Incidences of deliberate fire in West Yorkshire: Spatio-temporal patterns and influences on trends.

Annabel Elizabeth Whipp

200835263

BA Geography

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ABSTRACT.

As a form of crime which is no longer experiencing a notable decline, arson is of increasing concern to both the police force and the fire and rescue service. The potentially life threatening consequences of this crime, which is reportedly rising as a form of youth anti-social behaviour, make tackling the issue a key priority for the bodies involved. The stark spatial variations in the locations in which these crimes are committed are also a cause for concern for interested parties. The literature suggests a concentration of arson in locations which are associated with deprivation, young people, poor education and social housing. This study investigates the validity of these claims expressed in previous research, in relation to the case study of West Yorkshire utilising a variety of spatial statistical tools. It does so by defining the dispersion of the data through spatial autocorrelation and examining hot spots and cold spots in the region utilising Getis Ord Gi*. Anselin Local Moran's I is then used to analyse clusters and outliers present, prior to conducting a regression analysis to examine the relationship between rates of deliberate fire and socioeconomic variables previously deemed to be influential. The findings from each method of study are then discussed and then conclusions are drawn.

The analysis reveals that wards in the central areas of Bradford and Leeds experience the highest proportion of hot spots and clustering throughout 2008 to 2016, with a reduction of the number of hotspots in Leeds over time. The regression concluded that it was likely that there was a relationship between mean age, unemployment and household deprivation and the deliberate rates of fire and was found to be significant in all years of study.

Key words:

Fire, Arson, Deprivation, Spatial, Socioeconomic, Moran's I, Hotspot, Clusters, ArcMap.

WORD COUNT: 10,000

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1.0 INTRODUCTION

1.1 Introduction

This project will examine the spatial patterns of incidences of deliberate fire in the five Metropolitan Boroughs of West Yorkshire; Bradford, Calderdale, Kirklees, Leeds and Wakefield between the years of 2008 and 2016.

Fire poses a serious threat to both life and property and is commonly divided into two distinct categories; accidental and deliberate (Home Office a, 2016). In 2015/2016, 45% of the fires attended across England were deliberate, with the number of deliberate fires rising by 7% when compared to the data from 2014/2015 (Home Office b, 2016). 2015/2016 also marked the first year since 2006 that there had been an increase in the number of fire-related fatalities, 15% higher than the previous year (Home Office b, 2016). These sharp increases are a source of concern for both the police and the fire and rescue service who are responsible for responding to and managing incidences of deliberate fire. In order to address the issue, it is important that the spatiality of the problem is thoroughly understood in order to be able to target the problem areas effectively, thus reducing the number of deliberate fires. Studying the spatiality of the problem over time allows any changes in pattern to be observed which may reveal trends in the data. Understanding any evident trends may lead to them being predicted in the future, aiding efforts to prevent incidences of deliberate fire.

The relationship between rates of arson and underlying socioeconomic factors will be analysed, in order to determine whether there is a statistically significant relationship between any of the variables and the rate of deliberate fires. The results of the study have the potential to be utilised by the police forces and the fire and rescue services in West Yorkshire, in order to establish which wards are likely to experience high rates of deliberate fires; this can aid in the effective, spatially focused distribution of human and financial resources, in addition to the delivery of educational prevention schemes. Within academia, the study can be utilised to enable an assessment of the validity of existing studies, due to the age of a majority of the pre-existing research and the occurrence of demographic changes over time; in addition to the improved accuracy of methods and

availability of more advanced computer technology. West Yorkshire has not previously been the subject of a fire related research project, thus the study would analyse data that had not been utilised in pre-existing studies of fire and would add to the limited number of existing case studies concerning deliberate fire rates within the UK.

Research regarding deliberate fires first emerged in the United States during the 1970s (Jennings, 1999) (Federal Emergency Management Agency, 1997), however it was severely restricted due to the limited methods of analysis available at the time; consequently, findings were often inconclusive and lacked empirical evidence (Chetri at al, 2009). Studies were mainly concentrated within the United States with only a small quantity of studies being conducted within a UK context (Federal Emergency Management Agency, 1997). As the geodemographic structure of the population varies greatly between countries, it is challenging to be able to make comparisons between study areas in the United States and regions of the UK; thus it is key that there are investigations carried out into spatio-temporal patterns in the UK.

Recent advancements in technology and computer science have permitted the application of more complex and rigorous spatial statistical tests and has enabled larger data sets to be collected, stored and utilised for analysis. During early studies of fire rates the range and abilities of computer programmes were limited, restricting the mapping and spatial statistical analysis that could be conducted.

The overarching aim of the study is to examine the variation of spatial patterns of incidences of deliberate fires within the wards of West Yorkshire, between 2008 and 2016. The secondary aim is to establish any connections between the spatial pattern of deliberate fires and socioeconomic variables. These variables and the methods utilised are discussed in detail within the study. The analysis begins with a spatial autocorrelation (Moran's I) to test whether the data is clustered or is dispersed randomly. A cluster and outlier analysis is then conducted to analyse the pattern of clusters from 2008 to 2016, evident in the maps produced, with a descriptive commentary of how the spatial pattern has changed over time. Subsequently, a hotspot analysis is performed, utilising eight maps to identify cold or hot spots which consistently feature each annum. A regression analysis is then conducted in order to analyse whether there is a statistically significant

relationship between rates of deliberate fire and the socioeconomic variables which were selected for study following a review of findings from existing studies. A regression is carried out per annum in order to test whether the variables highlighted as being statistically significant occur in more than just a single year, suggesting that the factor is influential over the time period being examined. The limitations of the study are then discussed in addition to opportunities for further research within the field. Finally, a conclusion is drawn based on the primary findings of the study; noting key locations to be targeted by the police force and the fire and rescue service, the variables which exert the most influence on deliberate fire rates and the wards which demonstrated the most significant relationship with the variables studied.

1.2 AIMS AND OBJECTIVES.

Aims.

1. To examine the geographical variation of deliberate fires between 2008 and 2016 in the five Metropolitan boroughs of West Yorkshire, England.

2. To explore possible relationships between rates of deliberate fires and demographic and economic variables.

Objectives.

A.

i. Define spatial and temporal trends in incidences of deliberate fires within wards in Bradford, Calderdale, Kirklees, Leeds and Wakefield between 2008 and 2016.

ii. Determine whether the spatial pattern of the data is clustered or has occurred by chance through the spatial autocorrelation (Moran's I) tool in ArcMap.

iii. Produce and analyse maps produced in ArcMap utilising the cluster and outlier (Anselin Local Moran's I) tool.

iv. Analyse geographical change in the pattern of cold spots and hot spots using hotspot analysis (Getis Ord Gi*) in ArcMap.

B. Consider incidences of deliberate fires in relation to socioeconomic variables; including car or van access, deprivation, housing tenure, mean age, qualifications and unemployment, through correlation and regression techniques.

2.0 LITERATURE REVIEW.

2.1 Background to Fire.

Arson is a multi-faceted crime composed of different categories, with a range of possible underlying motives (U.S. Fire Administration, 2016); however, it has been relatively overlooked within criminology academia (Federal Emergency Management Agency, 2007), when compared to studies of crimes such as burglary. The existing literature on arson is primarily focussed around the influence of socio-economic factors on crime; however, there is a lack of modern methods of spatial statistical analysis and conclusive evidence as to whether there is a link between socio-economic variables and deliberate fire and if so how significant they are in the wider context or arson attacks. This literature review will provide a critique of existing studies, literature and the methods utilised within studies, in addition to highlighting the potential for further research.

An arsonist is defined in the Criminal Damage Act (1971, p1) as "a person who without lawful excuse destroys or damages any property belonging to another intending to destroy or damage any such property or being reckless as to whether any such property would be destroyed or damaged", and who does so by the use of fire.

Arson is the single largest cause of fire in England and Wales (Office of the Deputy Prime Minister, 2006) and has been recognised as one of the most destructive crimes, potentially resulting in loss of life, injury, and significant financial cost to both individuals and businesses (West Yorkshire Fire and Rescue Services, 2013). In the financial year 2012/2013, there were 4803 deliberate fires in West Yorkshire, which accounted for 62% of the total number of fires attended by the West Yorkshire Fire and Rescue Service (West Yorkshire Fire and Rescue Service, 2013). Arson damaged properties can induce feelings of vulnerability for some individuals within a community and can produce a fear of crime in the area (Merseyside Fire and Rescue Service, (no date)). In accordance with Kelling and Wilson's (1982) broken window theory, it can also induce further incidences of crime in the area, particularly vandalism and anti-social behaviour.

There has been an inconsistency in measures of arson between the fire and rescue service and the police force. The fire and rescue service record deliberate incidences of fire based upon the intent of the offender as the method of categorisation (West Yorkshire Fire and Rescue Service, 2013). Incidences in which there is only damage to items of insignificant value, such as grass, are classified as a deliberate fire by the fire and rescue service, but may not be termed as arson by the police force as there was no threat posed to life or property (West Yorkshire Fire and Rescue Service, 2013). Due to this discrepancy between term utilised, this report will refer to incidences of deliberate fire, rather than arson where appropriate.

The distinction between the two categories of deliberate fire is crucial when examining the distribution of spatial patterns. The term primary fire is used to identify those which involve buildings, either residential or commercial, or other property, such as vehicles or industrial machinery, and they often involve casualties and some form of rescue operation (West Yorkshire Fire and Rescue Service, 2013). Secondary fires are those which are outdoors, involve refuse or occur within refuse containers, and abandoned buildings and vehicles (West Yorkshire Fire and Rescue Service, 2013). Primary fires tend to be considered the most serious type of deliberate fire as they are more likely to involve a direct threat to human life, which in some circumstances can be fatal. Arson is committed for a variety of motives which are likely to influence the category of deliberate fire. Fires initiated as a form of vandalism, often as a manifestation of youth boredom are traditionally secondary fires; whereas fires ignited due to malicious intent are more commonly classified as primary fires.

