Confidential

Response Time Analysis of Fire and Rescue Services in Collaboration with Nottinghamshire Fire & Rescue Service

by

Melis Tan

Student ID:4337043

2019

A Dissertation presented in part consideration for the degree of
"Industrial Engineering and Operations Management"

Abstract

Fire and emergency service response times have been increasing in recent years, thus response time analysis has become more attractive for researchers. Although some researchers have identified the causes of this increase, it could not be prevented thus far. This study analyses the factors affecting response time with regard to increased collaboration with Nottinghamshire Fire and Rescue Service in the UK. Descriptive statistics and multiple regression are used to analyse incident records for two years. The study found that vehicle status, distance, and pumping appliances status have a great impact on response time.

Table of Contents

List of Figures

List of Tables

Acknowledgements

I wish to express my gratitude to my supervisor, Dr Luc Muyldermans, for all of his invaluable instruction, assistance, and support throughout the process of conducting this research.

I am also grateful to Nottinghamshire Fire & Rescue Service, without whose cooperation the completion of this dissertation would not have been possible.

I would like to express my special thanks to my family and my fiancée for their financial and moral support which helps me to finish my master's degree.

Chapter 1
Introduction

Total response time in fire stations is essential in rescuing lives, securing disaster areas, and saving infrastructure and materials from destruction. Any factor that increases the total response time in fire stations also increases the threat of losing lives and possessions, while escalating the scale of the emergency. Analysing the factors affecting the total response time in fire stations has been explored through the literature, but recently the topic started to get more attention due to the latest developments. There has been an increase in the total response time of fire stations to incidents over the last 20 years in England (Lader, 2018)

The increase in response time also creates a problem of trust in society. The National Fire Chiefs Council Chair, Roy Wilsher, noted that:

> "It is disappointing to see response times are increasing and it is imperative this trend does not continue. The public needs to have every confidence in their fire and rescue service and we must ensure we have the resources so we can meet the needs of the communities we serve". (National Fire Chiefs Council, 2018)

This lamentable situation has led many practitioners and scholars in England to explore the possible factors that affect the total response time to recover trust in the Fire and Rescue Service. In this study, Nottinghamshire is selected as a pilot region to evaluate these factors on total response time by the Nottinghamshire Fire & Rescue Service (NFRS). The objective of this study is to identify various factors that could affect fire response time in Nottinghamshire and analyse these factors in collaboration with NFRS. Response time is evaluated under three processes: call handling time, crew time, and drive time, as shown in Figure 1. Factors that have an impact on each group are analysed below.

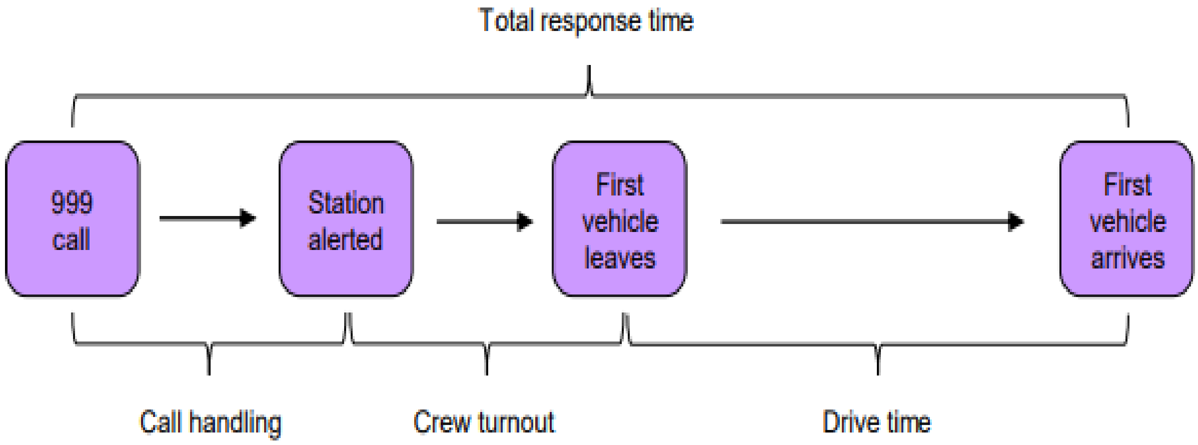

Figure 1: Total response time

Source: Lader (2019)

Call handling time is the time between receiving the call and pressing the button to send incident information to the fire station, or the call made by the first part-time worker who answers the call. The way callers get incident information (automated fire detector/ in person), time to reach part-time worker/ crew (day/ night), type of fire, and number of caller availability all have impacts on call handling time.

Crew time is calculated from the fire station being alerted to the first fire engine dispatched from the fire station. There are several factors affect crew time, such as methods of procedure implementation (same/ depending on station), operation strategy for each station (whole time/ whole time, & on call, mixed crewing, on call), crew members (same/ similar teams), time when fire station/ engine/ part-time worker informed (day/ night), type of call, number of fire station in the region, location of the fire station, traffic, dressing policy, and incident call frequency among fire stations in Nottinghamshire etc.

Drive time is calculated by the distance a fire engine has to travel from the dispatched fire station or from the fire engine's current location (if it is mobile) to the incident location. There are many factors that affect distance time, such as peak demands, rush/ non-rush hour, weather, season, road works, driving conditions, how cars are parked in front of buildings etc. These factors are explored in the interview with NFRS officers and the literature review. Moreover, level of centralisation/ decentralisation of the fire stations in Nottinghamshire and fire stations' response availability affect distance. If there is no fire engine available in the fire station, dispatch from another fire station is triggered, which might be far away from the incident place. The frequency of this circumstance has a considerable effect on response time. According to NRFS officers, there has been a significant increase in drive time, whereas call handling time and crew time have slightly changed (to a lesser extent) over the years. Therefore, most of the analysis presented in this study is focused on drive time and factors that affect it.

This analysis is explained under six topics. Firstly, the method and factors based on type of rescue service, and fire, ambulance, and police services are discussed in the literature review. Data obtained from the Incident Record System (IRS) in Nottinghamshire in 2017-2018 is explained in chapter 3, along with the methodology and research approach. The current and past system of NFRS is investigated in chapter 4, followed by the results for pump crewing status, time of the day, seasonality, incident day of the week, incident location, vehicle status, and fire station location factors affecting response time in chapter 5, with regression analysis for the processes of call handling, and crew and drive time. Chapter 6 concludes this dissertation by discussing the implications of the findings, and suggesting areas for future work.

Chapter 2
Literature Review

2.1. Fire response

After the Great Fire of London in 1666, fire brigades were established by private insurance companies, without any government legislation or regulation. In 1865 these brigades were gathered together to form the London Metropolitan Fire Brigade, reflecting the gradual professionalization of the fire service. The first modern fire department standards were published in Edinburgh in 1830, and these standards served as a guidance of how a fire department should be operated to be considered a successful fire department by the UK government (International Academies of Dispatch, n.d.).

Fires can be categorized under two groups: primary and secondary fires (Government UK, 2016). *Primary fires* are more severe, and can injure people or cause more extensive financial loss or damage to infrastructure. Primary fires are composed of mainly four groups: dwelling fires, other building fires, road vehicle fires, and other outdoor fires. *Dwelling fires* are commonly seen in residential places including houses, apartments, and residential organizations. They also includes fires in temporary architecture used for dwelling purposes, such as caravans. Secondly, *other building fires* are those that occur in other residential places such as hostels, hotels, student accommodation, or non-residential places like restaurants, religious structures, and factories and warehouses. *Road vehicle fires* are those that occur in machines used for transportation on roads, such as automobiles, coaches, and motorcycles. Lastly, *other outdoor fires* are fires that occur in outdoor locations and cause casualties, requiring at least five fire engines to get the fire under control. *Secondary fires* are mainly less serious outdoor fires, and are generally neglected until casualties or rescues are required (Sayer, 2010). As mentioned previously, the average total response times (minutes) to net fire incidents in England has increased dramatically from 1994 to 2018, as revealed by data shown in Figure 2, collected by the Home Office's online Incident Recording System (IRS) (Lader, 2019).

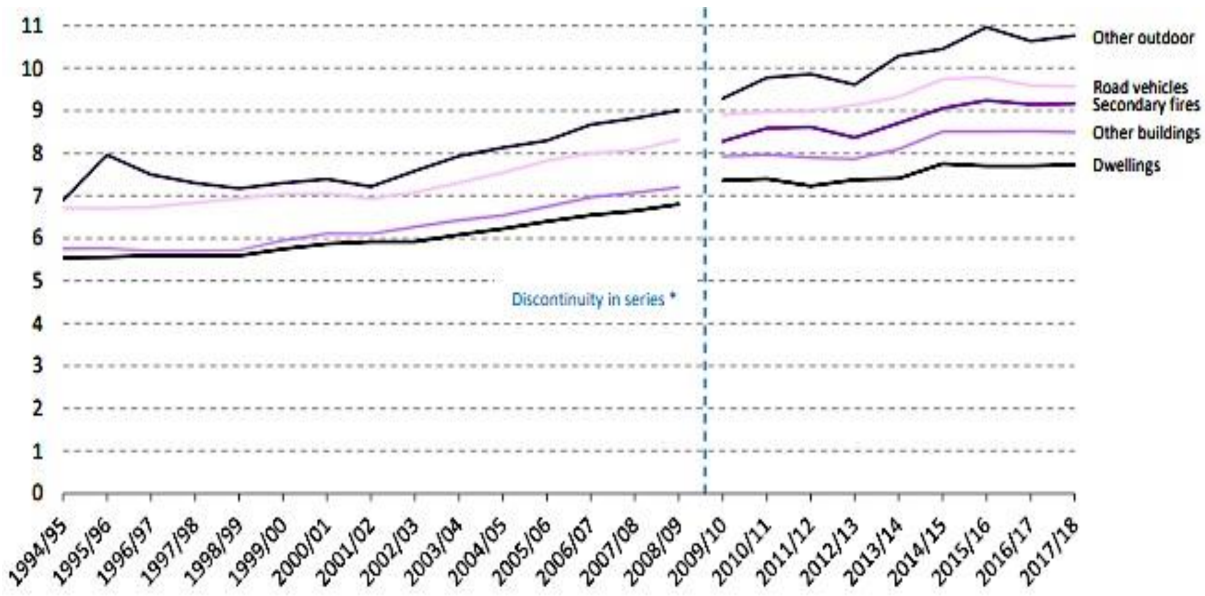

Figure 2: Aggregated response time (minutes) for fires in England, 1994-2018

The following section explores potential factors affecting response time for emergency services, including fire, ambulance, and police response time analysis. The subsequent sections critically analyse related literature concerning methods used in response time analysis.

2.2. Potential factors affecting response time

2.2.1. Fire

Researchers commonly study fire response time analysis and aim to find the potential factors affecting it. The type of fire department (industrial or municipal fire department) may affect response time. To understand potential factors and their impact on response time, two different structured fire departments were compared and factors affecting response times were found to be: firefighting experience, training, special qualifications, exercise training, education, commuting time, external work and demographic variables (Garver et al, 2005).

Some studies focused on the analysis of drive time. Kolesar et al. (1975), stated that engine acceleration, response velocity, and distance required to achieve constant velocity were determining characteristics of drive time, while the experimental test revealed that time of day and traffic have trivial impacts on travel time. A report published by the Fire Brigades Union in 2015 declared that travel distance from the fire station to incident, type of the road, weather conditions, traffic conditions regarding time of the day, number and types of intersections on the road, type of responding fire engine, local knowledge of the driver, and experience of driver are potential characteristics to evaluate response time. Although there is time difference between the publication dates of the studies above, these emphasized a lot of common potential factors that affect fire drive time, such as traffic and time of the day.

Material used for construction, building structures and construction methods have been evolving, and smoke detectors usage have been increasing. Therefore, researchers started to focus on investigating relationships between residential changes and fire response time. Fire services' response time depends on residential fire action, such as type of residence, construction material, availability and usage of smoke detectors, and fire stations' operational approach (Kerber, 2011). A report entitled *Review of Fire and Rescue Service Response Times: Fire Research Series 1/ 2009 Report* analysed potential factors in response time over the years in collaboration with eight Fire Rescue Services (FRS) in England. These eight FRS were located in different regions of England, selected from both rural and urban areas. The selected FRS were expected to show overall response time fluctuations in the country. The priority of selecting an FRS was dependent on the high increase in the response time compared to previous terms.

Firstly, five of the FRSs stated that traffic was the main source of high increase in response time. Traffic levels have been increasing dramatically over years according to the report. Table 1 shows the correlation between fire response time and traffic levels between 1996 to 2006 in Nottinghamshire. Moreover, traffic calming measures, traffic lights transformation, and prohibited parking have an impact on response time.

Table 1: Correlation between fire response time and traffic levels in Nottinghamshire between 1996 to 2006

Year	*Response time (mins)*	*Traffic levels (millions vehicles/ km)*
1996	5.7	7278
1997	5.4	7400
1998	5.1	7483
1999	5.5	7697
2000	5.5	7626
2001	5.4	7710
2002	5.5	7902
2003	5.7	8058
2004	5.6	8234
2005	5.9	8226
2006	5.7	8421

Source: *Review of Fire and Rescue Service Response Times: Fire Research Series 1/ 2009 Report*

Secondly, the partial impact on response time might be explained by obtaining new operational procedures according to two of FRSs. For example, the crew has to wear personal protective equipment in the fire station with the implementation of new policies, whereas previously crews donned their equipment in the fire engine itself, enroute to incidents. Thirdly, some of the FRSs declared that firefighters working for Community Fire Safety result in an increase of response time. Other factors with a minor impact on the response time increase were changes in crew's local area experience, shift changes, longer incident information messages sent to crews, and crews' waiting times in stations until receiving information on which engine will be dispatched to the incident for multi-engine stations. Finally, the researches mentioned that cuts in FRS resources and the rise in the number of fire incidents were obvious factors (Greenstreet Berman Ltd, 2009).

Average response times vary regarding to the type of fire, as shown in Table 2. The highest increase in response time between 1996 to 2006 was for *other building fires*, with a 19% increase. *Vehicle fires* and *dwelling fires* were followed with an increase of

18%. The least increase in response time was observed for *outdoor fires* (Greenstreet Berman Ltd, 2009).

Table 2: Average response time for primary fires in England

Year	*Dwellings*	*Other buildings*	*Vehicles*	*Outdoor*
1996	5.5	5.7	6.7	9.7
2006	6.5	6.8	7.9	11.1
Increase in response time (minutes)	18%	19%	18%	14%

Source: Fire Brigades Union Report (2015)

As a result, the factors affecting response time are complex and there is no silver bullet solution; no specific factor in the response time process explains the delay of response. The multifarious facts involved include dire engine travelling speeds; availability of engines; distance to incident place; waiting time by firefighters responding to calls; the quality and clarity of the information given by the caller; availability of emergency call centre employees; the training and competency of emergency call centre employees; weather conditions; type of responding fire engine; and drivers' local knowledge, all of which potentially contribute to time fluctuations (Claridgea and Spearpointb, 2013).

2.2.2. Ambulance

Response time has a crucial role for Emergency Medical Services (EMS) to minimise the impacts of emergency events, limit mortalities and injuries, and expedite patient recovery (Blanchard et al, 2012). Therefore, identifying potential factors should be the first step in improving ambulance response time. Research on ambulance dispatch and relocation problems indicated that potential factors include prioritization of the ambulance calls, ambulance location, and ambulance availability when the call is received (Andersson and Varband, 2007). Marinho and Silva (2010) stated that potential factors affecting the response time of EMS include ambulance speed, time of the day, distance to incident, month of the year, ambulance demand, frequency of calls, and number of available ambulances when call received. Moreover, Nehme, Andrew, and Smith (2016) examined factors such as distance to incident, patient priority, intensive care paramedic first on scene, number of total responses, number of time critical responses, ambulance capacity, number of calls in previous hours, and day of the week, all of which were identified as elements in response time. In addition to these factors, some studies also emphasized different additional issues such as public health cuts that affect the evaluation of current emergency system capabilities (Cabral et al., 2018).

2.2.3. Police

Potential factors that affect police response time include type of call, driving speed, distance to incident, police officers' location when the call is received, waiting time for assisting police officer, and waiting time by police officer who receives the call (Pate et al, 1976). Nehme, Andrew, and Smith (2016) stated that such factors could be investigated in two dimensions: the level of factors related with circumstantial contexts; and the regional level. Time of day, day of week, arms participation, and caller's race were categorized as circumstantial level factors, while housing stability, concentrated disadvantage, and immigration accumulation were essential factors of the regional level (Lee J.S., Lee J. and Hoover, 2016).

2.2.4. Collective emergency response

Some researchers have examined the emergency services collectively, including fire, ambulance, and police responses, rather than analysing them separately, reflecting that many accident types (e.g. car crashes) may require two or all emergency services' attendance. Car crashes pose a fire risk possibly warranting fire services as a precautionary measure, and in the actual event of a fire the attendance of a fire engine is mandatory. Someone might be injured due to car accident, therefore emergency medical service is necessary, and there is intrinsic property damage (by definition, i.e. damage of vehicles at a minimum, with possible damage to surrounding infrastructure or property), so police are needed for official reports. In this scenario, response time is valid for all emergency services. Some researchers have investigated the factors that affect emergency service response time regardless of the type of the emergency service, focusing on factors such as: average daily traffic, heavy vehicle involvement, urban or rural area, light condition, day of week, number of lanes, number of vehicles involved, highway location, speed limit, road condition, crash severity, and weather condition (Lee and Fazio, 2005). They may have many similarities compared to the factors that was discussed separately under each individual type of emergency service. Table 3 summarises potential factors that affect response time regarding the type of the emergency service.

Table 3: Summary of the discussed articles

Study	*Emergency service*	*Potential factors*
Kolesar, Walker, & Hausner, 1975	Fire	Engine acceleration, response velocity, distance necessary to achieve constant velocity, peak hour, time of the day, traffic
Pate, Ferrara, Bowers, & Lorence, 1976	Police	Type of call, driving speed, distance to incident, police officers' location when receive the call, waiting time for assisting police officer, waiting time by police officer responding to call
Garver et al, 2005	Fire	Firefighting experience, training, special qualifications, exercise training, education, commuting time, external work and demographic variables
Lee, J.T., & Fazio, 2005	Fire, ambulance and police	Average daily traffic, heavy vehicle involvement, urban or rural area, light condition, day of week, number of lanes, number of vehicles involved, highway location, speed limit, road condition, crash severity, weather conditions
Andersson, & Varbrand, 2007	Ambulance	Ranking of the ambulance calls, ambulance location, ambulance availability when call received
Greenstreet Berman Ltd, 2009	Fire	Traffic, new operational policy, crews' local knowledge, shift change, longer incident information messages, engine waiting time in the station, working for Community Fire Safety
Marinho, & Silva, 2010	Ambulance	Ambulance speed, time of the day, distance to incident, month of the year, demand, frequency of the call, number of available ambulances when call received
Kerber, 2011	Fire	Residential fire action and fire stations operation approach
Claridgea, & Spearpointb, 2013	Fire	Fire engine travelling speed, availability of engine, distance to incident place, waiting time by firefighter respond the call, the quality and clarity of the information given by the caller, availability of emergency call centre employee, the training, competency of emergency call centre employee, weather condition, type of responding fire engine, drivers' local knowledge
The Fire Brigades Union, 2015	Fire	Traffic condition, type of primary fire, time of the day, cut in resources
Nehme, Andrew, & Smith, 2016	Ambulance	Distance to incident, patient priority, intensive care paramedic first on incident location, number of total responses, number of time-critical responses, ambulance capacity, number of calls in previous hour, day of week
Nehme, Andrew, & Smith, 2016	Police	Time of day, day of week, arms participation, caller's race, housing stability, concentrated disadvantage, and immigration accumulation
Cabral et al, 2018	Ambulance	Traffic, urban vs. rural area, public health cuts

2.3. Methods used in response time analysis

Response time analysis is crucial for emergency services to improving their services. Simpson and Hancock (2009) investigated 50 years of response time data for emergency services and operations research for this field. Table 4 shows which operational research methods were used in articles published between 1967-2007 years for emergency service analysis: urban services, disaster services, hazard specific and general emergency (Simpson and Hancock, 2009). 361 articles were analysed by Simpson and Hancock (2009), 36.3% of which used math programming, including stochastic and constant programming, for analysing response time data. The following are the main methods used, in descending order of usage prevalence: probability and statistics, simulation, decision theory and MAUT, system dynamics, fuzzy sets and expert systems, queuing theory and soft operations research. The most commonly used method for urban service, disaster service, and general emergency analysis is math programming, although, probability and statistics are the most common methods for hazard-specific analyses.

Table 4: Emergency response research articles based on methodology

Subject	*No. articles*	*% of convenience sample*	*Ranking with focus group category*			
			Urban services	Disaster services	Hazard specific	General emergency
Math programming, including stochastic and constraint programming	131	36.3	1	1	2	1
Probability and statistics	75	20.8	2	4	1	3
Simulation	45	12.5	3	2	5	2
Decision theory and MAUT	35	9.7	7	3	3	5
System dynamics	27	7.5	4	7	6	4
Fuzzy sets and expert systems	24	6.6	8	6	4	6
Queuing theory	14	3.9	6	5	7	8
Soft operations research	10	2.8	5	8	8	7

Source: Simpson et al. (2017)

To examine whether the model type applied for emergency services after 2007 has changed, a few articles have been investigated which were published since then. In 2009, statistical analysis was used to identify and analyse fire performance measurements related with fire department essential functions by investigating one year (2008) of fire incident records in the USA (Flynn, 2009), and a partial correlation and multiple regression method study was conducted to examine response time analysis for fire services in the UK (Greenstreet Berman Ltd., 2009). In the latter report, fire incident data was obtained from Chartered Institute of Public Finance, while Department of Transport and employee records were used from 1996 to 2006.

Discrete event simulation was used to conduct ambulance response time research with hyper cube model (Budge, Ingolfsson and Erkut, 2009) and optimization (Marinho and Silva, 2010). In 2010, geographic information system and ambulance deployment strategy methods were applied to reduce ambulance response time in Singapore (Ong et al, 2010). It was found that ambulance deployment strategy was very straightforward, cost-saving, and had a great impact on reducing response time. Additionally, geospatial–time analysis was easy to implement for the Emergency Medical System.

Various types of models have been developed to measure travel time precisely and clearly, to measure the emergency system performance (Kolesar, Walker and Hausner, 1975). It was assumed that drive time equals to travel distance divided by average response velocity; however, Kolesar et al. (1975) claimed that drive time was directly related with the square root of distance for short travel distance, and solely in a linear relationship for long travel distance, based on analysis of over 200 observations among different fire companies in 1971 in New York. Linear regression model was used for this analysis.

There are many similarities and differences between industrial and municipal fire departments. In 2005, these two fire departments were compared based on fire fighters' age, exercise frequency, physical fitness, and type of call, using physical fitness test, surveys and analysis of variance (ANOVA) tests in the USA (Garver et al, 2005). Firefighters aged between 29–50 in 2001 were examined in the first phase, then a follow-up survey was conducted in 2003 with 14 firefighters who attended the first phase.

Probability and statistical analysis are still some of the most common methods for analysing response time according to current published papers. Descriptive statistics (Bahrami et al, 2011), linear probability model (Wilde, 2012), multivariable quantile regression model (Nehme, Andrew and Smith, 2016), and linear regression (Lader, 2019) were statistical models were used by researchers to investigate fire or ambulance response time. These articles indicate that regression analysis is the most popular statistical analysis tool. In addition, some articles used regression analysis with other methods for further investigation in emergency services, such as sensitivity analysis (Lee and Fazio, 2015). Methods other than those mentioned above for response time were; maximal expected survival location, Markov chain, three bi-objective models, Wilcoxon test, survey development, covering model, ABC algorithm, double standard model, issue of bottleneck assignment, Kruskal-Wallis test, and MCLP (Cabral et al., 2018). Table 5 summarises the discussed articles related with location (research geography), type of emergency (fire, ambulance, police), and analysed data.

Table 5: Summary of discussed articles

Study	*Location*	*Emergency service*	*Method*	*Data*
Kolesar, Walker, & Hausner, 1975	USA	Fire	Linear regression	More than 200 articles for different fire companies in 1971 in New York
Garver et al, 2005	USA	Fire	Physical fitness test, survey and ANOVA	Firefighters aged between 29–50 in 2001, and 14 firefighters for follow-up survey in 2003
Lee, & Fazio, 2005	USA	Fire, ambulance and police	Cox-regression model and Sensitivity Analysis	Rush hour and traffic crash data from Ohio State for 1999
Flynn, 2009	USA	Fire	Statistical analysis	Overall fire incidents between 2007-2008 in the USA from NFPA Fire Loss 2008 USA Report
Simpson, & Hancock, 2009	Global	Fire, ambulance and police	Literature review	1967-2007 years of emergency service records, including disasters and incidents in urban areas
Greenstreet Berman Ltd., 2009	UK	Fire	Partial correlations and multiple regression	Department for Transport data, Chartered Institute of Public Finance Accountants for incident records and staff records between 1996 to 2006.
Budge, Ingolfsson, & Erkut, 2009	Canada and USA	Ambulance	Hypercube model and discrete event simulation	Two data sets; 3,124 cases in South Carolina in 1986 and 55,403 cases in Alberta in 2003

Table 5: Summary of discussed articles (cont.)

Study	*Location*	*Emergency service*	*Method*	*Data*
Ong et al, 2010	Singapore	Ambulance	Geographic information system and ambulance deployment strategy	From October 1, 2001, to October 14, 2004 for individual out of-hospital cardiac arrest (OOHCA) patient records
Marinho, & Silva, 2010	Brazil	Ambulance	Discrete event simulation and optimization	1,734,416 calls which were made between October 2006 and August 2009 in Belo Horizonte
Bahrami, Maleki, Ezzatabadi, Askari, & Tehrani, 2011	Iran	Ambulance	Descriptive statistics	Between 2008-2009, 11,961 incident reports from 7 different EMS stations in Yazd
Wilde, & Ty, 2012	USA	Ambulance	Linear probability model	Utah Prehospital Incident Dataset for incident reports and mortality records from Utah Emergency Department Encounter Dataset between 2001 to 2002
Lee, & Fazio, 2015	USA	Fire, ambulance and police	Cox-regression model and Sensitivity Analysis	Rush hour and traffic crash data from Ohio State for 1999
Nehme, Andrew, & Smith, 2016	Australia	Ambulance	Multivariable quantile regression model	Each incident record between 2009 to 2014 in Melbourne
Cabral et al, 2018	Brazil	Ambulance	Literature review	Scopus/ Embase, NCBI (PubMed) and Science Direct databases for EMS articles between 2007 to 2017
Government UK, 2019	UK	Fire	Linear regression	1994 to 2018 fire incident records in England

Problem types vary according to the type of the emergency services (fire, ambulance, and police) involves. Firstly, problems related with the fire emergency services in the literature are divided into three main groups: assignment problems (number of firefighters assigned to fire engine or fire station), deciding the quantity of required engines, and the engines' positions in the region. The most important element the fire department must decide is the fire engine which has to be assigned to incident, and the quantity of engines for the specific incident (Swersey, 1994). Secondly, assignment problems such as assigning police cars to specific location or police officers to cars, are common police problems in the literature. Dispatching police cars is based on the priority of the call. Lastly, there were two type of ambulances: those equipped with specialized equipment, or those equipped with basic medical equipment.

Emergency medical services problems focus on deciding which type of vehicle to send the incident place. In 1994, emergency services were not only composed of ambulance or hospital staff, but also firefighters in charge of emergency medical services (Swersey, 1994). As a result, assignment problems are common among emergency services and can hamper emergency response if not managed efficiently.

Chapter 3
Materials and Methods

This chapter presents the research methodology, data collection procedures, and research approach undertaken for further analysis.

3.1. Research Methodology

Descriptive statistics and regression analysis are used in this study. All analyses were performed using Excel.

Descriptive statistics is used for describing and understanding the properties of a data set by providing summaries about the measures of the data (Peatman, 1947). The most common types of descriptive statistics are the mean, median, and mode. Descriptive statistics can be used for measuring central tendency or variability. The average values of the given data set are analysed on the central tendency measures and the dispersion of data is explored on variability measures. Both measures use tools such as graphs and tables. In central tendency measures, the centre position of a distribution of data set is analysed. Typically, the distribution is described by using the mean, median, or mode (presenting the most common patterns of a data analysis). Measures of variability are used to analyse the shape and spread of the data set. Range, quartiles, and variance are examples of variability measures.

In this study, the two-year data set was investigated based on monthly and mean and standard deviation values, calculated as shown in Table 6. Mean time and standard deviation for all processes were calculated for OC and WDS crews for 2017-year, 2018-year, and the two-year data set separately. The mean of the seasons was compared based on two-year data to investigate any seasonality in the two-year data set.

Table 6: Two-year data set

	Av. call handling time	*Av. crew time*	*Av. drive time*	*Av. response time*
Overall Av.	00:02:33	00:02:35	00:05:54	00:11:02
2017 Av.	00:02:30	00:02:39	00:05:42	00:100:51
2018 Av.	00:02:35	00:02:30	00:06:06	00:11:12
	Call handling time SD	*Crew time SD*	*Drive time SD*	*Response time SD*
Overall Std	00:03:19	00:01:52	00:04:01	00:05:57
2017 Std	00:03:00	00:01:55	00:03:47	00:05:30
2018 Std	00:03:35	00:01:49	00:04:13	00:06:21

Regression analysis is a statistical process to analyse and estimate relationships between variables. Generally, the analysis is conducted to explore how values of the dependent variable change when one of the independent variables is subject to change while the others are fixed. Other than exploring the relationship of dependent and independent variables, regression analysis is also commonly used to predict and forecast. In order to carry out regression analysis, techniques such as simple linear regression, multiple linear regression, or ordinary least squares have been developed. Regression analysis should be carried out with caution, especially with observational data, as it may give misleading results (Freedman, 2012).

In this study, linear regression analysis was used as an example of determine correlation degree with distance and drive time, number of mobilisation records, and drive time. Multiple regression analysis was used three times to determine the effect of factors on total response time processes; call handling; crew time; and drive time.

3.2. Data collection

NFRS stations, pumps, and mobilisation data between 01/ 01/ 2017 to 31/ 12/ 2018 in Nottinghamshire were obtained from NFRS.

3.2.1. Stations data

NFRS stations data, shown in Appendix A, Table A1, indicate each fire station's call sign, station number, number of pumps assigned for each station, station crewing status, postcode and coordinates of the corresponding fire station. Regarding the data, 24 fire stations were available in Nottinghamshire in 2017-2018 and their locations are shown in Figure 3. Each station is assigned a unique number and call sign is based on station number. Call sign used to determine which pumping appliance is dispatched from which station. Crew's working system are analysed under station crewing status and it is categorized under two groups: Wholetime Duty System (WDS) and On Call (OC). In WDS, crew members are in the station 24/ 7, depending on the station, except if they are on duty outside of the station, including going to incident locations. In OC system, crew members do not stay in the fire station. Crews are informed by a pager from work, house, or any location and they have at most five minutes to reach the fire station. Crewing status for each station in 2017/18 is shown in Figure 3.

3.2.2. Pumps data

Pumps data, shown in Appendix A, Table A2, indicates pump crewing status and call sign according to the fire station. According to data, 30 pumping appliances are available for 24 fire stations. London Road, Ashfield, Workshop, Retford, Newark, Stockhill fire stations have two pumps each. Each pumping appliance has a unique call sign number and this number is related with the fire station. A station crewing status is explained as the crewing status of the first appliance; this is followed by the crewing status of the second appliance (if available) assigned the fire station.

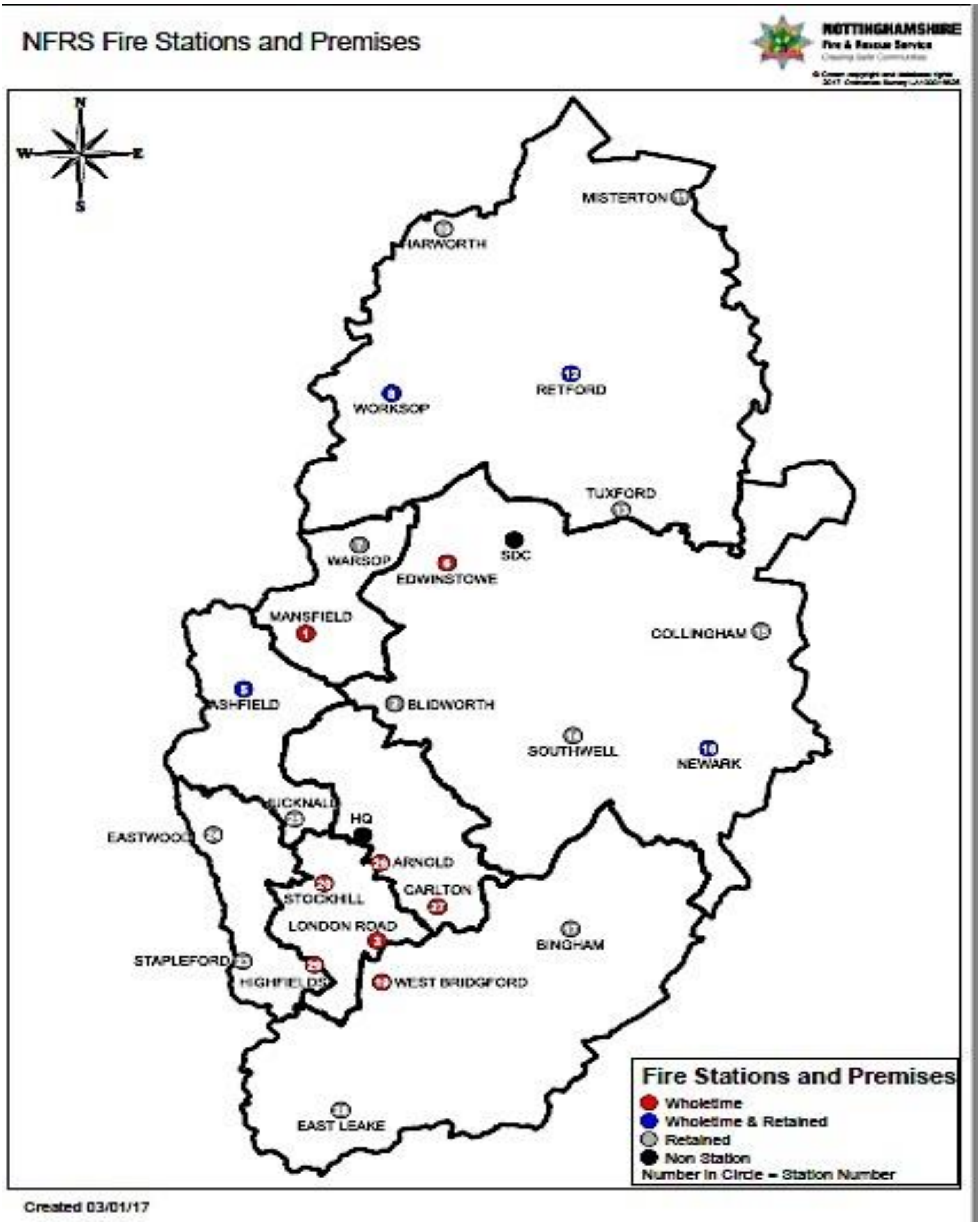

Figure 3: Fire station location and crew type, 2017-2018

3.2.3. Mobilisation data

Mobilisation data was collected from Incident Record System (IRS) in NFRS, which is an automated mobilised data collection system in England, with data for all fire and rescue service incidents that NFRS attended. It covers the years 2017 and 2018, which were studied in this research. 34,382 incident records were collected during this time interval. The data is divided into five groups: incident information, responding appliance information, time date information, location information, and record information. It is explained in the following section.

3.3. Mobilisation data information

3.3.1. Incident information

For each incident, incident number, initial incident type, incident type, incident subtype, motive, and property type were obtained, as described below.

3.3.1.1. Categorisation

Incident number is the number of each incident in IRS.

Initial incident type refers to the first incident type determined according to the caller report. Initial incident type is mainly categorized under six groups: alarms, civil disturbance/ unlawful act, fire, hazardous material, humanitarian or assistance, and rescues. Alarm types are AFA, gas alarms, and smoke alarms.

Civil disturbance/ unlawful act comprises two groups: bomb suspected, or call challenged. Fires are divided into 28 groups: abandoned call, barn, below ground fire, boat, building, caravan, chimney, chimney thatch, cylinder other, derelict property, electrical installations, fire, fire in open and large area, fire in open and small area, fire not out, late fire call, persons, persons on fire, post box, railway embankment, railway train passenger, road furniture, grain dryer, smoke in the open area, large vehicle and small vehicle.

Hazardous material is categorized into seven groups: gas involvement, major hazardous material, minor hazardous material, leaks, spills suspicious powder, and vehicle leaking fuel.

Humanitarian or assistance incidents are divided into ten groups: advice given, assist other agency, co-responder, dangerous structure, fire safety issue, flooding, persons collapsed, persons locked out, road traffic collision (RTC), and swill away.

Other incidents include aircraft accident light, large or small animal rescue, boat rescue, building collapse, lift persons shut in, persons trapped, railway accident, RTC persons trapped in large or small vehicles, suicide attempt, water, mud, height, entrapment and confined space.

3.3.1.2. Investigation

Incident type is the final wide incident categorization (fire, false alarm, special service) decided when the crew attend the incident location.

Incident subtype is the specification of the incident type, divided into seven groups: apparatus, chimney, good intent, malicious, primary, RTC, secondary, and other.

Motive is the cause of incident (either accidental or deliberate).

Property type is the type of area where the incident occurred. Residential or non-residential building, dwelling, grassland, other outdoor, other transport, refuse, road vehicle, structure and unknown are the types of property.

3.3.2. Responding appliance information

For each incident, call sign, vehicle status, arrival position and first appliance data were collected for corresponding incident number.

Call sign is the call sign of the dispatched appliance for the specified incident number.

Vehicle status is the dispatched appliance status with corresponding call sign, and it is divided into five groups: alert, available, in attendance, mobile available, and mobile to incident. Mobile available is defined as the appliance is available and moving at any location. Available status explained as the appliance is available but stable. Available appliances could be in the assigned fire station or any location.

Arrival position is the arrival position of the appliance with specified call sign at the incident specified number. Only first and second arrivals are indicated in the data.

First appliance is the call sign of the first appliance which arrived at the incident with a specified incident number.

3.3.3. Time-date information

For each incident, incident time of call, appliance sent, send time, appliance mobile, mobilise time, appliance arrive, and IRS arrival time data were gathered for the corresponding incident number.

Incident time of call is the time and date that the phone started to ring in the control room for the corresponding incident number.

Appliance sent is the time and date that crew assigned to the appliance with specified call sign start preparation for mobilization for the specified incident number.

Send time is the time and date of any appliance that was the first appliance started preparation for mobilization for the specified incident number.

Appliance mobile is the dispatched time and date of the appliance with specified call sign from the station.

Mobilise time is the first appliance time and date of dispatch from the station for the specified incident number.

Appliance arrive is the time and date that the appliance with specified call sign arrives at the incident with the specified incident number.

Irs arrival time is the time and date that the first appliance arrives the incident with the specified incident number.

3.3.4. Location information

For each incident, address, Uprn, easting, northing, WGS84 origin latitude and WGS84 origin longitude were gathered for corresponding incident number.

Address is the address of the incident with specified incident number.

Uprn is the Unique Property Reference Number of the specified address.

Easting is the British National Grid Easting of the specified address.

Northing is the British National Grid Northing of the specified address.

WGS84 Origin latitude is the latitude of the location with specified easting and northing, in the WGS84 geometric datum.

WGS84 Origin longitude is the longitude of the location with specified easting and northing, in the WGS84 geometric datum.

In the data set, most of the WGS84 Origin latitude and WGS84 Origin longitude information are not valid for incidents.

Veu pk is a primary key field for corresponding incident number.

3.3.5. Record information

Error code is a value generated when there is a problem in incident record. There are six types of error codes:

- Call to Arrive time (CtoA) is generated when *Irs arrival time - Incident time of call* is less than 1 minutes or greater than 60 minutes.
- Call to Send time (CtoS) is generated when *Send time - Incident time of call* is not between 0 and 10 minutes.
- Fire station (FStn) is generated when the incident happened at a fire station in Nottinghamshire.
- Late Fire Call (LFC), the time of call after the fire was quenched.
- Null is generated when one of the following essential times are missing: *Mobilise time, Send time, Irs arrival time, Incident time of call.*
- Send to Mobile time is generated when *Mobilise time - Send time* is not between and minutes.

If there is not a problem in the incident record, the error code is not valid for corresponding incident number.

30 mobilisation records in mobilisation data are shown as a sample of incident information, responding appliance information, time date information, and location information dataset in Appendix A, Table A3, Table A4, Table A5, and Table A6, respectively.

3.4. Data filtration

Data cleaning is divided into four steps.

First step – incident records with missing values in any of the following time date information are deleted from mobilisation data: *Appliance arrive, Appliance mobile, Appliance sent, Send time* and *Mobilise time*. After cleaning, 31,155 were records left.

Second step – Gemma Polmear, a GIS Analyst in NFRS, recommended excluding the following from mobilisation data exclude data:

- *Call sign* not corresponding a pumping appliance.
- Incident location not in Nottinghamshire or the City of Nottingham
- *First Appliance*'s call sign not valid.
- *First Appliance* not an NFRS appliance.
- *Error code* valid for incident number.
- *Appliance arrive* time manually corrected in IRS to make a difference of 2 or more minutes from the original *Appliance arrive* time.

In the second step, as per her suggestions, *Error codes* (if valid for incident number) were deleted. After cleaning, 29,747 records were left.

Third step – records with a total response time of over 1 hour were deleted, leaving, 29,142 records. The purpose of this subtraction is that most of these records do not have *Arrival Position* value, so there is a high probably these pumping appliances were next-day inspectors.

Fourth step – specified negative *incident numbers* for call handling time and drive time were deleted from mobilisation data.

After the above data cleansing process, 29,142 records of 2017-2018 mobile data remained for subsequent analysis.

3.5. Research approach

According to mobilisation data for 2017-2018, response time calculations are calculated based on the following section. Due to the data set being large, some assumptions are made and applied for each analysis and interpretation section.

3.5.1. Response time calculations

Response time is composed of three time intervals; call handling time, crew time, and drive time. Firstly, call handling time is the time difference between *Appliance Sent* and *Incident Time of Call*, as shown in Equation 1. Call handling is calculated for each *incident number. Appliance Sent* is used in this calculation instead of *Send Time*, because *Appliance Sent* shows the time that the pumping appliance with a specified *call sign* was mobilised to the specified incident number, whereas *Send Time* indicates the time of the first pumping appliance's mobilization. Secondly, crew time is the time between *Appliance Mobile* and *Appliance Sent*, as shown in Equation 2. *Appliance Mobile* is used in this equation instead of *Mobilise Time* to calculate each individual pumping appliance crew time. Thirdly, drive time is calculated by *Appliance Arrival* minus *Appliance Mobile*, as shown in Equation 3. *Appliance Arrival* is the arrival time of the pumping appliance with specified *call sign* to incident. Finally, *response time* is the sum of call handling, crew, and drive time with specified *incident number* and *call sign*. As a result, response time is calculated for each pumping appliance for each *incident number.*

Call Handling Time = *Appliance Sent – Incident Time of Call* (1)

Crew Time = *Appliance Mobile – Appliance Sent* (2)

Drive Time = *Appliance Arrival – Appliance Mobile* (3)

Response Time = Call Handling Time + Crew Time + Drive Time (4)

3.5.2. Assumptions

1. Cumulative factor impact is ignored. Each factor's individual impact on response time is analysed. For example, road work and weather have an impact on the drive time. Road work and weather impacts on drive time are analysed separately; their collective affect on drive time is not analysed.
2. The time between caller press button to send fire station about incident location information and fire station alerted is neglected. Sometimes, delays might be occurred due to mobilization device.
3. First fire engine receiving the call may not be the first engine which reaches the incident place. Therefore, drive time calculation starts when the specified engine receives the call, and finishes when the specified engine reaches the incident. Individual engines are tracked.
4. All fire engines' capacity, acceleration rate and weight are assumed as equal in Nottinghamshire (as advised by NFRS).

5. Crew time starts when first part-time worker receives the call (in the case of part-time workers). Callers' previous unanswered calls are accounted for in call handling time.

3.6. Ethical Concerns

Personal information was not included in the data set, which solely concerned publicly available incident-related information, and no private information was shared by NFRS.

Chapter 4
NFRS System

NFRS is the local emergency service provider in Nottinghamshire (NFRS, 2018). It is one of 45 Fire and Rescue Services across the UK (Government UK, 2016).

4.1. Fire department structure

There are two different type of fire departments; industrial and municipal. NFRS is a municipal fire department. Municipal firefighters are trained to focus on prevention and annihilation of various types of fires. Their main duty is sustaining prosperity and safety of local areas such as buildings, roads, hospitals (NFPA 1001, 2019). Municipal firefighters have higher frequency of calls than industrial firefighters, and they cope with different types of events, including medical accidents occurring in local areas. Industrial firefighter training is more specific, and the training depends on the industry (NPFA 600, 2015). Industrial firefighters' main duty is performing works to prevent fire before it occurs or spreads in industrial plants. NFRS is governed by the Nottinghamshire and City of Nottingham Fire Authority. The Council members are gathered from Nottingham City Council and Nottinghamshire County Council (NFRS, 2018).

4.2. Current operating system

There are currently 24 fire stations in Nottinghamshire, whose locations are shown in Figure 4, with a total of 30 active pumping appliances. There are four different types of fire station available in the Nottinghamshire: whole time; whole time and on call; and mixed crewing and on call. There are eight full-time stations open 24/7 (with 12 hour shifts per worker, and two shifts per day). There are only two full-time and on-call stations available in Nottinghamshire, both of which have both part-time and full-time workers (the latter of whom are known interchangeably as 'whole time' among firefighters). There are two mixed crewing stations available, with workers working 10 hours per day (only one shift/ day). There are 12 on-call stations available, in which only part-time workers work (at least one full-time worker is available in the station at any time).

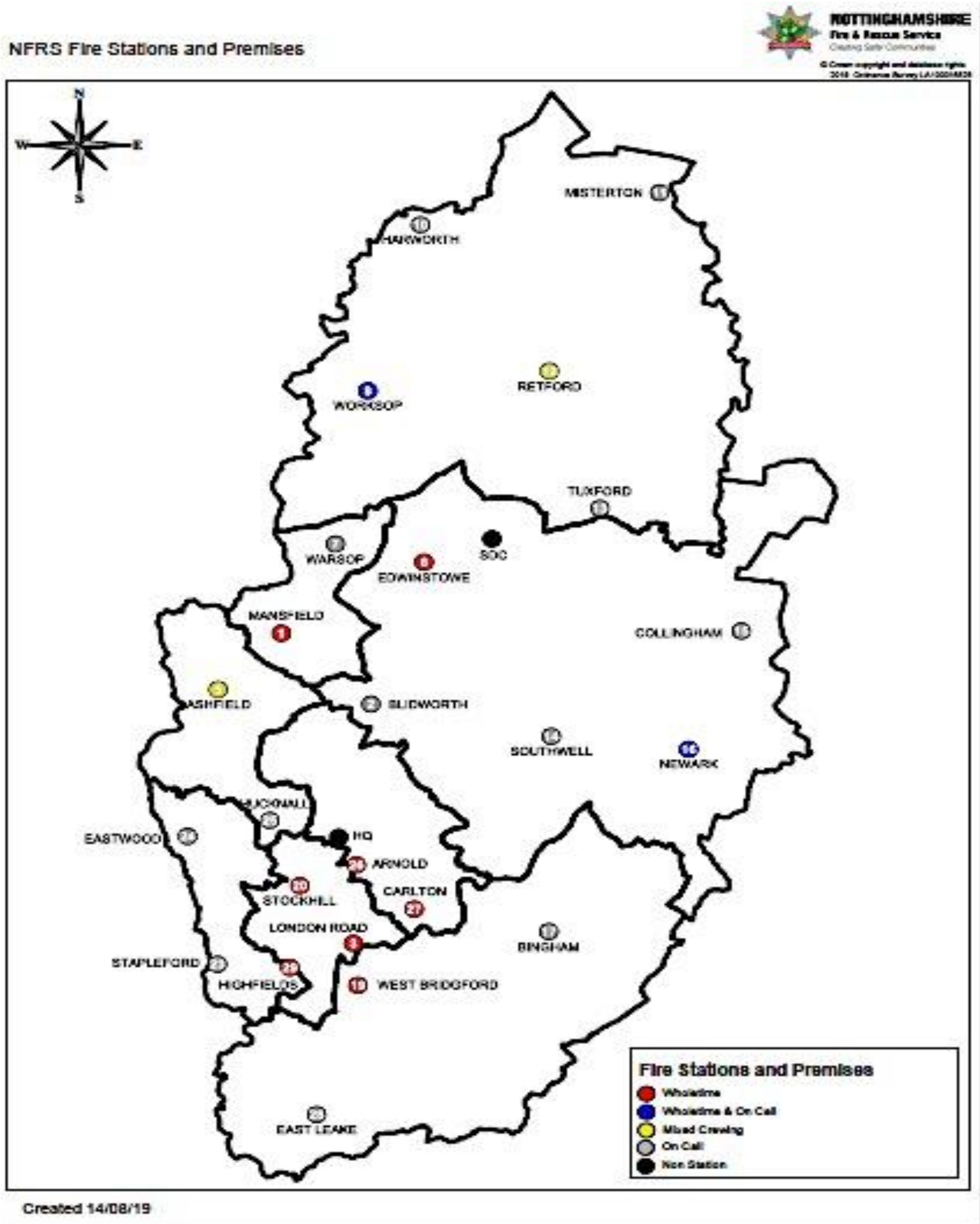

Figure 4: Nottinghamshire fire stations and premises

When part-time workers get the call, they have 5 minutes to reach the fire station. The part-time worker system is called ACA (Alternative Crew Appliance) and it took years to switch to the current system.

The current operating system is called dynamic mobilising. When an incident occurs in Nottinghamshire, a routing calculation is made and a turnout delay added, to work out who would be quickest to attend. As a result of this, there is no specific service area for each fire station.

