ANALYSIS AND MODELLING OF SOCIAL HOUSING REPAIR AND MAINTENANCE COSTS: A UK CASE STUDY

ABSTRACT

Effective use of resources for maintaining social housing has long been a common goal of public bodies across the world. However, maintenance cost data is quintessentially sensitive and thus difficult to obtain, rendering the dearth of empirical maintenance cost studies on social housing. This research investigates the complexities of repair and maintenance (R&M) associated with social housing and specifically, develops benchmark indicators for such works. The ambition being to provide a knowledge sharing analysis of costs expended that allows a social housing provider to learn from past works undertaken with a view to optimising future practice. A mixed philosophical approach is adopted that combines elements of both pragmatism and interpretivism. A case study and participant action researcher (PAR) strategy is adopted where the lead researcher is employed within a repairs and maintenance (R&M) department of a UK Housing Association. Longitudinal quantitative R&M cost data is analysed using summary statistical, regression analysis and performance statistics (to measure predictive accuracy). Focus groups are held with housing practitioners and the cross-sectional qualitative discourse is analysed using content analysis to explain emergent patterns and trends accrued form the quantitative analysis conducted. This research identified that R&M works for a UK Housing Association follow a non-parametric distribution that is heavily positively skewed. Housing Associations without sufficient planned investment will see more sporadic distributions leading to less cost certainty. Furthermore, linear regression analysis provides an accurate fit of the cumulative R&M spend with very little deviation between actual and predicted R&M costs; hence, accurate forecasting is possible for Housing Associations. Finally, the sub-categorisation of works packages has indicated that certain work packages expend greater funds (often considered as being outlier costs) than others but linear regression models did not fit all sub-categorisations accurately. This research presents a unique insight into R&M costs incurred on social housing by a UK Housing Association to provide a vignette of contemporary practice and costs incurred. The work proves useful to housing associations, contractors and policy makers who seek to optimally balance cost and service delivered for residents.

KEYWORDS

UK Social Housing, Repairs and Maintenance, Asset Management, Cost, Cross Comparative Analysis, Statistical Analysis, Linear Regression

1. INTRODUCTION

The traditional asset management process involves maximising the potential of a property portfolio through forward thinking, practical planning and repair and maintenance (R&M) cost prediction (Scarrett and Wilcox 2018; Au-Yong *et al.*, 2019). However, Larkin (2000) proffers that asset management in social housing encapsulates a process of ensuring the housing stock meets both current and future needs and standards in the most efficient way. Furthermore, Gruis and Nieboer (2004) explain that asset management for a social housing provider can be a task orientated process whereby the existing housing stock and tenants' needs take priority. A clear definition of asset management for a social housing provider is therefore obfuscated for UK social housing providers; a state of incertitude further exacerbated after a decade of substantial sector reform (Higham and Stephenson 2014) e.g., the Labour government's 2001 manifesto commitments to eradicate sub-standard housing by 2010 (Arkani, 2005). In 2003, the government incentivised Local Authorities to outsource the R&M of their assets (Hetherington, 2003). In response to these reforms, research by Albanese (2007) observed that social housing providers have progressively transmuted into a more market orientated approach to asset management and therefore, align with the traditional asset management definition proposed by Scarrett and Wilcox (2018). Conversely, Morrison's (2013) investigative study of three London based housing associations found that one organisation was still approaching asset management with the more traditional, task-based approach. Reasons for this were premised upon an entrenched belief that disposing of property to create cash flows opposed the organisation's ethos and detracted from the core goal of maximising the number of low cost housing units (*ibid*).

The prevailing discourse on definitions apart, Priemus *et al.* (1999) explains that technical management is a key aspect of social housing asset management that encapsulates the process of R&M. Technical management is quintessentially important for engendering social equality and augmenting economic performance because substandard housing is linked to occupants' indigent health and diminutive educational attainment which can manifest as reduced labour mobility and productivity (Hakim, 2004). R&M constitutes nearly 59% of local authorities' total construction work by value, which in turn makes up over 28% of all construction work (Arkani, 2005). Furthermore, according to Inside Housing's annual analysis of 218 housing associations, spend on repairs increased from £3.25bn in 2017/18 to 3.51bn in 2018/19 – with maintenance costs also rising by 13% over the same timeframe (Inside Housing, 2020). Evidently, the scale of R&M costs are appreciable and in the increase. If social housing providers are to achieve value for money their R&M strategies must be streamlined (Tucker *et al.,* 2014).