Incidences of deliberate fires are an ongoing issue within West Yorkshire and the county's fire and rescue service are already issuing residents with information and advice as to ways in which arson attacks can be reduced in the area (West Yorkshire Fire and Rescue Service, no date). This advice includes measures such as; storing wheelie bins out of public view, storing large volumes of rubbish in a secured area, not placing wheelie bins outside the property until the day of collection and ensuring all flammable liquids are stored in a safe location and locked away when not in use (West Yorkshire Fire and Rescue Service, no date). They also actively encourage people to contact the service if they are aware of

a young person playing with fire in the area or have concerns regarding incidences of fire in their local area. (West Yorkshire Fire and Rescue Service, no date).

2.2 Trends and influences.

Socioeconomic variables have been closely associated with incidences of deliberate fire within the literature. These variables typically include education levels (Guldåker and Hallin, 2014), poverty (Duncanson et al, 2000) and home ownership (Corcoran et al, 2007) (Federal Emergency Management Agency, 1997). However, evidence is somewhat inconclusive and further research needs to be conducted to be able to identify a clear correlation between socioeconomic factors and incidences of fire.

Levels of educational attainment are observed as a significant factor when attempting to address the causes of crime (Duncanson et al, 2002), with those with lower educational attainment being at a higher risk of death or injury from intentional fires (ODPM, 2004). Low levels of educational attainment are associated with low literacy skills which may hinder peoples' ability to comprehend fire safety instructions and advice. If educational arson prevention schemes administered by the fire service are targeted at those with low levels of education there is a higher likelihood of the scheme having a positive impact than if the scheme is propagated in more well educated area. A report produced by the ODPM (2004), stated that education negatively impacts on levels of deliberate fires, especially when vehicle crime is involved. In addition, previous research has indicated a positive relationship between children involved in anti-social behaviour and poor levels of educational attainment, thus there is a possibility that there is also a link between young people, their education levels, and numbers of deliberate fires (ODPM, 2006).

There is a general consensus within government and academia that those living in more deprived areas are at a higher risk of having their lives impacted by intentional fire setting (ODPM, 2004) (Jennings, 1992) (Chandler et al, 1984). However, deprivation can be measured in a variety of different ways, for example in studies based in the U.S. income is often used as a measure of deprivation. In the UK income data is not published via the census, thus unemployment information or numbers of benefit claimants are commonly

used as replacement data (House of Commons, 2009). Often those living in more deprived areas rent their property and research by Munson and Oates (1983) suggests tenants of rental accommodation are more prone to higher rates of death or injury from fires compared to those who own their own home. At the individual household level, the lack of a smoke detector in the home, is linked with an increased mortality risk as a result of fire (Chhetri et al, 2007), with the WYFS (no date) warning residents they are 4 times more likely to die in a fire if the household does not have a working smoke alarm. Households lacking smoke detectors tend to be located in more deprived areas (Goodsman et al, 1987) and Gorman et al (1985) concluded that initiatives to install smoke detectors to vulnerable households have resulted in reductions in fire injury rates. In addition, abandoned or derelict properties, which attract arsonists, are concentrated in more deprived areas which can exacerbate the issue (Jennings, 1999). The area then continues to decline, in accordance with broken window theory (Kelling and Wilson, 1982). Chhetri et al (2007) noted that low income households may be at a higher risk due to furnishings and carpets of a poorer quality which increase fire risk as they are flammable.

Karter (1977) concluded that all non-white populations were at an increased risk of a threat from fire, which has been supported by work produced by Duncanson et al. (2000) and Chandler et al. (1984) regarding ethnicity and fire, although further study is required to produce conclusive evidence. The number of deaths and injuries resulting from fire is disproportionately higher for those of an ethnic minority, but this disparity may be interlinked with other socioeconomic variables (Duncanson et al, 2000), such as deprivation and education.

Variables which correlate with high incidences of fire often interlink, such as low educational attainment and deprivation, thus it is not possible to identify which variable is the most influential, however it is possible to locate areas in which both these variables are of high frequency. Additionally, research regarding the relationship between socio-economic variables and incidences of deliberate fire is seldom irrefutable, with Chandler (1979) concluding that some more deprived areas have lower levels of deliberate fire due to community cohesion and bonds between members of the working class community.

2.3 Potential Issues.

The primary issue with analysis of deliberate fire is that arsonists do not always commit crimes in the ward in which they live and sometimes travel to locations in order to start a fire. Brantingham and Brantingham's (1981) crime pattern theory comprises of three factors which determine the behaviour of a criminal, including the criminal's familiarity with the area in which they commit a crime. However, research conducted by Fritzon (2001) concluded that the motive of the arsonist impacts the distance they are willing to travel to commit their crime. Arsonists who are motivated by an emotional element, tend to travel shorter distances than those seeking specific benefits from the attack, such as financial reward (Fritzon, 2001). In incidences in which a specific individual or group of individuals were the intended target of the arson attack, offenders were willing to travel the longest distance (Fritzon, 2001).

However, many arson attacks categorised as vandalism, are perpetrated by children and young people (Youth Justice Board, 2006), with 50% of arsonists convicted in courts in England and Wales aged 21 and under (Youth Justice Board, 2006). Arson committed as a form of vandalism is more likely to be located in the criminal's local vicinity, as it tends to be a result of boredom and anti-social behaviour, rather than a crime with malicious intent (Fritzon, 2001). As young people are limited by access to transport and resources, crimes are often committed in areas which they are familiar with, in accordance with crime pattern theory (Brantingham and Brantingham, 1981).

2.4 Previous Research.

2.41 GIS (Geographical Information Systems).

Incidences of fire are a complex issue, with links to several socio-economic and environmental variables which themselves may intertwine, and develop both spatially and temporally.

Geographic Information Systems (GIS) have made it possible to analyse a variety of issues in relation to a spatial dimension. The use of mapping techniques and examining a spatial

factor is a prevailing contemporary method within crime studies, thus it's application is far more advanced. In contrast, incident data collected by all regional divisions of the Fire and Rescue Services is not widely studied, with very little academic research being published on incidences of fire and its influences, particularly within the UK context.

The use of GIS increases the sophistication and functionality of the information available to fire and rescue services, enabling decisions to be made based on quantifiable empirical evidence (Merrall, 2001). Spatial analytical techniques based around GIS have the potential to aid the exploration of detailed patterns of fire incidences, which in turn can assist in the deployment of targeted prevention schemes. Corcoran et al (2008) also note that GIS has the ability to identify characteristics of households which are potentially correlated with the incidence of fires, therefore allowing areas of high risk to be identified at a highly detailed geographical scale.

2.42 Statistical Analysis.

Contemporary studies of deliberate fire utilise multivariate regression analysis in order to investigate the relationship between multiple socio-economic variables and rates of deliberate fires (Corcoran et al, 2007) (Chhetri et al, 2009). Although this is a useful technique to implement, research could benefit from a more in depth analysis of the spatial relationships, in combination with a statistical analysis. The homogenisation of methods is extremely beneficial, enabling the comparison of studies across both space and time. This is particularly useful due to the limited number of studies which have been conducted within a UK context, thus there is a lack of comparable data.

2.43 Spatial Statistics.

Spatial statistics involve statistical tools and techniques that involve spatial data. They are useful in aiding the GIS industry professionals and academics to uncover meaning in spatial data. There are a variety of spatial statistical methods currently in use within a range of academic studies including; pattern analysis, zoning, spatial association and

classification (Getis, 1999). The methods are valuable in a number of fields such as economics, transportation engineering and urban planning (Hung, 2016). An existing study conducted in Sweden in 2014 (Guldåker and Hallin, 2014) utilised spatial statistical methods such as the Kernel Density Estimation and cluster analysis. Grubbs and Nobles concluded in 2015 that the use of spatiotemporal techniques to identify patterns of arson would be greatly beneficial in reducing the severity of impacts. These methods have not been used extensively within existing analyses of fire, however this study highlights the utility and appropriateness of such methods within contemporary analysis in this field of study.

2.44 Regression Analysis.

Regression analysis has been utilised frequently within studies analysing the relationship between variables, including fire. Corcoran et al. (2007) study of patterns of fire in South Wales also conducted a regression analysis with ward level data, utilising variables such as; car ownership, educational attainment, white population, high owner occupation and long term limiting illness.

2.5 Opportunity for further research.

Due to the lack of existing research, particularly within a UK context there are many opportunities for further study, utilising popular methods and by applying different approaches of spatial and statistical analysis. Jennings (1999) noted that understanding why particular stratums of society experience higher incidences of fire than others is the key question in this kind of research, however before reasons why can be deduced, there must first be conclusive evidence that the there is a relationship between socioeconomic variables and arson rates. With regards to preventing deliberate fires it is key that fire and rescue service have information which enables them to target specific demographic groups and locations which are at high risk (Crawford, 2005). In order to be able to provide fire and rescue services this information more research must be conducted within a UK context and at low aggregation levels (Jennings, 1999). Micro level studies are very limited

and seldom report underlying socioeconomic factors (Jennings, 1999). A study conducted by ECOTEC on behalf of the UK government (ODPM, 2004) concluded that further research is required in order to establish exactly how poor education interacts with rates of deliberate fires. Grubb and Nobles (2015) noted the lack of empirical studies which focus jointly on spatial and temporal characteristics of fire, as a majority of pre-existing research focuses on one of the two features, highlighting the validity of this study.

3.0 DATA AND METHODOLOGY.

3.1 Study Area.

The chosen area of study is the county of West Yorkshire, which contains the five metropolitan boroughs of; Bradford, Calderdale, Kirklees, Leeds and Wakefield. These boroughs comprise of 124 wards and include both large cities and residential suburban localities (West Yorkshire Police, 2014). Examining incidences of deliberate fires at ward level, which are basic units of UK administrative geography (ONS, 2016), permits a detailed geographical analysis to be conducted which increases the potential benefits of discovering trends.