4.3. System changes over years

There have been many significant changes in fire stations' operating systems from over the years. In the past, a full-time duty system was implemented; crews had to wait in the fire station until they received a call, therefore all fire stations were full-time stations by default. There was a standard preparation time for each fire risk group (A-D) in the past (The Fire Brigades Union, 2015); however, currently there is no standard time for each type of fire due to Risk Management Plan implementation. Roadwork networks have been changing over the years. In addition, the new operating systems sometimes do not show the shortest time, so crew need to search it themselves. The dressing policy change and traffic increase are also notable changes. The number of fire stations in NFRS has decreased from 25 to 24 in the last 13 years, according to an NFRS officer. In April 2019, Retford and Ashfields's first pumps were switched from full-time to mixed crewing, shown in Figure 4.

Chapter 5
Data Analysis and Interpretation

Filtered mobilisation explained in the previous chapter was used in this section for each analysis (29,142 mobilisation records for 2017-2018). Some of the incident records have the same *incident number* if more than one pumping appliance arrived the incident location with a specified *incident number*. Therefore, it should be noted 29,142 is the number of the mobilisations, not the number of the incidents that occurred in Nottinghamshire in 2017-2018.

5.1. Response time analysis in 2017-2018

29,142 mobilisation records were analysed, 14,155 for 2017 and 14,987 for 2018. In this section average and standard deviations are calculated and examined based on monthly intervals. Mobilisation data is divided into 24 groups corresponding to one-month intervals. Firstly, for each month, average call handling, crew, drive, and response times are calculated. The results are shown in Figure 5. It can be seen that the average call handling and crew time remained steady during the years 2017-2018, although a high variation can be observed in call handling time shown in Figure 6. Fluctuation in the response time is due to fluctuation in drive time, and fluctuation patterns resemble each other. There is a seasonality in time series, particularly with response time reaching a peak point in the summer period.

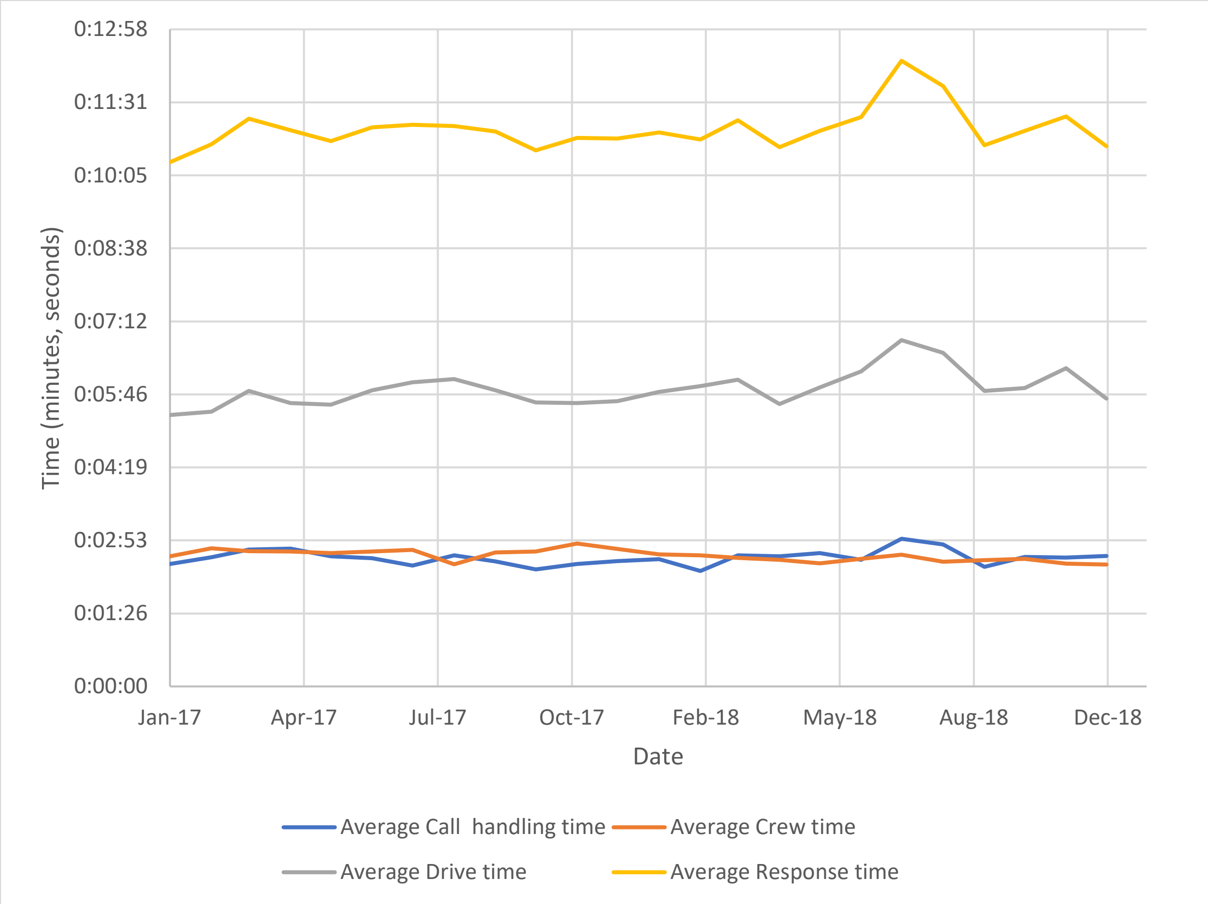

Figure 5: Average call handling, crew, drive and response time between 01/ 01/ 2017 to 31/ 12/ 2018

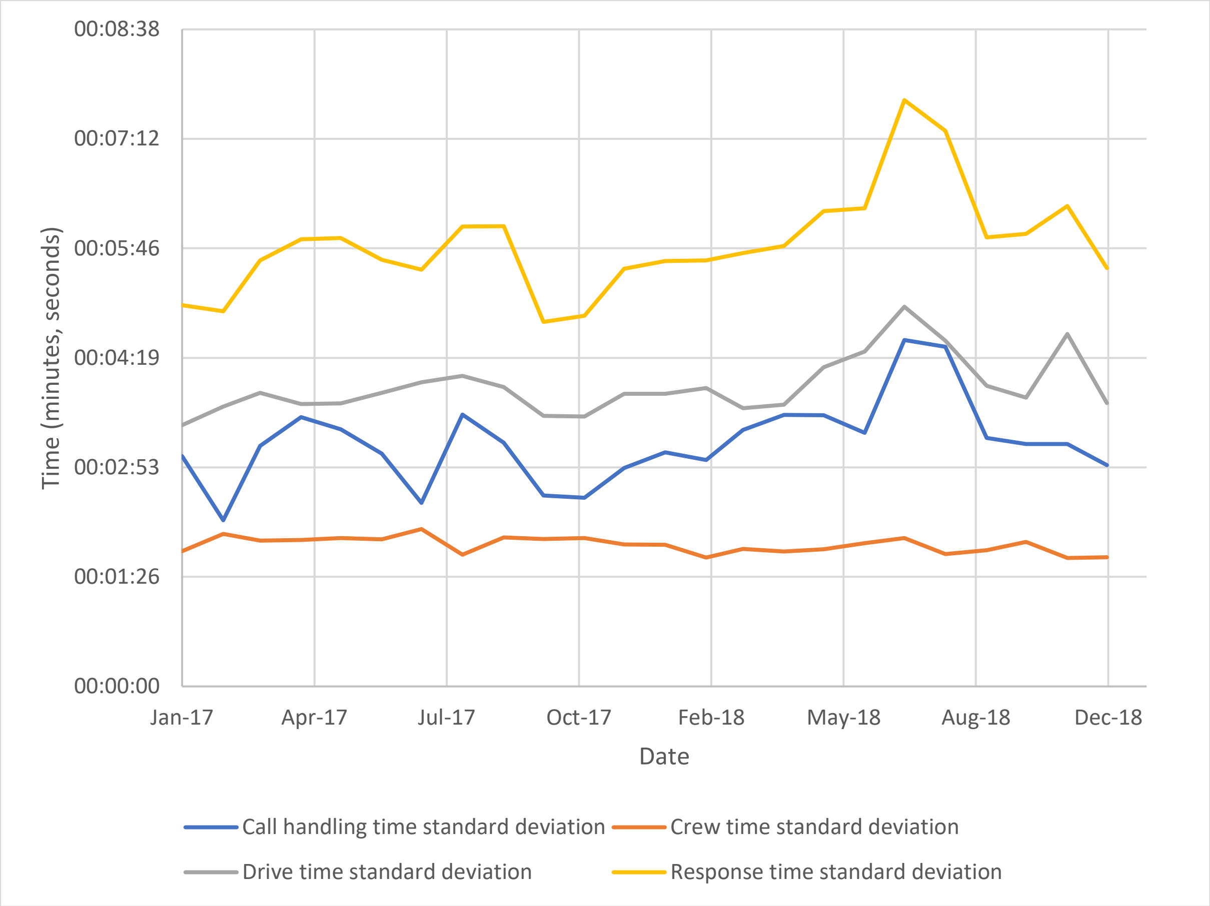

Figure 6: Call handling, crew, drive and response time's standard deviation in 2017 and 2018

Average call handling, crew, drive, and response times in 2017-2018 in Nottinghamshire are shown in Table 7. It can be seen that there were 832 more mobilisation records in 2018 than in the former year. Average response, call handling, and drive time were 21 seconds, 5 seconds, and 24 seconds higher in 2018, although average crew time was 9 seconds lower. It is obvious that there were some improvements in crew process, but drive time (the most time-consuming activity) had the greatest increase. Therefore, factors affecting driving time should be investigated in detail. According to Table 7., drive time is particularly high in summer periods, with a greater number of records in the summer months.

Table 7: Average call handling, crew, drive and response time, 2017-2018 in Nottinghamshire

Date	Av. call handling time	Av. crew time	Av. drive time	Av. response time	No. records
Jan-17	00:02:25	00:02:34	00:05:21	00:100:20	1220
Feb-17	00:02:33	00:02:44	00:05:25	00:100:42	1034
Mar-17	00:02:42	00:02:40	00:05:50	00:11:12	1016
Apr-17	00:02:43	00:02:40	00:05:35	00:100:58	1220
May-17	00:02:34	00:02:38	00:05:33	00:100:45	1225
Jun-17	00:02:32	00:02:40	00:05:50	00:11:02	1294
Jul-17	00:02:23	00:02:42	00:06:00	00:11:04	1283
Aug-17	00:02:35	00:02:24	00:06:04	00:11:03	1336
Sep-17	00:02:28	00:02:39	00:05:50	00:100:57	1094
Oct-17	00:02:19	00:02:40	00:05:36	00:100:34	1245
Nov-17	00:02:25	00:02:49	00:05:35	00:100:49	1103
Dec-17	00:02:28	00:02:43	00:05:37	00:100:49	1085
Jan-18	00:02:31	00:02:36	00:05:48	00:100:55	958
Feb-18	00:02:17	00:02:35	00:05:55	00:100:47	983
Mar-18	00:02:35	00:02:32	00:06:03	00:11:10	1180
Apr-18	00:02:34	00:02:30	00:05:34	00:100:38	1045
May-18	00:02:38	00:02:26	00:05:54	00:100:58	1320
Jun-18	00:02:30	00:02:31	00:06:13	00:11:14	1391
Jul-18	00:02:55	00:02:36	00:06:50	00:12:20	1843
Aug-18	00:02:48	00:02:28	00:06:35	00:11:50	1524
Sep-18	00:02:22	00:02:29	00:05:50	00:100:41	1260
Oct-18	00:02:33	00:02:31	00:05:53	00:100:57	1263
Nov-18	00:02:33	00:02:25	00:06:17	00:11:14	1218
Dec-18	00:02:34	00:02:24	00:05:41	00:100:39	1002
2017	00:02:30	00:02:39	00:05:42	00:100:51	14155
2018	00:02:35	00:02:30	00:06:06	00:11:12	14987
2017-2018	00:02:33	00:02:35	00:05:54	00:11:02	29,142

When the components of the response time are examined, it is observed that the most time is devoted to drive time, calling for further analysis of this aspect. The number of mobilisations of each month and average drive time relationship are examined and shown in Figure 7. It can be seen that drive time increases when the number of records increases, and average drive time and number of records have a strong relationship. Approximately 60% of the variability in drive time can be explained by demand for fire and rescue service. The maximum average response time in 2017-2018 was 6:50 minutes, observed in July 2018 (Table 7). As a result, when the number of records increases, drive time also increases.

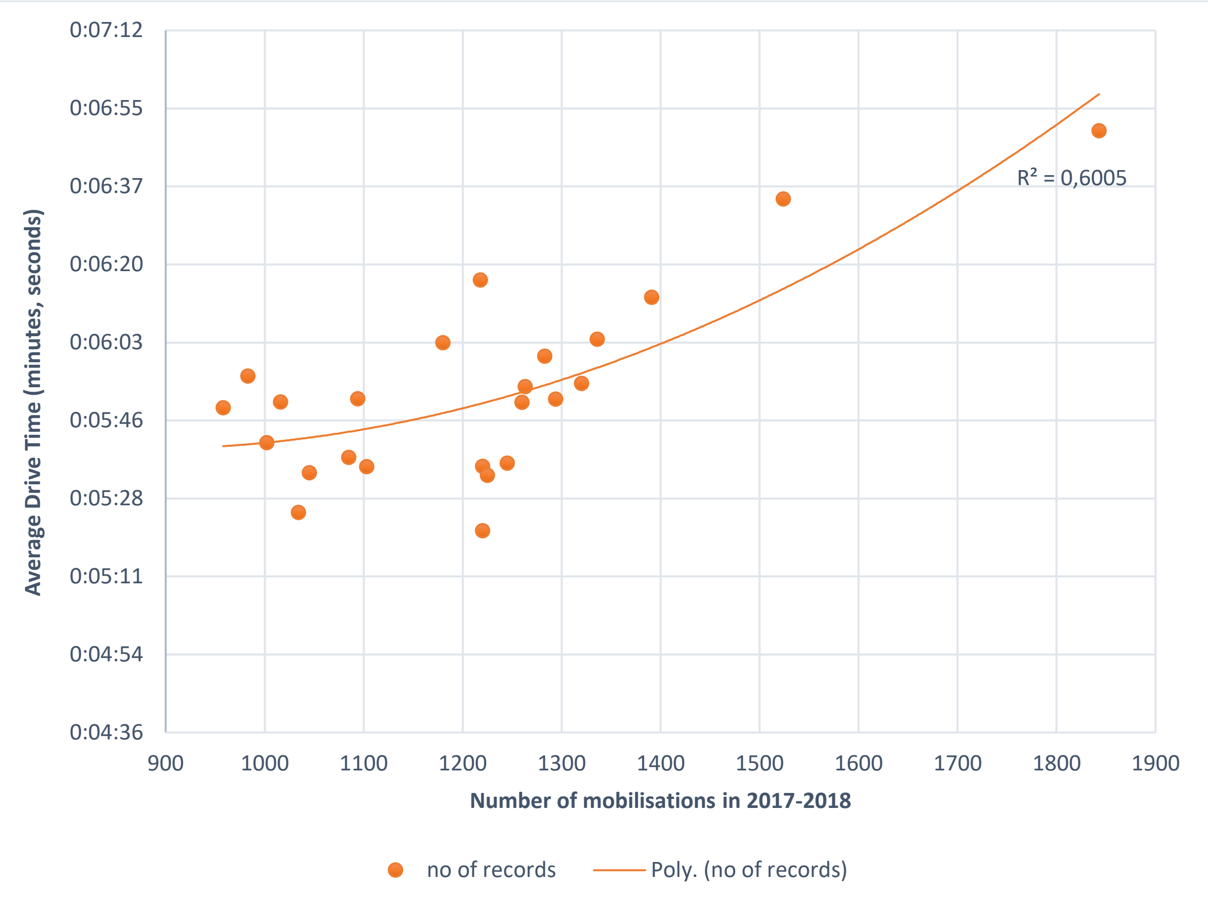

Figure 7: Average drive time and number of records in 2017 and 2018 relationship

Secondly, standard deviations are compared between different months for each process of response time. As mentioned previously, a high variation is observed in call handling time in 2017-2018. Maximum standard deviation values for call handling time and response time are observed to be 4:33 and 7:43 minutes (respectively) in July 2018; the highest standard deviation value for crew time was in July 2017, with 2:04 minutes (Appendix B, Table B1). Also, the highest standard deviation value for drive time was 5:00 minutes in July 2018. It is clear that seasonal factors have an impact on time variations.

The variations are explained by frequency distributions. Frequency table is used determine the number of each response time process in a specific time interval. The frequency table (Table 8) displays the number of mobilisations for call, crew, drive, and response time in two-minute time intervals, based on 29,142 mobilisation records. As shown in the table, approximately 60% of calls (n=17,402) took two minutes at most, and 48% of the time crews were prepared within two minutes. 28% of mobilisation records (n=8038) have driven time of 2-4 minutes; however, drive time took between 4-6 minutes in 27% of mobilisation records (n=7865). While these percentages are very close, further analysis is required to understand drive time .

Call handling, crew and drive time frequency distributions are positively skewed (Appendix B, Figure B1, B2, B3). Due to the frequency distributions being positively skewed, a high variation is inevitable. Response time frequency distribution is close to normal distribution (Appendix B, Table B4).

Table 8: Frequency table for call handling, crew, drive and response time according to 2017-2018 filtered mobilisation data

Time interval	*Call handling time*	*Crew time*	*Drive time*	*Response time*
0-01:59	17402	13955	2240	17
2-3:59	8634	11084	8038	133
4-5:59	1684	1818	7865	2300
6-7:59	513	1541	5073	6582
8-9:59	281	586	2581	6910
10-11:59	108	115	1328	4813
12-13:59	78	23	802	2991
14-15:59	45	11	484	1808
16-17:59	67	4	252	1155
18-19:59	64	2	150	714
>20	266	3	329	1719

5.2. Analysis of the factors

29,142 mobilisation records for 2017-2018 is used for each analysis in this section, but some sections have extra data filtration process implemented, depending on the analysis. Pump crewing status; time of the day (including a comparison of OC and WDS crews); seasonality; incident day of week; incident location; vehicle status; and fire station location are the potential factors that affect response time, as explained below.

5.2.1. Pump crewing status

In 2017-2018 there were two different types of pump crewing status, On Call (OC) or Whole Time (WDS). OC crew are not available in the fire station when they receive the call. Within five minutes they are expected to come to the fire station and get prepared for the incident. On the other hand, WDS crew is always available in the fire station, and are on-hand when a call is received.

For pump crewing status analysis, pumping appliance status under *call sign* head topic in the mobilisation data for 2017-2018 was considered. Only the *call signs* listed in Appendix A, Table A2 are examined. Therefore, the remaining records starting with *call sign* FED, FEEC, FES, and FETP are deleted from the filtered data. The total mobilisation records analysed was thus 28,727. Firstly, analysis was performed according to years, as shown in Table 9, and secondly according to months.

In the first analysis, it is clear that the majority of the crew were working whole time. Call handling time for OC was 27 seconds in 2017 and 35 seconds in 2018, more than WDS, as shown in Table 9. It can be seen that alerting the OC crew takes more time than WDS. For WDS, only one call for the station is adequate for alerting all WDS crew members; on the other hand, each member of the OC crew must called individually, and waiting for their response takes time. In 2018, both OC and WDS crews' call handling times increased. A high standard variation value is observed in call handling time for OC crew, but there is clearly a particular problem with reaching the latter.

In 2017, the OC crew response time was approximately four minutes longer than their WDS peers. OC crew have to drive the station from their current position, and this time was included in the crew time. In 2018, the crew time was only 5:25 minutes; whereas crew time was 6:12 minutes in 2017 for OC. It can be concluded that OC crew time is improved, and some improvement actions were taken in 2018. Drive time for OC was 30 seconds less than WDS in 2017, although there was a minor difference in 2018. Drive time difference may be explained by fire station location. Both drive times in 2018 increased.

Table 9: Response time analysis regarding crew status and years

Year	*Crew status*		*Call handling time*	*Crew time*	*Drive time*	*Response time*
2017	On call	Avg.	00:02:53	00:06:12	00:05:11	00:14:17
		SD	00:03:53	00:02:28	00:03:57	00:06:14
		No. records	1844			
2017	Whole time	Avg.	00:02:26	00:02:06	00:05:43	00:100:15
		SD	00:02:48	00:00:59	00:03:43	00:05:04
		No. records	12133			
2018	On call	Avg.	00:03:03	00:05:25	00:06:04	00:14:32
		SD	00:04:36	00:02:29	00:04:30	00:07:16
		No. records	2310			
2018	Whole time	Avg.	00:02:28	00:01.57	00:06:02	00:100:28
		SD	00:03:17	00:00:54	00:04:07	00:05:48
		No. records	12440			

In the second analysis, OC and WDS crew is analysed monthly in 2017-2018. Firstly, WDS and OC records are compared, as displayed in Figure 8. It is clear that most of the mobilisations were done by WDS, but there is a significant increase for OC incident records in 2018. As the number of OC crew is same in 2017 and 2018, OC crew workload increased by about 25% in 2018, and was particularly intense in the summer months. Although WDS workload has fluctuations by month, OC followed a more stable pattern in 2017-2018.

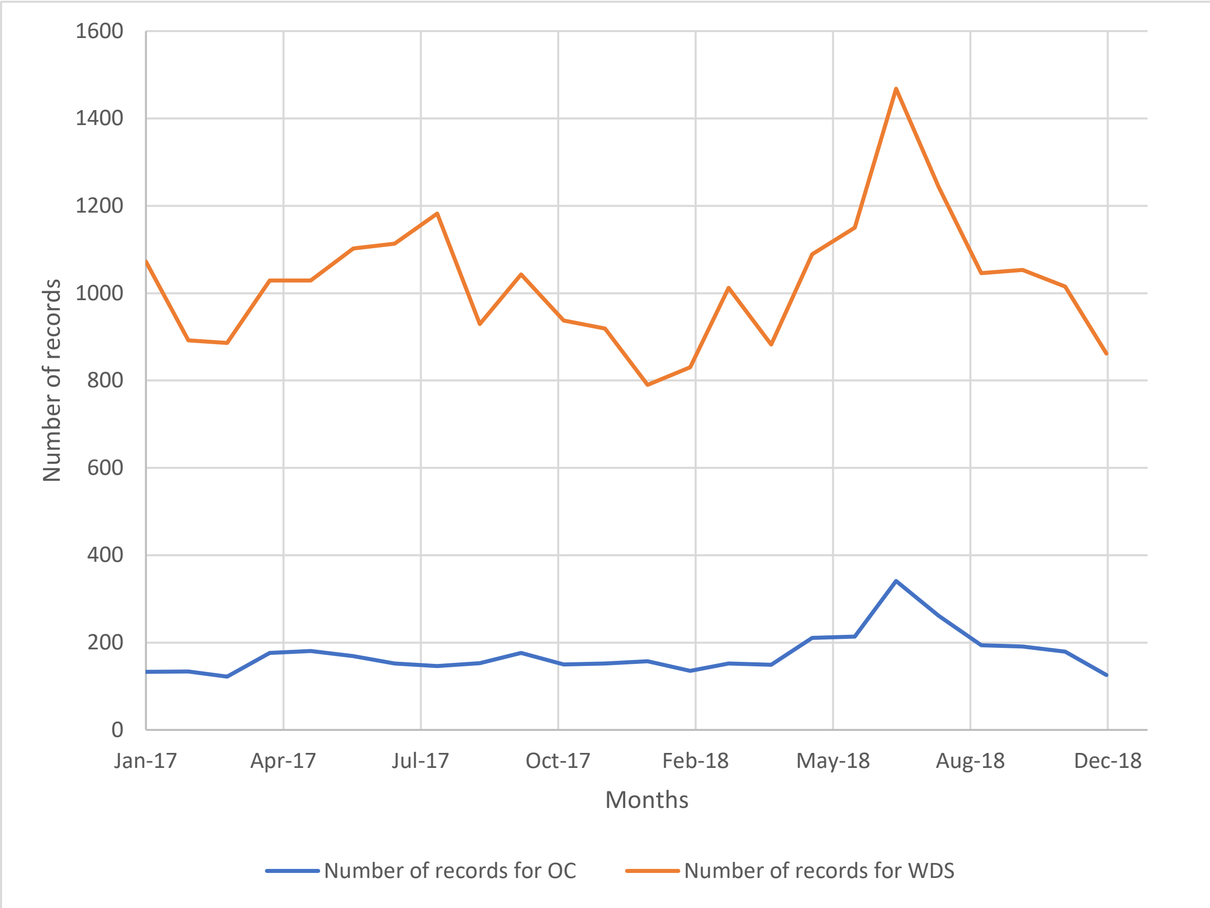

Figure 8: Incident records for OC and WDS, 2017-2018

OC crew response time exhibited a sharp drop in February 2017, but a steady increase in February 2018, as shown in Figure 9. This suggests that there is no seasonal effect in the time series, especially between April to August 2017, when there were fluctuations in call handling time for OC, and response time was directly affected by these fluctuations, as shown in Figure 9 and Figure10. A detailed analysis is available in the dataset displayed in Appendix B, Table B2. Minimum response time for OC crew was 13:10 minutes in September 2018. OC crew response time was around 14:30 minutes in 2017-2018.

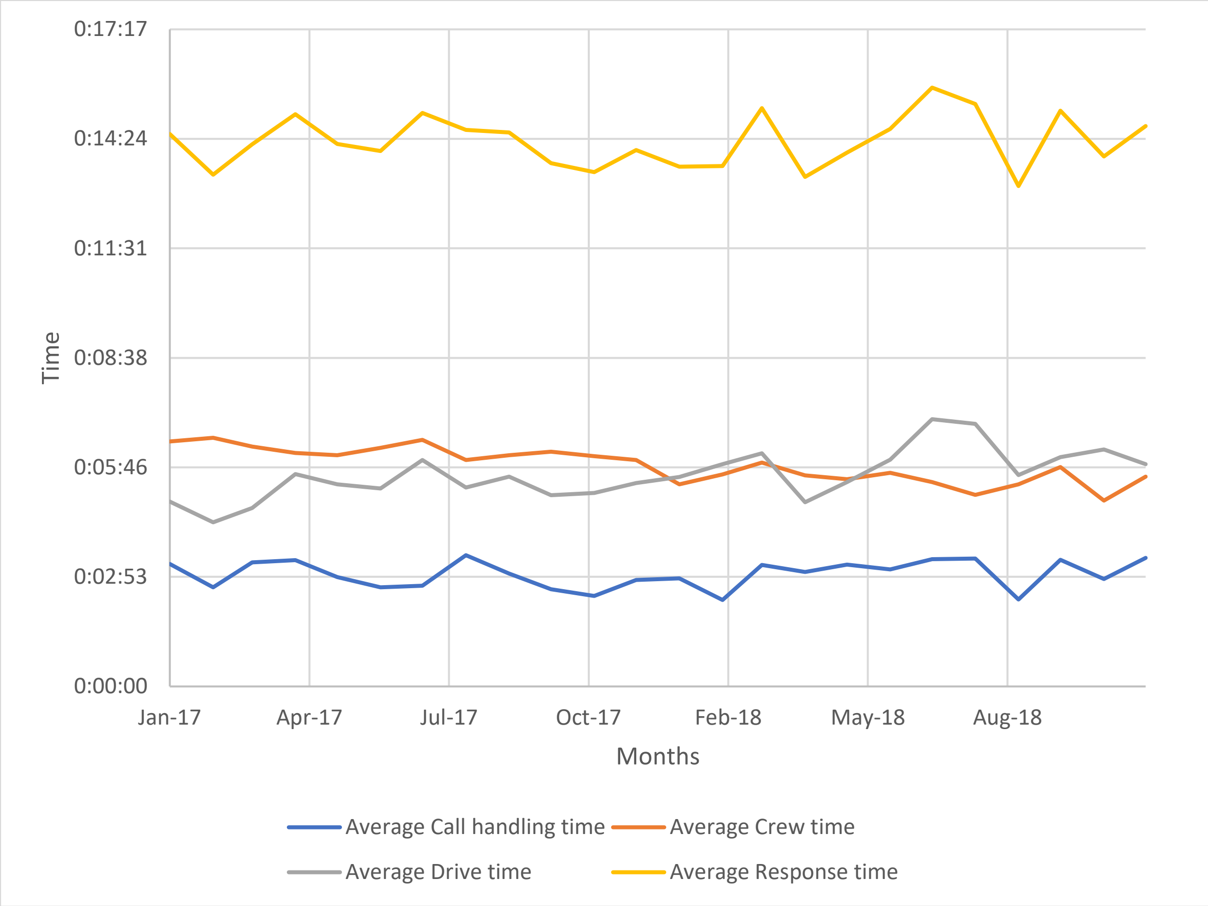

Figure 9: OC crew distribution by month

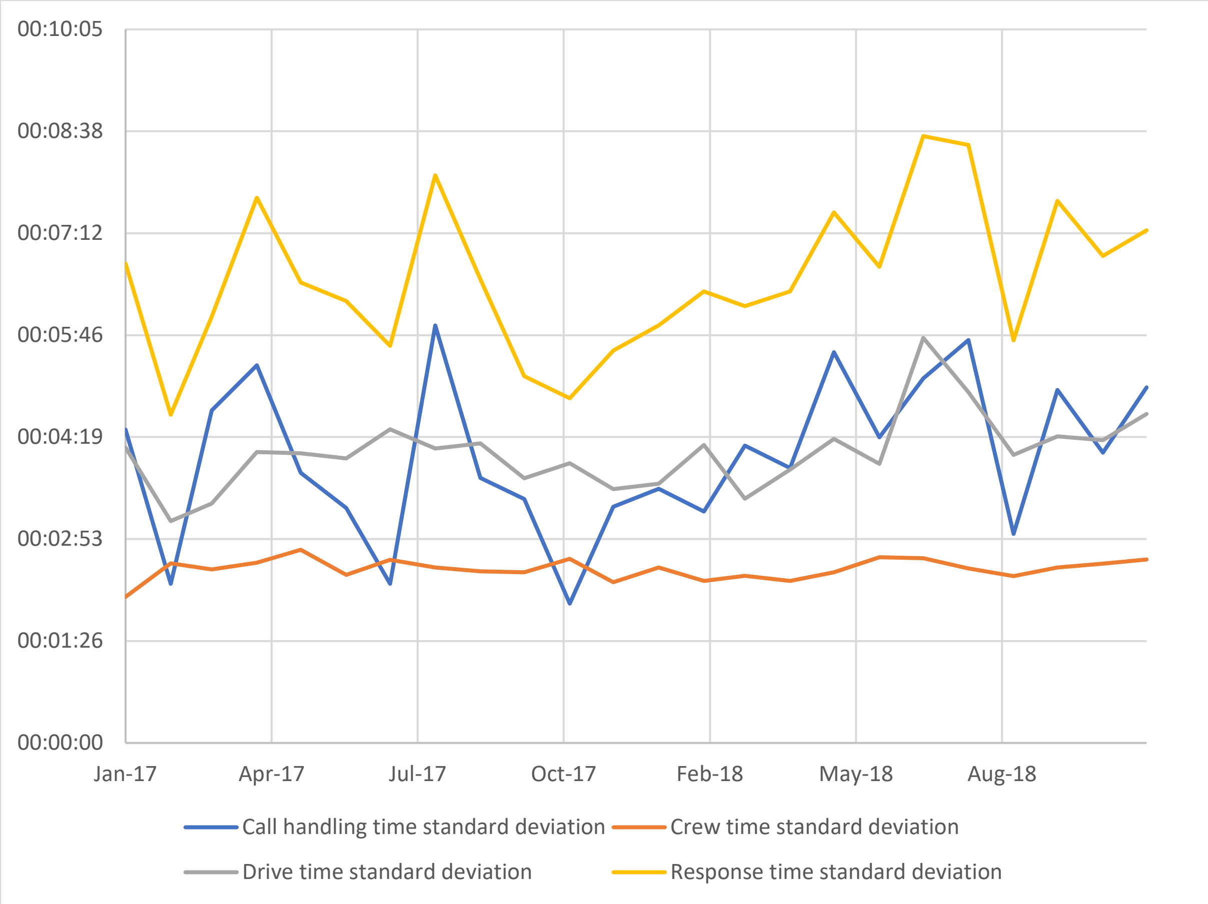

Figure 10: OC standard deviations

Average crew time for WDS is very steady by month, as shown in Figure 11. Average crew time improved and there was a slight change, as shown in the figure. Average call handling time increased in May 2018, explained by the increase in the number of records. The number of callers might not be adequate when the number of mobilisations is increased. Variation in call handling time and drive time is high compared to crew time, as shown in Figure 12. It is due to crew time being directly related to crew member availability and speed in the station, and crew members are not directly affected by external factors such as weather and traffic. For detailed analysis, the dataset for Figures 11 and 12 is available in Appendix B, Table B3. As a result, the majority of mobilisations were done by the WDS crew with a faster response time (of around 10 minutes).

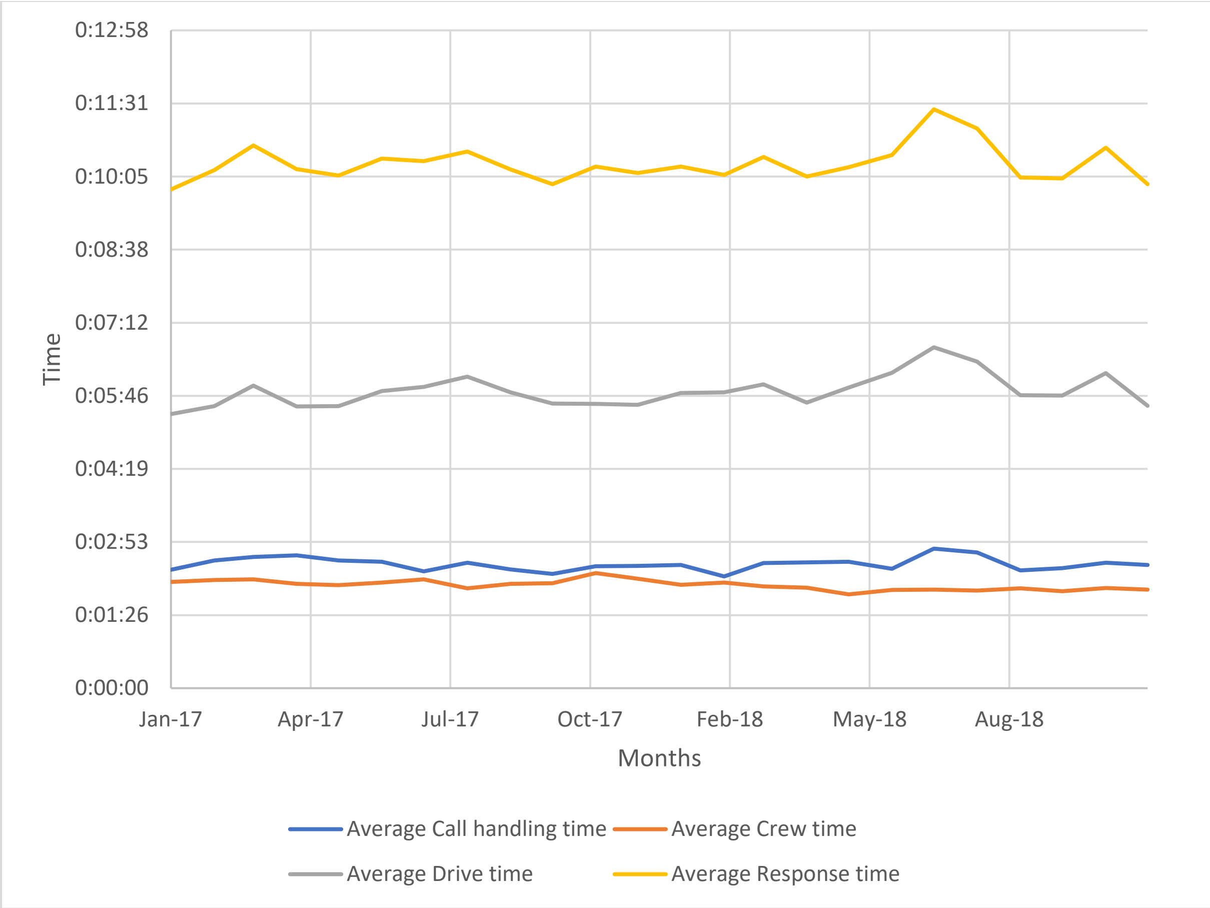

Figure 11: WDS crew distribution by month

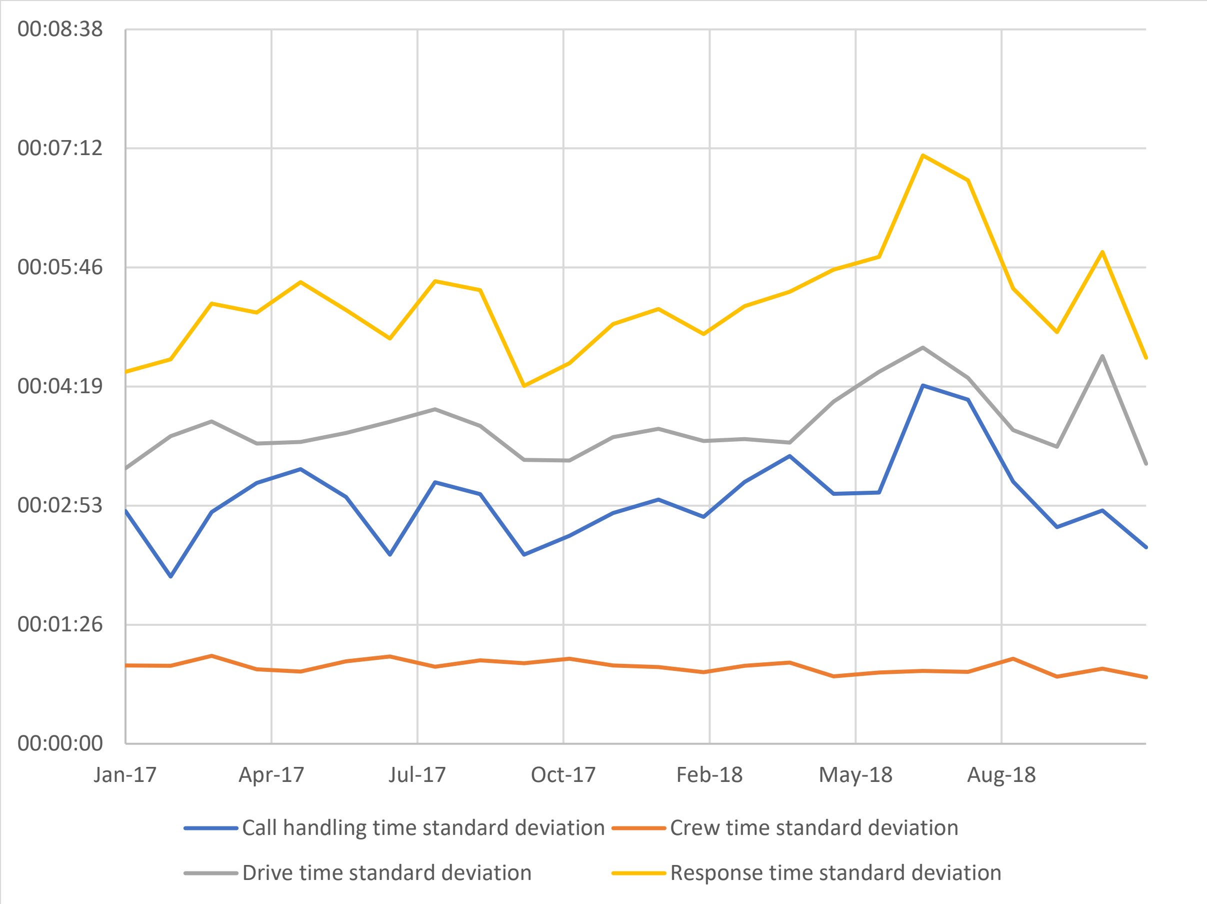

Figure 12: WDS standard deviations

5.2.1.1. Pumping appliance

Filtered mobilisation data for 2017-2018 was arranged from *call sign,* and total number of the mobilisation records was 28,727. In Nottinghamshire, 24 fire stations and 30 pumping appliances were valid in 2017-2018; 16 OC pumping appliances, and 14 WDS pumping appliances. In this section, two analyses were conducted. Firstly, call handling, crew, drive, and response time data for each pumping appliance are compared based on yearly analysis. Secondly, the workload of each fire pumping appliance is examined by monthly analysis during the two-year period (2017-2018). The goal for the first analysis to evaluate whether a relationship is valid between the pumping appliance and the response time or not. The second analysis is done to see which of the pumping appliances having a high response time changed between 2017 to 2018. The goal of the second analysis to evaluate a relationship between pumping appliance workload and response time.

5.2.1.2. Each pumping appliance's response time

In the first analysis, average call, crew, drive, and response time for each of the pumping appliances are calculated for the year 2017, as shown in Appendix B, Table B4, and for year 2018 in Appendix B, Table B5. Both tables show that majority of the mobilisations are done by WDS in 2017 and 2018 with a faster response time. In 2017, most WDS pumping appliances had a response time of around 10 minutes, but three pumping appliances took over 11 minutes: West Bridgford (FET19P1), Newark (FET16P1), and Retford (FET12P1). It is observed that these three pumping appliances had the highest drive time among WDS, which increased in 2018.

The potential reason for high drive time might be West Bridgford, Newark, and Retford fire stations being located in rural areas, or the areas they serve being wider than others. Newark and Retford have two pumping appliances and part-time crew is working for the second pumping appliances. It is observed that FET16P1 (Newark) drive time is 1:19 minutes longer than FET16P2 (Newark); and FET12P1 (Retford) drive time is 3:19 minutes longer than FET12P2 (Retford). It is interesting that there are huge drive time differences between two pumping appliances dispatched from the same fire station. Therefore, the potential reason for these differences might be crew knowledge about the local area, but the drive time is not related whether the fire station is in a rural area or not (West Bridgford fire station is located close to the City of Nottingham).

It is observed that most of most of the OCs had a very high call handling time in 2017-2018. 50% of the OC pumping appliance handling times increased, while approximately 44% of them improved, and 6.2% of them were unchanged from 2017 to 2018. 16 OC pumping appliances were valid in 2017-2018, and only FET14P1 (Southwell) crew handling time displayed a slight increase between 2017-2018 (the remaining pumping appliance crew time improved. Some OC pumping appliances had higher times of 8:52 minutes (FET15P1, Collingham) compared to WDS pumping appliance in 2017 (Appendix B, Table B4), although some of them had much lower times, such as FET24P1 (Eastwood) with 03:47 minutes in 2017.

Drive time increased for 14 OC pumping appliance among 16 between 2017-2018. Only, FET11P1 (Misterton) pumping appliance drive time was stable with 7:07 minutes, and FET13P1 (Tuxford) improved with 13 seconds. Due to increased drive time, 56% of the response times increased for OC pumping appliances between 2017 to 2018, and 44% of them decreased.

Table 10 shows response time changes for each pumping appliance between 2017-2018. Four WDS pumping appliances (FET03P1, FET02P1, FET03P2, FET29P1) had their response time decrease by approximately 3%, while it increased for 10 WDS pumping appliances, and three of them increased. There was a sharp percentage change for three pumping appliances; FET06P1 (Edwinstowe), FET16P1 (Newark), and FET12P1 (Retford), with 20.30%, 17.57%, and 11.69%, respectively. Five OC pumping appliance response times improved; FET05P2 (Ashfield), FET13P1 (Tuxford), FET24P1 (Eastwood), FET15P1 (Colingham), and FET14P1 (Southwell); the remaining OC pumping appliance response times increased, as shown in Table 10. Only nine out of 30 pumping appliances' response times increased between 2017-2018. Therefore, the total average response time in 2017 increased from 10:47 to 11:06 minutes, including all WDS and OC pumping appliances.

Table 10: Response time change between 2017 to 2018 regarding fire station and pumping appliance

Call sign	Fire station	Status	Response time % change 2017 to 2018
FET03P1	London Road	WDS	-4.87%
FET20P1	Stockhill	WDS	-6.45%
FET03P2	London Road	WDS	-3.85%
FET26P1	Arnold	WDS	3.78%
FET29P1	Highfields	WDS	-0.21%
FET20P2	Stockhill	WDS	2.53%
FET01P1	Mansfield	WDS	2.51%
FET06P1	Edwinstowe	WDS	20.30%
FET08P1	Worksop	WDS	4.57%
FET05P1	Ashfield	WDS	1.64%
FET27P1	Carlton	WDS	3.89%
FET19P1	West Bridgford	WDS	0.99%
FET16P1	Newark	WDS	17.57%
FET12P1	Retford	WDS	11.69%
FET25P1	Hucknall	OC	1.21%
FET10P1	Harworth	OC	0.23%
FET02P1	Blidworth	OC	8.99%
FET08P2	Worksop	OC	3.07%
FET23P1	Stapleford	OC	3.18%
FET07P1	Warsop	OC	1.62%
FET16P2	Newark	OC	15.24%
FET05P2	Ashfield	OC	-2.31%
FET17P1	Bingham	OC	2.70%
FET12P2	Retford	OC	2.31%
FET13P1	Tuxford	OC	-8.22%
FET24P1	Eastwood	OC	-8.93%
FET28P1	East Leake	OC	2.34%
FET15P1	Collingham	OC	3.93%
FET14P1	Southwell	OC	-0.43%
FET11P1	Misterton	OC	-8.46%
		Yearly Avg.	2.94%

As a result, the data indicates that WDS pumping appliances have a shorter response time compared to OC. Different pumping appliances have a different response time, even when dispatched from the same station, such as Newark and Retford, while there are marked differences in drive time. This might be explained in terms of crew status (OC or WDS). Different crew members might use different methods or local knowledge to go to incident places. One potential reason for drive time increasing might be the distance between incident location and fire station.

Firstly, to evaluate correlation between drive time and incident location, each of the pumping appliances' average straight-line distance between incident location to specified fire location is calculated based on each year. Average straight-line distance calculation is based on fire station and incident location's *easting* and *northing* coordinates. 30 pumping appliances were valid in 2017-2018, therefore the scatter chart shows 60 points corresponding to each pumping appliances' value for the specified year (Figure 13). Detailed data is shown in Appendix B, Tables B4 and B5. According to Figure 13, distance has a great impact on drive time (R^2 = 0,8213), and approximately 82% of drive time is explained due to distance.

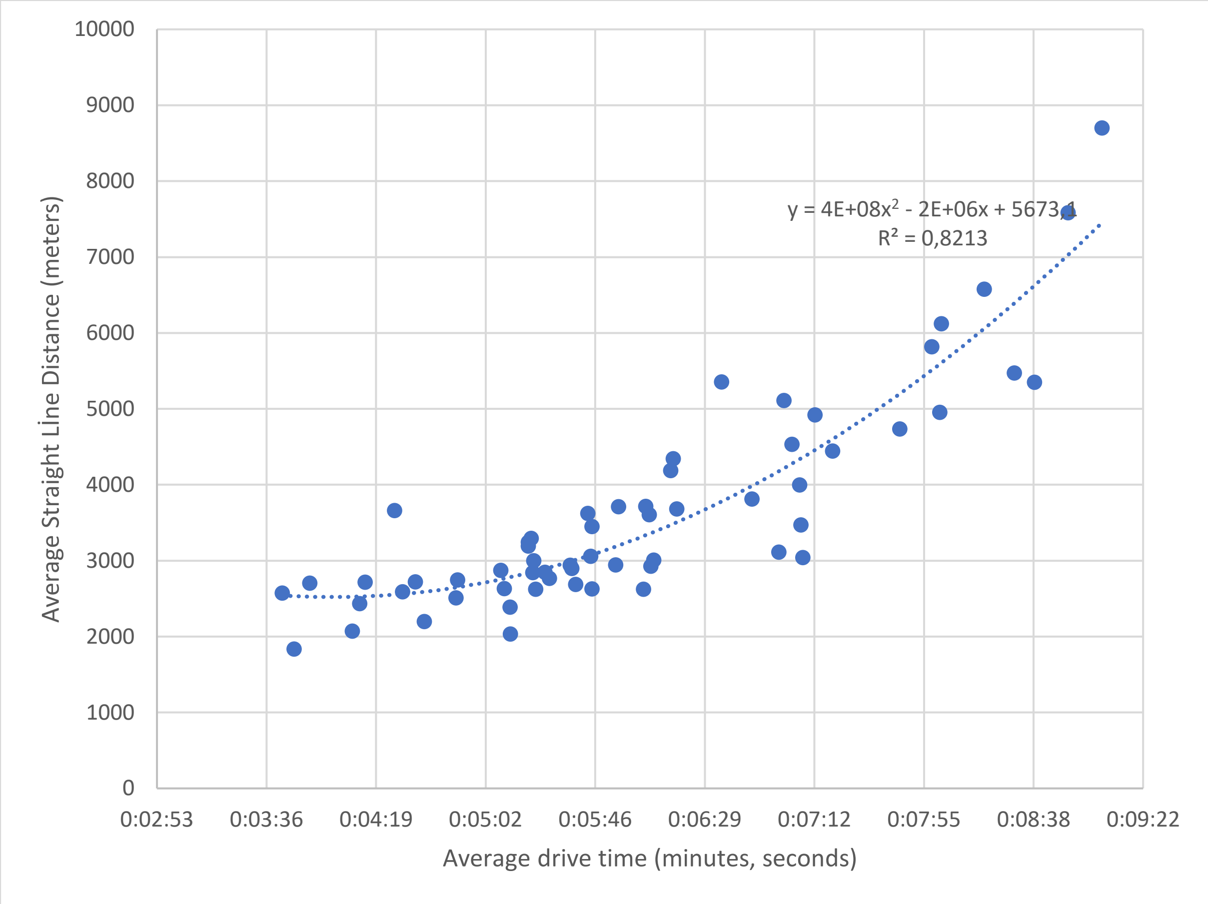

Figure 13: Average straight-line distance between fire station to incident location per pumping appliance versus average drive time drive per pumping appliance, 2017-2018

As discussed previously, crew status might have an impact on drive time. In order to evaluate the relationship between drive time to incident location regarding crew status, OC and WDS are assed separately, as shown in Figures 14 and 15, respectively. 16 OC crews were working in both 2017-2018, therefore Figure 14 has 32 points to show each OC pumping appliance's 2017 and 2018 values. This analysis is repeated for the 14 WDS crews working in the same period. As shown in Figure 14, the longest distance and drive time was observed in FET15P1 (Collingham), with approximately 9 minutes. Collingham is a largely rural area, therefore there is a high probability that incidents might occur further away from the fire station compared to stations located in greater proximity to urban regions in Nottinghamshire. Average drive time for OC crew and average straight-line distance have a polynomial relationship (R^2 = 0,8573). Aggregated data allows making predictions based on these insights.

