service staff. The data was exported to PDF for a number of reasons. Firstly, it meant that information could not be changed in error by staff using the tool. Secondly, people who were not authorised to see the vulnerability information could not access the sensitive information used to create the reports. It was important that information about vulnerable members of the community remained secure, therefore no sensitive information was included within the final report. Members of staff using the tool did not know what vulnerabilities were present at the property by looking at the status report: however, they could query the report by contacting the team responsible for maintaining the reports.

The vulnerability of a property was highlighted in the following way:

- 4 or more risk factors at an address = Red
- 3 risk factors at an address = Orange
- 2 risk factors at an address = Yellow
- 1 risk factor at an address = White

A conscious decision was made not to use a traffic light systems (e.g. red, amber, green) for these reports as staff members utilising them may mistakenly assume that properties highlighted in green did not present a risk, therefore would not require an intervention. An example of the generated report is shown in Figure 16.

Report Description: Properties Awaiting Initial Inspection

Campaign Code: -

Station Name:

Report Date: 18 September 2012
Report Time: 9:13:09 am

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ADDRESS	TELEPHONE NUMBER(S)	COMMUNITY NUDGE	PRIORITY
78 _ Bedford Road__ _	-		3
88 _ Bedford Road__ _	-		3
35 Bedford Court _ Bedford Road__ _	-		4
46 Bedford Court _ Bedford Road__ _	-		4
A 176 _ Bedford Road__ _	-		4
Flat 2 189 _ Bedford Road__ _			3
Flat 3 189 _ Bedford Road__ _	-		3
Flat 4 175 _ Bedford Road__ _	-		3
Flat 4 189 _ Bedford Road__ _			2
Flat 5 225 _ Bedford Road__ _	-		1
Beech Court			
7 _ Beech Court__ _	-		3
9 _ Beech Court__ _			3
Belmont Grove			
6 _ Belmont Grove__ _	-		3
Ben Nevis Road			
19 _ Ben Nevis Road__ _	-		4
70 _ Ben Nevis Road__ _	-		3
Bennetts Hill			

Report Name: T:\Crystal Reports\Vulnerable_Individuals_Liverpool_Data_v5.0_initial_visits.rpt

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Figure 16 - Sample Vulnerable Person Index Report

7.5 Summary of Integrating the Statistical Model

It was identified at an early stage of this research that the developed statistical models would be useful for understanding fire risk present, but they would not be particularly user friendly. A key aim of this research was to develop a framework that could be utilised by staff members with little knowledge of statistical techniques or concepts. Geographical Information Systems were utilised as a user friendly interface as many staff members had the skills and experience of operating such a tool.

As such, GIS was selected as the interface between the statistical model and the user. The development of the interface was completed using the MapBasic functionality. A number of tools and functions were created using MapBasic. These were:

- Creating the Community Risk map
- Creating maps of causal factors
- Creating a hotspot map of accidental dwelling fire risk
- Function to export information to a CSV text file
- Function to refresh the server that was used to hold risk data
- Creating the Customer Insight map (and also function to select a particular group to map individually)
- Function to open the profile group documentation directly from MapInfo
- Creating a report of vulnerable individuals

- Finally, function to close all open maps (to prevent corruption of the databases).

The key outputs of the framework are the community risk map, the 10 community profiles and the vulnerable person index reports. Each of these tools can be utilised by the user to understand risks and needs present within the local community.

Chapter 8– Testing the Framework

8.1 Introduction to Testing the Framework

The aim of this chapter is to explore the methods used to test the functionality of the developed framework and how well the framework performed under the test conditions. In addition, this chapter will look at the usability of the framework, which will be evaluated through user acceptance testing with the staff members who will take responsibility for using the toolkit in the future.

The geographical information systems testing framework developed involves running a number of tests which focuses on each component part of the framework and also tests that focus on how each of the component parts performs with the framework as a whole. The testing framework ensured that each aspect of the model, and its interactions with other components of the model was thoroughly tested in addition to testing the system in its entirety.

- **Data source testing** verifies that the data sources used within the statistical model are imported into the GIS correctly, and that changes to the source data are reflected in the system
- **Queries testing** ensure that the SQL queries in the code link to the correct data sources and that data joins are based on the correct field.

- **Calculations testing** verify that the code developed to calculate risk scores is robust and reliable, and displays the results expected when the calculations are performed independently.
- **Map layers testing** ensure that layers drawn in MapInfo are correct, and risk scores are banded correctly.
- **GIS reports testing** verify that data exported to Crystal Reports is correct and that the SQL queries select the expected data.
- **GIS systems testing** ensures that the system works in its entirety and that all elements work together correctly.
- **User acceptance testing** ensures that end users of the system are satisfied with how they can interact with the system.

Each of these tests ensures that that Merseyside Fire and Service can be confident that the outputs provided by the toolkit are accurate and reliable, therefore can be used for informed decision making. A diagrammatic representation of the testing process is shown in Figure 17.

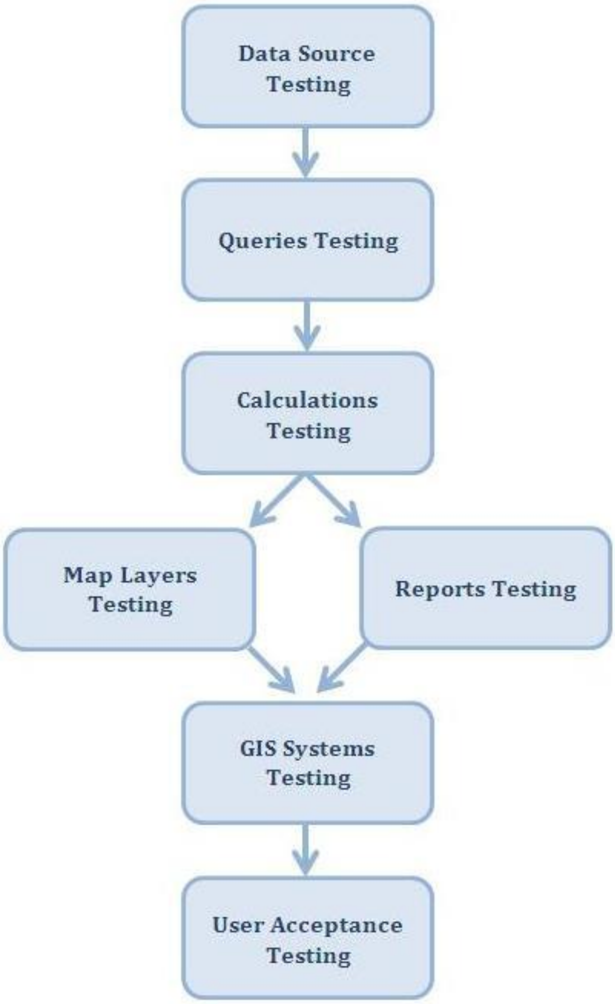

Figure 17 - A diagrammatic representation of the geographical information system-testing framework

The structured manner for GIS testing outlined in this research means that the system can be tested in a rigorous manner, which is reassures Merseyside Fire and Rescue Service that the outputs of the system are robust.

8.2 Outline of the GIS Testing Framework

Each stage of the GIS testing framework will be described in turn.

8.2.1 Data source testing

it is important to ensure that data sources are all up to date, cover all of the geographic area, and are reliable. This can be checked through the data source testing component of the framework.

Checking data sources are up to date is of particular importance when using data obtained from a variety of external sources. When data is collected from a variety of sources, it can be difficult to track which data sources are up to date and which are not. It is necessary to verify that the data sources cover all of the appropriate geographic areas and are not accidentally duplicated or omitted. For example, it may be that data sources are loaded for most of the areas within the county however, some may be missing. This can affect subsequent queries, calculations, map layers and reports. It will also be necessary to test that data sources cannot be accidentally corrupted by users when they operate the system or view the geographical information system output.

It is also important to test the reliability of data sources for the geographical information system. For example, some of the addresses generated by the system for fire prevention visits were for commercial properties that should not have been included within a database specifically for dwelling addresses.

8.2.2 Model testing

Some geographical information systems may simply be used to display geographical data; others, like the example discussed in this thesis, may include more complex processing. More advanced geographical information systems may include mathematical or statistical models that can provide predictive capabilities. It is necessary to test that any mathematical or statistical model used in a geographical system is accurate and robust enough to provide reliable outputs. The testing of the statistical model also involved testing the assumptions of the statistical technique that was used. For example, this included testing whether the variables were normally distributed, testing whether the model developed was linear and testing whether any of the variables within the model had a high degree of colinearity, suggesting that they could potentially have a strong relationship with each other and were not completely independent. The predictive element of the model was tested by investigating the coefficient of determination generated by the model.

8.2.3 Queries testing

Queries' testing is related to the interrogations of data and tables performed by the GIS. The aim of queries testing is ensuring that these interrogations function correctly.

GIS tools typically include facilities to generate different types of queries, for example data, spatial and themed queries or using menu options. The purpose of testing these queries is to ensure they link to the correct sources and perform the correct extractions. An error in the queries could result in the GIS returning an output, but if the query is incorrect then it is likely that the output may also be incorrect. For this framework, it is important to ensure that tables called upon by the GIS join correctly, using the correct primary key and that performing the join does not result in corruption of the source file. In this framework, bespoke menus were created and it was important to ensure that they functioned corrected and generated the expected results. The results generated by these spatial queries should be compared to expected results separately calculated from the source data. The queries in the GIS should be tested using an appropriate and representative sample of data from the geographical area of concern.

8.2.4 Calculations testing

Calculations' testing is related to the statistical computations embedded in the geographical information system, ensuring that they function correctly and are statistically reliable and valid.

It is important to complete the calculations independently from the GIS in order to ensure that these are functioning correctly. It is necessary to test all the calculations, using a representative proportion of the data on which the calculations are performed. Calculations within this framework were tested by comparing them with values calculated from the SPSS statistical model for fire risk.

8.2.5 Map layers testing

Map layers testing related to the visual representation of data, ensuring that each map layers is displayed as expected. This is important to ensure that the points, lines and polygons generated by the framework display in the correct locations. This can be compared with a manual generation of the map layers, for example, ensuring that the thematic banding generated by the automated toolkit matches with what is expected to be seen when the user manually completed this activity. Map layers testing should be performed using a representative sample of data from the geographic area of concern.

For the fire prevention framework, individual map layers for each of the predictor variables within the multiple linear regression model were tested by comparing sample values with values calculated from the SPSS statistical model. This was also done for combined map layers.

8.2.6 GIS reports testing

GIS report testing related to the running of reports created by the GIS, ensuring that they function correctly and that report data output matches map based data output. It is also important to ensure that the outcomes of this are suitable for operational use.

In order to test reports produced by the geographical information system it will be necessary to perform the relevant data extractions and calculations across a representative subset of data points and areas in order to confirm that the relevant output item in the report is correct.

8.2.7 GIS systems testing

GIS systems testing relates to the overall system, ensuring that it functions correctly with anticipated data volumes and user defined requests.

It is necessary to test the geographical information system in its entirety in order to ensure that all the elements of the system work together correctly. The system testing should involve completing all of the activities defined within the framework, ensuring that they operate in the intended way. The framework was tested using data from one of the five district areas within Merseyside.

In addition, the system testing should check that the system would function in a timely manner when the full data volumes are used. This can be particularly important when large volumes of geographic data sets are used. It is important that the time taken to run the queries are acceptable to the user and that they are informed of how long each query takes to run.

8.2.8 GIS user acceptance testing

GIS user acceptance testing related to understand how the user finds the operation of the GIS, in particular, whether it is straightforward to use.

It will be necessary to test that the geographical information system is simple for users to operate. If the developed activities are not user friendly, then the users may not wish to utilise them, or they may utilise them incorrectly. A representative sample of users from all the different user groups who will use the system should be involved in the acceptance testing. The user acceptance testing should cover all the GIS functions that will be used by the different user groups.

Feedback from the user acceptance testing can be used to make amendments or further developments to the tool, ensuring that it fully meets the needs of the end user.

8.3 Results of Testing

A summary report of the testing phase is shown in Table 8:

Programme	No. of tests planned	No. of tests successful	% success of tests completed	Number of defects noted	Number of outstanding Defects
Data Source	80	80	100%	0	0
Queries	80	80	100%	0	0
Calculations	20	20	100%	0	0
Map Layers	55	53	96%	2	0
GIS Reports	10	10	100%	0	0
GIS Systems	9	7	78%	2	0

Table 8 - Table illustrating the results of the Fire Prevention Support system's testing phase

Comments on the success of the testing and the severity and impact of the outstanding defects, for each stage, are set out below.

8.3.1 Data Source Testing

The summary figures in Table 8 indicate that data was imported from source databases and displayed correctly in MapInfo in all test cases. In order to ensure that data automatically imported by the GIS programming code was correct, it was compared with data imported manually. The data imported included source data for the community risk map, customer insight map and vulnerable person index. This test was completed 80 times and no errors were experienced.

When the data that was imported using the automated tool was compared with the manual import, there were some slight variations in the data. It was discovered that this was related to MapInfo rounding to the nearest whole number during the automated import. There did not appear to be a reason for MapInfo to do it in this way, but when interrogated further, it appeared that full information about the value was present, but it was just displayed as a rounded figure. This is not an issue for the system and it did not affect the functionality of the model. As an additional test, the data imported automatically was exported back to Microsoft Excel, where it was discovered that full information about the value was present and the numbers were not rounded.

In another test, data was changed in the source databases to reflect an update of source data. These changes were reflected when the bespoke programming opened the tables in MapInfo. For example, if the number of smokers was changed in the source data, then this was reflected when opened within MapInfo. Finally, attempts were made to change data in the MapInfo tables. This was not reflected in the source data, indicating that accidental changes to the tables generated by the SQL queries would not corrupt the source data. This was a desired objective of the programming.

8.3.2 Queries Testing

Summary figures in Table 8 indicate that the SQL queries embedded within the source code are linking and joining to the correct data sources. In order to test the queries, the source data and geographic information for community risk, hotspot, causal factor and customer insight maps were generated manually. This involved matching the source information with the geographic boundaries in MapInfo so the data could be displayed on the map. The primary key to join these datasets was the output area code. This was present in all the files to be matched.

The files were manually matched using the SQL query function within MapInfo and exported to Microsoft Excel. This information was compared with what was generated through the automated GIS tool. A total of four queries were tested, which were:

- Joining the community risk map source data with the geographic LSOA boundaries
- Joining causal factor source data with the geographic LSOA boundaries

- Joining hotspot mapping source data with the geographic LSOA boundaries
- Joining customer insight source data with the geographic output area boundaries

A total of 80 tests were completed, which was split to 20 tests for each mapping query.

The SQL query embedded into the framework's programming code was compared with a manual completion of the queries. Each time, an LSOA/output area was selected randomly and compared with the match that was completed manually. The data for that particular LSOA was compared with the expected data to see if it corresponded.

There were no errors identified within this phase of the testing, which meant that the queries performed by the developed GIS were running correctly. This allowed for an appreciation that the source code was joining tables together in an appropriate way.

8.3.3 Calculations Testing

Summary figures in Table 8 indicate that the sample of calculations tested matched what was calculated independently of the system. The calculations test specifically relates to testing the calculation performed when creating the community risk map through the bespoke GIS. As the statistical model was created in SPSS and the outputs of the linear regression model were documented, it was possible to manually calculate risk scores for each LSOA.

This was completed using Microsoft Excel. The expected results were compared with what was generated by the developed GIS tool.

This test was completed a total of 20 times, and LSOAs were randomly selected and compared with the expected results, which were generated in Microsoft Excel. All tests completed for this section of the process were successful, suggesting that the calculations performed within the GIS are functioning appropriately.

8.3.4 Map Layers Testing

The summary figures in Table 8 indicate that the sample of layers tested were drawn correctly in MapInfo, and were drawn with the correct coordinate system. It was important to check the both the positioning of the points and the coordinate system as errors in either of these factors would result in an inaccurate display of geographic information. To do this, a sample selection from each map layer generated by the tool was compared with map layers generated manually.

Points from the layer showing fire stations were selected, and points in MapInfo compared with their position on a map independent to the software. As there are only 26 stations within Merseyside, each station was checked for accuracy in location. In addition, polygons were checked for their completeness. The polygons checked included:

- Station boundaries
- Lower Super Output Areas

- Output Areas
- District boundaries
- Merseyside boundary

A random sample of polygons was selected to ensure there were no positional errors. In particular, polygons that formed boundaries of LSOA/Output Areas and districts were focussed on, as there was the potential for errors within these areas. This test was completed 50 times. From these tests, there was one defect noted, which related to map layers overlapping when they should match perfectly. LSOA/output area boundaries should match with Merseyside's district boundaries. This defect was noted and amended so it would not appear in future runs of the tool.

Finally, another test was completed in relation to the generation of thematic map layers. This was completed for the generation of each thematic map layers. There are:

- Generation of the Community Risk Map
- Generation of causal factor maps
- Generation of hotspot map
- Generation of customer insight map

Similar to testing other functions, each map was generated manually and compared with the automatic creation of the maps via the bespoke tool. The allocation of thematic bands was compared with what was expected. There was one defect noted, which related to the hotspot map not displaying risk relative to the population centroid. In the automated tool, the risk was displayed relative to the centre of the polygon rather than the location of the population with the LSOA. This was amended in the source code, which ensured that risk would be displayed relative to the population centroid in future.

8.3.5 GIS Reports Testing

The summary figures in Table 8 indicate that the sample of reports run were successful and extracted the correct data.

The GIS reports testing was related to the generation of Vulnerable Person Index reports, which are based on address information that illustrates where one of more fire risk causal factor may be present. The process was completed manually, which involved a manual export of information to a Crystal Report. This process was completed for 10 stations to see if the total number of records matched, and also the total number of properties within each risk banding also matched.

The numbers of properties extracted in each of the test reports match with what was expected and generated in the manual reports. In addition, the number of properties within each category also matched, highlighting that the system was classifying each property in the correct manner.

8.3.6 GIS Systems Testing

The summary figures in Table 8 indicate that two defects were noted during this process. This process related to how the framework operated in its entirety.

This process involved working through the GIS, making sure that there was a logical flow and that tools could only be accessed where it was appropriate to do so. The two defects identified related to flow control issues, which were later amended and resolved. The first defect was related to the user being unable to create thematic maps of causal factors after creating hotspot maps. At the point of testing, the option to create causal factor maps was still available to select after creating a hotspot map. The nature of the query to create a hotspot map meant that the source code to create a thematic causal factor map would not work correctly. It was important that this was resolved before leaving the testing phase as it could potentially result in dissatisfaction from the end user. This matter was resolved by including a flow control element which meant that the user could not create a causal factor map after creating a hotspot map. Further testing showed that this resolved the defect.

The second defect was also related to the creation of causal factor maps. This defect was specifically about the display of an error message to inform that a particular field was not defined. This error resulted in the map not displaying correctly, and appeared to be related to the first defect identifying with the creation of the hotspot map. This defect was rectified by checking the source code to ensure that all variables with the code were appropriately defined and could be used by the query.

After rectifying both defects, the full systems test was completed again to ensure no further errors were identified. The full system was checked to ensure that flow control was in the appropriate place and the user was lead logically though the tool. No further defects were identified after checking the full system again.

8.3.7 Summary of GIS testing

To summarise, a number of key features of the GIS framework was tested to ensure that it was fit for purpose and that the outputs from the tool were robust and reliable for the user. The elements tested were:

- Data source testing
- Queries testing
- Calculations testing
- Map layers testing
- GIS reports testing
- GIS systems testing

A small number of defected were noted and subsequently resolved. The table in Table 9, below lists the defects that were noted and any action that was taken to resolve the issue.

Testing Stage	Defect Ref.	Defect Description	Comments
Map Layers			
	ML1	Issue relating to completeness of layer 'LSOA' used in the system. Self-intersections, gaps and sliver polygons present at large scale. Similar issue relating to other polygon vector layers, including 'Station Grounds'.	Minor change Layers were cleaned in MapInfo and re-checked. No further problems found.
	ML2	Change of centroids in 'LSOA' layer to reflect population centroids	Minor change Centroids were amended in layer
GIS Systems			
	GS1	Unable to create 'Causal Factor Maps' after creating a 'Hotspot' map	Minor change Flow control amended so user will create causal factor maps before creating a hotspot map
	GS2	Cannot create Causal Factor Map – Variable or field not defined	Minor change Amended to ensure maps can be created

Table 9 - Table illustrating defects occurring during the GIS testing phase

Testing the GIS was important as it ensured the user could be confident in using the tool, however of equal important is the user acceptance testing to ensure that what was developed actually met the needs of the user.

8.4 User Acceptance Testing

In order to ensure that the developed product met the user's needs, some activities related to the user's acceptance was completed. The initial phase of user acceptance involved hosting a training and awareness session lasting approximately 90 minutes. During this session, a number of elements of the framework were discussed. This included:

- Background to the development of the framework, including a summary of the statistical modelling that was completed to understand accidental dwelling fire risk within Merseyside
- As all attendees to the session were competent MapInfo users, an overview of MapBasic was given to illustrate how bespoke tools could be created
- Detailed introduction and overview of each of the bespoke tools created, including what functionality they could provide and a demonstration of how each tool can be used and applied.

The purpose of the training and awareness session was to introduce staff members to the developed tool and provide an insight into the functionality available. The session was held with members of the Systems Support team at Merseyside Fire and Rescue Service, which included three analysts and the

Corporate Systems Support Manager. The session was held in a conference room at Merseyside Fire and Rescue Service Headquarters.

Following the session, staff members involved were provided with a training pack and asked to complete some training activities. The training activities involved the following:

- Create the Community Risk map
- Create a number of defined causal factor maps
- Create a hotspot map
- Create the customer insight map and access the documentation about specific profiles groups
- Export a Vulnerable Person Index report to Crystal Reports

As part of these activities, users were requested to note anything they found particularly good or useful and anything they found that didn't work, was confusing or was not useful.

Following the completion of the training pack, the staff members were invited to attend a focus group meeting to provide feedback. This session was attended by the three systems support analyst and the Corporate Systems Support Manager. The session held was semi-structured in nature, and lasted approximately one hour. The key aim of the focus group was to understand whether the tools developed as part of this research met the needs of the end user and whether there were any potential amendments that could be made to the framework that could improve usability.

The key areas for discussion as part of the focus groups included:

- What do you feel works particularly well with the system?
- Is there anything that you feel could be improved?
- Finally, do you feel that this framework will help you with your day to day job?

Each of these questions was posed to the group and feedback was noted.

In general, the attendees felt that the framework worked well because it provided a friendly interface. The staff members commented that they felt uneasy when they heard about the statistical modelling used for this approach, and were unsure whether the framework would be simple for them to navigate. One staff member commented that because GIS was used as the interface, the framework felt more accessible and friendlier. This staff member felt that this would be one of the key factors of acceptance. The Corporate Systems Support Manager commented that integrating the framework into software currently used was aligned with the corporate strategy of the organization. This also meant that staff could fully utilize the full range of functionality offered as they were so familiar with the tool.

Although staff members were very positive about the framework, they did feel that a number of things could be improved upon to ensure the tool was applied as fully as possible. In particular, staff members involved within the focus group felt that there was a need for a user guide that could accompany the framework. Although staff members felt comfortable that using the tool did not require any statistical input, they were concerned about being asked questions from other members of staff about how the framework was developed and the statistical methodology used. There were also some comments about the time it took maps to load. It was accepted that the volume of data would result in the system running slow, but staff members were unsure at times whether the map was taking time to load or whether the system had crashed. It was felt that there was a need for a status bar, or similar, informing the user of the progress. Finally, the group felt there was a need to ensure that warning messages were easy to understand as some of the standard MapBasic error messages were incomprehensible. The group felt that this would allow them to address the error more easily.

All staff members involved within the focus group felt that this framework would help them do their job more easily. It was agreed that access to this type of information had never been made available to them before, and access allowed them to perform more intelligent analysis. In particular, one member of the group commented that the automated nature of this framework allowed them to get through their activities quicker, leaving more time for other pieces of work.

After the focus group was completed, the comments were reviewed to understand whether anything could be done to ensure the framework was as user friendly as possible. This involved taking the comments where staff members felt improvements could be made. As a result, the following functionality was added to the framework:

- Development of a user guide, which staff members could refer to when using the framework or explaining it to a colleague
- Introduction of 'service messages' to state what they GIS was doing after a function was selected. For example 'loading data', 'running statistical model' or 'generating map'
- Standard error messages were amended to include more logical information. For example 'Cannot perform this function. Please select causal factor to map'

After these amendments were made, the framework was presented to the original focus group involved within the Soft Systems Methodology section of the framework. The framework was presented to the Strategic Management Team at Merseyside Fire and Rescue Service following approval from the original focus group. The Strategic Management Team approved the framework, allowing the research to move from the development phase to implementation.

8.5 Summary of Testing the Interface

It is important to ensure that any developed system of framework is appropriately tested to ensure it is fit for purpose and the outputs are robust and reliable. Within this research it was important to ensure that the following elements were tested and worked correctly:

- Data source testing
- Queries testing
- Calculations testing

- Map layers testing
- GIS reports testing

In addition to these, there is also a need to ensure that the framework operates correctly in its entirety, and also that the end users are satisfied with the product developed and how it is utilized.

When a GIS contains a statistical or mathematical model, there is a need to ensure that the formulae are replicated correctly within the GIS. Checking whether the GIS provides an output is not enough; it is important to compare that output with what is expected when it is replicated in other software. In relation to this, there is a need to ensure that the model queries the correct data sources and data fields. Again, this may produce an output, but this should be cross matched against what the output is expected to be.

As the nature of a GIS is to display information in a visual manner, it is important that the geographical information displayed is done so at the correct map projection and it displayed in the correct location. When creating thematic maps, it is important to ensure that the data is banded correctly and there are no unexpected defects occurring within this process. Finally, there is a need to ensure that any exports also match with what is expected to be seen.

Once these elements have been tested, the framework should be tested again as a whole to ensure there are no defects occurring when moving from one activity to the next. At this point, it is important to gain user feedback through user acceptance testing. Ultimately, the user needs to be satisfied that the framework is simple to use and provides them with results they are confident are robust and reliable.

Chapter 9 – Application of the Framework

9.1 Introduction to Application of the Framework

The aim of this chapter is to present ways that Merseyside Fire and Rescue Service have applied the developed framework to assist with their fire prevention activities. After developing and testing the framework, the Prevention and Protection directorate decided that the tool should be implemented in small phases to ensure that it was achieving the desired outcomes. Although the framework was tested for its statistical rigour and operational accuracies, it also required testing in the real world environment. A number of small pilots were launched based on ongoing local projects and activities within districts. This allowed Merseyside Fire and Rescue Service to understand and learn how to use the framework and how to refine some of the outputs and deliverables.

The application of the framework mainly focused on the utilisation of the community profiles tool and the vulnerable person index tool. These tools provide operational staff with enough detail of risks and needs present to focus community initiatives. The community risk map was used internally and presented within some strategic level documentation, such as the integrated risk management plan. The nature of the tool meant it was not as suitable to use for targeting services and initiatives.

9.2 Applications within Merseyside Fire and Rescue Service

The community profiles and vulnerable person index tools delivered through the framework were used within a number of real world scenarios by Merseyside Fire and Rescue Service. The pilots delivered using the tools started off as small scale projects that gradually lead to implementation into day to day activities. This implementation lead to a significant change within Merseyside Fire and Rescue Service, with a number of senior officers commenting that the research is "pivotal to our future strategy and is at the core of our work" [14]. The flow chart developed for the new strategy is illustrated in Appendix C.

Between the period of November 2011 and August 2013, a number of pilots were completed. After each pilot, the delivery mechanisms for the tools were reviewed to understand whether there were more effective and efficient ways of delivery. From this, it was discovered that communicating the framework to operational crews needed to be improved. This was achieved through the delivery of awareness sessions at fire stations, and information was cascaded down by the different Watches on duty. From August 2013, and after a number of smaller scale pilots, this framework was implemented into day to day work routines at Merseyside Fire and Rescue Service. Operational fire crews and community safety advocates utilise the vulnerable person index tool daily to target Home Fire Safety Checks. The community profiles are also used to gain an understanding of where to place specific resources or to analyse why certain types of incident are occurring within particular areas.

9.2.2 Community Profiles

At the point of developing the community profiles, Merseyside Fire and Rescue was utilising another commercially available geodemographic toolkit. However, they recognised the advantages of utilising the developed community profiles over the other tools available. This was because the community profiles were developed specifically to understand levels of risk and need present within their own local communities.

An initial pilot commissioned by Merseyside Fire and Rescue Service was about the application of the community profiles in one station area in the Liverpool district where there had been a large number of kitchen fires. An analysis of kitchen fires by the Business Intelligence team at the Merseyside Fire and Rescue Service showed that one station area in Liverpool had a significantly higher rate of kitchen fires when compared with other station areas in Merseyside. To understand this, an analysis was completed using the community profiles to understand whether there were any particular needs, risks or behaviours that could highlight why more fires were occurring within this area. By understanding this, Merseyside Fire and Rescue Service staff could target initiatives towards these communities to prevent similar fires occurring in the future. The station area selected for the project contained a good distribution of all ten community profile groups. An analysis of kitchen fires with the community profiles showed that over 70% of kitchen fires occurred within two community profile groups. These groups were:

- Young families with a high level of benefit need
- Young urban population in high deprivation

After identifying the profile groups most at risk, operational crews targeted Home Fire Safety Checks to areas where these groups were most prevalent. Advice was targeted based on the needs present within the area and also had a focus on safer cooking methods. The number of kitchen fires within these areas fell by 12% [12] between 2012/13 and 2013/14. The implementation of the community profiles methodology may have contributed to this reduction.

Another piece of analysis requested as part of the implementation process was an analysis into alcohol consumption, smoking and cooking fires. The analysis was completed to understand whether there was a relationship between these three factors if so, and where these factors were prevalent within Merseyside.

Data about alcohol consumption was obtained from the Liverpool Centre for Public Health at Liverpool John Moores University [133]. This information was based on an analysis of alcohol consumption patterns. The data split alcohol consumption into four main groups. These groups are:

- Non-drinkers = Reported as never, or very occasionally, consuming alcohol;
- Moderate drinkers = For males, under 22 units of alcohol per week; for females, under 15 units

- Hazardous drinkers = For males, between 22 and 50 units; for females, between 15 and 35 units
- Harmful drinkers = For males, over 50 units; for females, over 35 units.

This information was matched with every Output Area within Merseyside so it could be mapped. The information was also matched with the Community Profiles. This analysis was focused on investigating whether 'harmful' or 'hazardous' alcohol consumption were likely to be prevalent in areas at greatest risk from cooking fires.

Data about smoking was obtained from Merseyside Fire and Rescue Service Home Fire Safety Check data. This was also matched to Output Areas within Merseyside to allow for comparison.

The alcohol consumption and smoking information was compared with cooking fires, injuries and fire fatalities occurring in the period 01/04/2010 to 01/07/2013. The information was analysed using the 'Pivot Table' function in Microsoft Excel, and mapped using MapInfo version 10.0.

An analysis of cooking fires with alcohol consumption found the following:

- Approx. 35% of cooking fires occurred in areas with a prevalence of 'harmful' alcohol consumption;
- Approx. 29% of cooking fires occurred in areas with a prevalence of 'hazardous' alcohol consumption;

- Approx. 13% of cooking fires occurred in areas with a prevalence of ‘moderate’ alcohol consumption;
- Approx. 23% of cooking fires occurred in areas with a prevalence of ‘non-drinkers’.

This analysis would suggest individuals living in areas with a prevalence of ‘harmful’ levels of alcohol consumption may be at greatest risk to accidental cooking fires.

When this information was matched with accidental dwelling fire injury and fatality information, it was found that:

- Approx. 20% of accidental dwelling fire injuries were within areas with a prevalence of ‘harmful’ alcohol consumption and a further 21% of injuries were within areas with a prevalence of ‘hazardous’ alcohol consumption;
- Approx. 15% of accidental dwelling fire fatalities were within areas with a prevalence of ‘harmful’ alcohol consumption and a further 26% of fatalities were within areas with a prevalence of ‘hazardous’ alcohol consumption.

This analysis would suggest that residents living in areas with a prevalence of ‘harmful’ or ‘hazardous’ alcohol consumption may be more at risk of injury or fatality in an accidental dwelling fire.

When this information was matched with smoking prevalence data, it was found that there was a small overlap between ‘harmful’ and ‘hazardous’ alcohol consumption and smoking prevalence. Approximately 11% of Output Areas within Merseyside display these characteristics. Approximately 10% of cooking fires occurred in areas with a prevalence of ‘harmful’ alcohol consumption and a high proportion of smokers. Additionally, approximately 7% of cooking fires occurred in areas with a prevalence of ‘hazardous’ alcohol consumption and a high proportion of smokers.

When this information was matched with accidental dwelling fire injury and fatality information, it was found that:

- Approx. 6% of accidental dwelling fire injuries were within areas with a prevalence of ‘harmful’ alcohol consumption and high rates of smokers and approx. 1% of accidental dwelling fire injuries were within areas with a prevalence of ‘hazardous’ alcohol consumption and high rates of smokers;
- Approx. 7% of accidental dwelling fire fatalities were within areas with a prevalence of ‘harmful’ alcohol consumption and high rates of smokers and approx. 4% of accidental dwelling fire fatalities were within areas with a prevalence of ‘hazardous’ alcohol consumption and a high rate of smokers.

Finally, when this information was matched back to the Customer Insight Community Profiles, it was found that cooking fires within areas with a prevalence of ‘Harmful’ or ‘Hazardous’ alcohol consumption and high rates of smoking were most likely to be found within profile groups 5, 7 or 10. Across Merseyside, approximately 86% of cooking fire incidents occurred within these three groups:

- Group 5 (Students living in city centre locations) = 17%
- Group 7 (Young families with high benefit need) = 14%
- Group 10 (Younger, urban population living in high levels of deprivation) = 55%

From this analysis, it was found that there appears to be a link with cooking fire incidents and areas with a prevalence of ‘harmful’ or ‘hazardous’ levels of alcohol consumption. There also appears to be a link with ‘harmful’ and ‘hazardous’ alcohol consumption and injuries and fatalities in accidental dwelling fires.

There appears to be only a few areas within Merseyside where there was an overlap between ‘harmful’ and ‘hazardous’ alcohol consumption and smoking prevalence. However, approximately 17% of cooking fires occurred within these areas. This demonstrates that there is a link between cooking fires, alcohol consumption and smoking prevalence. In addition, 7% of fire injuries and 11% of fire fatalities occurred within these areas.

Finally, there appears to be a link between alcohol consumption and the Customer Insight Community Profiles. In particular, it was found that cooking fires involving ‘harmful’ or ‘hazardous’ consumption and smoking were most likely to be found in groups 5, 7 or 10. This could support the development of communications or a campaign to target individuals within these groups. At the time of publishing this thesis, Merseyside Fire and Rescue Service was considering developing bespoke communication packs for each community profile group based on the main fire risks present.