The West Yorkshire Fire and Rescue Authority is responsible for fire and rescue services, including arson, within the county, which comprises of over two million people, and covers an 800 square mile area (West Yorkshire Fire and Rescue Service, [no date]). West Yorkshire Police are also responsible for responding to and alleviating incidences of arson in the area and are the fourth largest force in the country (West Yorkshire Police, 2014).

Demonstrated in figure 3.1, from 2008 there was a steady year on year decrease in the number of deliberate fires, until 2012-2013. Since then, there has been a sharp increase followed by a plateau in the number of recent deliberate fires. Therefore, it is important to understand why levels have not continued to decrease and identify potential reasons for the increase or potential hotspot locations. Identifying possible reasons for this pattern could potentially aid in the resolution of this problem. The close relationship between incidences of deliberate fire and socioeconomic variables requires an in depth understanding of the demographic composition of the study location.

As is evident in Figure 3.2, Bradford experiences the highest rate of total deliberate fires out of the five metropolitan boroughs of West Yorkshire by a significant margin, which may be linked to it's socioeconomic characteristics; including level of unemployment, crime rates, percentage of the population which is an ethnic minority and high youth population. Interestingly, Calderdale has higher levels of deliberate fires than Leeds and Kirklees, despite lower crime rates, lower unemployment and a lower percentage of the

population identifying as being of an ethnic minority (InFuse, 2011). Thus, it is important that these patterns are investigated at ward level, in order to identify particular locations which may be affecting overall rates and discussing possible influences.

Leeds has the highest crime rate of the five areas (Police, 2016), which also suggests that rates of deliberate fires should also be highest in this locality. Unsurprisingly the more densely populated areas tend to have higher rates of crime. As deliberate fires are often crimes, it would be expected that areas with the highest level of all crimes, also have the highest levels of deliberate fires.

The metropolitan borough of Bradford experiences the highest rates of unemployment in the county with levels currently at 7.1 % (InFuse, 2011), 1.6% higher than rates in Leeds (InFuse, 2011). High unemployment is often associated with high levels of crime, due to two factors; financial difficulty and high quantities of free time (Aaltonen et al, 2013). Bradford is also the youngest major city in the UK, with over 23% of the population aged 16 years old and under (Bradford Observatory, 2016), this may be a significant factor as deliberate fires are commonly started by youths (Merseyside Fire and Rescue Services, (No date)).

Previous research notes the lack of local level case studies of incidences of fire within England (Corcoran et al, 2007), which deems West Yorkshire an appropriate and potentially interesting choice of location.

Figure 3.1: Shows the total number of deliberate fires in West Yorkshire between 2008 and 2016.

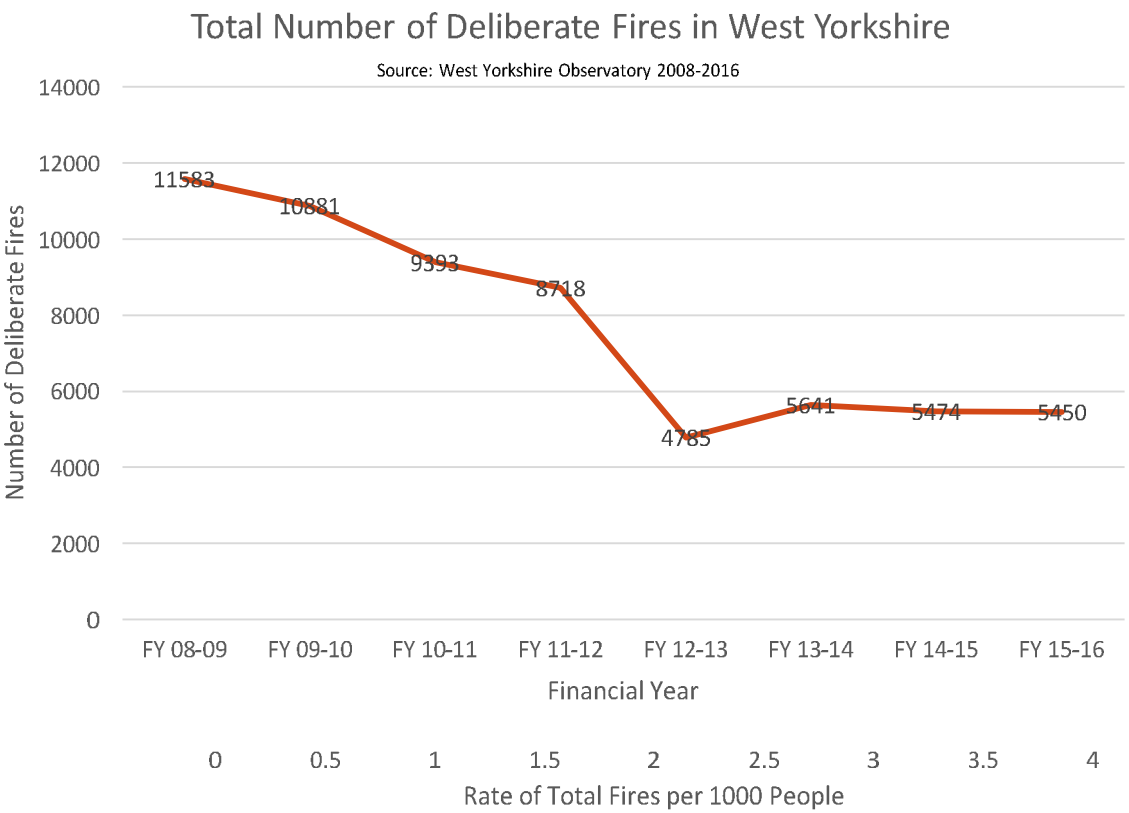


Figure 3.2: Displays the rate of deliberate fire per 1000 people in each metropolitan borough of West Yorkshire in 2015-2016

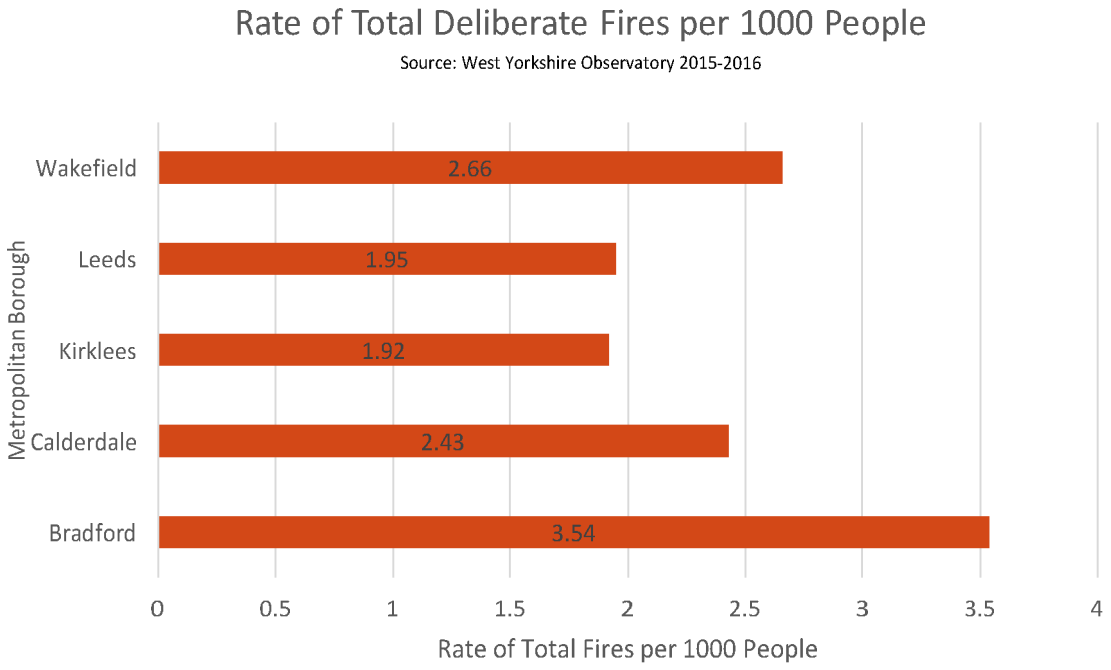


Figure 3.3: The county of West Yorkshire aggregated to ward level.

Figure 3.4: West Yorkshire highlighted on a map of England aggregated to borough level.

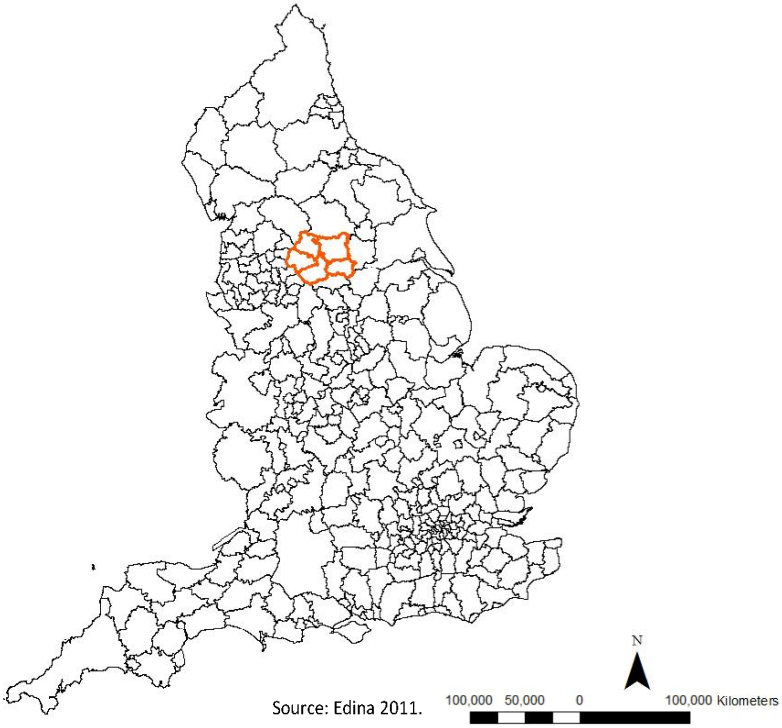


Figure 3.3 and 3.4 are provided to illustrate the chosen study area and the position of the county in relation to the rest of the country.