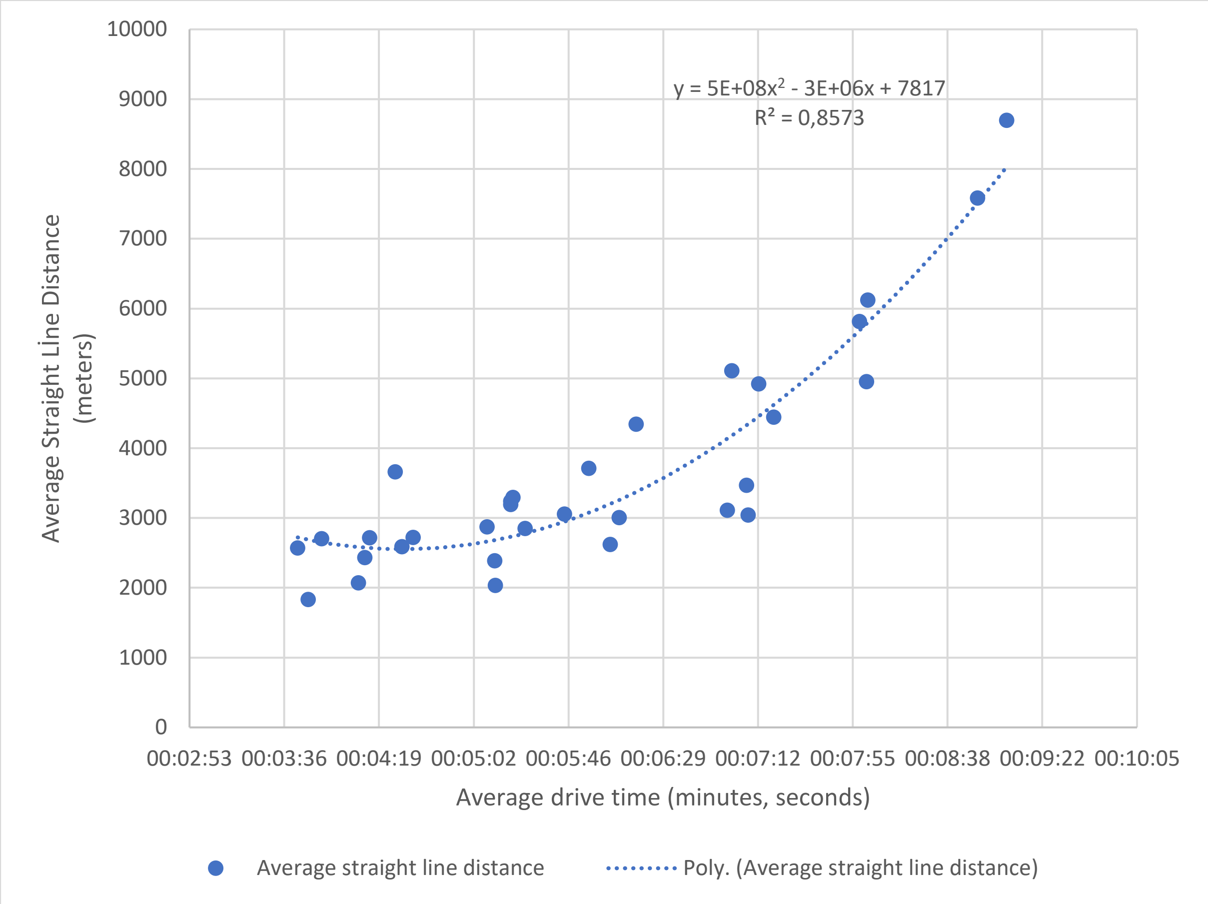

Figure 14: OC pumping appliances drive time corresponding with average straight-line distance, 2017-2018

Average drive time for WDS crew and average straight-line distance have a linear relationship, with R^2 = 0,8257. Aggregated data allows making predictions on drive time, and it is clear that when straight-line distance increases, drive time increases with high probability. Extreme points are observed in FET06P1 (Edwinstowe) for 6:15 drive time with 5354 meters, and 8:19 minutes with 6574 meters. Only two whole time stations are located in rural regions, including Edwinstowe. Therefore, this variation can be explained by the region of the fire station.

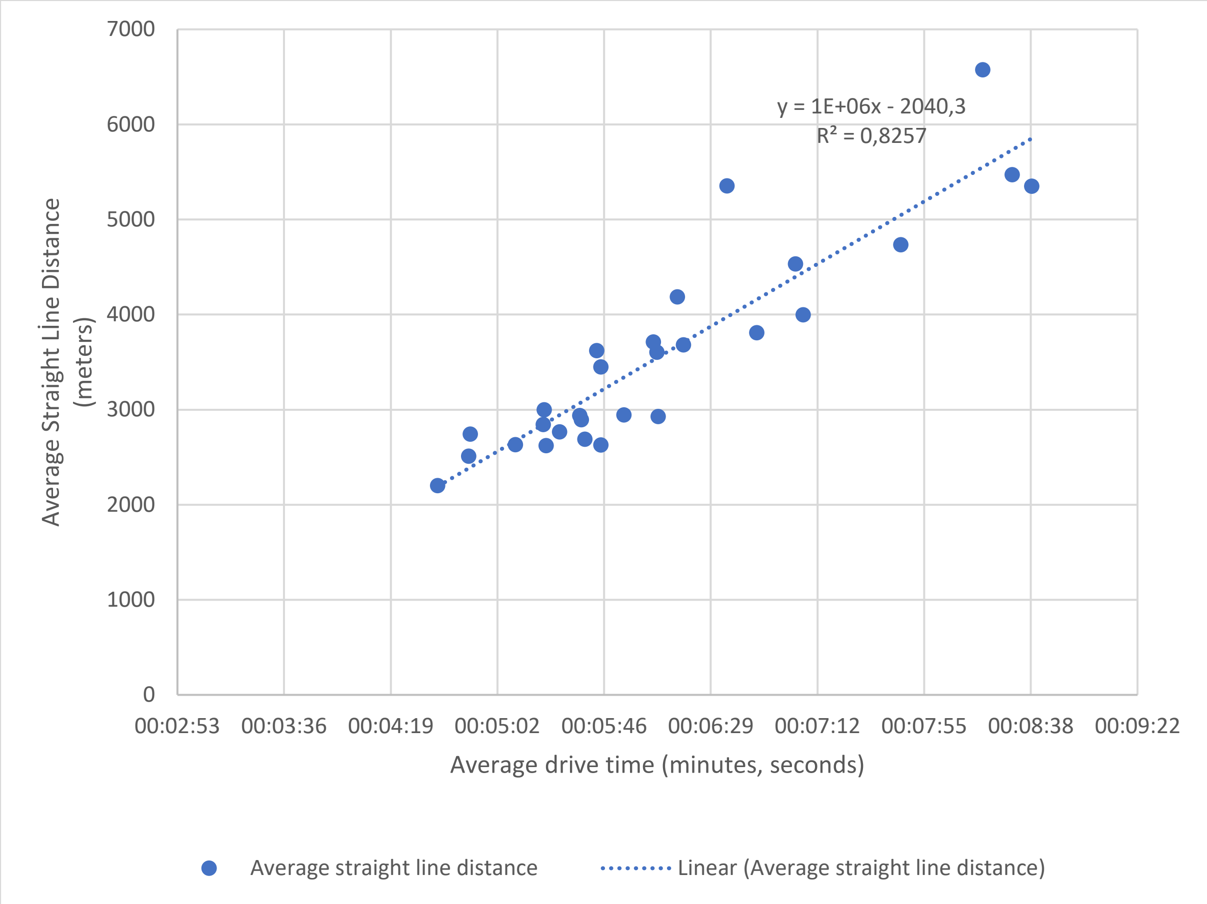

Figure 15: WDS pumping appliances drive time corresponding with average straight-line distance, 2017-2018

As a result, distance has an impact on drive time. WDS crew drive time is more consistent and predictable compared to OC. Straight-line distance is used for this analysis. The reason for this is that straight line distance is good enough to predict response time analysis. To reach this conclusion, four pumping appliances' yearly individual incident records were analysed. FET16P1 (Newark) was selected because it has WDS and an average drive time value observed in 2018 of 8:39 minutes, the highest among other WDS stations in 2017-2018 (Appendix B, Table B4 and B5). FET16P2 (Newark) is selected because their home station is the same. FET23P1 (Stapleford) was chosen because its average drive time value of 3:42 minutes in 2017 was the lowest among all OCs in both years 2017-2018 (Appendix B, Table B4 and B5). FET13P1 is selected because its drive time value is high among other OCs both in 2017-2018, and incident records are enough to make interpretation. According to these four pumping appliances, network distance and straight-line distance over drive time are differentiated.

The following steps are conducted for this analysis;

1. 1766 mobilisation records were obtained for these four pumping appliances based on *call sign.*
2. 79 mobilisation records with average crew time equal to or less than 30 seconds were deleted for the feasibility.
3. Network distance for each incident was calculated for three fire stations, calculated based on incident and fire station addresses. AA route planner was used to find the network distance and first optimal route selected for this analysis (AA, 2019).
4. 109 incidents mobilisation records were deleted due to infeasible drive time and network distance relationship, such as the 30 miles network distance with a drive time of 3 minutes.
5. 66 mobilisation records were deleted in the network distance calculation data set, because their network distance was not found (they remained in the straight-line distance data set). 1512 mobilisation data were left for network distance, and 1578 for straight line distance, including OC and WDS.
6. Straight line distance for each incident was calculated for four pumping appliances based on fire station and incident location easting and northing coordinates.
7. OC pumping appliances' records were differentiated from WDS records. 1578 records were left for straight line analysis, and 1512 for network analysis for available vehicles.
8. A scatter chart was created with straight-line distance and drive time for OC crew for FET13P1, FET16P2, and FET23P1, as shown in Figure 16.
9. A scatter chart was created with straight-line distance and drive time for WDS crew for FET16P1, as shown in Figure 17.
10. A scatter chart was created with network distance and drive time for OC for FET13P1, FET16P2, and FET23P1, as shown in Figure 18.
11. A scatter chart was created with network distance and drive time for WDS for FET16P1, as shown in Figure 19.

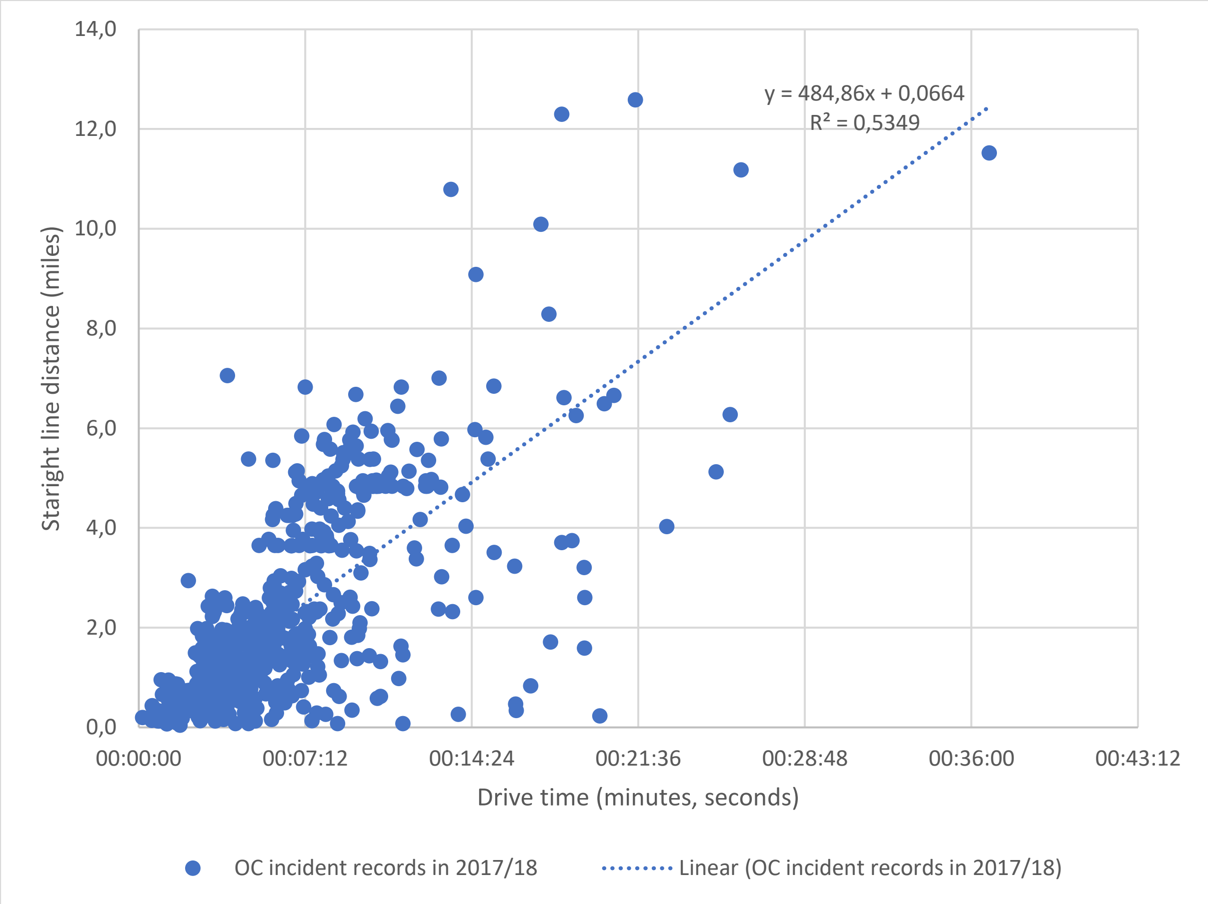

Figure 16: FET13P1, FET16P2, and FET23P1 incident records, 2017-2018 based on straight line distance

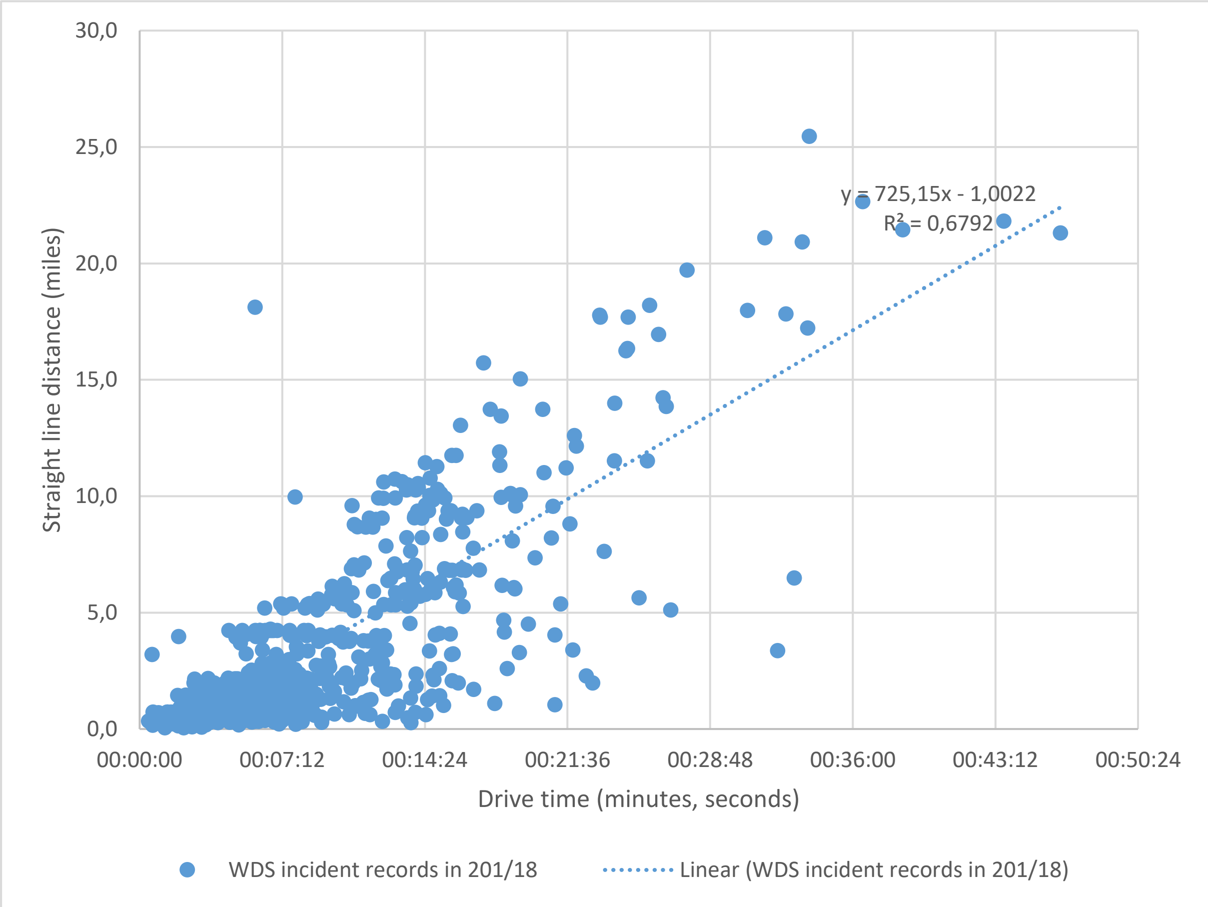

Figure 17: FET16P1 incident records, 2017-2018 based on straight line distance

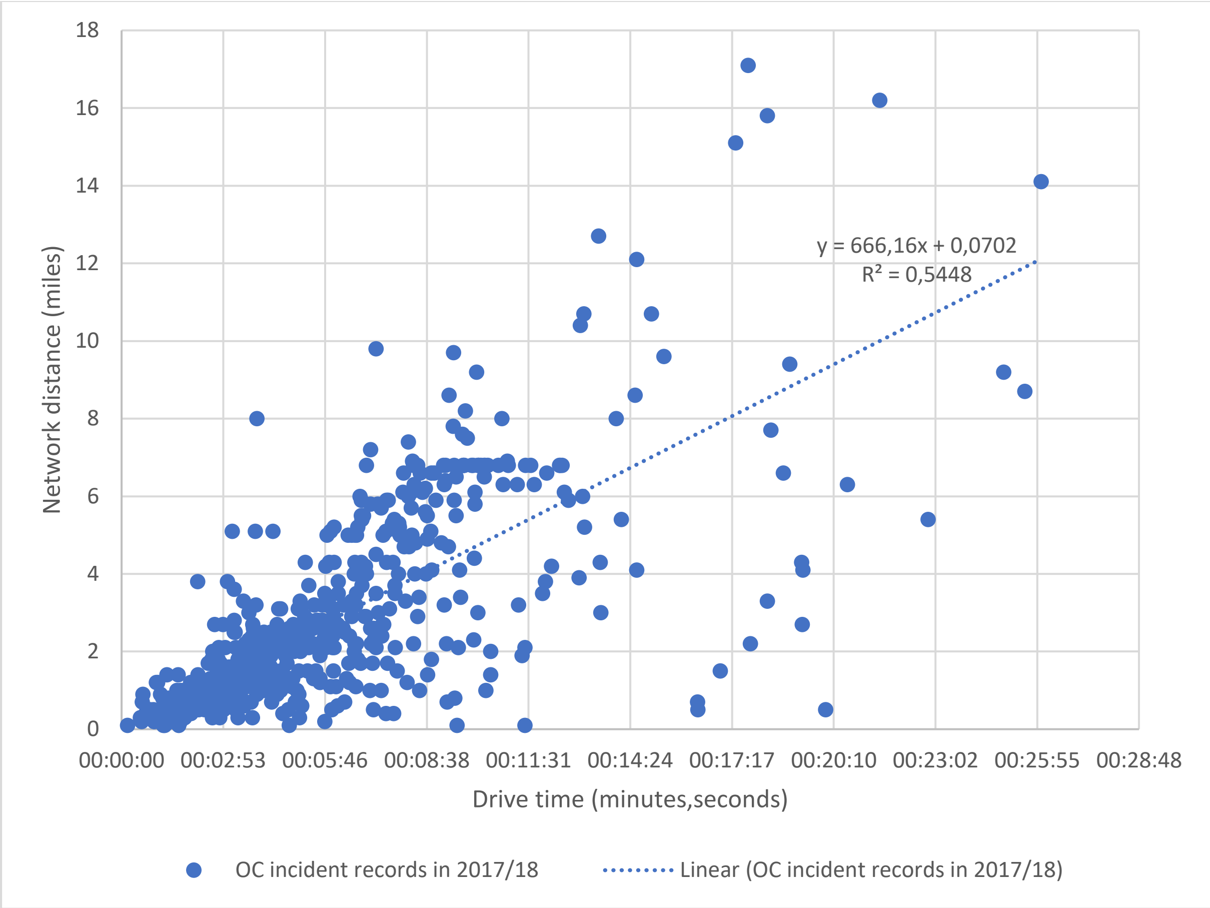

Figure 18: FET13P1, FET16P2, and FET23P1 incident records, 2017-2018 based on network distance

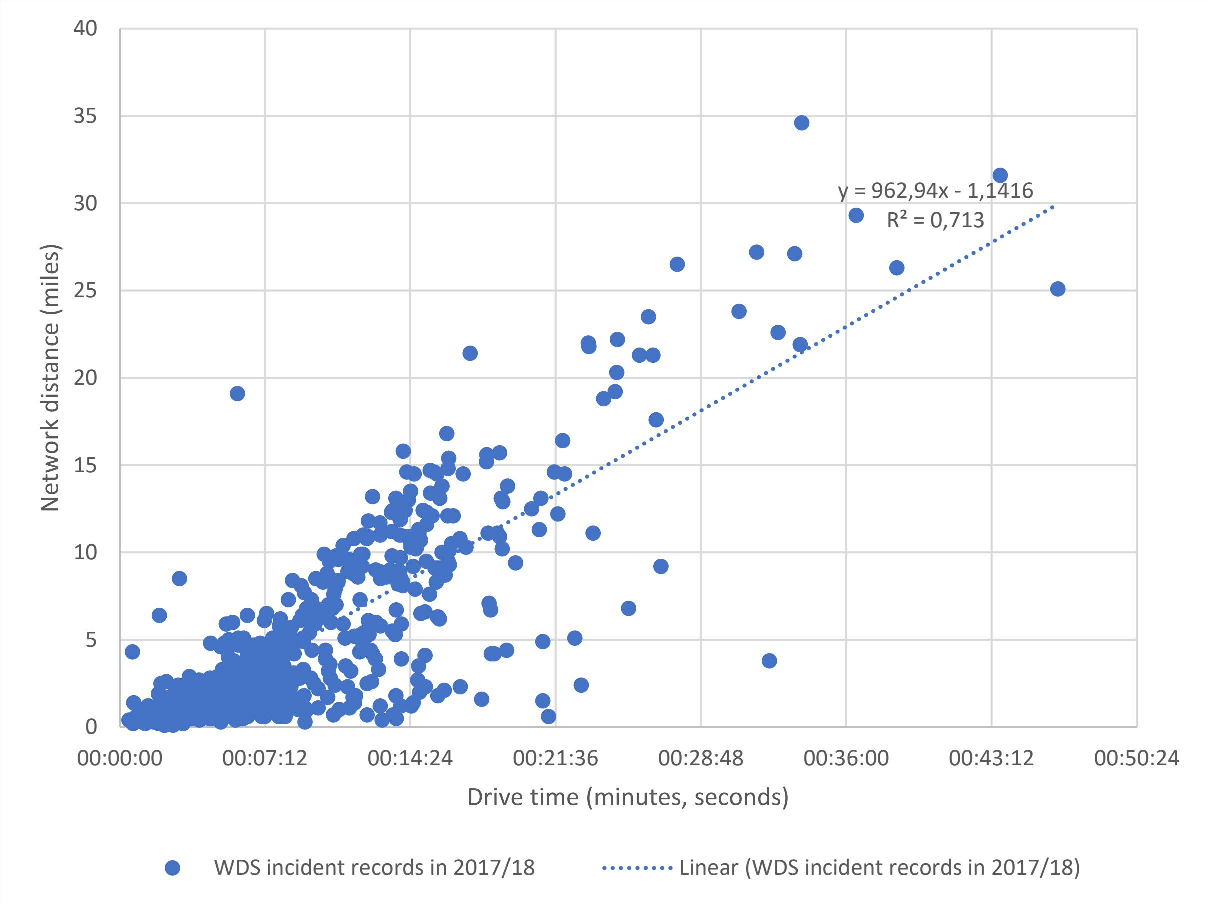

Figure 19: FET16P1 incident records, 2017-2018 based on network distance

According to these results, it is hard to predict response time regarding individual records, because of great variability in the data set. Consequently, aggregated data was analysed to compare WDS and OC crew response time. It is clear that network distribution improved relationship with distance and drive time for both OC and WDS, although straight line distribution is adequate to predict response time for OC and WDS crew. It is observed that WDS drive time and distance relationship are better than OC.

5.2.1.3. Pumping appliance and fire station workload

This section examines each pumping appliance workload over time. Figure 20 shows the workload of each pumping appliance in Nottinghamshire in 2017-2018, and Figure 21 shows the workload of the fire stations in 2017-2018. 48.85% of mobilisation records were obtained from Station 3 (London Road), Station 20 (Stockhill), Station 26 (Arnold), and Station 29 (Highfields). These four fire stations are in the City of Nottingham. Furthermore, Stations 3 and 20 have two pumping appliances, with high mobilisation records (Figure 21). Monthly fire station workload is shown in Appendix B

Table B6 and Table B7. It is clear that some of the most of the WDS pumping appliances have a high utilisation rate than OC.

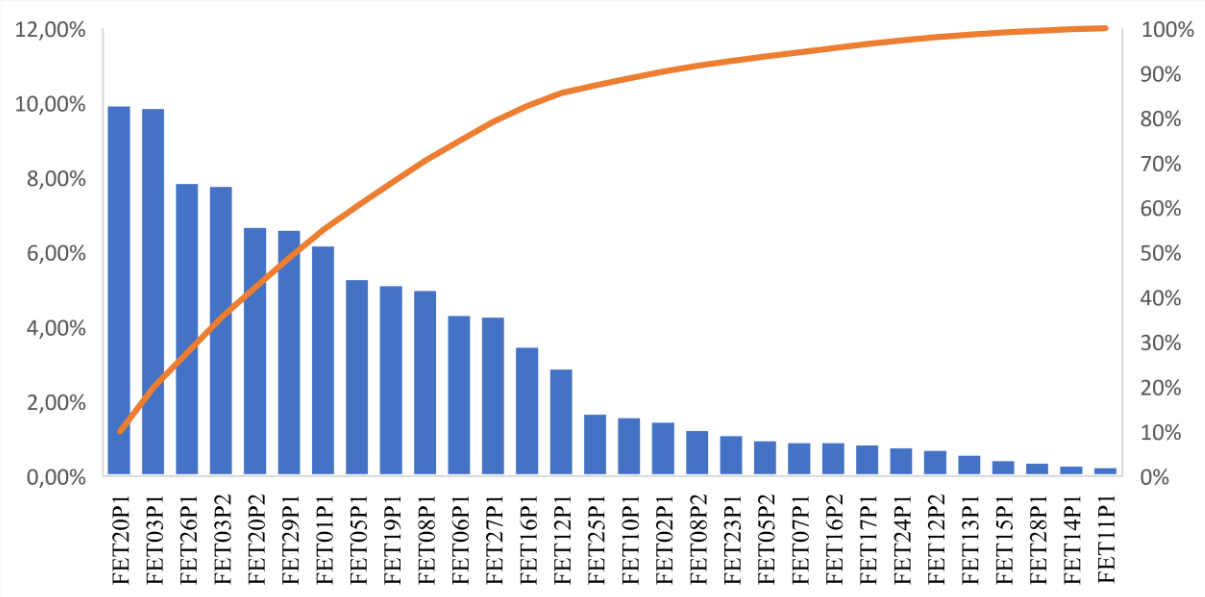

Figure 20: Workload of each pumping appliance, 2017-2018

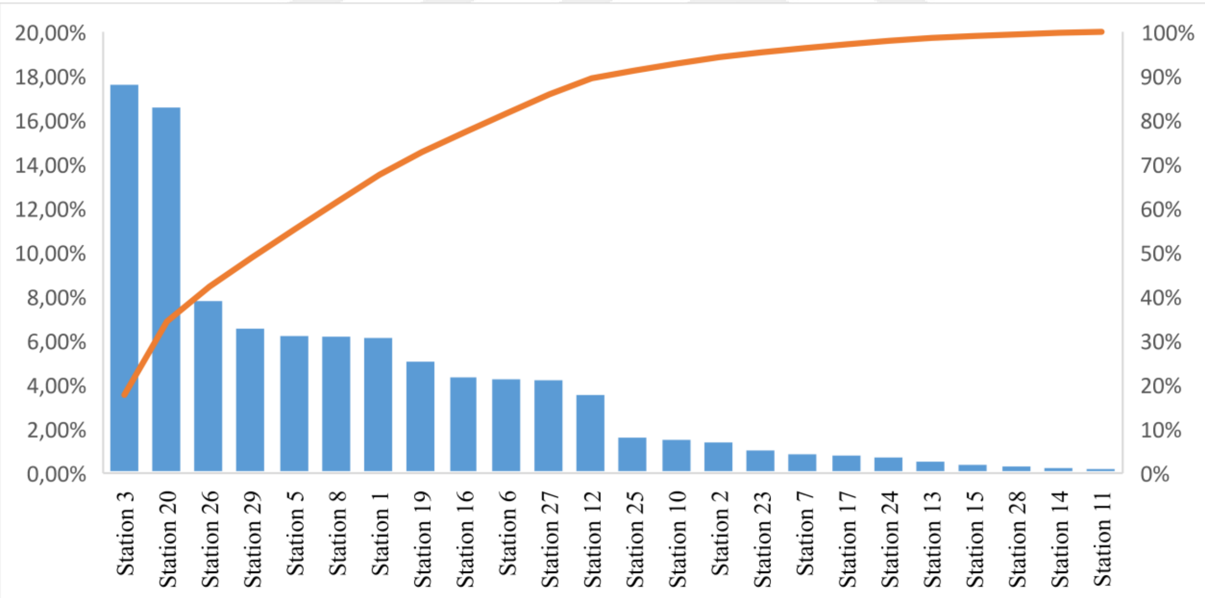

Figure 21: Workload of each fire station, 2017-2018

To see how often FET01 and FET03P1 were sent together from Station 3 (London Road) to incidents, the mobilisation records for each pumping appliance were examined separately for each month in 2017-2018. 24 data points were obtained according to this analysis, as displayed in Figure 22. According to the scatter chart, there is a strong linear relationship between the number records between FET03P2 and FET03P1, with R^2=0,5861. In 60 percent of pumping appliances being sent from station 3 in 2017-2018, two pumping appliances were sent together. This analysis was also done for Station 20, as shown in Figure 23. FET20P1 and FET20P2 have a linear relationship, with R^2 = 0,508. Moreover, these two pumping appliances are WDS. It is concluded that approximately half of the incidents that FET20P1 attended are the incidents that FET20P2 attended.

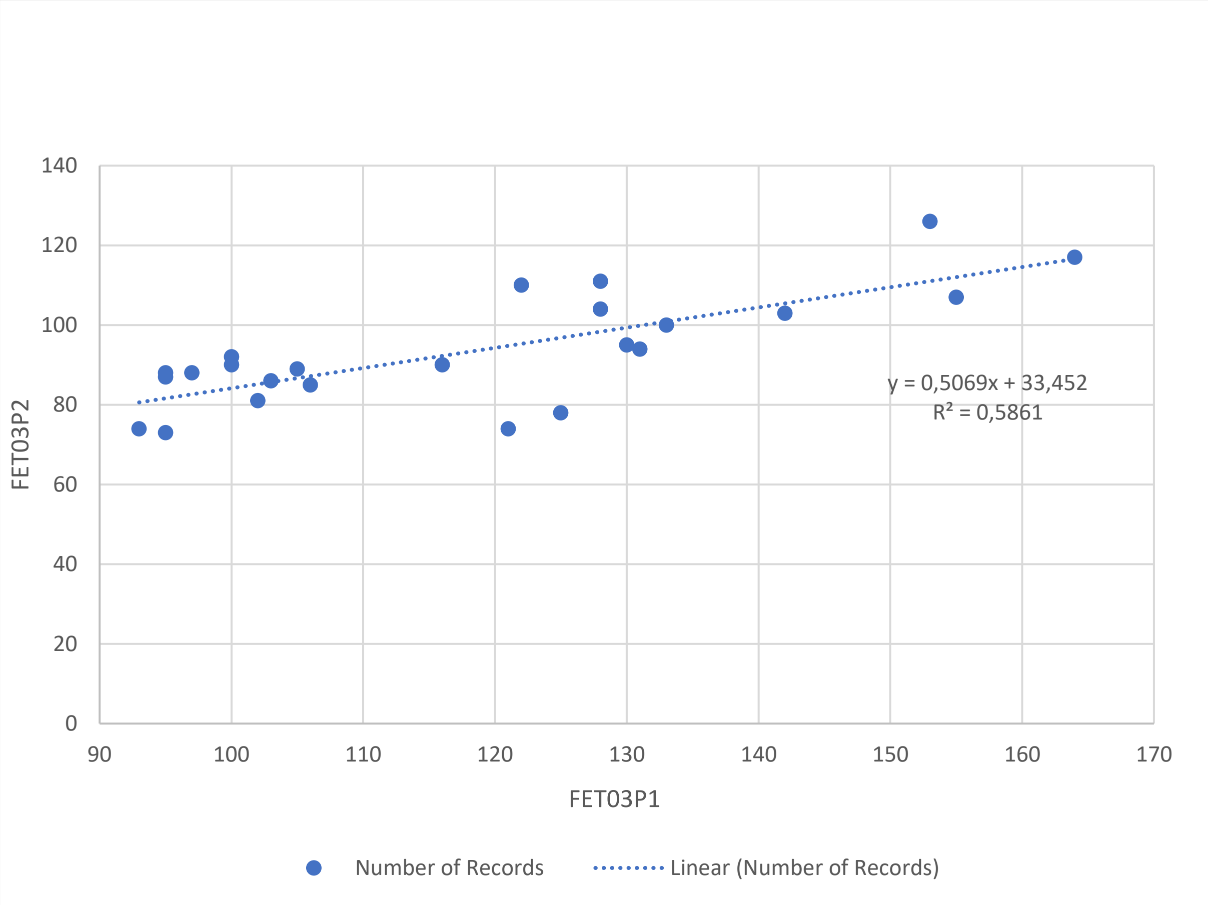

Figure 22: Mobilisation record relationship for FET03P2 and FET03P1 in 2017-2018

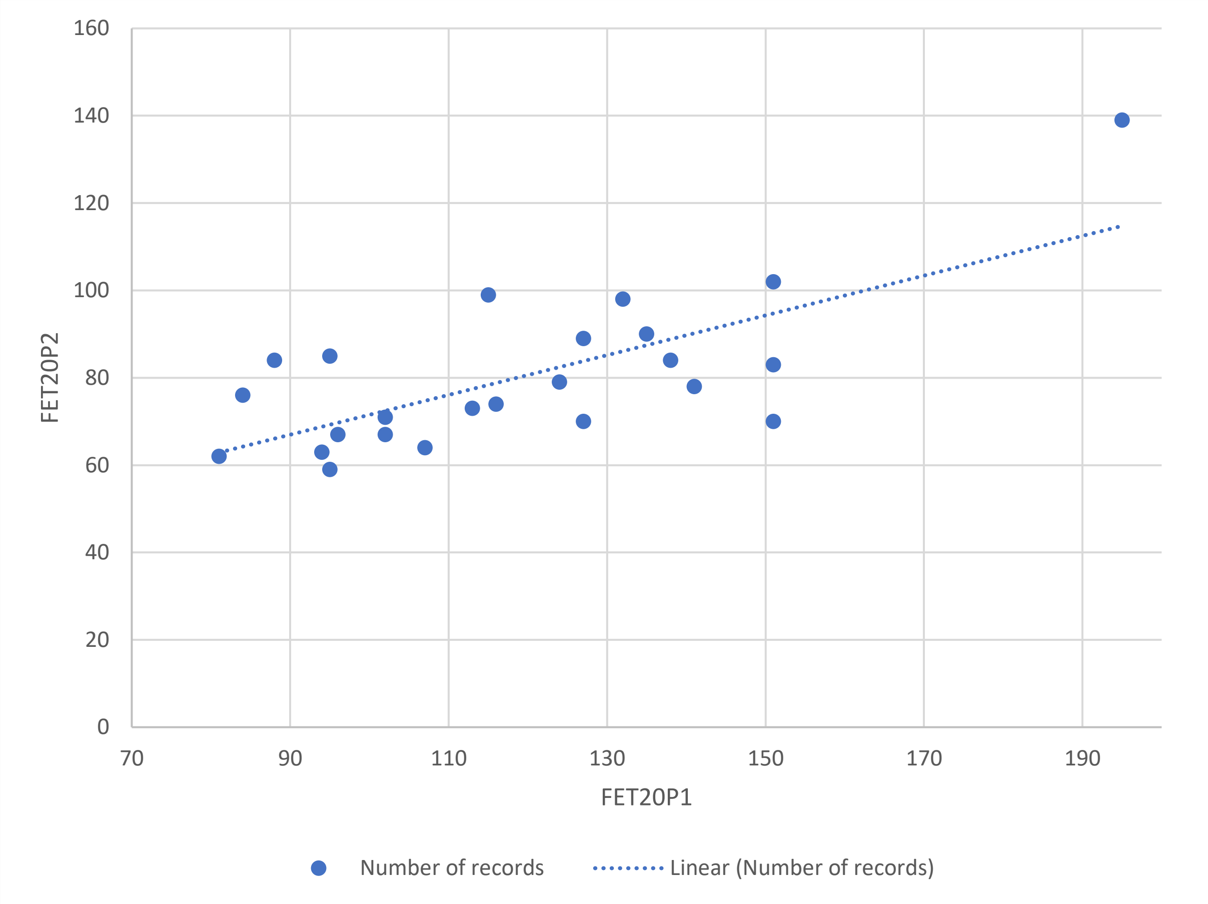

Figure 23: Mobilisation record relationship for FET20P2 and FET20P1 in 2017-2018

As a result, when there was an emergency in the area for which Station 3 and Station 20 are responsible, no pumping appliance was available in the stations at least 50% of the time. This situation might have an impact on drive time, and consequently drive up response time.

5.2.2. Time of the day

Whether the time of day affects call handling, crew, drive, and response time was examined. Mobilisation records for 2017-2018 (29,142 mobilisation records). The number of mobilizations differed according to the time of the day, as shown in Figure 24. There was a significant increase between 6 to 14, and the highest number of records was observed around at 20. Night and early morning records are much lower than day mobilisation records.

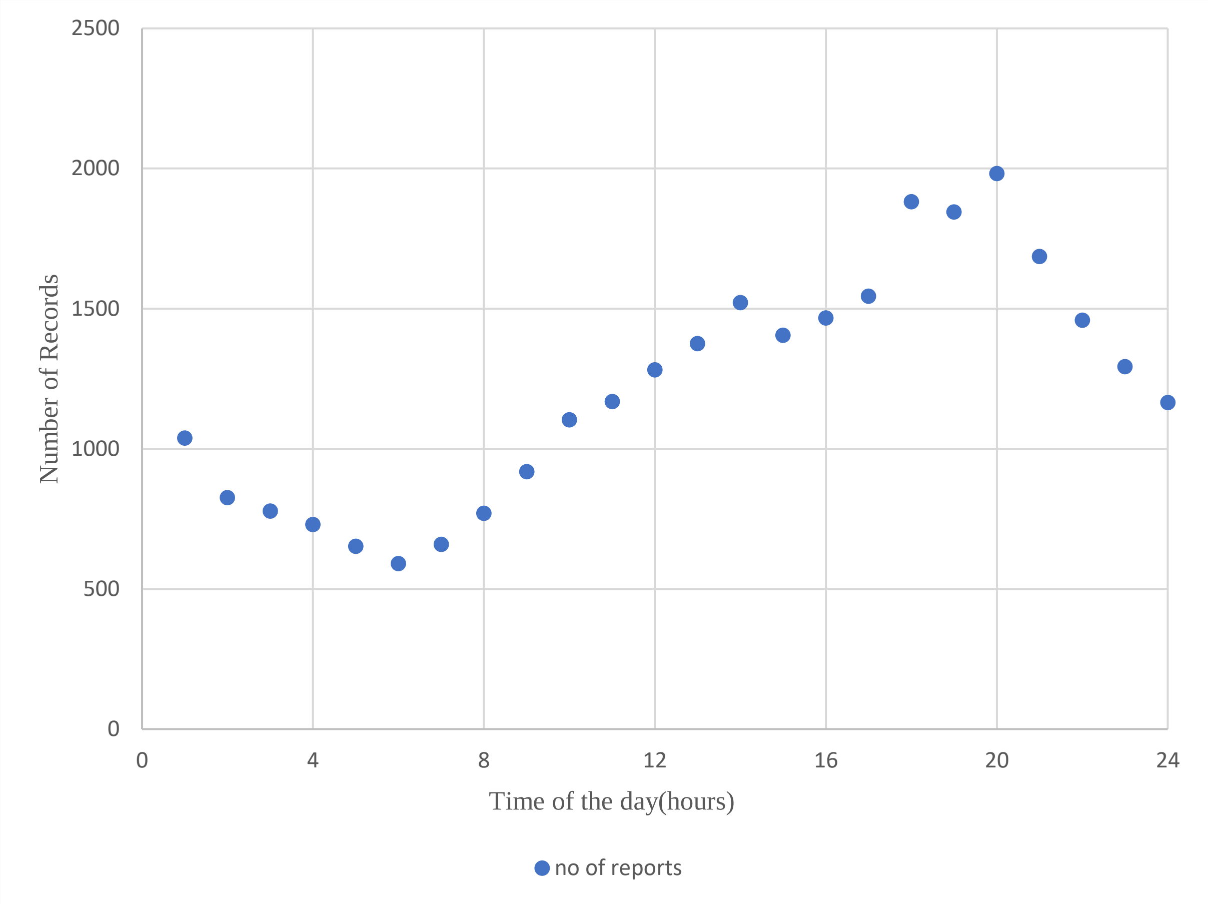

Figure 24: Number of the mobilisation records over time of the day, 2017-2018

Average call handling time is high between 2 to 6 at around 3 minutes, and the longest time was observed between 17 to 18, with 2.57 minutes (Figure 25). The variation in average call handling time is high between 14 to 19, with a standard deviation value of roughly 3:30 minutes (Figure 26). Average crew time is approximately 30 seconds longer at night compared to day time (7-19), reaching a peak between 5 to 6. High drive time values are observed between 7 to 9, and 15 to 18 is when it reaches its peak value. Peak hours were 7 to 9 and 15 to 18 in 2017-2018 (TomTom, 2018). Therefore, the time increase in drive time might be explained by the traffic congestion. Drive time varies more during the day time (7-19) compared to night (Figure 26). Precise time information is shown in Appendix B Table B8. It is observed that response time decreased from 19 to 23, then it increased until 4 due to crew time increase, and time fluctuates more in the day time.

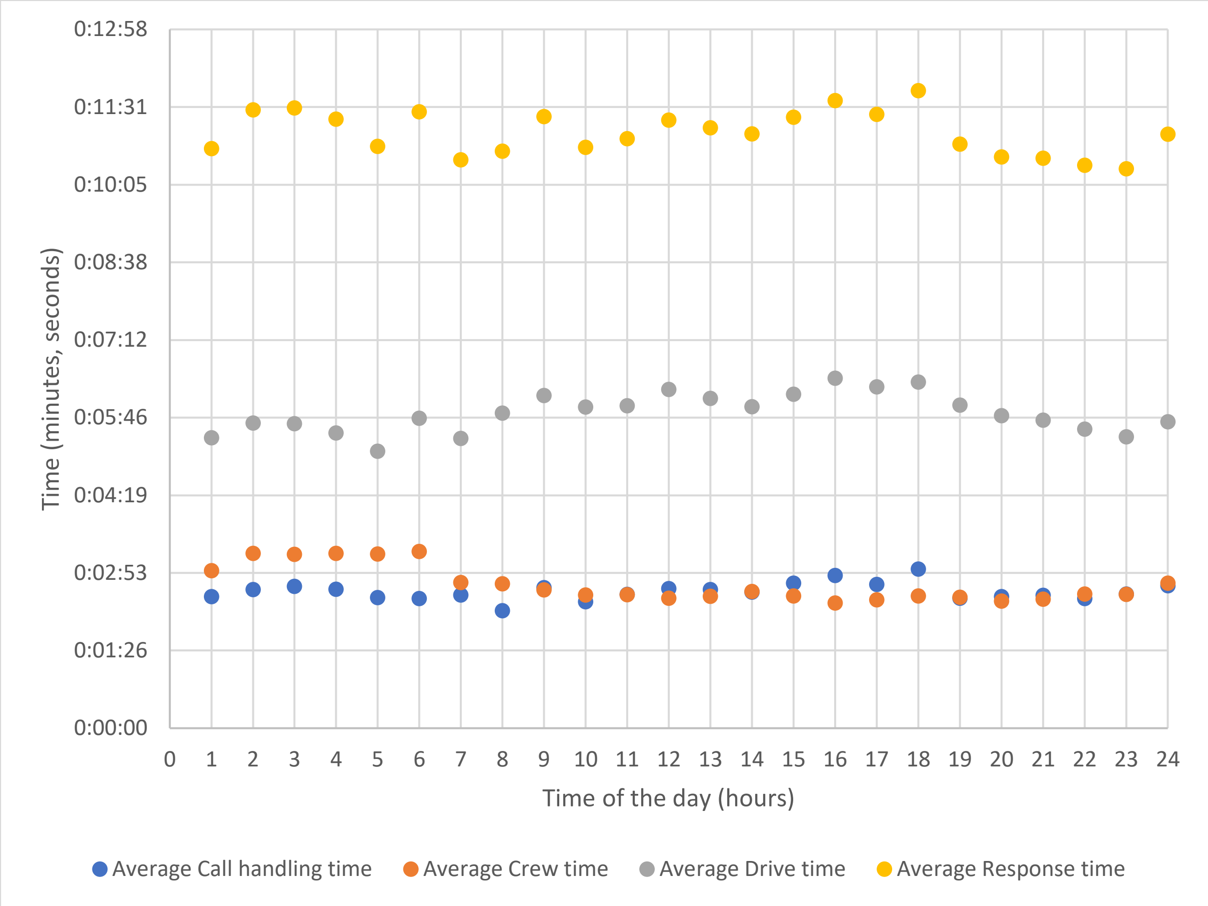

Figure 25: Average call handling, crew, drive, and response time regarding time of the day based 29,142 mobilisation records, 2017-2018

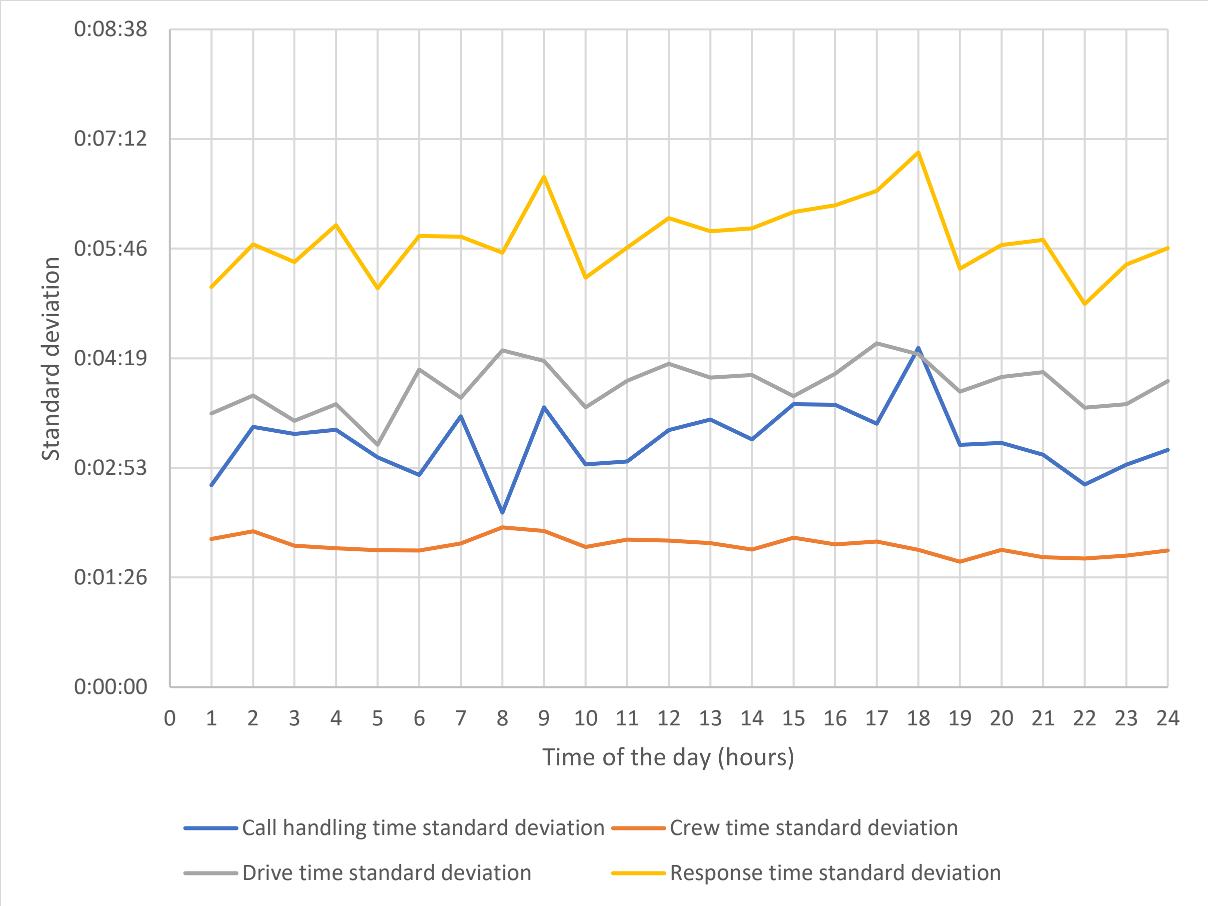

Figure 26: Standard deviation for call handling, crew, drive, and response time regarding time of the day based 29,142 mobilisation records, 2017-2018

This method of analysis is repeated below to evaluate OC and WDS crews to compare their mobilisation by time of day.