It may be beneficial to complete a more through statistical analysis to test the relationship between alcohol consumption, smoking prevalence and accidental dwelling fire incidents. This may lead to a more robust understanding of the relationship between these factors. This was outside the scope of this research, but may be something Merseyside Fire and Rescue Service wish to investigate further. The maps in Figures 18, 19, 20 and 20 illustrate this analysis

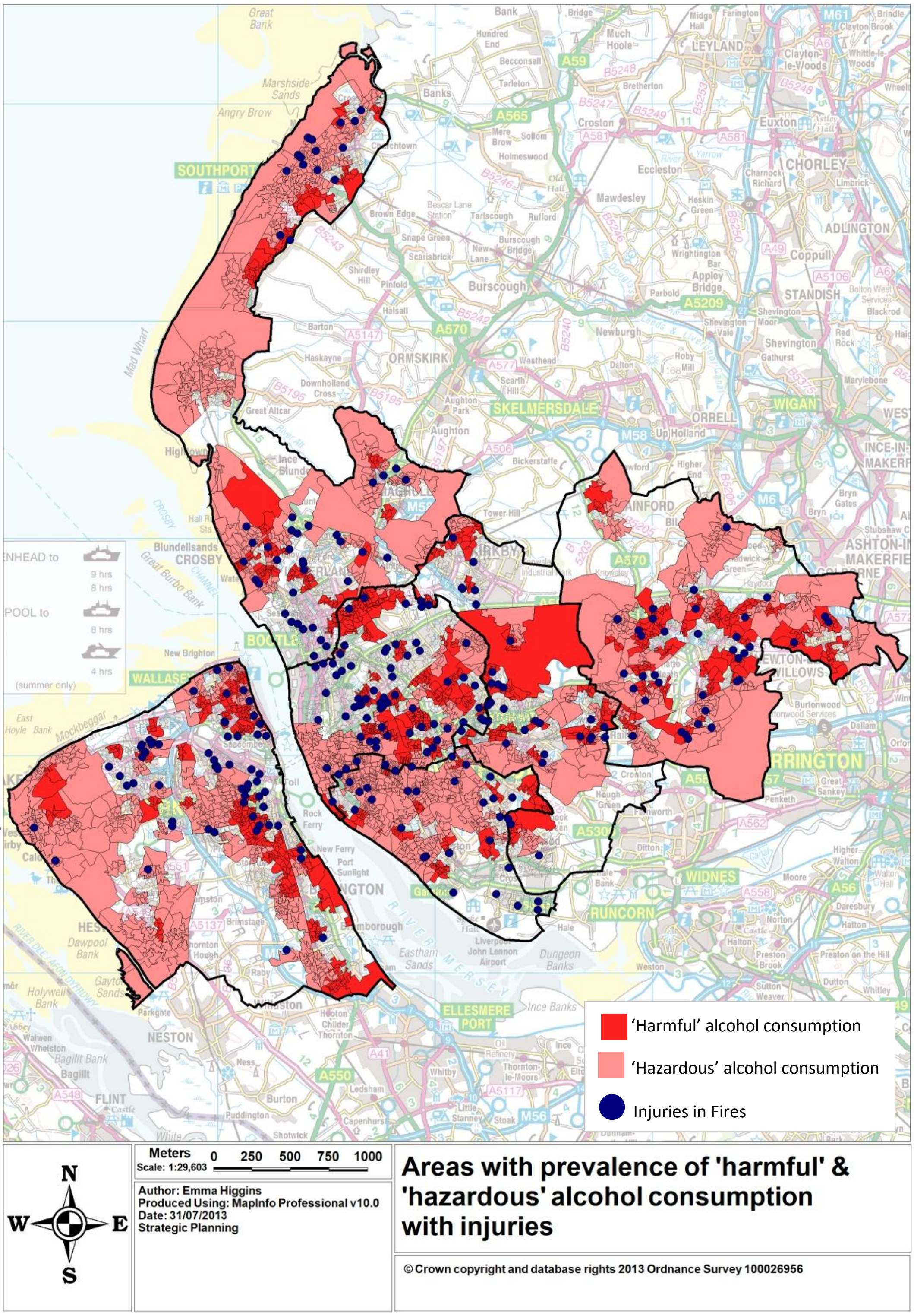

Figure 18 - Map illustrating areas with a prevalence of 'harmful' or 'hazardous' alcohol consumption and injuries in accidental dwelling fires

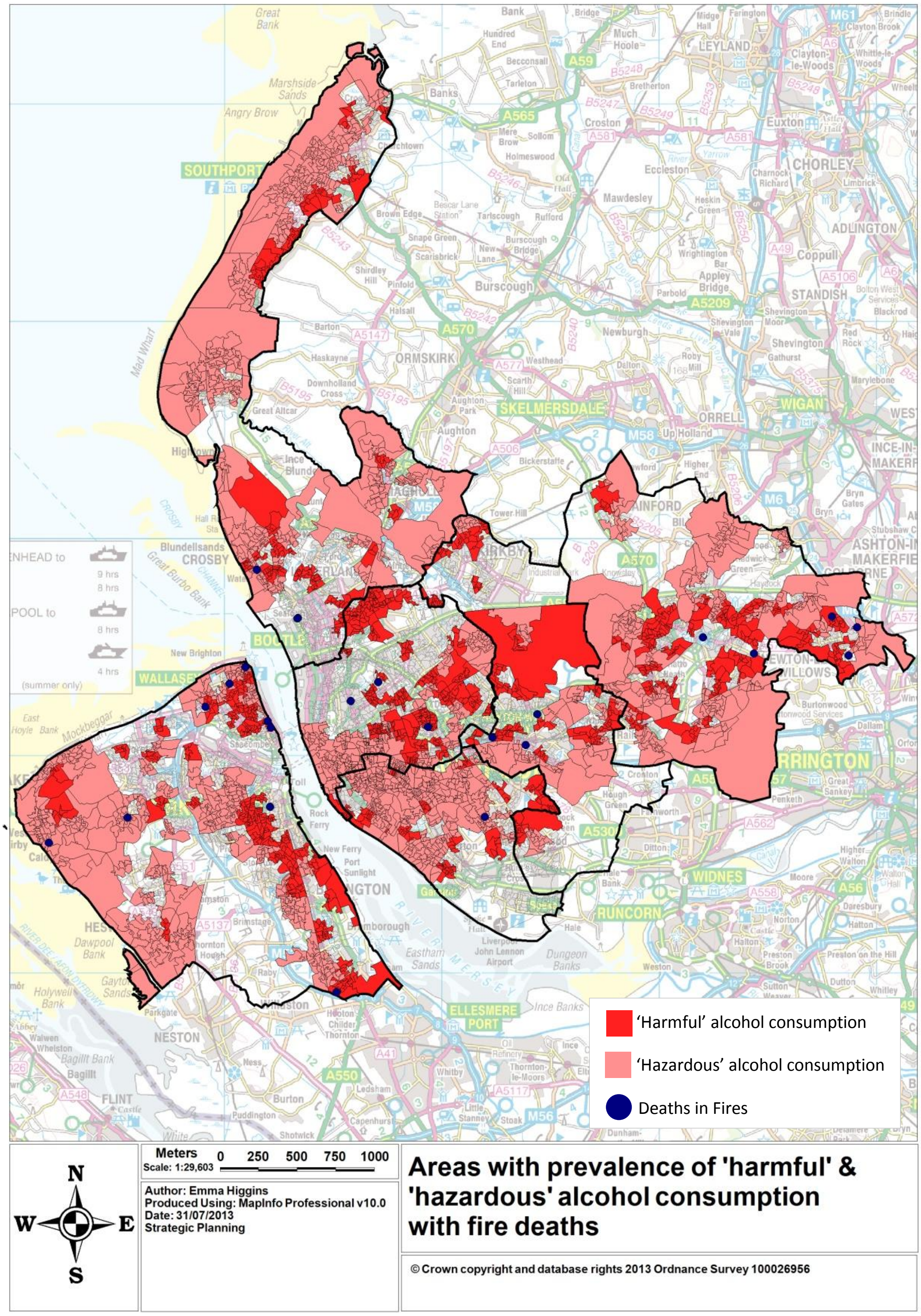

Figure 19 - Map illustrating areas with a prevalence of 'harmful' or 'hazardous' alcohol consumption and deaths in accidental dwelling fires

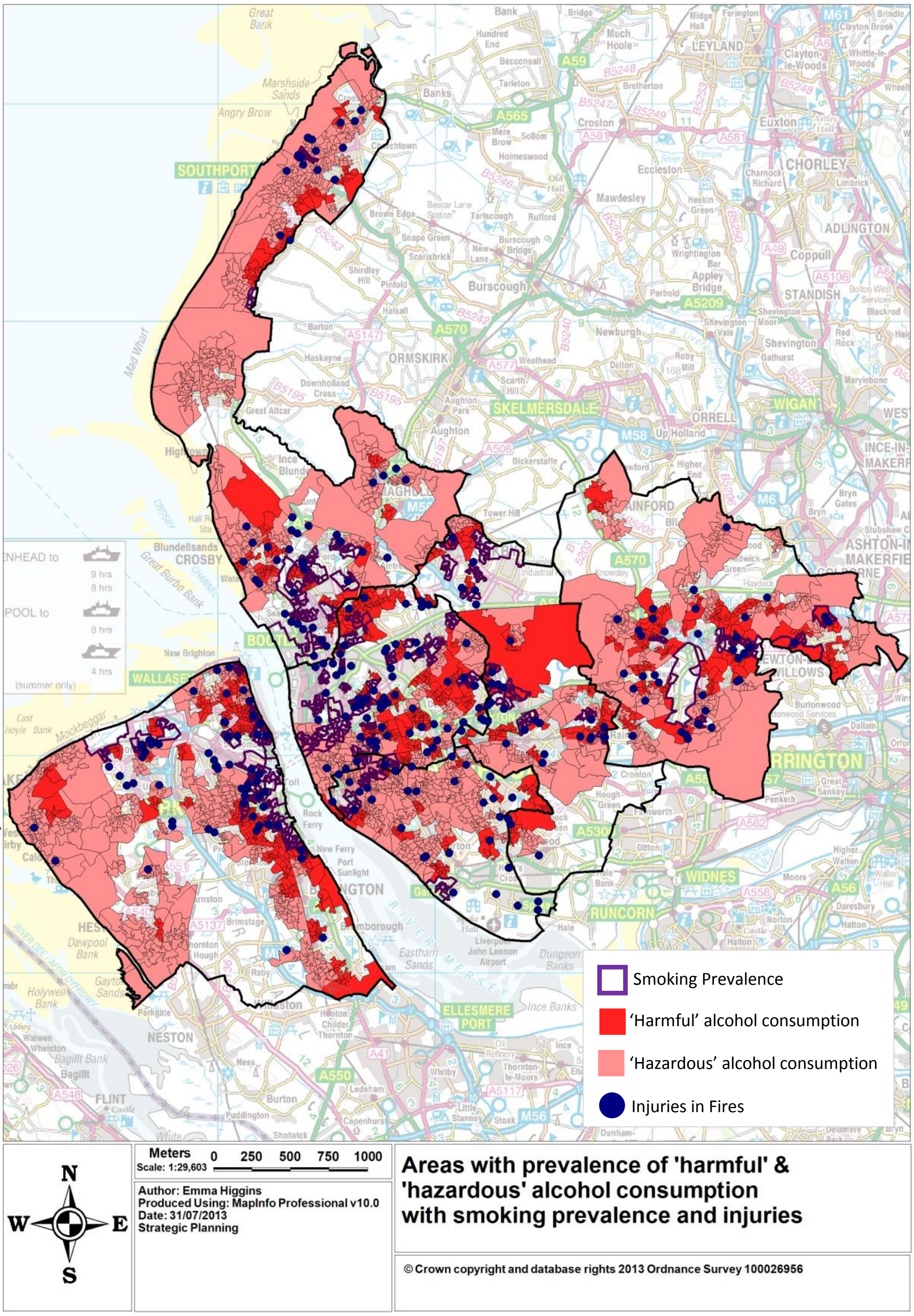

Figure 20 - Map illustrating areas with a prevalence of 'harmful' or 'hazardous' alcohol consumption with smoking prevalence and injuries in accidental dwelling fires

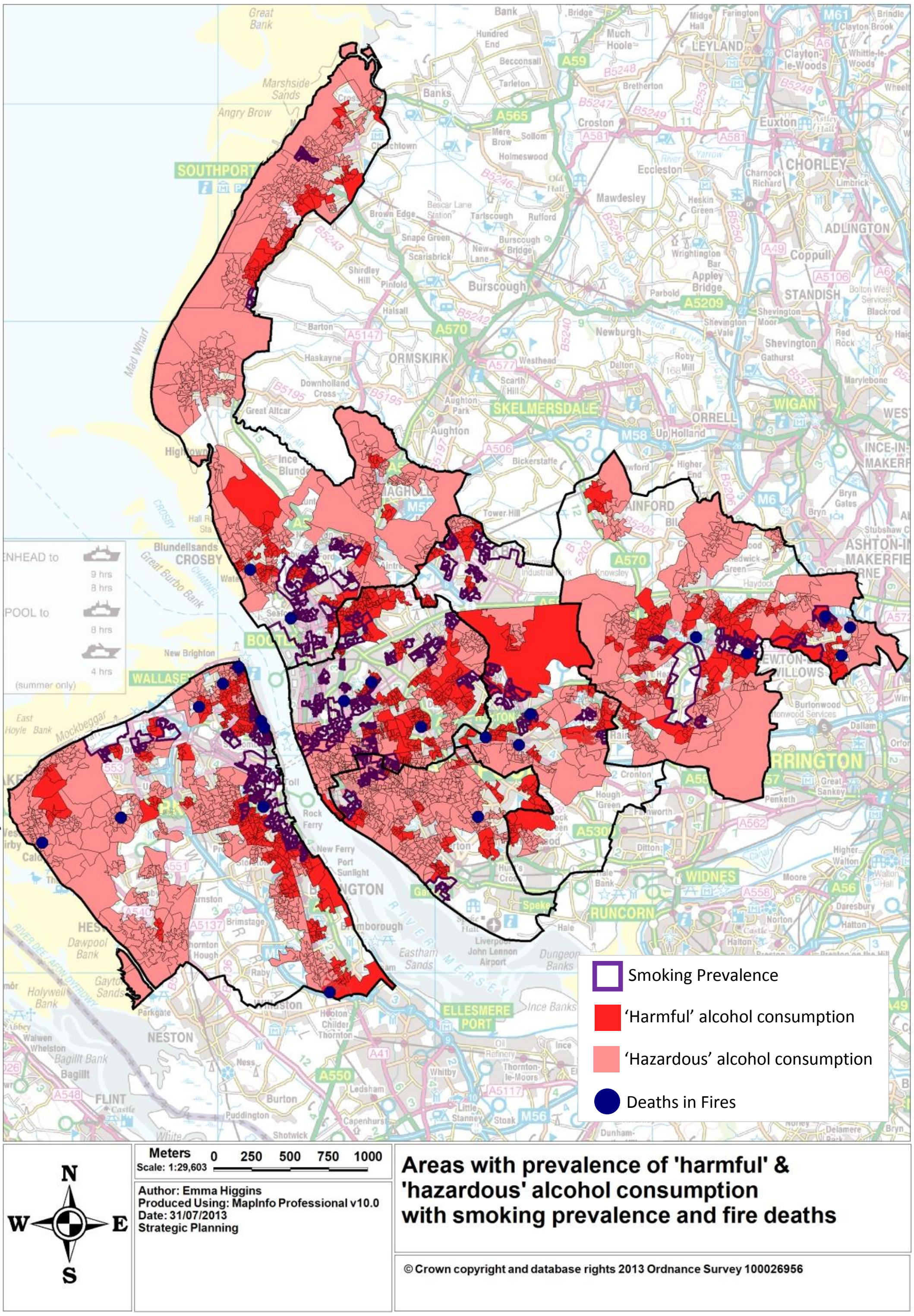

Figure 21 - Map illustrating areas with a prevalence of 'harmful' or 'hazardous' alcohol consumption with smoking consumption and deaths in accidental dwelling fires

9.2.3 Vulnerable Person Index

To test the methodology, a short pilot was completed in the Wirral district, specifically in the wards of Birkenhead and Heswall. These wards were selected because of the vastly differing demographics, risks and needs present. By demonstrating the usability of the methodology in these wards, Merseyside Fire and Rescue Service could be confident that the framework could be applied successfully across other Merseyside areas. The initial pilot ran for eight weeks and started in November 2011. This pilot involved only Prevention Advocates, and they were set a target of visiting 40 properties during the eight week period. This was to be completed on top of additional workloads.

The methodology used for this pilot involved the following:

- Reviewing the data received from our external partners;
- Cross matching the database to filter out individuals/properties that are flagged on more than one dataset that we receive from our partners;
- Filter out the properties that have never received an intervention from Merseyside Fire and Rescue Service.

A full table of results can be found in Table 10. The table includes the details of the properties visited and findings, as recorded by Prevention and Protection Advocates.

Some findings from the pilot were:

- Prevention and Protection Advocates attempted to make 42 visits during the eight week pilot period. 23 (55%) successful visits were completed, and 19 (45%) households were either non-contactable after three visits, or refused a visit.
- Of the 23 visits, 12 (52%) occupants were signposted or referred onto a service offered by a partner agency. Some residents were signposted or referred onto a number of agencies.
- None of the residents visited were classified as high risk of fire (as calculated from the Home Fire Safety Check form), however a significant number of residents (78%) visited had a combination of risk factors present (i.e. health, age, smoking etc.). Although the resident may not be classified as high risk at the moment, they could have the potential to become high risk in the future based on their circumstances. This demonstrates that the framework has the potential to identify risks at an earlier stage, which is a key aim of the Prevention agenda at Merseyside Fire and Rescue Service.

As a result of the eight week pilot, 12 residents (52%) were signposted or referred onto another service. In particular, many of the residents visited (78%) had needs present, such as ill health related to poor quality housing or inappropriate housing. Of the 12 residents visited, three residents (25%) were signposted to NHS Smoking Cessation Services and ten residents (83%)

were signposted or referred onto housing services / Healthy Homes for problems related to poor quality housing or hazards in the home. In addition, five residents (42%) were signposted or referred onto another service outlined in the list below.

Analysis of the paperwork completed during the visits indicated that the advocates signposted or referred onto the following agencies:

- POPIN (Promoting Older People's Independence Network)[11]
- Age UK
- Energy Projects Plus[12]
- Housing Services / Healthy Homes
- Merseyside Police
- Smoking Cessation Services
- Homestart[13]

Of the 12 residents who were signposted or referred onto another service, a total of six residents (50%) were signposted or referred onto multiple partner organisations. This suggests that many residents had more complex risks or needs present. The services offered might be ones that the resident was not aware of, did not know how to contact or did not realise they were eligible for.

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[11] POPIN: http://www.wirral.gov.uk/my-services/social-care-and-health/support-stay-home/popin

[12] Energy Projects Plus: http://www.epplus.org.uk/

[13] Homestart Wirral: http://www.homestartwirral.co.uk/

Unique ID	***Any Other Comments***	***Signposted to another service?***
VPI1	Accommodation Unsuitable for Occupier, Referred to POPIN, Age UK, Energy Projects Plus and Housing Services. ASB problems reported	Yes
VPI2	No Details from CFS	No
VPI3	Single parent, health problems (some caused by damp in property), advice given on stop smoking services. ASB around the property reported to Merseyside Police. Problems with property inc. Damp, loose tiles on roof, security problems with front door. Referred to housing services	Yes
VPI4	Single mother - daughter deaf	No
VPI5	No concerns noted	No
VPI6	Property very poor condition referred to Homestart. 2 young children. Partner has COPD and on oxygen. Trip hazards and cluttered, untidy house. Concerns from advocate about whether the occupant can cope with pressures of looking after an ill partner, 2 young children and looking after a household	Yes
VPI7	No smoke alarms. Two smokers, property poor condition, liaised with Wirral Partnership Homes. Tripping hazards in upstairs hallway. Advised of NHS Stop Smoking Scheme. Resident with mobility problems.	Yes
VPI8	Single, elderly resident. Occupier has mobility difficulties, managing well. Damp in property. Referral to Housing Services	Yes
VPI9	Mould or damp in property. Disrepair to roof and doors/windows. Problems with boiler. Referral to housing services	Yes
VPI10	Poor Health but no further assistance required	No
VPI11	Smoker but careful with smoking material. Referred to Healthy Homes regarding possible security issues.	Yes
VPI12	Occupier health problems and previously had falls, refused assistive technology and any adaptations at the moment. Provided the occupier with telephone number to contact should things deteriorate. Occupant smokes a pipe. Gave occupant advice regarding safety of electrical items in the home.	No
VPI13	No concerns noted	No
VPI14	Some disrepair to property - failed damp proofing course. Daughter (aged 3) has asthma, might be because of mould and damp in property. Referral to housing services	Yes

Unique ID	***Any Other Comments***	***Signposted to another service?***
VPI15	Single male lives on own smokes. Some housing issues with roof and windows, referred to housing and Energy Projects Plus	Yes
VPI16	Advice on Stop Smoking Services	Yes
VPI17	Resident has hearing problems but does not require further support	No
VPI18	Elderly resident with some health problems	No
VPI19	ASB issues reported to Wirral Partnership Homes. Resident has health problems and needs to rest, but unable to because of ASB problems. Health has suffered as a result of living in property. Also referred to Energy Projects Plus	Yes
VPI20	Some health problems. Healthy Homes to look at radiator in kitchen	Yes
VPI21	Poor Health but no further assistance required	No
VPI22	No Details from CFS	No

Table 10 - Results of initial Vulnerable Person Index pilot

Following the completion of the initial pilot, a larger scale pilot was complete covering the whole of the Wirral district. The larger scale commenced on 01/12/2012 for approximately four months and all six stations in the district were involved in the delivery of the pilot. This pilot involved fire-fighters and fire prevention advocates. An analysis of Home Fire Safety Checks indicated that 31.1% of properties that appeared on the Vulnerable Person Index for the Wirral district received a Home Fire Safety Check during the pilot period. This represents approximately 32% of all Home Fire Safety Check activity in the district between 01/12/2012 and 11/04/2013.

Of the 1,602 Home Fire Safety Check completed using the Vulnerable Person Index reports, there was only one Home Fire Safety Check refusal. Of the visits, 244 (15.2%) were completed in high-risk Lower Super Output areas (LSOAs), 873 (54.5%) were completed in medium-risk LSOAs and 485 (30.3%) were completed in low-risk LSOAs. The areas defined as high, medium and low risk were defined by the community risk map.

Approximately 73% of properties (1,174 properties) visited had 1 vulnerability factor present, 22% (351 properties) had 2 vulnerability factors present, 4% (70 properties) had 3 vulnerability factors present and 1% (7 properties) had 4 vulnerability factors present. The greatest proportion of referrals to district Prevention teams came from properties with three or more vulnerability factors present. Approximately 6% of properties with three or more vulnerability factors present were referred by crews to district Prevention teams. This finding is significant when compared to stations that do not use the Vulnerable Person Index to target Home Fire Safety Check visits. Only 1.6% of occupants visited during these Home Fire Safety Check visits are referred onto their district Prevention team, suggesting that application of the Vulnerable Person Index has the potential to enhance the identification of vulnerable individuals.

An investigation was completed to understand the proportion of occupants visited as part of the pilot who had multiple risk factors present. Approximately 44% of occupants visited lived alone. Of the occupants that lived alone, approximately 59% were aged over 65. Of the occupants that lived alone and were over 65, approximately 18% were found to be smokers. When compared with properties visited on the other districts during the same period that were not using the Vulnerable Person Index methodology, it was found that 31% of occupants lived alone. Of those occupants living alone, 54% were aged over 65. Of those occupants living alone and aged over 65, approximately 20% were found to be a smoker.

The analysis Home Fire Safety Check completed during the pilot period indicate that the Vulnerable Person Index methodology has an increased likelihood of identifying an individual that may be more vulnerable to fire. There were large numbers properties that crews noted to have issues or concerns. Some of these are outlined in the case studies in the following section of this thesis.

9.2.3.1 Case Studies

Below are some case studies from properties that were flagged from the pilot of the vulnerable person index in the Wirral district. There a number of examples of properties with significant risks, that could escalate if not addressed. A number of these case studies were referred onto the district Prevention team for further intervention.

Case Study 1

Crews visited a property in Wallasey that was highlighted as a priority on the Vulnerable Person Index (VPI). The property was flagged because it was known to Wirral Revenue and Benefit Service because an occupant was in receipt of Housing Benefit and requiring assistance under the Safeguard Policy.

When completing the Home Fire Safety Check, the crew noted that six occupants lived in the property. There were two children aged under 5 years old. One of the children is registered blind and has mobility problems. The crews also noted that one of the occupants is a smoker.

The property did not have any smoke alarms fitted, so the crews fitted four new units.

Although the property did not rank as a high risk after the Home Fire Safety Check, it was referred to the district Prevention team because of the complex risks present.

Case Study 2

Crews visited another property in Wallasey that was highlighted as a priority on the Vulnerable Person Index. The property was flagged because it was known to Wirral Revenue and Benefit Service because an occupant was in receipt of Housing Benefit and requiring assistance under the Safeguarding Policy.

When completing the Home Fire Safety Check, the crew noted that ten occupants lived in the property. It was also noted by the crews that some of the occupants may be living in caravans in the garden of the property.

There were three or more children aged under 10, one of these children was aged under 5. There was another two children aged under 16. It was noted that two of the occupants have a disability and would require depend on assistance in the event of a fire. One of the residents was a smoker and although smoke alarms were fitted, there was no working battery.

As a result of the Home Fire Safety Check, crews fitted a new smoke alarm and referred the occupants to the district Prevention team, who would be able to assist further with the complex risks present.

Case Study 3

Crews visited a property in Birkenhead that was highlighted as a priority on the Vulnerable Person Index. This property was flagged because it was known to Wirral Revenue and Benefit Service because the occupant lived alone.

Crews noted that the occupant appeared to be very intoxicated and refused access to the property. However, they were able to find out that the occupant lived on their own and was a smoker. The occupant also said that they used a chip pan and had no smoke alarms fitted.

This property was ranked as high risk by the crews because of the combination of the occupant living alone, smoking and signs of alcohol misuse. This case was referred onto the district Prevention team for further intervention.

Case Study 4

Crews visited a property in Birkenhead that was highlighted on the Vulnerable Person Index. It was flagged as a priority because the occupant was known to be over 65.

Crews noted that the occupant was over 65 and lived on their own. In addition, the occupant used oxygen cylinders and was hard of hearing. As a result, the individual was referred onto the district Prevention team for further intervention, which included fitting a specialist smoke alarm and advice about the use and care of the oxygen cylinders.

Case Study 5

Crews visited a property in Birkenhead that was highlighted on the Vulnerable Person Index. It was flagged because the occupant was known to be over 65.

When completing the Home Fire Safety Check, the crews noted that two occupants normally lived in the property and both were over 65. It was noted that the female occupant lives with dementia and is currently in respite care. It is not known when she will return to the property. Crews also noted that there were factors present that would affect the occupants' awareness of fire: this may be related to the occupant with dementia.

There were no smoke alarms fitted at this property, therefore as a result of the Home Fire Safety Check, new alarms were fitted and the property will be visited again in 2 years.

Case Study 6

Crews visited a property in Upton that was highlighted on the Vulnerable Person Index. It was flagged because the occupant was known to be over 65.

When completing the Home Fire Safety Check, the crews noted that the elderly occupant lived alone. The occupant had a disability, and the nature of this would mean that they would need assistance evacuating in the event of a fire. The occupant depended on a stair lift and was not able to use the stairs in the property without one.

There were smoke alarms fitted at the property and crews checked to ensure they were in good working order.

Case Study 7

Crews visited a property in Bromborough that was highlighted on the Vulnerable Person Index. It was flagged because the occupant required assistance under the Safeguarding Policy.

When completing the Home Fire Safety Check, the crew noted that three occupants lived at the property and one of them was a smoker. All three occupants living in the property had mental health issues and because of this, a carer visits the property daily, in the evening.

There were working smoke alarms fitted at the property and crews checked to ensure they were in good working order.

Case Study 8

Crews visited a property in Wallasey that was highlighted on the Vulnerable Person Index. It was flagged because the property was known to Wirral Landlord Accreditation Scheme and Wirral Revenue and Benefits because the occupant was a lone parent.

When completing the Home Fire Safety Check, the crew noted that three occupants lived at the address. The adult occupant was a lone parent. There was one smoker living at the property. The crews also noted that one child had been playing with fire; therefore, a referral to the youth intervention team was made.

Although there were working smoke alarms in the property, a new unit was fitted in the child's bedroom.

Case Study 9

Crews visited a property in Wallasey that was highlighted on the Vulnerable Person Index. It was flagged because the property was known to Wirral Landlord Accreditation Scheme and Wirral Revenue and Benefits because the occupant was a lone parent.

When completing the Home Fire Safety Check, the crew noted that nine occupants were living at the address. The adult occupant had a mobility problems that could affect their ability to escape from the address should a fire occur. One of the children was aged under 5, and there were three or more children aged under 10. One of the children had been playing with fire. One occupant was a smoker.

There were working smoke alarms in the property, therefore no new units were fitted. This case was referred to CFS because of the high occupancy and history of children playing with fire.

Case Study 10

Operational crews visited this property because a lone occupant, aged over 65 with a disability was flagged on the Vulnerable Person Index. Crews noted that resident's ability to respond in the event of fire would be impaired and there was limited fire safety awareness even after Home Fire Safety Check. The resident has narcolepsy along with other disabilities. The resident regularly forgets about pans of food on the hob. A new smoke alarm was fitted and a referral made to the district Prevention team for further intervention.

Case Study 11

Crews visited this property as it was flagged as a resident aged over 65 on the Vulnerable Person Index. On visiting the property, crews noted that the occupant was a lone, elderly resident who is a smoker. The resident is a victim of anti-social behaviour and hate crime. There was a previous incident involving firework through letterbox and vehicle fire. As a result, the occupant received a referral to the district Prevention team who would work with Merseyside Police to resolve the anti-social behaviour issues.

Case Study 12

Crews visited an elderly resident who was a smoker and had a disability. An existing smoke alarm was fitted, but not working. The occupant would be dependent on assistance in the event of a fire and their ability to respond in the event of a fire would be impaired. There was a history of arson attacks at the property. An RM1[14] was issued for extreme mobility issues.

Case Study 13

Crews visited a lone occupant, aged over 65. The occupant uses a chip pan. There was no existing smoke alarm in property. A smoke alarm was fitted and a referral was made to district Prevention team because of evidence of carelessness with fire.

Case Study 14

Crews visited an occupant who lives alone and is a smoker. The battery on existing smoke alarm was missing. A referral to the district Prevention team was made as evidence of ASB was present. The occupant was very agitated and said they had been targeted by a gang. The crews were concerned about the occupant's mental health. As such, an urgent referral was made to the Prevention team so they could engage with the relevant agencies to resolve the concerns.

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[14] Following on from Home Fire Safety Checks, if a risk is identified to the property or the person, then an RM1 form is completed and the information is transferred onto the mobilising system. Operational crews will have access to this information should an incident occur in the future

9.3 Summary of Application of the Framework

This chapter presents some findings of real world projects that were completed using the tools developed as part of this framework. One of the aims of completing a number of smaller pilots was to increase Merseyside Fire and Rescue Service staff confidence in the framework and its outputs. This was key to ensuring its success and implementation into the day to day work routine within the Service.

Each of the pilots provided a learning opportunity with regards to how the framework performed in reality. While the tool produced reliable and accurate results, it was the communication of applying the framework that required improvement. This improved with the delivery of each pilot, and now the framework is embedded into the day to day work routines of operational and fire prevention staff at Merseyside Fire and Rescue Service.

It is recognised that further data and information is required to build upon the framework that has been developed. In particular, it is well understood at Merseyside Fire and Rescue Service that further work on accessing personal information through data sharing agreements is needed to ensure that the Vulnerable Person Index is realising its full potential. Although the research with Liverpool John Moores University has been completed, Merseyside Fire and Rescue Service are continuing to set up data sharing agreements with appropriate agencies to feed into the modelling process. As of August 2014, Merseyside Fire and Rescue Service had received more detailed and accurate information about over 65s across Merseyside, and were progressing data sharing agreements with mental health trusts about patients with dementia and complex mental health needs.

The development of this framework is a ongoing and evolving process, however the mechanisms behind the framework are in place and a robust phase of knowledge transfer ensured that Merseyside Fire and Rescue Service can progress using their own public sector networks.

Chapter 10 – Conclusions

10.1 Introduction to Conclusions

This thesis presents a framework developed for Merseyside Fire and Rescue Service to improve targeting of prevention resources related to reducing anomalous accidental dwelling fire risk. Ongoing budgetary cuts within the public sector means it is now of vital importance for organisations to target their services towards those individuals most vulnerable or at highest risk. In addition, changes to operational resources going forward means fire prevention initiatives are even more important, especially in a time of fire station closures and fire appliances being removed from service. Until this research commenced, there were no examples of practical applications of intelligence led modelling focusing fire prevention resources towards an individual most at risk.

This thesis has presented how the practical application of intelligence can lead to enhanced targeting of services and initiatives towards more vulnerable members of the community. Of importance, this thesis has outlined examples of practical application of this research within Merseyside Fire and Rescue Service.

This chapter concludes the thesis and provides a summary of how this research has contributed to knowledge in the field of accidental dwelling fire risk management and a how the key aims and objectives outlined in the Chapter 1 have been addressed.

10.2 Aims and objectives of research

As stated in Chapter 1, the aims of the research were to develop a framework to assist community fire prevention teams within Merseyside Fire and Rescue Service deliver Home Fire Safety Checks towards those most at risk or vulnerable. There was a particular focus on the move to associate accidental dwelling fire risk with an individual rather than an area. It was anticipated that this would improve the identification of anomalous accidental dwelling fires occurring in unexpected localities that are not flagged as at risk in current methodologies. It was accepted that there is still a need for an area based approach for assessing risk for strategic purposes; however, this approach should also focus on the characteristics of the communities living within them rather than solely focusing on past incidents. It was also anticipated that both the area based and person specific approaches should complement each other for strategic and operational purposes.

Of particular importance was enhancing the way a fire and rescue service can utilise existing data resources to effectively target and deliver services. Most organisations still work in silos; however each have rich information and data resources that, if shared, can enhance how other organisations target their high risk, target groups. This research has touched on a framework to help these agencies to work together and it has demonstrated that if information about vulnerable people is shared, it can be used effectively to deliver services to that individual. The pilot of the Vulnerable Person Index showed that this process can even be beneficial for other agencies as it allows for proactive signposting and referral onto other services.

10.3 Summary of key findings

Chapter 1 provided an overview of the thesis, including the motivations for completing this research. It outlined the key aims and objectives that the research looked to address and the anticipated contribution this research will make to the fire community and their ability to understand anomalous accidental dwelling fire risk.

Chapter 2 outlined the current situation of anomalous accidental dwelling fire risk identification both in the United Kingdom and overseas. In particular, it focused on the structure of Merseyside Fire and Rescue Service and their current risk identification methodologies within their Prevention team. This chapter identified the gap in knowledge that would be addressed through this research.

Chapter 3 focussed on the methodologies used to develop the proposed framework. The methodologies used fell broadly into three categories, which were:

- Qualitative research, to understand the user requirements, needs and expectations;
- Quantitative research, which takes the findings from the qualitative research and applied some 'hard' statistical techniques resulting in a model of accidental dwelling fire risk;

- GIS development and testing, ensuring that the framework developed is user friendly, robust and reliable

Each of the methodologies was described in their respective chapters. For the qualitative research, a number of interviews were completed with key stakeholders and this information was translated using Soft Systems Methodology to unravel the complex problem domain. However, while the qualitative methodologies provided an understanding of the problem, the quantitative research methodologies were required to provide an understanding of the statistical relationship between accidental dwelling fire causal factors and accidental dwelling fire incidents. Finally, a key requirement of this research was to present the information in a user friendly manner to allow Merseyside Fire and Rescue Service staff members to use. This was achieved through the creation of a bespoke MapInfo tool. This tool could allow the user to query and manipulate the data without needed to understand some of the more complex statistical modelling.

Chapter 8 outlined the methodology used to test the developed GIS framework. This methodology also presented new knowledge, as there was no known literature on a comprehensive way of testing a GIS framework that incorporated a statistical model. The GIS testing methodology outlined a number of steps including testing calculations, maps layers and report testing to ensure that the developed tool works in its entirety. One of the most important parts of the testing methodology was the user acceptance testing. This was the final piece in ensuring that the developed risk identification framework was fit for purpose and delivered what the key stakeholders expected.