3.2 Scale.

The study has been conducted at a ward level which is fitting with methods used in existing literature. As deliberate fires can be a sensitive issue with vulnerable victims involved, suppression is commonly used to protect individuals who may be at risk. Thus, low geographical scale studies, such as LSOA level, can be limited as data has to be withheld. Consequently, ward level data was selected, which was deemed to be a suitable scale following a review of methods used in previous research (ODPM, 2004).

The modifiable areal unit problem (MAUP) is a rudimentary problem within geography, inherent in all studies of spatially aggregated data as the results of geographical studies are always determined by the level of aggregation utilised (Jelinski and Wu, 1996). MAUP was noted by Fotheringham and Rogerson (1993) to be one of the eight issues which arise in spatial analysis.

MAUP is an issue which cannot be resolved; nevertheless, there are several approaches which can be taken in order to deal with the issue in research. Firstly, MAUP can simply be ignored (Johnston, 2009) or the results produced at the chosen scale can be assumed to be correct (Johnston, 2009). Alternatively, different regionalisations can be used and then compared and an optimum regionalisation can be chosen for the selected study (Johnston, 2009)

In this instance the modifiable areal unit problem will be ignored, however in future work, this research could be repeated at a different scale and the results compared.

3.3 Data Sources.

3.31 Incidences of Deliberate Fire Data.

The data regarding regarding deliberate primary and secondary fires was downloaded, from the 'Observatory' websites for the metropolitan boroughs of Bradford, Calderdale, Kirklees, Leeds and Wakefield, into Excel. The data was then compiled into two data sets for primary and secondary fires for each ward within West Yorkshire. The data was subsequently cleaned as any incidences of fires lower than three cases was suppressed,

thus these values were substituted with a blank, through the use of a logical IF statement in Excel. The data is suppressed prior to publication, in accordance with the Data Protection Act (1998), in order to minimise attribute, identity and residual disclosure risk (Hilary, 2013).

The clean data sets were then utilised to calculate the total number of fires in each ward, which were assembled as a third data set, entitled total fires. This provided the number of both primary and secondary fires within each ward between the financial year 2008-2009 to 2015-2016, thus incidences of deliberate fires could be analysed as an aggregate unit.

Although supplied by the respective statistics offices for each of the metropolitan boroughs, the data is originally collected and collated by the fire and rescue service and is publicly available under the Open Government Licence (The National Archives, (no date)).

3.32 Socioeconomic Variables.

Data relating to socioeconomic variables was acquired from the 2011 census via the Infuse website. Although it would have been desirable to utilise annual data regarding socioeconomic factors, it was challenging to obtain data relating to socioeconomic variables for each of the metropolitan boroughs for the same year and measured using the same method as there were numerous inconsistencies in the information available from the different metropolitan boroughs. Due to this factor, census data was consequently selected due to it's consistency. A primary disadvantage of utilising census data is that it is only collected every 10 years, rather than on a yearly basis which would permit a more thorough temporal analysis.

The data was downloaded from Infuse as an Excel file for spatial and statistical analysis and compiled into a single spreadsheet prior to use in Minitab17.

Table 3.1: Descriptions of variables utilised and their source.

Variable	Description	Source
Deliberate primary fires from the financial year 2008-2009 to 2015-2016	The raw number of incidences of deliberate primary fires for each ward within West Yorkshire, with values less than 3 subject to suppression.	Bradford Observatory. 2016. Calderdale Observatory. 2016. Kirklees Observatory. 2016. Leeds Observatory. 2016. Wakefield Observatory. 2016.
Deliberate secondary fires from the financial year 2008-2009 to 2015-2016	The raw number of incidences of deliberate secondary fires for each ward within West Yorkshire, with values less than 3 subject to suppression.	Bradford Observatory. 2016. Calderdale Observatory. 2016. Kirklees Observatory. 2016. Leeds Observatory. 2016. Wakefield Observatory. 2016.
Car or van availability	The number of households in who have no access to a car or van.	Census. 2011. InFuse.

Deprived households	The number of households which are deprived in four dimensions.	Census. 2011. InFuse.
Educational qualifications	The number of people with no educational qualifications.	Census. 2011. InFuse.
Housing tenure	The number of households which are socially rented.	Census. 2011. InFuse.
Mean age	The mean age of people in a ward.	Census. 2011. InFuse.
Population	The number of people living in a ward.	Census. 2011. Infuse.
Unemployment	The number of people in a ward who are long term unemployed (over two years).	Census. 2011. Infuse.

Indicators of socioeconomic deprivation have been used in previous studies including those by the UK Government (ODPM, 2004), with domains such as education, housing, employment and wealth being utilised.

Rates were calculated for the socioeconomic variables highlighted in table 3.1 per 1000 people in Microsoft Excel using population data collected from the 2011 Census and rounded to two decimal places, using the following equation:

=ROUND(socioeconomic variable/ total population*10000, 2)

3.4 Potential Data issues: The Under Reporting of Crime.

Under reporting is substantial for every crime, particular for crimes against the property (Tarling and Morris, 2010). The willingness of victims to report crimes is a key aid to the police, fire service and data analysts as a true reflection of crime allows for a better understanding of how crime affects both individuals and communities (Tarling and Morris, 2010) and allows a relationship to be established between crime levels and socioeconomic characteristics where appropriate. There are a number of factors which may influence a victim's decision to report a crime, with studies noting that individuals from higher income households, those who have achieved higher level educational attainment and the employed are the most likely to report a crime being committed (Baumer, 2002). In some incidences victims may be concerned about their privacy and being vulnerable to further crimes, either from the initial perpetrator or other people within the offender's network (Tarling and Morris, 2010), which may be particularly relevant in the case of arson.

3.5 Method of Analysis and Reasons for Use.

3.51 Spatial Autocorrelation (Moran's I)

The spatial autocorrelation (global Moran's I) is an inferential statistic which measures spatial autocorrelation based of locations and values of features. It evaluates whether the pattern produced is clustered, dispersed or random in nature (Lee and Li, 2017). A z-score and a p-value are also produced by the tool in order to evaluate the significance of the index produces. The tool is most reliable when over 30 features are inputted, which will not impact upon this project as 124 features, the wards, are being utilised. The values produced by the tool range from +1 which indicates a strong positive spatial autocorrelation, 0 meaning a random pattern with no correlation to -1 indicating a strong negative spatial autocorrelation (Sawada, 2009).

3.52 Hotspot Analysis (Getis Ord Gi*)

This statistical tool produces Getis-Ord Gi* for each feature in the data set (ESRI, (no date)). The Z-scores and p-values produced tell you where features with high or low values cluster spatially (ESRI, (no date). The tool works by examining each feature within the context of neighbouring features (ESRI, (no date). To be statistically significant as a hot spot a feature has to have a high value and be surrounded by features that also have a high value, and vice versa for a cold spot. The hot spot and cold spot analysis is a useful tool for this research as it clearly identifies problem areas which could then be utilised by both police and fire and rescue service. It also enables the study of the socioeconomic characteristics of hot spots and cold spots which can then be compared and contrasted in order to identify any potential differences between the two.

3.53 Cluster and Outlier Analysis (Anselin Local Moran's I)

Cluster and outlier analysis identifies statistically significant hot spots, cold spots and outliers (ArcGIS Pro, (no date) a). This test requires count or rate data rather than point data, thus count data will be utilised (ArcGIS Pro, (no date) b). High-High clusters are particularly useful as they enable areas of high rates of arson to be identified which may indicate that there is a significant problem with arson in the area. High-Low clusters are also of interest in this study as they indicate areas of high rates of arson, surrounded by those with low rates. Thus, it is essential that these locations are identified in order to determine what characteristics these areas have which result in arson rates being significantly higher than those for the surrounding area.

3.54 Regression Analysis

To assess the relationship between rates of deliberate fire and socioeconomic factors associated with fires a statistical regression was executed in MiniTab17. This method of analysis has been widely used within academic literature relating to incidences of fire,

(Corcoran et al, 2007) (ODPM, 2004) (Jennings, 1999) (Karter and Donner, 1977) thus can be deemed an appropriate method.

Each of the rates of the socioeconomic variables per 10,000 people is measured against the rate of fire. A p value is produced, which indicated the correlation's levels of significance. A p-value of 0.05 or below is deemed to be significant and infers that the relationship between the two variables is not coincidental (Frost, 2013).

4.0 ANALYSIS.

4.1 Global Moran's I.

Moran's I is a global measure of spatial autocorrelation, which signals if data is clustered, random or dispersed. Values produced by the tool are between negative 1 and positive 1. A negative value demonstrates a negative spatial correlation, i.e. dispersion, and a positive value represents a positive spatial autocorrelation, i.e. clustering. A value of zero is indicative of a random spatial pattern. A p-value is also produced by the tool to provide the statistical significance of the Moran's I value. A p-value above 0.05 is not of significance, whereas a value of 0.05 or below is significant and 0.01 or below is very statistically significant.

Table 4.1: Shows the results of the global Moran's I analysis of deliberate fire rates.

Year	Moran's I value	p-value
2008-2009	0.181971	0.000005
2009-2010	0.171677	0.000015
2010-2011	0.164353	0.000032
2011-2012	0.169795	0.000000
2012-2013	0.215299	0.000000
2013-2014	0.167589	0.000022
2014-2015	0.278397	0.000000
2015-2016	0.1911022	0.000002

The values in Table 4.1 indicate that in every year between 2008 and 2016 the patterns of deliberate fire rates across West Yorkshire are clustered, thus is a relevant data set to study. As the pattern has not occurred randomly, it indicates the presence of underlying factors which influence the locations in which incidences of deliberate fires occur.