5.2.2.1. Time of the day for OC crew

The number of the records for OC crew pattern, is shown in Figure 27, resembles the time of the analysis regardless of the crew type, shown in Figure 24. They both peaked between 19 to 20, but the OC crew response time was 13:33 minutes, lower than the average response time of all OC crew records (14:26 minutes). This shows that OC crews do not confront any capacity problem. 71% of incidents appeared between 23 to 24.

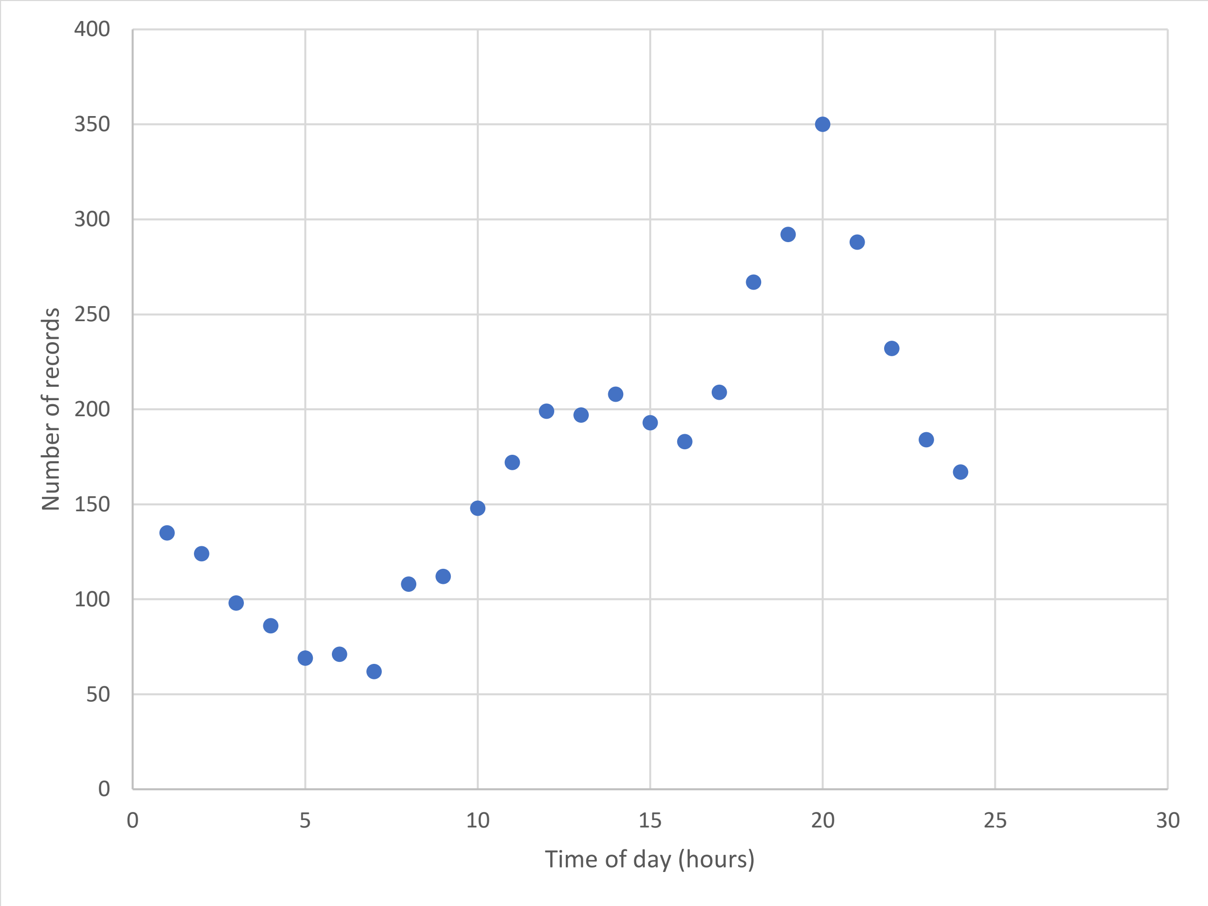

Figure 27: Number of the mobilisation records over time of the day, 2017-2018 for OC crew

OC call handling times have variations that follow a pattern, as shown in Figure 28. The reason for the fluctuation has not found, but a potential reason could be the break times of call handling employees. OC crew drive time is high between 0 to 9 compared to rest on the day. Average drive time is between 9 to 20 compared to the remaining day times, with an average 5 minutes 53 seconds to 5 minutes 21 seconds.. While evaluating all mobilisation records regardless of crew type, the most effective response time component is drive time, although crew time for OC crew is higher than drive time at night shifts(0-7 and 19-24). If crew time is decreased at night, response time improves for OC crew at night.

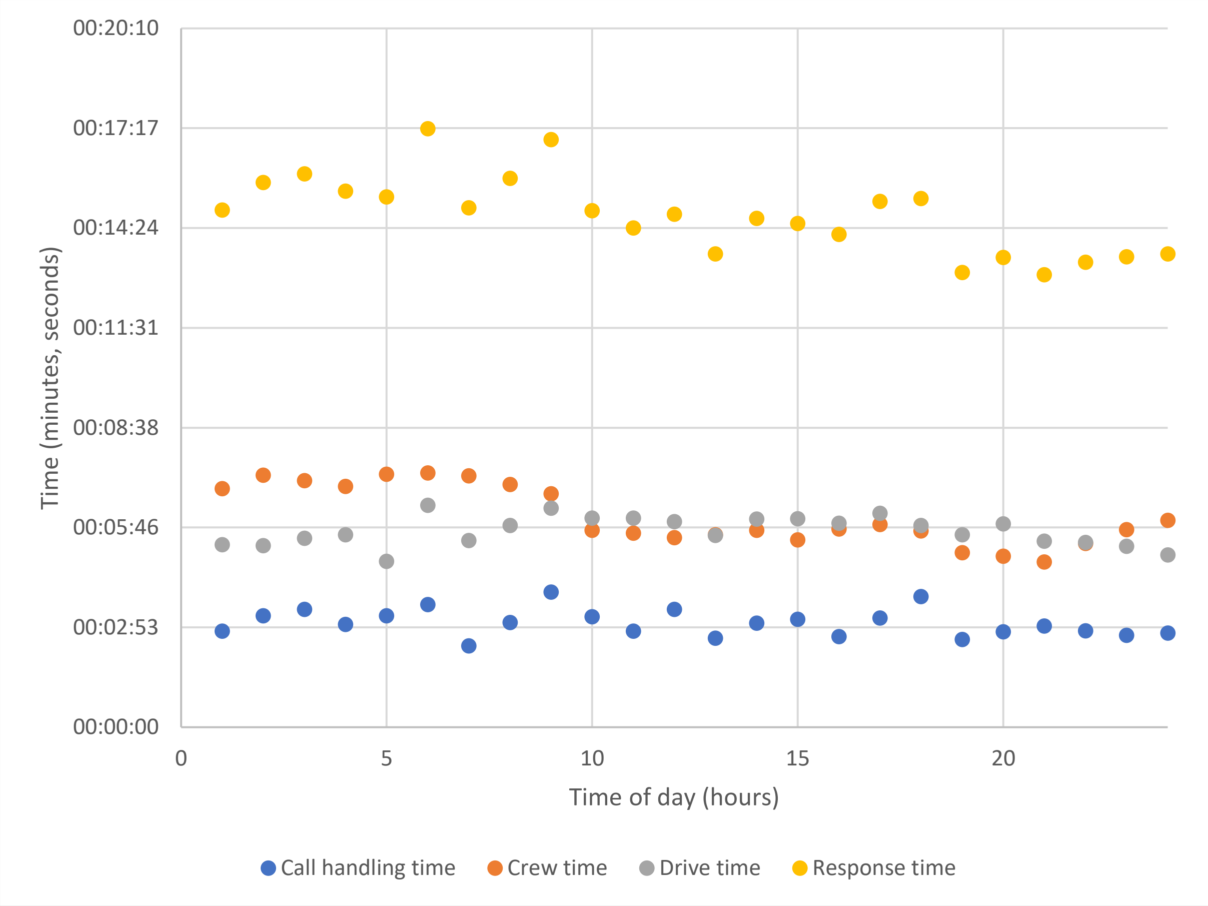

Figure 28: Average call handling, crew, drive, and response time regarding time of the day for OC crew, 2017-2018

5.2.2.2. Time of the day for WDS crew

The number of records distributions over time follows same pattern of the first time of day analysis without differentiating crew type, as shown in Figure 29. This pattern is expected, because most of the mobilisation data consists of WDS crew. 68% of the incidents occurred between 11 to 24.

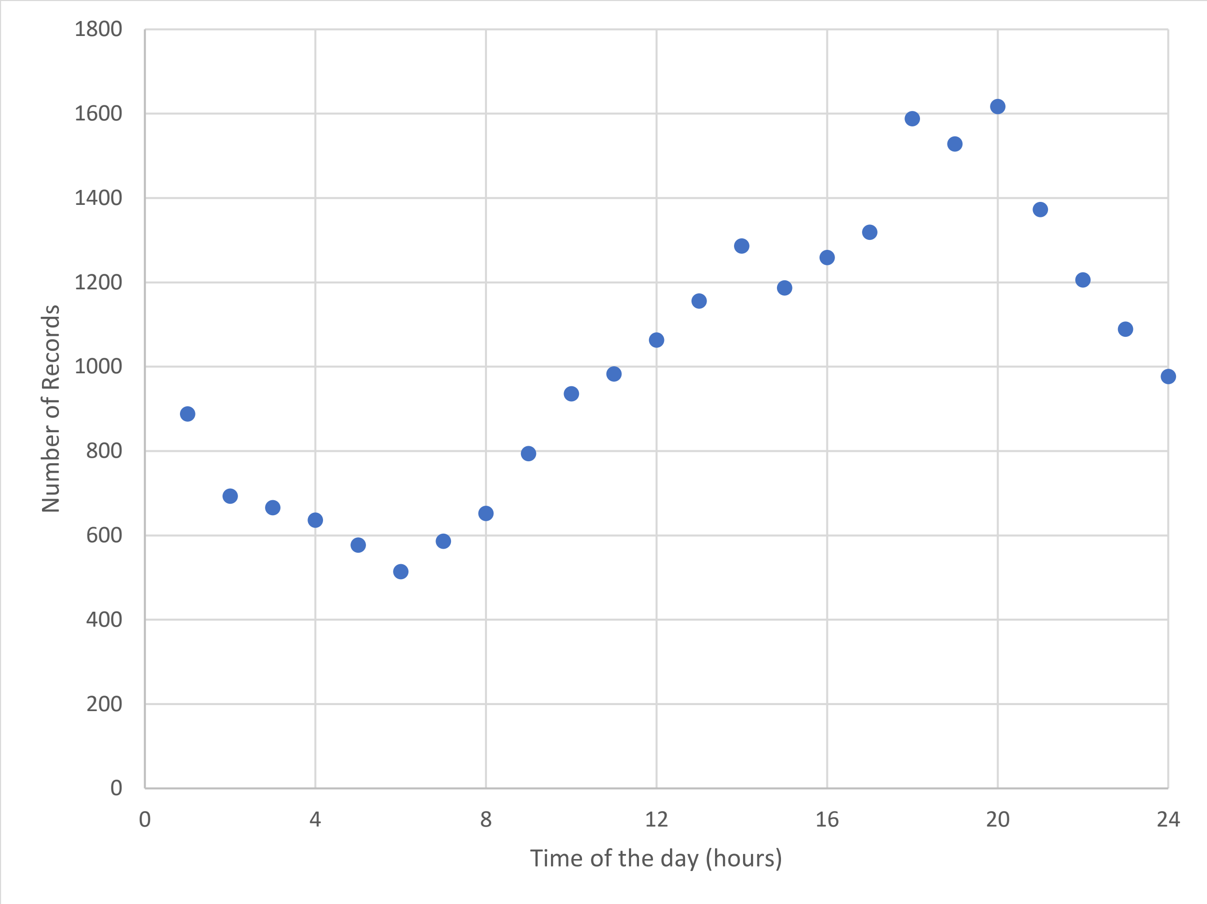

Figure 29: Number of the mobilisation records over time of the day, 2017-2018 for WDS crew

WDS crew response time analysis shown in Figure 30. Average call handling time is almost stable at any time. For OC, average crew time is approximately 40 seconds higher during the night shift compared to the day shift for WDS (7 -19). Between 7 to 19, average drive time is high with 6:10 seconds, whereas average drive time is 5:14 seconds for the rest of the day. Average crew time and average drive time increase at different times of the day, so average response time has a related limited variability.

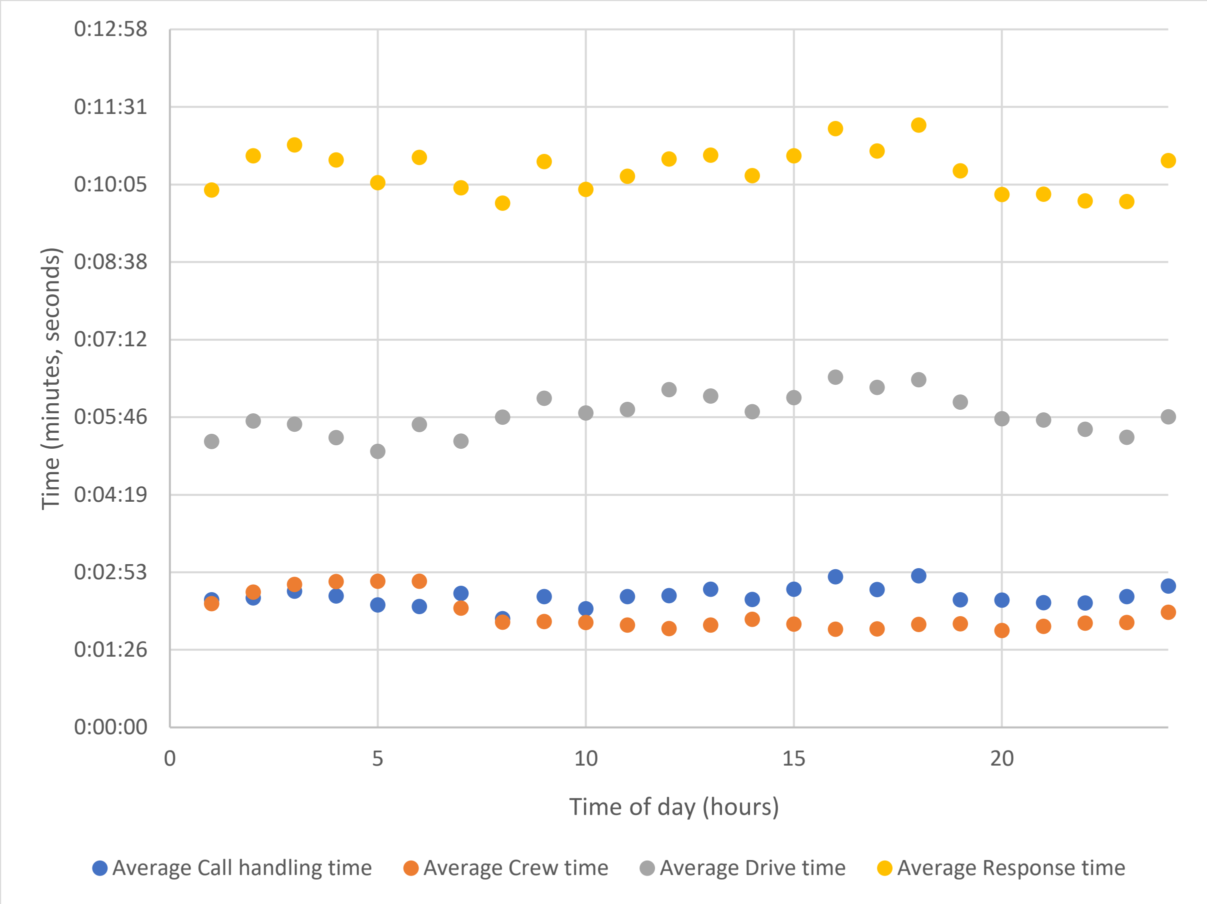

Figure 30: Average call handling, crew, drive, and response time regarding time of the day for WDS crew, 2017-2018

5.2.3. Seasonality

This section examines the mobilisation data for 2017-2018 based on seasons: spring, summer, fall, and winter. The results of these 29,142 mobilisation records are shown in Table 11. Comparing these two years' seasons, the number of the records peaked in the summer period, with the highest response time, whereas the lowest number of mobilisation records was observed in winter period, with the lowest response time. Call handling time was approximately 2:30 minutes, and crew time was approximately 2:50 minutes during each season in 2017-2018, and was stable regardless of year and season, as shown in Table 11. Drive time increased in the summer period and decreased in the winter in both 2017 and 2018. As a result, response time increased in summer periods and decreased in winter periods, so a seasonal factor is seen in the mobilisation records.

Table 11: Average call handling, crew, drive, and response time regarding seasons, 2017-2018

	Call time	Crew time	Drive time	Total	No. records
Spring 2017	00:02:40	00:02:39	00:05:40	00:100:58	3461
Summer 2017	00:02:30	00:02:35	00:05:58	00:11:03	3913
Fall 2017	00:02:24	00:02:42	00:05:41	00:100:47	3442
Winter 2017	00:02:29	00:02:40	00:05:28	00:100:37	3339
Spring 2018	00:02:36	00:02:29	00:05:50	00:100:55	3545
Summer 2018	00:02:44	00:02:32	00:06:32	00:11:48	4758
Fall 2018	00:02:29	00:02:29	00:06:00	00:100:57	3741
Winter 2018	00:02:27	00:02:32	00:05:48	00:100:47	2943
Spring overall	00:02:38	00:02:34	00:05:45	00:100:57	7006
Summer overall	00:02:37	00:02:33	00:06:15	00:11:26	8671
Fall overall	00:02:26	00:02:35	00:05:50	00:100:52	7183
Winter overall	00:02:28	00:02:36	00:05:38	00:100:42	6282

5.2.4. Incident day of week

29,142 records were examined based on day of the week, as shown in Table 12. Average call handling time and average crew time were approximately 2:30 minutes, regardless of the day of the week. It is interesting that drive time is roughly 10 seconds less at the weekend compared to weekdays. The highest number of records was obtained at weekends, and the numbers of records for Saturday and Sunday were 4369, and 4435, respectively, although response time was lower at the weekend compared to weekdays, as shown in Table 12. As a result, the response time difference between the weekend and weekdays is negligible.

Table 12: Average call handling, crew, drive, and response time regarding day of the week, 2017-2018

Day		Av. call handling time	Av. crew time	Av. drive time	Av. response time	No. records
Mon	1	00:02:35	00:02:35	00:05:54	00:11:04	4184
Tues	2	00:02:32	00:02:35	00:06:02	00:11:09	3971
Wed	3	00:02:38	00:02:31	00:05:59	00:11:08	3986
Thurs	4	00:02:30	00:02:32	00:05:56	00:100:58	4119
Fri	5	00:02:30	00:02:37	00:05:57	00:11:05	4078
Sat	6	00:02:29	00:02:35	00:05:46	00:100:50	4369
Sun	7	00:02:36	00:02:36	00:05:49	00:11:01	4435

5.2.5. Incident location

Incident location has the potential to affect response time because as distance increases, pumping appliances must drive more generally. 28,727 mobilisation data based on *call sign* is analysed in this section. Using *easting* and *northing* coordinates of each mobilisation record in the data and fire station coordinates, the incident records distribution map in 2017-2018 is generated, as shown in Figure 31. According to the map, the majority of mobilisation records are seen in the southern and west parts of Nottinghamshire, which is the urban region. Therefore, 12 fire stations among 24 are in the south-west of Nottinghamshire.

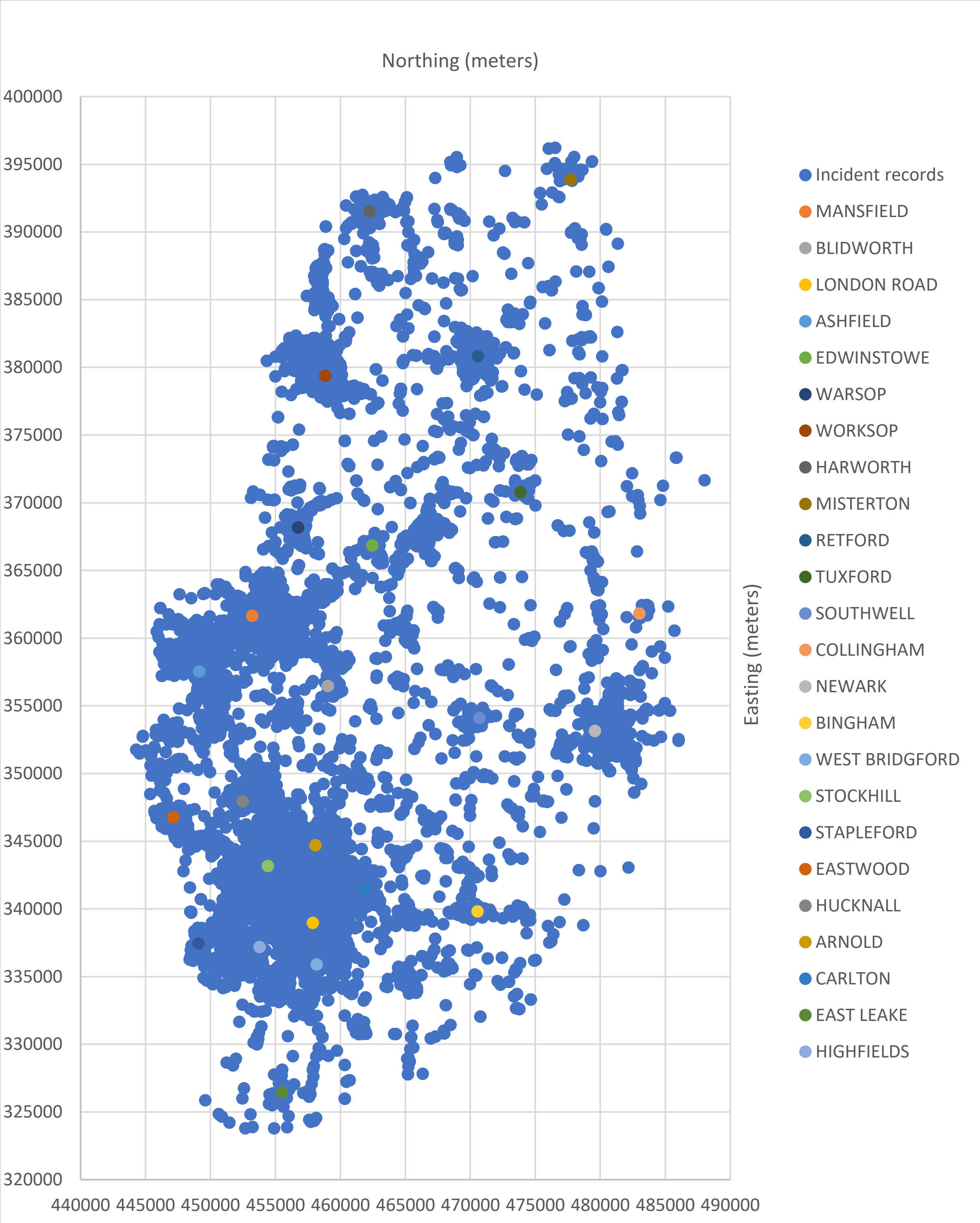

Figure 31: Incident records and fire stations location in Nottinghamshire, 2017-2018

In this section, in order to identify factor on response time, incident location for each pumping appliance attended in 2017-2018 is analysed. Type of call and crew type factors' effect on drive time are investigated. Incidents might appear close to fire stations or far away from them. Therefore, the type of the call is divided into two groups, local and remote calls. To identify whether a station receives mostly local or remote calls, each station's mobilisation records distribution needed to be investigated. Some stations have two pumping appliances, and types of crew (OC or WDS) differ. Therefore, 30 pumping appliances' mobilisation incident records are used to create a map separately, as shown in Appendix B, Figure B5-B24.

Easting and northing coordinates of each fire station and mobilisation records are used in this analysis. Average straight-line distance is calculated for each pumping appliance. Average straight-line distance is the average distance between a fire station with corresponding pumping appliance to incident location in 2017-2018, and it is assumed that all pumping appliances are dispatched from the specified fire station. Average straight-line distance is calculated based on pumping appliance, not station. The aim of this analysis is to distinguish the incident location regarding the crew type, even if they are dispatched from the same station. In the northeast of each map, the average straight-line distance of all incidents at that region in 2017-2018 is shown. According to these maps, local and remote calls can be differentiated. If most of the mobilisation data is located close to a fire station, it is assumed to be a local call; if most of the mobilisation data is located far away from a fire station it is assumed to be a remote one. Incident location analysis is investigated under two categories: fire station type, and region classification.

5.2.5.1. Incident location based on fire station

This analysis investigates the distance between fire station and incident location based on fire station type: WDS and OC for stations with have one pumping appliance; and WDS-WDS and WDS-OC for stations with two pumping appliances. Blue points on the maps show individual incidents that happened in 2017-2018, and red points shows fire stations whence the pumping appliance was dispatched to attend an incident at that time. Firstly, fire stations 8 (Worksop), 12 (Retford), 16 (Newark), and 5 (Ashfield) are compared. These have both OC and WDS pumping appliances. The first appliance is WDS and the second is WDS. FET08P1 and FET08P2 are shown in Figures 32 and 33, respectively. Retford, Newark and Ashfield pumping appliances are shown in Appendix B, Figures B5-B10, respectively. According to these maps, OC incident locations are more concentrated at the fire station than the WDS crew. As a result, the

OC crew responds more to local calls compared to the WDS crew in this case. Average straight-line distances for WDS crew are higher than for OC crew.

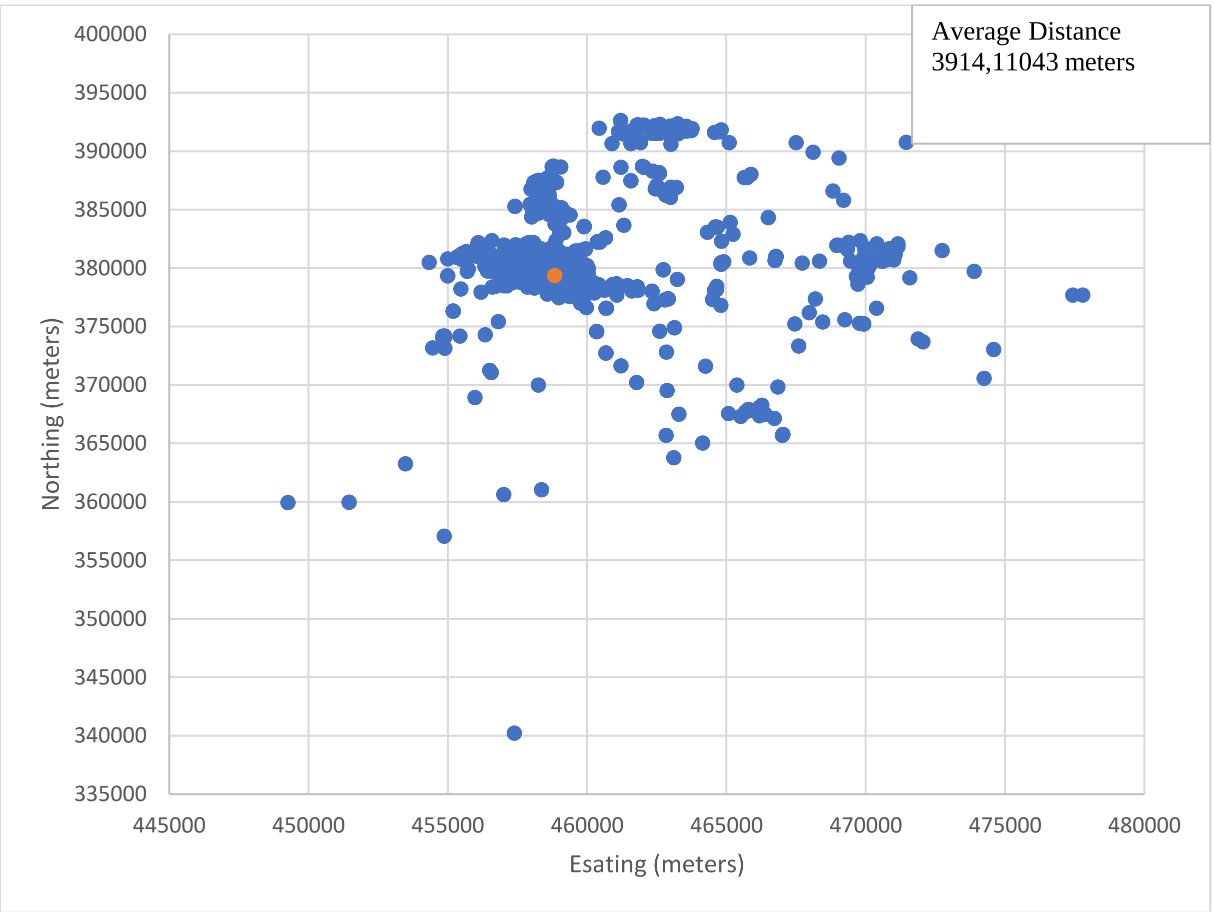

Figure 32: Incident records that FET08P1 pumping appliance attended, 2017-2018 (WDS crew)

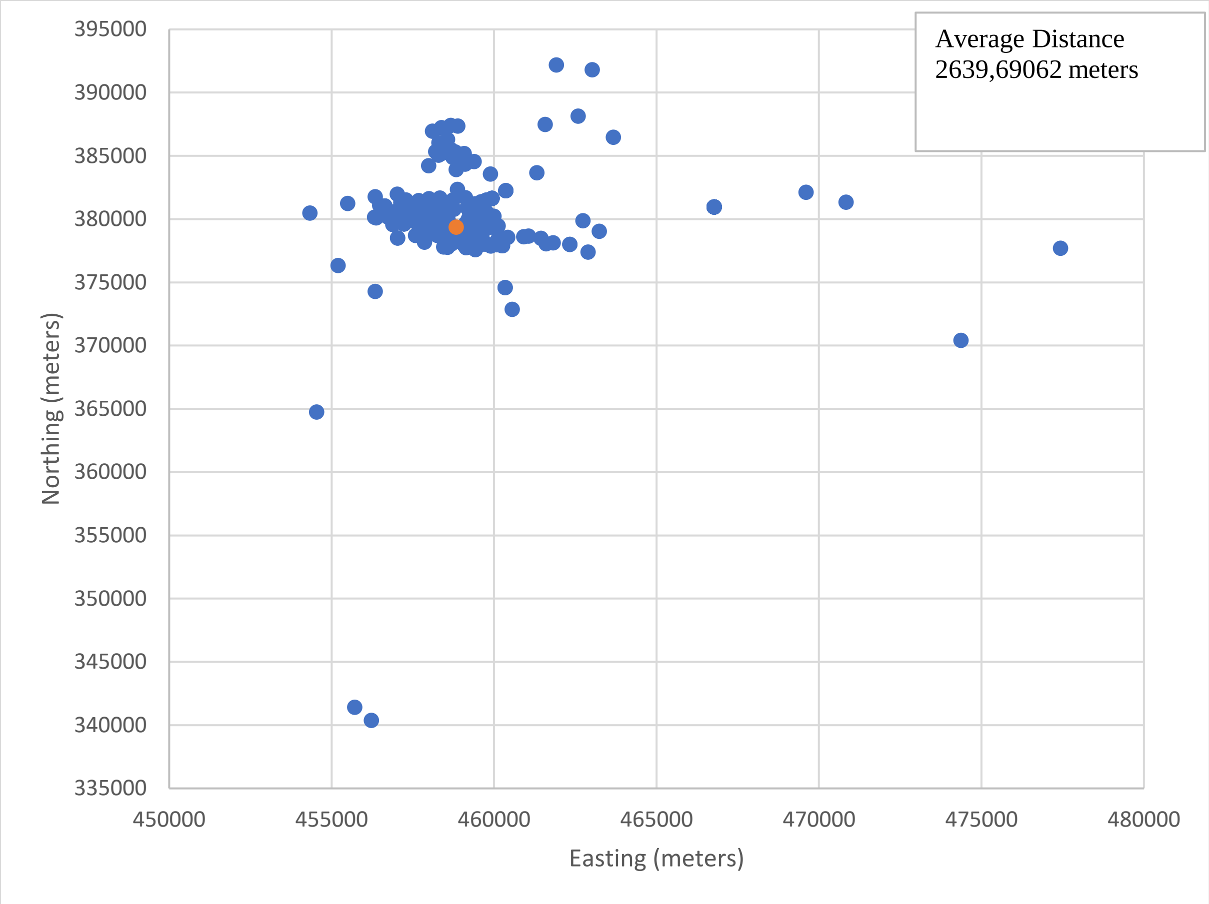

Figure 33: Incident records that FET08P2 pumping appliance attended, 2017-2018 (OC crew)

Secondly, fire stations with two WDS pumping appliances are evaluated: fire stations 3 (London Road) and 20 (Stockhill). Fire station 3 pumping appliances are shown in Figures 34 and 35, and those of station 20 are shown in Appendix B, Figure B11-B12. The average straight-line distance between the first and second pumping appliances are 385 meters and 53 meters for Stations 3 and 20, respectively. Also, the maps show incident distributions for two WDS pumping appliances for each station are very similar. Therefore, if a station has two WDS pumping appliances, both pumping appliances are responding to local calls.

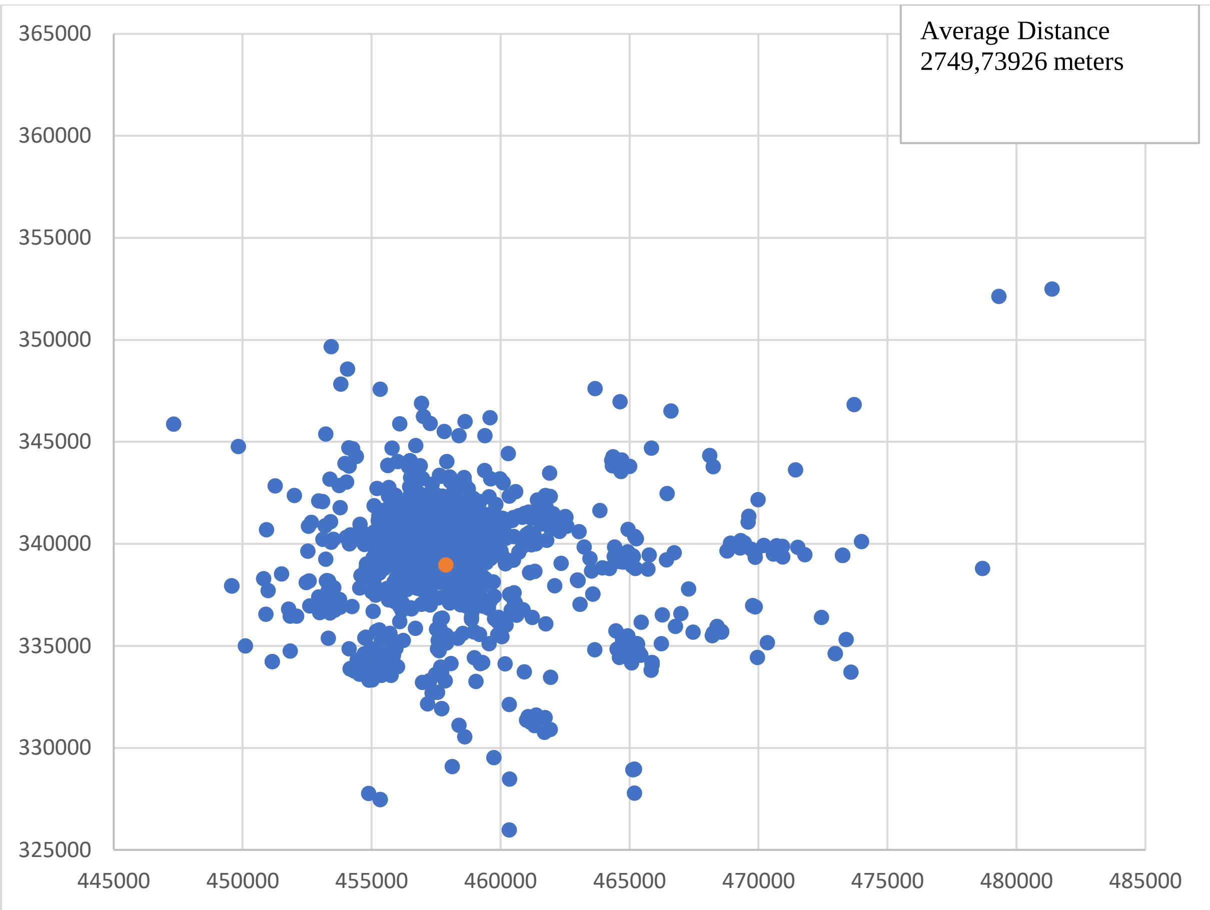

Figure 34: Incident records that FET03P1 pumping appliance attended, 2017-2018

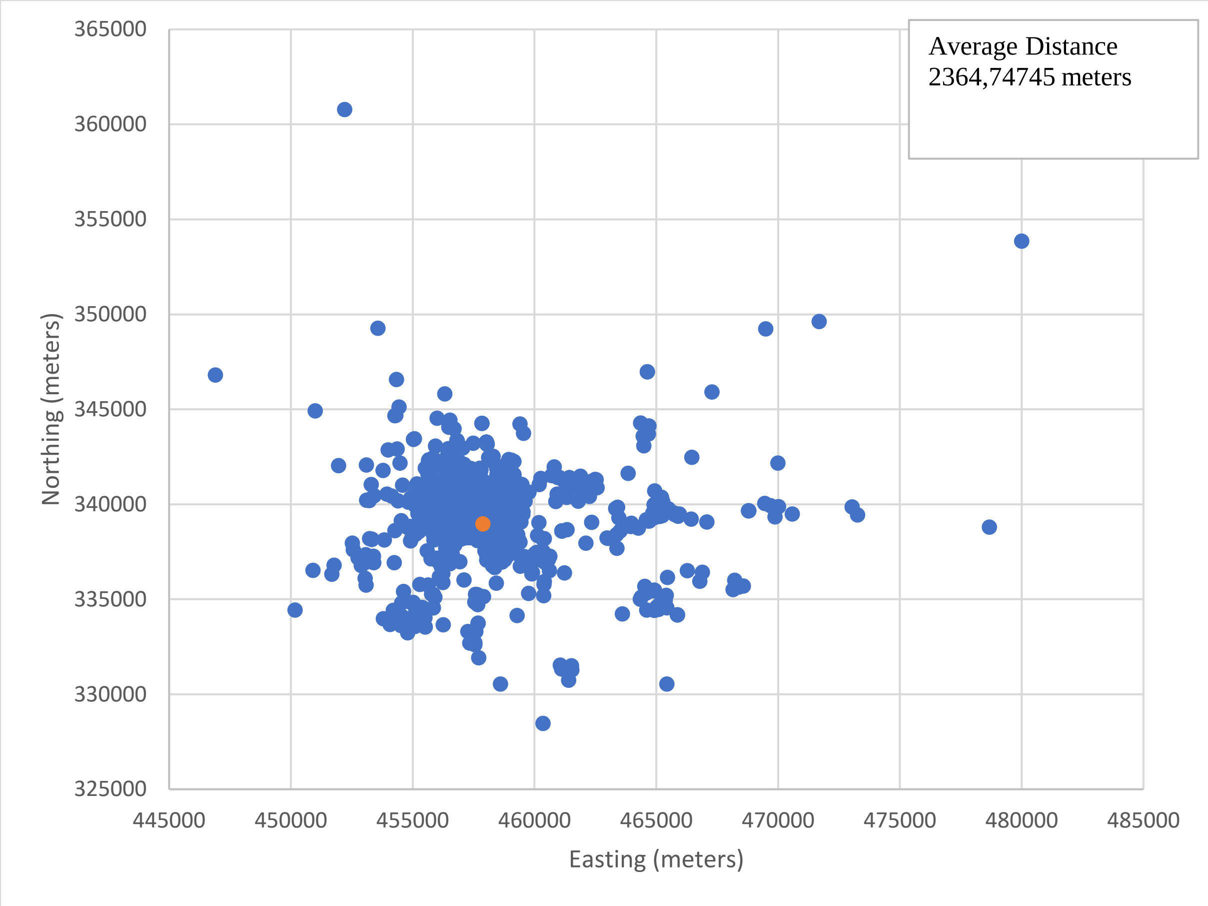

Figure 35: Incident records that FET03P2 pumping appliance attended, 2017-2018

Thirdly, the following WDS fire stations are compared to each other: fire station 1 (Mansfield), 6 (Edwinstowe), 19 (West Bridgford), 26 (Arnold), 27 (Carlton), and 29 (Highfields), as shown in Figures 36 and 37, and Appendix B, Figures B13-1B6, respectively. According to the figures, it is clear that WDS fire stations respond to local calls, excluding fire station 6 (Edwinstowe).

Stations 6 and 19 are both WDS stations located in rural areas. Station 19's location is very close to the City of Nottingham, which has very close stations and WDS, whereas most of the surrounding stations for Station 6 are OC, and the distance between other fire stations and Station 6 is relatively large, therefore it is expected that the latter will have a high average distance, along with Station 19, with 5785 and 3919 meters respectively, compared to other WDS fire stations with an average of approximately 3000 meters.

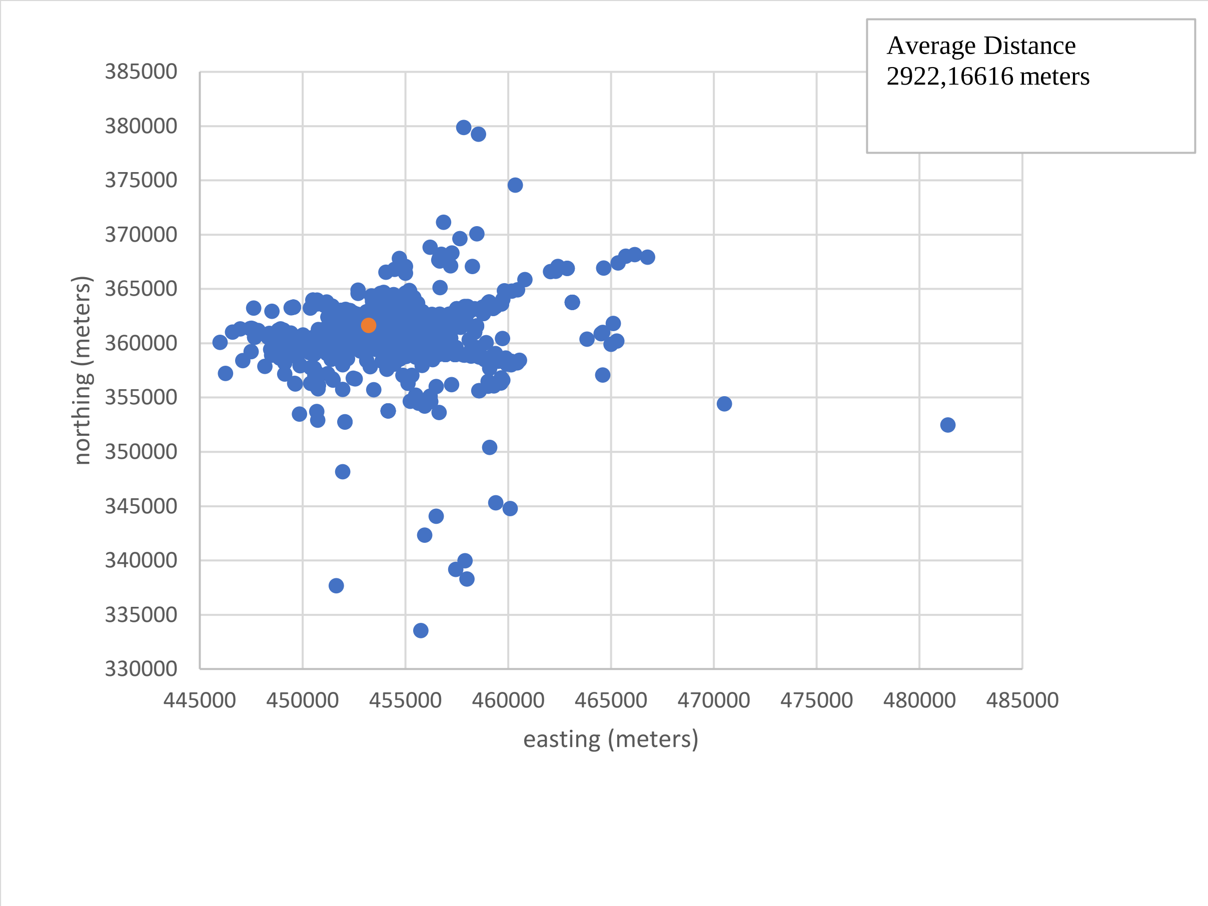

Figure 36: Incident records that FET01P1 pumping appliance attended, 2017-2018

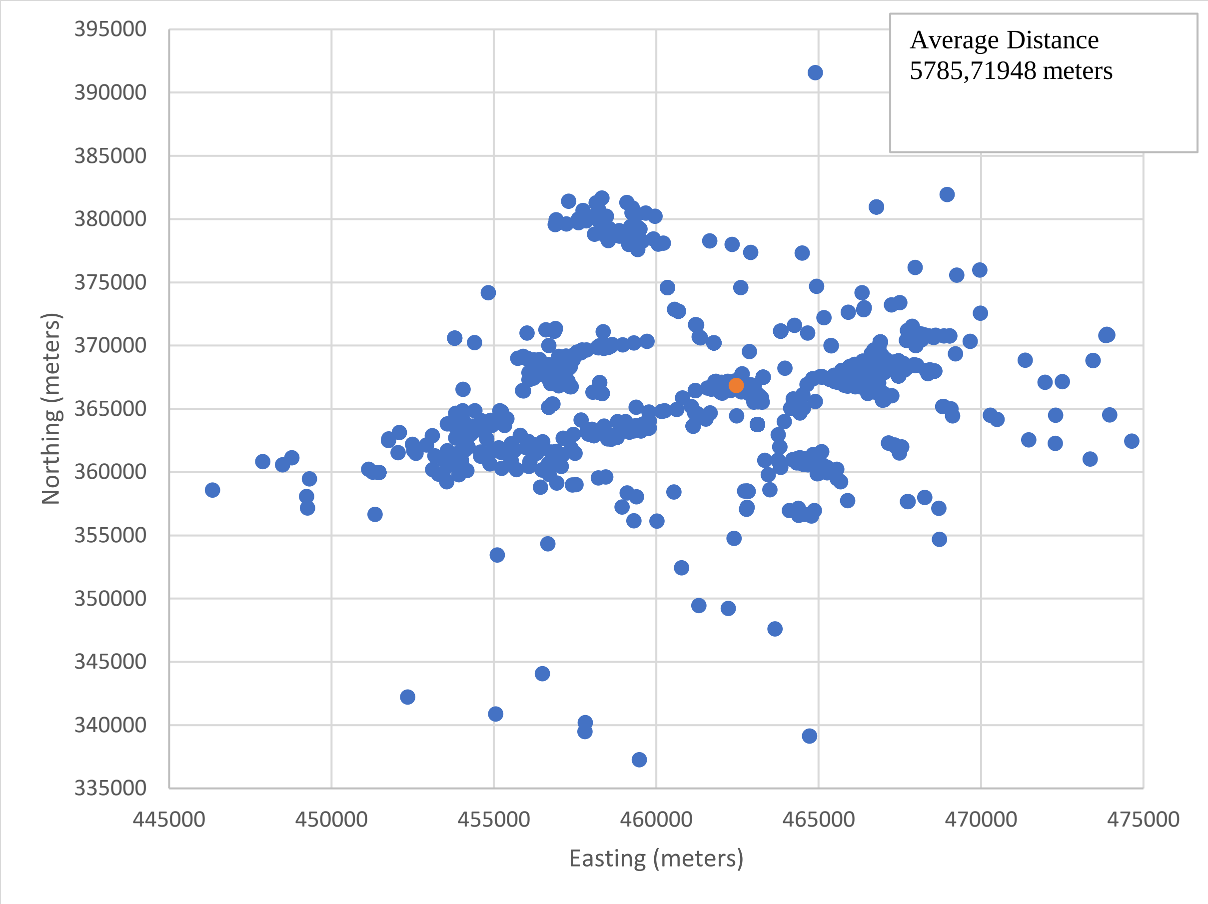

Figure 37: Incident records that FET06P1 pumping appliance attended, 2017-2018

Finally, 11 OC fire station were analysed: Fire station 7 (Warsop), 10 (Harworth), 13 (Tuxford), 14 (Southwell), 17 (Bingham), 23 (Stapleford), 24 (Eastwood), and 28 (East Leake) (Appendix B, Figures B17-B24); and 2, 25, and 11, as shown in Figures 38-40. According to these maps, incident distribution for OC crew is very unpredictable. Therefore, for individual mobilisation it is difficult to predict response time due to high variability. Also, the number of the incidents that OC fire stations attended is very low to compared to WDS, such as Station 11, as shown in Figure 40. This makes it difficult to analyse OC fire stations. According to these incident records, OC responds to more remote calls.