Given the prevailing context, this research aims to explore the complexities of R&M costs associated with social housing in the UK. Previous research has attempted to estimate such costs (cf. Alshibani and Hassanain, 2018) or predict them using a survey strategy (cf. Weerasinghe *et al.,* 2020) but notably, neither study used actual R&M data – most likely due to the commercially sensitive nature of financial data. Hence, this work investigates two of the three most common work streams provided within social housing over a 12-month period viz: 1) routine repairs; and 2) non-safety critical gas and heating servicing and routine repairs. The findings are then presented to technical experts working within the participating case study organisation to further elucidate upon and explain the statistical trends and analysis conducted. Analysis of this qualitative discourse generated could then be used as a basis for engendering future R&M cost efficiencies. Associated objectives are to: further sub-categorise the work streams to conduct cross comparative statistical analysis to gain greater insight into cost occurrences; conduct cumulative month-on-month regression to enable future forecast predictions; and ensure that the provider is securing value for money on works undertaken which is essential for residents' quality of life.

2. A REVIEW OF SOCIAL HOUSING IN THE UK

Social housing provisions are essential to prevent widespread homelessness and poverty in society (Reeves 2015), and the UK has traditionally played a pioneering role in delivering social housing (Stephens *et al.* 2003). Enabling acts of parliament such as the Homelessness Act 2002 encouraged social housing providers to adopt a more assertive approach to tackling homelessness. Post 2003, the reduction in official homelessness numbers can be described as remarkable and by the end of 2006, homelessness acceptances had fallen by 50% (Pawson 2007). In England, social housing is predominantly provided by the Council/Local Authority, an Arm's Length Management Organisation (ALMO) or Housing Association (Coupar 2009). Until the 1990's, over 90% of social housing was provided by Local Authorities (Gibb and Trebeck 2009). However, with the introduction of the Housing Act 1988, Housing Associations were freed financially by excluding their new tenancies from statutory rent protection and could borrow money privately to supplement government grants awarded (Schmickler and Park 2013). Local Authorities relinquished further responsibility of their housing stock in 2003 when the government incentivised outsourcing R&M to ALMO's (Arkani 2005). The first UK social housing ALMO was launched in 2010 and within eight years 70 organisations had been established in 66 Local Authorities managing over one million social homes (Cole and Powell 2010).

Social housing tenure has radically changed since the 1990's. In the 20 years before 2008 more than 1.3 million homes were transferred from Local Authorities to Housing Associations, creating approximately 250 new Housing Associations in the process (Pawson and Smith 2009). In 1991, 87% of all social housing was rented from Councils whereas in 2019 this figure has more than halved to 39% (MHCLG 2020). Figure 1 illustrates this significant change in social housing provision. Since the 1980's, growing concerns have been expressed regards the conditions of social housing stock (Cooper and Jones 2007). In 2000, the Decent Home Standard (DHS) was introduced as the government recognised a backlog of R&M works (estimated at £19 billion) was causing 1.6 million homes (39% of all social housing at the time) to be classified as *non-decent* (National Audit Office 2010). Where a Local Authority had insufficient funds to meet the new DHS they were advised to relinquish management of R&M to either: 1) an ALMO; or 2) a Private Finance Initiative (PFI) provider; or 3) a Housing Association (following a tenant ballot) (National Audit Office 2010).

<Insert Figure 1 about here>

Housing Associations, who are becoming the predominant provider of social housing in the UK, have responsibility to create long-term business plans to meet new governance whilst remaining financially viable (Gibb and Nygaard 2006). The government expects Housing Associations to fund these improvements at their own expense and at no additional cost to the taxpayer (Morrison 2013). Consequently, Housing Associations must implement their own asset management strategies in response to changing government regulation - an area with scant academic attention (Gruis *et al.* 2004). However, Morrison (2013) reviews how three London based Housing Associations implement asset management in response to the DHS and found that the Housing Associations were either selling assets to fund the DHS or completing the least amount of repair possible with existing rent income on retained assets. Despite the DHS challenging Housing Associations to change their unsustainable asset management perspective, it has been successful at increasing the number of decent homes. In 2001 37.6% of all social housing was considered non-decent whereas in 2019 this proportion reduced to 1.8% (MHCLG, 2020).

2.1 Repair and Maintenance

Wordsworth (2001) explains that social housing maintenance can be classified into two dichotomous groups viz: 1) *responsive* (otherwise known as 'corrective') - where faults are repaired as and when they are reported upon ; and 2) *cyclical or planned preventative* - where fault occurrence is predicted and preventative action is taken before the fault occurs (particularly on 'safety critical' items such as gas servicing) (Sharp and Jones, 2012). Executing such maintenance is crucial to tenant satisfaction and concurrently improves the market position of the asset portfolio (Gruis *et al.* 2005). Historically, maintenance was mainly directed at conforming to regulation whereas contemporary practice seeks to attain and preserve tenant satisfaction as a principal priority (cf. Van Mossel and Van de Valk 2006); where the latter approach hence, seeks to exceed the basic conformance standards. The Home Standard 2012 is the foremost regulation that covers R&M for social housing in the UK. However, the document only briefly references the R&M service, and instead places emphasis on meeting the requirements already set out within the DHS. Kempton (2006) explains that social housing providers will therefore revise their R&M policy so that works which aid the satisfaction of the DHS take priority vis-à-vis the Home Standard 2012. Importantly, guidance provided offers a generic framework of principles only and does not specify operational good practice with which to implement optimum R&M.