4.2 Cluster and outlier analysis (Anselin local Moran's I).

The following section of analysis is based on eight maps, figures 4.1 to 4.8, produced in order to identify concentrations of low or high values, i.e. whether there are high or low rates of deliberate fire in wards of West Yorkshire. They enable any changes in cluster patterns to be noted and highlight any possible outliers or areas which may be of interest for further study. The tool distinguishes between statistically clusters of high values (High-High), clusters of low values (Low-Low), outliers in which a high value is prominently surrounded by low values (High-Low) and outliers in which a low value has mainly high values around it (Low-High). Table 4.2 indicates what these clusters mean in the context of this research:

Table 4.2: Definitions of cluster meanings.

High-High	Statistically significant clusters of high rates of deliberate fire
Low-Low	Statistically significant clusters of low rates of deliberate fire
Low-High	Wards which have a low rate of deliberate fires, surrounded by wards with a high rate of deliberate fires

High-Low	Wards which have a high rate of deliberate fires, surrounded by wards with a high rate of deliberate fires

Figure 4.1-4.8: Showing the results of the cluster and outlier analysis.

Figure 4.1: 2008-2009

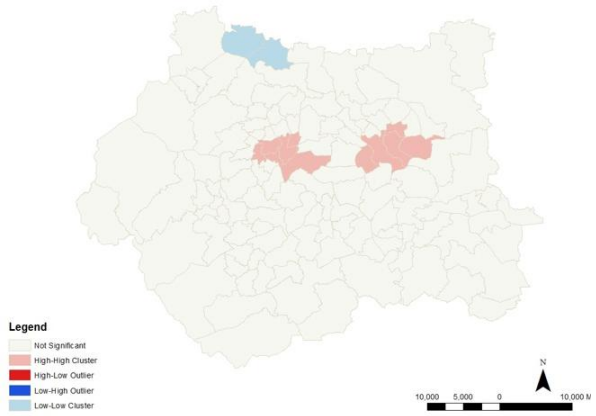


Figure 4.2: 2009-2010

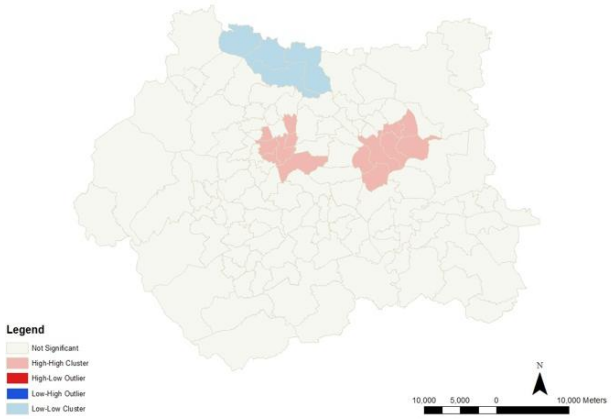


Figure 4.3: 2010-2011

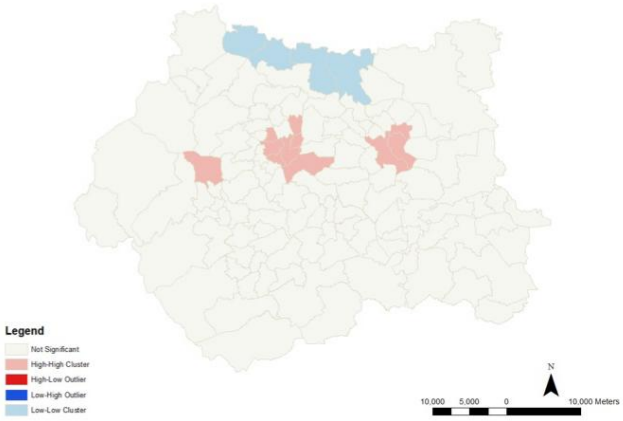


Figure 4.4: 2011-2012

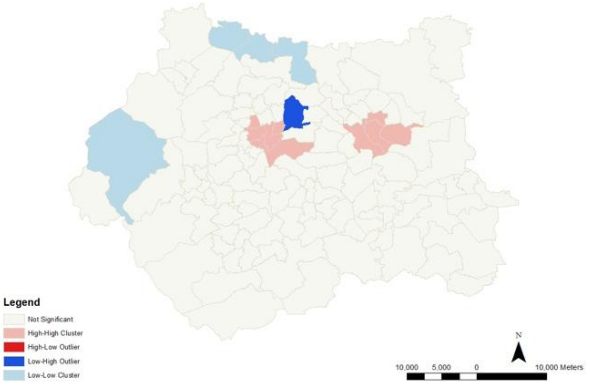


Figure 4.5: 2012-2013

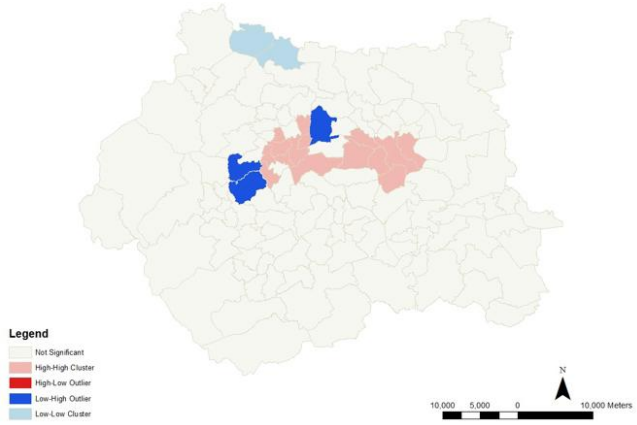


Figure 4.6: 2013-2014

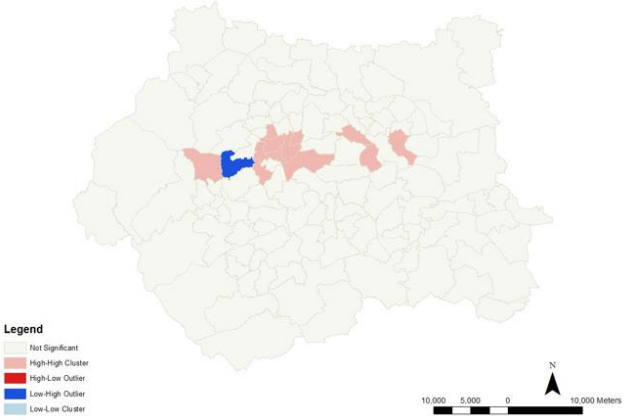


Figure 4.7: 2014-2015

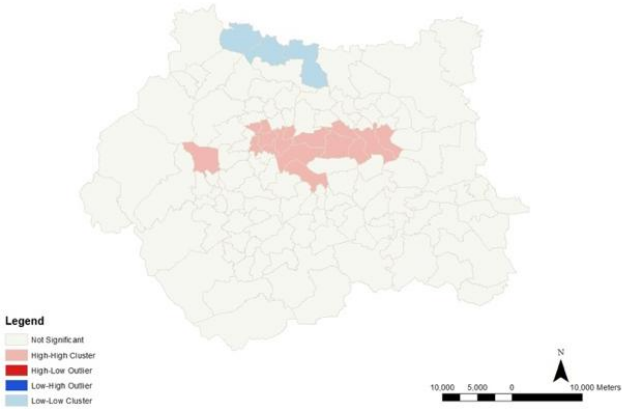
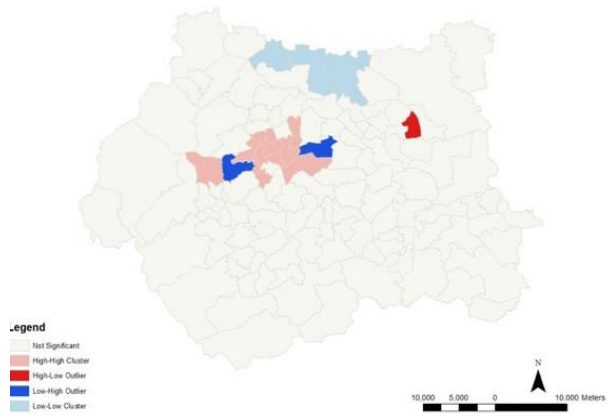


Figure 4.8: 2015-2016



Sources for figures 4.1-4.8:

Edina, 2011.

Kirklees Observatory, 2016.

Leeds Observatory, 2016.

Wakefield Observatory, 2016.

Bradford Observatory, 2016.

Calderdale Observatory, 2016.

Table 4.3: Shows the metropolitan boroughs in which high-high clusters are featured.

High-High Cluster Ward	Metropolitan Borough
Clayton and Fairweather Green	Bradford
Royds	Bradford
Toller	Bradford
Manningham	Bradford
Bowling and Barkerend	Bradford
Eccleshill	Bradford
City	Bradford
Little Horton	Bradford
Greater Horton	Bradford
Bradford Moor	Bradford
Wibsey	Bradford
Tong	Bradford
Illingworth and Mixenden	Calderdale

Overview.

The low-low cluster pattern remains similar throughout the eight-year period, remaining in the north of the county, with the exception of 2013-2014 (Figure 4.6), where there were no low low clusters. This may indicate that there are underlying socioeconomic features of the area which result in deliberate fire rates remaining low.

In 2008-2009 (Figure 4.1), high-high clusters were concentrated around the areas of central Leeds and Bradford. This pattern remains evident until 2012-2013 (Figure 4.5), when a block of high-high clusters spans the area between the two pre-existing concentrations of clusters. This suggests that the patterns of high fire rates are expanding across the county. This pattern is evident from the maps until 2015-2016 (Figure 4.8), when the clusters around Leeds diminish, thus Bradford contains most of the high high clusters. Over the period, no high-high clusters appear on the periphery of the county are concentrated centrally, however it is possible that this is a consequence of the features of those wards. In order to conclude whether the map demonstrate a lessening of deliberate fire issues in Leeds, further research would need to be conducted in forthcoming years in order to monitor any development of the pattern.

In 2015/2016 13 out of 14 wards with a high high cluster are in Bradford, demonstrated in Table 4.3, which is significant as it clearly identifies that the borough of Bradford has a significant problem with incidences of fire, in comparison to the other wards of West Yorkshire

High-low areas would be useful to analyse in order to examine the socioeconomic characteristics of those wards, in order to determine why they have high rates of fire, unlike the surrounding area. However, in this study there was only one year with a high-low ward present, thus would not be of significance to undertake further study.