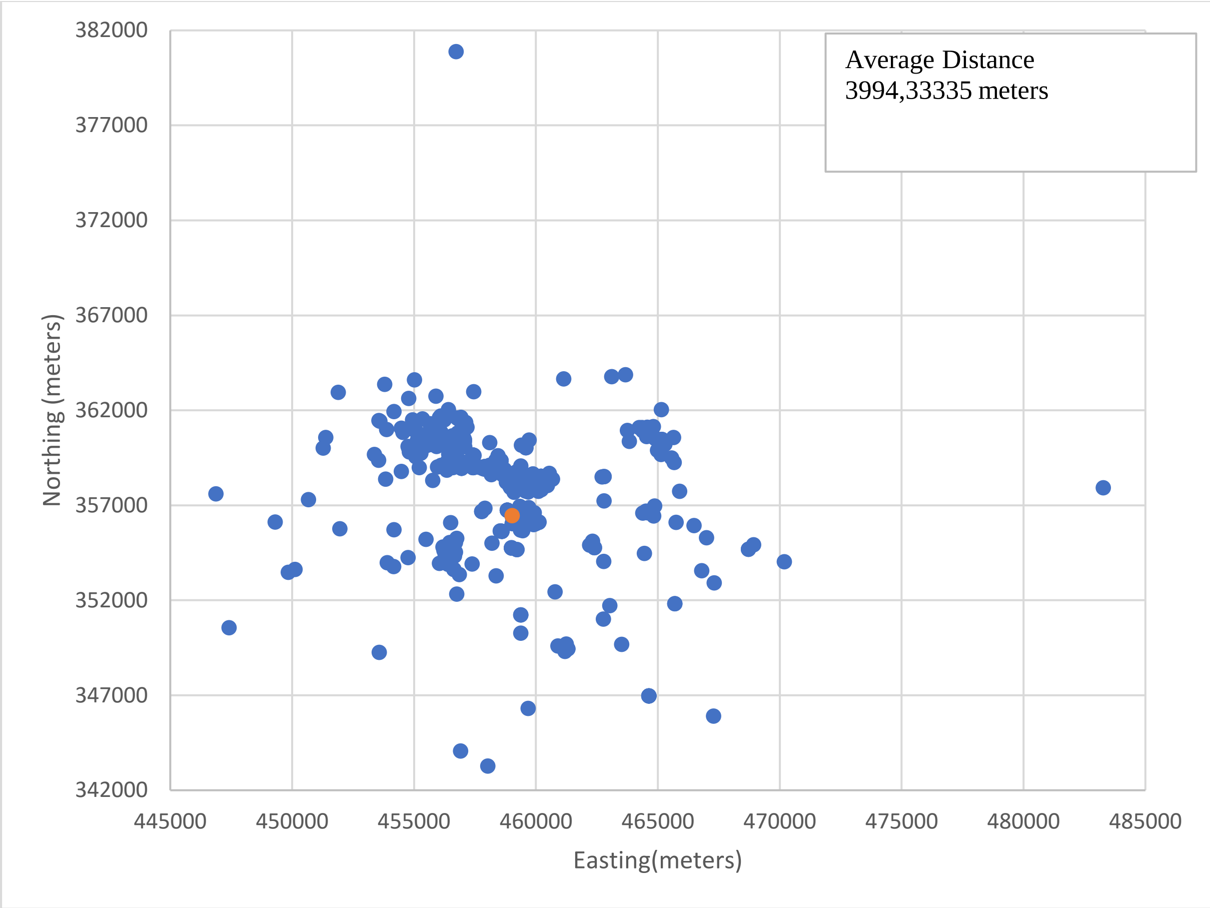

Figure 38: Incident records that FET02P1 pumping appliance attended, 2017-2018

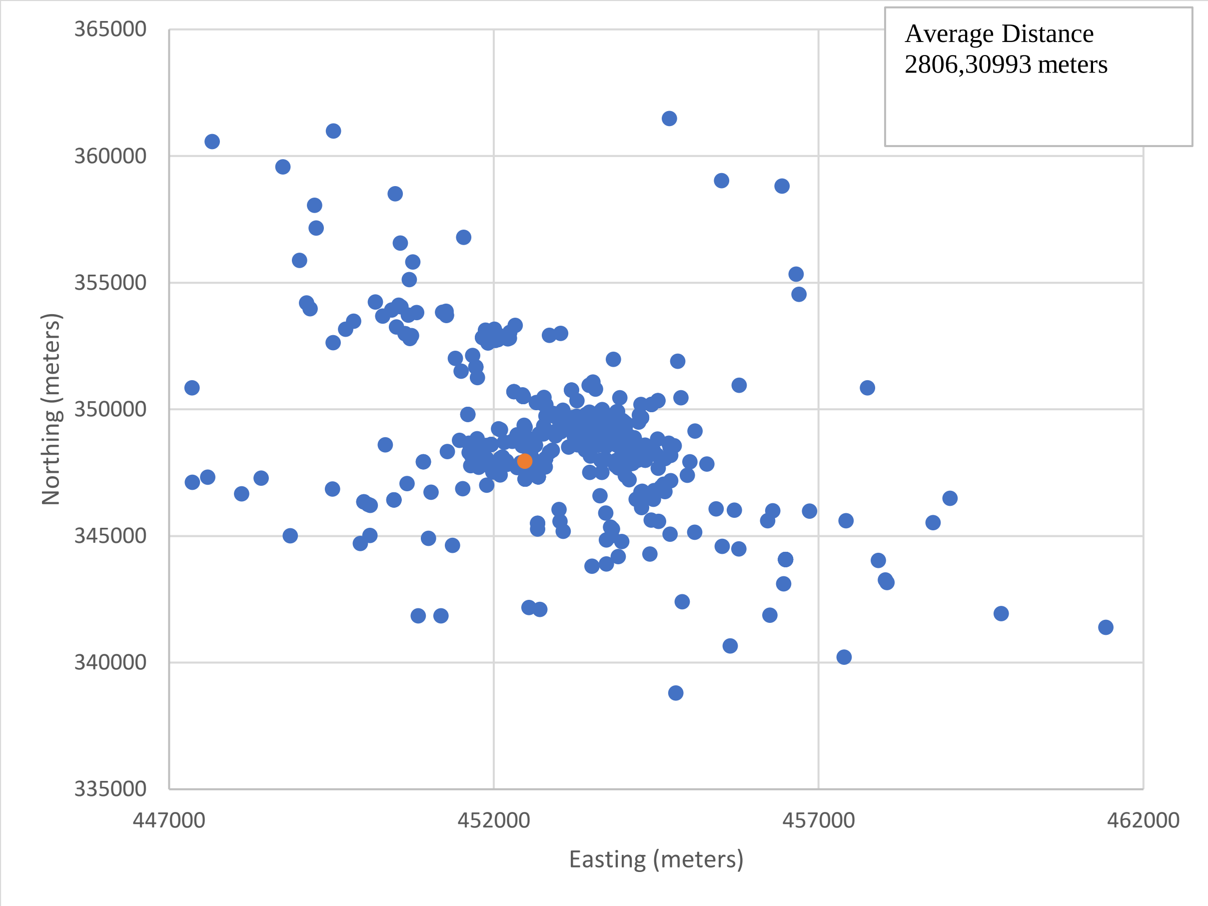

Figure 39: Incident records that FET25P1 pumping appliance attended, 2017-2018

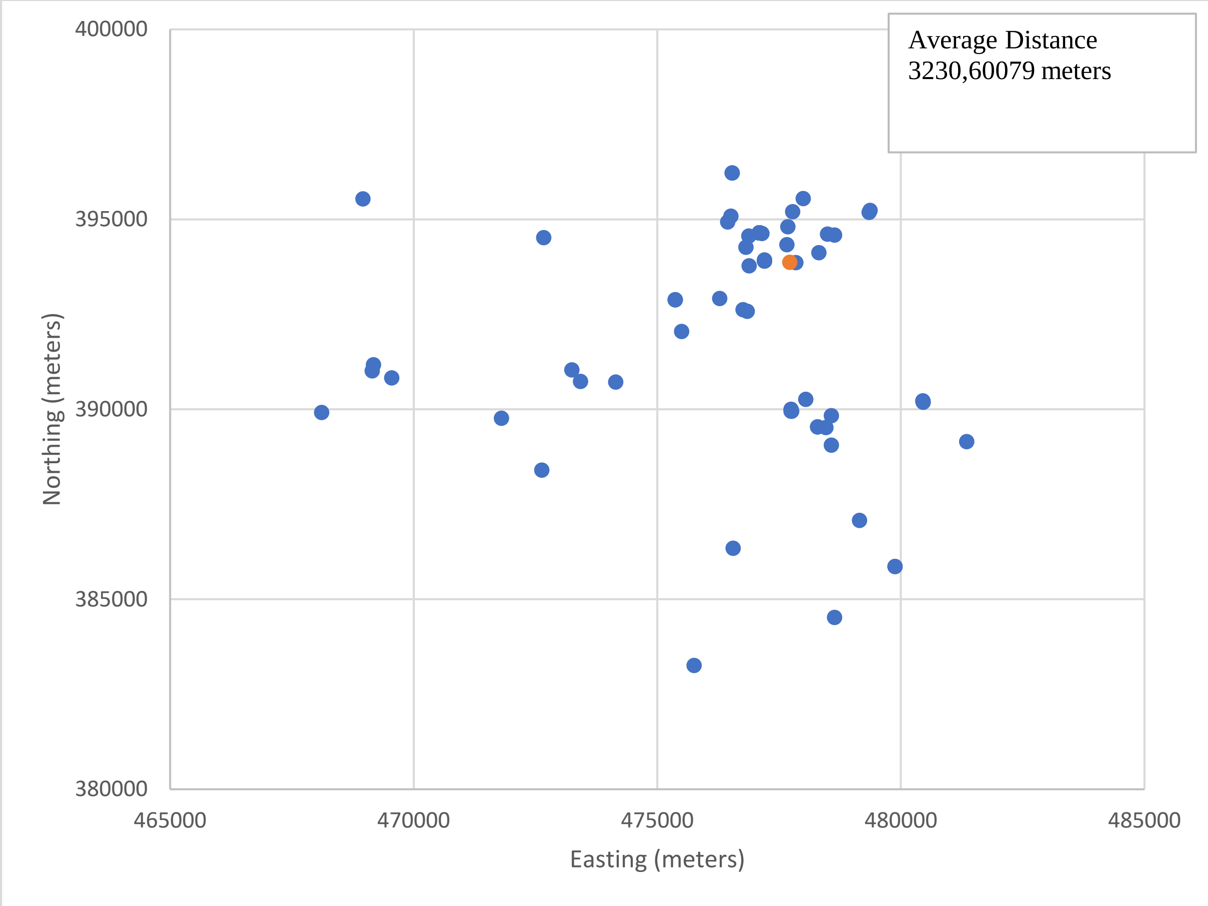

Figure 40: Incident records that FET11P1 pumping appliance attended, 2017-2018

5.2.5.2. Region classification

Nottinghamshire is composed of three regions; largely rural, predominantly rural, and urban with city and town (Defra Rural Statistics, 2015)**.** Average call handling, crew, drive, and response time values for fire stations in urban with city and town, urban, and rural in 2017-2018 are shown in Tables 13,14, and 15 respectively.

Call handling time in urban with city and town is 0:02:25 minutes. OC pumping appliance crew time is 0:04:13; whereas WDS pumping appliance crew time in urban with city town is 02:05 minutes. Crew time was longer than drive time for appliances FET23P1 and FET24P1 in 2017. Both of their crew times improved with less drive time in 2018, but it remained high compared to other pumping appliances. Average drive time was 5:07 minutes, and less in Nottingham City. Therefore, the highest response time was observed in Carlton, Stapleford, and Eastwood fire stations, as shown in Table 13. Average straight-line distance based on incidents and specified fire stations was 2,708,563,135 meters in this region.

Table 13: Average call handling, crew, drive and response time for fire stations in urban with city and town area based on 15,820 mobilisation records, 2017-2018

Year 20__	*Call sign*	*Station*	*Status*	*Call handling time*	*Crew time*	*Drive time*	*Response time*	*No. records*	*Avg. distance*
17	FET26P1	ARNOLD	WDS	00:02:15	00:02:08	00:04:51	00:09:15	1069	2744001
18	FET20P1	STOCKHILL	WDS	00:02:03	00:01:50	00:05:22	00:09:15	1466	26221121
18	FET03P2	LONDON ROAD	WDS	00:02:37	00:02:05	00:04:38	00:09:20	1052	21995842
18	FET26P1	ARNOLD	WDS	00:02:12	00:02:03	00:05:21	00:09:36	1194	29988889
18	FET03P1	LONDON ROAD	WDS	00:02:20	00:02:10	00:05:10	00:09:39	1273	26333715
17	FET03P2	LONDON ROAD	WDS	00:02:39	00:02:13	00:04:51	00:09:43	1190	25107573
17	FET20P1	STOCKHILL	WDS	00:02:16	00:02:01	00:05:36	00:09:53	1394	29383191
17	FET20P2	STOCKHILL	WDS	00:02:33	00:02:05	00:05:28	00:100:06	886	27658116
17	FET03P1	LONDON ROAD	WDS	00:02:31	00:02:17	00:05:21	00:100:09	1566	28443345
18	FET29P1	HIGHFIELDS	WDS	00:02:10	00:01:52	00:06:07	00:100:09	1014	29290194
17	FET29P1	HIGHFIELDS	WDS	00:02:26	00:02:01	00:05:44	00:100:11	890	26270898
17	FET27P1	CARLTON	WDS	00:02:18	00:02:11	00:05:44	00:100:13	639	34483614
18	FET20P2	STOCKHILL	WDS	00:02:49	00:01:55	00:05:38	00:100:21	1040	26875328
17	FET23P1	STAPLEFORD	OC	00:02:51	00:03:51	00:03:42	00:100:24	152	25724891
18	FET24P1	EASTWOOD	OC	00:02:16	00:04:01	00:04:10	00:100:27	142	20729137
18	FET27P1	CARLTON	WDS	00:02:26	00:02:04	00:06:07	00:100:37	595	36056318
18	FET23P1	STAPLEFORD	OC	00:02:23	00:03:46	00:04:35	00:100:44	170	27198235
17	FET24P1	EASTWOOD	OC	00:02:29	00:05:13	00:03:47	00:11:29	88	18340947
			Total Avg.	00:02:25	00:02:33	00:05:07	00:100:05		2708,563

Average call handling, crew, drive, response time, and straight-line values for predominantly urban areas are higher than urban with city and town areas, and lower than rural areas, shown in Table 14. The majority of the response time increase is due to drive time in urban regions. Therefore, the average straight-line distance between fire station and incident and drive time should be investigated. They have a linear relationship with $R^2 = 0{,}5289$, shown in Appendix B, Table B25. The remaining 48% of drive time might be explained by the time of the day and traffic in urban areas.

Table 14: Average call handling, crew, drive and response time for fire stations in predominantly urban area based on 4,351 mobilisation records, 2017-2018

Year 20__	*Call sign*	*Station*	*Status*	*Call handling time*	*Crew time*	*Drive time*	*Response time*	*No. records*	*Av. distance*
17	FET01P1	MANSFIELD	WDS	00:02:34	00:01:55	00:05:36	00:100:05	842	28955811
18	FET01P1	MANSFIELD	WDS	00:02:37	00:01:50	00:05:54	00:100:20	941	29459543
17	FET05P1	ASHFIELD	WDS	00:02:30	00:02:00	00:06:06	00:100:35	680	37134398
18	FET05P1	ASHFIELD	WDS	00:02:38	00:01:50	00:06:18	00:100:46	844	368305
17	FET25P1	HUCKNALL	OC	00:02:25	00:06:33	00:04:15	00:13:13	211	27180606
18	FET25P1	HUCKNALL	OC	00:02:36	00:05:39	00:05:08	00:13:23	278	28732905
17	FET07P1	WARSOP	OC	00:02:36	00:06:31	00:05:19	00:14:27	129	32415131
18	FET07P1	WARSOP	OC	00:03:06	00:05:40	00:05:55	00:14:41	142	37119514
18	FET05P2	ASHFIELD	OC	00:03:42	00:05:41	00:06:05	00:15:27	172	2622289
17	FET05P2	ASHFIELD	OC	00:03:57	00:06:29	00:05:26	00:15:52	112	28476546
Total Avg.				00:02:52	00:04:25	00:05:36	00:12:53		3125,2784

The highest average call handling, crew, drive and response time values is observed in rural areas, with 3:00, 4:46, 6:41, and 14:27 minutes respectively, as shown in Table 15. Also, average straight-line distance in rural areas is 4,300,475 meters, much higher than in urban regions. Some of the OC pumping appliances shown in Table 15, crew time is much higher than drive time, such as FET15P1 in 2017. In this circumstance, response time increase is directly affected by high crew time rather than drive time. Furthermore, average straight-line distance is 4,300,475 meters, which is higher than in urban areas. As a result of this, drive time is especially high in Tuxford and Bingham. The distance between fire station and incident and drive time have a strong linear relationship, with R^2 = 0,6854, as shown in Appendix B Figure B26.

Table 15: Average call handling, crew, drive and response time for fire stations in rural area based on 8,556 mobilisation records, 2017-2018

Year 20__	*Call sign*	*Station*	*Status*	*Call handling time*	*Crew time*	*Drive time*	*Response time*	*No. records*	*Av. distance*
17	FET08P1	WORKSOP	WDS	00:02:22	00:02:09	00:05:43	00:100:13	695	36211923
18	FET08P1	WORKSOP	WDS	00:02:29	00:01:57	00:06:15	00:100:41	744	41877369
17	FET06P1	EDWINSTOWE	WDS	00:02:16	00:02:03	00:06:35	00:100:54	806	53549828
17	FET19P1	WEST BRIDGFORD	WDS	00:02:23	00:02:03	00:06:47	00:11:14	625	38108352
18	FET19P1	WEST BRIDGFORD	WDS	00:02:14	00:02:01	00:07:06	00:11:21	851	39990233
17	FET16P1	NEWARK	WDS	00:02:32	00:01:57	00:07:03	00:11:33	457	45332762
17	FET12P1	RETFORD	WDS	00:02:32	00:02:03	00:07:46	00:12:21	394	47359233
17	FET28P1	EAST LEAKE	OC	00:02:28	00:06:12	00:04:13	00:12:53	58	24336573
18	FET06P1	EDWINSTOWE	WDS	00:02:57	00:01:51	00:08:19	00:13:07	440	65747508
18	FET28P1	EAST LEAKE	OC	00:02:28	00:05:31	00:05:12	00:13:11	52	203397
18	FET16P1	NEWARK	WDS	00:02:58	00:01:58	00:08:39	00:13:35	545	53510372
18	FET12P1	RETFORD	WDS	00:03:22	00:01:55	00:08:31	00:13:48	441	54710786
17	FET08P2	WORKSOP	OC	00:02:51	00:07:05	00:03:53	00:13:49	158	2704836
17	FET02P1	BLIDWORTH	OC	00:03:17	00:05:33	00:05:20	00:14:10	166	32932827
17	FET10P1	HARWORTH	OC	00:02:18	00:06:42	00:05:12	00:14:12	208	23883539
18	FET10P1	HARWORTH	OC	00:02:30	00:05:35	00:06:09	00:14:13	252	30069578
18	FET08P2	WORKSOP	OC	00:03:20	00:06:25	00:04:30	00:14:14	205	2589481
18	FET11P1	MISTERTON	OC	00:02:19	00:05:24	00:07:07	00:14:51	43	30406622
17	FET16P2	NEWARK	OC	00:02:43	00:06:36	00:05:44	00:15:03	119	3055618
17	FET12P2	RETFORD	OC	00:02:13	00:08:25	00:04:27	00:15:04	104	36611999
18	FET12P2	RETFORD	OC	00:03:26	00:06:39	00:05:19	00:15:24	105	31938837
18	FET02P1	BLIDWORTH	OC	00:02:57	00:05:10	00:07:19	00:15:27	259	44436554
18	FET13P1	TUXFORD	OC	00:03:12	00:04:34	00:07:58	00:15:44	83	58166298
17	FET17P1	BINGHAM	OC	00:03:27	00:05:26	00:07:00	00:15:53	111	51086225
17	FET11P1	MISTERTON	OC	00:02:59	00:06:08	00:07:07	00:16:13	34	34708172
18	FET17P1	BINGHAM	OC	00:03:05	00:05:12	00:08:01	00:16:19	141	49552942
17	FET13P1	TUXFORD	OC	00:02:52	00:06:14	00:08:02	00:17:08	90	61195895
18	FET16P2	NEWARK	OC	00:04:03	00:06:19	00:06:58	00:17:20	150	3111236
18	FET14P1	SOUTHWELL	OC	00:03:05	00:07:20	00:07:12	00:17:37	41	49216911
17	FET14P1	SOUTHWELL	OC	00:04:20	00:07:06	00:06:16	00:17:42	48	43423483
17	FET15P1	COLLINGHAM	OC	00:04:34	00:04:48	00:08:52	00:18:13	56	75842185
18	FET15P1	COLLINGHAM	OC	00:05:41	00:04:09	00:09:05	00:18:56	75	86993487
			Total Avg.	00:03:00	00:04:46	00:06:41	00:14:27		4300475

As a result, type of the fire station and fire station region have an impact on response time. It is observed that OC response time is generally longer than WDS response. Crew time and drive times have greater impacts on response time for OC and WDS crews, respectively. As urbanization decreases, the number of the OC pumping appliances increases, and the number of the WDS pumping appliances decreases. OC pumping appliance crew time is very high, which might be a major reason for response time increase over the years. In this analysis, fire station service area is not investigated, because mobilisation system means that closest and available pumping appliances assigned to the incident. Therefore, there is no specific service boundary for each station.

5.2.6. Vehicle status

Vehicle status is the status of the pumping appliance with a specified *call sign* when it was mobilised. In the data set, there are five types of vehicles status: alert, available, in attendance, mobile available, and mobile to incident. In this section, only two types of vehicle status are investigated: mobile available and available. Mobile available means that pumping appliances are on the move somewhere and are available. Their coordinates are unknown when they received a call. Available means that they are available but not mobile. They might be in the home station or on an incident ground when they are no longer needed or another place. In the analysis, it is assumed that available vehicles are available and in the home station.

23 alert records, 24 in attendance records, and 27 mobile to incident records were deleted in the data set. Only mobile and available and available vehicle status were left under vehicle status group. This data set thus had 28,653 mobilisation records (from the original 28,727 records based on call sign).

Two different analyses were conducted related with vehicle status in this section. In the first analysis, vehicle status distribution by month for two years is analysed to see differences between mobile available and available over the studied years in terms of the number of records and average straight-line distances. In the second analysis, each of the pumping appliance yearly response time analyses is conducted based on vehicle status. Mobile available pumping appliances are gathered, and available pumping appliance are collected separately, then interpreted.

In the first analysis, 24,414 mobilisation records were obtained for available and 4,239 records from mobile available pumping appliances, as shown in Figure 41. The majority of pumping appliances are available when they receive a call, while high fluctuation is observed in available vehicles by month.

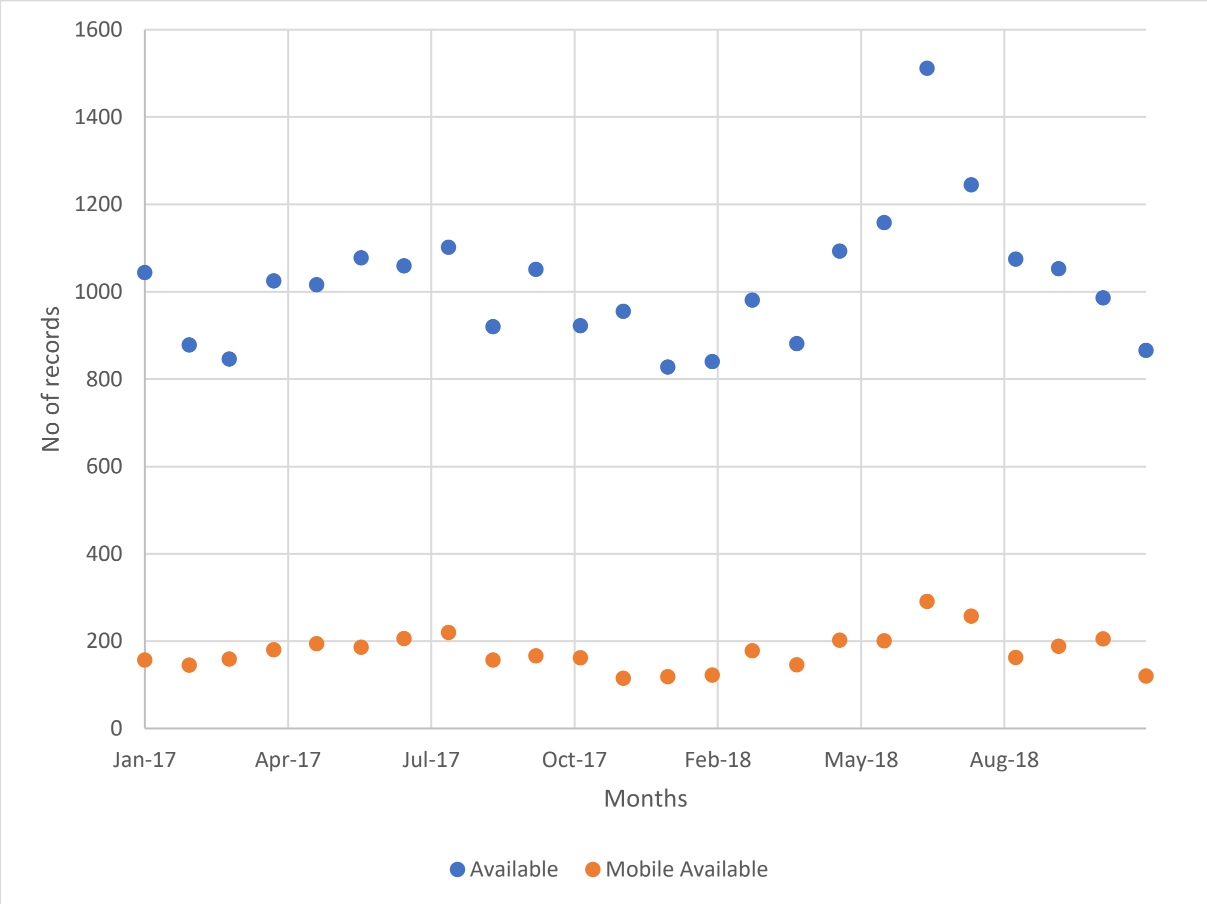

Figure 41: Mobile available and available records over time, 2017-2018

Average drive time distribution follows a pattern; it reduces in autumn and increases spring, as shown in Figure 42. Average call handling time and crew time is stable over time, with 2:26 and 2:36 minutes respectively, whereas, significant fluctuation can be observed in call handling time. Response time is the reflection of the drive time for available vehicles with average 10:53 minutes, and its affect time is very crucial to decrease response for available pumping appliances. One effective issue in drive time is distance. Drive time and average straight-line distance between incident location to fire station have a polynomial relationship, with $R^2 = 0,601$, as shown in Appendix B Figure B27. Therefore, 60% of drive time is explained by distance. Detailed information about available vehicles over time is shown in Appendix B, Table B9.

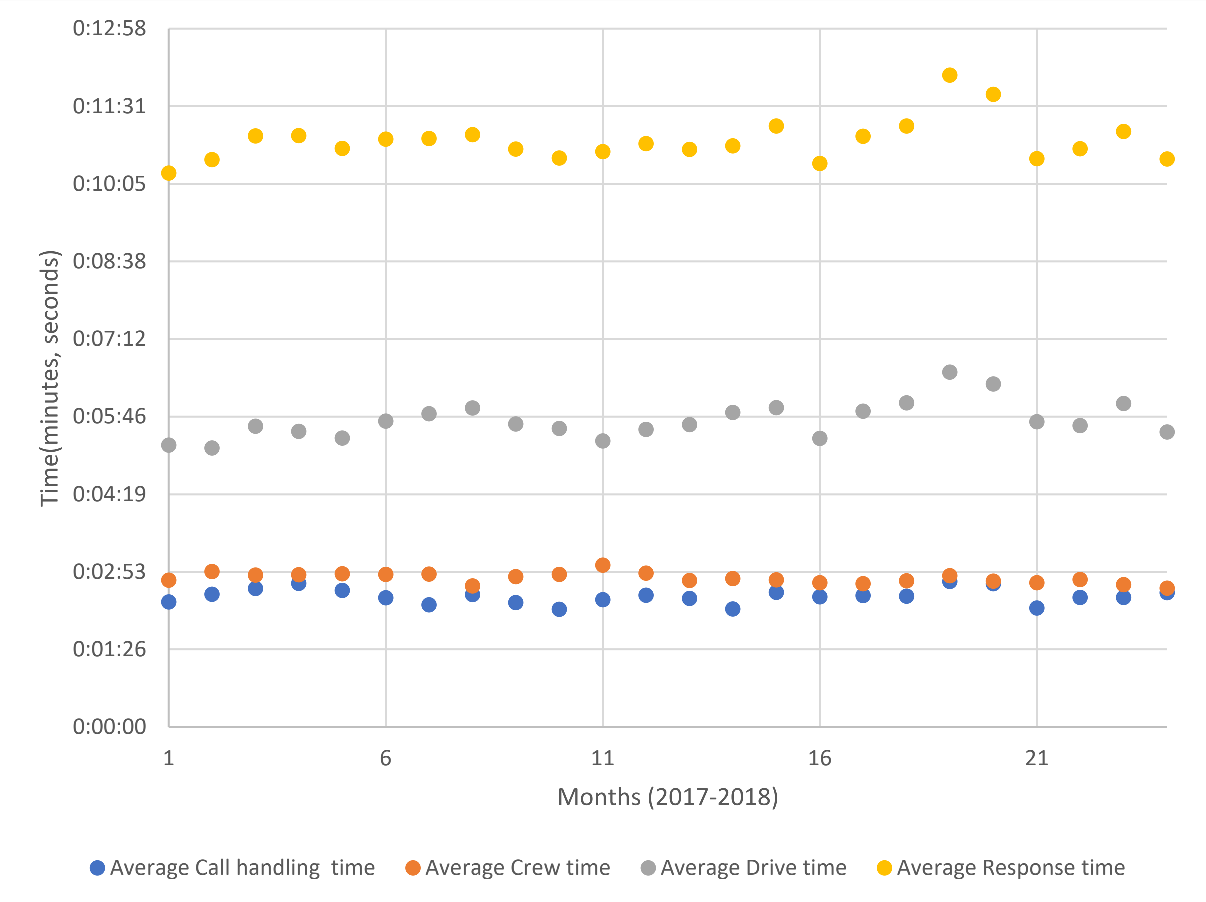

Figure 42: Average call handling, crew, drive and response time for available pumping appliances, 2017-2018

Average crew time for available mobile is 1:28 minutes (Figure 43). This is expected, because crew members are already in the pumping vehicles. Average call handling time fluctuates by month and reaches peak points in the Winter and Summer periods. Average call handling time in 2017-2018 is 3:02 minutes, 36 seconds longer than available average call handling time. Also call handling average standard deviation fluctuates a lot. This indicates that caller might be having some problems to reach mobile available vehicles in some periods. Average drive time in 2017-2018 was 6:31 minutes, which is approximately 1 minute longer than available vehicle. Drive time has variations over time, and both mobile available and available vehicles most of the response time is devoted to drive time. Drive time and average straight-line distance cannot be identified, because pumping appliance location is unknown. Response time is 11:01 minutes for mobile available vehicles, higher than available vehicles. This is interesting because the closest mobile available vehicles are usually sent to incident location. These vehicles should have been mobilized in closer locations than the fire station. Detailed information about mobile available vehicles over time is shown in Appendix B, Table B10.

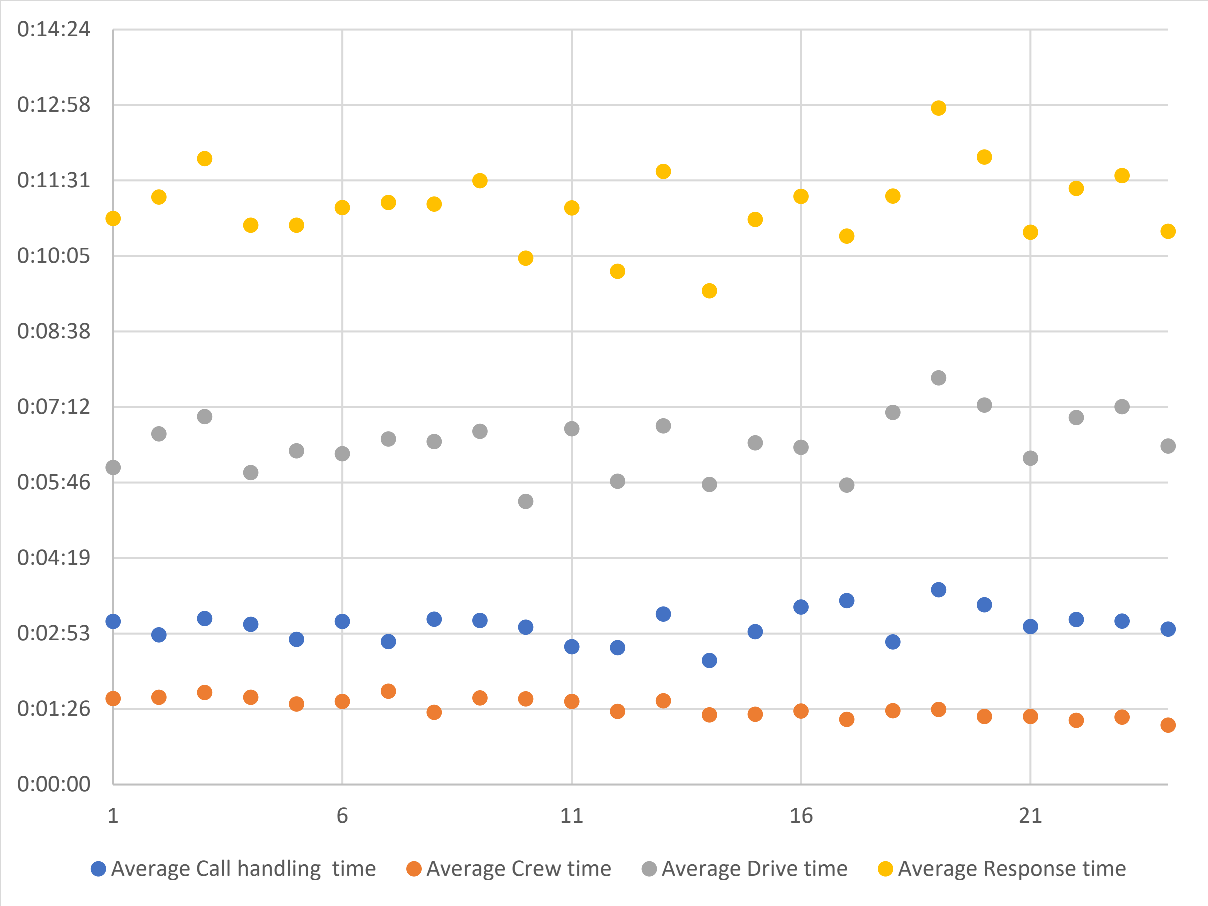

Figure 43: Average call handling, crew, drive and response time for mobile available pumping appliances, 2017-2018

Table 16 and 17 shows comparison response times for available and mobile available pumping vehicles in 2017 and 2018. Although, travel distance is higher in mobile available vehicles, there is not significant difference between response times in 2017-2018.

Table 16: Available pumping appliances in 2017-2018 summary

	Avg. distance (miles)	Avg. call time	Avg. crew time	Avg. drive time	Avg. total
Overall Av.	1,93	0:02:26	0:02:46	0:05:41	0:10:53
Av. 2017	1,92	0:02:25	0:02:49	0:05:31	0:10:45
Av. 2018	1,93	0:02:26	0:02:42	0:05:51	0:11:00

Table 17: Mobile available pumping appliances in 2017-2018 summary

	Avg. distance (miles)	Avg. call time	Avg. crew time	Avg. drive time	Avg. total
Overall Av.	2,74	0:03:02	0:01:28	0:06:31	0:11:01
Av. 2017	2,61	0:02:57	0:01:36	0:06:21	0:10:54
Av. 2018	2,87	0:03:08	0:01:20	0:06:41	0:11:09

In the second analysis, pumping appliances are grouped based on vehicle status (available or mobile available). Each of the available pumping appliances' yearly average call handling, crew, drive, response time and average straight-line distance are shown in Appendix B, Table B11, and each of the mobile available pumping appliances' yearly average call handling, crew, drive, and response time are shown in Appendix B, Table B12. Four of the mobile available vehicles' average call time is longer than drive time among 60 mobile available vehicles: FET05P2 and FET14P1 in 2017, and FET12P2 and FET28P1 in 2018. All four of these vehicles are manned by OC crews. As mentioned previously, callers might have trouble to contact crews when they are mobile available, especially OC. Average crew time is approximately 1 minute, as expected, because crew are already on standby in the pumping vehicle. As a result, most of the response time is composed of drive time for mobile available vehicles.

It is observed that call handling time does not change compared to different available pumping appliances. Crew time is longer than drive time in 35% of the available pumping appliances in 2017-2018. This ratio is high, and it means that the crew takes more time in preparing than driving. Dressing policy has changed in recent years, and crew must wear dressing equipment in the home fire station (UK government, 2018). Drive time is longer than crew time in 65% of the available pumping appliances in 2017-2018, as shown in Appendix B, Table B11. Therefore, the majority of the response time is allocated drive time for available vehicles. Therefore, drive time should be investigated for available vehicles.

Real-life distance between two locations is calculated based on network distance and the optimal road that minimize driving time, but calculating network distance for all incidents is time consuming. Straight line distance is time saving, but reliability needs to be checked. In order to check straight-line distance between fire station and incident feasibility of all records, four pumping appliances were selected for pilot comparison between average straight-line distance to network distance; FET16P1 (Newark), FET16P2 (Newark), FET13P1 (Tuxford), and FET23P1 (Stapleford). Stapleford and Tuxford were selected because both are OC; drive time move varies in OC than WDS. Also, FET23P1 has the lowest average drive time value among all mobile pumping vehicles. Newark is selected because it has two pumping appliances, one of which is OC, while the other is WDS. This enables representative identification of OC variation and WDS consistency together. The following steps were conducted for this analysis;

1. 1766 mobilisation records were obtained for these three fire stations, with vehicle status available and mobile available in 2017-2018.
2. 79 mobilisation records with average crew time equal to or less than 30 seconds were deleted for feasibility.
3. Network distance for each incident was calculated for the three fire stations based on incident and fire station addresses. AA route planner was used to find network distance, and the first optimal route was selected for this analysis (AA, 2019).
4. 109 incidents' mobilisation records were deleted due to infeasible drive time and network distance relationships, such as 30 miles' network distance with a drive time of three minutes.
5. 66 mobilisation records were deleted in the network distance calculation data set, because their network distance was not found (they remained in the straight-line distance data set). 1512 mobilisation data were left for network distance, and 1578 for straight line distance, including mobile available and available records.
6. Straight line distance for each incident was calculated for three fire stations based on fire station and incident location easting and northing coordinates.

7. Available pumping appliances' data for these three stations was differentiated from mobile available to available data. 1384 records were left for straight line analysis, and 1442 for network analysis for available vehicles.
8. A scatter chart was created with straight-line distance and drive time for available FET13P1, FET16P1, FET16P2, and FET23P1 data, as shown in Appendix B Figures B28-B31, respectively.
9. A scatter chart was created with network distance and drive time for available FET13P1, FET16P1, FET16P2, and FET23P1, as shown in Appendix B Figures B32-B35, respectively.
10. Linear distribution results for network and straight-line distances are shown in Table18.

.

Table 18: Network and straight-line distance versus drive time distribution results according to pumping appliance

R^2 value for linear distribution	Network distance	Straight line
FET13P1	0,4758	0,4589
No. records	145	159
FET16P1	0,7307	0,6934
No. records	789	820
FET16P2	0,448	0,5037
No. records	223	234
FET23P1	0,5533	0,4517
No. records	227	229

It is difficult to predict individual response times using both straight line and network distances. Working aggregate level creates more predictable data for response time. FET13P1, FET16P1, and FET23P1's R^2 value is higher in network distance than straight line distance, and FET16P2's R^2 values are very close (Table 18). Therefore, drive time and distance relationship is improved by network distance.

Therefore, straight line implementation is good enough to predict response time. As a result, average straight-line distance and drive time analysis was done based on 30 pumping appliances. In order to check straight line distance results, each pumping appliances' values were aggregated yearly, obtaining 60 data points for 2017-2018. Drive time and average straight-line distance have a linear relationship with R^2 = 0,7752, as shown in Appendix B Figure B36.

5.2.7. Fire station location

Fire station location is a crucial factor for quick response. If the location is far away from the incident, even if crew and call handling time is low, drive time might be excessive. In that case, total response time is directly affected by fire station location.

Each of the fire station locations is analysed and its location is checked based on the incident easting and northing coordinates that each pumping appliance attended in 2017-2018 for incidents. Based on the pumping appliances, their home station easting and northing coordinate is used for the calculation. In this analysis, filtered mobilisation data 2017-2018 is eliminated based on *call sign*, therefore 28,727 mobilisation data are obtained. Using *easting* and *northing* coordinates of each mobilisation record in the data and fire station coordinates, the following model is created and implemented for 24 fire station in Nottinghamshire.

This model is implemented for 24 fire stations separately to minimise the straight-line distance between the fire station and incident, as shown in Equation 1. Determination of the new location of the station used only mobilisation records of pumping appliances connected to the home station. Therefore, the distance between stations is not taken into account. Easting and northing coordinates are formed based on Equations 2 and 3 respectively, with corresponding objective function values. In order to find better coordinates for the proposed fire station, models were run many times until an objective function value is very close to previous iteration objective value. The results are shown in Table 19. Stations 15, 3, and 25 have 16,3%, 13,03%, and 10,76% improvements if fire station location is moved from the current to the proposed location. Also, it is observed that fire stations 23, 2, 26 have an 9,97%, 9,93%, and 9,16% improvement in the proposed station locations.

Notations;

m = incident locations

w_i= 1 (each incident location weight is equal)

X_i = Easting coordinate of the incident location corresponding M

Y_i = Northing coordinate of the incident location corresponding M

X_n = Easting coordinate of the fire station location (n=0,1,2, 3,)

Y_n = Northing coordinate of the fire station location (n=0,1,2, 3,)

(n=0 is the fire station current location coordinates)

Objective function,

$$Min \sum_{i=1}^{m} \sqrt{(X_i - X_n)^2 + (Y_i - Y_n)^2} \tag{1}$$

Subject to;

$$X_{(n)} = \frac{\sum_{i=1}^{m} \frac{X_i}{\sqrt{(X_i - X_{(n)})^2 + (Y_i - Y_{(n)})^2}}}{\sum_{i=1}^{m} \frac{w_i}{\sqrt{(X_i - X_{(n)})^2 + (Y_i - Y_{(n)})^2}}} \tag{2}$$

$$Y_{(n)} = \frac{\sum_{i=1}^{m} \frac{Y_i}{\sqrt{(X_i - X_{(n)})^2 + (Y_i - Y_{(n)})^2}}}{\sum_{i=1}^{m} \frac{w_i}{\sqrt{(X_i - X_{(n)})^2 + (Y_i - Y_{(n)})^2}}} \tag{3}$$

These stations have a significant improvement, and station location change has to be considered, especially for fire station 15, but there are some factors that is not included in this analysis. Firstly, the distance between the stations must be considered for reconstruction. Secondly, due to mobilisation system, there is no specific service area for each fire station. Some of the pumping appliances are attend incidents close to other fire stations, not the home fire station, if there is no available pumping appliance at the neighbour fire station. In this analysis, this situation is not considered. Thirdly, the straight-line distance between incident location and fire station is used based on easting and northing coordinates. Network distance might give more accurate results. Fourthly, the proposed coordinates suitability needed to be checked. Proposed easting and northing coordinates might be in private property or in natural features such as rivers. Finally, the cost of construction is not calculated. It is very important to undertake a cost analysis before making a decision.

Table 19: Current and proposed fire station information and improved ratio based on fire station

Station no.	CFSEC	CFSNC	OFVCFS	PFSEC	PFSEC	OFVPFS	DCPFS	Improved %
1	453215	4E+05	5210222,26	454039,86	361159,54	4862190,22	348032,04	6,68
2	459028	4E+05	1697591,67	458738,95	358142,47	1528852,28	168739,39	9,94
3	457883	3E+05	13108273,57	457308,21	339920,11	11399212,85	1709060,72	13,04
5	449133	4E+05	6403604,35	450125,76	358267,3	5900806,19	502798,16	7,85
6	462461	4E+05	7209006,48	463025,42	366687,34	7144427,21	64579,26	0,90
7	456730	4E+05	945252,29	456809,12	368145,18	944344,08	908,21	0,10
8	458837	4E+05	6590612,61	459022,09	379837,35	6491134,07	99478,54	1,51
10	462226	4E+05	1254530,98	462516,25	391512,82	1228741,73	25789,25	2,06
11	477719	4E+05	248756,26	477138,91	393927,03	238030,23	10726,03	4,31
12	470574	4E+05	4994821,99	470273,37	380948,71	4966971,93	27850,06	0,56
13	473850	4E+05	1033543,32	474111,86	371316,21	1021168,44	12374,89	1,20
14	470700	4E+05	410222,06	470196,04	354004,39	404239,97	5982,08	1,46
15	483008	4E+05	1077167,39	481358,2	357058,22	901526,91	175640,48	16,31
16	479595	4E+05	5818326,45	479938,64	353439,33	5756638,23	61688,21	1,06
17	470547	3E+05	1265753,59	470029,52	339789,35	1249507,69	16245,90	1,28
19	458181	3E+05	5784940,86	456968,06	336641,51	5432984,18	351956,68	6,08
20	454420	3E+05	13185576,40	455016,67	343012,3	12911134,09	274442,30	2,08
23	449086	3E+05	853388,34	450022,43	337758,6	768230,14	85158,21	9,98
24	447146	3E+05	455754,07	447168,81	346628,64	452834,93	2919,15	0,64
25	452474	3E+05	1372285,56	453293,06	348822,66	1224533,73	147751,83	10,77
26	458081	3E+05	6514010,35	456929,38	344230,45	5917174,48	596835,87	9,16
27	461832	3E+05	4348853,85	460702,51	341772,97	4018181,65	330672,20	7,60
28	455507	3E+05	246918,57	455431,07	326408,14	246633,75	284,82	0,12
29	453779	3E+05	5308135,62	454008,39	338271,54	4910978,61	397157,01	7,48

Key

CFSEC	Current fire station easting coordinate	PFSEC	Proposed fire station easting coordinate
CFSNC	Current fire station northing coordinate	PFSNC	Proposed fire station northing coordinate
OFVCFS	Objective function value based on current fire station	OFVPFS	Objective function value based on proposed fire station
DCPFS	Differences between current and proposed fire station straight line distance		

5.3. Multiple regression analysis

In order to find out the importance of the factors affecting each process of response time, multiple regression analysis was performed for each process separately. 28,653 mobilisation records were analysed for call handling, crew time analysis, and drive time, for five factors; day/night time, pumping appliance status (OC/WDS), vehicle status (available/ mobile available), region classification(urban/rural), seasonality, and distance from station to incident. Day time was determined according to whole time workers' day shift (7 am to 7 pm). The confidence interval degree is 95% for all analyses.

Regression model has constant values and decision variables. Constant values are the coefficients of the values, and they depend on the type and number of the factors investigated for analysis, such as distance. Five binary decision variables were determined:

- Pumping appliance status (X_i= 1 if OC; otherwise 0)
- Vehicle status (Y_i= 1 if available; otherwise 0)
- Cumulative factor (Z_i=1 if OC and available; otherwise 0)
- Time of the day (M_i=1 if day time; otherwise 0)
- Region classification (T_i = 1 if incident in rural area; otherwise 0)
- Seasonality (U_i= 1 spring and summer; otherwise 0)

For call handling model, all factors are investigated, and highest R^2 value obtained in Equation 4. Analysis shows that pumping appliance and vehicle status are significant factors for call handling (p values are very low), but they have a weak relationship with call handling time (R^2= 28%). According to regression, call handling times are shown in Table 20, based on these 2 factors. Due to high variation observed in call handling, strong relationship is not found. Remaining factors do not have an impact on call handling process.

$$\text{Call handling time} = 0.002237716 + 0.000559955 * X_i - 0.000717206 * Y_i \qquad (4)$$

Table 20: Regression results for call handling times

Regression result	*Pumping appliance status*	*Vehicle status*
00:03:00	OC	Available
00:02:11	WDS	Available
00:04:02	OC	Mobile available
00:03:13	WDS	Mobile available

In the crew time regression model, 95% of crew time can be explained by vehicle status, and pumping appliance status shown in Equation 5, therefore there is a strong relationship between these factors and crew time, and these factors have a great impact on response time. Crew status alone and shifts do not affect crew time. Regression results are shown in Table 21. The analysis shows that average crew time is 6:40 minutes if it is OC and available.

$$\text{Crew time} = 0.000958979 + 0.002894848 * Z_i + 0.000525811 * Y_i \qquad (5)$$

Table 21: Regression results for crew time

Regression result	*Pumping appliance status*	*Vehicle status*
00:06:40	OC	Available
00:01:38	OC	Mobile available
00:02:12	WDS	Available
00:01:38	WDS	Mobile available

For drive time analysis, average straight-line distance from fire station to incident location is calculated. 85% of the mobilisation records are available. Therefore, this analysis was done only for mobile pumping appliances, and the regression model is shown in Equation 6. 93% of drive time is explained by pumping appliance status and distance. These factors are very crucial for drive time. According to analysis, 11 minutes' drive time is for OC, and 6:30 minutes' drive time is for WDS. No significant factor was found for mobile available vehicles.

$$\text{Drive time for available} = 0.00449767 + 0.00312795 * X_i + 8.3429E\text{-}07 \qquad (6)$$

As a result, response is mostly driven by drive time for available vehicles, pumping appliance and distance are important factors for response time.

Chapter 6
Conclusion

The response time of fire rescue services is vital for saving lives and preventing the disastrous escalation of fire emergencies. Although there have been studies in the literature about the factors affecting response time, this topic has to be revisited due to the recent increase in the total response time. In order to understand the reasons of this increase, all the possible factors should be carefully analysed and compared to the past studies. There has been a steady increase in response time in England during the past 20 years. Therefore, NFRS was selected as a case study to analyse the possible reasons for this increase by exploring factors affecting the response time of the fire department in Nottinghamshire.