Finally, Chapter 9 is possibly the most important chapter in this thesis, as it outlines how the risk identification framework was applied by Merseyside Fire and Rescue Service. The framework was initially utilised in one district within Merseyside, but gradually rolled out to all districts once the value was demonstrated. The case studies within this chapters show the true reason why this framework was developed, which was to assist with the identification of individuals most at risk from accidental dwelling fire. It is impossible to say whether these individuals would have experienced an accidental dwelling fire without intervention; however, each individual visited had a number of factors present that increased their risk. Statistically, these individuals were more at risk from fire than an individual who did not possess these risk factors. Based on previous methodologies, these individuals may not have been visited, as they typically did not live in high risk localities. As a researcher, the application of the framework has been very rewarding as it demonstrates the impact of intelligence driven approaches on delivering services.

10.4 Limitations of research

Whilst this research has paved the way for improving accidental dwelling fire risk identification within the fire and rescue service setting, there are some limitations. The limitations are mainly related to accessing data. Data sharing between organisations must improve for such a tool to realise its full potential. Many important steps were made by Merseyside Fire and Rescue Service throughout the course of this research with regards to data sharing, particularly in the Liverpool and Wirral districts. However, it is recognised that more work needs to be done and staff members within the Strategy and Performance directorate are continuing to work with partners to secure access to data. Of course it is important that personal information remains secure, however there is a case to share information should it be of benefit to the individuals wellbeing. This may be interpreted by different partners in different ways, however steps are being made by fire and rescue services nationally to ensure information about vulnerable occupants can be accessed. At the time of writing in October 2014, this work was being led nationally by the Chief Fire Officers Association [134].

10.5 Recommendation for future work

This research paves the way for future work, both academically and practically within Merseyside Fire and Rescue Service. From an academic perspective, it was realised that more work is required investigating how each of the different accidental dwelling causal factors link with each other and how this impacts on risk. For example, does substance misuse and living alone present more of a risk than being elderly and living alone? Anecdotally, most, if not all, operational fire crews would be able to say which combinations of risk factors have the greatest impact on accidental dwelling fire risk, but there is very little evidence to support this. Liverpool John Moores University School of Computing and Mathematics are currently working with Public Health England developing a tool called iHIT [135]. Primarily, this tool looks at associations between public health indicators; however there is potentially the scope to apply this methodology to the accidental dwelling fire example. This would vastly improve the understanding of accidental dwelling fire causal factors and the levels of risk they present.

From a practical perspective, Merseyside Fire and Rescue Service have the potential to complete further work related to this research, in particular around securing new sources of information and working with national groups to promote data sharing with fire and rescue services. As mentioned previously, the Chief Fire Officers Association is currently working to ensure partners share information about vulnerable individuals to prevent accidental dwelling fire incidents. In addition, there is the potential for Merseyside Fire and Rescue Service to apply this methodology to understanding other types of incident, for example deliberate fire setting, and to work with other fire and rescue services to promote using this methodology for understanding accidental dwelling fire risk.

10.6 Concluding Remarks

The current economic situation has dictated that all public sector services must become more efficient in how they use their resources. For fire and rescue services, this can mean more effective use of prevention resources. The benefit of this can be two-fold as it has the potential to raise awareness and improve education, but can also reduce the likelihood of fire and therefore the risk to fire-fighters. Within Merseyside Fire and Rescue Service, there has been an understanding that there is a need to move towards a person centric approach for identifying risk for many years, however there has been a gap in knowledge in how to achieve that. Whilst this research does not present any new methodologies or modelling techniques, it does demonstrate a novel application of existing methodologies, particularly in an area where there is little existing literature on such an application.

Perhaps one of the most important aspects related to the success of this research is access to person level data to inform the model. Ultimately, good quality, reliable datasets are required in order to ensure the modelling process is as effective as it can be. Inputting unreliable, out of date information will only provide incorrect results. Part of embedding this research into the Service has involved making sure all members of staff across the Prevention directorate are aware of the importance of this and are actively involved with working with partners to set up data sharing agreements. As data is refreshed on a regular basis, personnel using the tool can be assured that the outputs are robust. As mentioned previously, Merseyside Fire and Rescue Service are continuing to work with partners to share personal information about vulnerable groups to expand the modelling across all Merseyside districts.

Finally, the proof of the success of this framework is how it is currently being applied within Merseyside. The framework is currently being used in a number of Merseyside districts and is the methodology at the core of the home safety agenda at the Service. The framework has enhanced risk based targeting of Home Fire Safety Checks within Merseyside, which benefits local residents. In addition to receiving vital fire safety advice, vulnerable residents can also access advice about other services through signposting and referral. The case studies (Chapter 9) gathered as part of the pilot demonstrates this benefit. Whilst developing an accidental dwelling fire risk identification framework has been a comprehensive piece of research, the benefits are much wider. This research has expanded the understanding of the importance of a data driven, person centric approach to risk identification and acts as a mechanism for partnership working that will continue to expand and grow. Ultimately, this benefits local residents of Merseyside by keeping them safe from fire and other incidents in the home. This is the most important finding that comes from this research.

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Appendix A – Data Testing for Customer Insight Modelling

Data Testing for Segmentation Modelling

(Extract of management report submitted to Merseyside Fire and Rescue Service)

The first stage in understanding whether data is fit for purpose is to analyse their descriptive statistics. Descriptive statistics include the standard deviation, skewness and kurtosis. Each will be described in turn.

- The standard deviation is a measure of dispersion around the mean. A low standard deviation value indicates that most values are found close to the mean. A high standard deviation value indicates that there is greater dispersion, and values are spread out over a larger range of values. When a dataset is normally distributed, approximately 68% of values can be found within one standard deviation of the mean, and approximately 99% of values can be found within 3 standard deviations from the mean. Ideally, we would like this to be the case for datasets used in this analysis.
- The skewness is a measure of symmetry within the data. A normal distribution of a skewness of 0. A skewness value greater than twice the standard deviation for that dataset is considered to have a departure from symmetry
- The Kurtosis is a measure of how a dataset clusters around a central point. For a normal distribution, the kurtosis value is 0. This changes as the distribution departs from symmetry.

All of these statistics allow for an analysis of the distribution of a dataset. For many statistical techniques, including the ones to be used in the customer insight project, data should be approximately normally distributed. This data testing activity will allow us to understand whether the data collected can taken forward and used for future analysis.

The table below shows the skewness statistics for the datasets identified for analysis. It is apparent that none of the datasets are exactly normally distributed, which would be unlikely due to the nature of the data. However, it can be seen that most are approximately normally distributed. The exceptions to this are ***CT_Band_H%, CT_Band_I%, CT_Band_X%, Crime*** and ***ADF_Fatalities.***

The table below shows the kurtosis statistics for data identified for analysis. Variables with a positive kurtosis value indicate that observations have a tendency to cluster; variables with a negative kurtosis indicate that observations cluster less. As a general rule of thumb, the kurtosis can be accepted if it is between +/-2.

From the table below, it can be identified that there are a number of variables that have a kurtosis value greater than the acceptable limit. Some variables, such as ***ADF_Fatalities*** and ***Crime*** have very high kurtosis values. It is likely that this is the case because there is a very small range of values within these variables, therefore indicating that there is a greater tendency for the values to cluster.

Variable	***N***	***Mean***	***Skewness Statistic***	***Skewness Standard Error***	***Kurtosis Statistic***	***Kurtosis Standard Error***
%Aged_0_15	4586	18.09	-0.06	0.036	0.842	0.072
%Aged_16_24	4586	13.35	4.92	0.036	34.132	0.072
%Aged_25_49	4586	32.43	0.45	0.036	2.351	0.072
%Aged_50_64	4586	15.62	-0.18	0.036	0.796	0.072
%Aged_65_Plus	4586	20.52	0.84	0.04	1.433	0.072
%All_Child_Benefit_recipients	4586	12.77	0.62	0.04	2.764	0.072
%All_Tax_Credit_recipients	4586	11.51	0.18	0.04	0.15	0.072
%Care_Higher_Rate	4586	27.03	0.35	0.04	1.411	0.072
%Care_Lower_Rate	4586	25.21	-0.28	0.04	0.403	0.072

%Care_Middle_Rate	4586	32.44	-0.16	0.04	0.019	0.072
%Care_Nil_Rate	4586	15.33	0.51	0.04	1.262	0.072
%DLA_Claimants	4586	9.28	0.56	0.04	0.098	0.072
%Fuel_Poverty	4586	11.37	0.61	0.04	0.236	0.072
%Mobility_Higher_Rate	4586	63.67	-0.54	0.04	0.695	0.072
%Mobility_Lower_Rate	4586	26.02	0.65	0.04	1.249	0.072
%Mobility_Nil_Rate	4586	10.31	0.54	0.04	1.69	0.072
%Of_Incapacity_Claimants	4586	6	0.76	0.04	0.34	0.072
%Pension_Claimants_70_74	4586	21.68	0.45	0.04	1.496	0.072
%Pension_Claimants_75_79	4586	17.57	0.17	0.04	0.932	0.072
%Pension_Claimants_Under_70	4586	38.16	0.55	0.04	1.605	0.072
%Pension_Claimants80	4586	22.58	0.42	0.04	0.554	0.072
%Population_Inflow	458	4.76	1.71	0.04	4.11	0.072

	6					
%Population_Outflow	4586	4.93	1.63	0.04	2.548	0.072
%Severe_Disablement_Allowance	4586	11.24	1.83	0.04	8.098	0.072
ADF	4586	0.2	2.77	0.04	9.441	0.072
ADF_Fatalities	4586	0	14.68	0.04	213.62	0.072
Average_Weekly_Income	4586	528.2	1.02	0.036	1.781	0.072
Combined_Health_Deprivation_and	4586	1.18	0.23	0.04	-0.784	0.072
Combined_Living_Environment_Indicator	4586	32.44	0.55	0.04	-0.838	0.072
Comparative_Illness_and_Disabil	4586	185.2	0.41	0.04	-0.672	0.072
Crime	4586	2.46	36.13	0.04	1858.142	0.072
CT_Band_A%	4586	48.02	0.08	0.04	-1.698	0.072
CT_Band_B%	4586	19.21	1.39	0.04	1.084	0.072
CT_Band_C%	458	17.0	1.58	0.04	1.622	0.072

	6	2				
CT_Band_D%	4586	8.22	2.64	0.04	7.718	0.072
CT_Band_E%	4586	4.09	3.49	0.04	14.112	0.072
CT_Band_F%	4586	1.95	4.77	0.04	26.949	0.072
CT_Band_G%	4586	1.34	7.01	0.04	58.787	0.072
CT_Band_H%	4586	0.11	20.17	0.04	502.452	0.072
CT_Band_I%	4586	0	.	.	.	.
CT_Band_X%	4586	0	.	.	.	.
CWI_Score	4586	228	0.46	0.04	-0.893	0.072
Emergency_Admissions_to_Hospital	4586	127.8	0.51	0.04	0.133	0.072
Females_Life_expectancy_at_birth	4586	78.96	-0.18	0.036	-0.714	0.072
Housing_In_Poor_Condition	4586	0.32	0.5	0.04	-0.509	0.072
Males_Life_expectancy_at_birth	4586	73.67	-0.23	0.036	-0.594	0.072

Mental_Health_Indicator	4586	1.01	0.28	0.04	-0.502	0.072
Number_Other_Income_Benefits	4586	1.28	3.31	0.04	39.648	0.072
Persons_Life_expectancy_at_birth	4586	76.4	-0.18	0.036	-0.737	0.072

Appendix A: Table 1 – List of variables used within the Cluster Analysis

In order to understand the distributions of the variables visually, a series of diagrams were created. Firstly, Q-Q plots were created to demonstrate how close the distribution of values within a variable is to a normal distribution. The Q-Q Plots can be found at the end of Appendix A

Many of the Q-Q Plots illustrated an approximately normal distribution; however some variables indicated that their distribution was not normal. These included the variables ***%Aged_16_24, CT_BandA%, CT_Band_B%, CT_Band_C%, CT_Band_D%, CT_Band_E%, CT_Band_F%, CT_Band_G%, CT_Band_I%, CT_Band_X%, CWI_Score, Crime, ADF, ADF_Fatalities, Number_Other_Income_Benefits, %Population_Inflow, %Population_Outflow*** and ***Combined_Living_Environment_Indicator.***

Looking at the Q-Q plots for the variables highlighted above, it was apparent that the distribution may be due to some outliers within the data. An outlier can be defined as an observation that is found distant from the other data observations within that dataset. To display this information graphically, a series of boxplots were created to find out whether outliers were present in the data. These diagrams can also be found at the end of this Appendix.

Each of the variables highlighted in the Q-Q Plot analysis as having a non-normal distribution were found to have outliers within the data. The plots produced indicate the data observation where the outliers are found, and this may help give reasoning as to why these outliers exist.

Investigation into each of the highlighted variables found the following:

- ***%Aged_16_24* –** The boxplot showed that there were some significant outliers within this variable. This is further indicated in the histogram and the stem and leaf plot, which showed a positive skew (i.e. presence of a tail to the right of the distribution). It is likely that this skew is present due to the high number of students within this age bracket living in certain output areas within Merseyside. Therefore, although this distribution is not 'normally distributed', it would not be appropriate to remove the outliers as it is an accurate reflection of the population
- ***CT_BandA%*** - The boxplot showed that there were no outliers within this dataset. However, analysis of the histogram and the stem and leaf diagram indicates that there are two 'peaks' within the dataset at approximately 0%-1% and 95%-100%. This denotes that the dataset is not normally distributed. The likely reasoning for this is due to what the data represents. For example, it is likely that there either very small or very high percentage of properties falling within this council tax band.
- ***CT_Band_B%, CT_Band_C%, CT_Band_D%, CT_Band_E%*** - The boxplot indicates that there are some outliers within each of the variables, including some significant outliers in the variables ***CT_Band_D%*** and ***CT_Band_E%***. The histogram and stem and leaf diagrams indicate that there is clustering around the 0% area, with a positive skew present. It is likely this is present due to the nature of the data. For example, the variables represent the percentage of properties within Merseyside that fall into each council tax band. A large proportion of the population fall within Council Tax band A (represented by the variable ***CT_Band_A%***) and very few areas see a range of different council tax bands. It is likely that this is the reason

why there is a cluster of data at the 0% within these variables. However, as this variable is not based on a sample of data, it does not seem to be appropriate to remove the outlying data and analyse again.

- ***CT_Band_F%, CT_Band_G%, CT_Band_I%, CT_Band_X%*** - From the boxplots for these variables, it was apparent that there are an extremely high number of outliers. In addition, through further analysis of the raw data, it was apparent that there were a high number of zero values, which would skew the data greatly. Infact, these variables showed a high skewness and kurtosis value. As the number of actual observations within the dataset is so low, I think it would be appropriate to remove these variables from further analysis as it seems evident that they will not add additional value to the analysis.
- ***CWI_Score*** – Analysis of the boxplot indicates that there are no outliers within the dataset. However, it is apparent in the histogram and the steam and leaf diagram that there is a positive skew within the data. A plausible reason for this distribution is due to the differing levels of deprivation within Merseyside. A low CWI_Score (Child Well-Being Index Score) represents an area that is typically less deprived, therefore Child Well-Being is typically improved. The converse is also true.
- ***Crime*** – The boxplot shows that there is one very significant outlier in particular. This was checked to ensure that there was no data error, but it was indeed discovered to be correct. As the data is aggregated to a small geography, it is typical that the number of crimes within each area is quite low, however, there are some exceptions to this, particularly in city centre areas where there are higher levels or robbery and drug offences. This data is collated from actual crime statistics, therefore is a true representation of the area it is related to. I think it is acceptable to include these outliers within further analysis as they are an accurate reflection on crime levels. The histogram and the stem and leaf diagram also suggest that there is a positive skew

within the data, supporting the theory that many areas have typically low numbers of reported crime, but that there are exceptions to this.

- ***ADF*** – This variable represents the number of accidental dwelling fires. Similar to the variable ***Crime***, there are typically low numbers of accidental dwelling fires within each geographic area; however there are exceptions to this. This is indicated by the boxplot. There are some significant outliers, but as this data is collated from actual incident data, it does not seem to add value to future analysis if the outliers were to be removed. The histogram indicates that there is a positive skew within the data, again supporting the theory that many areas have low numbers of accidental dwelling fire, but there are a few areas with significantly higher numbers of incidents.
- ***ADF_Fatalities*** – The boxplot indicates that there are a number of outliers, however, the areas where a fatality has occurred is represented by the outliers. Analysis of the boxplot shows that there has been no more than one fatality per geographic area. Further analysis indicates that the number of fatalities is very small compared with the sample size. Therefore, it seems to be appropriate that this variable is not included within further analysis
- ***Number_Other_Income_Benefits*** – The boxplot indicates that there are a number of significant outliers within the dataset. It is also apparent from the histogram that there is a positive skew within the dataset. The likely reason for this is related to the fact that many areas will have no individuals claiming this benefit, while a small number of areas will have a much higher proportion. Again, this is linked with the levels of deprivation found within Merseyside and is representative of the population as a whole.
- ***%Population_Inflow*** – The boxplot indicates that there are some outliers within this dataset, some of which are flagged as significant. The histogram and stem and leaf diagram indicate that the variable is positively skewed, but also that there are a number of smaller peaks within the data. This variable is an indicator of how transient the

population is within each area, and again may be linked with deprivation. Some areas within Merseyside typically high rates of population inflow, therefore this is representative of the population.

- ***%Population_Outflow*** – Similar to ***%Population_Inflow,*** there are also some significant outliers within the data. The histogram indicates a positive skew, but this variable does not have the multiple, smaller peaks that were found in ***%Population_Inflow.*** Again, this variable is representative of the population as a whole, therefore it does not seem to be sensible to remove the outliers from analysis.
- ***Combined_Living_Environment_Indicator*** – The boxplot highlights that there are no outliers within this dataset. However the data seems to be positively skewed. Like other variables that have been discussed, this variable relates to the deprivation within an area and is therefore representative of the population of Merseyside.

It is also important to note that other data is available from Mosaic, especially about communication preferences. However, it is not appropriate to analyse this data statistically as it is derived from existing customer profiles. It is for this reason that Mosaic data has not been included within the data testing report.

Summary of Data Testing

This section of the Fire Risk Research explored the data testing techniques that could be used to check whether data was fit for purpose. A total of 49 datasets were checked, and the majority were found to have an approximately normal distribution and an acceptable level of skewness and kurtosis.

However, a few datasets did not meet the criteria set for normality, skewness and kurtosis, and these were analysed further on a case-by-case basis to discover whether they could be used for further analysis, and also understand the reason why they may not fit the criteria set.

From the 49 datasets initially chosen for analysis, 5 were considered to be unfit for future analysis. These variables were

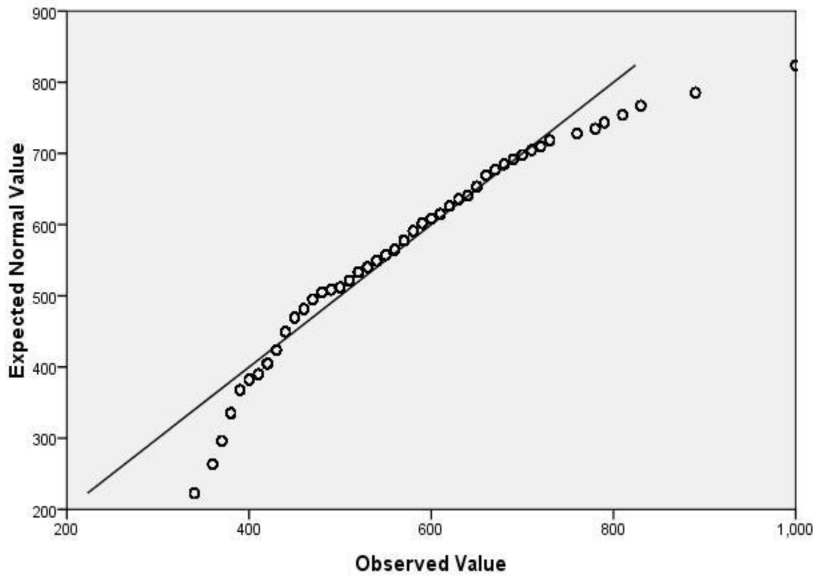
- ***CT_Band_F%,***
- ***CT_Band_G%,***
- ***CT_Band_I%,***
- ***CT_Band_X%***
- ***ADF_Fatalities***

Through analysis of the raw data, Q-Q Plots and boxplots, it was highlighted that these variables would not add value to any future analysis. The other variables that did not meet the criteria were also analysed, but considered to be relevant for future analysis. As this task is related to risk, which is determined by population and other socio-demographic factors, it did not seem sensible to reject variables because they did not fit with the criteria of normality, skewness and kurtosis. Each of these variables accurately reflected the differing nature of the Merseyside population, therefore would be an accurate representation of risk. When assessing risk, we are particularly interested in the outlying variables as these can give an understanding of why an area may be at risk.

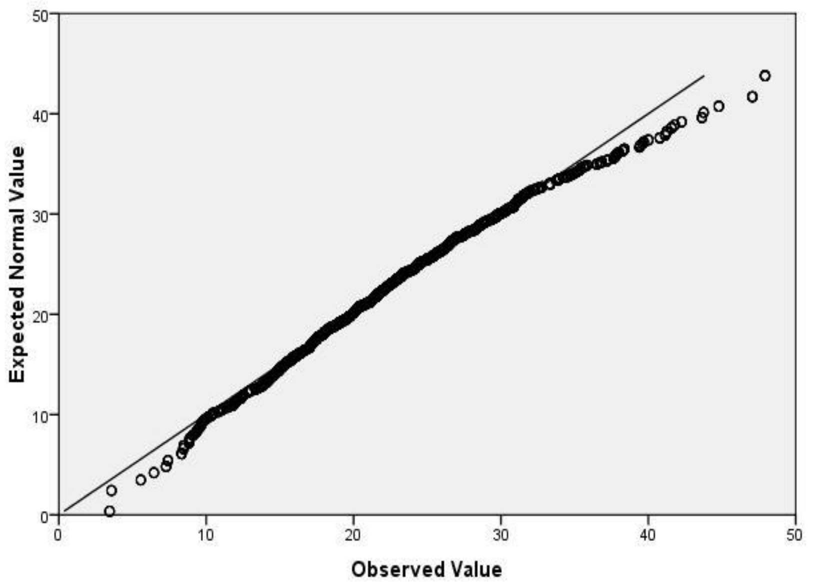
This section illustrates the Q-Q plots that were created for the data testing report.

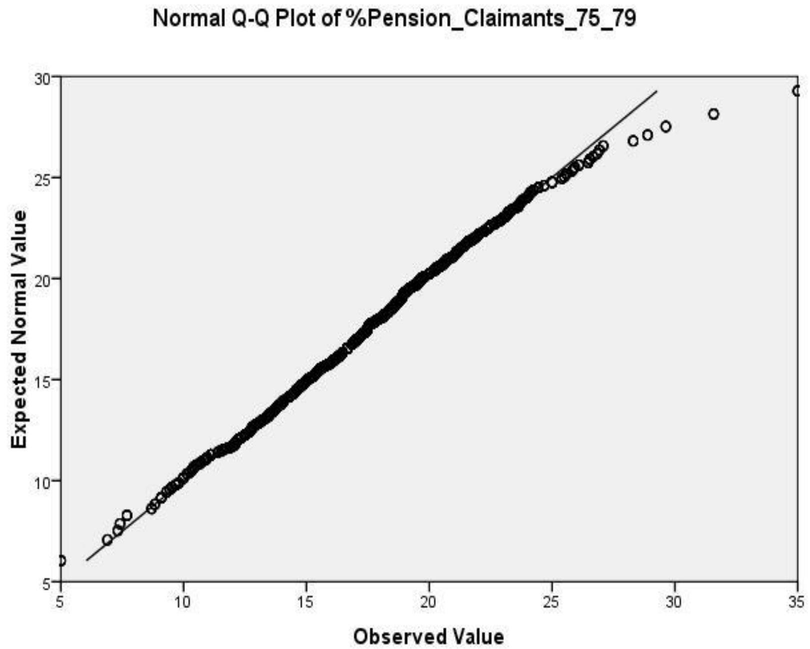
The important pattern to look for is data points (denoted by the circles) lying approximately on the diagonal line. Is this pattern is approximately followed, then the data set is normally distributed.

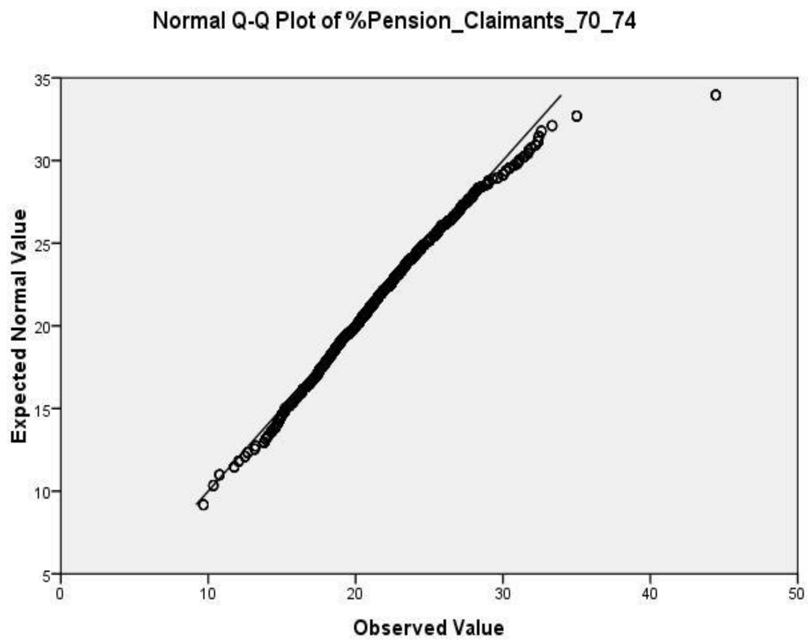
Normal Q-Q Plot of Average_Weekly_Income



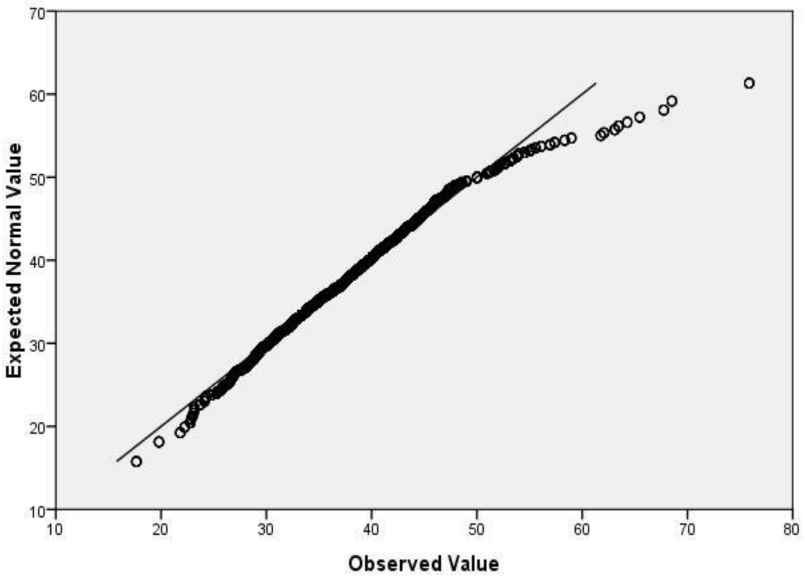
Normal Q-Q Plot of %Pension_Claimants80



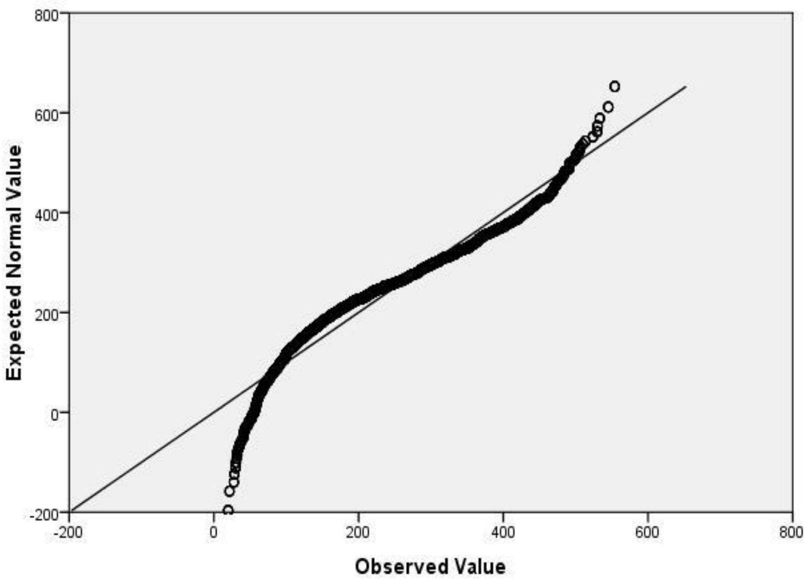

Normal Q-Q Plot of %Pension_Claimants_75_79
Expected Normal Value
Observed Value
30
25
20
15
10
5
5
10
15
20
25
30
35


Normal Q-Q Plot of %Pension_Claimants_70_74
Expected Normal Value
Observed Value
35
30
25
20
15
10
5
0
10
20
30
40
50

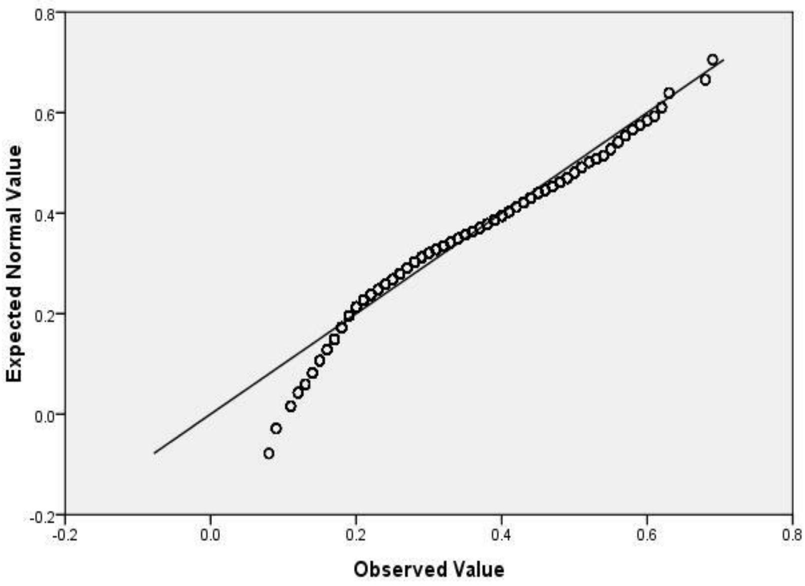
Normal Q-Q Plot of %Pension_Claimants_Under_70



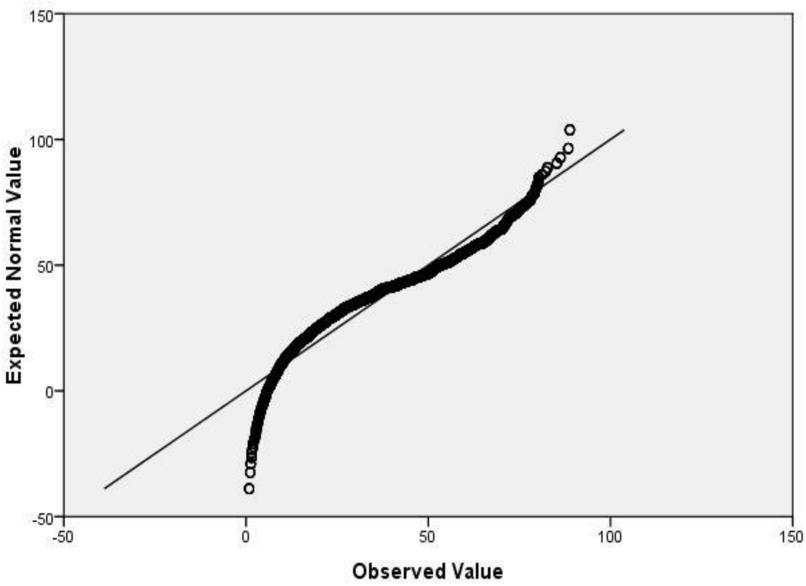
Normal Q-Q Plot of CWI_Score

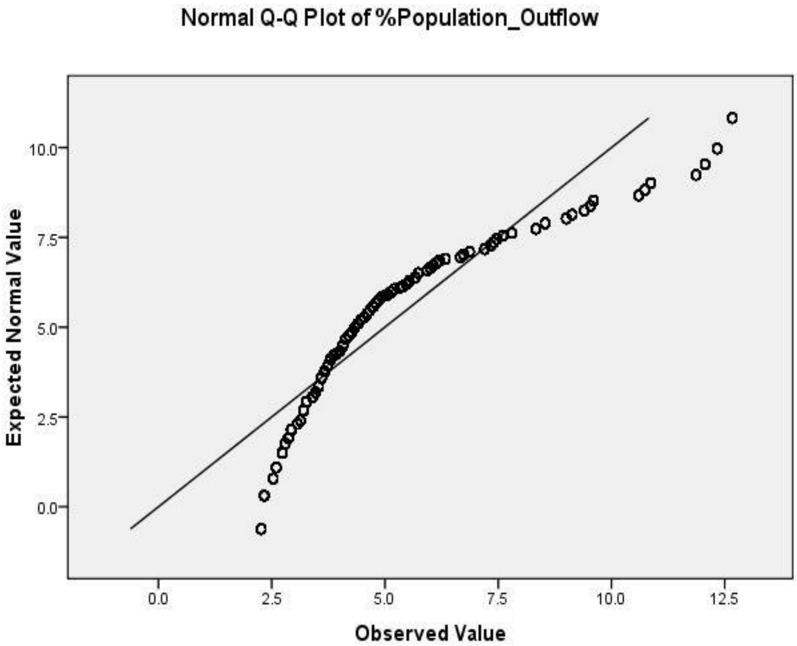


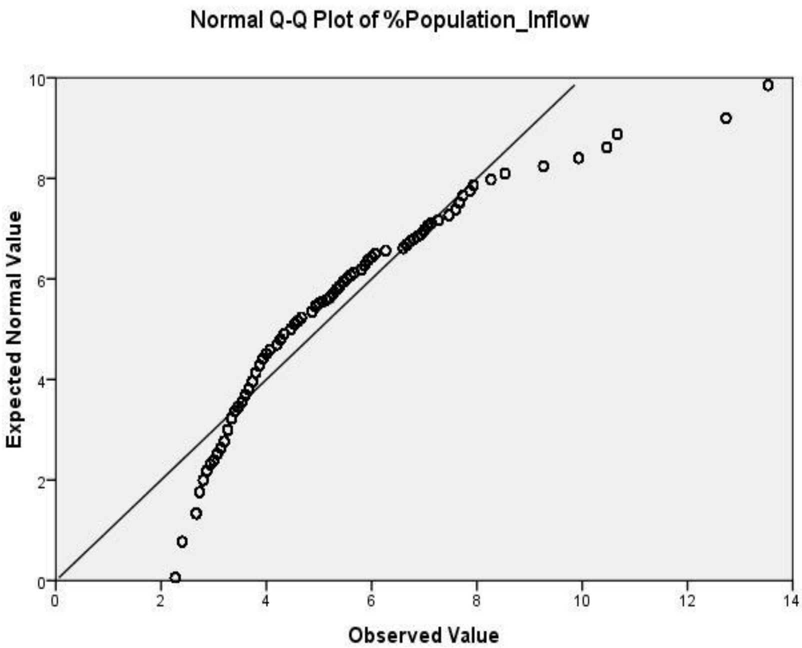
Normal Q-Q Plot of Housing_In_Poor_Condition