It is difficult to accurately quantify the total annual R&M spend in the UK due to the variety of providers involved and sector size (estimated to over 5% of Gross Domestic Product or £36 Billion in 1996 (El-Haram and Horner, 2002)). However, there are notable variations in R&M cost estimates quoted. For example, Cooper and Jones (2007) estimate R&M costs to be in the region of £1 billion per annum. The Credo Research Paper (2011) estimated that in 2011 Local Authorities, Registered Providers (Housing Associations) and ALMO's will spend £13 billion on R&M to improve their existing housing stock (as cited by Tucker *et al*., 2014). This £13 billion estimation covers every provider whereas The National Housing Federation 2020 and Inside Housing 2020 explain Housing Associations alone will spend £3.5bn on R&M per year, including major repairs, planned and routine maintenance. The differences in estimations are likely to be caused by the inclusion or exclusion of certain R&M work such as planned renovation programs (i.e., window and door improvements) and other works such as cyclical electrical inspections.

There is little consistency in the delivery of R&M services: some are outsourced; others are retained in house via a direct labour organisation (DLO); and others use a mixture of both (Tucker *et al.* 2014). It is difficult to establish which option is more effective (Yik and Lai, 2005) as the success is often dependent on the individual parties involved. In reality, the dearth of proper maintenance data often makes it difficult to investigate performance of maintenance work (Lai, 2015). Thus, not many empirical studies have been conducted to analyse maintenance data in detail. Among the limited volume of such studies, correlation analyses were used in the data analysis of Lai and Yik (2012a; 2012b), where performance curves were also developed for benchmarking purposes. Using statistical, regression and correlation analyses, Lai (2012) developed statistical benchmarks and regression models of demand, manpower and performance of maintenance work.

Given that cost data is sensitive, it is even more difficult to collect maintenance cost data for analysis. Nevertheless, some studies that managed to collect detailed maintenance cost data resulted in useful findings. For instance, the study of Lai et al. (2008) revealed that the extent of maintenance outsourcing bore little correlation with maintenance cost or building income. According to the findings of Lai and Yik (2008), a larger building can enjoy a lower unit maintenance cost. Preventive maintenance and corrective maintenance are interrelated; Lai et al. (2009) identified factors that affect the cost relation between preventive maintenance and corrective maintenance. In the study of Róka-Madarász et al. (2016), data mining techniques and analysis methods including correlation analysis and one-way ANOVA were used to determine differences in annual operation and maintenance costs by age, number of users and heritage. Recently, Kwon et al. (2020) completed a study where a model adopting case-based reasoning and a genetic algorithm was developed to predict the maintenance cost for aging residential buildings. Evidently, research on social housing R&M costs remains limited. Total expenditure for social housing R&M is not clearly defined and delivery of R&M work is equally complex. This research therefore seeks to provide some clarity into how a particular housing association approaches R&M and what levels of cost they experience throughout a typical year.

3. METHODOLOGY

This research epistemology adopts a mixed philosophical approach that combines elements of both pragmatism (Kaushik and Walsh 2019) and interpretivism (Roberts *et al.* 2019); where pragmatism uses words and thought as tools to augment prediction and interpretivism involves the researcher interpreting the evidence and findings emanating from the study. Pragmatism is extensively used throughout literature, for example: Pansiri, (2005) adopted this philosophy to research strategic alliances in tourism; Goldkuhl (2012) cross compared pragmatism against interpretivism in qualitative information systems research; and Kelly and Cordeiro (2020) applied pragmatism to organisational processes. Interpretivism has also been commonly adopted within literature, for example: Al-Saeed *et al.* (2019) used interpretivism to review the existing literature on building information modelling (BIM) to explore extant literature on the applications of BIM digital objects; Sepasgozar *et al.* (2020) conducted a systematic review of additive manufacturing applications within the construction industry; and Neman *et al.* (2020) reviewed Industry 4.0 applications in the construction industry using bibliometric analysis. Interpretivism is however, prone to an individual researcher's subjective bias which can influence the interpretation of literature, verbal discourse and the analysis results derived (Alharahshehl and Pius 2020). Combining interpretivism with pragmatism will guard against researcher introduced bias and provide a practical and meaningful insight into the costs associated with R&M for social housing.