Descriptive statistics and regression analysis with linear regression was used in the analysis of 29,142 mobilisation records in 2017-2018, provided by NFRS. Eight factors were subsequently identified, and their individual impacts on response time were evaluated: pump crewing status, incident time, seasonality, incident day, incident location (including region classification), vehicle status, and fire station location. The analysis confirmed that the response time increased from 10:51 minutes to 11:12 minutes in 2017-2018. When the number of mobilisation records increased over time, drive time increased, and response time was directly affected by this increase. High variability in workload between different pumping appliances was observed. 85% of mobilisation records are for WDS, while OC pumping appliances' workload increased by 25% in 2018.

The analysis revealed that the number of mobilisation records varies seasonally throughout the year, peaking during late spring and summer. The highest drive time was observed in the summer period in both years 2017-2018, with the highest response time observed with 11:03 and 11:48 minutes for the summers of each year (respectively). It has been concluded that pump crewing status has a great impact on response time. OC pumping appliance average response time was 4 minutes longer than WDS in 2017-2018, which is attributable to two possible reasons: OC crew time is 4 minutes longer than WDS; or OC call handling time is 30 seconds longer than WDS.

The OC crew is not in the station when the incident occurs, therefore reaching them and drive time from their current location to home fire station takes more time. Drive time constituted about 60% of the response time for WDS and 40% of the response time for OC. Incident time has an impact on response time. The majority of incidents occurred between 11 am to 12 pm and peaked between 7-8 pm. Also, there are differences between night (0-7 am to 7 pm-0) and day shifts (7 am to 7 pm) for both the OC and WDS crews. The analysis revealed that the OC and WDS crew times are longer during night shift compared to day shift, with 1:30 minutes and 40 seconds, respectively. Average drive time during the day is approximately 35 seconds longer than during the night, especially in rush hours (7 am to 9 am and 15 pm to 18 pm). High drive time is observed to be due to traffic congestion, regardless of crew type.

Vehicle status affects response time. 85% of records indicate available pumping appliances. Response time is approximately 10 seconds lower for available pumping appliance compared to mobile available for 2017-2018. Although crew time is 1:10 minutes longer with available pumping appliances, mobile available pumping appliance call handling and drive time is longer with 1:24 and 1:10 minutes, respectively. Call handling time difference be explained by operational problems for reaching mobile available vehicles.

In the analysis, there is a strong relationship between average drive time and the straight-line distance between incident location and the fire location to the corresponding fire appliance. OC relationship is stronger than WDS in this analysis. Straight line distance between fire station and incident to drive time has a strong relationship with available pumping appliances.

There was no response in time difference between weekend and weekday average response time, which was approximately 11 minutes regardless of the day. Incident location and fire station location affect the response time. In the analysis, 70% of the mobilisation records occurred in urban areas, and response time was longer by about 1:30 minutes in rural areas. Call handling, crew, and drive time were 15 seconds 1 minute, 1:30 minutes longer than in rural areas. Average drive time and straight-line distance between incident and the fire station location of the corresponding pump have a strong polynomial relationship. The majority of crews in urban areas were of WDS type, whereas the majority of crews were OC in rural areas. This reflects that OC crews in rural area respond to more remote calls compared to WDS crews in urban area.

Fire station location determines the distance between the fire station and incidents, therefore it affects drive time. Fire station location is analysed and most of the fire stations are located in in central proximity to incidents.

Multiple regression analysis was conducted for the factors call handling, crew, and drive time. In the analysis, vehicle status and pump crewing status have a weak relationship with call handling, but this factor is significant. According to analysis, vehicle status and the cumulative effect of vehicle status and pump crewing status have a great impact on crew time, explaining 94% of the latter. The time of incident does not have an impact on crew time.

There some limitations in the study due to ambiguous data. It is assumed that available pumping appliances are waiting in the home fire station, but the pumping appliance might be located somewhere else. Mobile available pumping appliance locations when they receive a call is not given in the data, because IRS was not collected. As a result, network distance and drive time relationship was not analysed in this study, due to time limitations. For expediency, all distance calculations were conducted based on a straight-line model in this analysis. It is assumed that each response time process is transferred to the data as it is, such that drive time starting exactly when the pumping appliance is dispatched from the fire station.

For future studies, factor analysis of the variables affecting response time can be conducted, and other statistical techniques for the discovery of more complex relationships between the variables can be explored. Distance calculation based on network distance can be implemented to give more precise results.

References

AA, 2019. AA Route Planner. [Online] Available at: https://www.theaa.com/route-planner/route [Accessed 27 August 2019].

Andersson, T. and Varbrand, P., 2007. Decision support tools for ambulance dispatch and relocation. Journal of the Operational Research Society, 2(58), p. 195–201.

Bahrami, M.A., Maleki, A., Ezzatabadi, M.R., Askari, R. and Tehrani, G.H.A., 2011. Pre-Hospital Emergency Medical Services in Developing Countries: A Case Study about EMS Response Time in Yazd, Iran. Iranian Red Crescent Medical Journal, 13(10), pp. 735-738.

Blanchard, I.E., Doig, C.J., Hagel, B.E., Anton, A.R., Zygun, D.A., Kortbeek, J.B., Powell, D.G., Williamson, T.S., Fick, G.H. and Innes, G.D., 2012. Emergency medical services response time and mortality in an urban setting. Prehospital Emergency Care, 16(1), pp.142-151.

Budge, S., Ingolfsson, A. and Erkut, E., 2009. Approximating Vehicle Dispatch Probabilities for Emergency Service Systems with Location-Specific Service Times and Multiple Units per Location. Operations Research, 57(1), pp. 251-255.

Cabral et al., 2018. Response time in emergency services. Systematic Review. Acta Cirurgica Brasileria.

Claridgea, E. and Spearpointb, M., 2013. New Zealand fire service response times to structure fires. Procedia Engineering, Issue 62, p. 1063 – 1072.

Defra Rural Statistics, 2015. The 2011 Rural-Urban Classification for Local Authority Districts in England, England: Governmnet Statistical Service.

Flynn, J. D., 2009. Fire Service Performance Measurements, Massachusetts: National Fire Protection Association.

Freedman, D. A., 2012. Statistical Models: Theory and Practice. 7th ed. New York: Cambridge University Press.

Garver et al, 2005. Physical Fitness of an Industrial Fire Departmnet vs. A Municipal Fire Department. Journal of Strength and Conditioning Research, Issue 19(2), p. 310–317.

Government UK, 2016. GOV.UK. [Online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/610453/fire-statistics-definitions.pdf [Accessed 20 07 2019].

Greenstreet Berman Ltd, 2009. Review of Fire and Rescue Service response times, England: Department for Communities and Local.

International Academies of Dispatch, n.d.. Emergency Dispatch. [Online] Available at: https://www.emergencydispatch.org/articles/historyoffirefighting.html [Accessed 11 07 2019].

Kerber, S., 2011. Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes. Fire Technology, 48(4), pp. 865-891.

Kolesar, P., Walker, W. and Hausner, J., 1975. Determining the Relation between Fire Engine Travel Times and Travel Distances in New York City. Operation Research, 23(4), pp. 603-840.

Lader, D., 2018. Response times to fires attended by fire and rescue services: England, April 2016 to March 2017 , England: UK Government.

Lader, D., 2019. Response times to fires attended by fire and rescue services: England,April 2017 to March 2018, England: UK Home Office.

Lee, J.S., Lee, J. and Hoover, L.T., 2016. What Conditions Affect Police Response Time? Examining Situational Examining Situational Factors. Police Quarterly, 20(1), pp. 61-80.

Lee, J.T. and Fazio, J., 2005. Influential Factors in Freeway Crash Response and Clearance Times by Emergency Management Services in Peak Periods. Traffic Injury Prevention, 6(4), pp. 331-339.

Silva, P.M.S. and Pinto, L.R., 2010, December. Emergency medical systems analysis by simulation and optimization. In Proceedings of the 2010 winter simulation conference (pp. 2422-2432). IEEE.

National Fire Chiefs Council, 2018. National Fire Chiefs Council. [Online] Available at: https://www.nationalfirechiefs.org.uk/news/Page-6/new-home-office-figures-show-an-increase-in-fire-response-times/192405 [Accessed 28 August 2019].

Nehme, Z., Andrew, E. and Smith, K., 2016. Factors influencing the timeliness of emergency medical service response to time critical emergencies. Prehospital emergency care, 20(6), pp.783-791.

NFPA 1001, 2019. NFPA 1001 Standard for Fire Fighter Professional Qualifications, USA: National Fire Protection Association.

NFRS, 2018. Nottnghamshire Fire & Rescue Service. [Online] Available at: https://www.notts-fire.gov.uk/about/brief-history [Accessed 10 08 2019].

NPFA 600, 2015. NFPA 600: Standard on Facility Fire Brigades, USA: National Fire Protection Association.

Ong et al, 2010. Reducing Ambulance Response Times Using Geospatial–Time Analysis of Ambulance Deployment. Academic Emergency Medicine, 17(9), pp. 951-957.

Pate, T., Ferrara, A, Bowers, R.A., and Lorence, J., 1976. Police Response Time Its Deteminants and Effects, Washington: Police Foundation.

Peatman, J. G., 1947. Descriptive and sampling statistics. 1st edition ed. Oxford: Harper & Brothers.

Sayer, G., 2010. Fire Statistics Monitor, UK: Crown.

Simpson, N.C. and Hancock, P.G. , 2009. Fifty years of operational research and emergency response. Journal of the Operational Research Society, pp. 126-139.

Appendix A: NFRS data information

Table A 1: NFRS stations data in 2017-2018

Fire Station	*Station Call Sign*	*Station Number*	*Number of Pumps*	*Station Crewing Status*	*Easting*	*Northing*	*Postcode*
MANSFIELD	FET01	1	1	WDS	453214,8087913290	361640,9664624780	NG19 6AB
BLIDWORTH	FET02	2	1	OC	459027,5607065780	356463,5126908080	NG21 0PN
LONDON ROAD	FET03	3	2	WDS and WDS	457882,95	338963,47	NG2 3EN
ASHFIELD	FET05	5	2	WDS and OC	449133,0364563610	357533,9175481980	NG17 8HX
EDWINSTOWE	FET06	6	1	WDS	462460,8209739150	366847,1326747010	NG21 9QT
WARSOP	FET07	7	1	OC	456730,3814119550	368169,5366145620	NG20 0AJ
WORKSOP	FET08	8	2	WDS and OC	458837,4980196930	379375,8462177970	S81 7BH
HARWORTH	FET10	10	1	OC	462226,0131390660	391519,2410772630	DN11 8JW
MISTERTON	FET11	11	1	OC	477718,9220771050	393866,9918230600	DN10 4ER
RETFORD	FET12	12	2	WDS and OC	470574,3169915610	380822,3432657690	DN22 6EN
TUXFORD	FET13	13	1	OC	473849,7123449500	370786,8416620060	NG22 0NA
SOUTHWELL	FET14	14	1	OC	470700,4615670960	354098,1605127070	NG25 0ES
COLLINGHAM	FET15	15	1	OC	483008,0101658160	361811,4004036370	NG23 7LT
NEWARK	FET16	16	2	WDS and OC	479595,1463172700	353156,2211768420	NG24 4AT
BINGHAM	FET17	17	1	OC	470546,7598448310	339820,7485399480	NG13 8AH
WEST BRIDGFORD	FET19	19	1	WDS	458181,4024920330	335890,7800637330	NG2 7FA
STOCKHILL	FET20	20	2	WDS and WDS	454420,0000000000	343178,0000000000	NG6 0LG
STAPLEFORD	FET23	23	1	OC	449086,2213720630	337440,4372213470	NG9 8DL
EASTWOOD	FET24	24	1	OC	447146,2329780710	346786,0388018690	NG16 3GL
HUCKNALL	FET25	25	1	OC	452474,1747924930	347954,9283832540	NG15 6EP
ARNOLD	FET26	26	1	WDS	458080,5970692300	344700,3249512010	NG5 6JR
CARLTON	FET27	27	1	WDS	461831,5272797770	341471,7817617830	NG4 3AY
EAST LEAKE	FET28	28	1	OC	455507,1928159210	326432,3150077870	LE12 6JG
HIGHFIELDS	FET29	29	1	WDS	453779,0000000000	337181,0000000000	NG9 2GQ

Table A 2: Pump data in 2017-2018

Fire Station	*Call Sign*	*Pump Crewing Status*	*Fire Station*	*Call Sign*	*Pump Crewing Status*
MANSFIELD	FET01P1	WDS	SOUTHWELL	FET14P1	OC
BLIDWORTH	FET02P1	OC	COLLINGHAM	FET15P1	OC
LONDON ROAD	FET03P1	WDS	NEWARK	FET16P1	WDS
LONDON ROAD	FET03P2	WDS	NEWARK	FET16P2	OC
ASHFIELD	FET05P1	WDS	BINGHAM	FET17P1	OC
ASHFIELD	FET05P2	OC	WEST BRIDGFORD	FET19P1	WDS
EDWINSTOWE	FET06P1	WDS	STOCKHILL	FET20P1	WDS
WARSOP	FET07P1	OC	STOCKHILL	FET20P2	WDS
WORKSOP	FET08P1	WDS	STAPLEFORD	FET23P1	OC
WORKSOP	FET08P2	OC	EASTWOOD	FET24P1	OC
HARWORTH	FET10P1	OC	HUCKNALL	FET25P1	OC
MISTERTON	FET11P1	OC	ARNOLD	FET26P1	WDS
RETFORD	FET12P1	WDS	CARLTON	FET27P1	WDS
RETFORD	FET12P2	OC	EAST LEAKE	FET28P1	OC
TUXFORD	FET13P1	OC	HIGHFIELDS	FET29P1	WDS

Table A 3: Incident Information in Mobilisation data in 2017-2018

Incident No	*Initial Incident Type*	*Incident Type*	*Incident Subtype*	*Motive*	*Property Type*
1733000002	Fire - Fire in the open - small	Fire	Secondary	Accidental	Grassland
1733000003	Fire - Fire in the open - small	False Alarm	Good Intent		Dwelling
1733000004	Fire - Fire in the open - small	Fire	Secondary	Deliberate	Grassland
1733000006	Fire - Fire in the open - small	Fire	Secondary	Deliberate	Refuse
1733000008	Fire - Fire in the open - small	Fire	Secondary	Accidental	Refuse
1733000010	Fire - Building	Fire	Primary	Accidental	Building: Residential
1733000010	Fire - Building	Fire	Primary	Accidental	Building: Residential
1733000011	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000012	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000013	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000014	Alarms - AFA	False Alarm	Apparatus		Dwelling
1733000016	Alarms - AFA	False Alarm	Apparatus		Building: Non-Residential
1733000018	Rescues - Persons locked in	Special Service	Other Ssc		Dwelling
1733000019	Humanitarian or Assistance - Assist other agency	Special Service	Other Ssc		Grassland
1733000020	Alarms - AFA	False Alarm	Malicious		Dwelling
1733000020	Alarms - AFA	False Alarm	Malicious		Dwelling
1733000020	Alarms - AFA	False Alarm	Malicious		Dwelling
1733000021	Humanitarian or Assistance - Assist other agency	Special Service	Other Ssc		Dwelling
1733000022	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000023	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000024	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000026	Fire - Fire in the open - small	Fire	Secondary	Deliberate	Refuse
1733000027	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000030	Humanitarian or Assistance - Co responder	Special Service	Other Ssc		Dwelling
1733000031	Alarms - AFA	False Alarm	Apparatus		Building: Residential
1733000031	Alarms - AFA	False Alarm	Apparatus		Building: Residential
1733000032	Fire - Fire in the open - small	Fire	Secondary	Accidental	Grassland
1733000033	Fire - Fire in the open - small	False Alarm	Good Intent		Dwelling
1733000034	Fire - Fire in the open - small	Fire	Secondary	Deliberate	Grassland
1733000036	Rescues - Persons locked in	Special Service	Other Ssc		Building: Non-Residential

Table A 4: Responding Appliance Information in Mobilisation data in 2017-2018

Callsign	*Vehicle Status*	*Arrival Position*	*First Appliance*
FET01P1	Available	1	FET01P1
FET16P1	Available	1	FET16P1
FET29P1	Available	1	FET29P1
FET16P1	Mobile available	1	FET16P1
FET29P1	Available	1	FET29P1
FET03P1	Available	1	FET03P1
FET03P2	Available	2	FET03P1
FET27P1	Available	1	FET27P1
FET06P1	Available	1	FET06P1
FET06P1	Available	1	FET06P1
FET03P1	Available	1	FET03P1
FET03P1	Available	1	FET03P1
FET16P1	Available	1	FET16P1
FET03P1	Mobile available	1	FET03P1
FET03P2	Available	1	FET03P2
FET19P1	Available	2	FET03P2
FET27P1	Available		FET03P2
FET16P1	Available	1	FET16P1
FET27P1	Available	1	FET27P1
FET06P1	Available	1	FET06P1
FET27P1	Available	1	FET27P1
FET26P1	Available	1	FET26P1
FET06P1	Available	1	FET06P1
FET06P1	Available	1	FET06P1
FET03P1	Available	2	FET03P2
FET03P2	Available	1	FET03P2
FET26P1	Available	1	FET26P1
FET06P1	Available	1	FET06P1
FET27P1	Available	1	FET27P1
FET01P1	Available	1	FET01P1

Table A 5: Time-Date Information in Mobilisation data in 2017-2018

Incident Time of Call	*Appliance Sent*	*Send Time*	*Appliance Mobile*	*MobiliseTime*	*Appliance Arrive*	*Irs Arrival Time*
1.01.2017 00:07	1.01.2017 00:08	1.01.2017 00:08	1.01.2017 00:10	1.01.2017 00:10	1.01.2017 00:12	1.01.2017 00:12
1.01.2017 00:13	1.01.2017 00:16	1.01.2017 00:16	1.01.2017 00:18	1.01.2017 00:18	1.01.2017 00:21	1.01.2017 00:21
1.01.2017 00:16	1.01.2017 00:17	1.01.2017 00:17	1.01.2017 00:19	1.01.2017 00:19	1.01.2017 00:40	1.01.2017 00:40
1.01.2017 00:37	1.01.2017 00:38	1.01.2017 00:38	1.01.2017 00:39	1.01.2017 00:39	1.01.2017 00:42	1.01.2017 00:42
1.01.2017 00:58	1.01.2017 00:59	1.01.2017 00:59	1.01.2017 01:00	1.01.2017 01:00	1.01.2017 01:06	1.01.2017 01:06
1.01.2017 01:21	1.01.2017 01:23	1.01.2017 01:23	1.01.2017 01:25	1.01.2017 01:25	1.01.2017 01:30	1.01.2017 01:30
1.01.2017 01:21	1.01.2017 01:23	1.01.2017 01:23	1.01.2017 01:25	1.01.2017 01:25	1.01.2017 01:30	1.01.2017 01:30
1.01.2017 01:35	1.01.2017 01:36	1.01.2017 01:36	1.01.2017 01:38	1.01.2017 01:38	1.01.2017 01:49	1.01.2017 01:49
1.01.2017 01:40	1.01.2017 01:41	1.01.2017 01:41	1.01.2017 01:44	1.01.2017 01:44	1.01.2017 01:49	1.01.2017 01:49
1.01.2017 02:37	1.01.2017 02:38	1.01.2017 02:38	1.01.2017 02:41	1.01.2017 02:41	1.01.2017 02:50	1.01.2017 02:50
1.01.2017 02:42	1.01.2017 02:45	1.01.2017 02:45	1.01.2017 02:49	1.01.2017 02:49	1.01.2017 02:52	1.01.2017 02:52
1.01.2017 03:25	1.01.2017 03:28	1.01.2017 03:28	1.01.2017 03:31	1.01.2017 03:31	1.01.2017 03:34	1.01.2017 03:34
1.01.2017 03:45	1.01.2017 03:49	1.01.2017 03:49	1.01.2017 03:52	1.01.2017 03:52	1.01.2017 03:56	1.01.2017 03:56
1.01.2017 04:04	1.01.2017 04:06	1.01.2017 04:06			1.01.2017 04:06	1.01.2017 04:06
1.01.2017 04:05	1.01.2017 04:07	1.01.2017 04:07	1.01.2017 04:11	1.01.2017 04:09	1.01.2017 04:13	1.01.2017 04:13
1.01.2017 04:05	1.01.2017 04:07	1.01.2017 04:07	1.01.2017 04:11	1.01.2017 04:09	1.01.2017 04:15	1.01.2017 04:13
1.01.2017 04:05	1.01.2017 04:07	1.01.2017 04:07	1.01.2017 04:09	1.01.2017 04:09	1.01.2017 04:17	1.01.2017 04:13
1.01.2017 04:23	1.01.2017 04:25	1.01.2017 04:25	1.01.2017 04:29	1.01.2017 04:29	1.01.2017 04:31	1.01.2017 04:31
1.01.2017 04:34	1.01.2017 04:36	1.01.2017 04:36	1.01.2017 04:38	1.01.2017 04:38	1.01.2017 04:41	1.01.2017 04:41
1.01.2017 08:57	1.01.2017 08:58	1.01.2017 08:58	1.01.2017 09:01	1.01.2017 09:01	1.01.2017 09:07	1.01.2017 09:07
1.01.2017 09:28	1.01.2017 09:29	1.01.2017 09:29	1.01.2017 09:31	1.01.2017 09:31	1.01.2017 09:36	1.01.2017 09:36
1.01.2017 10:47	1.01.2017 10:49	1.01.2017 10:49	1.01.2017 10:51	1.01.2017 10:51	1.01.2017 10:57	1.01.2017 10:57
1.01.2017 10:51	1.01.2017 10:52	1.01.2017 10:52	1.01.2017 10:53	1.01.2017 10:53	1.01.2017 10:58	1.01.2017 10:58
1.01.2017 12:25	1.01.2017 12:27	1.01.2017 12:27	1.01.2017 12:29	1.01.2017 12:29	1.01.2017 12:33	1.01.2017 12:33
1.01.2017 13:02	1.01.2017 13:13	1.01.2017 13:09	1.01.2017 13:13	1.01.2017 13:12	1.01.2017 13:17	1.01.2017 13:17

1.01.2017 13:02	1.01.2017 13:09	1.01.2017 13:09	1.01.2017 13:12	1.01.2017 13:12	1.01.2017 13:17	1.01.2017 13:17
1.01.2017 14:01	1.01.2017 14:03	1.01.2017 14:03	1.01.2017 14:05	1.01.2017 14:05	1.01.2017 14:07	1.01.2017 14:07
1.01.2017 15:08	1.01.2017 15:10	1.01.2017 15:10	1.01.2017 15:12	1.01.2017 15:12	1.01.2017 15:17	1.01.2017 15:17
1.01.2017 16:02	1.01.2017 16:03	1.01.2017 16:03	1.01.2017 16:05	1.01.2017 16:05	1.01.2017 16:12	1.01.2017 16:12
1.01.2017 16:09	1.01.2017 16:10	1.01.2017 16:10	1.01.2017 16:12	1.01.2017 16:12	1.01.2017 16:19	1.01.2017 16:19

Table A 6: Location Information in Mobilisation data in 2017-2018

Address	*Uprn*	*Easting*	*Northing*	*WGS84 Origin Latitude*	*WGS84 Origin Longitude*	*Veu Pk*
95 FAIRHOLME DRIVE,MANSFIELD, NG19 6DX	1,00031E+11	452495	362198			00000002-00-17-01-03-001-001
14 HAWTON LANE,BALDERTON, NG24 3DL	1,00031E+11	481437	351763			00000003-00-17-01-03-001-001
ATTENBOROUGH NATURE RESERVE,BARTON LANE,ATTENBOROUGH, NG9 6DB	1,00032E+11	452420	335091			00000004-00-17-01-03-001-001
ETON AVENUE,NEWARK ON TRENT, NG24 4JA	10008177875	479420	352834			00000006-00-17-01-03-001-001
38 BOUNDARY ROAD,BEESTON, NG9 2RF	1,00031E+11	452836	337860			00000008-00-17-01-03-001-001
CHATTERLEY COURT,WRAGBY ROAD,NOTTINGHAM_NTG, NG7 2AY	10009153109	455059	340044			00000010-00-17-01-03-001-001
CHATTERLEY COURT,WRAGBY ROAD,NOTTINGHAM_NTG, NG7 2AY	10009153109	455059	340044			00000010-00-17-01-03-002-001
25 ANSTEY RISE,NOTTINGHAM_NTG, NG3 2BY	1,00032E+11	458773	340224			00000011-00-17-01-03-001-001
43 MICKLEDALE LANE,BILSTHORPE, NG22 8RE	1,00031E+11	464605	360969			00000012-00-17-01-03-001-001
24 TRIUMPH CLOSE,EAKRING, NG22 0DP	1,00031E+11	467555	361992			00000013-00-17-01-03-001-001
COMMUNAL ROOMS,CARROLL GARDENS,NOTTINGHAM_NTG, NG2 2JS	2,00001E+11	457040	338210			00000014-00-17-01-03-001-001
32A STONEY STREET,NOTTINGHAM_NTG ,NG1 1PS	1,00032E+11	457685	339717			00000016-00-17-01-03-001-001
14 CRANMER ROAD,NEWARK ON TRENT, NG24 4ET	1,00031E+11	479760	352468			00000018-00-17-01-03-001-001
32 STONEY STREET AND 5,BROADWAY,NOTTINGHAM_NTG, NG1 1LL	1,00032E+11	457678	339742			00000019-00-17-01-03-001-001
SEELEY HOUSE,MALIN HILL,NOTTINGHAM_NTG, NG1 1JQ	1,00032E+11	457821	339610			00000020-02-17-01-03-001-001
SEELEY HOUSE,MALIN HILL,NOTTINGHAM_NTG ,NG1 1JQ	1,00032E+11	457821	339610			00000020-00-17-01-03-001-001

SEELEY HOUSE,MALIN HILL,NOTTINGHAM_NTG, NG1 1JQ	1,00032E+11	457821	339610			00000020-01-17-01-03-001-001
17 ST MARYS GARDENS,NEWARK ON TRENT, NG24 4JQ	2,00004E+11	479523	352375			00000021-00-17-01-03-001-001
26 PERLETHORPE AVENUE,GEDLING, NG4 4GG	1,00031E+11	461010	342688			00000022-00-17-01-03-001-001
33 SHERWOOD PARK,BRAKE ROAD,WALESBY, NG22 9NH	2,00004E+11	467701	370416			00000023-00-17-01-03-001-001
6 MUSTERS CROFT,COLWICK, NG4 2EY	1,00031E+11	461576	339508			00000024-00-17-01-03-001-001
15 HOGAN GARDENS,NOTTINGHAM_NTG, NG5 9JE	1,00032E+11	456232	346258			00000026-00-17-01-03-001-001
1 MAID MARION WAY,BOUGHTON, NG22 9TP	2,00001E+11	466934	368812			00000027-00-17-01-03-001-001
2 BRIAR COURT,OLLERTON, NG22 9SR	1,00031E+11	466419	368021			00000030-00-17-01-03-001-001
PALMER COURT,6 PARK STREET,NOTTINGHAM_NTG, NG7 2EL	10090906650	455634	339585			00000031-01-17-01-03-001-001
PALMER COURT,6 PARK STREET,NOTTINGHAM_NTG, NG7 2EL	10090906650	455634	339585			00000031-00-17-01-03-002-001
11 MEADOW ROAD,NETHERFIELD, NG4 2FF	1,00031E+11	461896	340996			00000032-00-17-01-03-001-001
BESTWOOD PARK DRIVE WEST,NOTTINGHAM_NTG, NG5 9JJ	10009154523	455645	346175			00000033-00-17-01-03-001-001
21 CHEWTON CLOSE,BILSTHORPE, NG22 8RN	1,00031E+11	464532	360644			00000034-00-17-01-03-001-001
7 FIRBECK ROAD,ARNOLD, NG5 8BB	1,00031E+11	459425	345910			00000035-00-17-01-03-001-001

Appendix B: Data analysis and interpretation results

Table B 1: Call handling, crew, drive and response time standard deviations in 2017-2018

Date	*Call handling time standard deviation*	*Crew time standard deviation*	*Drive time standard deviation*	*Response time standard deviation*
Jan-17	00:03:02	00:01:47	00:03:26	00:05:01
Feb-17	00:02:11	00:02:00	00:03:41	00:04:56
Mar-17	00:03:10	00:01:55	00:03:52	00:05:36
Apr-17	00:03:33	00:01:56	00:03:43	00:05:53
May-17	00:03:23	00:01:57	00:03:43	00:05:54
Jun-17	00:03:04	00:01:56	00:03:52	00:05:37
Jul-17	00:02:25	00:02:04	00:04:00	00:05:29
Aug-17	00:03:34	00:01:44	00:04:05	00:06:03
Sep-17	00:03:12	00:01:58	00:03:56	00:06:03
Oct-17	00:02:31	00:01:56	00:03:34	00:04:48
Nov-17	00:02:29	00:01:57	00:03:33	00:04:52
Dec-17	00:02:52	00:01:52	00:03:51	00:05:30
Jan-18	00:03:05	00:01:52	00:03:51	00:05:36
Feb-18	00:02:59	00:01:42	00:03:56	00:05:36
Mar-18	00:03:22	00:01:49	00:03:39	00:05:42
Apr-18	00:03:34	00:01:46	00:03:42	00:05:48
May-18	00:03:34	00:01:48	00:04:12	00:06:15
Jun-18	00:03:20	00:01:53	00:04:24	00:06:17
Jul-18	00:04:33	00:01:57	00:05:00	00:07:43
Aug-18	00:04:28	00:01:45	00:04:33	00:07:18
Sep-18	00:03:16	00:01:48	00:03:57	00:05:54
Oct-18	00:03:11	00:01:54	00:03:48	00:05:57
Nov-18	00:03:11	00:01:41	00:04:38	00:06:19
Dec-18	00:02:55	00:01:42	00:03:43	00:05:30

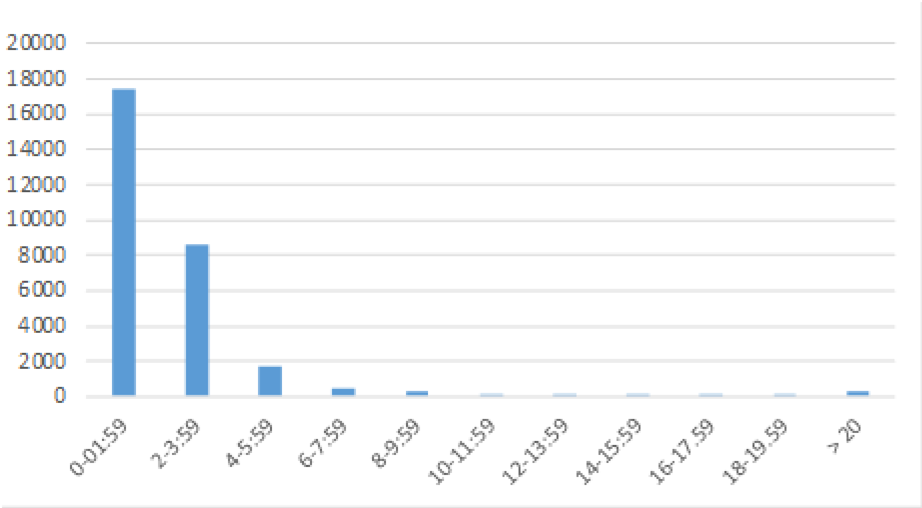

Figure B 1: Frequency diagram for Call handling time in 2017-2018

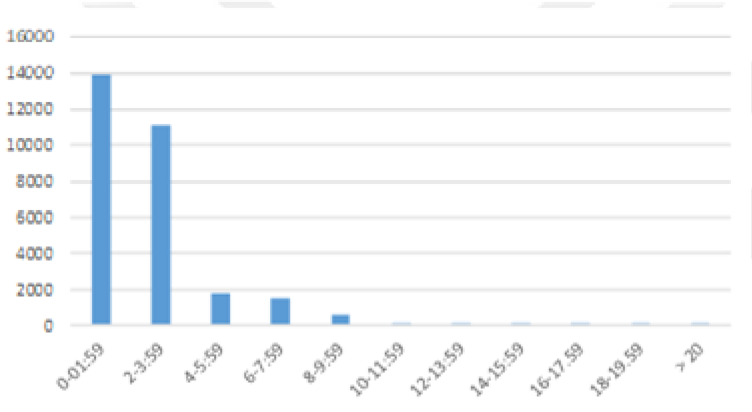

Figure B 2: Frequency diagram for Crew time in 2017-2018

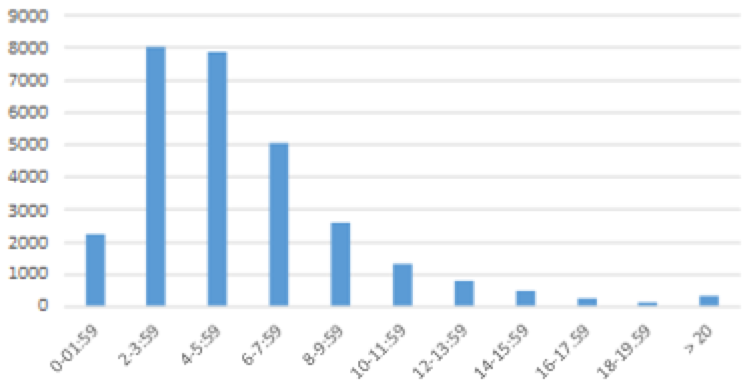

Figure B 3: Frequency diagram for Drive time in 2017-2018

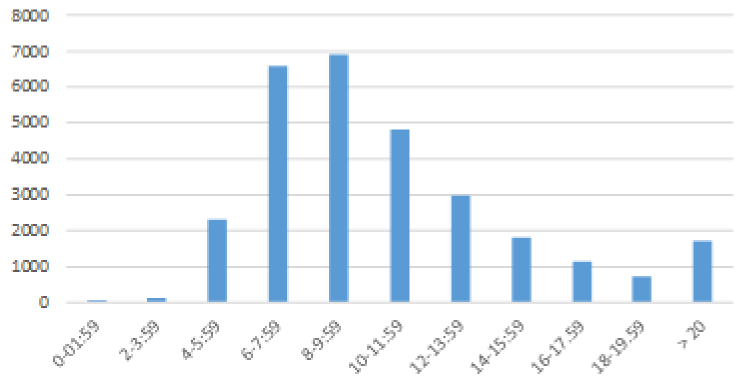

Figure B 4: Frequency diagram for Response time in 2017-2018

Table B 2: OC crew monthly call handling, crew, drive and response time averages and standard deviations in 2017-2018

Date	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*Call handling time SD*	*Crew time SD*	*Drive time SD*	*Response time SD*
Jan-17	0:03:13	0:06:27	0:04:52	0:14:32	00:04:25	00:02:04	00:04:10	00:06:46
Feb-17	0:02:36	0:06:32	0:04:19	0:13:27	00:02:15	00:02:32	00:03:08	00:04:38
Mar-17	0:03:16	0:06:18	0:04:42	0:14:15	00:04:42	00:02:27	00:03:23	00:06:01
Apr-17	0:03:20	0:06:08	0:05:35	0:15:03	00:05:20	00:02:33	00:04:07	00:07:42
May-17	0:02:52	0:06:05	0:05:19	0:14:16	00:03:49	00:02:44	00:04:06	00:06:30
Jun-17	0:02:36	0:06:17	0:05:12	0:14:05	00:03:19	00:02:22	00:04:01	00:06:14
Jul-17	0:02:39	0:06:29	0:05:57	0:15:05	00:02:15	00:02:35	00:04:26	00:05:36
Aug-17	0:03:27	0:05:57	0:05:14	0:14:38	00:05:54	00:02:29	00:04:10	00:08:01
Sep-17	0:02:58	0:06:05	0:05:31	0:14:34	00:03:45	00:02:26	00:04:14	00:06:33
Oct-17	0:02:34	0:06:11	0:05:02	0:13:46	00:03:27	00:02:25	00:03:44	00:05:11
Nov-17	0:02:23	0:06:04	0:05:05	0:13:32	00:01:58	00:02:36	00:03:57	00:04:52

Dec-17	0:02:48	0:05:57	0:05:21	0:14:06	00:03:20	00:02:16	00:03:35	00:05:32
Jan-18	0:02:51	0:05:19	0:05:31	0:13:40	00:03:35	00:02:29	00:03:40	00:05:54
Feb-18	0:02:16	0:05:34	0:05:51	0:13:41	00:03:16	00:02:17	00:04:13	00:06:23
Mar-18	0:03:12	0:05:53	0:06:08	0:15:13	00:04:12	00:02:22	00:03:27	00:06:10
Apr-18	0:03:01	0:05:33	0:04:51	0:13:24	00:03:53	00:02:17	00:03:52	00:06:23
May-18	0:03:12	0:05:27	0:05:23	0:14:02	00:05:31	00:02:25	00:04:18	00:07:30
Jun-18	0:03:04	0:05:37	0:05:58	0:14:40	00:04:19	00:02:37	00:03:57	00:06:44
Jul-18	0:03:21	0:05:22	0:07:02	0:15:45	00:05:09	00:02:37	00:05:43	00:08:34
Aug-18	0:03:22	0:05:02	0:06:54	0:15:19	00:05:42	00:02:28	00:04:57	00:08:27
Sep-18	0:02:17	0:05:19	0:05:34	0:13:10	00:02:57	00:02:21	00:04:04	00:05:41
Oct-18	0:03:20	0:05:46	0:06:02	0:15:08	00:04:59	00:02:29	00:04:20	00:07:40
Nov-18	0:02:49	0:04:53	0:06:14	0:13:56	00:04:06	00:02:32	00:04:16	00:06:53
Dec-18	0:03:23	0:05:31	0:05:51	0:14:44	00:05:01	00:02:35	00:04:39	00:07:14

Table B 3: WDS crew monthly call handling, crew, drive and response time averages and standard deviations in 2017-2018

Date	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*Call handling time SD*	*Crew time SD*	*Drive time SD*	*Response time SD*	*No records*
Jan-17	0:02:20	0:02:06	0:05:24	0:09:50	00:02:49	00:00:57	00:03:20	00:04:30	1072
Feb-17	0:02:31	0:02:08	0:05:33	0:10:12	00:02:01	00:00:57	00:03:43	00:04:39	892
Mar-17	0:02:35	0:02:09	0:05:58	0:10:42	00:02:48	00:01:04	00:03:54	00:05:19	886
Apr-17	0:02:37	0:02:03	0:05:33	0:10:14	00:03:09	00:00:54	00:03:38	00:05:13	1029

May-17	0:02:31	0:02:02	0:05:33	0:10:06	00:03:19	00:00:52	00:03:39	00:05:35	1029
Jun-17	0:02:30	0:02:05	0:05:51	0:10:26	00:02:59	00:01:00	00:03:45	00:05:15	1102
Jul-17	0:02:18	0:02:09	0:05:56	0:10:23	00:02:17	00:01:03	00:03:54	00:04:54	1113
Aug-17	0:02:28	0:01:58	0:06:08	0:10:34	00:03:10	00:00:56	00:04:03	00:05:36	1182
Sep-17	0:02:20	0:02:03	0:05:50	0:10:13	00:03:01	00:01:00	00:03:51	00:05:29	929
Oct-17	0:02:15	0:02:04	0:05:37	0:09:56	00:02:17	00:00:58	00:03:26	00:04:20	1043
Nov-17	0:02:24	0:02:16	0:05:36	0:10:17	00:02:31	00:01:02	00:03:26	00:04:36	937
Dec-17	0:02:25	0:02:09	0:05:35	0:10:09	00:02:47	00:00:57	00:03:43	00:05:04	919
Jan-18	0:02:26	0:02:02	0:05:49	0:10:17	00:02:57	00:00:56	00:03:49	00:05:15	790
Feb-18	0:02:12	0:02:05	0:05:50	0:10:07	00:02:45	00:00:52	00:03:40	00:04:57	830
Mar-18	0:02:28	0:02:00	0:05:59	0:10:28	00:03:10	00:00:57	00:03:41	00:05:18	1012
Apr-18	0:02:29	0:01:59	0:05:37	0:10:05	00:03:29	00:00:59	00:03:39	00:05:28	882
May-18	0:02:29	0:01:51	0:05:55	0:10:16	00:03:01	00:00:49	00:04:08	00:05:44	1089
Jun-18	0:02:21	0:01:56	0:06:13	0:10:30	00:03:02	00:00:52	00:04:30	00:05:53	1150
Jul-18	0:02:45	0:01:56	0:06:43	0:11:24	00:04:20	00:00:53	00:04:47	00:07:07	1468
Aug-18	0:02:40	0:01:56	0:06:26	0:11:02	00:04:10	00:00:52	00:04:25	00:06:49	1243
Sep-18	0:02:19	0:01:58	0:05:46	0:10:04	00:03:10	00:01:02	00:03:48	00:05:30	1046
Oct-18	0:02:22	0:01:55	0:05:46	0:10:03	00:02:37	00:00:49	00:03:36	00:04:59	1053
Nov-18	0:02:28	0:01:58	0:06:12	0:10:39	00:02:49	00:00:54	00:04:41	00:05:57	1015
Dec-18	0:02:26	0:01:57	0:05:34	0:09:56	00:02:23	00:00:48	00:03:23	00:04:40	862

Table B 4: Pumping appliance's Response time analysis in 2017

Call sign	Fire Station	Status	Avg. Call handling time	Avg. Crew time	Avg. Drive time	Avg. Response time	No records	Avg. Distance
FET03P1	London Road	WDS	0:02:31	0:02:17	0:05:21	0:10:09	1566	2844,33453
FET20P1	Stockhill	WDS	0:02:16	0:02:01	0:05:36	0:09:53	1394	2938,319062
FET03P2	London Road	WDS	0:02:39	0:02:13	0:04:51	0:09:43	1190	2510,757314
FET26P1	Arnold	WDS	0:02:15	0:02:08	0:04:51	0:09:15	1069	2744,000994
FET29P1	Highfields	WDS	0:02:26	0:02:01	0:05:44	01:10:11	890	2627,089773
FET20P2	Stockhill	WDS	0:02:33	0:02:05	0:05:28	0:10:06	886	2765,811605
FET01P1	Mansfield	WDS	0:02:34	0:01:55	0:05:36	0:10:05	842	2895,581056
FET06P1	Edwinstowe	WDS	0:02:16	0:02:03	0:06:35	0:10:54	806	5354,98279
FET08P1	Worksop	WDS	0:02:22	0:02:09	0:05:43	0:10:13	695	3621,192299
FET05P1	Ashfield	WDS	0:02:30	0:02:00	0:06:06	0:10:35	680	3713,439828
FET27P1	Carlton	WDS	0:02:18	0:02:11	0:05:44	0:10:13	639	3713,439828
FET19P1	West Bridgford	WDS	0:02:23	0:02:03	0:06:47	0:11:14	625	3810,835199
FET16P1	Newark	WDS	0:02:32	0:01:57	0:07:03	0:11:33	457	4533,276195
FET12P1	Retford	WDS	0:02:32	0:02:03	0:07:46	0:12:21	394	4735,92329
FET25P1	Hucknall	OC	0:02:25	0:06:33	0:04:15	0:13:13	211	2718,060604
FET10P1	Harworth	OC	0:02:18	0:06:42	0:05:12	0:14:12	208	2388,353901
FET02P1	Blidworth	OC	0:03:17	0:05:33	0:05:20	0:14:10	166	3293,283
FET08P2	Worksop	OC	0:02:51	0:07:05	0:03:53	0:13:49	158	2704,836
FET23P1	Stapleford	OC	0:02:51	0:03:51	0:03:42	0:10:24	152	2572,489
FET07P1	Warsop	OC	0:02:36	0:06:31	0:05:19	0:14:27	129	3241,513
FET16P2	Newark	OC	0:02:43	0:06:36	0:05:44	0:15:03	119	3055,618
FET05P2	Ashfield	OC	0:03:57	0:06:29	0:05:26	0:15:52	112	2847,655
FET17P1	Bingham	OC	0:03:27	0:05:26	0:07:00	0:15:53	111	5108,623
FET12P2	Retford	OC	0:02:13	0:08:25	0:04:27	0:15:04	104	3661,2
FET13P1	Tuxford	OC	0:02:52	0:06:14	0:08:02	0:17:08	90	6119,589
FET24P1	Eastwood	OC	0:02:29	0:05:13	0:03:47	0:11:29	88	1834,095
FET28P1	East Leake	OC	0:02:28	0:06:12	0:04:13	0:12:53	58	2433,657
FET15P1	Collingham	OC	0:04:34	0:04:48	0:08:52	0:18:13	56	7584,219
FET14P1	Southwell	OC	0:04:20	0:07:06	0:06:16	0:17:42	48	4342,348
FET11P1	Misterton	OC	0:02:59	0:06:08	0:07:07	0:16:13	34	3470,817
Avg.Total			0:02:30	0:02:38	0:05:39	0:10:47	13977	3267,322

Table B 5: Pumping appliance's Response time analysis in 2018

Call sign	*Fire Station*	*Status*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*No records*	*Avg. Distance*
FET03P1	London Road	WDS	0:02:20	0:02:10	0:05:10	0:09:39	1273	2633,371
FET20P1	Stockhill	WDS	0:02:03	0:01:50	0:05:22	0:09:15	1466	2622,112
FET03P2	London Road	WDS	0:02:37	0:02:05	0:04:38	0:09:20	1052	2199,584
FET26P1	Arnold	WDS	0:02:12	0:02:03	0:05:21	0:09:36	1194	2998,889
FET29P1	Highfields	WDS	0:02:10	0:01:52	0:06:07	0:10:09	1014	2929,019
FET20P2	Stockhill	WDS	0:02:49	0:01:55	0:05:38	0:10:21	1040	2687,533
FET01P1	Mansfield	WDS	0:02:37	0:01:50	0:05:54	0:10:20	941	2945,954
FET06P1	Edwinstowe	WDS	0:02:57	0:01:51	0:08:19	0:13:07	440	6574,751
FET08P1	Worksop	WDS	0:02:29	0:01:57	0:06:15	0:10:41	744	4187,737
FET05P1	Ashfield	WDS	0:02:38	0:01:50	0:06:18	0:10:46	844	3683,05
FET27P1	Carlton	WDS	0:02:26	0:02:04	0:06:07	0:10:37	595	3605,632
FET19P1	West Bridgford	WDS	0:02:14	0:02:01	0:07:06	0:11:21	851	3999,023
FET16P1	Newark	WDS	0:02:58	0:01:58	0:08:39	0:13:35	545	5351,037
FET12P1	Retford	WDS	0:03:22	0:01:55	0:08:31	0:13:48	441	5471,079
FET25P1	Hucknall	OC	0:02:36	0:05:39	0:05:08	0:13:23	278	2873,291
FET10P1	Harworth	OC	0:02:30	0:05:35	0:06:09	0:14:13	252	3006,958
FET02P1	Blidworth	OC	0:02:57	0:05:10	0:07:19	0:15:27	259	4443,655
FET08P2	Worksop	OC	0:03:20	0:06:25	0:04:30	0:14:14	205	2589,481
FET23P1	Stapleford	OC	0:02:23	0:03:46	0:04:35	0:10:44	170	2719,823
FET07P1	Warsop	OC	0:03:06	0:05:40	0:05:55	0:14:41	142	3711,951
FET16P2	Newark	OC	0:04:03	0:06:19	0:06:58	0:17:20	150	3111,236
FET05P2	Ashfield	OC	0:03:42	0:05:41	0:06:05	0:15:27	172	2622,289
FET17P1	Bingham	OC	0:03:05	0:05:12	0:08:01	0:16:19	141	4955,294
FET12P2	Retford	OC	0:03:26	0:06:39	0:05:19	0:15:24	105	3193,884
FET13P1	Tuxford	OC	0:03:12	0:04:34	0:07:58	0:15:44	83	5816,63
FET24P1	Eastwood	OC	0:02:16	0:04:01	0:04:10	0:10:27	142	2072,914
FET28P1	East Leake	OC	0:02:28	0:05:31	0:05:12	0:13:11	52	2033,97
FET15P1	Collingham	OC	0:05:41	0:04:09	0:09:05	0:18:56	75	8699,349
FET14P1	Southwell	OC	0:03:05	0:07:20	0:07:12	0:17:37	41	4921,691
FET11P1	Misterton	OC	0:02:19	0:05:24	0:07:07	0:14:51	43	3040,662
Avg.Total			0:02:34	0:02:30	0:06:02	0:11:06	14750	3367,47

Table B 6: Fire Station workload in 2017-2018

	Station 1	Station 2	Station 3	Station 5	Station 6	Station 7	Station 8	Station 10	Station 11	Station 12	Station 13
Time	MANSFIELD	BLIDWORTH	LONDON ROAD	ASHFIELD	EDWINSTOWE	WARSOP	WORKSOP	HARWORTH	MISTERTON	RETFORD	TUXFORD
Jan-17	54	6	245	53	110	5	73	26	2	35	11
Feb-17	54	11	225	40	66	4	62	14	1	45	4
Mar-17	63	8	203	75	37	11	67	11	1	33	3
Apr-17	87	17	262	70	76	15	86	19	1	33	9
May-17	85	11	225	69	99	11	77	16	4	45	9
Jun-17	77	18	239	64	103	11	88	15	5	43	10
Jul-17	77	14	279	65	91	15	69	25	4	45	8
Aug-17	77	11	281	90	81	11	79	17	2	46	9
Sep-17	59	16	189	63	44	12	66	14	2	37	6
Oct-17	81	20	233	79	44	15	61	18	3	53	8
Nov-17	66	17	183	62	27	5	78	14	5	48	7
Dec-17	62	17	192	62	28	12	47	19	4	35	6
Jan-18	61	12	167	48	29	9	55	15	3	37	9
Feb-18	59	14	182	72	31	10	55	11	3	28	4
Mar-18	62	15	194	83	35	9	62	22	0	40	4
Apr-18	78	16	168	84	31	7	60	13	4	33	5
May-18	90	25	183	115	36	13	85	33	2	39	3
Jun-18	92	25	195	92	46	18	104	18	4	62	11
Jul-18	120	51	232	142	53	25	121	36	8	70	8
Aug-18	98	24	206	88	54	13	108	31	6	73	11
Sep-18	76	25	185	74	39	11	93	20	5	43	10
Oct-18	90	20	190	86	36	10	77	18	3	42	8
Nov-18	59	23	232	63	23	9	73	24	3	49	6
Dec-18	56	9	191	69	29	8	56	11	2	30	4
Total	1783	425	5081	1808	1248	269	1802	460	77	1044	173