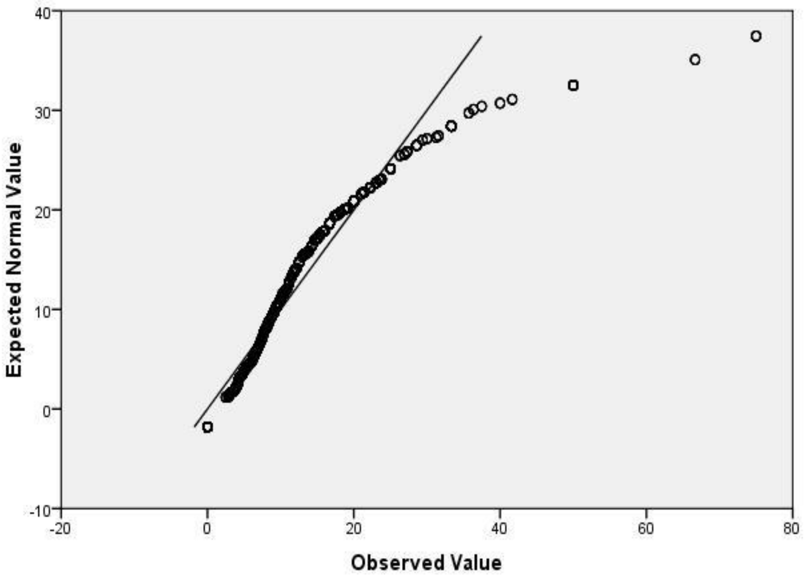
Normal Q-Q Plot of Combined_Living_Environment_Indicator



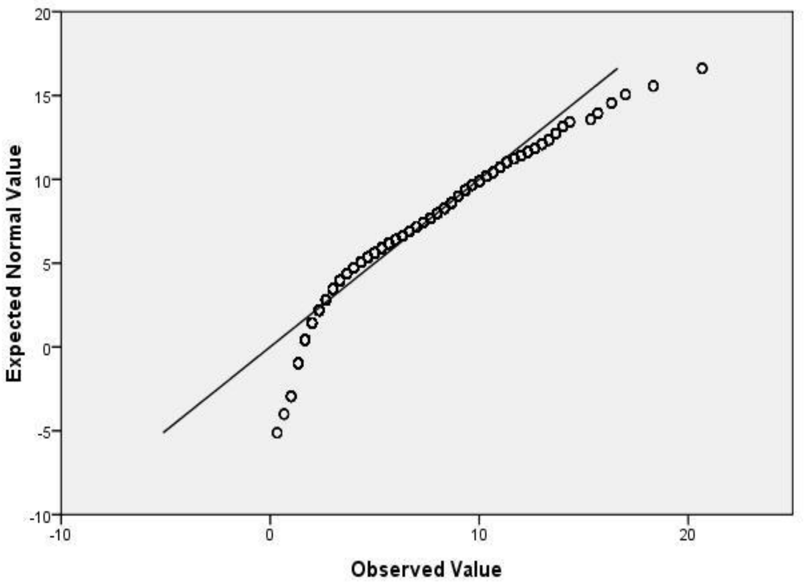

Normal Q-Q Plot of %Population_Outflow
Expected Normal Value
Observed Value
10.0
7.5
5.0
2.5
0.0
0.0
2.5
5.0
7.5
10.0
12.5


Normal Q-Q Plot of %Population_Inflow
Expected Normal Value
Observed Value
10
8
6
4
2
0
0
2
4
6
8
10
12
14

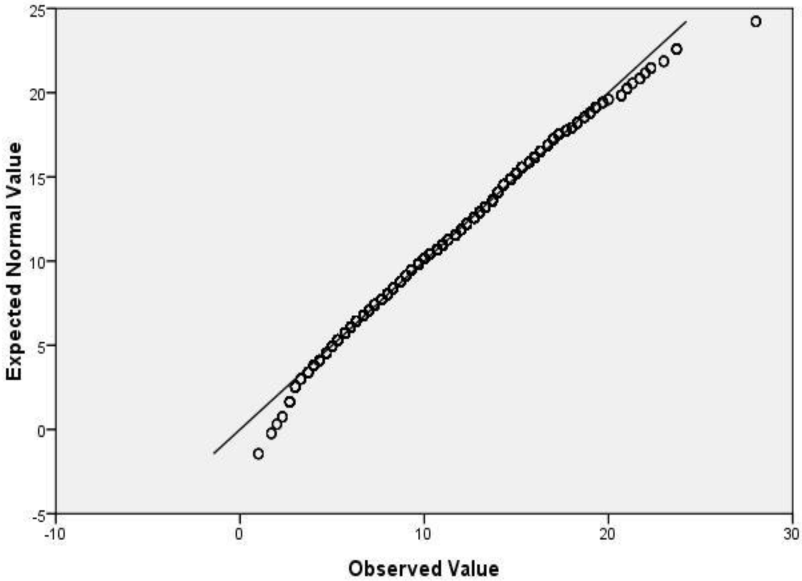
Normal Q-Q Plot of %Severe_Disablement_Allowance



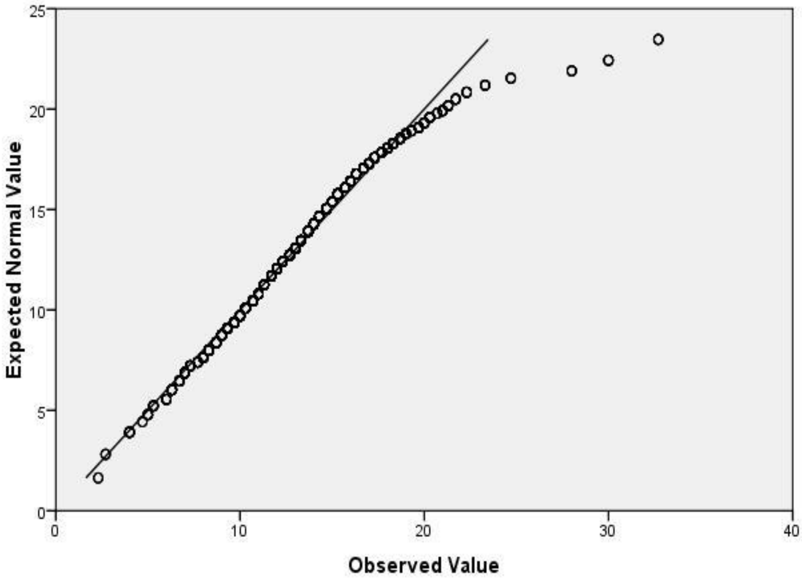
Normal Q-Q Plot of %Of_Incapacity_Claimants



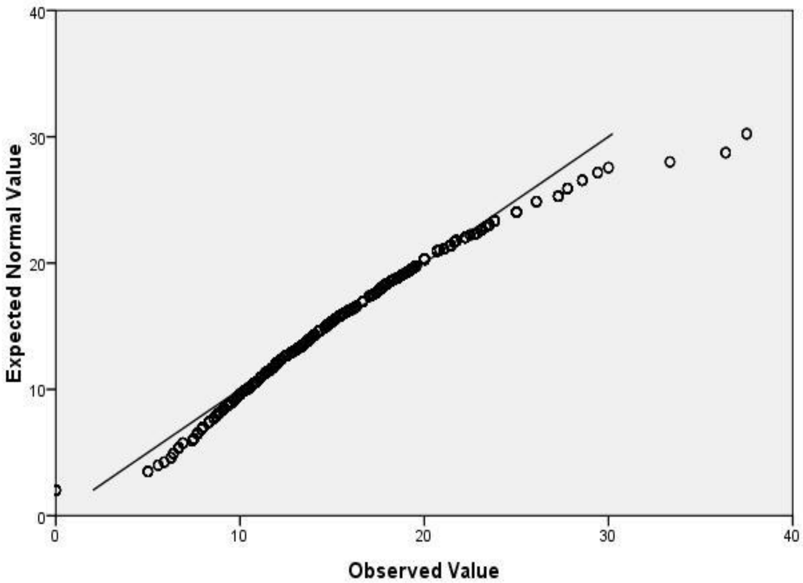
Normal Q-Q Plot of %All_Tax_Credit_recipients



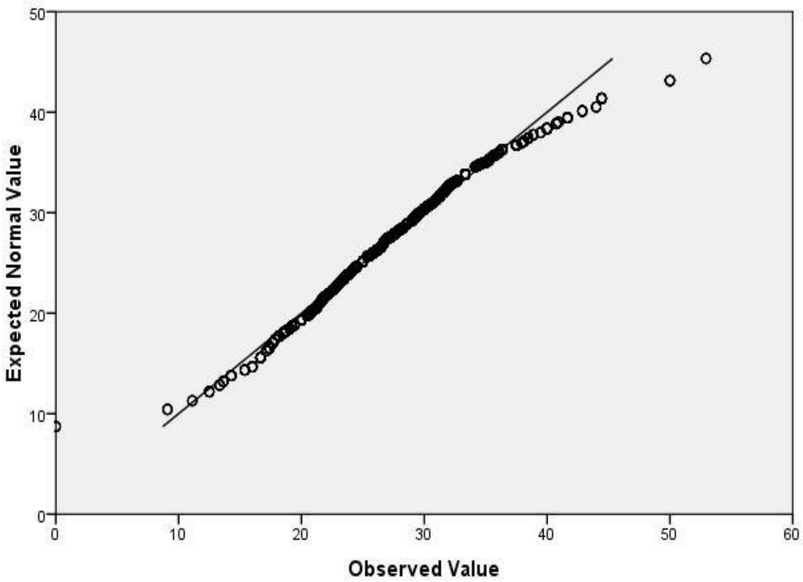
Normal Q-Q Plot of %All_Child_Benefit_recipients



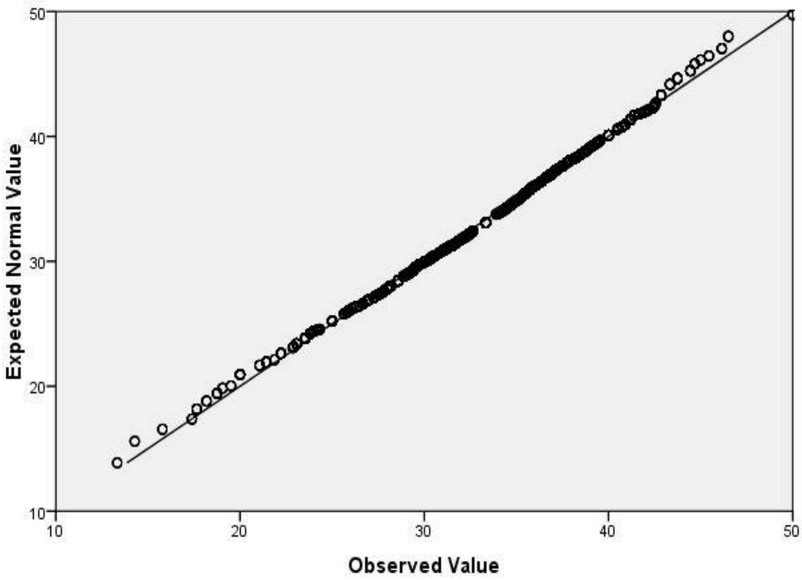
Normal Q-Q Plot of %Care_Nil_Rate



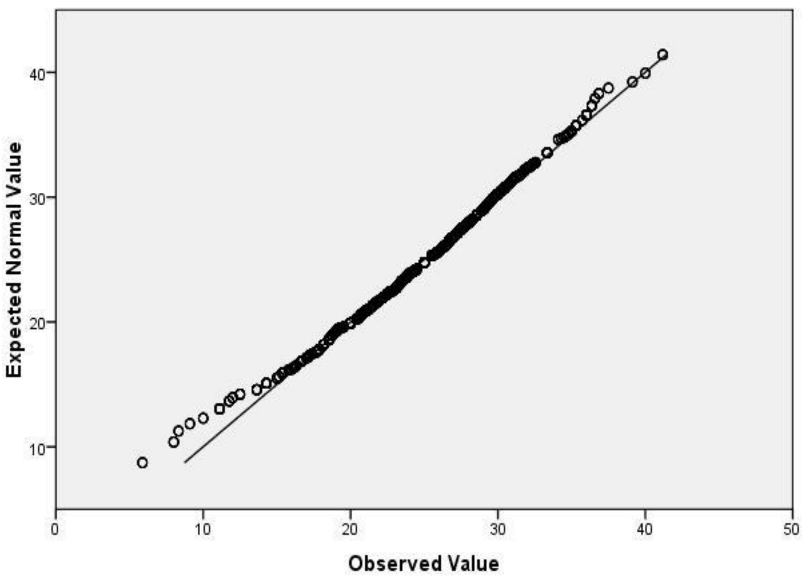
Normal Q-Q Plot of %Care_Higher_Rate



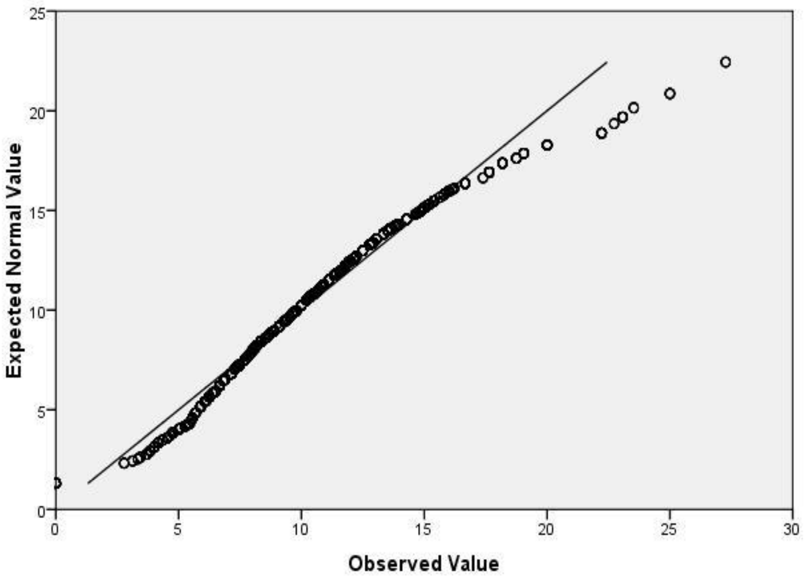
Normal Q-Q Plot of %Care_Middle_Rate



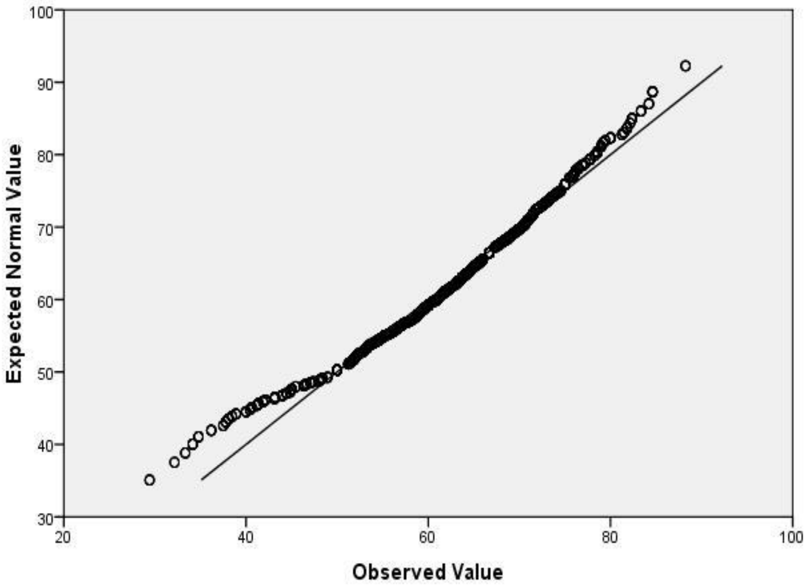
Normal Q-Q Plot of %Care_Lower_Rate



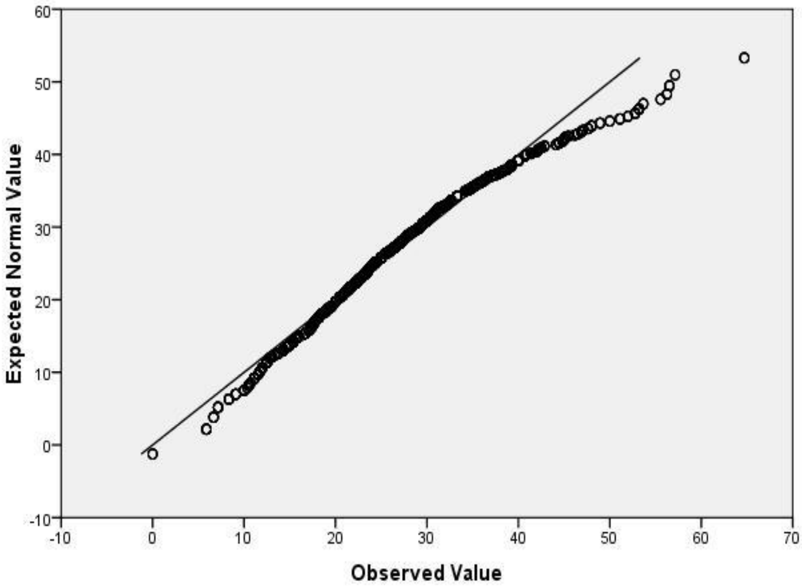
Normal Q-Q Plot of %Mobility_Nil_Rate



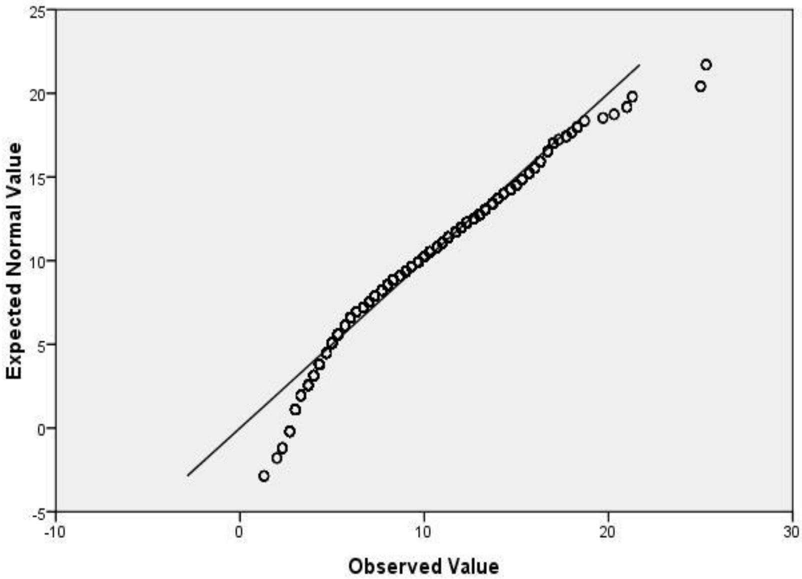
Normal Q-Q Plot of %Mobility_Higher_Rate



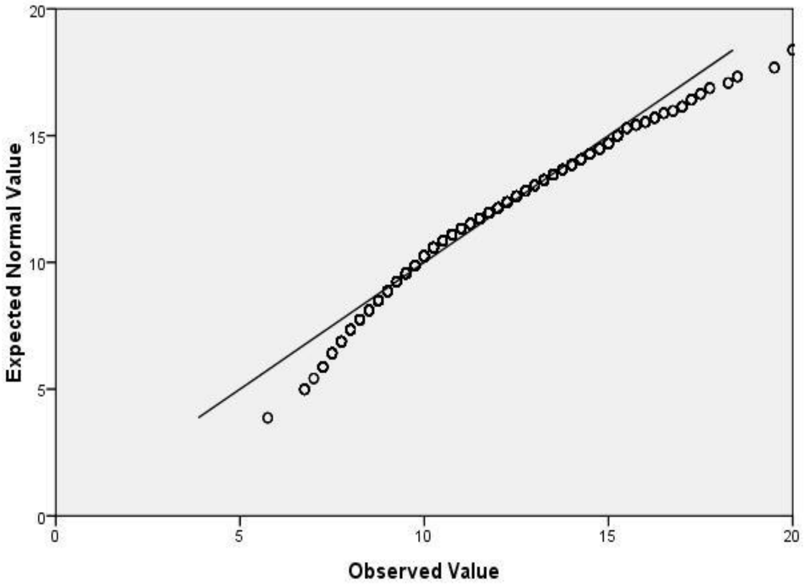
Normal Q-Q Plot of %Mobility_Lower_Rate



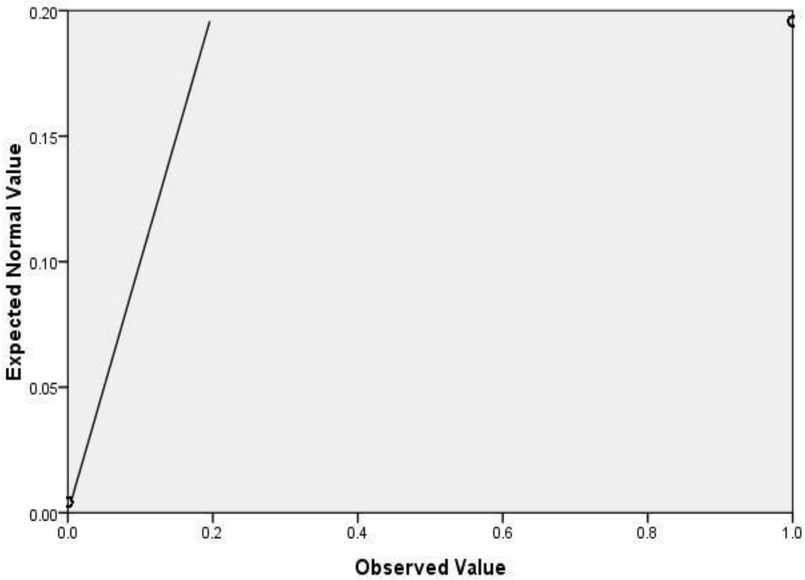
Normal Q-Q Plot of %DLA_Claimants



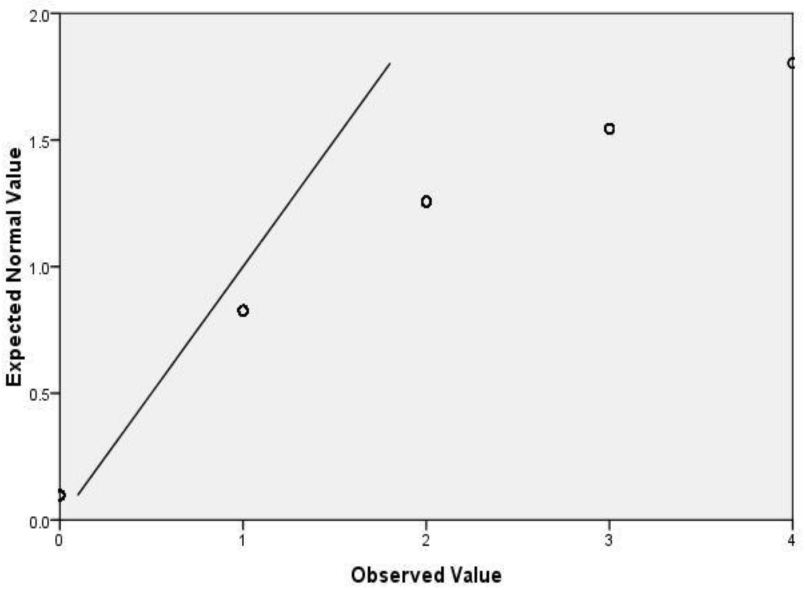
Normal Q-Q Plot of %Fuel_Poverty



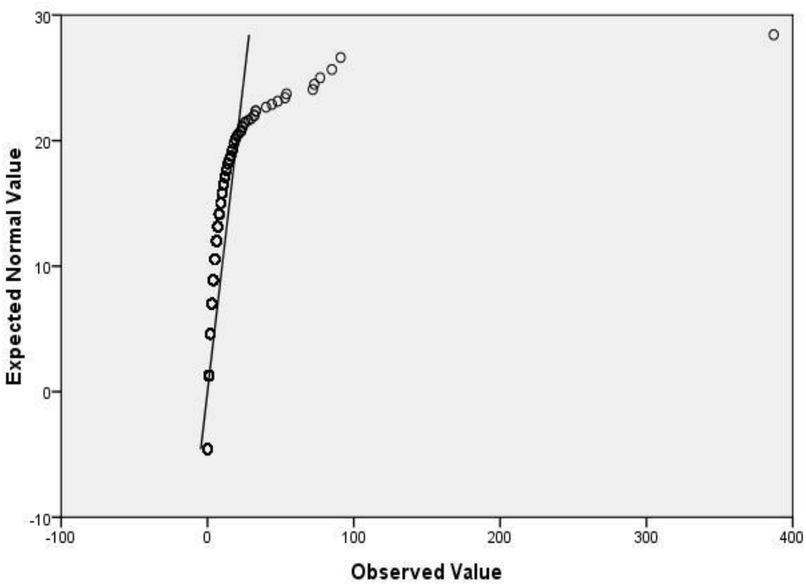
Normal Q-Q Plot of ADF_Fatalities

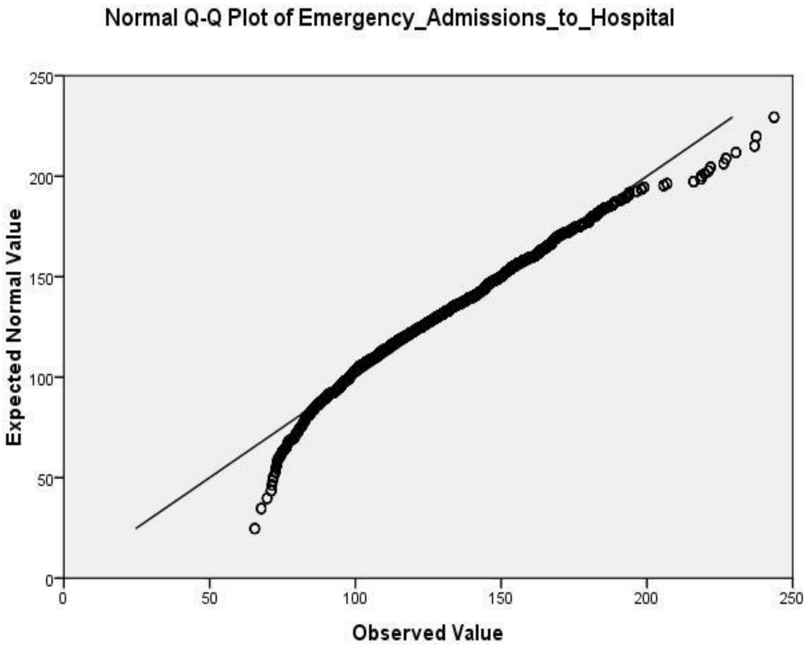


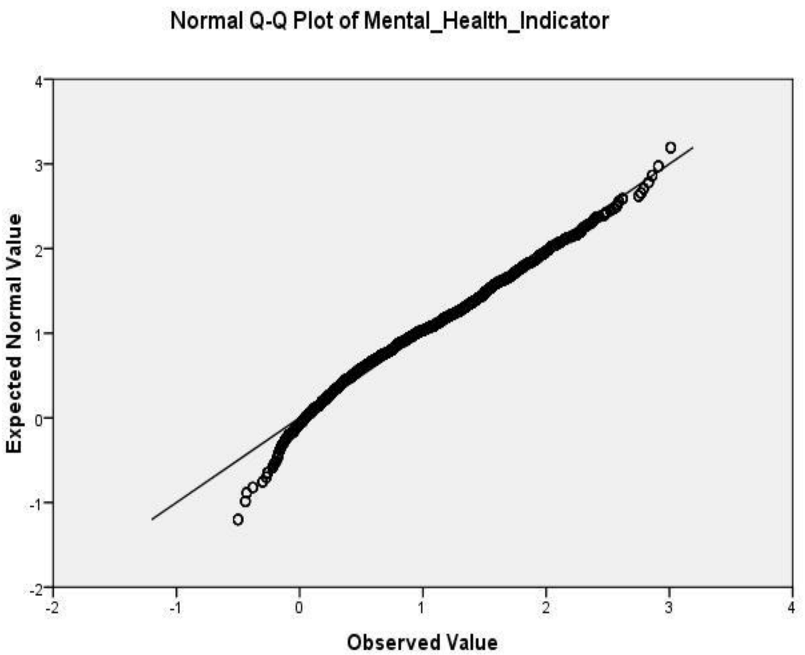
Normal Q-Q Plot of ADF

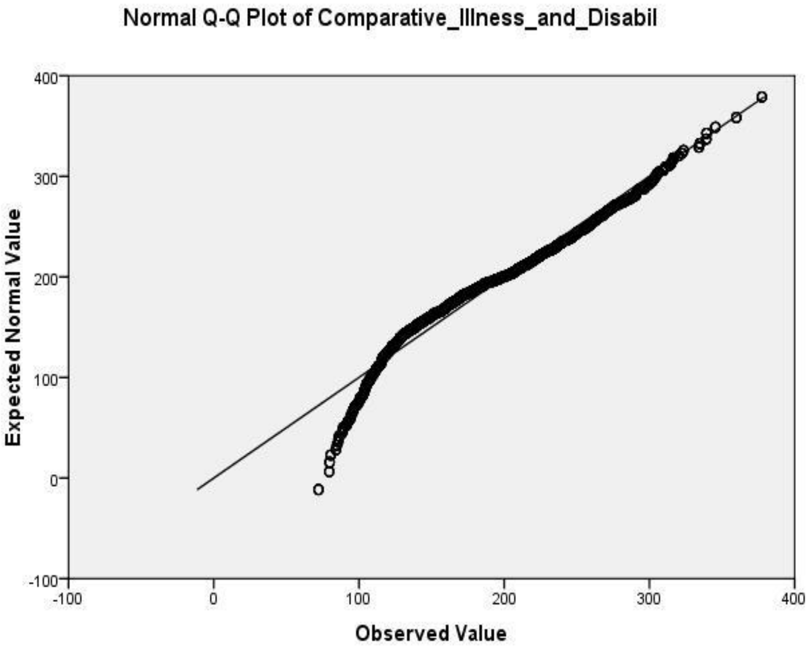


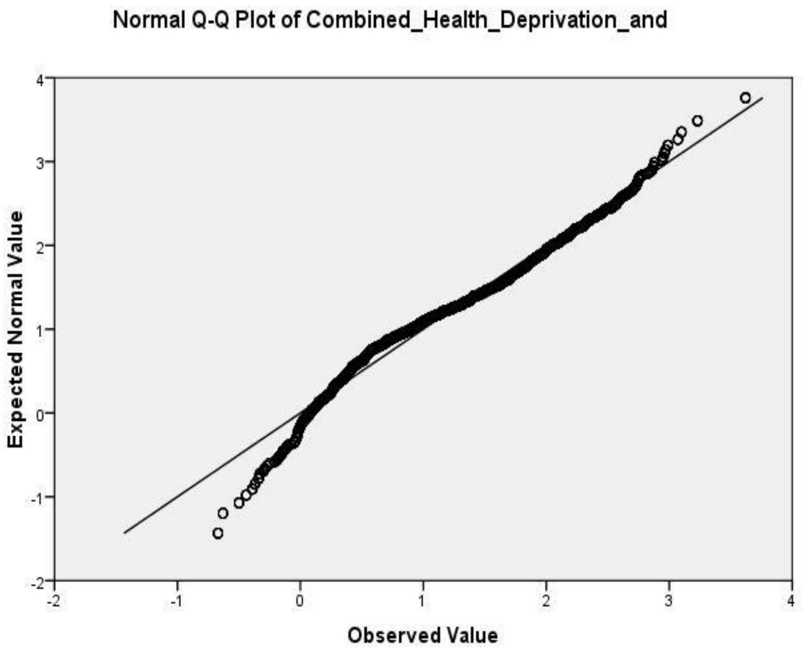
Normal Q-Q Plot of Crime



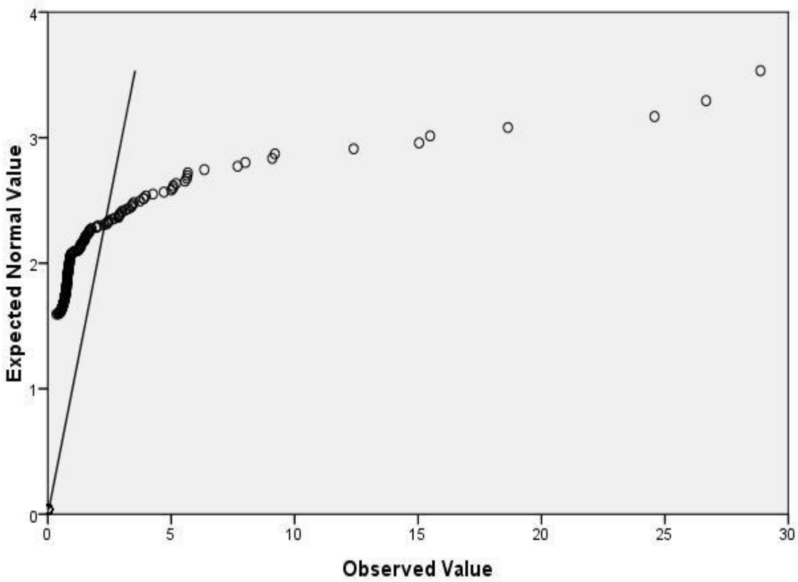

Normal Q-Q Plot of Emergency_Admissions_to_Hospital
Expected Normal Value
Observed Value
0
50
100
150
200
250


Normal Q-Q Plot of Mental_Health_Indicator
Expected Normal Value
Observed Value
-2
-1
0
1
2
3
4

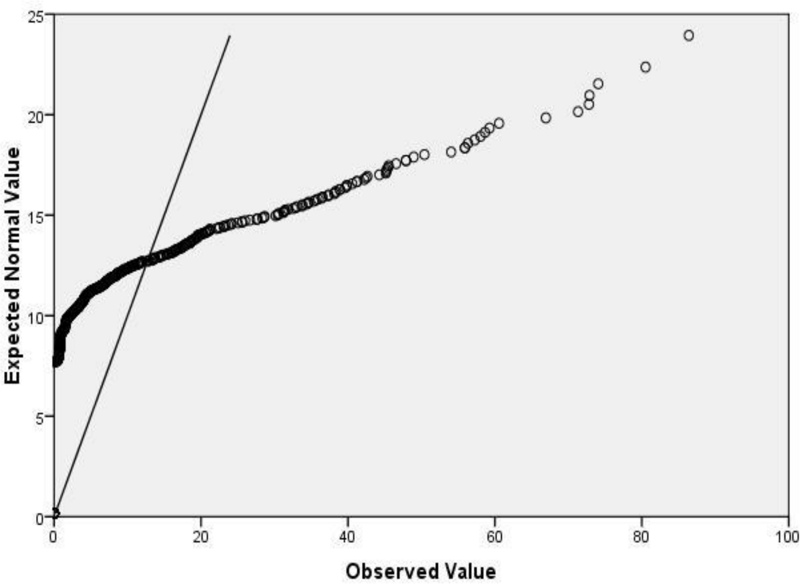

Normal Q-Q Plot of Comparative_Illness_and_Disabil
Expected Normal Value
Observed Value
400
300
200
100
0
-100
-100
0
100
200
300
400


Normal Q-Q Plot of Combined_Health_Deprivation_and
Expected Normal Value
Observed Value
4
3
2
1
0
-1
-2
-2
-1
0
1
2
3
4