From an operational perspective multiple strategies will be adopted to pursue the data collection phase of this research. Primarily a case study strategy will be adopted where the lead researcher is embedded within a R&M department of a non-profit making Housing Association. Consequently, the lead researcher will undertake participant action research (PAR) that will strive to analyse longitudinal quantitative data for domestic property R&M and involve: 1) routine (corrective) repairs; and 2) non-safety critical gas and heating routine repairs across 3,850 properties in the West Midlands conurbation, UK. All works conducted consisted of routine maintenance only and on a disparate property portfolio where each home aged anywhere between 10 to 200 years old. Such diversity precludes a cross comparative cost analysis between individual properties but the purpose of this work was to examine costs across the entire property portfolio. The organisation was founded in 1900 and the R&M department was later established in the 1920's. The branch of the organisation responsible for managing and delivering R&M is also based in the West Midlands, it employs fifty-two workers and has an annual turnover is circa £5 million per annum (UK Sterling). The delivery model for the service is predominantly DLO with minimal outsourcing of specialist trades. To analyse primary quantitative and qualitative data emerging from this case study, a three stage 'waterfall' process was adopted viz: 1) data mining was conducted to better understand the data set and identify any outliers that may be present; 2) a cumulative month-on-month bi-variate linear regression was calculated for costs arising from individual categories of R&M works conducted as well as the entire data set (across all categories). Performance statistics were then generated to measure model(s) accuracy; and 3) focus groups with R&M professionals (employed by the case study organisation) were then convened. Analytical findings emanating from this work were presented to the focus group members who were subsequently invited to comment upon the emergent statistics and trends. Such as approach gave a fuller and deeper understanding of R&M costs and the reasons for any trends apparent within.

4. DATA ANALYSIS

4.1 Data Mining

Quantitative cost data accrued for each of the aforementioned work streams of R&M works was analysed to determine thematic sub-categories of expenditure occurring to enable a cross-comparative analysis between the sub-categories. The sub-categories chosen were based upon the National Housing Federation of rates which is an all-encompassing schedule of rate book for R&M work within social housing. In total, 14,009 data points were recorded over a 12 month period but a manual cleansing of the data was required to remove superfluous entries that had no costs relevance. It was identified that 621 erroneous data observations were recorded viz: order duplication; order raised in error; ICT issues where labour or stock cost does not populate on the system; and operative error. Removal of these erroneous data points left a total of 13,388 valid R&M cost instances for analysis within a range of £0.34 to £10,067 (UK Sterling as at December 2020).

To better understand where the costs occur, frequency clusters per sub-category were established. Initial data mining revealed that 96.58% of the data entries occurred within the £0 - £500 range but that 71.84% of the total cost occurred within the £0.01 - £1,000 range. Creating a single histogram to illustrate all data was impractical as the inherent skewness meant that many observed cost instances recorded were rendered invisible when assigned a given cost interval. Hence, to overcome this issue, two histograms were created to further interrogate the cost data (i.e. £0.01 to £500.00 at £25 intervals and £501 to £10,500 at £500 intervals) – (Figure 2). Both histograms reveal a clear non-parametric distribution heavily positively skewed to the left. Figure 2a reveals that the highest proportion of data entries existed within the first cluster of £0 - £25 (e.g. 41% or frequency (*f*) =5,304). Similarly, Figure 2b illustrates that 61% of data entries which are > £500 exist within the first cluster of £501 - £1,000 with a frequency (*f*) = 281.

<Insert Figure 2 about here>

Non-parametric summary statistics were calculated for each sub-category to gain greater insight and understanding of the data (Table 1). The interquartile range was much smaller than the range for each sub-category indicating that the data set may contain outliers. To identify outliers, the interquartile range (IQR) for each sub-category is multiplied by 1.5 and taken away from quartile one (Q1) and added to quartile 3 (Q3). Any data entry with a cost $< Q1 - 1.5 \times IQR$ or $> Q3 + 1.5 \times IQR$ is statistically classed as an outlier (Boslaugh, 2012). Using this equation therefore, 1,288 data entries across the categories can be classified as outliers. The average number of outliers within each category is 9% which causes a high average standard deviation of £302.03 across the sub-categories. The data therefore, has a low consistency and requires cross comparative analysis with the outliers removed.

<Insert Table 1 about here>

Box and whisker diagrams were produced and plotted onto the same chart (Figure 3) to allow detailed comparison between the sub-categories without the outliers. The 'Metal' sub-category was removed from the chart as only 2 data entries occurred over the year therefore, statistics such as IQR are meaningless. The 'Heating Systems – Installations' sub-category was also removed because it has a substantially higher average cost than all other sub-categories which obscures cross comparisons between other categories. This sub-category is also the cause of the slight discrepancy within the data distribution (Figure 2b). It can be observed that the distribution follows a skewed distribution and then at the cost bracket £2,001 - £2,500 and £2,501 - £3,000 it rises then returns to expected frequencies thereafter. If the Heating Systems – Installations sub-category is removed this slight bell-shaped bump would not occur within the distribution. That said, heating systems engineering are high cost occurrences that include periodic activities such as boiler and/or radiator replacement.

There are some clear similarities between the plots for all other categories. The mean is above the median and in some sub-categories (such as 'carpentry'), the mean lies outside of the IQR.