Table B 7: continue Fire Station workload in 2017-2018

	Station 14	Station 15	Station 16	Station 17	Station 19	Station 20	Station 23	Station 24	Station 25	Station 26	Station 27	Station 28	Station 29
Time	*Southwell*	*Collingham*	*Newark*	*Bingham*	*West Bridgford*	*Stockhill*	*Stapleford*	*Eastwood*	*Hucknall*	*Arnold*	*Carlton*	*East Leake*	*Highfields*
Jan-17	7	1	43	4	47	169	10	12	8	84	127	4	67
Feb-17	3	2	39	11	44	172	15	7	17	65	68	3	54
Mar-17	3	4	44	4	37	186	14	3	18	77	37	5	64
Apr-17	4	4	53	15	53	197	8	9	18	64	37	6	63
May-17	3	10	54	7	38	190	13	8	25	94	35	9	72
Jun-17	5	3	44	16	40	216	8	7	22	111	53	9	64
Jul-17	7	1	50	11	41	219	7	7	14	107	46	4	59
Aug-17	0	6	51	5	64	221	12	8	15	95	47	2	98
Sep-17	2	12	47	9	64	173	13	9	19	93	46	6	81
Oct-17	5	7	52	10	63	203	20	7	16	87	50	3	81
Nov-17	4	5	52	10	62	171	15	4	22	89	43	2	96
Dec-17	5	1	47	9	72	163	17	7	17	103	50	5	91
Jan-18	6	3	50	15	65	143	16	10	16	64	35	1	78
Feb-18	2	5	42	6	67	160	6	12	14	77	34	3	68
Mar-18	3	7	37	9	67	214	17	7	18	96	56	6	101
Apr-18	1	2	52	7	52	154	12	13	15	77	51	10	86
May-18	1	8	65	11	63	222	12	20	26	115	50	3	80
Jun-18	4	10	65	15	85	234	12	3	24	101	55	0	89
Jul-18	9	5	87	19	76	334	19	15	52	148	61	9	109
Aug-18	5	9	79	26	86	253	22	14	23	127	58	8	83
Sep-18	4	6	51	5	70	230	19	10	23	107	47	4	82
Oct-18	1	9	57	10	72	225	5	10	41	111	49	2	72
Nov-18	2	3	56	9	93	180	21	16	17	88	54	4	85
Dec-18	3	8	54	9	55	157	9	12	9	83	45	2	81
Total	89	131	1271	252	1476	4786	322	230	489	2263	1234	110	1904

Table B 8: Time of day data based on 29,142 mobilisation records in 2017-2018

Time Intervals	Average Call handling time	Average Crew time	Average Drive time	Average Response time	Number of reports	Call handling time standard deviation	Crew time standard deviation	Drive time standard deviation	Response time standard deviation
00:00 - 01:00	0:02:26	0:02:55	0:05:23	0:10:45	1038	0:02:39	0:01:57	0:03:36	0:05:15
01:00 - 02:00	0:02:34	0:03:14	0:05:39	0:11:28	826	0:03:25	0:02:03	0:03:50	0:05:49
02:00 - 03:00	0:02:38	0:03:14	0:05:39	0:11:30	778	0:03:20	0:01:51	0:03:30	0:05:35
03:00 - 04:00	0:02:35	0:03:14	0:05:29	0:11:18	730	0:03:23	0:01:49	0:03:43	0:06:04
04:00 - 05:00	0:02:25	0:03:14	0:05:08	0:10:47	652	0:03:01	0:01:48	0:03:11	0:05:14
05:00 - 06:00	0:02:24	0:03:17	0:05:45	0:11:26	590	0:02:47	0:01:48	0:04:10	0:05:56
06:00 - 07:00	0:02:28	0:02:42	0:05:22	0:10:33	659	0:03:33	0:01:53	0:03:48	0:05:55
07:00 - 08:00	0:02:11	0:02:41	0:05:51	0:10:42	770	0:02:18	0:02:06	0:04:25	0:05:42
08:00 - 09:00	0:02:36	0:02:34	0:06:10	0:11:20	918	0:03:40	0:02:03	0:04:17	0:06:42
09:00 - 10:00	0:02:21	0:02:28	0:05:57	0:10:46	1104	0:02:56	0:01:51	0:03:41	0:05:23
10:00 - 11:00	0:02:29	0:02:28	0:05:59	0:10:56	1169	0:02:58	0:01:56	0:04:01	0:05:46
11:00 - 12:00	0:02:35	0:02:25	0:06:17	0:11:17	1282	0:03:23	0:01:55	0:04:15	0:06:10
12:00 - 13:00	0:02:34	0:02:27	0:06:07	0:11:08	1375	0:03:31	0:01:53	0:04:04	0:05:59
13:00 - 14:00	0:02:31	0:02:32	0:05:58	0:11:01	1522	0:03:15	0:01:48	0:04:06	0:06:01
14:00 - 15:00	0:02:41	0:02:27	0:06:12	0:11:20	1405	0:03:43	0:01:58	0:03:49	0:06:14
15:00 - 16:00	0:02:50	0:02:19	0:06:30	0:11:39	1467	0:03:43	0:01:52	0:04:07	0:06:20
16:00 - 17:00	0:02:40	0:02:23	0:06:20	0:11:23	1545	0:03:28	0:01:55	0:04:31	0:06:31
17:00 - 18:00	0:02:57	0:02:27	0:06:25	0:11:49	1882	0:04:27	0:01:48	0:04:22	0:07:01
18:00 - 19:00	0:02:25	0:02:26	0:05:59	0:10:50	1845	0:03:11	0:01:39	0:03:53	0:05:30
19:00 - 20:00	0:02:26	0:02:21	0:05:48	0:10:36	1982	0:03:12	0:01:48	0:04:05	0:05:49
20:00 - 21:00	0:02:28	0:02:24	0:05:43	0:10:34	1686	0:03:03	0:01:42	0:04:08	0:05:53
21:00 - 22:00	0:02:24	0:02:29	0:05:33	0:10:26	1459	0:02:40	0:01:41	0:03:40	0:05:02
22:00 - 23:00	0:02:29	0:02:29	0:05:24	0:10:22	1293	0:02:55	0:01:44	0:03:43	0:05:33
23:00 - 00:00	0:02:39	0:02:41	0:05:41	0:11:01	1165	0:03:07	0:01:48	0:04:01	0:05:46

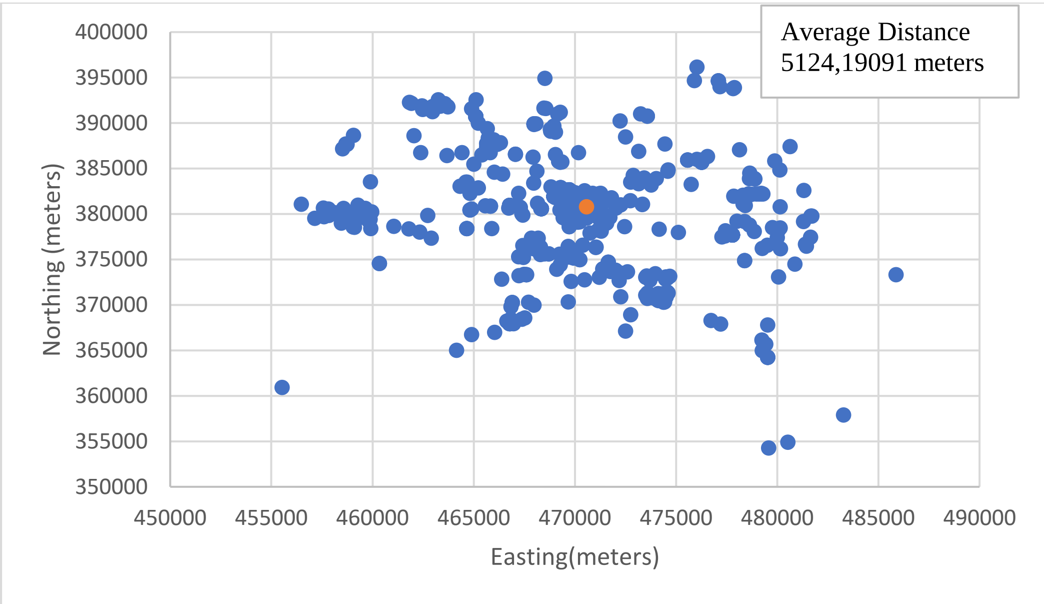

Figure B 5: FET12P1 pumping appliance mobilisation record distribution in 2017-2018

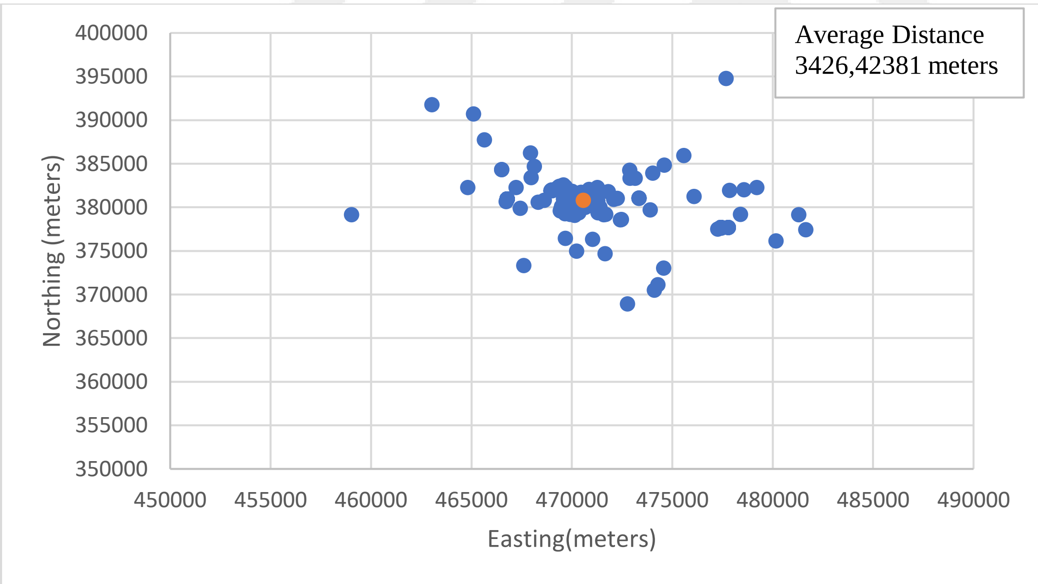

Figure B 6: FET12P2 pumping appliance mobilisation record distribution in 2017-2018

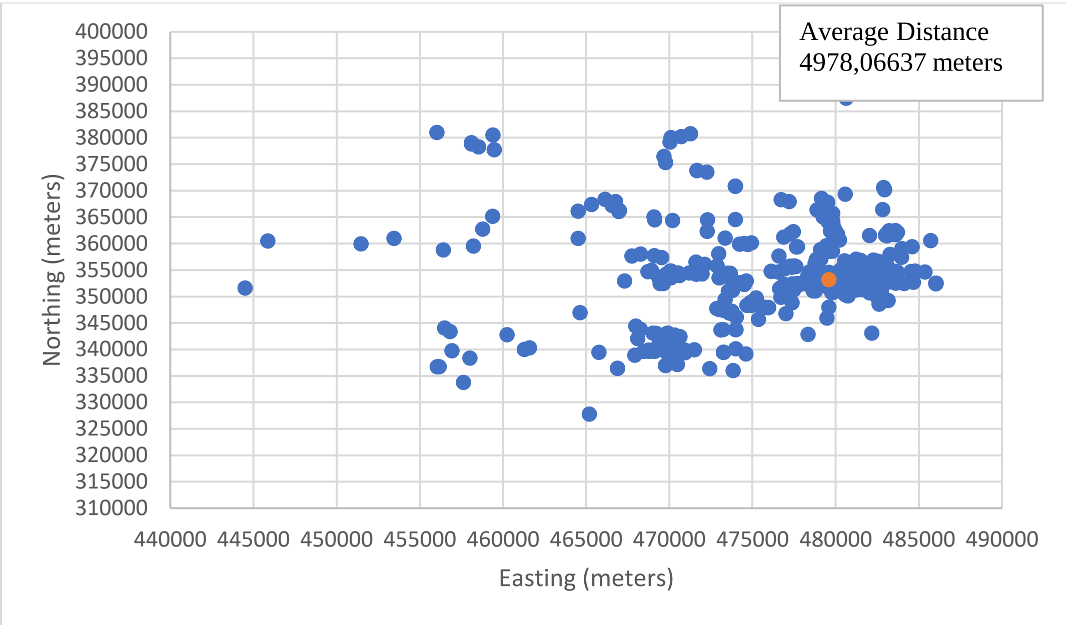

Figure B 7: FET16P1 pumping appliance mobilisation record distribution in 2017-2018

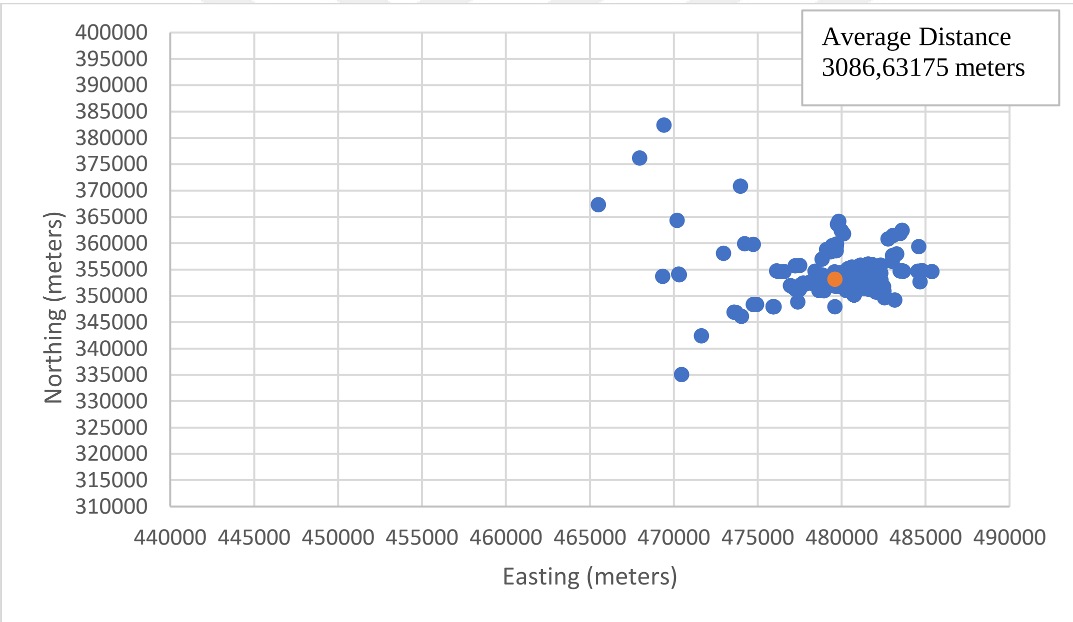

Figure B 8: FET16P2 pumping appliance mobilisation record distribution in 2017-2018

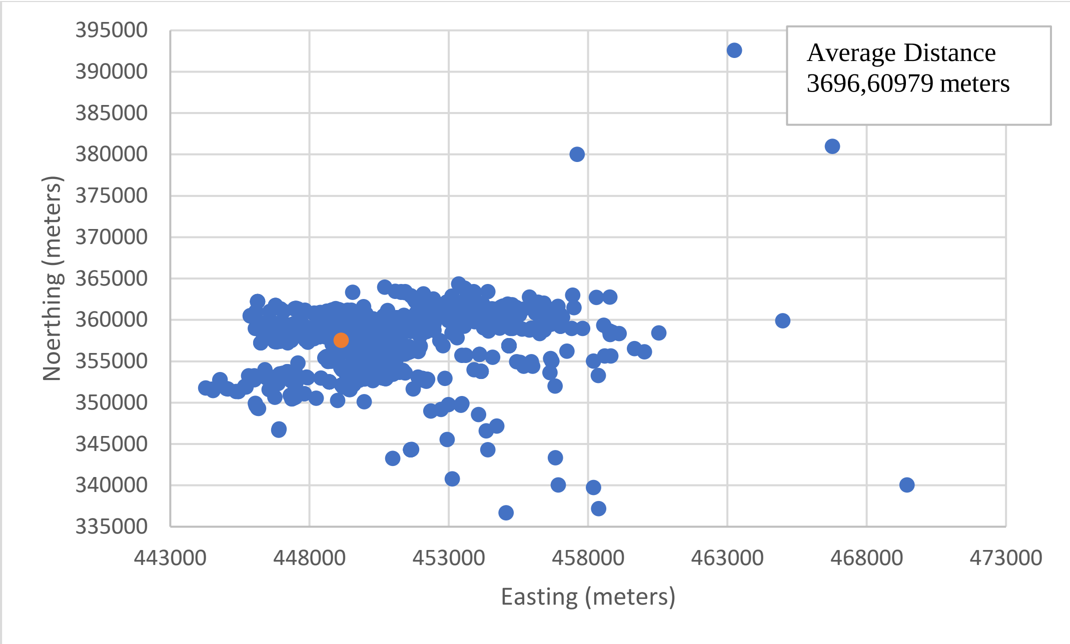

Figure B 9: FET05P1 pumping appliance mobilisation record distribution in 2017-2018

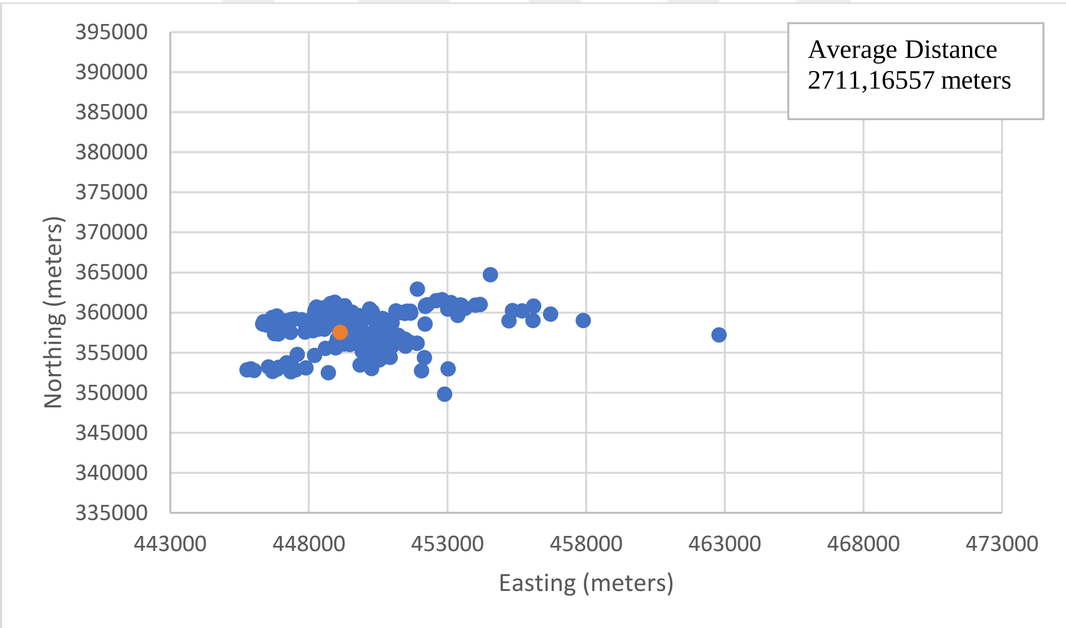

Figure B 10: FET05P2 pumping appliance mobilisation record distribution in 2017-2018

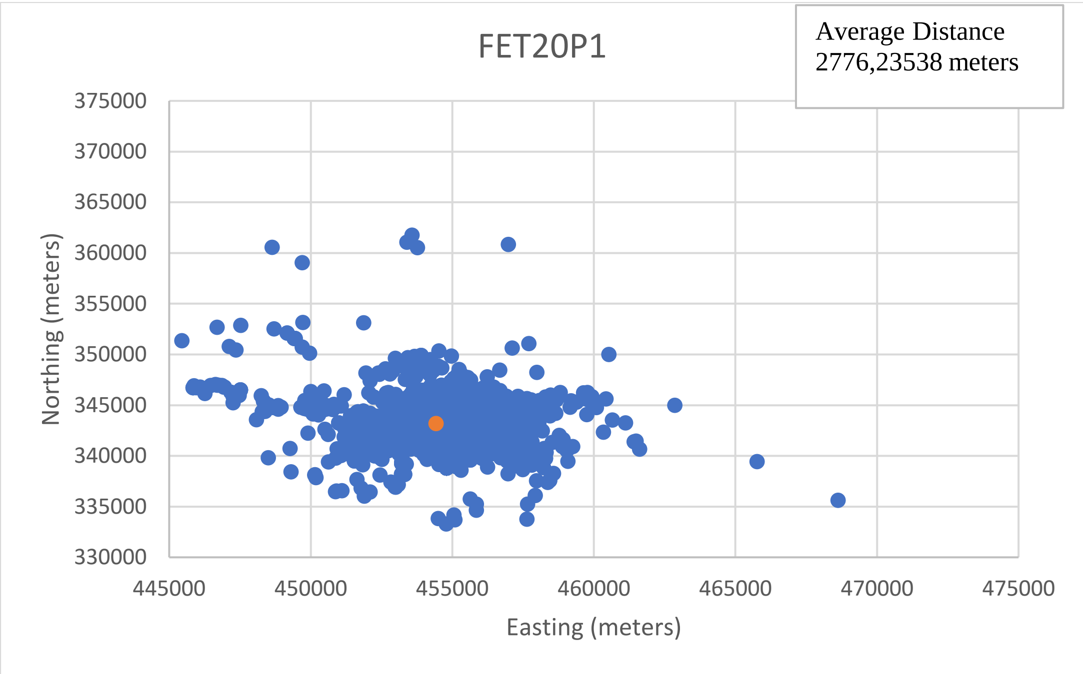

Figure B 11: FET20P1 pumping appliance mobilisation record distribution in 2017-2018

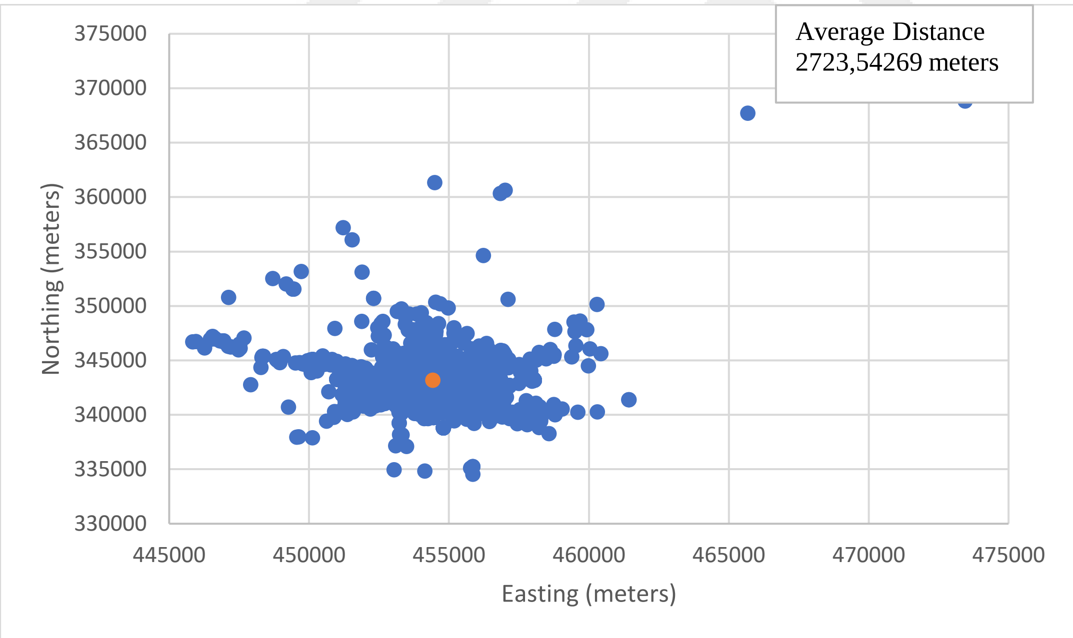

Figure B 12: FET20P2 pumping appliance mobilisation record distribution in 2017-2018

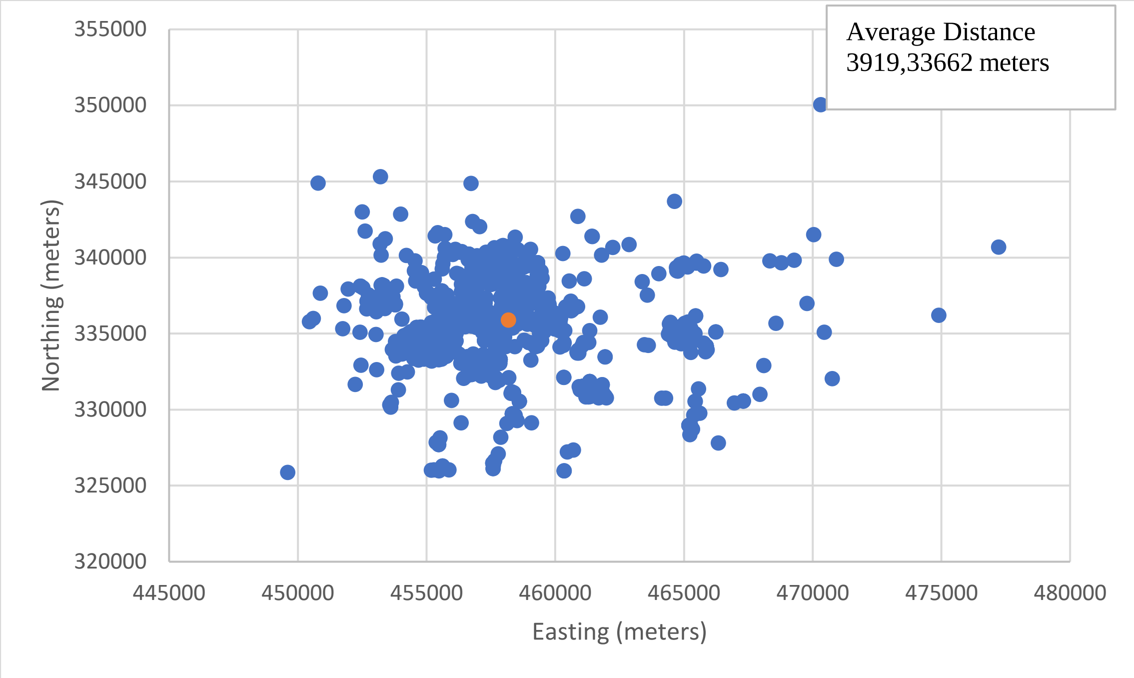

Figure B 13: FET19P1 pumping appliance mobilisation record distribution in 2017-2018

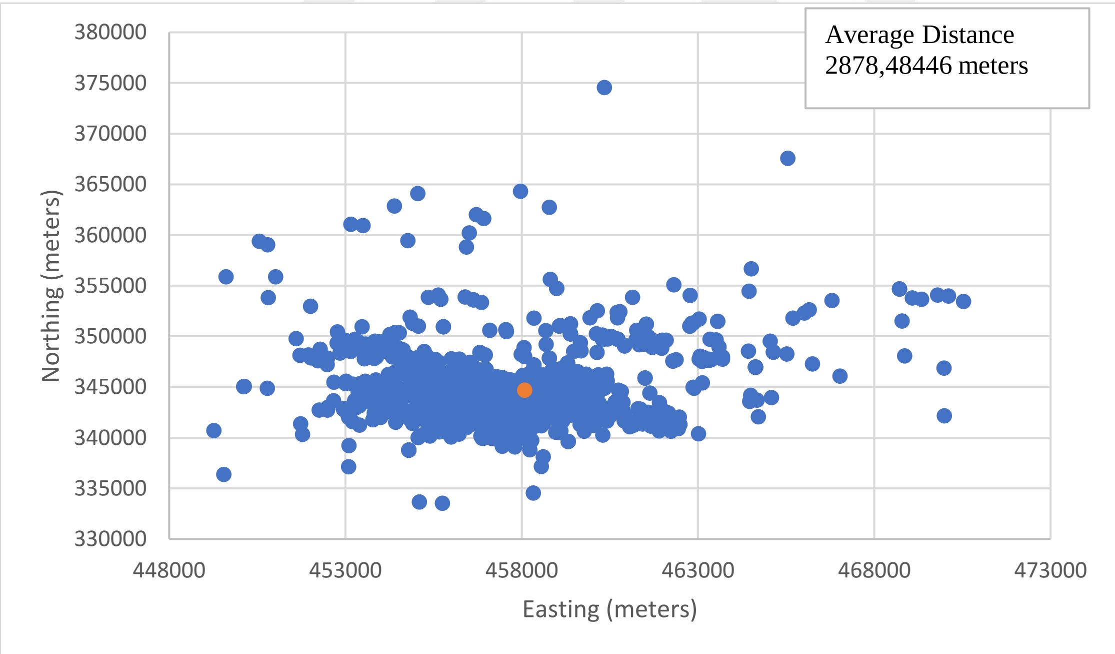

Figure B 14: FET26P1 pumping appliance mobilisation record distribution in 2017-2018

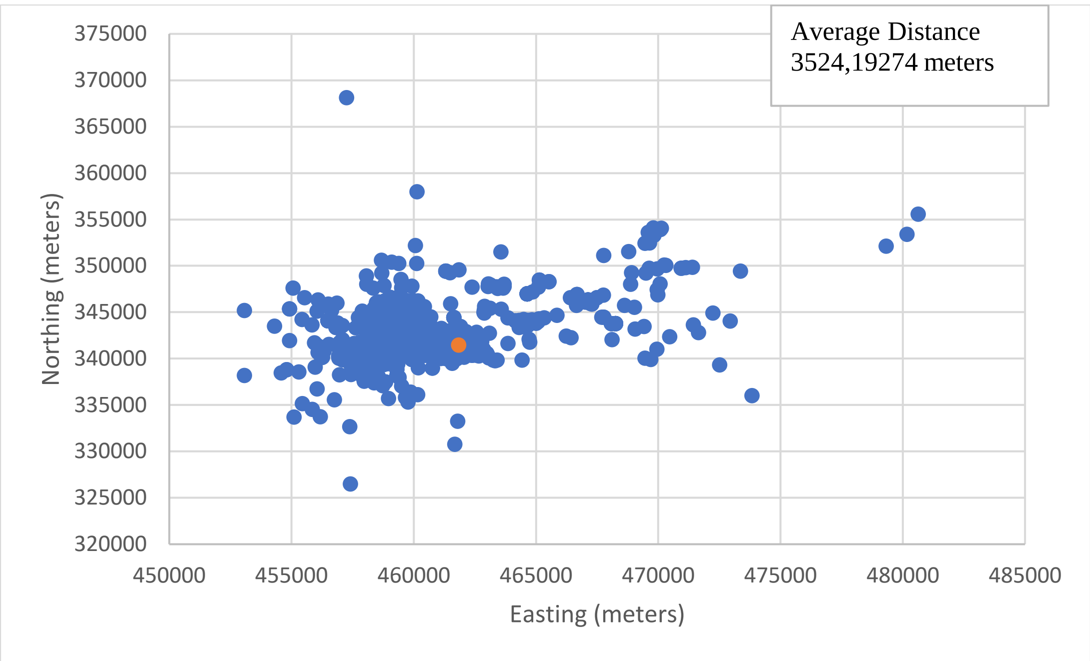

Figure B 15: FET27P1 pumping appliance mobilisation record distribution in 2017-2018

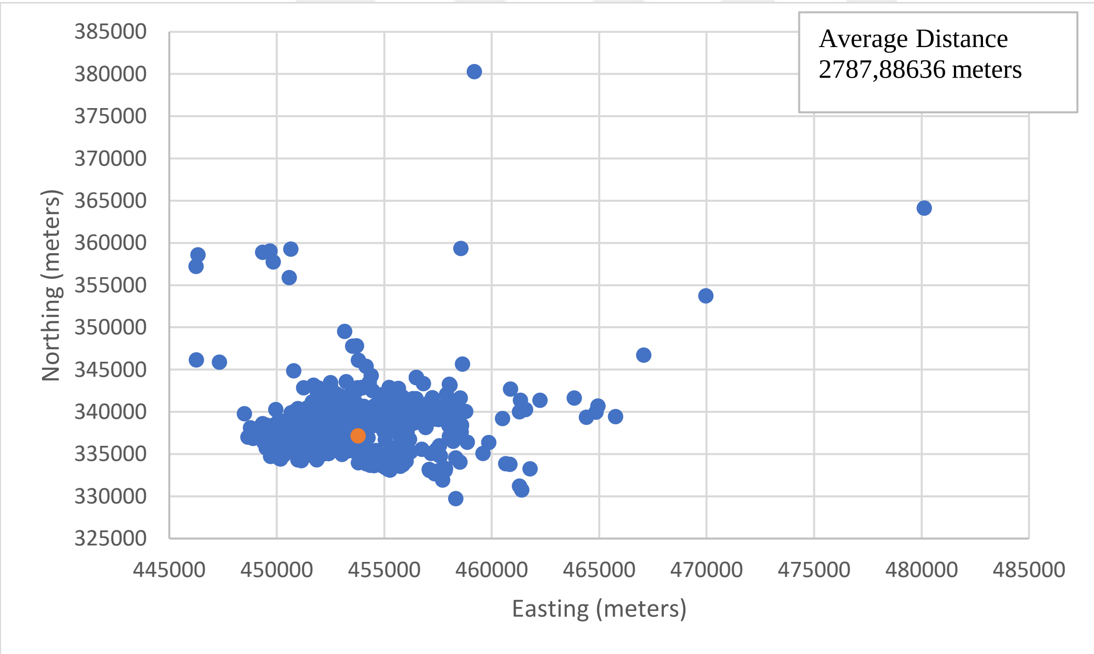

Figure B 16: FET29P1 pumping appliance mobilisation record distribution in 2017-2018

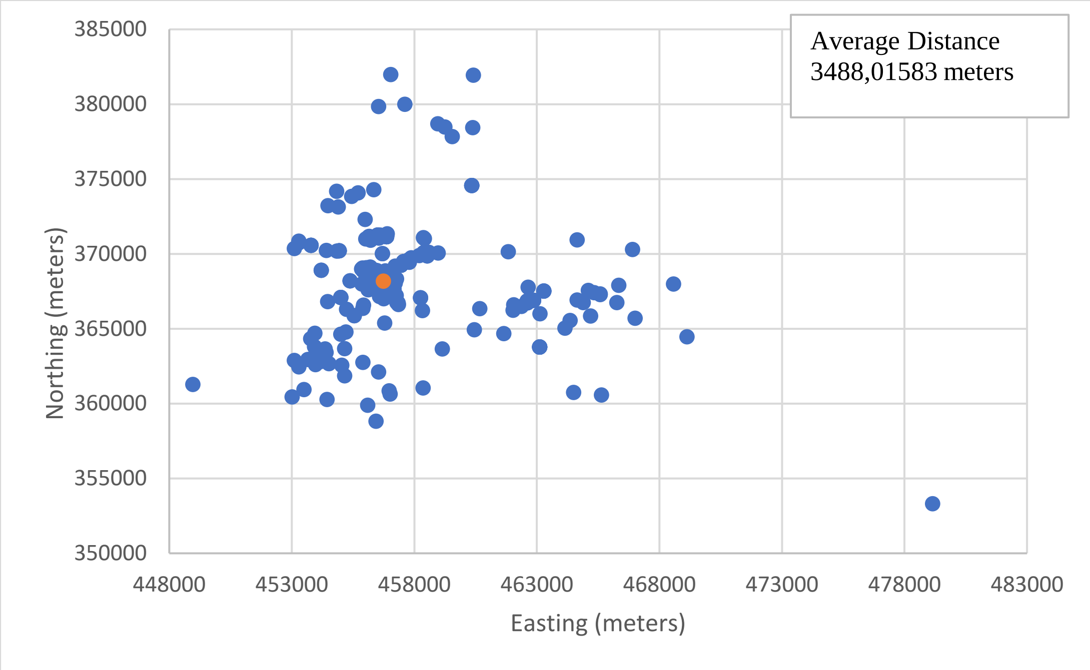

Figure B 17: FET7P1 pumping appliance mobilisation record distribution in 2017-2018

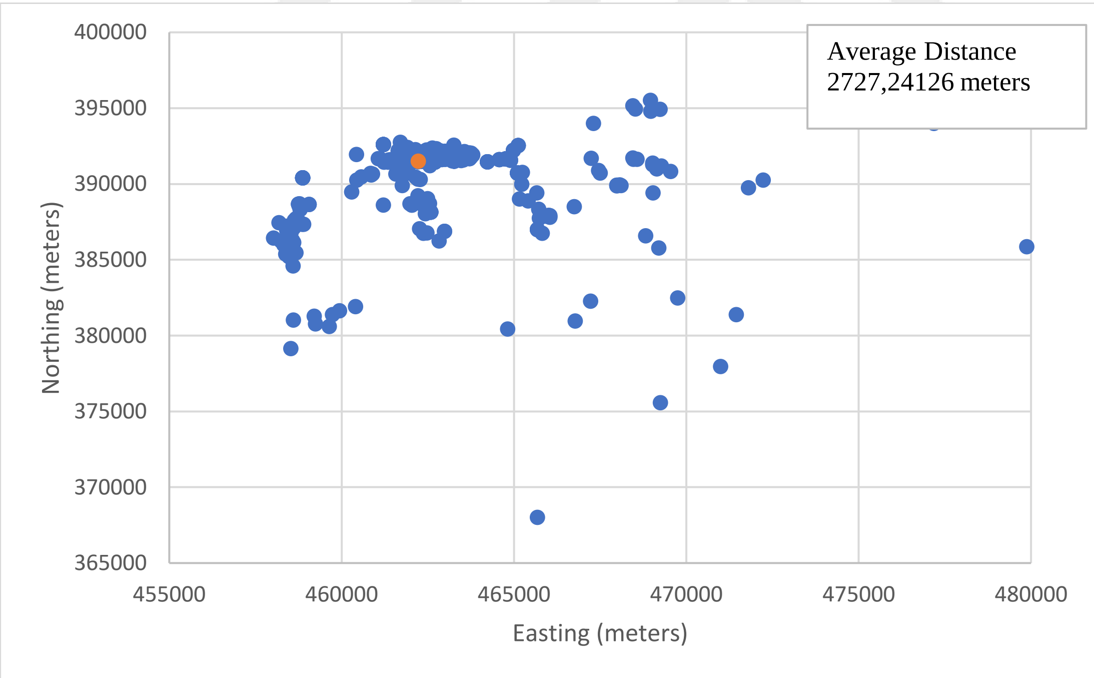

Figure B 18: FET10P1 pumping appliance mobilisation record distribution in 2017-2018

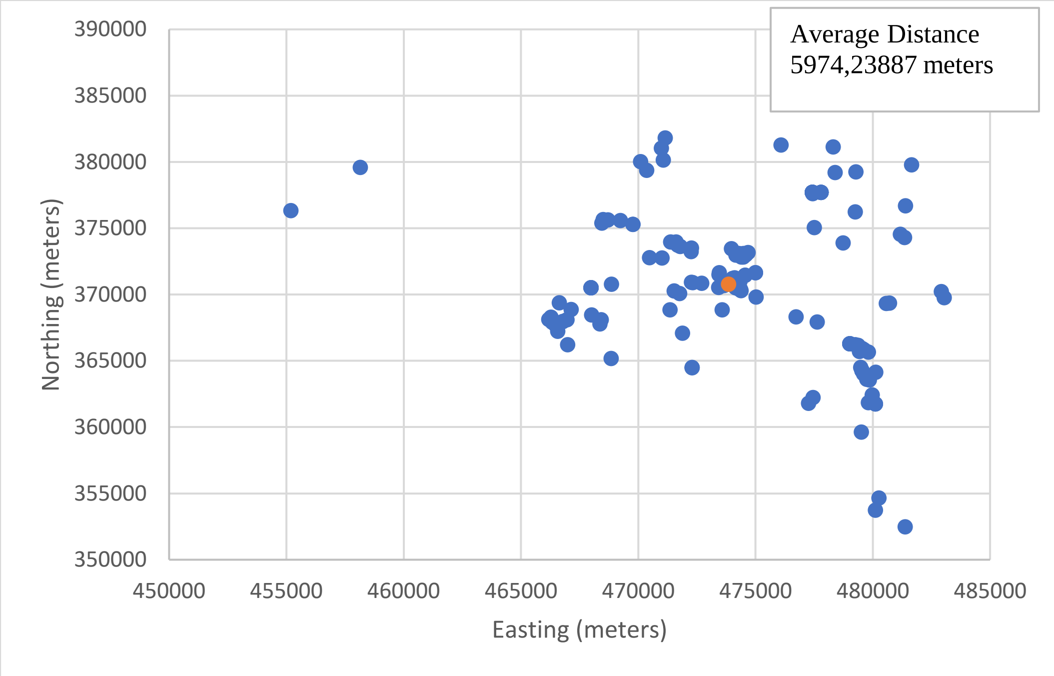

Figure B 19: FET13P1 pumping appliance mobilisation record distribution in 2017-2018

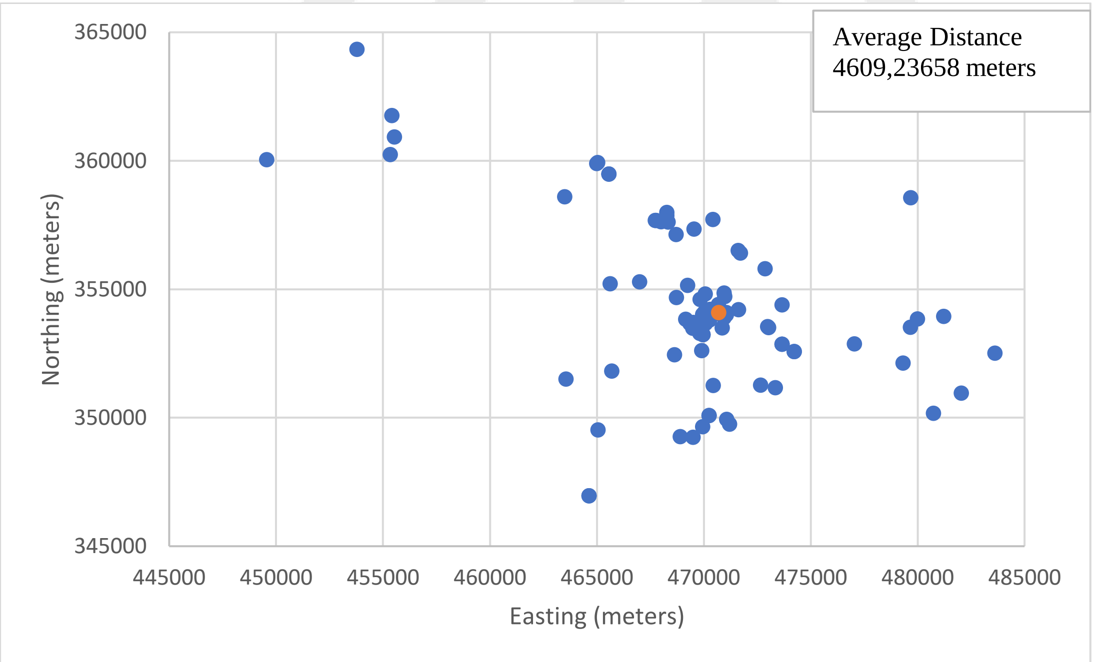

Figure B 20: FET14P1 pumping appliance mobilisation record distribution in 2017-2018

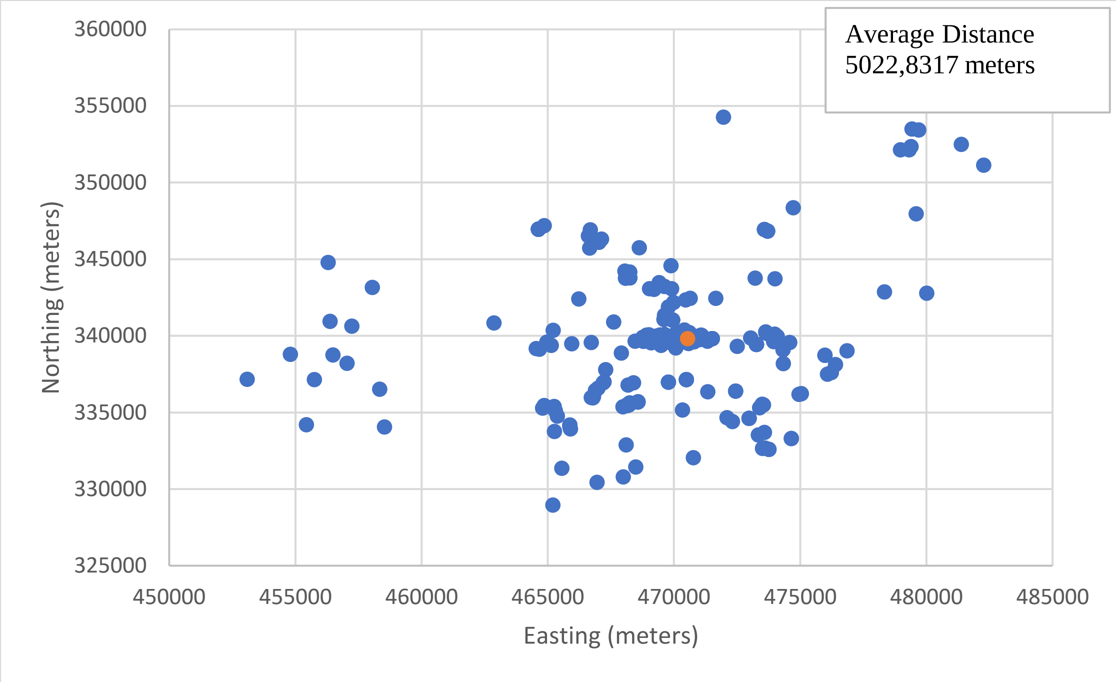

Figure B 21: FET17P1 pumping appliance mobilisation record distribution in 2017-2018

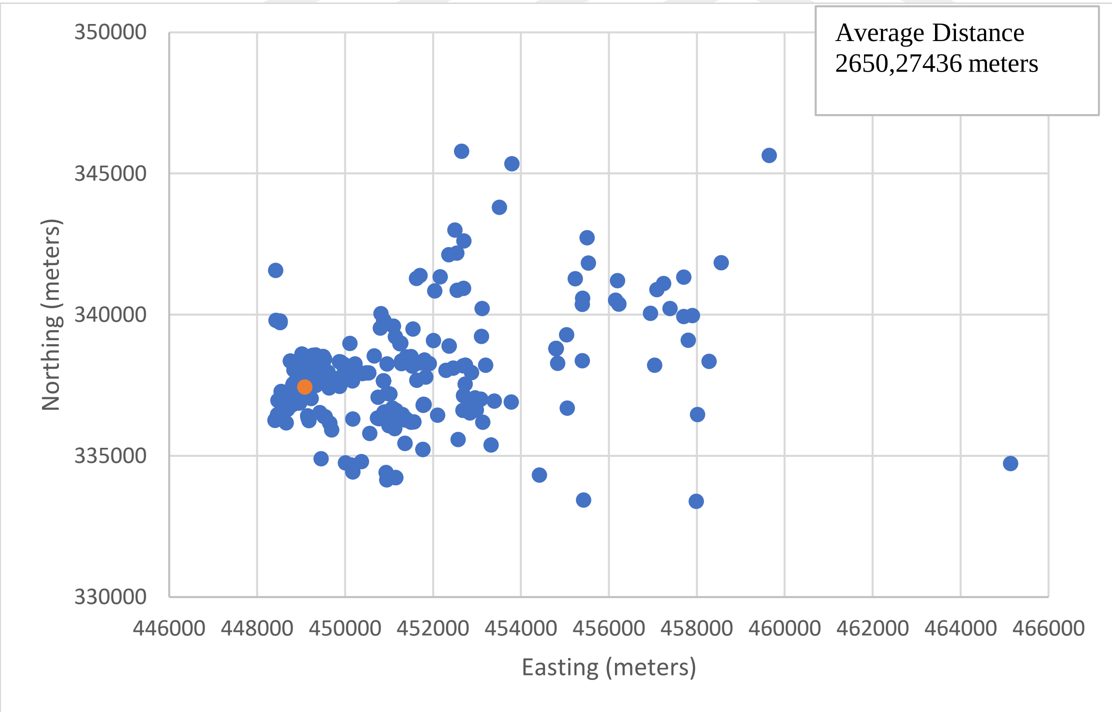

Figure B 22: FET23P1 pumping appliance mobilisation record distribution in 2017-2018

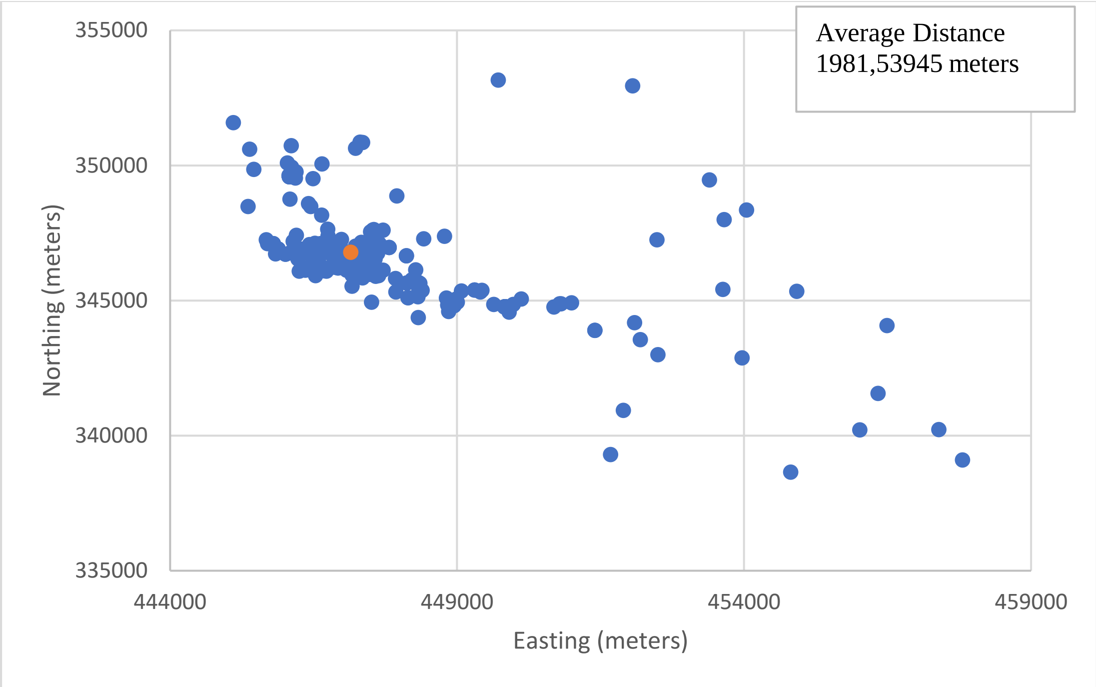

Figure B 23: FET24P1 pumping appliance mobilisation record distribution in 2017-2018