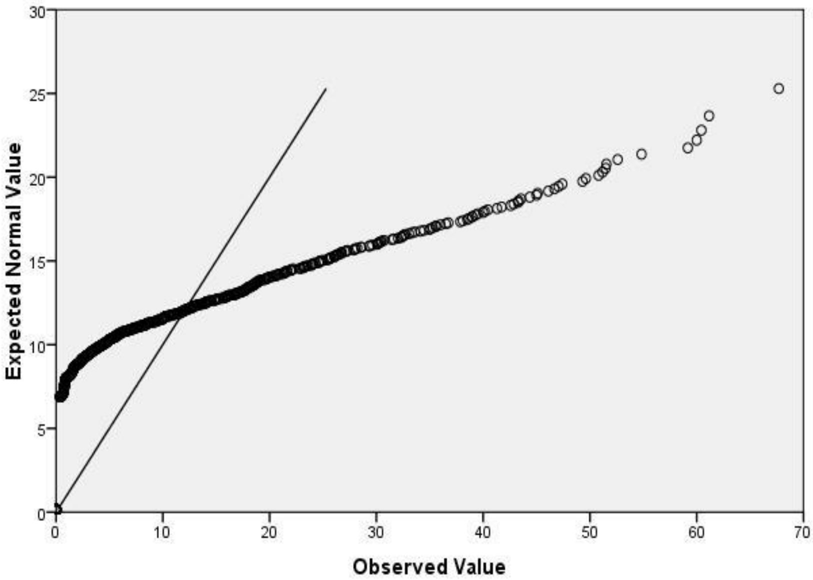
Normal Q-Q Plot of CT_Band_H%



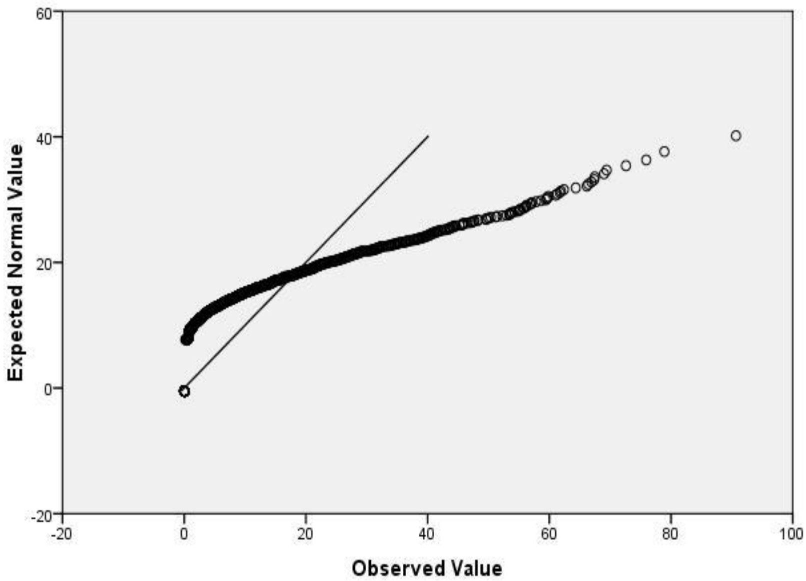
Normal Q-Q Plot of CT_Band_G%



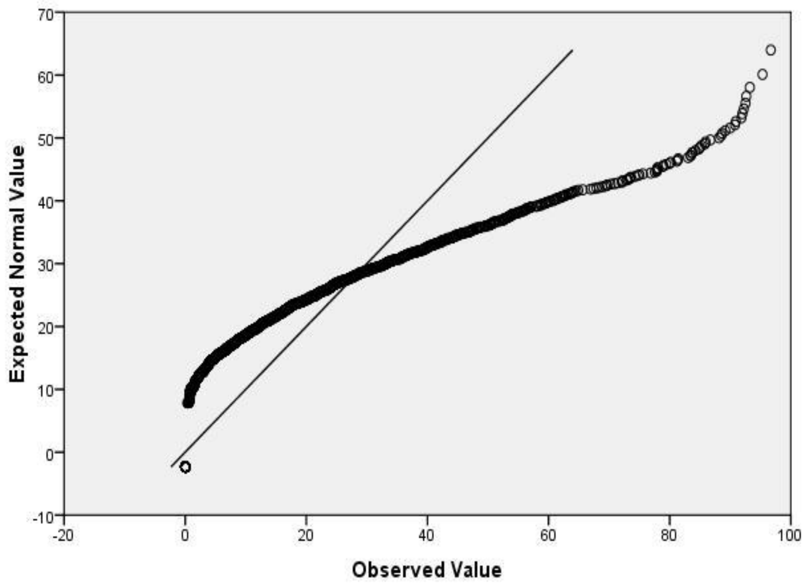
Normal Q-Q Plot of CT_Band_F%



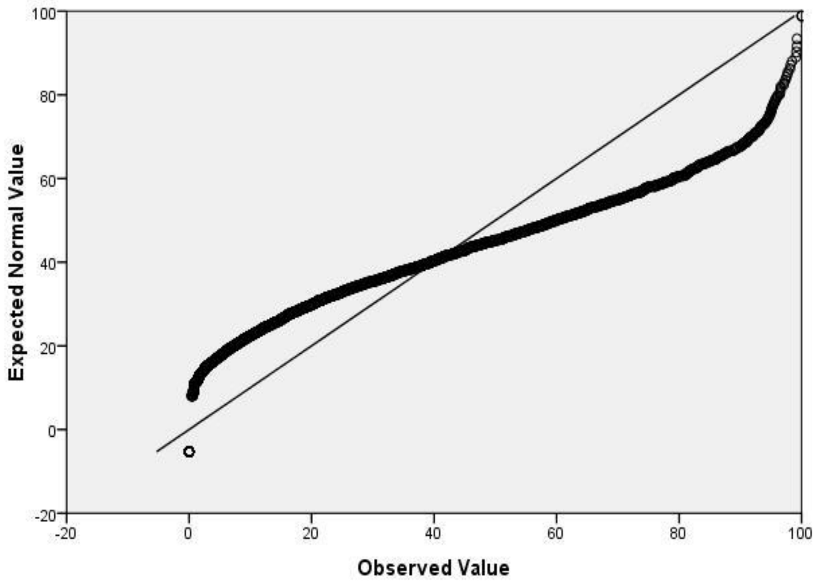
Normal Q-Q Plot of CT_Band_E%



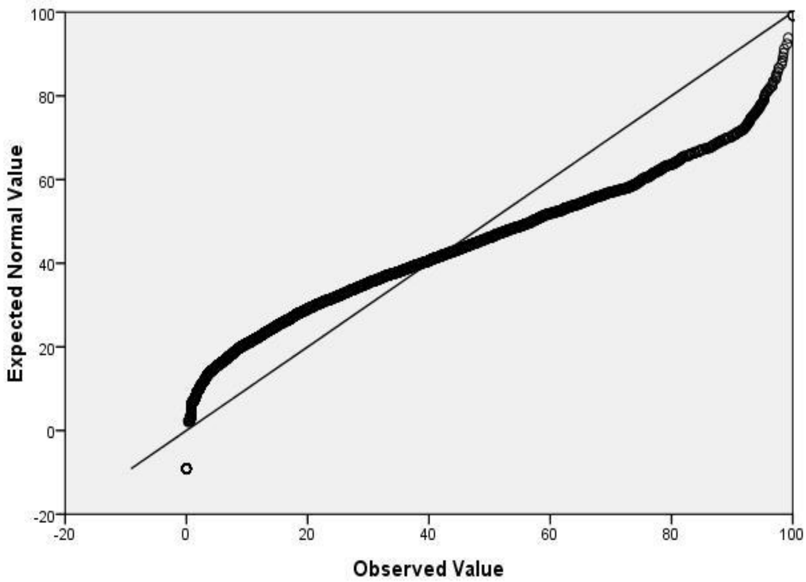
Normal Q-Q Plot of CT_Band_D%



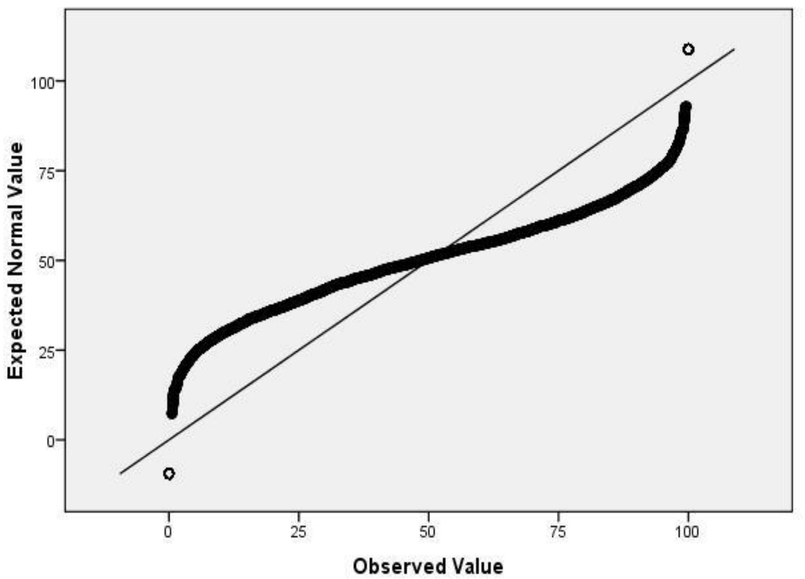
Normal Q-Q Plot of CT_Band_C%



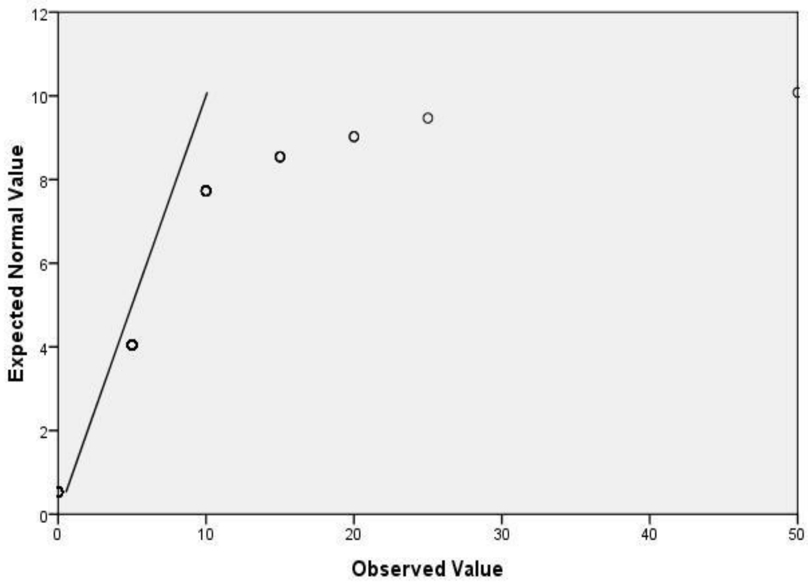
Normal Q-Q Plot of CT_Band_B%



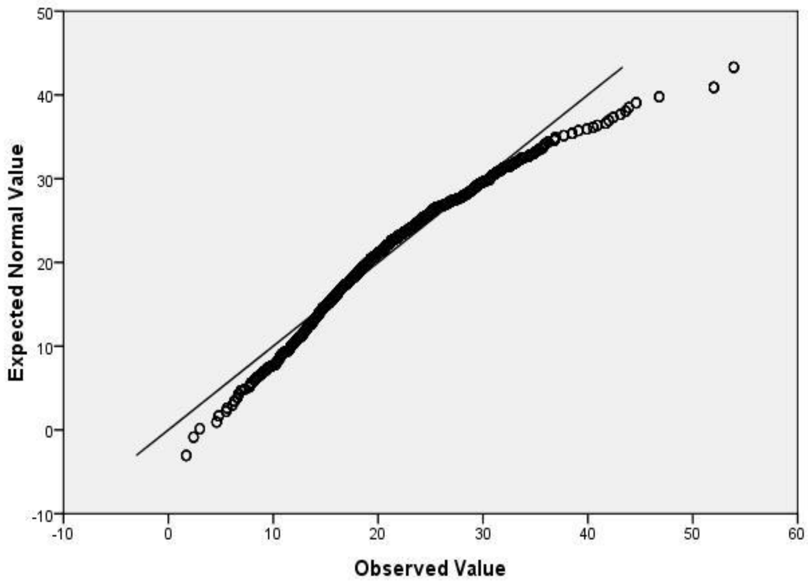
Normal Q-Q Plot of CT_Band_A%

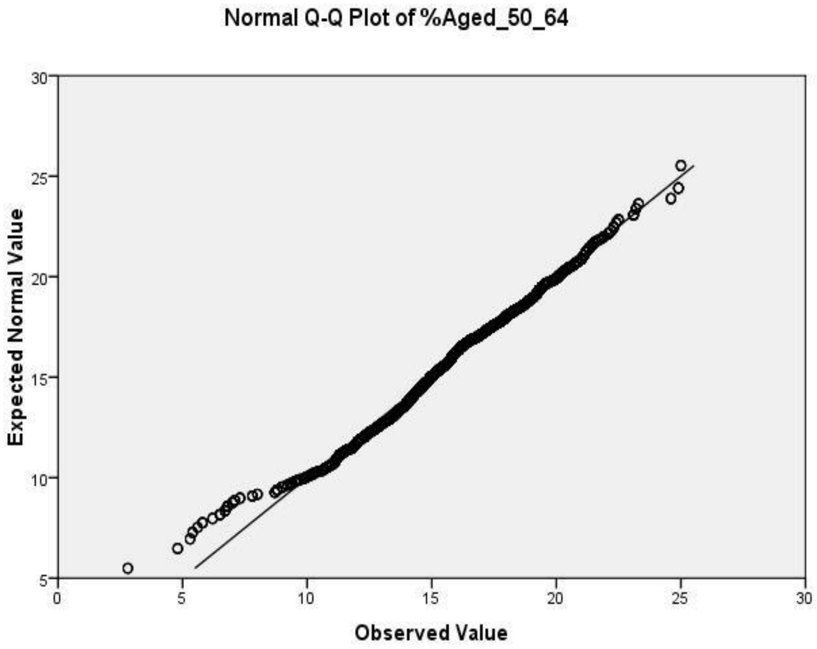


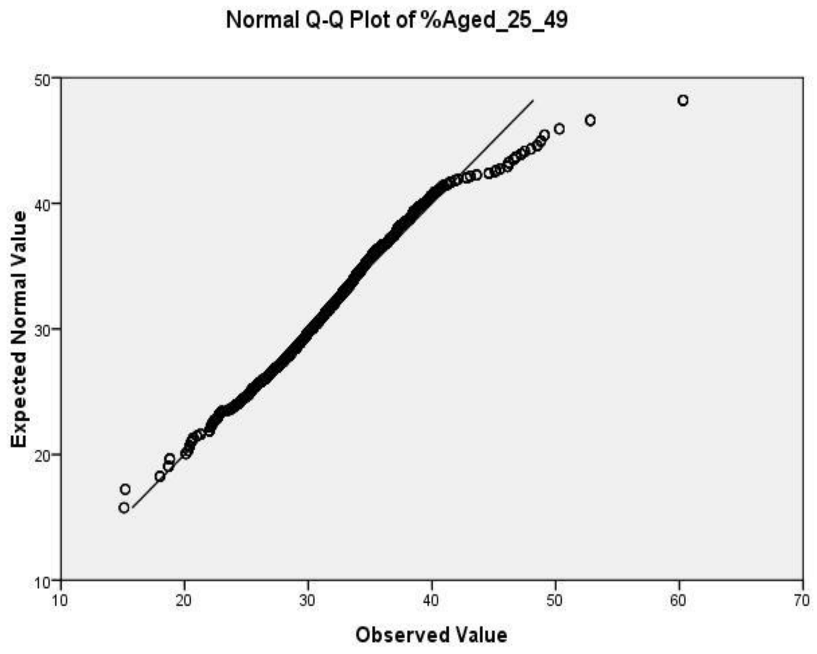
Normal Q-Q Plot of Number_Other_Income_Benefits



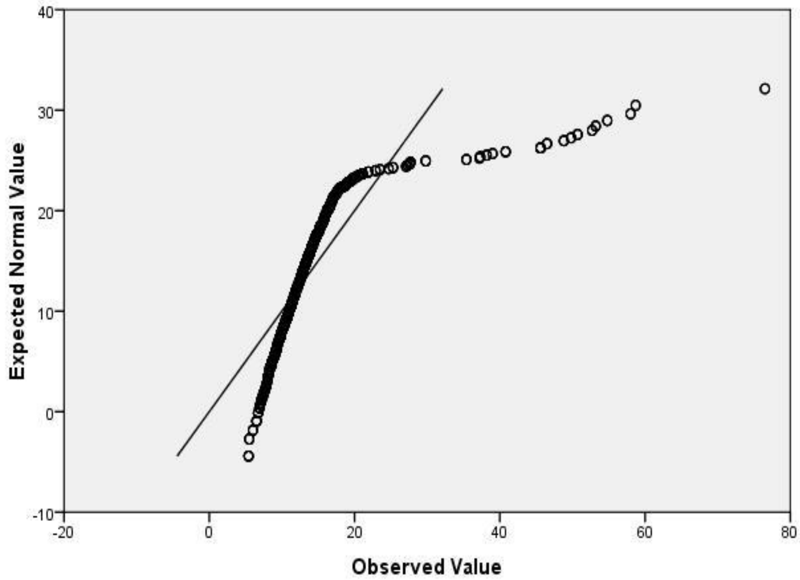
Normal Q-Q Plot of %Aged_65_Plus



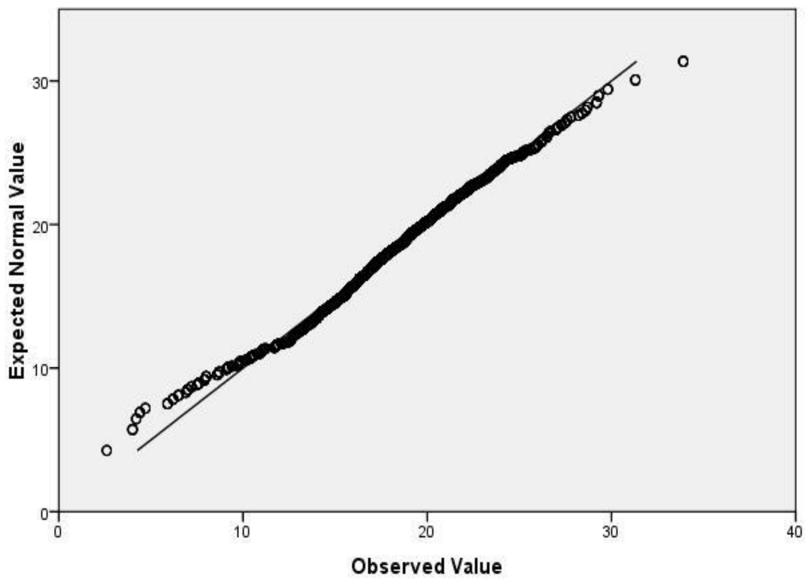

Normal Q-Q Plot of %Aged_50_64
Expected Normal Value
Observed Value
30
25
20
15
10
5
0
5
10
15
20
25
30


Normal Q-Q Plot of %Aged_25_49
Expected Normal Value
Observed Value
50
40
30
20
10
10
20
30
40
50
60
70

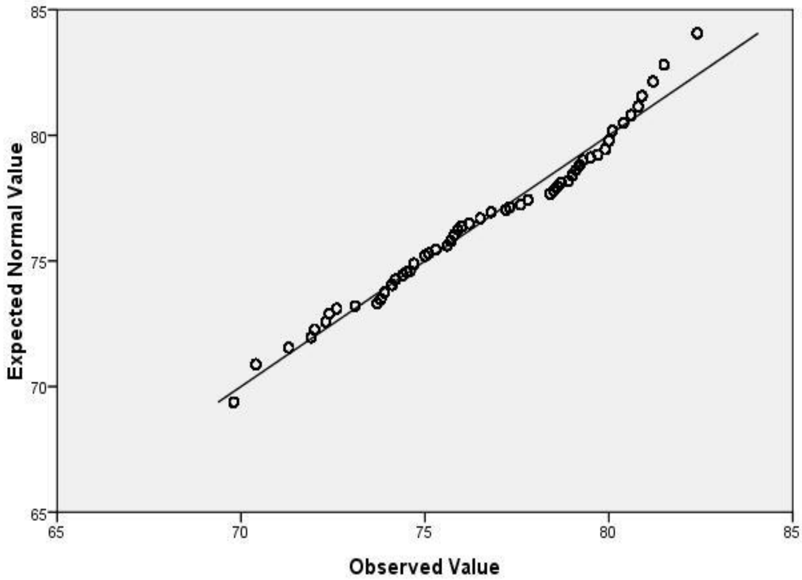
Normal Q-Q Plot of %Aged_16_24



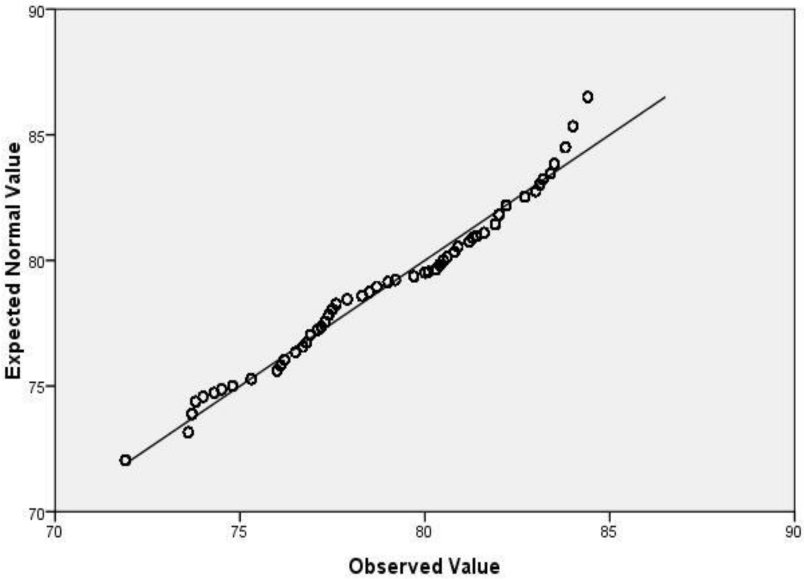
Normal Q-Q Plot of %Aged_0_15



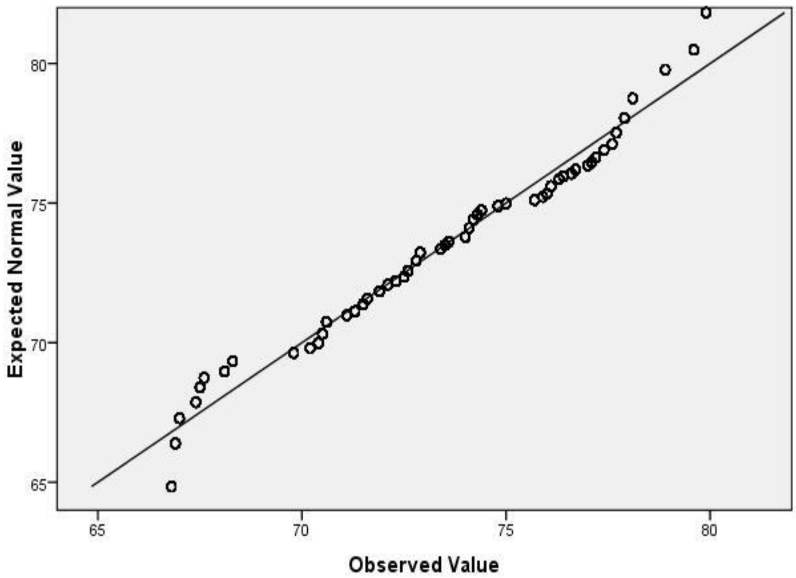
Normal Q-Q Plot of Persons_Life_expectancy_at_birth



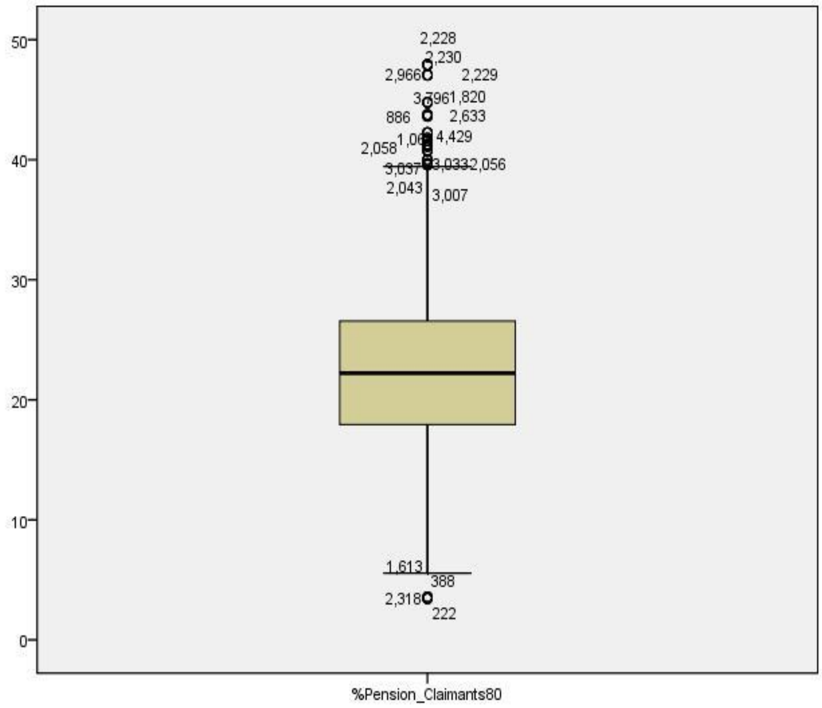
Normal Q-Q Plot of Females_Life_expectancy_at_birth



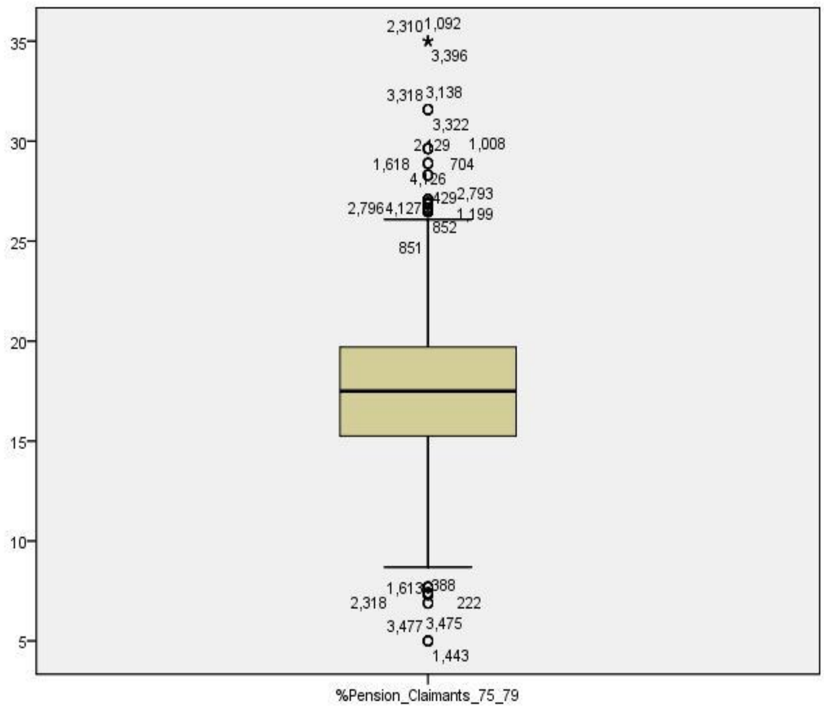
Normal Q-Q Plot of Males_Life_expectancy_at_birth



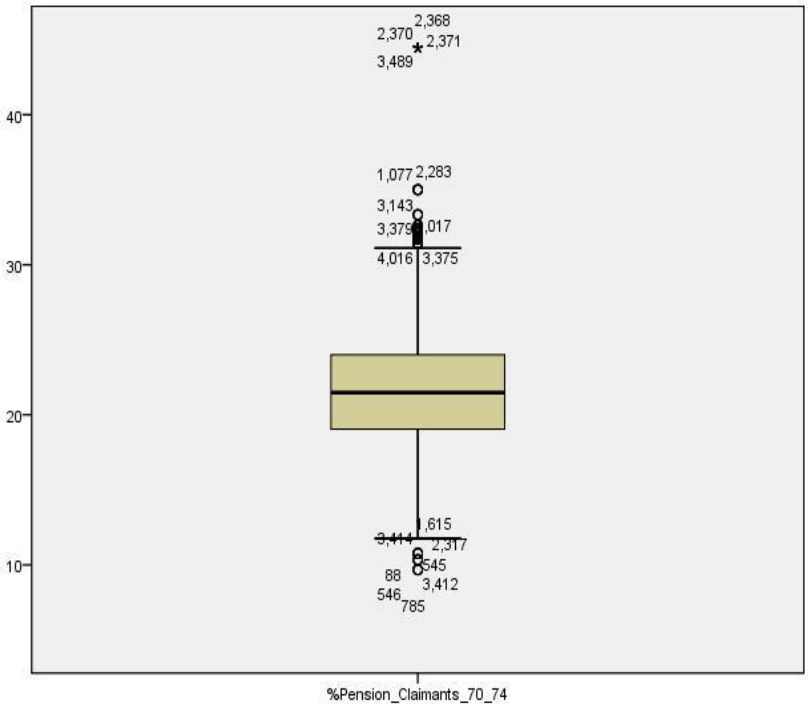
This section illustrates the boxplots created for the statistical data testing report. Data points that are denoted with the circle symbol illustrate data points that are outliers. Data points denoted by the star symbol are significant outliers.

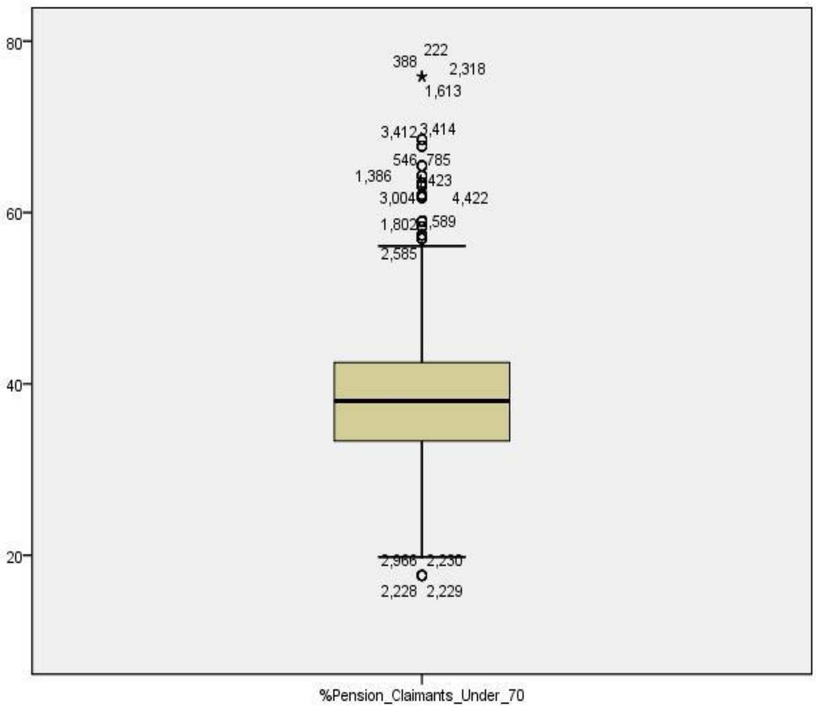


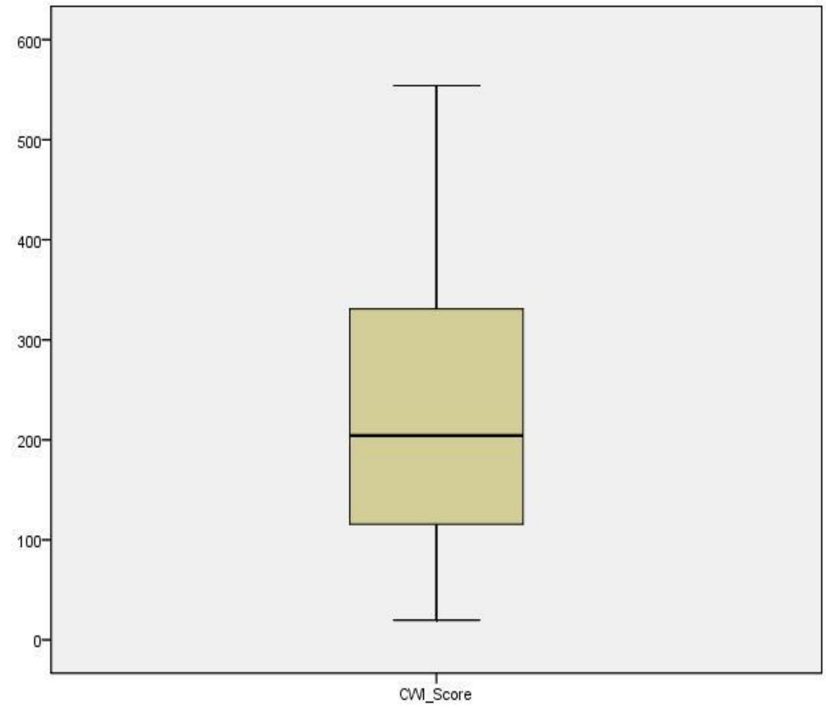
50
40
30
20
10
0
%Pension_Claimants80



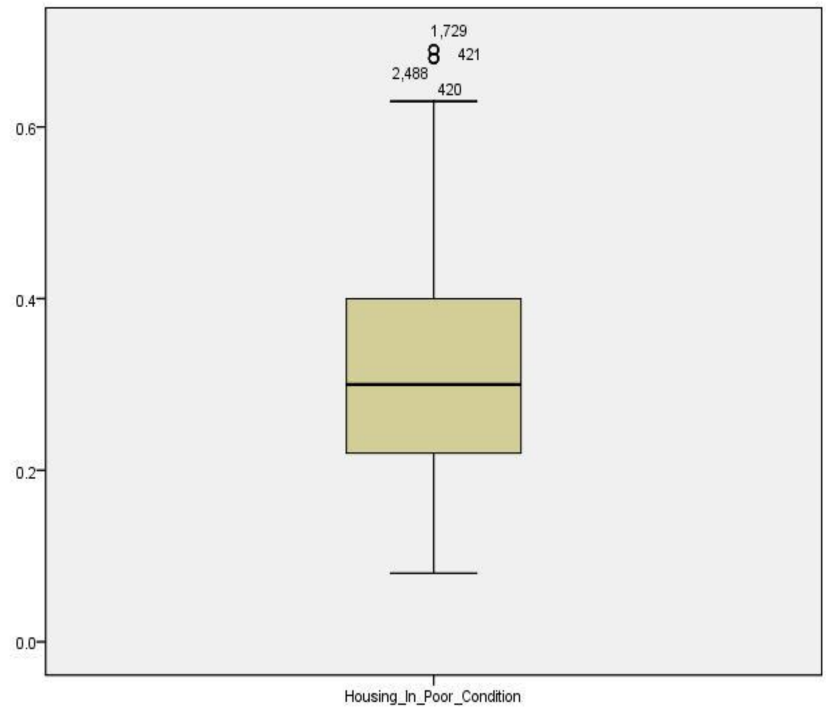
35
30
25
20
15
10
5
%Pension_Claimants_75_79


2,368
2,370
2,371
3,489
40
1,077
2,283
3,143
30
4,016
3,375
20
1,615
2,317
10
545
88
3,412
546
785
%Pension_Claimants_70_74

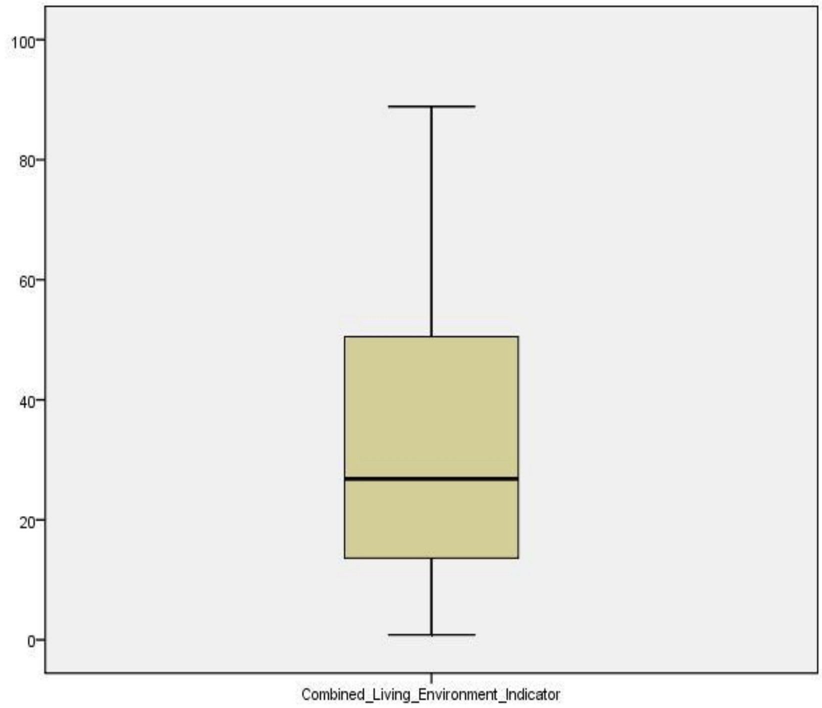

80
222
388
2,318
1,613
3,412
3,414
546
785
1,386
3,004
4,422
60
2,585
40
20
2,228
2,229
%Pension_Claimants_Under_70