This is because the mean is affected by high frequencies of data which occur outside of the IQR (again illustrating skewness even with outliers removed). Other similarities are that the whiskers of each sub-category are disproportionate. The whisker which extends from Q1 to the minimum range is much shorter than the whisker that extends from Q3 to the maximum range which supports the fact that data is heavily positively skewed. This is the case in every sub-category other than 'electrical' and 'gas servicing' which have similar length whiskers, indicating that the distribution of these two sub-categories is parametric. The boxes of these two sub-categories are also much smaller than the other sub-categories which indicates the cost range is more consistent and predictable. These two sub-categories are completed by the repairs department and are classed as cyclical maintenance. These two sub-categories do not impact the distribution for all cost incurred as their IQR's still occur at the same cost levels as the other sub-categories.

<Insert Figure 3 about here>

4.2 Regression analysis

To predict future cost expenditure, a cumulative month-on-month bi-variate linear regression was calculated. Figure 4 reveals that the data points are almost perfectly linear with a coefficient or determination (R^2) value of 0.9875 thus allowing accurate short-term predictions of future cost expenditure to be made. To measure model predictive performance the mean absolute percentage error (MAPE) and mean percentage error (MPE) were calculated (Edwards, 2002). With an MAPE =13%; and a MPE = 7% predictive performance statistics illustrate that the model produced could accurately forecast future cost expenditure. Using the trend line equation $y = 120{,}298x - 104{,}877$ it can be predicted that an additional £120,297 will be spent in each of the following months after the last month of the case study. Cumulative total spend for the case study three months after the final month is therefore forecasted below:

$$y\ (cummulitive\ spend) = 120{,}298\ \times 15\ (months) - 104{,}877 =\ \ £1{,}699{,}593$$

Extending predictions past this point is not advisable since other external factors can impact upon the trend e.g. wield perturbations in global economic circumstances (Sing *et al.*, 2015); national increases in interest rates (Ren and Lin, 1996); and/or in the UK Brexit (Tetlow and

Stojanovic, 2018). Estimating the impact of these external factors beyond two to three years is problematic.

<Insert Figure 4 about here>

Bi-variate regression was then used to analyse month-by-month cost data for each sub-category to allow a cross comparative analysis between sub-categories and future predictions to be made. Figure 5 illustrates how the gradient in trend lines vary for each sub-category thus demonstrating that for certain sub-categories spend is increasing at a greater rate than others. There are six sub-categories with a monthly spend increase coefficient > £10,000, namely: roofing (= £17,292); heating systems – installations (= £17,080); carpentry (= £14,873); gas repairs (= £13,253); electrical repairs (= £13,238); and plumbing (= £12,113). These six sub-categories also have the greatest total cost per annum, but their total cost ranking is not always equal to their gradient ranking. For example, carpentry has the fifth greatest total spend (= £170,399) and the third greatest gradient (= 14,873) indicating that, if trends remain the same, carpentry's total cost will exceed gas and electrical repair spends in the future. There are other instances like this between the sub-categories such as ground and brickwork has a greater total cost than specialist treatments but a lower gradient therefore if trends remain the same specialist treatments total cost will exceed ground and brickworks total cost. The average R^2 value across the sub-categories remains at 0.93 which still indicates a strong relationship between time and cost. Using the trendline equation forecasts for percentage spends for each sub-category can be calculated. Roofing, carpentry, gas repairs, electrical repairs, heating systems – installations and plumbing have a total forecasted cumulative spend three months after the case study conclusion of £1,261,660 which contributes to 74% of total forecasted spend. Therefore, to reduce costs significantly these six sub-categories must be targeted. As expected, the total cumulative cost forecasted for carpentry is £219,532 which is higher than both gas repairs (£218,802) and electrical repairs (£208,363). However, the *y* intercept for the regression lines produced are predominantly negative for all but three sub-categories i.e., mix, electrical repairs and gas repairs (Table 2). Obtaining negative values is illogical but in this instance, it simply means that the expected cumulative cost will be less than 0 when all independent variable are set to 0.

<Insert Figure 5 and Table 2 about here>

5. FOCUS GROUP DISCUSSION OF THE FINDINGS

Following the primary data analysis, an inter-organisational focus group was convened and was attended by all key R&M staff as resident experts employed within the participating case study organisation (Table 3). The professionals were presented with the data and data analysis and asked open questions about the trends observed and the reasons for them. Qualitative responses given during the prevailing discourse were analysed using content analysis. Due to COVID restrictions, the focus group was convened on Microsoft Teams and recorded. Responses to questions posed were analysed and thematically grouped. Based upon the qualitative discourse recorded, three key emergent themes became evident; 1) confirmation that the data is as expected; 2) explanation of the data and trends; and 3) application of the data to engender a process designed to create future cost efficiencies – that is, by identifying the areas that incurred the highest costs, further investigative work could be undertaken to see how such costs could be reduced. The discussion then focused on asset management and R&M delivery which are supplementary to the findings of the literature review.