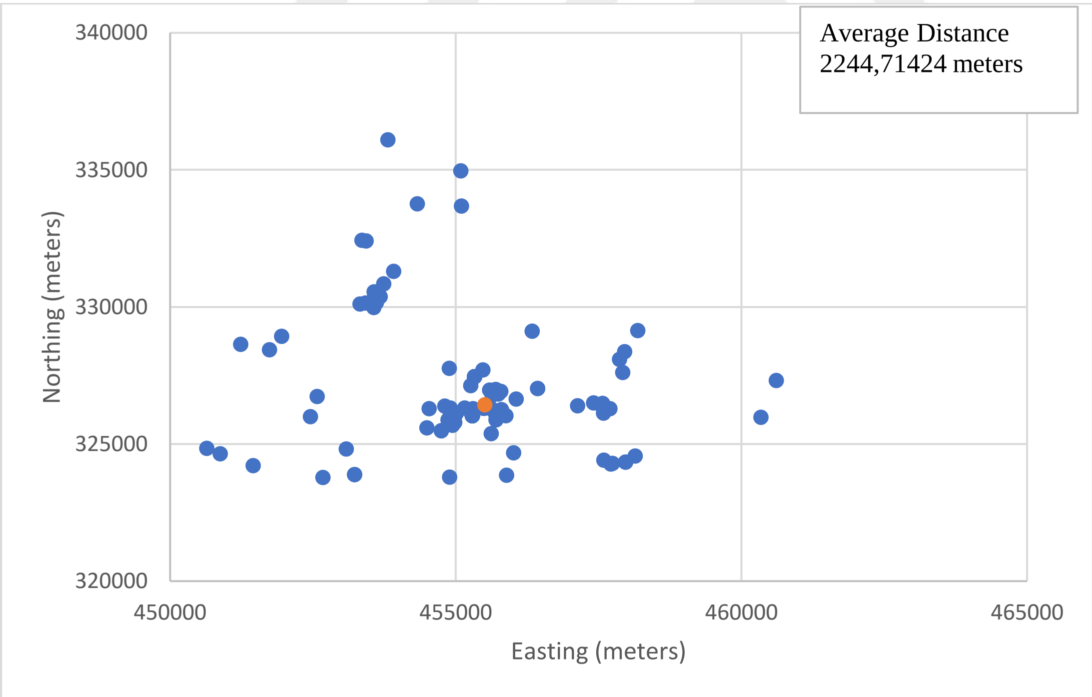

Figure B 24: FET28P1 pumping appliance mobilisation record distribution in 2017-2018

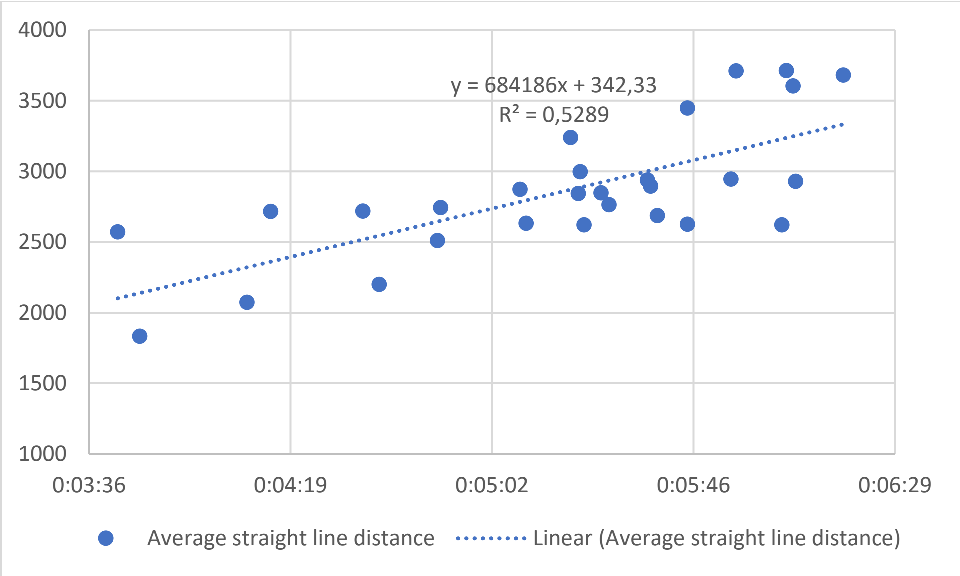

Figure B 25: Average straight-line distance(meters) and drive time relationship for fire stations in urban area in 2017-2018

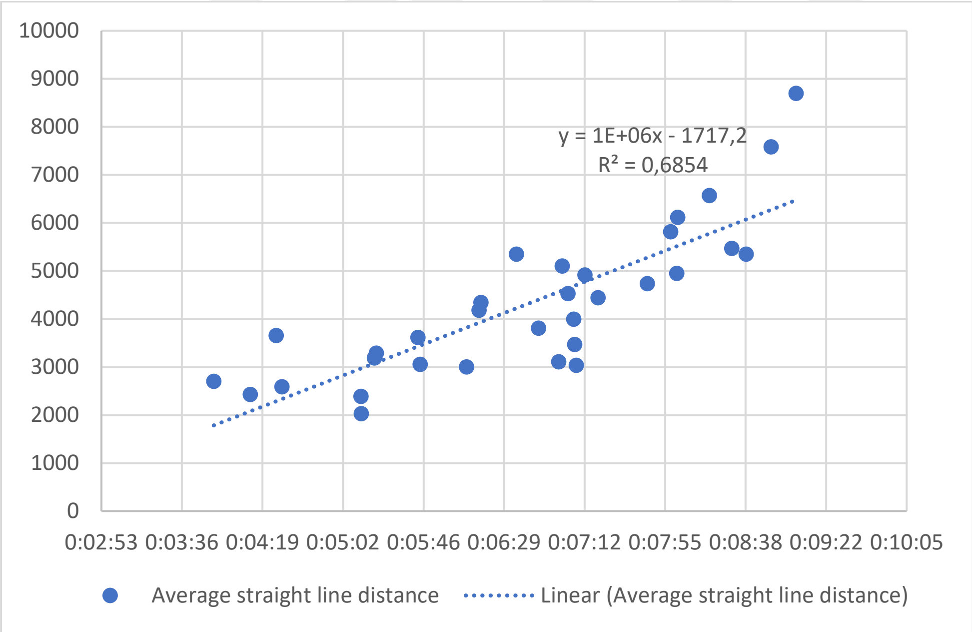

Figure B 26: Average straight-line distance(meters) and drive time relationship for fire stations in rural area in 2017-2018

Table B 9: Available vehicles monthly analysis in 2017-2018

Time	*Avg. straight-line distance (miles)*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*No of records*	*Call handling time SD*	*Crew time SD*	*Drive time SD*	*Response time SD*
Jan-17	1,85	0:02:19	0:02:43	0:05:14	0:10:17	1044	00:02:29	00:01:45	00:03:27	00:04:53
Feb-17	1,80	0:02:28	0:02:53	0:05:11	0:10:32	878	00:02:03	00:01:59	00:03:30	00:04:42
Mar-17	1,90	0:02:34	0:02:49	0:05:35	0:10:58	846	00:03:03	00:01:54	00:03:31	00:05:24
Apr-17	1,94	0:02:40	0:02:50	0:05:29	0:10:59	1025	00:03:38	00:01:57	00:03:36	00:05:58
May-17	1,91	0:02:32	0:02:51	0:05:22	0:10:44	1016	00:03:25	00:02:00	00:03:38	00:05:58
Jun-17	2,06	0:02:24	0:02:50	0:05:40	0:10:54	1078	00:02:59	00:01:55	00:03:48	00:05:32
Jul-17	2,01	0:02:16	0:02:50	0:05:49	0:10:55	1059	00:02:04	00:01:58	00:03:47	00:05:03
Aug-17	2,06	0:02:28	0:02:37	0:05:55	0:11:00	1102	00:03:16	00:01:46	00:04:05	00:05:55
Sep-17	1,92	0:02:18	0:02:48	0:05:37	0:10:43	920	00:02:27	00:01:54	00:03:50	00:05:25
Oct-17	1,95	0:02:11	0:02:50	0:05:33	0:10:33	1051	00:02:02	00:01:57	00:03:32	00:04:30
Nov-17	1,79	0:02:22	0:03:00	0:05:18	0:10:41	922	00:02:30	00:01:53	00:03:18	00:04:42
Dec-17	1,87	0:02:27	0:02:51	0:05:31	0:10:50	955	00:02:52	00:01:49	00:03:39	00:05:20
Jan-18	1,90	0:02:23	0:02:43	0:05:37	0:10:43	828	00:03:00	00:01:48	00:03:41	00:05:26
Feb-18	1,95	0:02:11	0:02:45	0:05:50	0:10:47	840	00:02:43	00:01:40	00:03:50	00:05:22
Mar-18	1,97	0:02:30	0:02:44	0:05:55	0:11:09	981	00:03:18	00:01:48	00:03:39	00:05:44
Apr-18	1,79	0:02:25	0:02:41	0:05:22	0:10:27	881	00:03:16	00:01:46	00:03:24	00:05:29
May-18	1,90	0:02:27	0:02:40	0:05:52	0:10:58	1093	00:02:54	00:01:49	00:04:09	00:06:03
Jun-18	2,00	0:02:26	0:02:43	0:06:01	0:11:09	1158	00:03:18	00:01:54	00:04:11	00:06:07
Jul-18	2,06	0:02:42	0:02:49	0:06:35	0:12:06	1512	00:04:11	00:01:54	00:04:48	00:07:23
Aug-18	2,20	0:02:40	0:02:43	0:06:22	0:11:44	1245	00:04:15	00:01:46	00:04:27	00:07:13
Sep-18	1,83	0:02:13	0:02:41	0:05:40	0:10:33	1075	00:02:55	00:01:46	00:03:49	00:05:36
Oct-18	1,88	0:02:24	0:02:44	0:05:36	0:10:44	1053	00:02:52	00:01:51	00:03:29	00:05:25
Nov-18	1,94	0:02:24	0:02:39	0:06:00	0:11:03	986	00:02:49	00:01:41	00:04:30	00:06:04
Dec-18	1,72	0:02:30	0:02:35	0:05:28	0:10:32	866	00:02:49	00:01:41	00:03:29	00:05:18

Table B 10: Mobile Available vehicles monthly analysis in 2017-2018

Time	Avg. Call handling time	Avg.Crew time	Avg. Drive time	Avg. Response time	No of records	Call handling time SD	Crew time SD	Drive time SD	Response time SD
Jan-17	0:03:07	0:01:38	0:06:03	0:10:48	157	00:05:26	00:01:35	00:03:22	00:05:55
Feb-17	0:02:51	0:01:40	0:06:41	0:11:12	145	00:01:59	00:01:26	00:04:21	00:05:06
Mar-17	0:03:10	0:01:45	0:07:01	0:11:56	159	00:03:19	00:01:34	00:05:11	00:06:10
Apr-17	0:03:03	0:01:40	0:05:57	0:10:40	180	00:03:05	00:01:27	00:04:14	00:05:29
May-17	0:02:46	0:01:32	0:06:22	0:10:40	194	00:03:16	00:01:13	00:04:01	00:05:38
Jun-17	0:03:07	0:01:35	0:06:18	0:11:00	186	00:03:16	00:01:28	00:03:42	00:05:33
Jul-17	0:02:43	0:01:47	0:06:36	0:11:06	206	00:03:09	00:01:34	00:04:43	00:06:02
Aug-17	0:03:09	0:01:23	0:06:32	0:11:04	220	00:04:50	00:01:07	00:03:55	00:06:36
Sep-17	0:03:08	0:01:39	0:06:44	0:11:31	157	00:05:41	00:01:43	00:04:13	00:07:55
Oct-17	0:03:00	0:01:38	0:05:24	0:10:02	166	00:04:22	00:01:25	00:03:12	00:05:37
Nov-17	0:02:38	0:01:35	0:06:47	0:11:00	162	00:02:09	00:01:20	00:04:18	00:05:10
Dec-17	0:02:37	0:01:24	0:05:47	0:09:47	115	00:02:58	00:00:58	00:04:01	00:05:09
Jan-18	0:03:15	0:01:36	0:06:51	0:11:42	119	00:03:25	00:01:26	00:04:20	00:06:00
Feb-18	0:02:22	0:01:20	0:05:43	0:09:25	122	00:03:29	00:01:15	00:03:03	00:04:55
Mar-18	0:02:55	0:01:21	0:06:31	0:10:47	178	00:03:27	00:01:14	00:03:37	00:05:10
Apr-18	0:03:23	0:01:24	0:06:26	0:11:13	146	00:04:53	00:01:21	00:05:00	00:07:04
May-18	0:03:30	0:01:15	0:05:43	0:10:28	202	00:05:54	00:01:12	00:04:20	00:07:03
Jun-18	0:02:43	0:01:24	0:07:06	0:11:13	201	00:03:11	00:01:10	00:05:32	00:06:47
Jul-18	0:03:43	0:01:26	0:07:45	0:12:54	291	00:05:51	00:01:37	00:05:45	00:08:40
Aug-18	0:03:26	0:01:18	0:07:14	0:11:58	257	00:05:23	00:01:06	00:04:51	00:07:46
Sep-18	0:03:01	0:01:18	0:06:14	0:10:32	163	00:04:17	00:01:30	00:04:01	00:05:57
Oct-18	0:03:09	0:01:13	0:07:00	0:11:22	188	00:04:15	00:01:15	00:04:38	00:07:29
Nov-18	0:03:07	0:01:17	0:07:13	0:11:37	205	00:03:57	00:00:57	00:05:08	00:06:52
Dec-18	0:02:58	0:01:08	0:06:27	0:10:33	120	00:03:15	00:00:57	00:04:04	00:05:29

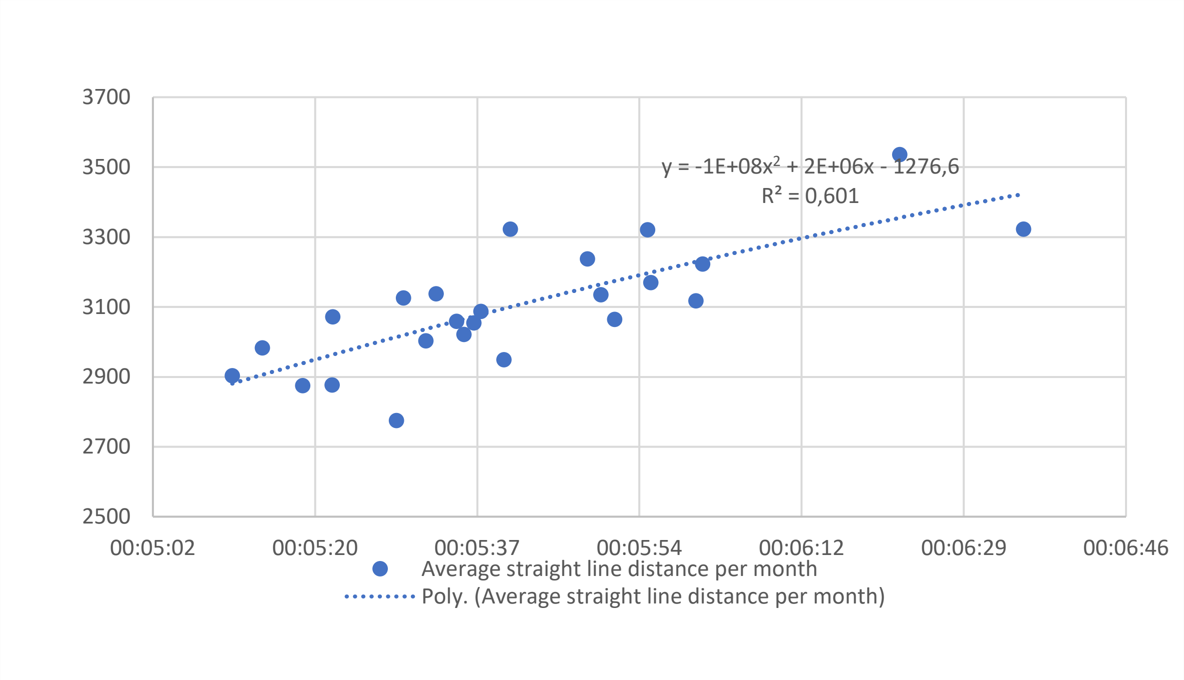

Figure B 27: Monthly average drive time for available vehicles in 2017-2018 to straight line distance

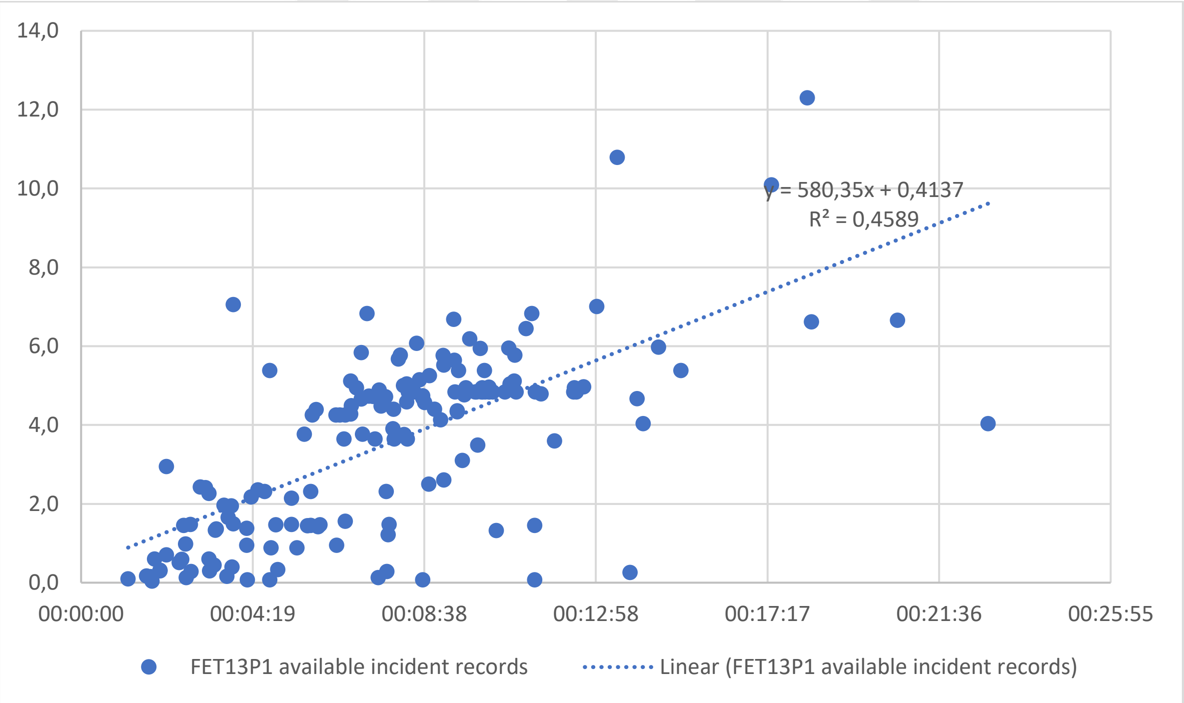

Figure B 28: FET13P1 available vehicles straight line distance (miles) compare to drive time in 2017-2018

Table B 11: Available pumping appliances in 2017-2018

			2017 year						*2018 year*					
Callsign	*Fire Station*	*Crew status*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*No of records*	*Avg. straight line distance*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*No of records*	*Avg. straight line distance*
FET01P1	MANSFIELD	wds	0:02:27	0:01:58	0:05:26	0:09:51	718	2723,10	0:02:35	0:01:56	0:05:43	0:10:13	815	2807,99
FET02P1	BLIDWORTH	oc	0:03:06	0:05:56	0:05:10	0:14:11	151	2979,55	0:03:04	0:04:59	0:07:18	0:15:22	237	4002,19
FET03P1	LONDON ROAD	wds	0:02:23	0:02:23	0:05:16	0:10:02	1279	2776,79	0:02:08	0:02:18	0:04:57	0:09:23	1041	2424,56
FET03P2	LONDON ROAD	wds	0:02:36	0:02:21	0:04:41	0:09:39	982	2406,57	0:02:33	0:02:14	0:04:26	0:09:13	852	2030,47
FET05P1	ASHFIELD	wds	0:02:24	0:02:03	0:05:57	0:10:25	601	3577,86	0:02:28	0:01:55	0:06:13	0:10:36	721	3419,93
FET05P2	ASHFIELD	oc	0:03:47	0:06:54	0:05:27	0:16:08	103	2762,80	0:03:27	0:06:10	0:06:00	0:15:38	157	2554,20
FET06P1	EDWINSTOWE	wds	0:02:11	0:02:10	0:06:18	0:10:39	666	4944,28	0:02:34	0:01:58	0:08:25	0:12:57	353	5941,30
FET07P1	WARSOP	oc	0:02:36	0:06:58	0:05:20	0:14:54	118	2966,03	0:03:03	0:06:16	0:05:42	0:15:00	126	3048,25
FET08P1	WORKSOP	wds	0:02:19	0:02:14	0:05:34	0:10:07	618	3486,46	0:02:24	0:02:04	0:06:07	0:10:34	650	3842,82
FET08P2	WORKSOP	oc	0:02:51	0:07:31	0:03:55	0:14:18	146	2220,90	0:03:08	0:06:44	0:04:20	0:14:12	194	2444,72
FET10P1	HARWORTH	oc	0:02:17	0:06:53	0:05:00	0:14:11	199	2286,71	0:02:07	0:05:59	0:05:52	0:13:58	228	2672,21
FET11P1	MISTERTON	oc	0:02:54	0:06:18	0:07:12	0:16:25	33	3545,73	0:02:19	0:05:24	0:07:07	0:14:51	43	3040,66
FET12P1	RETFORD	wds	0:02:32	0:02:08	0:07:29	0:12:09	349	4563,10	0:03:19	0:02:00	0:08:36	0:13:56	382	5213,74
FET12P2	RETFORD	oc	0:02:14	0:08:42	0:04:20	0:15:16	98	3579,22	0:03:14	0:06:53	0:05:15	0:15:21	101	3216,56
FET13P1	TUXFORD	oc	0:02:51	0:06:18	0:07:50	0:16:59	89	5986,14	0:03:05	0:04:45	0:07:55	0:15:45	78	5446,04
FET14P1	SOUTHWELL	oc	0:03:51	0:07:38	0:06:14	0:17:43	44	3538,07	0:03:01	0:08:14	0:07:08	0:18:24	36	3432,99
FET15P1	COLLINGHAM	oc	0:04:34	0:05:20	0:08:45	0:18:39	49	7195,40	0:05:56	0:05:06	0:08:54	0:19:57	56	7057,31
FET16P1	NEWARK	wds	0:02:23	0:02:02	0:06:59	0:11:23	410	4292,93	0:02:43	0:02:06	0:08:34	0:13:22	456	5355,15
FET16P2	NEWARK	oc	0:02:32	0:07:02	0:05:33	0:15:07	110	2923,89	0:03:49	0:06:40	0:06:50	0:17:19	141	2690,41
FET17P1	BINGHAM	oc	0:03:12	0:06:08	0:07:04	0:16:23	94	4602,67	0:02:53	0:05:41	0:08:00	0:16:34	125	4202,26
FET19P1	WEST BRIDGFORD	wds	0:02:21	0:02:09	0:06:47	0:11:17	535	3665,42	0:02:06	0:02:09	0:07:02	0:11:17	723	3900,05
FET20P1	STOCKHILL	wds	0:02:12	0:02:06	0:05:31	0:09:49	1136	2801,58	0:01:58	0:01:56	0:05:16	0:09:10	1226	2463,28
FET20P2	STOCKHILL	wds	0:02:33	0:02:12	0:05:18	0:10:02	757	2657,04	0:02:44	0:02:02	0:05:29	0:10:15	881	2528,11
FET23P1	STAPLEFORD	oc	0:02:21	0:04:40	0:03:23	0:10:25	113	1694,12	0:02:16	0:04:51	0:03:29	0:10:36	103	1694,98
FET24P1	EASTWOOD	oc	0:02:20	0:05:24	0:03:17	0:11:01	82	1512,60	0:02:20	0:04:23	0:03:49	0:10:31	125	1541,06
FET25P1	HUCKNALL	oc	0:02:16	0:07:09	0:04:05	0:13:30	187	2226,47	0:02:24	0:06:24	0:04:45	0:13:34	237	2309,51

FET26P1	ARNOLD	wds	0:02:10	0:02:14	0:04:41	0:09:05	895	2597,32	0:02:10	0:02:09	0:05:10	0:09:28	983	2796,04
FET27P1	CARLTON	wds	0:02:15	0:02:19	0:05:30	0:10:04	520	3192,72	0:02:20	0:02:11	0:05:57	0:10:28	495	3303,38
FET28P1	EAST LEAKE	oc	0:02:10	0:06:37	0:03:55	0:12:42	53	1980,36	0:02:20	0:05:37	0:05:13	0:13:10	51	2010,62
FET29P1	HIGHFIELDS	wds	0:02:21	0:02:05	0:05:45	0:10:11	761	2598,42	0:02:06	0:01:58	0:06:05	0:10:09	881	2810,60

Table B 12: Mobile Available pumping appliances in 2017-2018

			2017 year					*2018 year*				
Callsign	*Fire Station*	*Crew status*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*No of records*	*Avg. Call handling time*	*Avg. Crew time*	*Avg. Drive time*	*Avg. Response time*	*Nor of records*
FET01P1	MANSFIELD	wds	0:03:08	0:01:32	0:06:35	0:11:15	123	0:02:51	0:01:09	0:07:01	0:11:01	121
FET02P1	BLIDWORTH	oc	0:05:03	0:01:50	0:07:06	0:13:59	15	0:03:12	0:01:12	0:09:37	0:14:00	22
FET03P1	LONDON ROAD	wds	0:03:09	0:01:50	0:05:42	0:10:41	277	0:03:11	0:01:35	0:06:09	0:10:54	228
FET03P2	LONDON ROAD	wds	0:02:50	0:01:35	0:05:37	0:10:02	208	0:02:55	0:01:26	0:05:32	0:09:53	198
FET05P1	ASHFIELD	wds	0:03:11	0:01:32	0:07:06	0:11:48	77	0:03:39	0:01:19	0:06:49	0:11:47	120
FET05P2	ASHFIELD	oc	0:05:52	0:01:36	0:05:15	0:12:43	9	0:06:11	0:00:33	0:06:49	0:13:33	15
FET06P1	EDWINSTOWE	wds	0:02:39	0:01:33	0:07:58	0:12:09	140	0:04:32	0:01:25	0:07:57	0:13:53	85
FET07P1	WARSOP	oc	0:02:34	0:01:41	0:05:15	0:09:30	11	0:03:30	0:00:57	0:07:38	0:12:05	16
FET08P1	WORKSOP	wds	0:02:50	0:01:21	0:06:54	0:11:06	75	0:03:06	0:01:09	0:07:15	0:11:31	93
FET08P2	WORKSOP	oc	0:02:46	0:01:41	0:03:31	0:07:59	12	0:06:51	0:00:41	0:07:21	0:14:53	11
FET10P1	HARWORTH	oc	0:02:28	0:02:28	0:09:29	0:14:24	9	0:06:07	0:01:45	0:08:46	0:16:38	24
FET11P1	MISTERTON	oc	0:05:31	0:00:08	0:04:04	0:09:43	1	0:00:00	0:00:00	0:00:00	0:00:00	0
FET12P1	RETFORD	wds	0:02:34	0:01:21	0:09:47	0:13:42	44	0:03:43	0:01:20	0:07:59	0:13:02	58
FET12P2	RETFORD	oc	0:01:44	0:03:43	0:06:11	0:11:38	6	0:08:45	0:00:47	0:07:14	0:16:46	4
FET13P1	TUXFORD	oc	0:04:21	0:00:36	0:26:02	0:30:59	1	0:05:01	0:01:41	0:08:45	0:15:27	5
FET14P1	SOUTHWELL	oc	0:09:36	0:01:11	0:06:47	0:17:34	4	0:03:31	0:00:58	0:08:07	0:12:35	4
FET15P1	COLLINGHAM	oc	0:04:33	0:01:00	0:09:39	0:15:12	7	0:04:59	0:01:12	0:10:01	0:16:11	18
FET16P1	NEWARK	wds	0:03:58	0:01:16	0:07:30	0:12:43	45	0:04:16	0:01:17	0:09:14	0:14:47	87
FET16P2	NEWARK	oc	0:04:50	0:01:22	0:07:52	0:14:04	9	0:07:41	0:00:52	0:08:58	0:17:30	9
FET17P1	BINGHAM	oc	0:05:03	0:01:34	0:06:25	0:13:02	17	0:04:43	0:01:24	0:08:11	0:14:18	16
FET19P1	WEST BRIDGFORD	wds	0:02:39	0:01:26	0:06:48	0:10:53	90	0:02:59	0:01:11	0:07:30	0:11:40	127

FET20P1	STOCKHILL	wds	0:02:37	0:01:40	0:05:58	0:10:14	253	0:02:26	0:01:21	0:05:53	0:09:41	230
FET20P2	STOCKHILL	wds	0:02:33	0:01:28	0:06:29	0:10:30	126	0:03:18	0:01:12	0:06:30	0:11:00	157
FET23P1	STAPLEFORD	oc	0:04:17	0:01:28	0:04:37	0:10:21	39	0:02:34	0:02:06	0:06:16	0:10:56	67
FET24P1	EASTWOOD	oc	0:04:31	0:02:46	0:10:30	0:17:46	6	0:01:55	0:01:23	0:06:28	0:09:46	16
FET25P1	HUCKNALL	oc	0:03:38	0:01:53	0:05:31	0:11:01	24	0:03:41	0:01:18	0:07:21	0:12:20	41
FET26P1	ARNOLD	wds	0:02:41	0:01:40	0:05:42	0:10:03	168	0:02:21	0:01:35	0:06:15	0:10:11	209
FET27P1	CARLTON	wds	0:02:32	0:01:33	0:06:48	0:10:53	118	0:02:55	0:01:28	0:06:56	0:11:19	100
FET28P1	EAST LEAKE	oc	0:05:33	0:01:56	0:07:24	0:14:53	5	0:09:16	0:00:30	0:04:15	0:14:01	1
FET29P1	HIGHFIELDS	wds	0:02:51	0:01:39	0:05:42	0:10:12	128	0:02:39	0:01:12	0:06:26	0:10:17	131

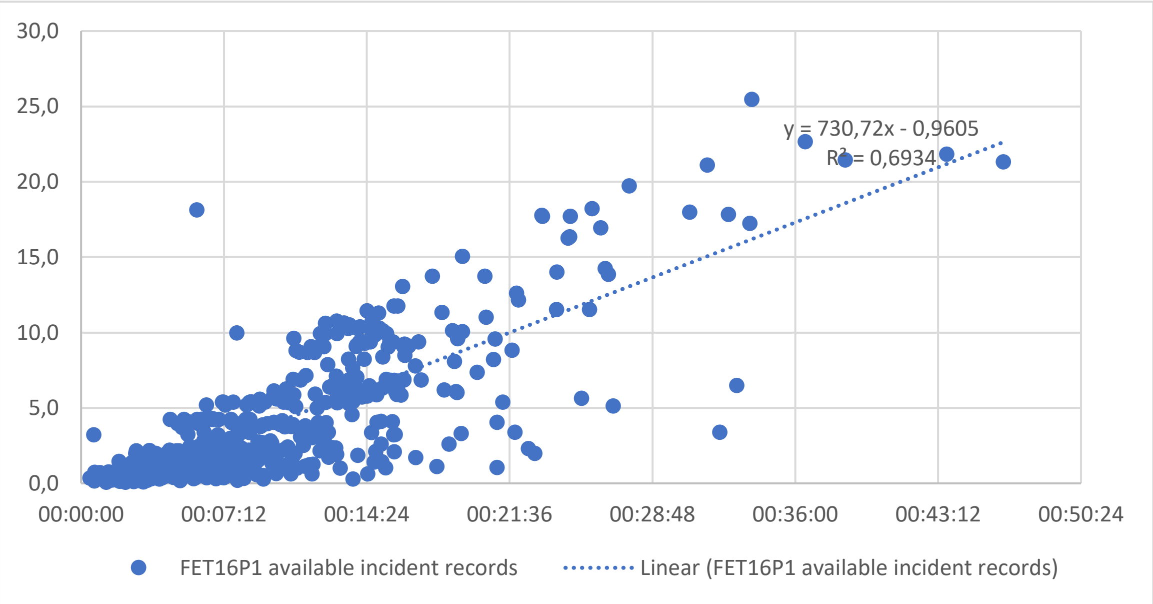

Figure B 29: FET16P1 available vehicles straight line distance (miles) compare to drive time in 2017-2018

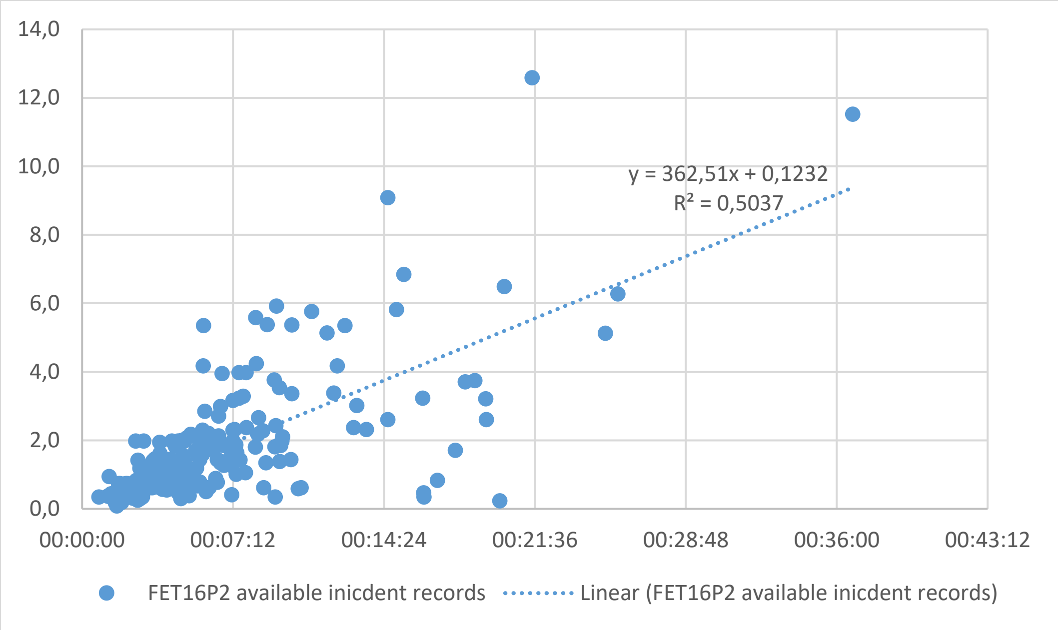

Figure B 30: FET16P2 available vehicles straight line distance (miles) compare to drive time in 2017-2018

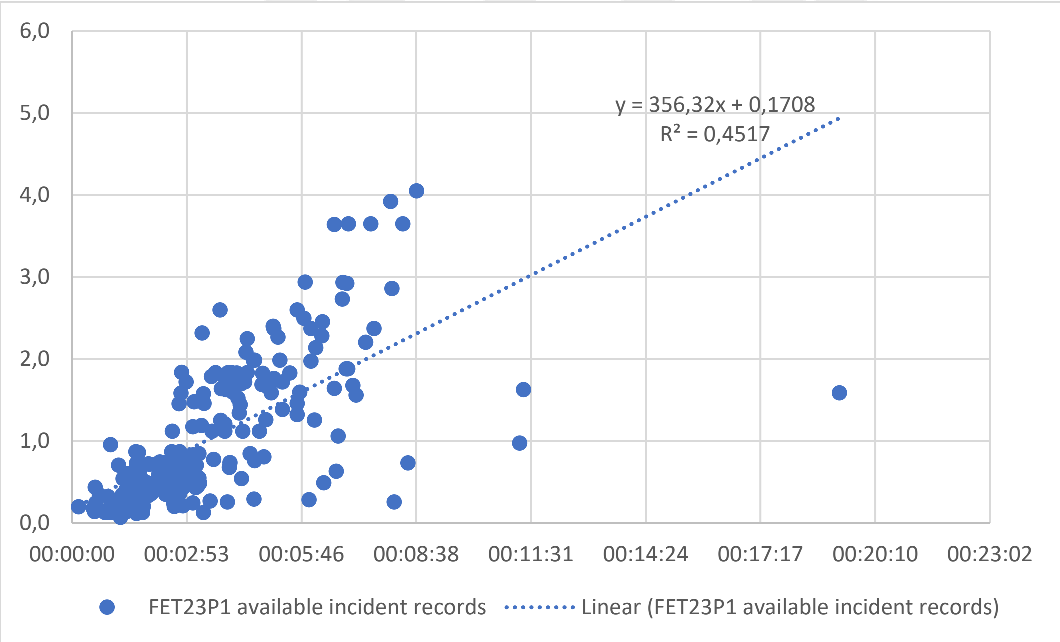

Figure B 31: FET23P1 available vehicles straight line distance (miles) compare to drive time in 2017-2018

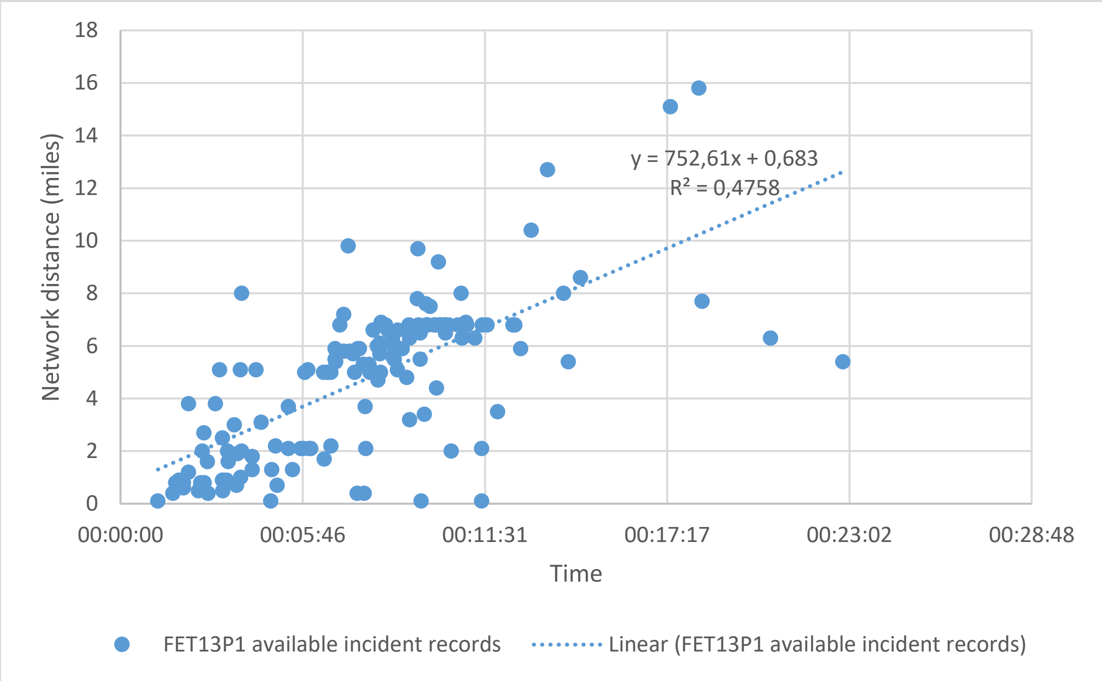

Figure B 32: FET13P1 available vehicles network distance (miles) compare to drive time in 2017-2018

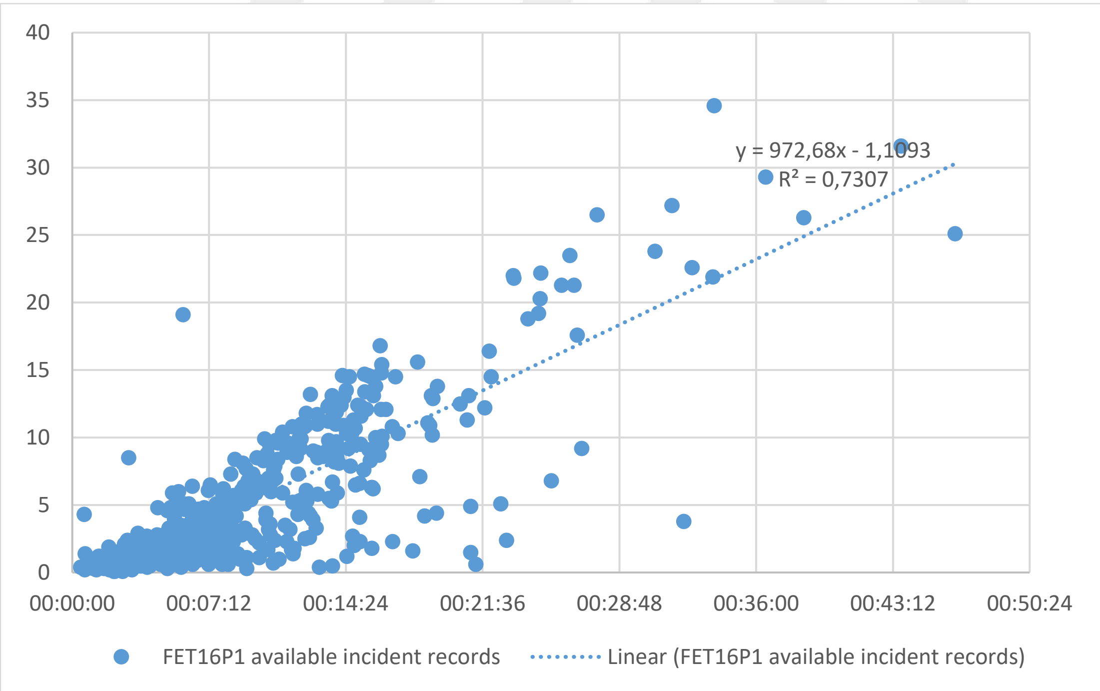

Figure B 33: FET16P1 available vehicles network distance (miles) compare to drive time in 2017-2018

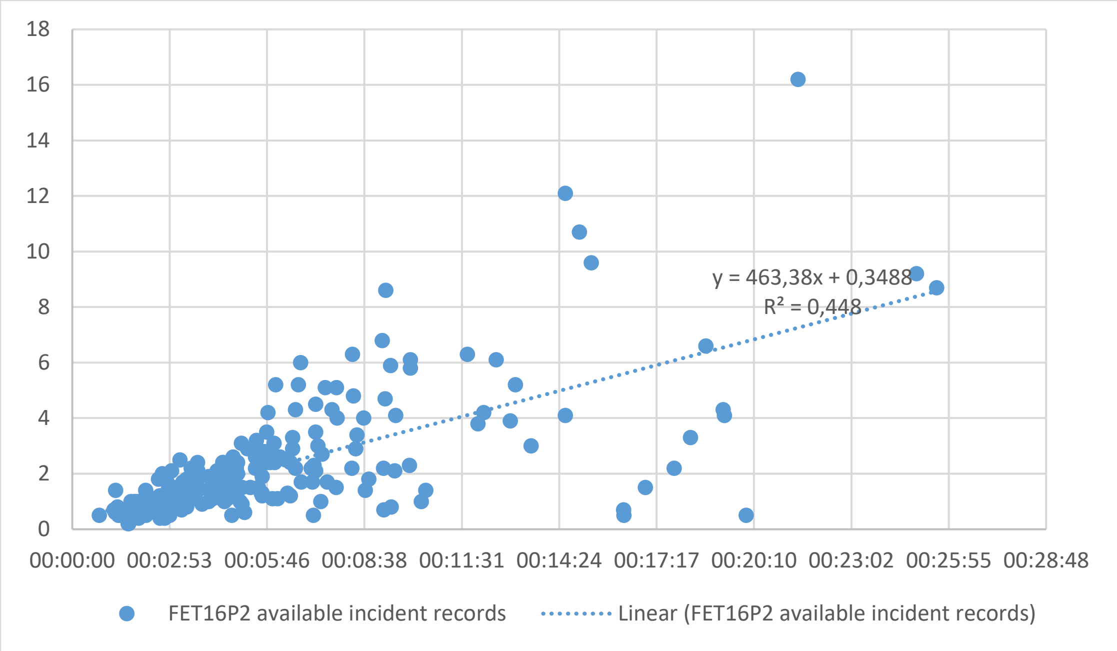

Figure B 34: FET16P2 available vehicles network distance (miles) compare to drive time in 2017-2018

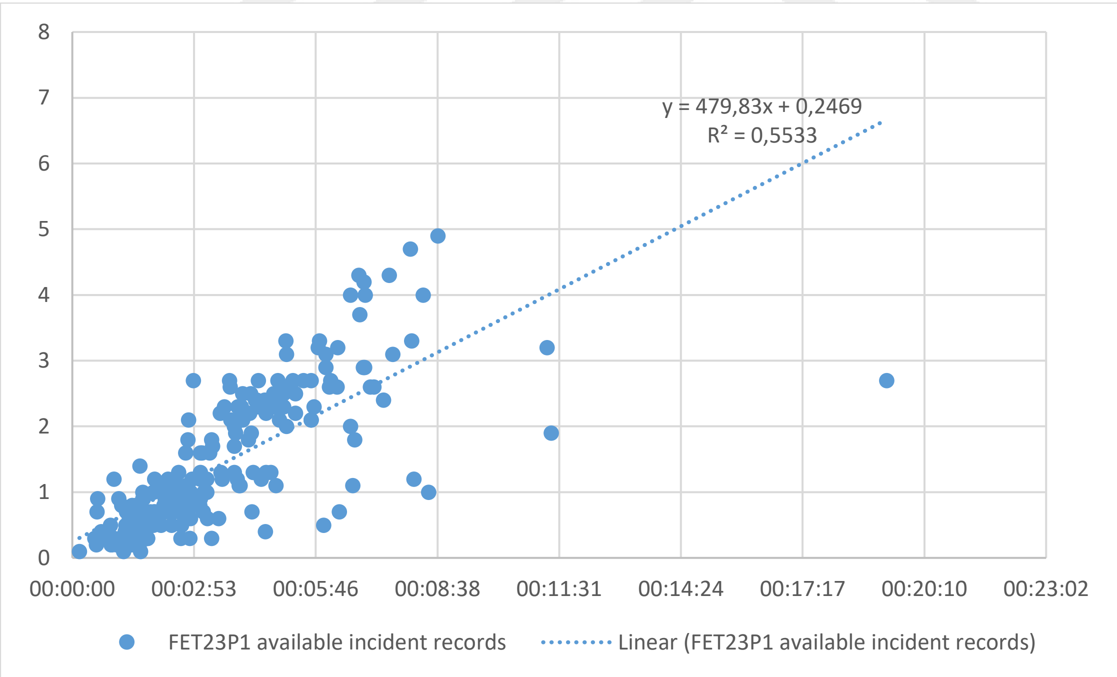

Figure B 35: FET23P1 available vehicles network distance (miles) compare to drive time in 2017-2018

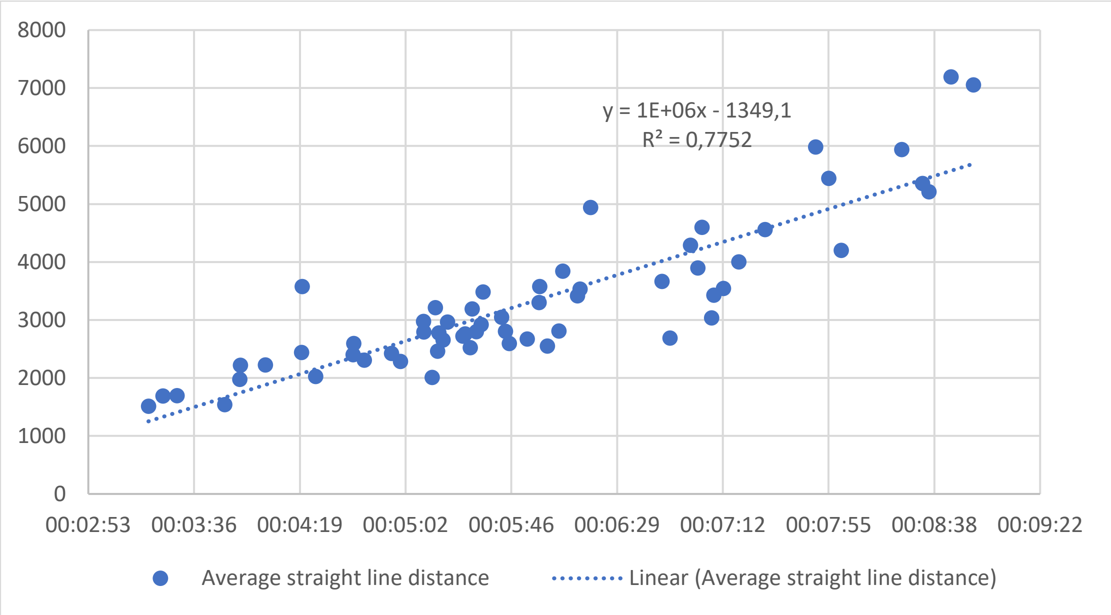

Figure B 36: Average drive time for available vehicles in 2017-2018 according to pumping appliance to average straight-line distance