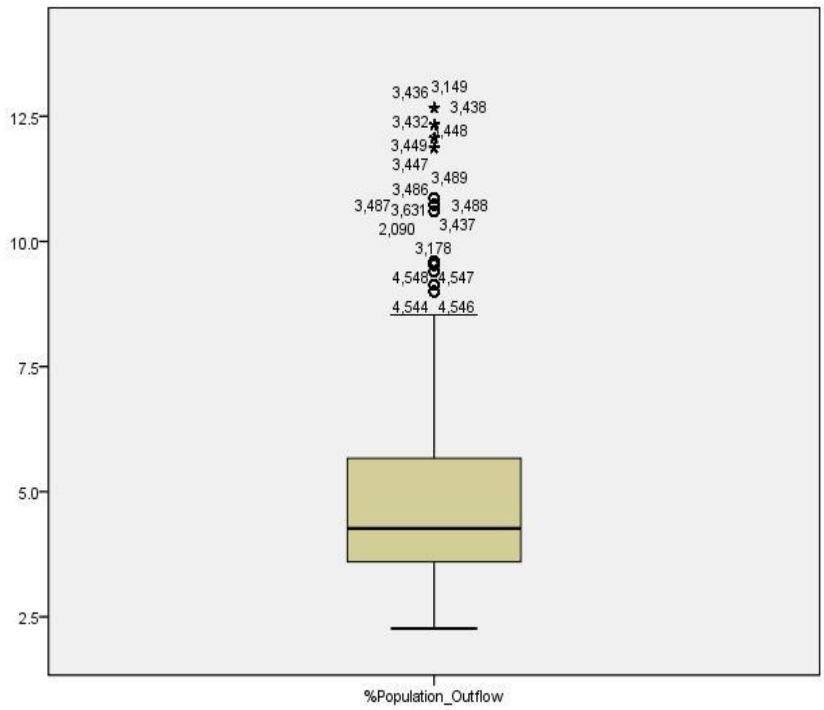


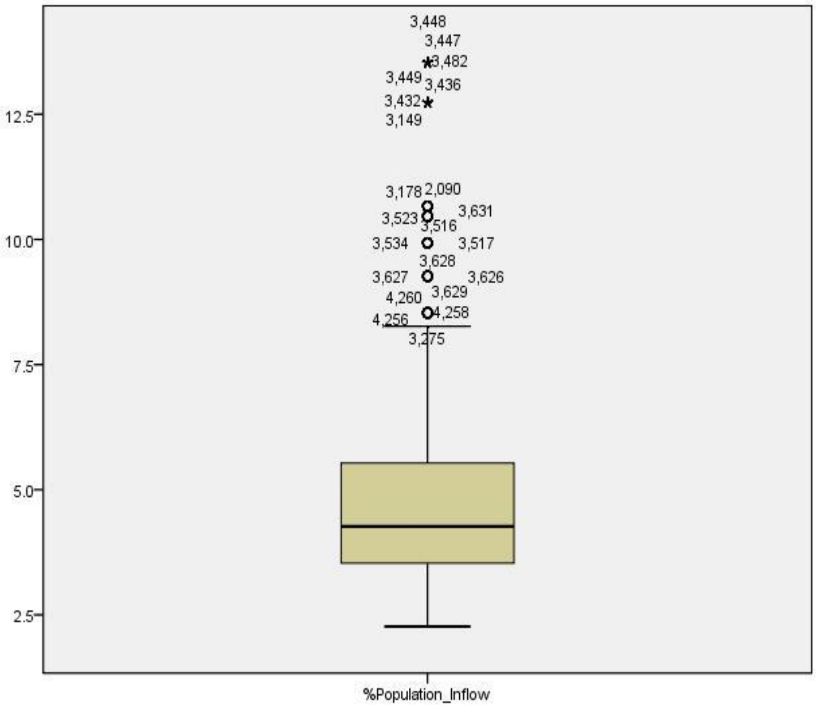
600
500
400
300
200
100
0
CWI_Score

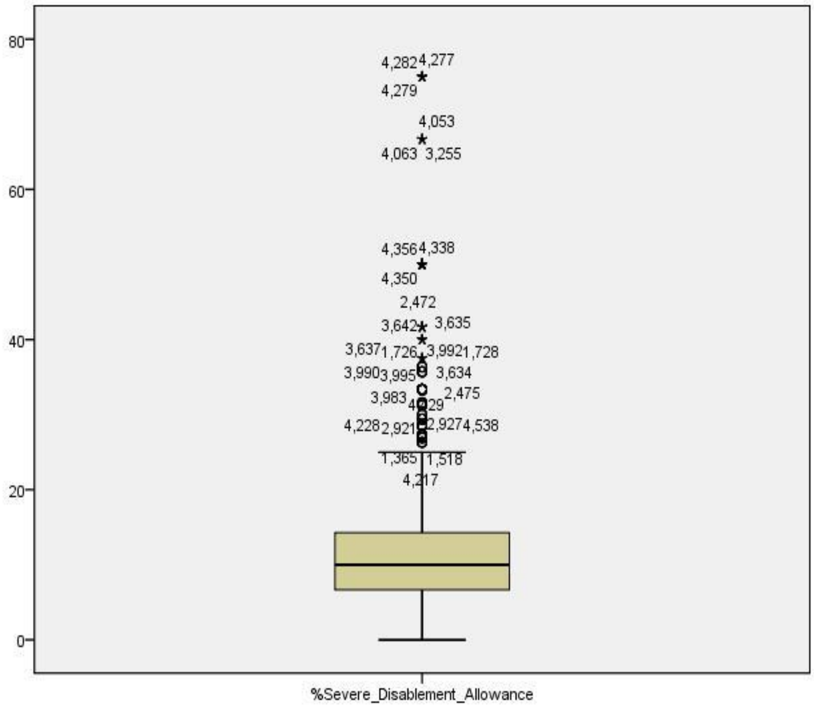


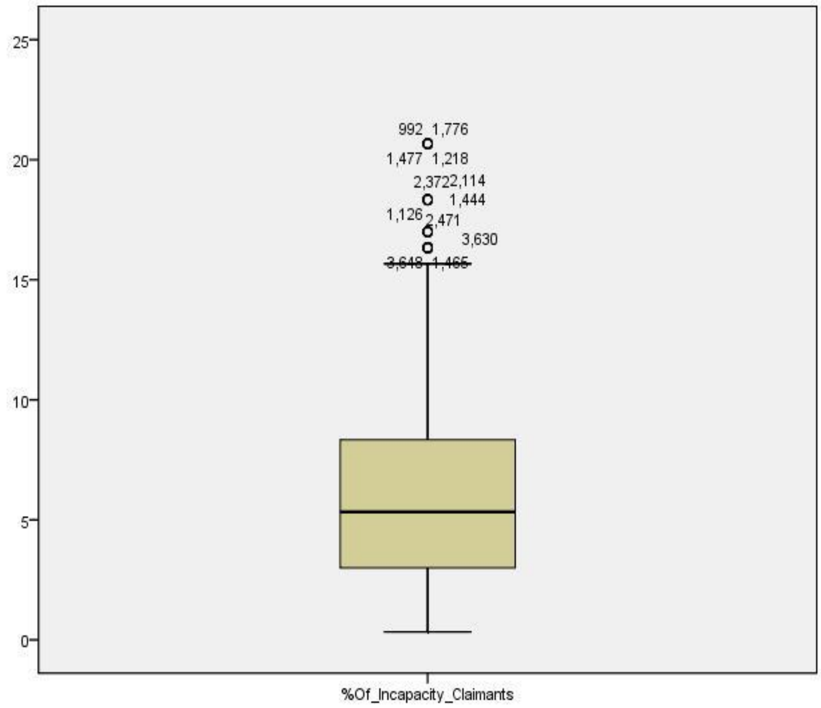
1,729
421
2,488
420
0.6
0.4
0.2
0.0
Housing_In_Poor_Condition

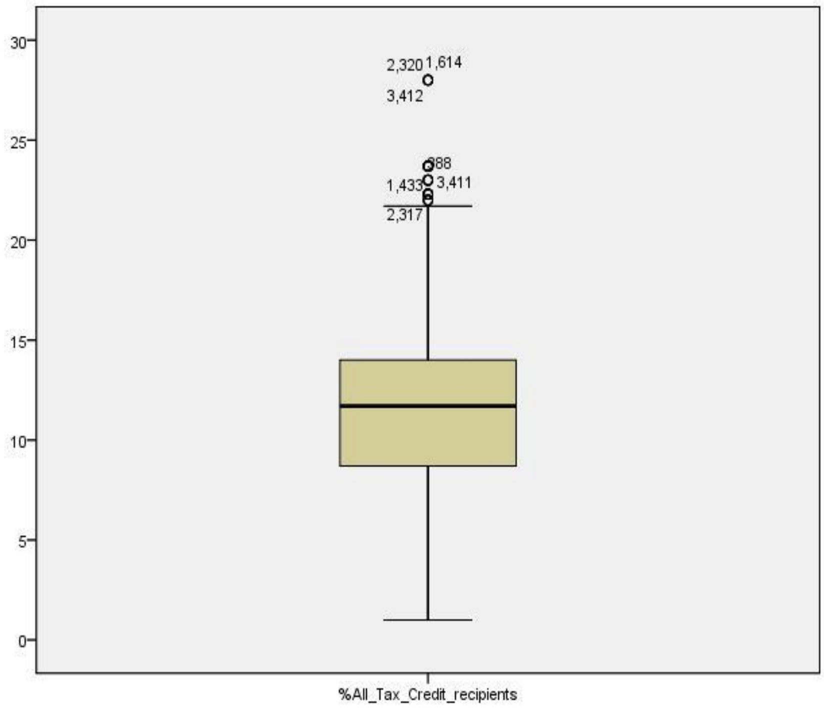

100
80
60
40
20
0
Combined_Living_Environment_Indicator

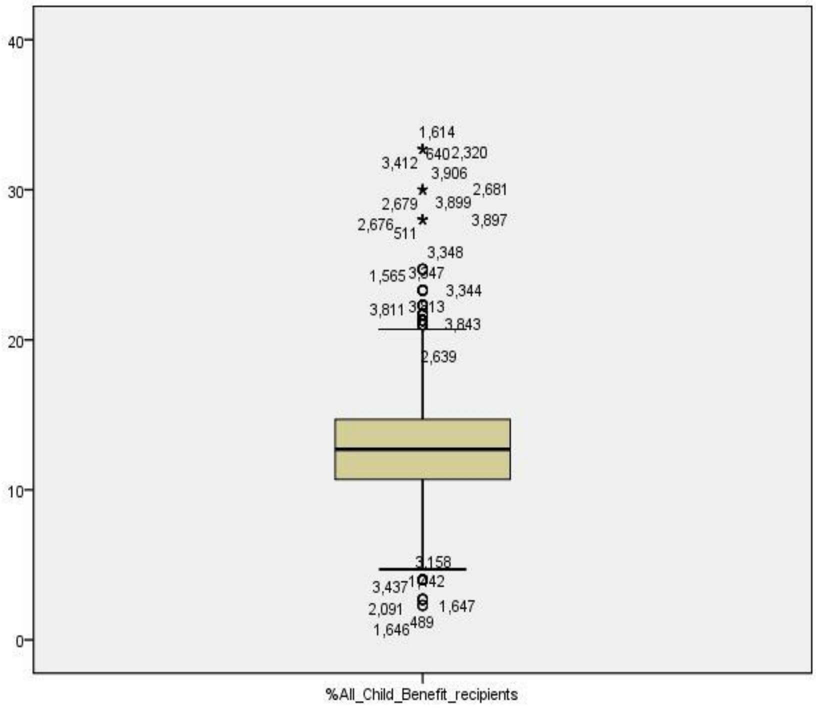

12.5
10.0
7.5
5.0
2.5
3,436
3,149
3,438
3,432
3,448
3,449
3,447
3,489
3,486
3,487
3,631
3,488
2,090
3,437
3,178
4,548
4,547
4,544
4,546
%Population_Outflow

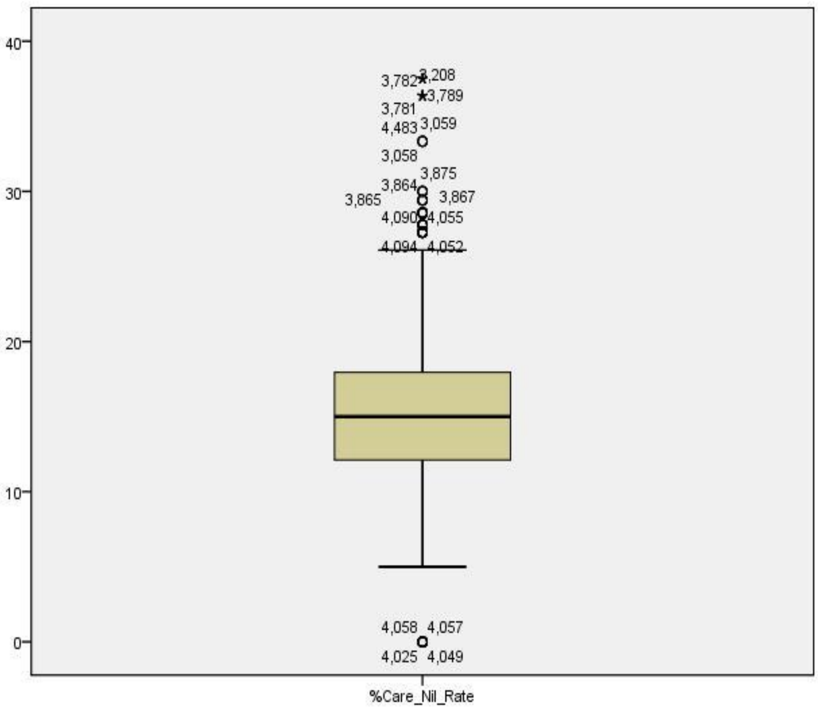

%Population_Inflow

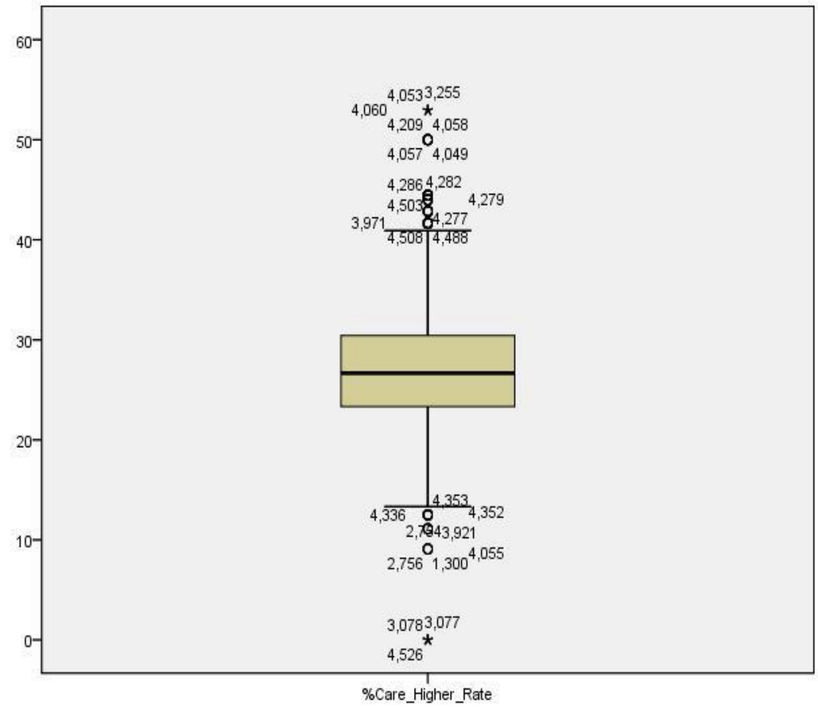

%Severe_Disablement_Allowance

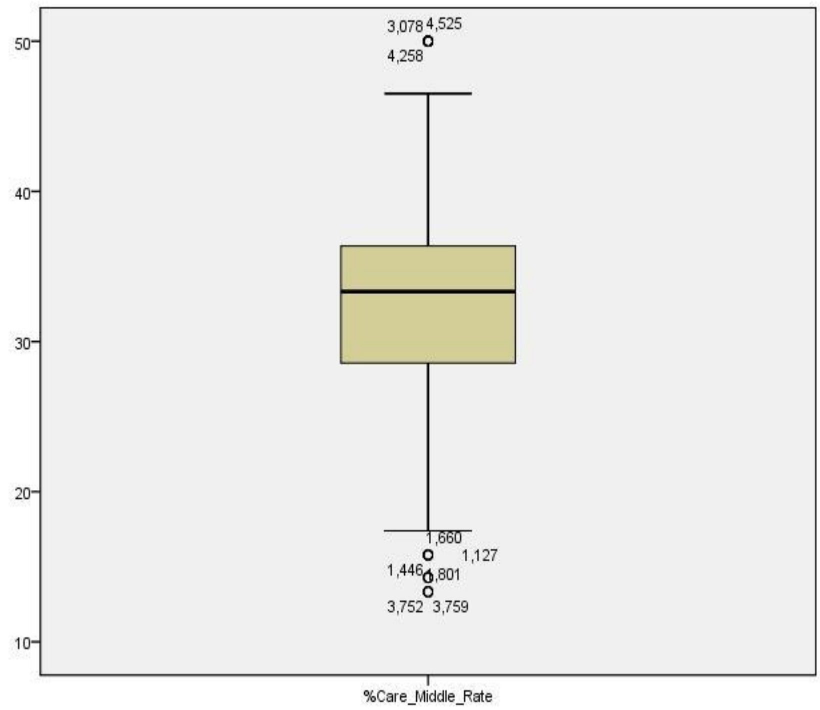

25
20
15
10
5
0
992 1,776
1,477 1,218
2,3722,114
1,444
1,126 2,471
3,630
3,648 1,465
%Of_Incapacity_Claimants

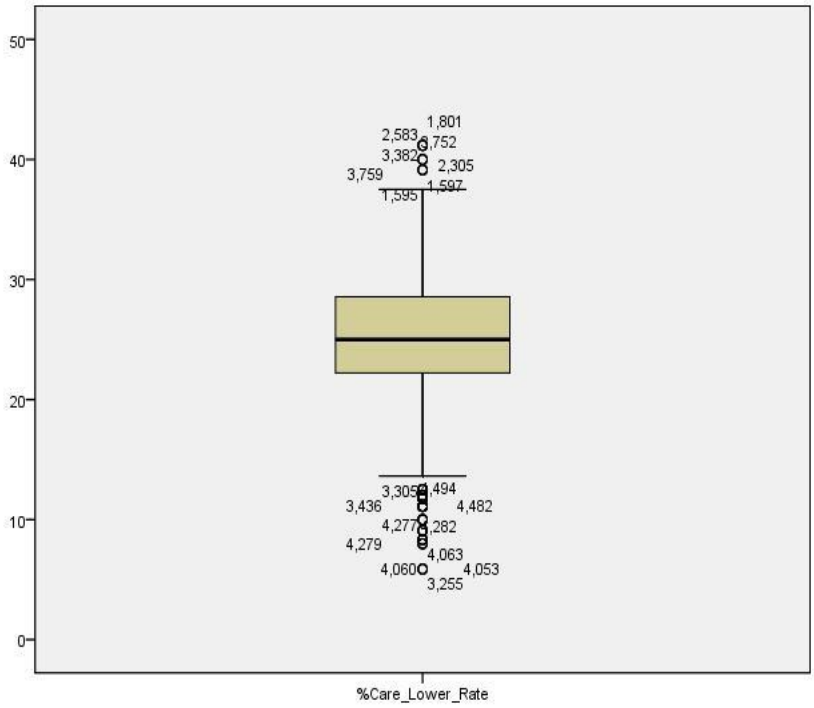

30
25
20
15
10
5
0
2,320 1,614
3,412
388
1,433 3,411
2,317
%All_Tax_Credit_recipients

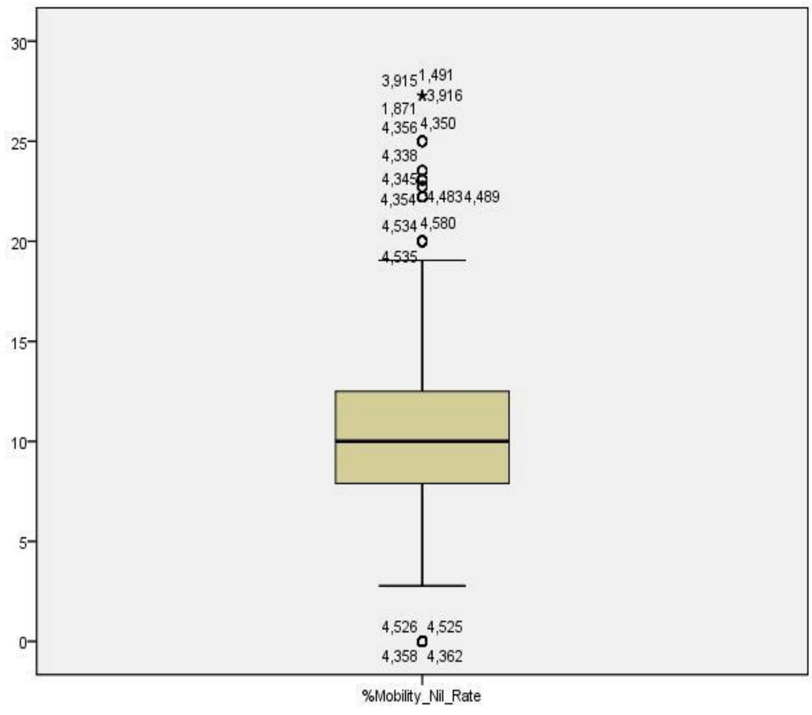

40
30
20
10
0
%All_Child_Benefit_recipients

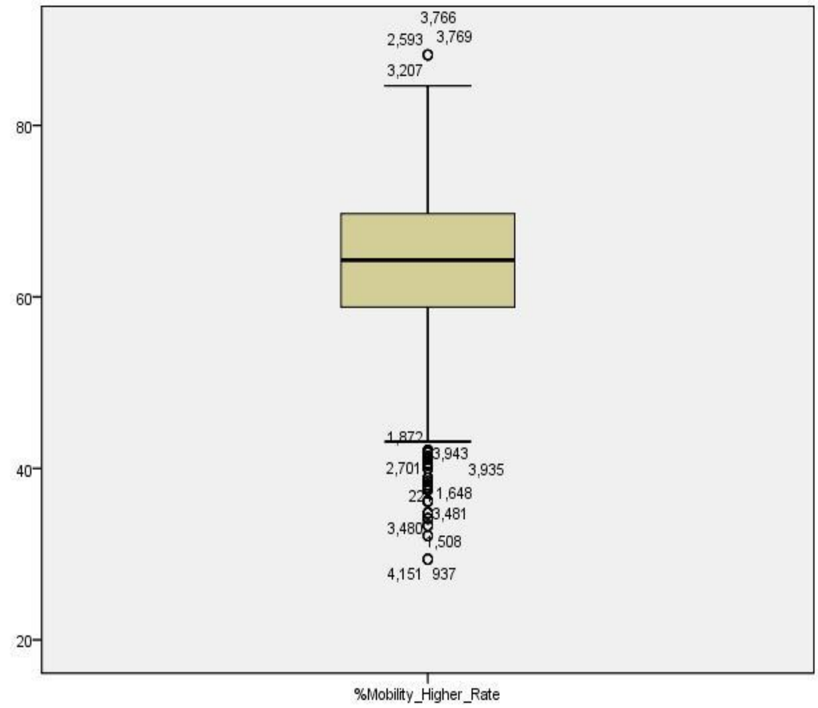

40
30
20
10
0
%Care_Nil_Rate

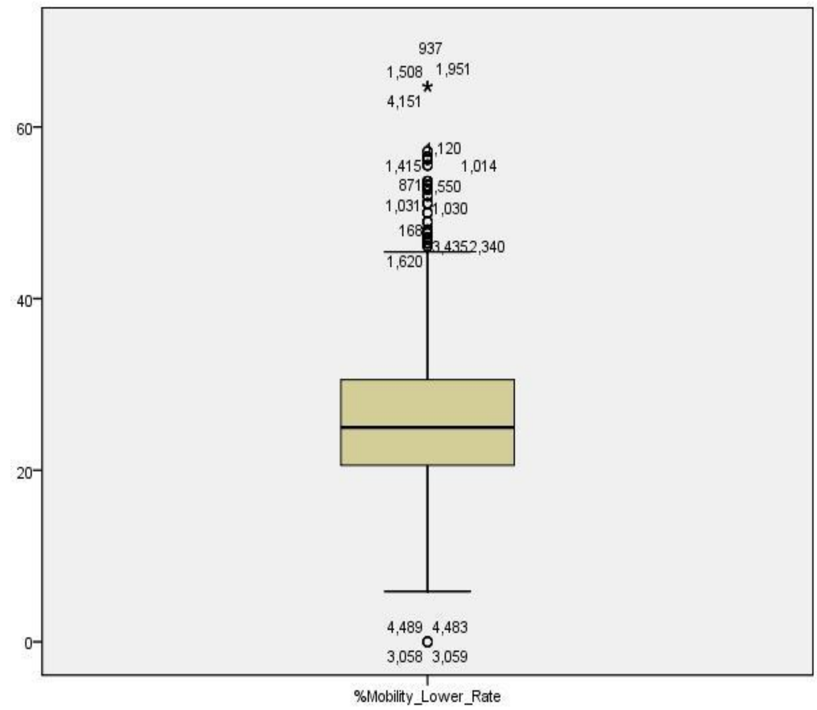

60
50
40
30
20
10
0
4,053
3,255
4,060
4,209
4,058
4,057
4,049
4,286
4,282
4,279
4,503
3,971
4,277
4,508
4,488
4,353
4,336
4,352
3,921
2,756
1,300
4,055
3,078
3,077
4,526
%Care_Higher_Rate

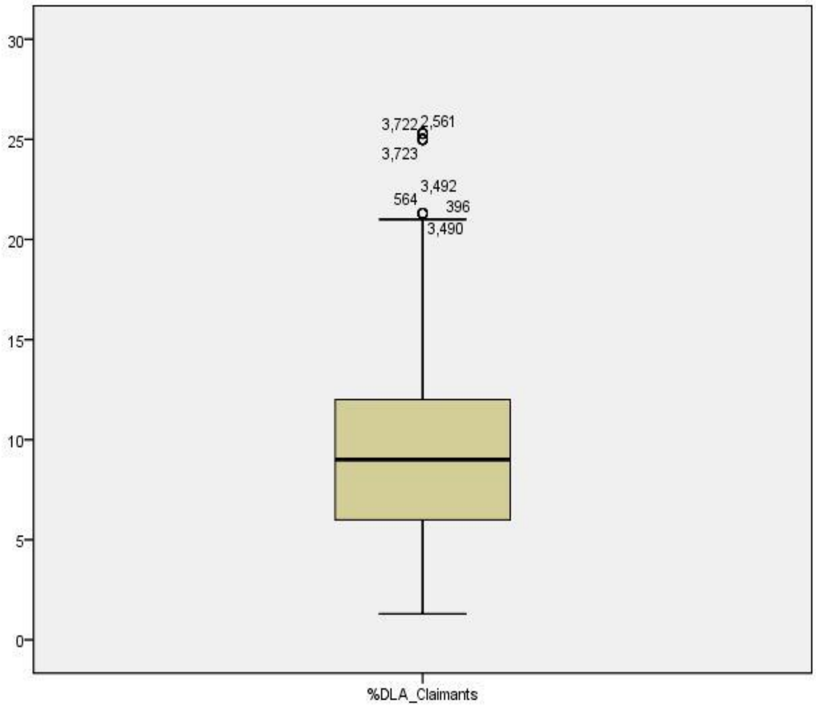

50
40
30
20
10
3,078
4,525
4,258
1,660
1,127
1,446
3,752
3,759
%Care_Middle_Rate

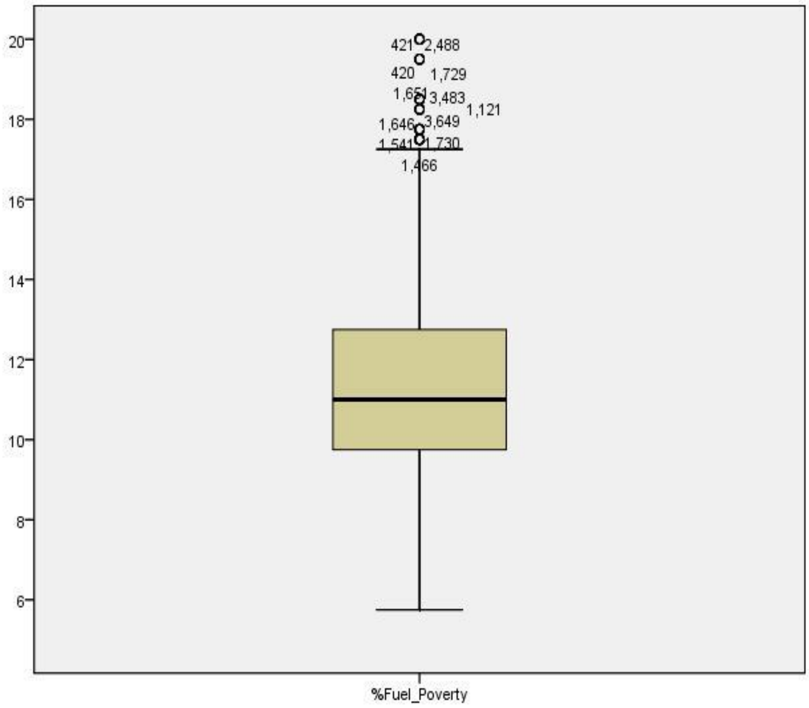

50
40
30
20
10
0
1,801
2,583
3,752
3,382
2,305
3,759
1,597
1,595
3,305
4,494
3,436
4,482
4,277
4,282
4,279
4,063
4,060
4,053
3,255
%Care_Lower_Rate

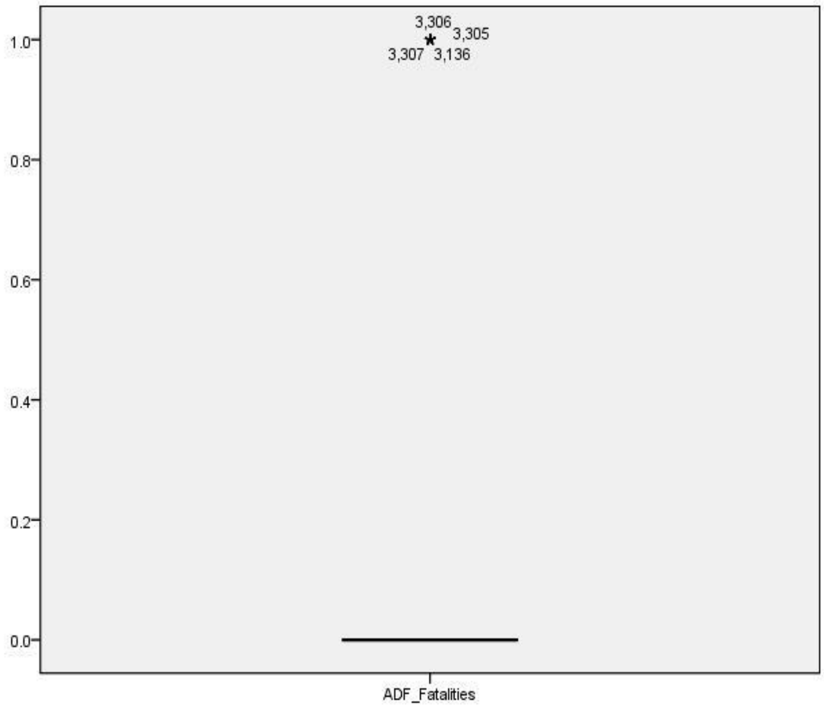

30
25
20
15
10
5
0
3,915
1,491
3,916
1,871
4,356
4,350
4,338
4,345
4,354
4,483
4,489
4,534
4,580
4,535
4,526
4,525
4,358
4,362
%Mobility_Nil_Rate

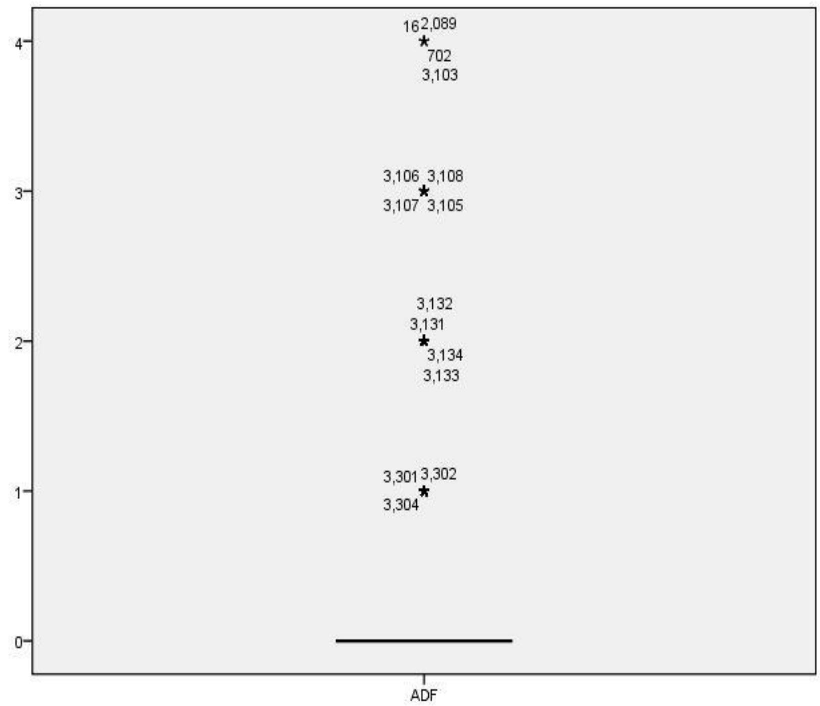

3,766
2,593 3,769
3,207
80
60
1,872
3,943
2,701
3,935
22
1,648
3,481
3,480
1,508
4,151 937
40
20
%Mobility_Higher_Rate