<Insert Table 3 about here>

5.1 Confirmation that the data is as expected

First, the statistical analysis conducted was presented to focus group members to determine the accuracy of predictions made and representativeness of social housing R&M costs for the organisation. When observing Figure 2 and Table 2, participant A stated that the graph is: "*responsive repairs in a nutshell*" and that when tendering for R&M contracts, costs estimates would be based on an average cost of repair from £80 to £150 maximum, which is in keeping with Table 1. Participant B reviewed Figure 4 and stated that the approximate £120,000 monthly cumulative cost increase was based upon circa 1,000 R&M jobs per month with an average job cost of £120 per job. Therefore, the *x* coefficient of the overall cumulative trend line is accurate. Participant B did however highlight that there were issues within the Housing Management System which was used as the data source. For example, "*issues with labour population on the jobs as operatives were incorrectly using the PDA*" and that "*no job costs 34p(!)* [the minimum cost recorded in the dataset]*.*" Nevertheless, the group agreed that despite these minor queries, the data was a good representation of costs for the organisation.

5.2 Explanation of the data and trends

The analysis revealed that cost data is positively skewed and that the majority of data entries exist within the very lowest cost intervals. Participant F explained this was because jobs are usually "*overhaul, 'ease and adjust' – jobs that usually do not require materials necessarily … usually it is a loose screw here or oil hinges there."* The group collectively explained examples of this across the sub-categories, for example: carpentry repairs on doors would mainly be overhaul; plumbing repairs would normally only require the tightening of leaking joints; drainage repairs would normally require the clearing of a blockage; and repairs to finishes would normally only require patching of plasterwork in small quantities. Further to this, participant C explained the cost variances using the example of an external door: "*the key is to ensure that the repair lasts 18 months as this will take the component into a new financial year… if you are sent to a job and the door is not in a great state but you can repair it to ensure it is wind and water tight, you will repair it with the intention to include the door on a planned programme for replacement in the future.*" The quote explains that if building components can be made fit for purpose then they will be retained vis-à-vis renewed or replaced.

A small second peak in the data was apparent which is caused by heating systems installations. When asked whether this is typical for a R&M department, participant A explained that such peaks in the distribution are: "*typical in organisations were there is not a planned replacement programme"* and that "*we have not had a sufficient planned heating programme therefore, we have had to complete a large number of boiler replacements within the repairs department as no preventative steps were taken to stop boilers failing within our properties."* Therefore, the distributions of R&M costs will be erratic with multiple peaks if the organisation does not invest in planned programmes as building components nearing end of life expectancy have increased probability of failure and require replacement across the property portfolio.

The cumulative month-on-month cost diagrams show a clear linear regression with little indication that the gradient of the trend line is reducing. Therefore in 2019 it would seem few cost efficiencies are being achieved. The group were asked how to improve this trend. Participant A explained: "*new self-reporting materials could be introduced. The technology sends a notification when an incipient failure is about to occur so that preventative steps can be taken. They are even introducing self-reporting light-switches."* Participant B said: "*we have just started to invest in data capturing condensation fans which report on moisture levels within the property and if the fans are being disconnected. This means that we are protected against damp and mould litigation claims, but this saving will not yet be evident in the data."*

Participant D also advised: "*that the introduction of more planned programmes will inevitably save us large amounts of money as building components close to their life expectancy will not require frequent repair and maintenance just to see them into the next financial year.*"

Next the group observed the month-on-month regression for each sub-category. Participant B explained that roofing had the greatest gradient because: "*the work required both a roofing and scaffolding sub-contractor for each job as we do not have these skills in house.*" Participant E went onto explain that: "*we have now taken on an in-house roofing team, so we do not have to sub-contract the roof works.*" Supplementary to that question, the group were asked if this would generate a cost saving. The group concluded that the likely costs would be relatively similar, but the organisation now has more control over quality, health and safety which is a known issue amongst the organisation's previous roofing subcontractors. This indicates that the organisation makes service delivery changes in an attempt to reduce cost but considers wider factors too.

The group were asked which approach to asset management they believe their organisation adopts. Participant C stated that: "*we were definitely task approach with little commercial emphasis.*" Participant A added that the organisation was: *"further behind the curve because we were neither* [approach] *because the tenants' needs were not looked at nor were we commercially orientated. However now we are moving to the only option which is sustainable and that all housing associations must be moving towards which is the traditional profit for purpose approach. We do this by increasing the number of market rent properties and increasing rents within our portfolio to create revenue for re-investment into the planned programmes."* Fellow focus group members concurred with this observation. The organisation is therefore only now adopting a traditional approach to asset management. At this point it is notable that, excluding Participant D, the average experience in the current role is 2.6 years indicating that the department has recently undergone significant changes in personnel.