Low-high areas are seldom present, which indicates that areas of high rates of deliberate fires and those with low rates, tend to be concentrated together, rather that spatially dispersed across the county. This does indicate that there are underlying demographic features of areas which result in the clustering of rates of deliberate fires, as wards tend to have similar geodemographic characteristics to the surrounding areas.

The wards surrounding the city wards of Leeds and Bradford are consistently of significance, thus selected wards will be analysed in more detail. Wards within Calderdale, Kirklees and Wakefield rarely appear as significant in any of the maps, suggesting that the main problem wards are within Bradford and Leeds, and tackling deliberate fire rates within those areas may significantly reduce the county's problem with fire.

In order to determine any potential influences of the spatial patterns of clusters, a regression analysis will aid in detecting potential positive correlations between socio-economic variables and rates of deliberate fire.

4.3 Hotspot analysis (Getis Ord Gi*)

This section of the analysis is focussed on eight maps of West Yorkshire each demonstrating cold spots and hot spots from the financial year 2008-2009 to 2015-2016, demonstrated in Figures 4.9 to 4.16. A descriptive analysis of key wards and patterns in each map is provided and will later to be used to select wards to be studied utilising a regression analysis in order to determine any significant underlying demographic factors which influence the likelihood of ward being a cold spot or hot spot. Maps have been produced over an eight-year period in order to determine which wards are identified as hot spots or cold spots on multiple occasions, thus there is a higher probability of there being a significant influence of rates of deliberate fire in the area.

2008-2009

The two wards identified as hot spots with a 99% confidence level in 2008-2009 were Tong, in Bradford, and Pudsey, in the metropolitan borough of Leeds. These two wards are surrounded by wards with hot spots confidence levels of 90% and 95% covering an area spanning Bradford and Leeds. The concentration of hotspots in this area suggests that the geographical area experiences high rates of arson in comparison to the rest of West Yorkshire. There is also evidence of a cluster of hot spots in the South East of West

Yorkshire in the wards of Ackworth, North Elmsall and Upton, Pontefract North, Pontefract South, Knottingley and Hemsworth, suggesting that Wakefield may also be vulnerable to incidences of deliberate fire.

Wards detected as 95% and 99% cold spots evidently have a different spatial pattern and are predominantly concentrated in the North of the county in the wards of Ilkley, Wharfedale and Otley and Yeadon.

2009-2010.

In 2009-2010, the location of the cold spots in the North of West Yorkshire have remained the constant, however there has been a reduction in the number of cold spots in the West of the county with only the cold spot of the Calder ward remaining. This indicates that the rate of fire has remained relatively low during the period, thus the pattern remains the same.

The pattern of hotspots has changed however, not dramatically. The clustering in the South East remains similar to the previous year in the wards of Pontefract North, Pontefract South, Airedale and Ferry Fryston and Castleford Central. Hot spots are now more common in the wards of Leeds; for example with the wards of City and Hunslet, Burmantofts and Richmond Hill and Temple Newsam, with the number of hot spots in Bradford remaining significant. This indicates an increasing severity of the rates of deliberate fires in Leeds, whilst areas of Bradford continue to have significantly higher rates of deliberate fire.

2010-2011

In the year of 2010-2011, there is a distinct change in the spatial pattern of hot spots, with a majority concentrated around Bradford wards, and a significant reduction of the number of hot spots in Leeds when compared to the previous year (2009-2010). Additionally, the hot spots in Bradford have become increasingly significant, i.e. have a

higher level of significance, with a majority of wards now being at confidence levels of 95% and 99%, symbolising a worsening of the issue.

With regards to the presence of cold spots they continue to be located in the wards of Wharfedale, Otley and Yeadon and Ilkley, thus remaining relatively static, especially when compared to the locations of hot spots over time.

2011-2012.

The spatial distribution of hot spots has altered from 2010-2011, now showing more similarities to the maps from 2008-2009 (Figure 4.9) and 2009-2010 (Figure 4.10) as hot spots span the area across Leeds and Bradford. This raises questions as to why deliberate fire rate has once again become a more significant issue for the county. Further analysis of the following years may provide a sense of the general trend across Bradford and Leeds in particular.

In 2011-2012, the wards of Ilkley, Wharfedale, Otley and Yeadon and Adel and Wharfedale remain cold spots, with the addition of the wards of Calder, Todmorden, and Ryburn in Calderdale.

2012-2013.

In this annum, there is now a large cluster of hot spots present across the areas of Bradford and Leeds, with a majority of the 99% confidence hot spots centred around Bradford. This indicates that out of the five metropolitan boroughs wards in Bradford tends to experience the highest rates of incidence of deliberate fire.

Otley and Yeadon and Wharfedale continue to be identified as cold spots, with additional cold spots located in Dalton, Greenhead, Almondbury and Ashbrow in Kirklees.

2014-2015.

In 2014-2015 (Figure 4.15) cold spots are present in wards of Kirklees and the Calder ward in Calderdale with the wards of Ilkley, Wharfedale, Otley and Yeadon and Adel and Wharfedale in the North of West Yorkshire. Hot spots are still present in wards within the metropolitan borough of Leeds; however hot spots are clearly of higher significance in Bradford, once again suggesting a lessening of the fire problem in Leeds. Overall, cold spots tend to be featured on the periphery of the county, with hot spots clustered in the centre, predominantly around the City ward of Bradford.

2015-2016.

In 2015-2016 (Figure 4.16), there has been a further intensification of deliberate fire hot spots in Bradford, combined with a further reduction in Leeds. 25 of 26 hot spots are concentrated around Bradford, with 22 of those hot spots having a 99% significance level. Cold spots are again concentrated in the North of the county, with Otley and Yeadon, Adel and Wharfedale and Guiseley and Rawdon, in addition to the presence of three cold spots within Kirklees.

Overview.

Overall, the hot spot analysis has enabled the examination of a clear pattern of cold spots and hot spots and how they have changed over an eight-year period. The location of cold spots was more consistent than that of hotspots, with the wards most commonly being in North Leeds. As the cold spots in the wards of Otley and Yeadon and Adel and Wharfedale were present during most years of the study, it indicates that there are possibly underlying socio-economic factors which may be associated with the low rate of deliberate fire in these wards. The pattern of hot spots fluctuated over time, however were predominantly concentrated in wards surrounding the spatially central wards of Leeds and Bradford wards. Between 2008 and 2016, the issue of deliberate fire in Bradford worsened with

hotspots in the area becoming more concentrated and densely clustered within the wards surrounding the City ward. In addition, the significance of hotpots over time increased, reaching a peak in 2015-2016, demonstrated in Figure 4.16. The number of hot spots in Leeds was higher than that for the metropolitan boroughs of Calderdale, Kirklees and Wakefield, however Leeds also features cold spots each annum. The significance of fires in Leeds were lower than for the wards of Bradford and the number of hotspots noticeably diminished in the years of 2014-2015 and 2015-2016, which possibly suggests a reduction of deliberate fire rates in the borough in recent years.

Figures 4.9 to 4.16: Exhibit the results of the hotspot analysis.