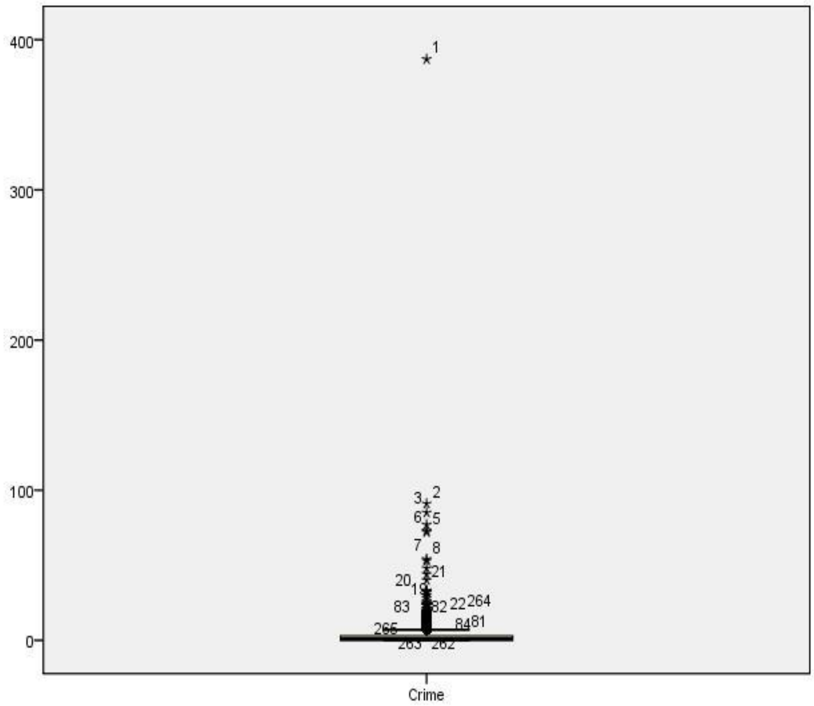

937
1,508 1,951
4,151
60
1,120
1,415 1,014
871 1,550
1,031 1,030
168
3,435 2,340
1,620
40
20
4,489 4,483
0
3,058 3,059
%Mobility_Lower_Rate

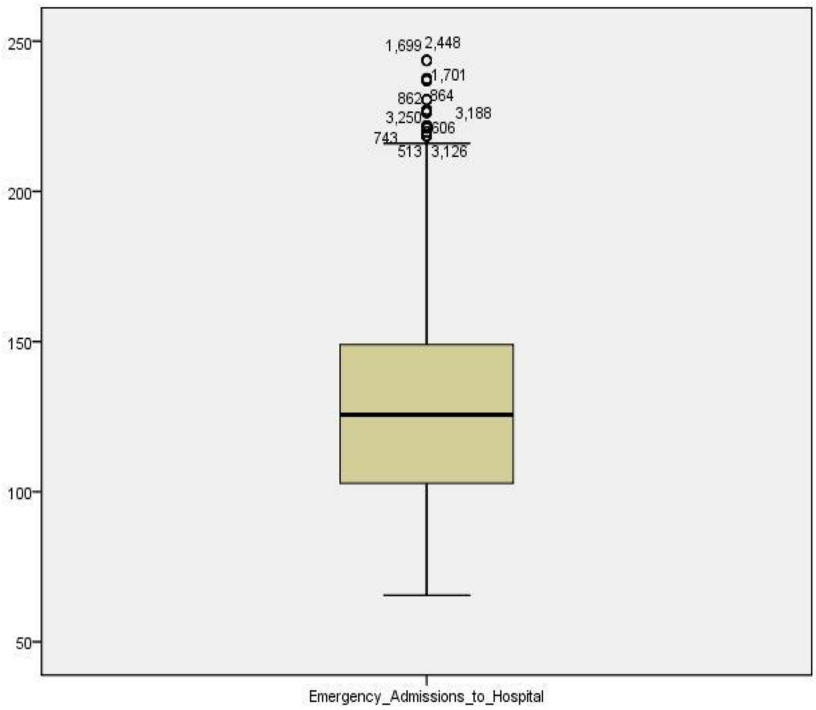

30
25
20
15
10
5
0
3,722
2,561
3,723
3,492
564
396
3,490
%DLA_Claimants

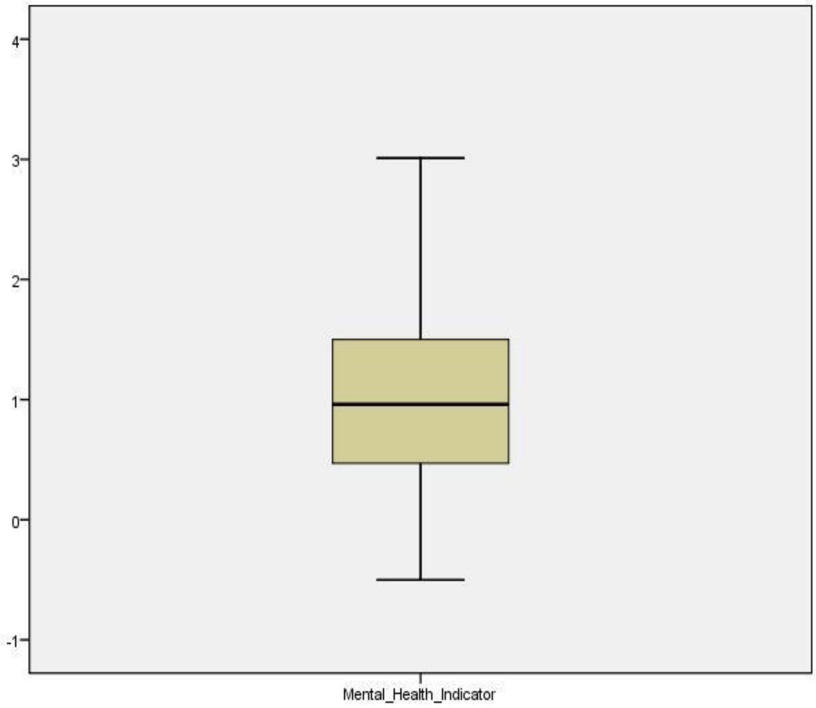

20
18
16
14
12
10
8
6
421
2,488
420
1,729
3,483
1,121
3,649
1,466
%Fuel_Poverty

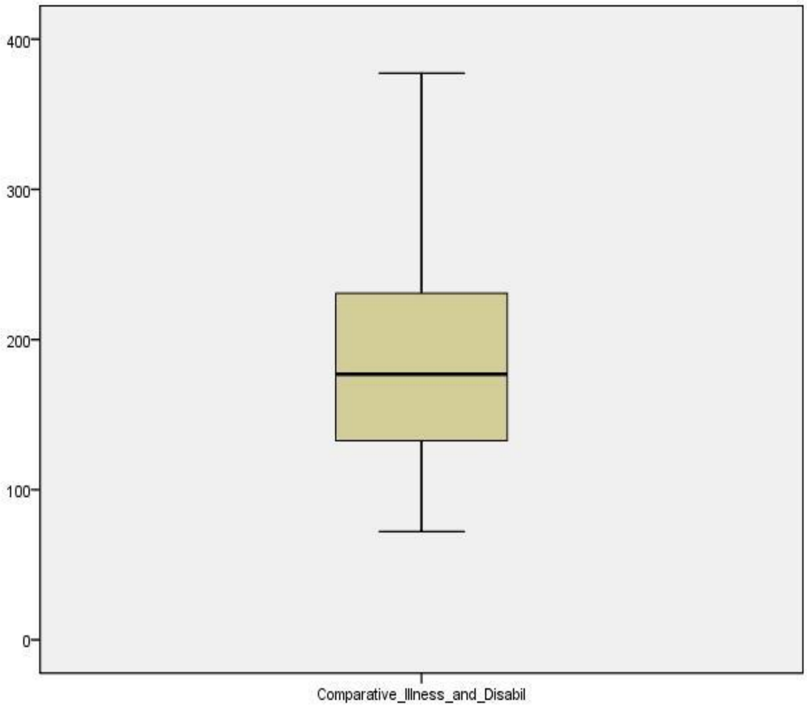

3,306
3,305
3,307
3,136
1.0
0.8
0.6
0.4
0.2
0.0
ADF_Fatalities

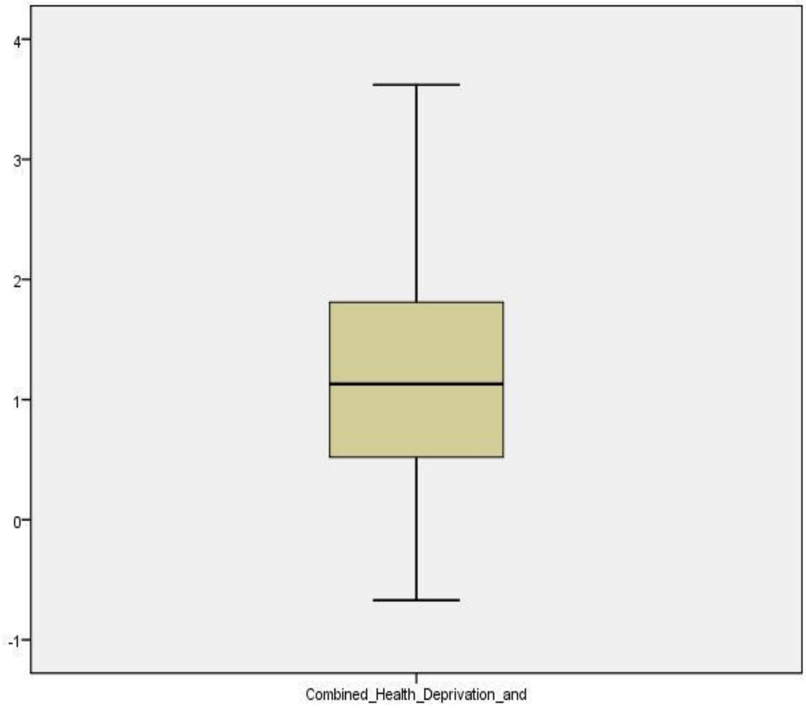

16
2,089
702
3,103
3,106
3,108
3,107
3,105
3,132
3,131
3,134
3,133
3,301
3,302
3,304
4
3
2
1
0
ADF


400
300
200
100
0
Crime

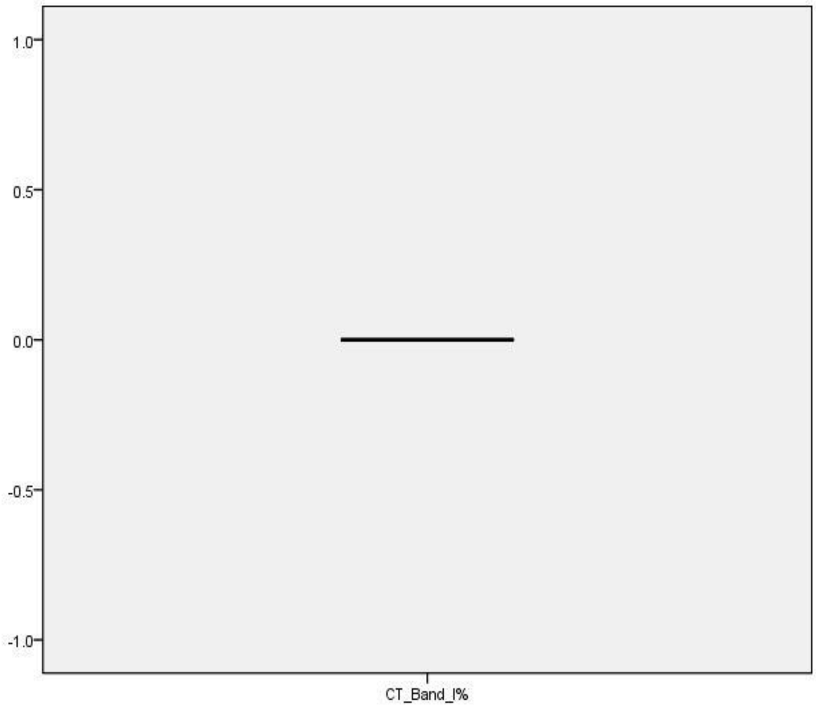

250
200
150
100
50
Emergency_Admissions_to_Hospital

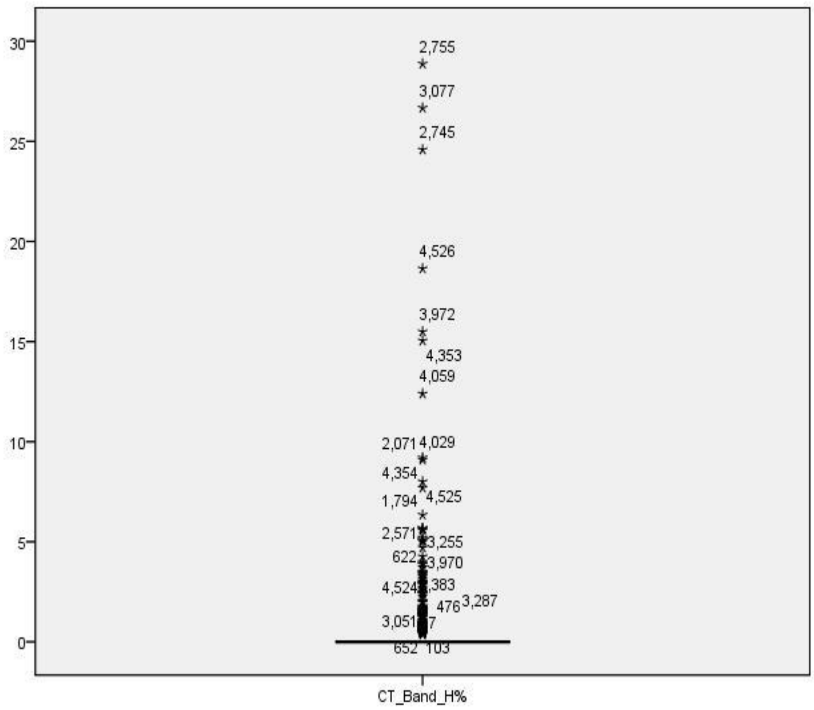

4
3
2
1
0
-1
Mental_Health_Indicator

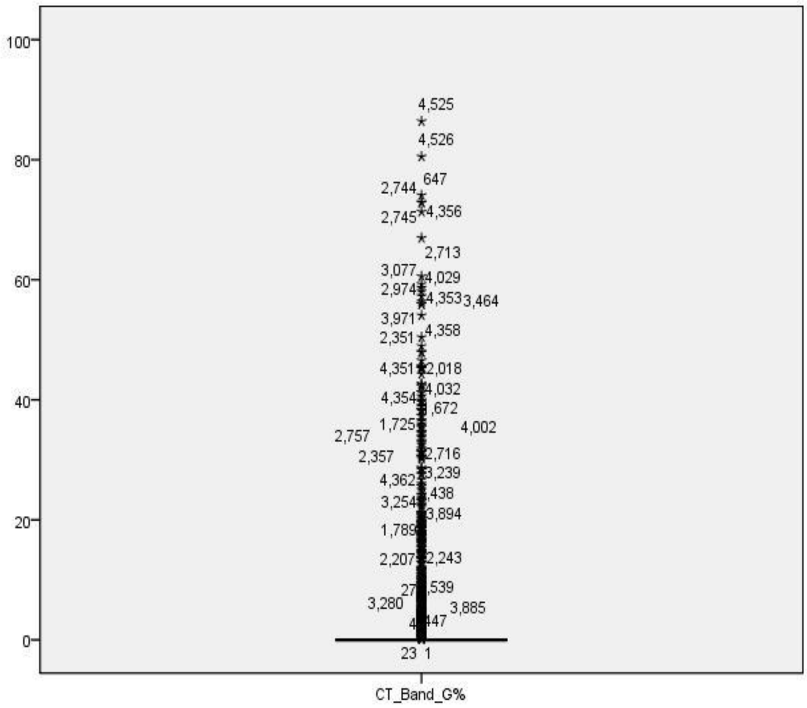

400
300
200
100
0
Comparative_Illness_and_Disabil

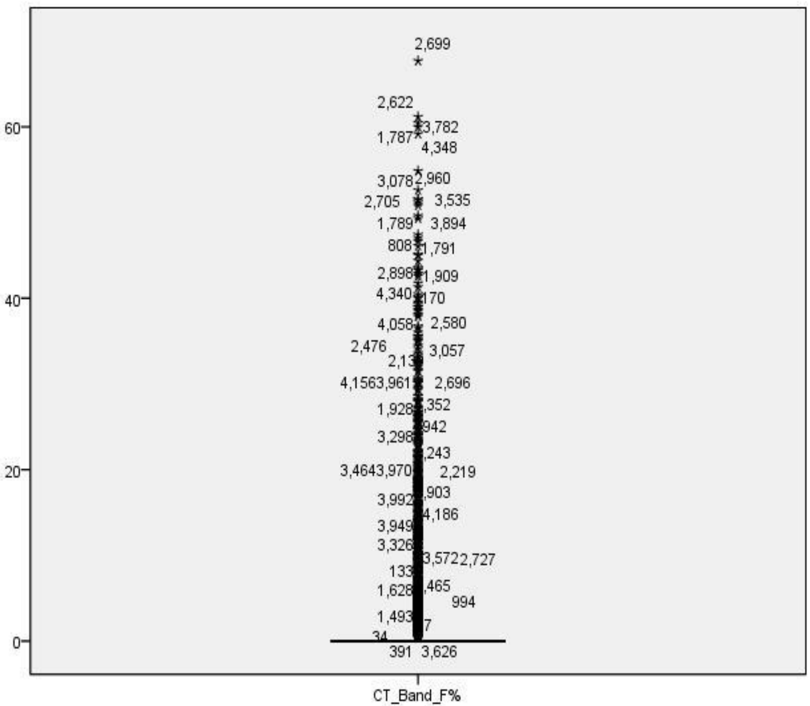

4
3
2
1
0
-1
Combined_Health_Deprivation_and

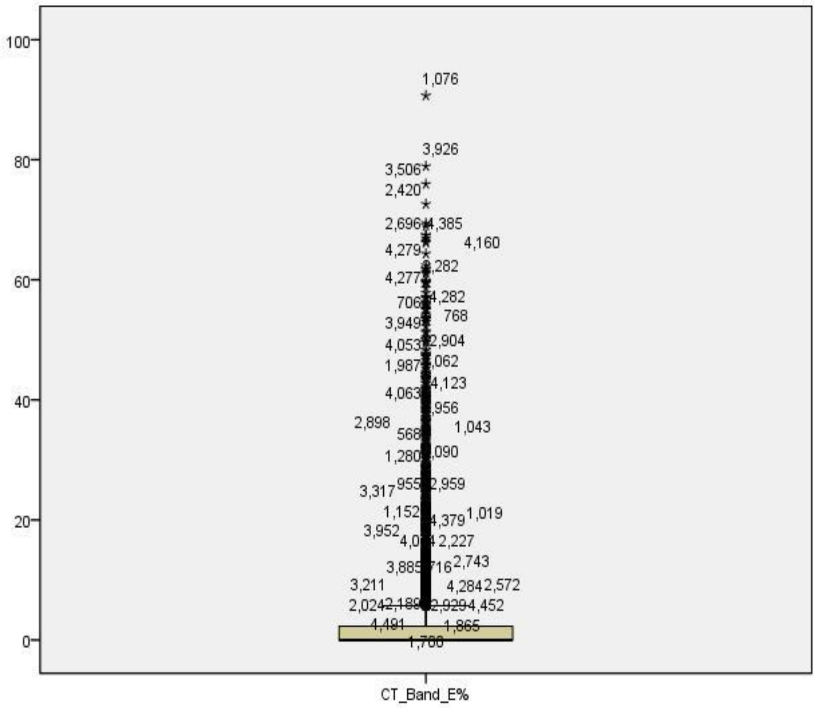

1.0
0.5
0.0
-0.5
-1.0
CT_Band_X%

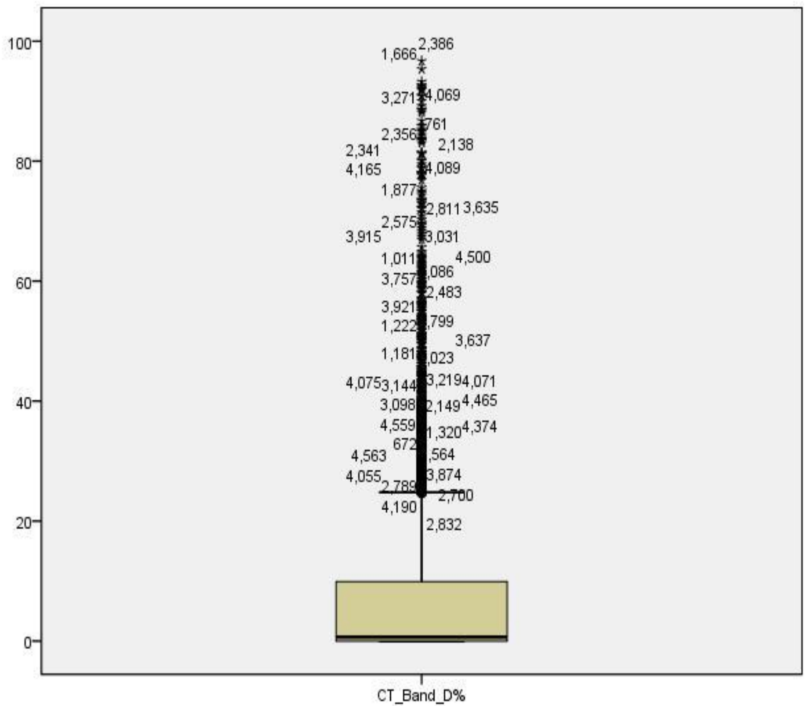

1.0
0.5
0.0
-0.5
-1.0
CT_Band_I%

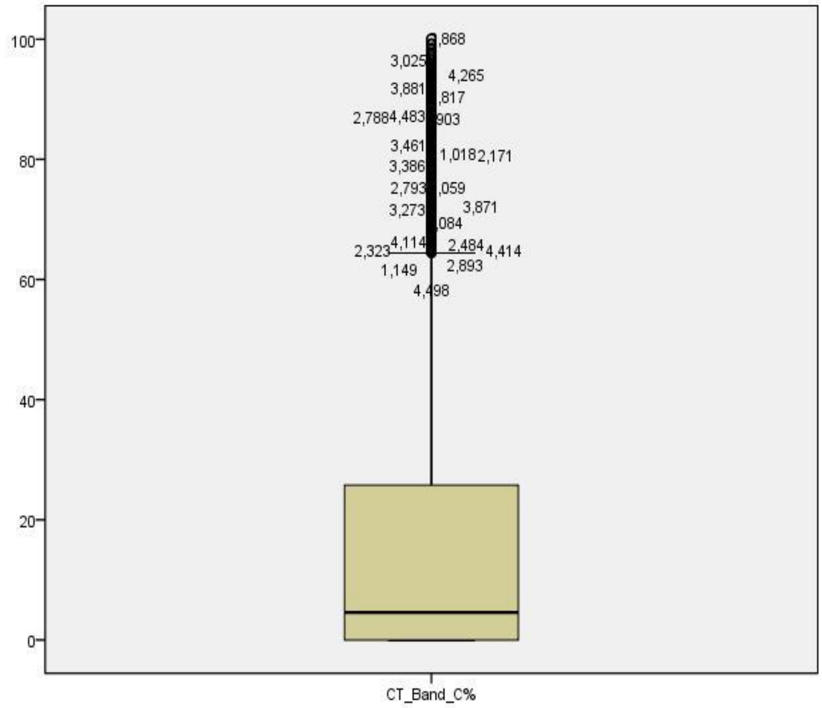

30
25
20
15
10
5
0
2,755
3,077
2,745
4,526
3,972
4,353
4,059
2,071
4,029
4,354
1,794
4,525
2,571
3,255
622
3,970
4,524
3,287
652
103
CT_Band_H%

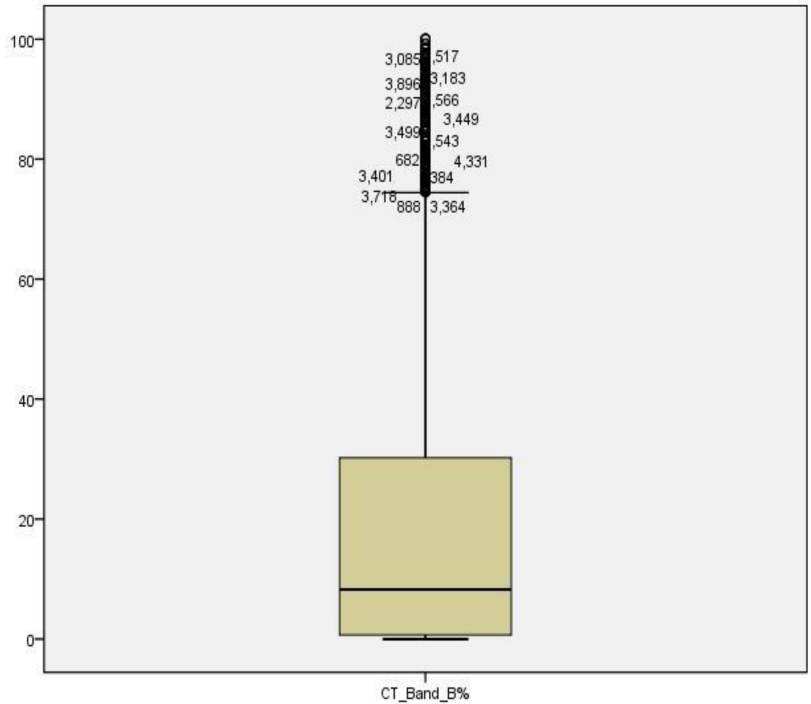

100
80
60
40
20
0
CT_Band_G%


60
40
20
0
CT_Band_F%


100
80
60
40
20
0
CT_Band_E%


100
80
60
40
20
0
CT_Band_D%


100
80
60
40
20
0
,868
3,025
4,265
3,881
,817
2,788
4,483
903
3,461
1,018
2,171
3,386
2,793
,059
3,273
3,871
,084
4,114
2,484
2,323
4,414
1,149
2,893
4,498
CT_Band_C%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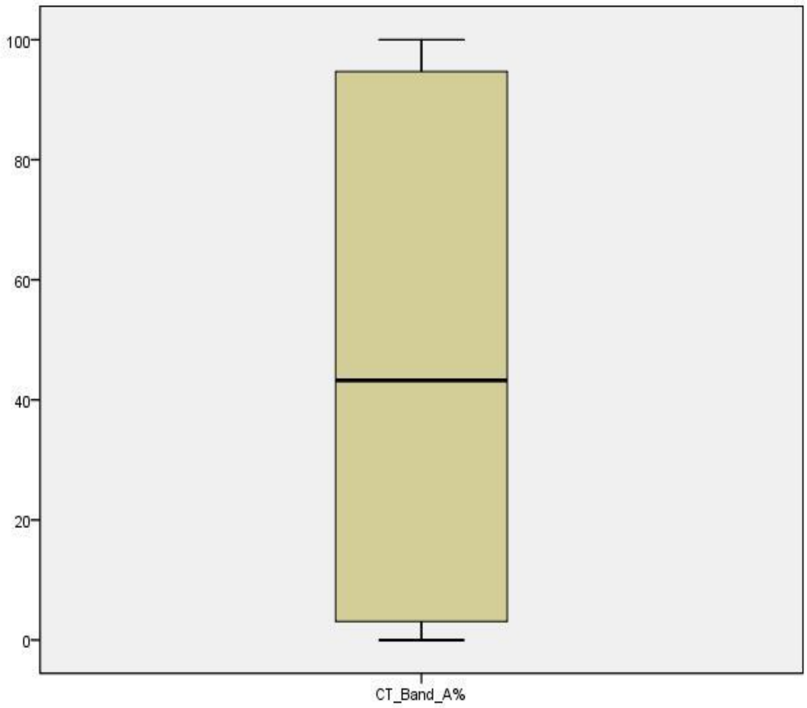
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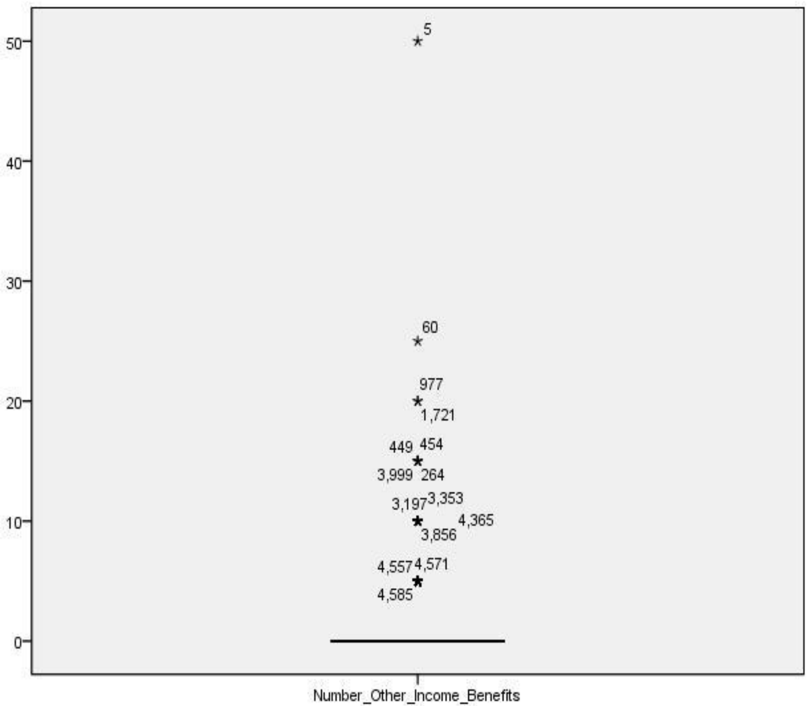
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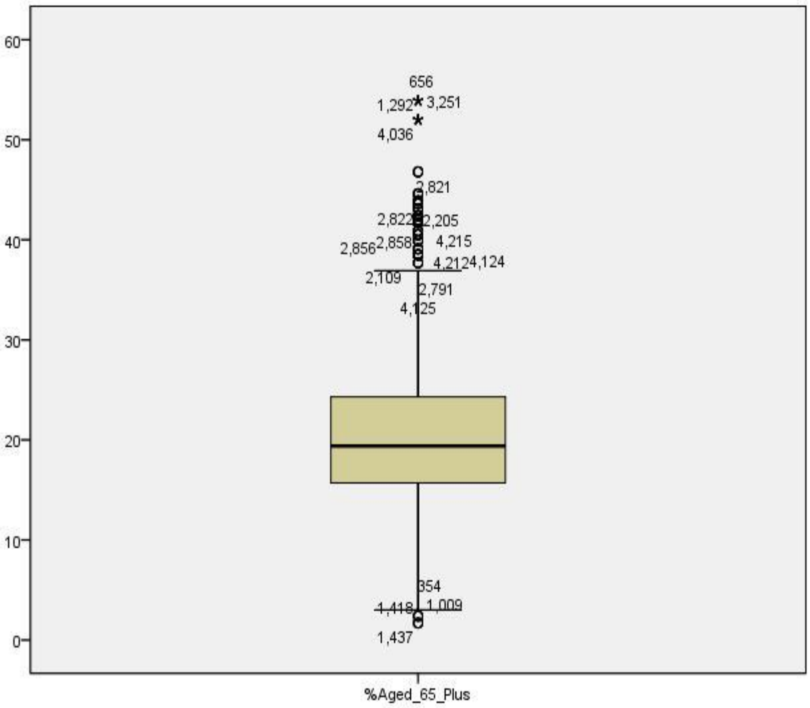

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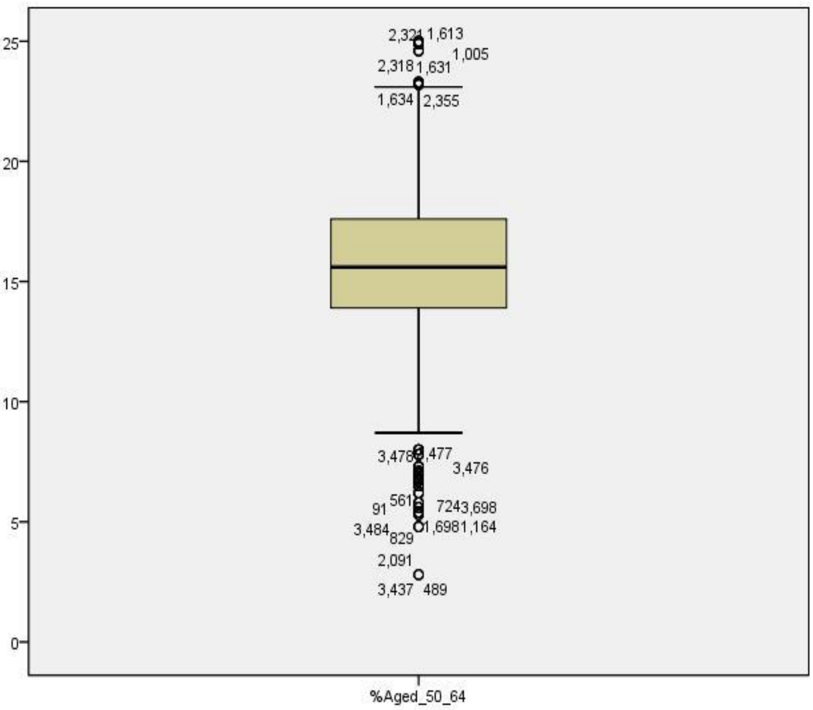

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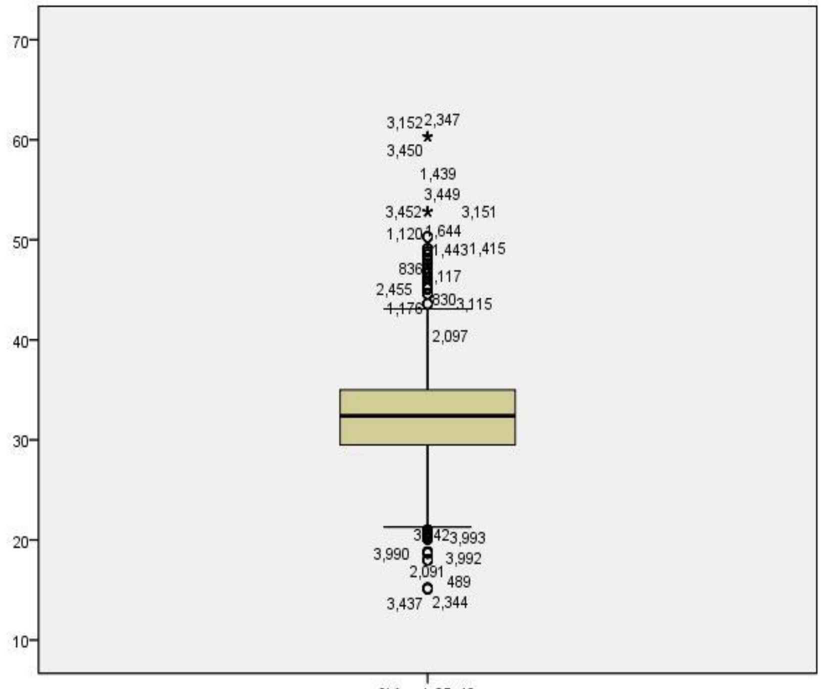
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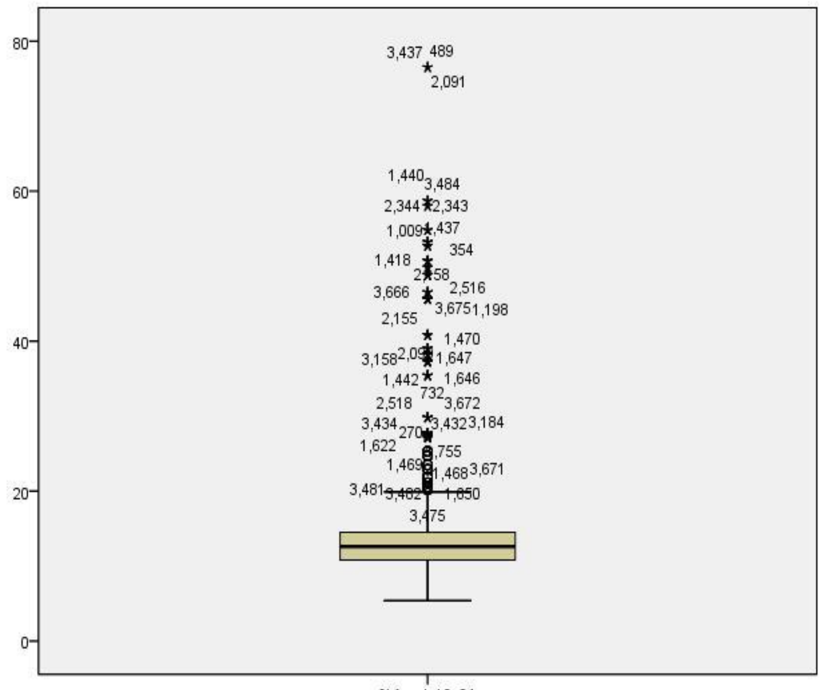
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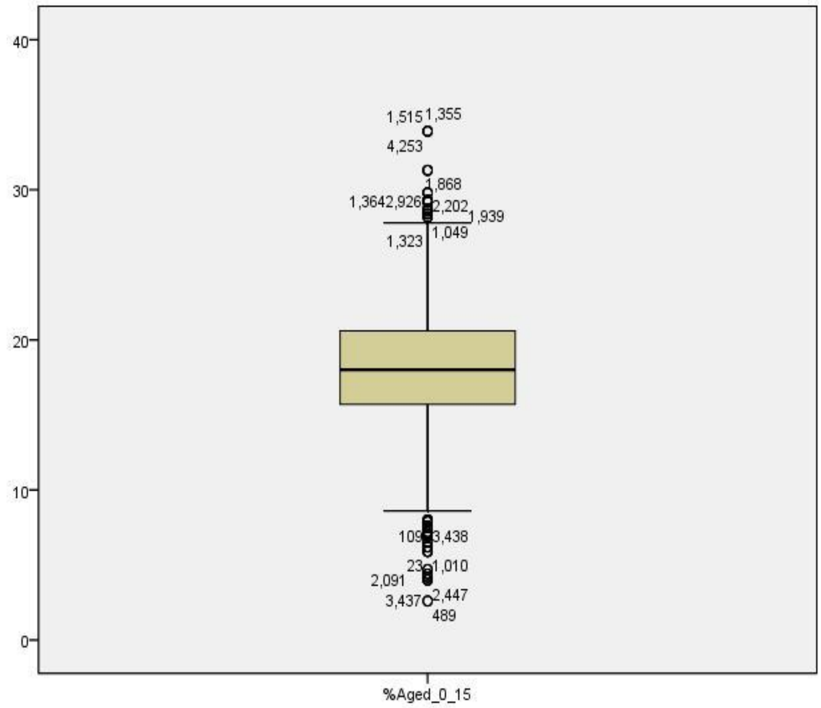