5.3 Application of the data to create cost efficiencies

Finally, the group where asked which delivery of R&M they consider to be more effective, namely: outsourcing to an external supplier or DLO delivery. This organisation currently delivers R&M via a DLO and therefore there may be some bias in the responses. Participant C drew from past experience where he worked for a main contractor where the R&M service was outsourced to: "*we had to be completely cost focused which meant corners would be cut at* *every opportunity. This is because we were working on a PPP contract* (price per property) *where you are not paid per job instead your price was fixed per property. Therefore, the incentive is to do as little as possible otherwise you would make a loss."* Participant A further explained that: "*if you want a race to the bottom line you would go to an external contractor, but you will have numerous complaints and quality issues. This is why the industry is moving away from this."* Participant A continued by suggesting that the most effective R&M delivery model: "*has to be a modern DLO because a traditional DLO based on a traditional way of working failed as they were not managed by commercially minded people which is what we are doing here now. You can get the blend of both in a new DLO."* Participant A therefore believes that the most effective R&M delivery must be managed commercially to ensure costs are sustainable and delivered via a form of DLO to ensure the tenants are receiving a quality and value for money service. Participant F added to this by using the organisation's drainage delivery (which has recently been brought in-house) as an example: "*you can see it already with the work that X has done* (where X is a new in-house drainage operative), *once you have someone internally employed who is a specialist you see massive quality benefits. In the past we have repeatedly sent a sub-contractor to drainage jobs, but they would continually make easy temporary repairs which would likely re-occur which they get paid to re-attend whereas X completes long term repairs which may be more expensive initially but in the long term will cause less disruption to the tenants and save money."*

6. DISCUSSION

The quantitative and qualitative analysis provides a detailed insight into the real life R&M costs incurred over a typical year for the case study's participating Housing Association that employed the lead researcher as an Assistant Quantity Surveyor. Consequently, the results build upon previous studies that sought to estimate or predict R&M costs in the absence of real life data (cf. Alshibani and Hassanain, 2018; Weerasinghe et al., 2020). The organisation completes cost analysis periodically as part of the organisation's key performance indicators (KPIs) and commercial management processes but further granulation into individual work packages and statistical analysis (such as standard deviation and month-on-month cumulative regression) have not hitherto been completed. This work therefore provides a better understanding of the cost incurred over a typical year and identifies trends and information which has not been previously calculated. The work will improve the ability to monitor and control direct R&M costs and also, importantly, make forecasting possible, specifically the forecasting of cumulative growth as well as predicting elemental cost growth of individual sub-categories. Plans to create cost savings can be targeted at the particular packages which have the most significant effect on total annual cost. This may form the basis for future procurement and operational processes that allow an optimisation of cost and service within the delivery of these sub-categories to provide a better value of service for the tenants. Furthermore, the work details which sub-categories are causing the greatest financial burden on the property portfolio thus, identifying which building components require investment and prioritisation for a planned works programme for replacement in the coming years.

This research has converted data extracted from a live housing asset management system into information using sub-categorisation, and summary and inferential statistics. The research provides a deeper and richer understanding of the information so that new theories can be generated via inductive reasoning – such as the causes of trends observed. While the focus group participants validate the reliability and representative of the data further advancements in knowledge and wisdom is possible using benchmark trends created with regression. Theoretically, the results reveal that linear cumulative trends can be accurately forecast using bi-variable regression analysis for the vast majority of data points albeit, outliers may need to be treated differently – perhaps predicted using fixed time to maintenance techniques (Edwards *et al.*, 1998) to prevent incipient breakdown and further cost expenditure.

There are limitations with the research conducted. First, only a one year snapshot of data was collected and analysed, preventing comparison between years to be made. It is therefore difficult to determine if the same sub-categories cause the greatest financial burden year-on-year. It is also impossible to identify whether cost savings could be made in years where there has been significant investment into planned replacement programmes – a more extensive longitudinal data set covering many more years would be required. It would be interesting to compare 2019 to a year with large investment and adjust the costs based on inflation to enable a true comparison. Second, this research only analyses direct costs of R&M i.e. labour, material and sub-contractor costs. To gain a more comprehensive analysis of cost, overheads and indirect costs could also be included to understand how efficient the organisation is overall. However, this information is confidential and potentially sensitive so less likely to be disclosed publicly. Third, the analysis did not include a third work package ‘empty property refurbishment’ (known as “voids”) to create a lettable standard property ready for an incumbent tenant. Analysis was not completed as part of this research because each individual ‘empty property refurbishment’ will usually require almost every sub-category of work at varying quantity and cost. For example, in 2019 the case study organisation completed 197 ‘empty property refurbishments’ with a total cost of £961,859 therefore, the average cost of an ‘empty property refurbishment’ was £4,882. This average cost is considerably higher than the average costs calculated for the repairs analysed by this research (£104.78) because by definition property refurbishment (vis-à-vis R&M) requires far more extensive work to be undertaken. Future studies will be required to analyse property refurbishment work to gain greater insight into the costs and activities involved. Finally, there are many other ways to analyse the data which could form the basis for future work such as: 1) location analysis – to determine whether there is any relationship between property location and costs; 2) demographic analysis – to identify if there is any relationship between tenants and costs. Contributing factors to review could be tenant age, family size, length of tenancy etc.; 3) property type analysis – to identify if there is any relationship between property type and cost. Contributing factors to review could include property age, size, construction method, etc.; 4) component analysis – to further sub-categorise the sub-categories to determine if for example windows cost more money than doors to repair each year. Further to this, app software could be formalised which works as a decision support tool allowing real-time finer granulation of the data and information enabling better decision making and optimisation of operations, cost and service for tenants moving forward.