Figure 4.9: 2008-2009

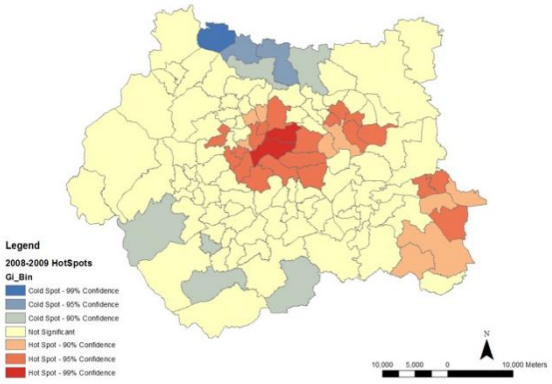


Figure 4.10: 2009-2010

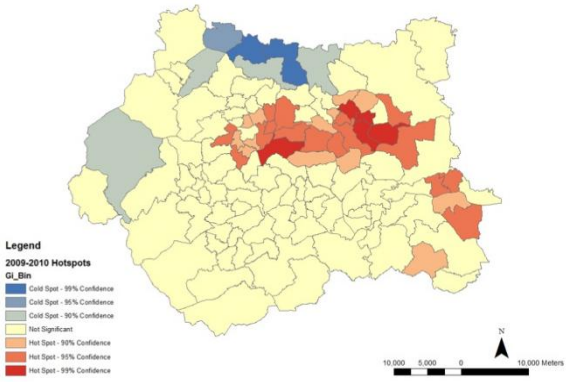


Figure 4.11: 2010-2011

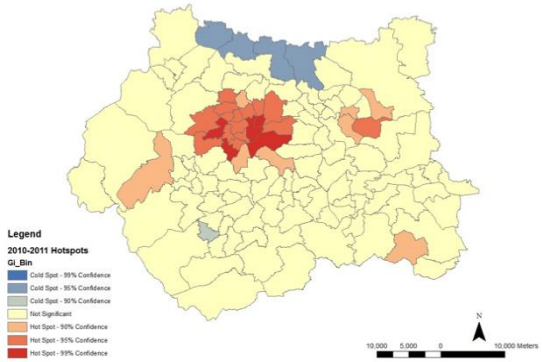


Figure 4.12: 2011-2012

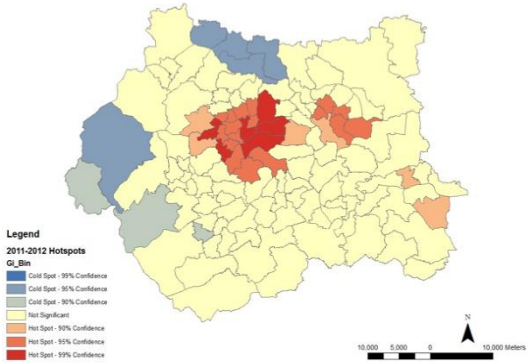


Figure 4.13: 2012-2013

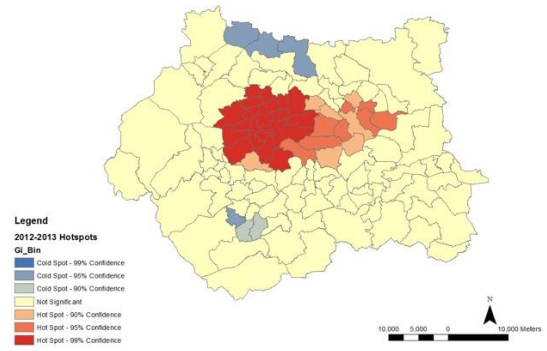


Figure 4.14: 2013-2014

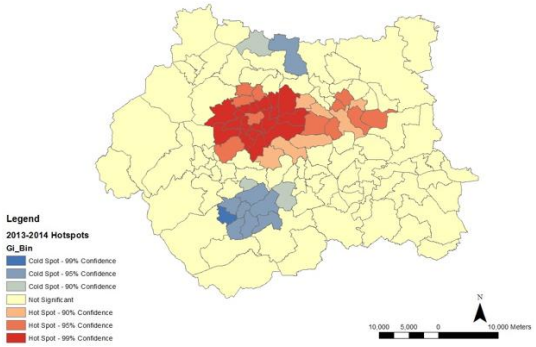


Figure 4.15: 2014-2015

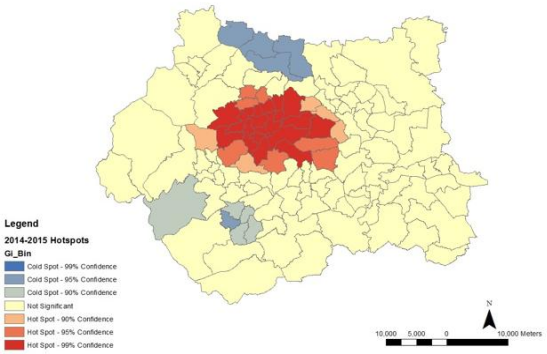
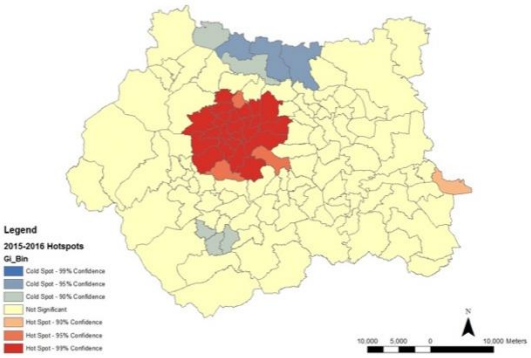


Figure 4.16: 2015-2016



Sources for Figures 4.9-4.16:

Edina, 2011.

Bradford Observatory, 2016.

Calderdale Observatory, 2016.

Kirklees Observatory, 2016.

Leeds Observatory, 2016.

Wakefield Observatory, 2016.

Regression Analysis.

Table 4.3: Coefficient and significance values calculated using a regression for six socio-economic variables for 2015-2016 data.

Very significant	P= <0.01	
Significant	P= <0.05	

Socioeconomic Variables	2015-2016 Fire Rate per 1000 People	
	Coefficient	Significance
Rate of people with no car or van access (per 1000 people)	0.02254	0.019
Mean Age	-0.2596	0.000
Rate of people with no qualifications (per 1000 people)	0.00285	0.622
Rate of households deprived in at least four dimensions (per 1000 households)	0.7582	0.000
Rate of people long term unemployed (per 1000 people)	0.2466	0.000
Rate of socially rented households (per 1000 households)	0.00053	0.925

Table 4.3 provides an example of the regression analysis conducted for each year of the study. The variables highlighted as being significant in this stage of study were consequently counted for the period between 2008 and 2016 to produce Table 4.4, which was then utilised for further analysis.

Table 4.4: Displays the number of years each socioeconomic variable was deemed significant.

Socioeconomic Variables	Number of years the variable was identified as being statistically significant (out of a possible eight)
Rate of people with no car or van access (per 1000 people)	4
Mean Age	8
Rate of people with no qualifications (per 1000 people)	1
Rate of households deprived in at least four dimensions (per 1000 households)	8
Rate of people long term unemployed (per 1000 people)	8
Rate of socially rented households (per 1000 households)	1

Table 4.4 demonstrates which variables were identified as being statistically significant through regression analysis. Three variables were of significance for each year between 2008 and 2016; mean age (the lower the mean age of the ward the higher the rate of deliberate fire), the number of households deprived in four dimensions (the higher the rate of deprived households, the higher the rate of fire) and the number of long term unemployed people (the higher the rate of deprived households, the higher the rate of fire).

This indicates that these three variables do have a relationship with the rate of deliberate fire in all eight years. Although this does not necessarily mean that this relationship will be evident in every county, it is clearly relevant in West Yorkshire.

The rate of people with no car access was significant in four years, which does suggest that there may be a relationship between deliberate fire rates. This would need to be tested further in order to determine whether it is a coincidence or a correlation.

The correlation between low mean age and deliberate fire rate corresponds with the identification of Bradford as a hotspot of fires. Bradford is the youngest city in the country and additionally corresponds with arson commonly being a crime associated with youths.

Arson rates are also closely associated with deprivation within existing literature, thus it was unsurprising that the rate of households deprived in at least four dimensions was positively correlated with deliberate fire rate. However, factors such as socially rented households and low rates of educational qualifications, commonly associated with deprivation, were only identified as statistically significant in one annum. The rate of long term unemployed people, which is also associated with deprivation was identified as a statistically significant factor in every year.

The significance of car or van access is significant during the first four years of the study; however, is not significant between 2012 and 2016, indicating there is no longer a relationship between car access and fire rate. The regression cannot offer an explanation for this change, however the co-efficient value was relatively low which suggests it was a weak relationship.

From the results of regression analysis, information can be provided to the West Yorkshire fire and rescue service and local police forces, regarding the demographic features of the areas which they should be targeting. From the evidence found in this study the wards which should be targeted are those which are deprived, have a low mean age and high rates of unemployment. Building on previous studies, this research project has clearly identified three factors which influence the rate of deliberate fires in West Yorkshire.

Interestingly, in much of the existing literature there was a suggestion of a relationship between housing tenure and fire rate (Duncanson et al, 2002), which was not evident in this study. This highlights the importance of regional case studies which are updated on a regular basis to provide the most accurate and reliable evidence on which to base prevention schemes.

4.5 Links between regression analysis and hotspot analysis.

From the regression analysis several wards were highlighted as large residuals, which are extreme in the direction of the y-axis, relative to the line of regression. The ward of Bolton and Undercliffe in Bradford was highlighted as a residual in the study of; long term unemployment, no car or van access, mean age, socially rented property and the rate of no qualifications. Bolton and Undercliffe was identified as a hot spot, in the hot spot analysis. Thus, the study suggests that Bolton an Undercliffe experiences a high rate of deliberate fires due to these underlying demographic factors. Tong, also in Bradford, was also detected as a residual in the study of no qualifications, socially rented housing, no car or van access and mean age, in addition to be found to be a hot spot. This further supports the initial evidence between fire rates and the underlying factors. With similar evidence been found for the ward of Calverley and Farsley in Leeds which was identified as a residual in long term unemployment and the number of dimensions in which a household is deprived. Although not every ward identified as a hot spot was found to be a residual, this method identifies areas in which it is highly likely that the demographic factors are responsible for high fire rates. It is also a useful tool in identifying which wards should be targeted by the fire and rescue service and the police, however it must be noted that the study does not suggest that efforts in other wards should be diminished as a result of these findings.

4.6 Hotspots and deprivation rates.

From the regression analysis it is evident that the rate of households which are deprived in four or more dimensions is the most significant factor which coincides with deliberate fire rates. In Excel the mean of the rate of households deprived in four or more dimensions was calculated, which was 2.62; then wards which had the ten highest rates of households deprived in four or more dimensions were studied. As demonstrated in Table 4.5 all ten wards are located within the metropolitan boroughs of Leeds or Bradford, which also have the highest rates of deliberate fire and are where the majority of hotspots and concentrated. This cannot prove emphatically a relationship between deliberate fire rates and household depravity, due to the number of underlying factors and influences of crime, it highlights the quantity of evidence which indicates the deprivation is a significant influence.

Table 4.5: Displays the wards with the ten highest rates of household deprivation.

Ward	Rate of households which are deprived in four or more dimensions	Metropolitan Borough
Middleton Park	9.16	Leeds
Killingbeck and Seacroft	11.34	Leeds
Bowling and Barkerend	7.43	Bradford
Tong	7.53	Bradford
City and Hunslet	10.9	Leeds
Beeston and Holbeck	10.22	Leeds
Gipton and Harehills	9.69	Leeds
Armley Ward	9.59	Leeds
Manningham	11.56	Bradford
City	11.84	Bradford

5.0 DISCUSSION.

5.1 Findings.

This study has identified multiple wards in West Yorkshire which have experienced high rates of incidences of deliberate fire. The identification of these wards allows spatially targeted measures to be implemented by police forces and fire and rescue services across the county. These areas include the metropolitan borough of Bradford and Leeds; with specific focus on Bolton and Undercliffe (Bradford), Killingbeck and Seacroft (Leeds) and Tong (Bradford).

In addition to identifying wards of concern, the study has investigated the relationship between deliberate fire rate and a variety of socioeconomic variables. The findings from the regression analysis were notable with four of six socioeconomic variables being identified as statistically significant in all eight years of study. This evidences a clear trend in West Yorkshire between factors including; mean age, unemployment and household deprivation with deliberate fire. This does not provide evidence of possible trends across the country, however the same methods could be applied to different regions. The characteristic identified can then be identified within wards, providing further empirical evidence for arson reduction schemes.