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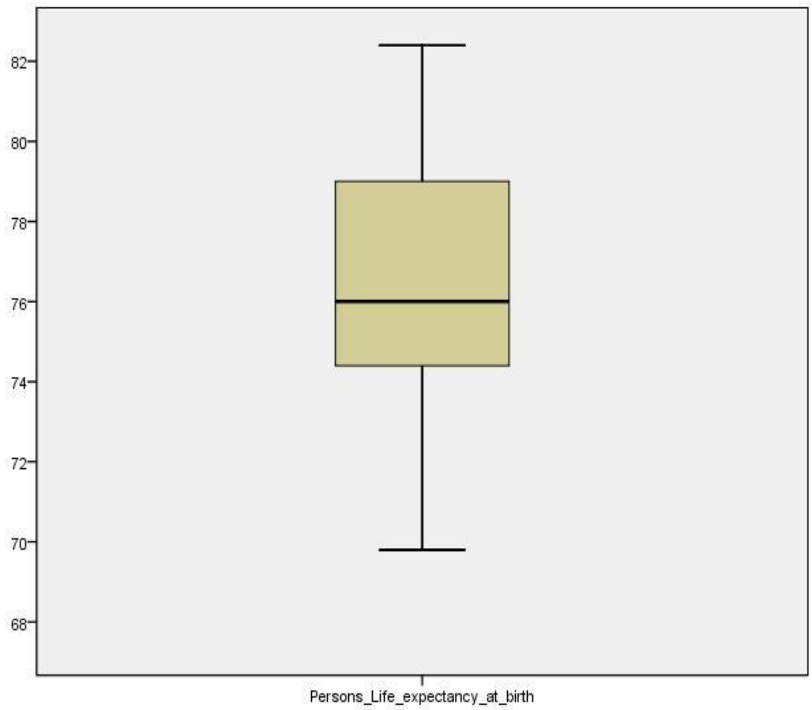

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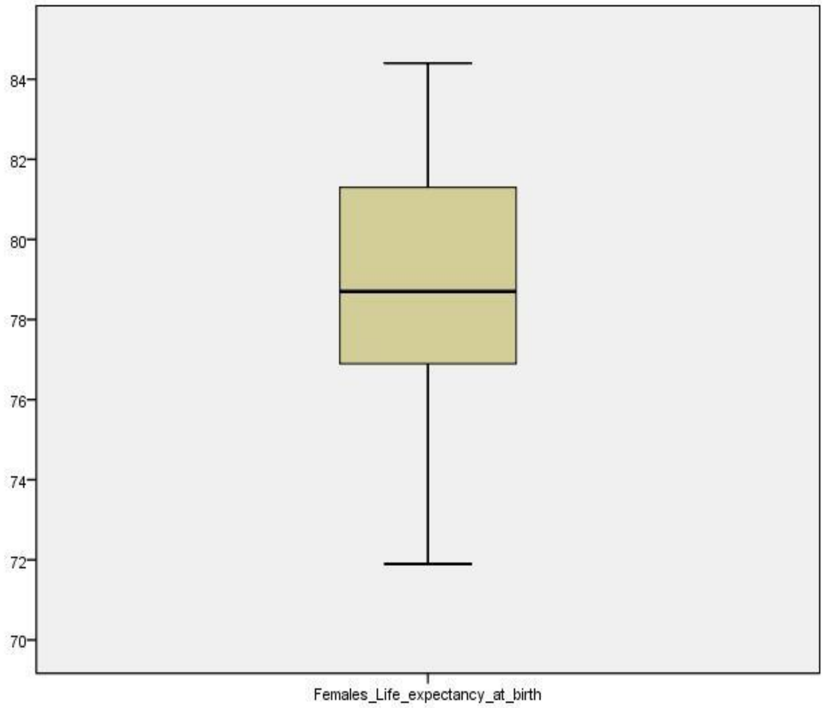
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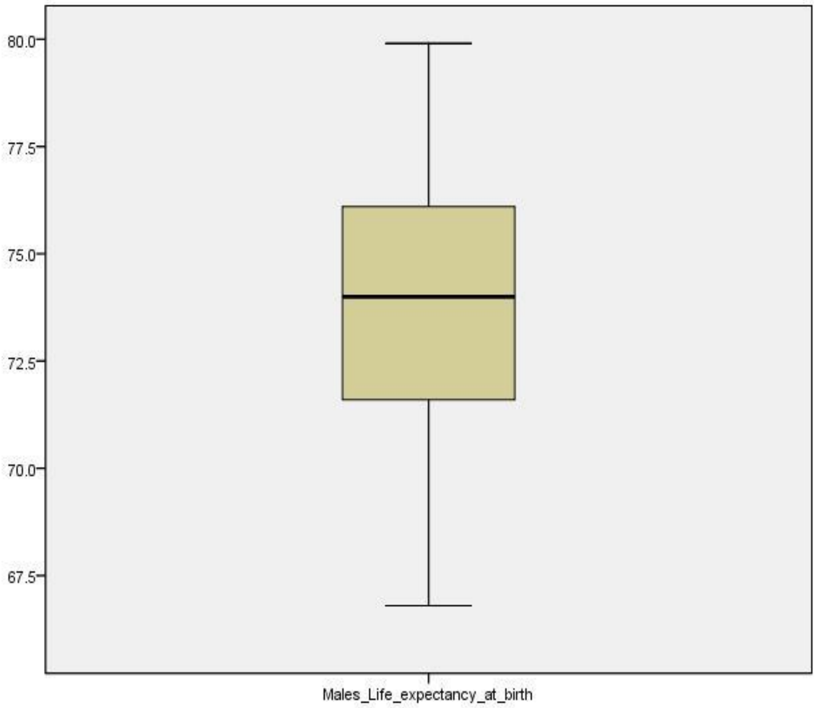
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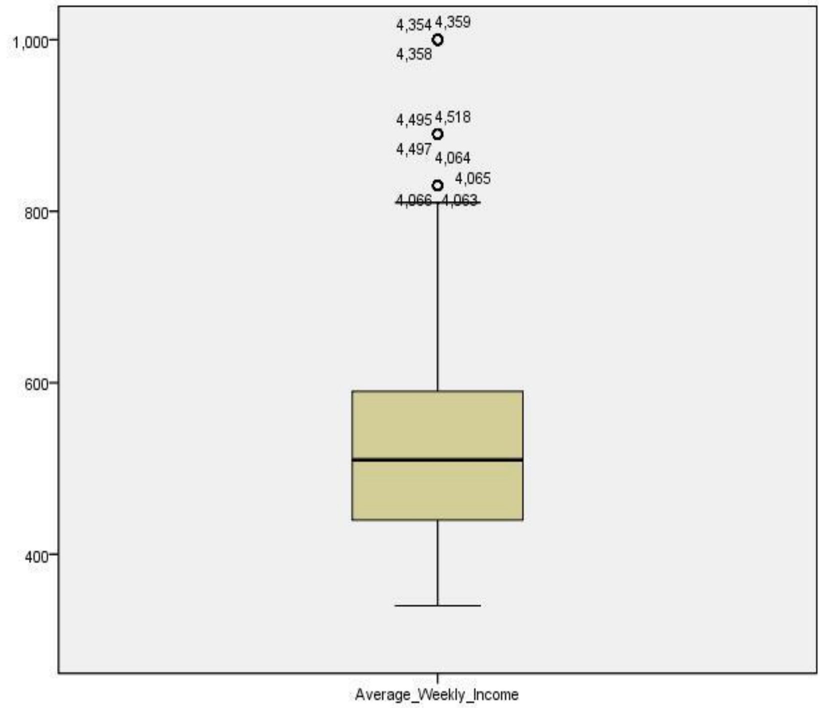

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Appendix B – Customer Insight Community Profiles

(The following images show summary pages of the Customer Insight Community Profiles developed for Merseyside Fire and Rescue Service)

Profile Group 1

Wealthy Over 50 Population in Semi-Rural Locations

577 Output Areas in Merseyside, 11.79% of Output Areas, Approx. 72,125 Households

Key information about Profile Group 1:

1. Wealthy, older population, in particular larger 65+ population

2. Privately owned, high value detached properties

3. High life expectancy

4. Households composition typically one family households, occupants aged over 65

5. Good levels of general health, with low obesity rates and low rates of emergency admissions to hospital

6. Low levels of health inequalities

7. Generally low benefit need, however there may be a need for disability related benefits

8. Low crime levels within the local area

9. Low numbers of accidental fires and related fatalities

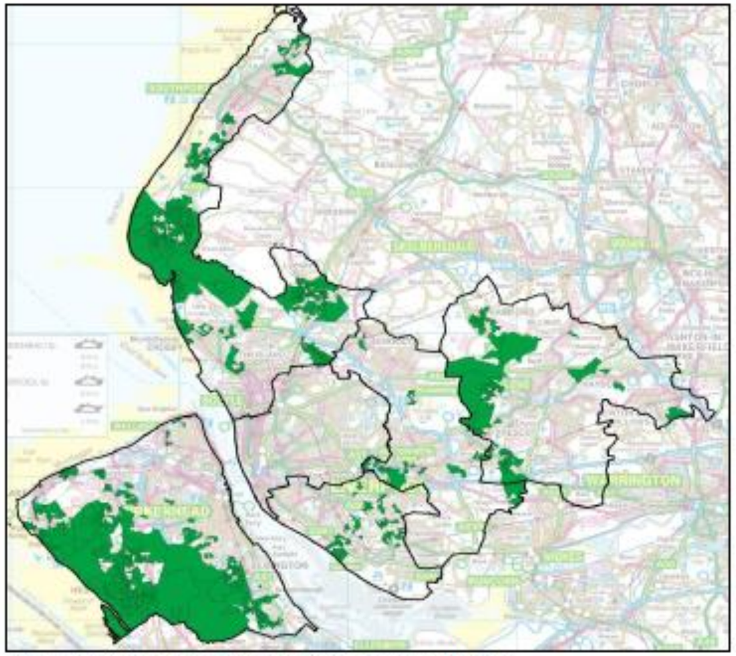
10. Less likely to participate in sport, however activities such as golf and bowls appeal. Improving access to facilities is likely to increase participation

11. Generally low levels of fuel poverty and low levels of poor quality housing

12. May be willing to volunteer within their local community

Communication Preferences:

Almost 89% of residents within this group have a landline telephone. In addition, approximately 80% have a mobile telephone. However, nearly 35% of residents do not have internet access at home.



Profile 1 – Wealthy Over 50 Population in Semi-Rural Locations

Profile Group 2

Older Retirees

223 Output Areas in Merseyside, 4.56% of Output Areas, Approx. 27,875 Households

Key information about Profile Group 2:

1. Older population. Most overrepresented group is 75-84. Most underrepresented group is 30-44

2. Privately owned or rented, high value detached properties

3. Higher life expectancy than average

4. Household composition is most likely to be single residents aged over 65

5. Fair levels of general health and high rates of emergency admissions to hospital

6. Higher than average number of deaths to heart disease, cerebrovascular disease and cancers

7. Low levels of health inequalities

8. Generally low benefit need, however there may be a need for disability related benefits

9. Low crime within the local area

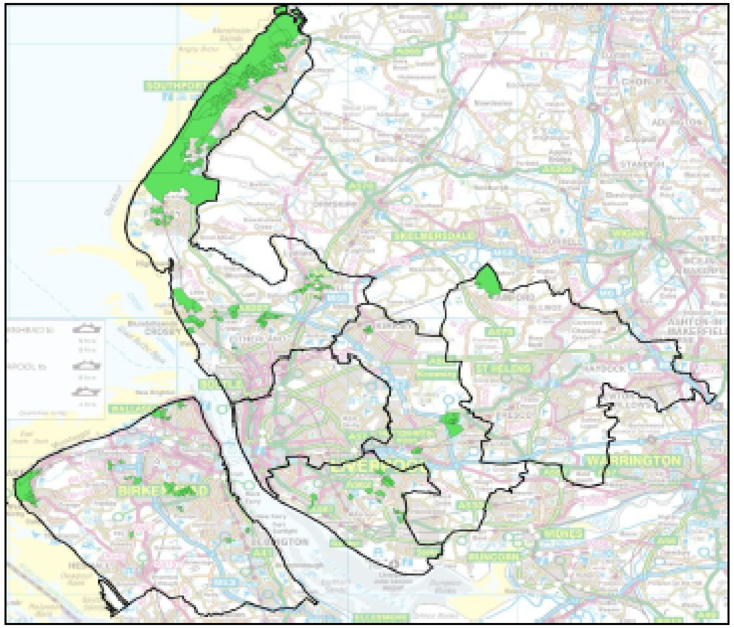
10. Generally low rate of accidental dwelling fire fatalities

11. Very unlikely to participate in sport, and also unlikely to want to participate in more sport. However activities such as golf, bowls and dance appeal

12. May need to be aware of fuel poverty and issues relating to housing conditions

Communication Preferences:

Approximately 67% of residents within this profile group have access to a landline telephone, however approximately 88% of residents have a mobile telephone. There is a high proportion of residents with internet access.



Profile Group 3

Middle Income Residents Families in Privately Owned Properties

812 Output Areas in Merseyside, 16.59% of Output Areas, Approx. 101,500 Households

Key information about Profile Group 3:

1. Overrepresented in age bands 45-64. Of the over 65 population, the 85-89 group is most populous.

2. Privately owned semi-detached properties

3. Typically the living environment for residents within this profile group is better than what is seen on average across Merseyside

4. Higher life expectancy than average

5. Household composition is typically one family households with children

6. Good levels of general health with low rates of emergency hospital admissions and low rates of illness and disability

7. Low levels of health inequalities

8. Generally low benefit need, however there may be a need for disability related benefits.

9. Low crime levels. Crimes are most likely to be related to anti-social behaviour

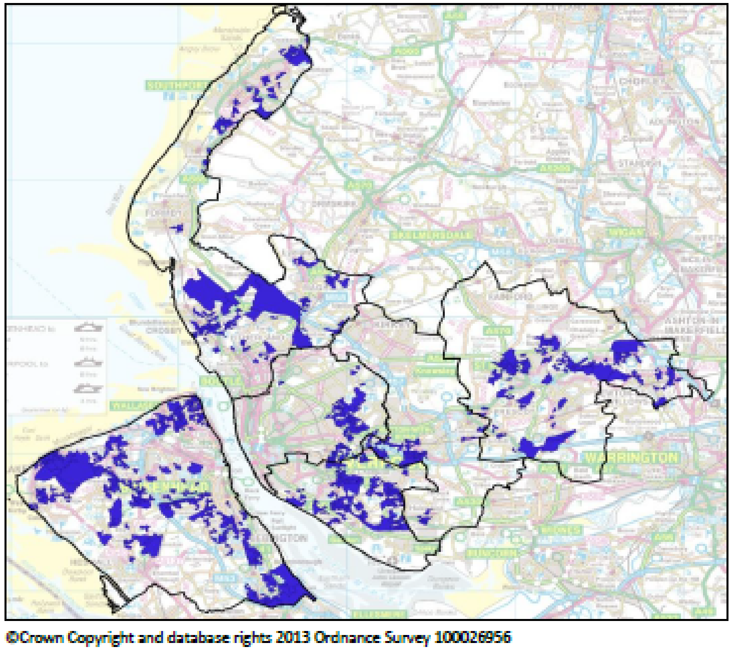
10. Approximately average number of accidental dwelling fires, but historically higher rate of accidental dwelling fire fatalities

11. Approx. 47% would like to participate in more sport.

12. More likely to volunteer or participate in local community groups.

Communication Preferences:

Over 90% of residents within this profile group have a landline telephone in their home. In addition to this, approximately 94% have a mobile telephone and 80% have internet access



Profile Group 4

Average Income, Older Residents

556 Output Areas in Merseyside, 11.36% of Output Areas, Approx. 69,500 Households

Key information about Profile Group 4:

1. Most populous age groups are 45-59 and 60-64

2. Privately owned semi-detached properties

3. Low levels of fuel poverty and better housing quality and living environment

4. Higher life expectancy than average and lower birth rate

5. Typically married couples with children

6. Good levels of general health with low rates of emergency hospital admissions and low rates of illness and disability

7. Low levels of health inequalities

8. Low need for income related benefits, but may be an increased need for some disability benefits, such as Disability Living Allowance

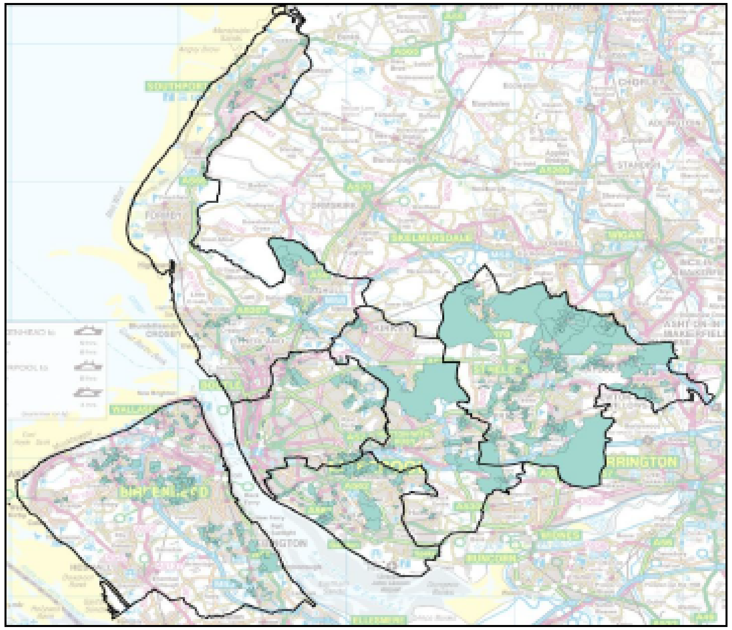
9. Low crime levels. Crimes are most likely to be related to anti-social behaviour. Slightly increased number of vehicle crime incidents

10. Approximately average number of accidental dwelling fires and related Fatalities

11. Less likely to participate in sport, but 47% would like to participate in more. Activities such as swimming are likely to appeal

Communication Preferences:

Approximately 80% of residents within this profile group have a landline telephone in their home. In addition to this, approximately 86% have a mobile telephone and 60% have internet access



Profile Group 5

Students and Young Professionals in City Centre Locations

123 Output Areas in Merseyside, 2.51% of Output Areas, Approx. 15,375 Households

Key information about Profile Group 5:

1. Significantly large 18-24 and 25-29 populations, likely to be related to the student and young professional population in Liverpool

2. Very diverse ethnic population

3. Privately rented purpose built and converted flats

4. Typically living in communal establishments or shared dwellings

5. Higher levels of fuel poverty, poor quality housing and poor living environment

6. Very transient population

7. Very good levels of general health but high rates of emergency hospital admissions

8. Low obesity rate

9. High need for income related benefits, but lower need for child related benefits

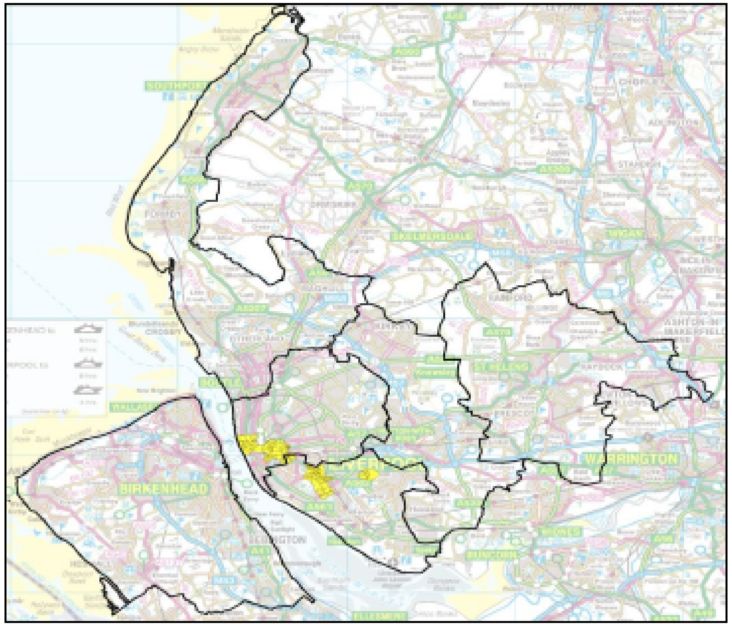
10. High crime rates. Burglary and violent crimes most overrepresented

11. Higher number of accidental dwelling fires, but low fatality rate

12. Very likely to participate in at least 3 sessions of sport each week. Activities such as athletics, basketball, boxing, football and dance appeal

Communication Preferences:

Approximately 65% of residents within this profile group have a landline telephone in their home. In addition to this, approximately 87%
Have a mobile telephone and 87% have internet access



Profile Group 6

Young Families in Privately Owned Properties

574 Output Areas in Merseyside, 11.73% of Output Areas, Approx. 71,750 Households

Key information about Profile Group 6:

1. Large 0 -17 and 30-44 population, representing families with children

2. Living in privately owned semi-detached or terraced properties

3. Lower levels of fuel poverty and typically good quality homes and living environment

4. High birth rate

5. Household composition is typically cohabiting couples with children

6. General health of residents is good with low rates of emergency hospital admissions and low health inequalities

7. Higher rates of obesity in children

8. High need for child related benefits, but low levels of child poverty. Low levels for income related benefits

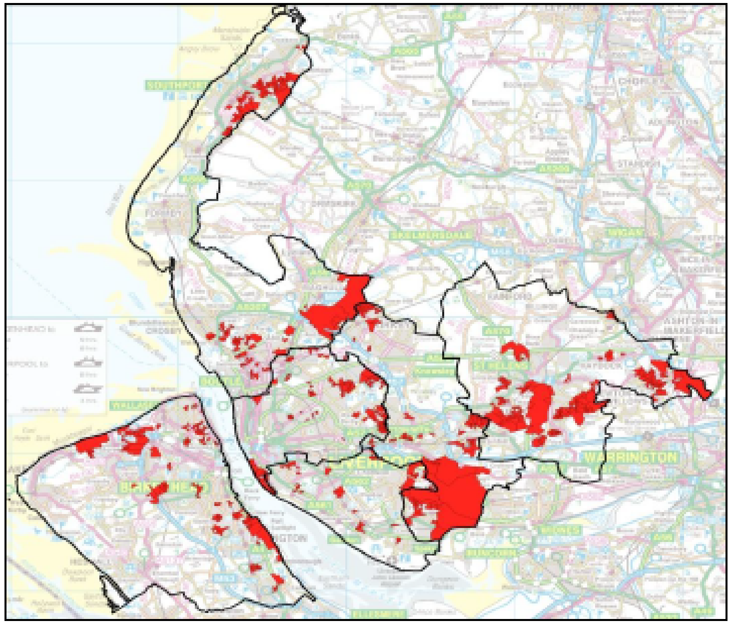
9. Low crime rates. Most common crimes are anti-social behaviour or burglary

10. Low number of accidental dwelling fires and low fatality rate

11. Very likely to participate in at least 3 sessions of sport each week. Improved childcare and less busy facilities may increase participation. Activities such as basketball and netball appeal

Communication Preferences:

Approximately 70% of residents within this profile group have a landline telephone in their home. In addition to this, approximately 95% have a mobile telephone and 67% have internet access at home



Profile Group 7

Families with High Benefit Need

833 Output Areas in Merseyside, 17.02% of Output Areas, Approx. 104,125 Households

Key information about Profile Group 7:

1. Large 0-15 population. Also large 25-34 population. Of the over 65 population, the most significant group is 60-64

2. Rented terraced properties

3. High levels of fuel poverty and typically poorer quality homes and living environment

4. High birth rate and lower life expectancy

5. Higher rates of lone parent families and cohabiting couples with children

6. Higher levels of poor general health and high rates of emergency hospital admissions and health inequalities. Prevalence of mental health problems

7. Higher rates of obesity in children and adults

8. Need for child related benefits and high levels of child poverty. High need for income related benefits and disability benefits. High need for adult social care services

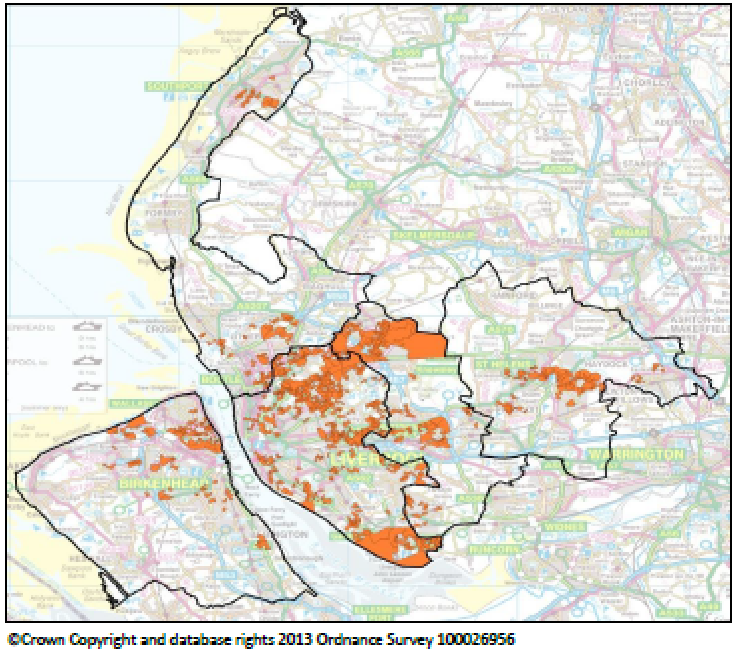
9. High rates of anti-social behaviour and robbery.

10. High number of accidental dwelling fires but lower fatality rate

11. Less likely to participate sport, but 52% would like to participate in more sport. Barriers include opening hours and admission fees. Activities such as boxing, rounders and netball appeal

Communication Preferences:

Approximately 63% of residents within this profile group have a landline telephone in their home. In addition to this, a high proportion of residents
have a mobile telephone and 55% have internet access at home



Profile Group 8

Residents in Social Housing

304 Output Areas in Merseyside, 6.21% of Output Areas, Approx. 38,000 Households

Key information about Profile Group 8:

1. Large 0-17 population. The 16-49 population is similar to average

2. Terraced properties rented from a social landlord

3. Low levels of fuel poverty and typically decent quality homes and living environment

4. Lower than average life expectancy

5. Household composition typically single occupancy households or lone parent families

6. General health is typically poor and high rates of emergency hospital admissions and health inequalities. Prevalence of mental health problems

7. Higher rates of obesity in children and adults

8. Need for child related benefits and high levels of child poverty. High need for income related benefits, especially job seekers allowance, and disability benefits

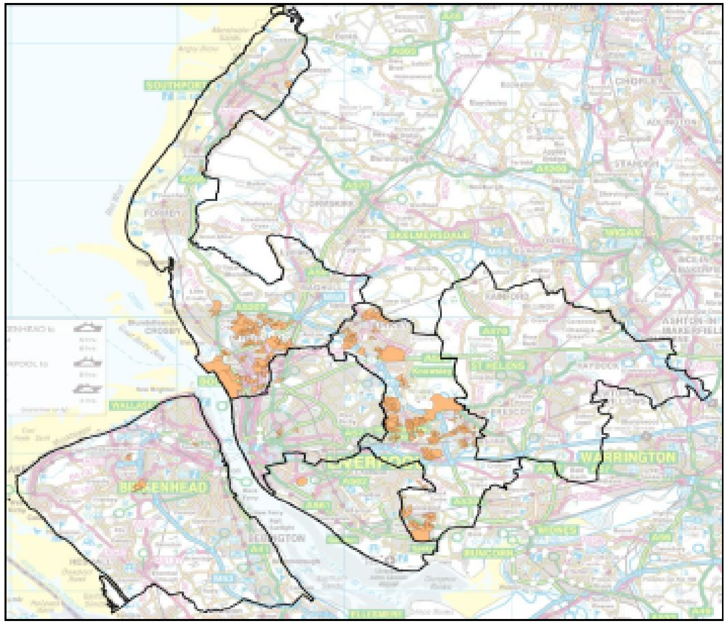
9. High rates of anti-social behaviour, robbery and vehicle crime.

10. High number of accidental dwelling fires but lower fatality rate

11. Less likely to participate sport, but 52% would like to participate in more sport. Barriers include access to childcare and admission fees. Activities such as dance, rounders and netball appeal

Communication Preferences:

Approximately 97% of residents within this profile group have a landline telephone in their home. In addition to this, a high proportion of residents
have a mobile telephone and 70% have internet access at home



Profile Group 9

Transient Population in Poor Quality Housing

175 Output Areas in Merseyside, 3.56% of Output Areas, Approx. 21,875 Households

Key information about Profile Group 9:

1. Large population aged under 45

2. Terraced properties or flats rented from a social landlord. Increased likelihood of shared dwellings

3. High levels of fuel poverty and typically poorer quality homes

4. Higher than average Asian population

5. Lower than average life expectancy, high birth rate and transient population

6. Higher levels of poor general health and high rates of emergency hospital admissions and health inequalities. Prevalence of mental health problems.

7. Higher rates of obesity in children and adults.

8. Need for child related benefits and high levels of child poverty. High need for income related benefits, especially job seekers allowance, and disability benefits

9. Need for council tax and housing benefits

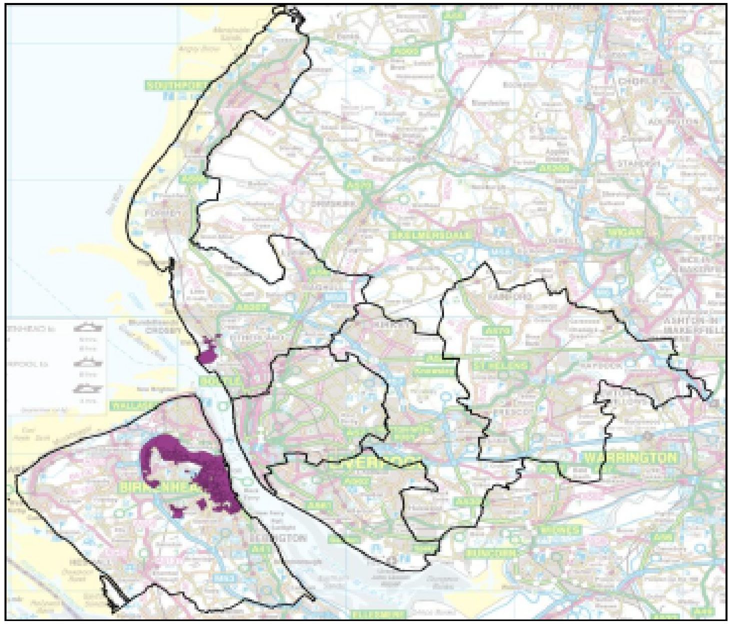
10. Very high crime rate

11. Lower number of accidental dwelling fires but high fatality rate

12. Likely to participate sport, but 57% would like to participate in more sport.

Communication Preferences:

Approximately 96% of residents within this profile group have a landline telephone in their home. In addition to this, a high proportion of residents have a mobile telephone and 53% have internet access at home



Profile Group 10

Urban Population in High Levels of Deprivation

717 Output Areas in Merseyside, 14.65% of Output Areas, Approx. 89,625 Households

Key information about Profile Group 10:

1. Larger under 35 population.

2. Terraced properties or flats rented from a private landlord

3. High levels of fuel poverty and typically poorer quality homes

4. Lower than average life expectancy, high birth rate and very transient population

5. Very diverse ethnic population

6. Higher levels of poor general health and high rates of emergency hospital admissions and health inequalities. Prevalence of mental health problems

7. Higher rates of obesity in children and adults.

8. Need for child related benefits and high levels of child poverty. High need for income related benefits, especially employment and support allowance, and disability benefits

9. Need for adult social care services

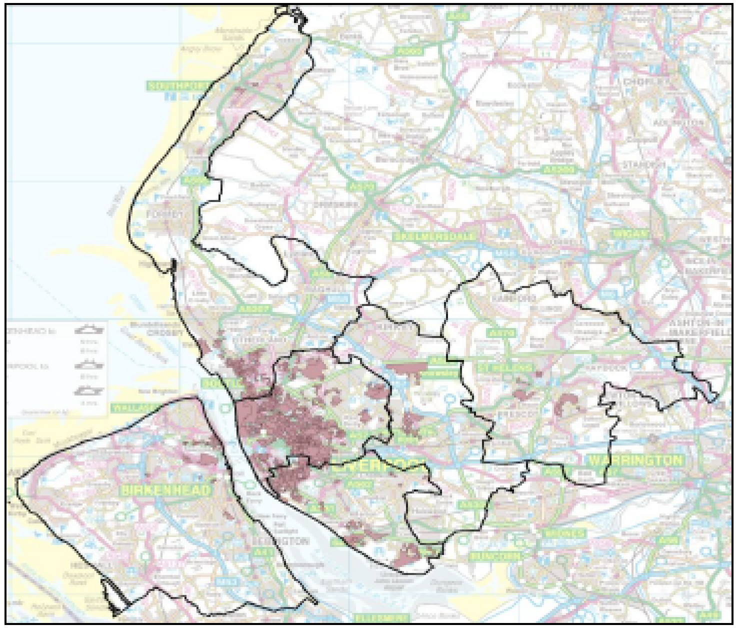
10. Very high crime rate.

11. Higher number of accidental dwelling fires and high fatality rate

12. Likely to participate sport, but 55% would like to participate in more sport.

Communication Preferences:

Approximately 48% of residents within this profile group have a landline telephone in their home. In addition to this, a high proportion of residents have a mobile telephone and 75% have internet access at home



Appendix C – Flow Chart Describing Both Strands of Customer Insight