However, although the regression shows a relationship between the variables, the model is a statistical estimation, consequently the results are based on a correlation. Thus not every ward with high rates of deliberate fire will have the characteristics identified as being potentially influential; mean age, unemployment and household deprivation. A study conducted at a lower level of aggregation, such as Lower Layer Super Output Area (LSOA), would be able to provide more reliable results; however, this is challenging due to the sensitivity of the data and the consequent suppression.

5.2 Limitations.

One of the major limitations to the research is the suppression of data, as data regarding deliberate fire cannot be released if there are fewer than three incidences per annum.

This restricts the choice of units of aggregation for the study as if it were to be conducted at LSOA, more locations would have no data available which has the possibility to impact upon findings. Consequently, ward level is the most appropriate aggregation scale to utilise in this context, however this does mean that any areas of significance cannot be analysed at a finer geographical scale which potentially could have provided a more in depth understanding.

An additional limitation is that there is no information available regarding the effectiveness of arson reduction schemes run by the police force and the fire and rescue service. In some locations these schemes may directly produce low rates of arson, however this is not reflected or examined in this study nor any pre-existing studies. Data regarding these schemes would be extremely challenging to collect and quantify, however the information may be useful in order to assess whether they are an appropriate and effective method of arson reduction.

The data regarding socioeconomic variables was collated from the 2011 census, due to the lack of information collected on an annual basis. The socioeconomic data utilised in the study was the same for 2008 to 2016. Data recorded annually would have improved the validity of the research but was unavailable.

A factor which may impact upon the validity of results produced is whether arsonists travel to a ward to commit their crime. Although arson against the individual provides the most significant motive to travel to commit the crime (Fritzon, 2001), arsonists do not always commit crime outside their ward of residence. The socioeconomic variables associated with high rate of deliberate fire assume that arsonists mainly commit crimes in their local area, rather than travelling to start fires in less deprived locations. A possible way to determine the residence of arsonists would involve the use of personal information collected by the police and would not be able to be analysed and published under the Data Protection Act (1998).

5.3 Opportunity for Further Research.

A key opportunity for further research is the study of more counties within England to allow comparison between regions and to test whether certain socio-economic variables consistently have a relationship with fire rate; rather than being specific to the case study of West Yorkshire. Due to the lack of previous studies using cluster and outlier analysis (Anselin local Moran's I) and hotspot analysis (Getis Ord Gi*) in England, an increase in the volume of available research would be advantageous to both the police force and the fire and rescue service. A more conclusive base of research would provide reliable results produced by homogenous methods on which to base intervention schemes.

The regression analysis confirmed findings from pre-existing literature, however more research needs to be conducted within other areas of the UK. Several variables were found to be statistically significant in some years, but not all; thus it may be useful to study their variables with data from forthcoming years. In addition; a wider range of variables could be studied in order to expand the study, with the inclusion of factors such as crime and household income.

In this study total deliberate fire rates are utilised for analysis, however this could be narrowed down further to primary and secondary fires, to enable an investigation as to whether spatial and temporal patterns differ between the two types of fire. In addition to this a freedom of information request could allow data to be collected as to what was targeted by the arson to see if certain types of primary and secondary fires were clustered in different locations; for example, whether abandoned cars set on fire are more common in a particular ward or metropolitan borough.

Due to the ward level of aggregation utilised in this study conclusions are subject to the restrictions of the Modifiable Areal Unit Problem (Jelinski and Wu, 1996). Further studies may be able to obtain and utilise point data which could then be utilised for a study more akin to the heat maps utilised by Corcoran et al. (2007), in a notable UK based study. However, this data may be subject to suppression under the Data Protection Act (1998).

6.0 CONCLUSIONS.

6.1 Conclusion.

Conducting a spatial autocorrelation (Moran's I) concluded that in each annum from 2008 to 2016, the rates of deliberate fire were spatially clustered, indicating that there may be potential reasons for the pattern.

The cluster and outlier analysis (Anselin Local Moran's I) produced evidenced the primary clustering of deliberate fires around the wards of central Bradford and Leeds. This highlighted the two main areas around which the West Yorkshire police force and fire and rescue service could base their prevention schemes.

The production of maps displaying a hotspot analysis (Getis Ord Gi*) emphasised the problem areas revealed in the cluster and outlier analysis, finding that a majority of hotspots were located in Bradford, with some in the wards of Leeds, such as City and Hunslet, Burmantofts and Richmond Hill and Armley. Cold spots were prominently featured in the North of the county in Ilkley, Otley and Yeadon and Adel and Wharfedale.

The regression analysis revealed mean age, unemployment, household deprivation and car access, to be correlated with the rate of deliberate fire and the aforementioned variables were statistically significant in every year of study. Household deprivation was the most significant influencing variable, which is in accordance with fire rates in the wards with the ten highest rates of household deprivation. The low mean age of residents in the Bradford may account for the high proportion of wards experiencing high rates of deliberate fires, although cannot be confirmed due to the range of influencing factors. However, the study cannot account for the slight increase from 2012-2013 to 2013-2014, due the large number of factors which influence an individual's decision to commit a crime and the location in which it is perpetrated.

The conclusions of this study have the potential to be utilised by the police and fire and rescue service to aim arson prevention schemes at areas which are most severely effected. In addition, initiatives can be instigated in the highlighted locations to limit the opportunities for fire; including strategies such as ensuring refuse and bins are not

permitted to accumulate for long periods outside a property and ensuring abandoned buildings or vehicles are properly secured. The conclusions confirm findings of earlier studies, suggesting that studies conducted over a decade ago are still valid. The study has added to the very limited numbers of UK based studies, providing an in-depth investigation of the county of West Yorkshire.

6.2 Closing statements.

- Mean age, the rate of households deprived in at least four dimensions and the rate of people long term unemployed are all significantly correlated with the rate of deliberate fires.
- The variable which has the largest impact on the rate of deliberate fire is the rate of households deprived in at least four dimensions, with high rates of deprivation being associated with areas experiencing high rate of deliberate fires.
- The wards most severely affected by incidences of deliberate fire are the most deprived wards of Bradford and Leeds.
- The study found that three wards demonstrated the strongest relationship between fire rates and the underlying demographic factors analysed; which are Bolton and Undercliffe (Bradford), Killingbeck and Seacroft (Leeds) and City (Bradford).

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APPENDIX.

Appendix Table 1: Demonstrating the coefficient and significance for the regression analysis for 2014-2015.

	2014-2015 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.02909	0.003
Mean Age	-0.3042	0.000
Rate of people with no qualifications (per 1000 people)	-0.00398	0.503
Rate of households deprived in at least four dimensions (per 1000 households)	0.8611	0.000
Rate of people long term unemployed (per 1000 people)	0.2615	0.000
Rate of socially rented households (per 1000 households)	-0.00439	0.453

Appendix Table 2: Demonstrating the coefficient and significance for the regression analysis for 2013-2014.

	2013-2014 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.03337	0.001
Mean Age	-0.2725	0.000
Rate of people with no qualifications (per 1000 people)	-0.00373	0.528
Rate of households deprived in at least four dimensions (per 1000 households)	0.8024	0.000
Rate of people long term unemployed (per 1000 people)	0.2617	0.000
Rate of socially rented households (per 1000 households)	-0.00356	0.540

Appendix Table 3: Demonstrating the coefficient and significance for the regression analysis for 2012-2013.

	2012-2013 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.03775	0.000
Mean Age	-0.2499	0.000
Rate of people with no qualifications (per 1000 people)	-0.00367	0.459
Rate of households deprived in at least four dimensions (per 1000 households)	0.7291	0.000
Rate of people long term unemployed (per 1000 people)	0.2299	0.000
Rate of socially rented households (per 1000 households)	-0.00467	0.336

Appendix Table 4: Demonstrating the coefficient and significance for the regression analysis for 2011-2012.

	2011-2012 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.0238	0.064
Mean Age	-0.3783	0.000
Rate of people with no qualifications (per 1000 people)	-0.00753	0.326
Rate of households deprived in at least four dimensions (per 1000 households)	1.101	0.000
Rate of people long term unemployed (per 1000 people)	0.3506	0.000
Rate of socially rented households (per 1000 households)	0.00086	0.910

Appendix Table 5: Demonstrating the coefficient and significance for the regression analysis for 2010-2011.

	2010-2011 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.0213	0.138
Mean Age	-0.4079	0.000
Rate of people with no qualifications (per 1000 people)	0.00277	0.748
Rate of households deprived in at least four dimensions (per 1000 households)	1.162	0.000
Rate of people long term unemployed (per 1000 people)	0.3857	0.000
Rate of socially rented households (per 1000 households)	-0.01298	0.123

Appendix Table 6: Demonstrating the coefficient and significance for the regression analysis for 2009-2010.

	2009-2010 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	0.0142	0.404
Mean Age	-0.4808	0.000
Rate of people with no qualifications (per 1000 people)	-0.03205	0.001
Rate of households deprived in at least four dimensions (per 1000 households)	1.495	0.000
Rate of people long term unemployed (per 1000 people)	0.4662	0.000
Rate of socially rented households (per 1000 households)	-0.03499	0.000

Appendix Table 7: Demonstrating the coefficient and significance for the regression analysis for 2008-2009.

	2008-2009 Fire Rate per 1000 People	
Socioeconomic Variables	Co.	Sig.
Rate of people with no car or van access (per 1000 people)	-0.0075	0.663
Mean Age	-0.4507	0.000
Rate of people with no qualifications (per 1000 people)	-0.0175	0.088
Rate of households deprived in at least four dimensions (per 1000 households)	1.409	0.000
Rate of people long term unemployed (per 1000 people)	0.4471	0.000
Rate of socially rented households (per 1000 households)	-0.02450	0.014

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Sarah Burdall

Health and Safety Manager (Faculty of Environment)

Environmental Compliance Manager Biological Safety

Health and Safety Services

5-9 Willow Terrace Road

University of Leeds, LS2 9JT

0113 3438042 | 0750 6707339 | s.e.burdall@leeds.ac.uk