7. CONCLUSION

This work provides a detailed insight into the costs of repairs and maintenance for a Social Housing provider in the UK. The work uses a one-year longitudinal case study as the basis for the research allowing the analysis of over 13,000 data records so that a vignette of contemporary practice can be produced and dissected to provide the reader with a unique narrative which reflects current industry practices and R&M costs incurred. The work analyses costs by sub-categorising each type of repair completed over a typical year. The sub-categories and data holistically can then be compared using statistical averages and theories so that a better understanding of R&M cost can be attained by the researcher, reader and case study organisation. Key findings of the work include: 1) R&M costs are non-parametric, heavily skewed towards low side and dominated by a few work subcategories (including fencing and gates; finishes; and roofing) as demonstrated by the distribution histograms and box and whisker diagrams; 2) there are outliers of R&M cost. Organisations delivering R&M should allow for a minority of such high cost repairs which are inconsistent with the calculated averages; 3) there are certain sub-categories which have a greater financial impact on the total annual cost which is likely due to a lack of capital investment within recent years. This work can form the basis for capital investment moving forward; 4) there is a very strong relationship between time and cost as indicated by the month-on-month linear regression trend line hence, this work has the ability to accurately forecast future spend, not only for total expenditure, but also for each sub-category; and 5) this work also includes qualitative expert commentary on asset management, outsourcing and costs incurred.

Historically, within the case study organisation, bottom-line cost values have been largely used to benchmark profitability and future budget levels. Despite being a zero-profit organisation, profit is still required to reinvest into the business to achieve longevity and better customer care. Because the organisation is zero profit, cost management must be paramount as the organisation cannot rely upon high levels of revenue coming from external sources. Furthermore, as previous years' bottom line costs form the basis for future budgets, there seems to be little incentive to optimise spend. This research has found that from collecting the data and analysing the data in finer granulation and with different techniques that is has created a basis for knowledge management within the business so that the optimisation of decisions can be ensured for service delivery, capital investment, procurement, and customer experience. Future work is however needed to: determine the probabilities of individual routine R&M costs occurring, particularly for those high cost items that inflate expenditure unduly and complete similar work for planned preventative maintenance costs; model all R&M costs, including overheads to obtain a complete picture of costs incurred; and establish benchmark cost criteria for each sub-category to measure future R&M performance and establish measure needed to optimise expenditure.

REFERENCES

Albanese, F. C. (2007) *Decision-making in the Housing Association Sector: The case of asset management*. Ph.D. Thesis. Sheffield Hallam University. Available at: http://shura.shu.ac.uk/3206/ [Accessed 2 December 2020].

Alharahsheh, H. H. and Pius, A. A. (2020) Review of key paradigms: positivism vs interpretivism. *Global Academic Journal of Humanities and Social Sciences*, 2(3), pp. 39-43.

Al-Saeed, Y., Pärn, E.A., Edwards, D.J. and Scaysbrook, S. (2019) *A conceptual framework for utilising bim digital objects (bdo) in manufacturing design and production: a case study*. Journal of Engineering Design and Technology. Vol. 17 No. 5, pp. 960-984 DOI:10.1108/JEDT-03-2019-0065

Alshibani, A. and Hassanain, M.A. (2018) *Estimating facilities maintenance cost using post-occupancy evaluation and fuzzy set theory*, Journal of Quality in Maintenance Engineering, Vol. 24 No. 4, pp. 449-467. DOI: https://doi.org/10.1108/JQME-05-2017-0038

Arkani, S. (2005) Outsourcing repair and maintenance in local authority housing in the UK: directions for research. In: *Housing in Europe: Challenges and Innovations.* European Network for Housing Research (ENHR) International Housing Conference. Reykjavik, Iceland, 29 June – 03 July. Available at: https://westminsterresearch.westminster.ac.uk/download/1f7556016a9dd9f8f409e9229d732998d8901e24c5f7643ccf58f63501785da1/118718/Arkani_2005_final.pdf [Accessed 2 December 2020].

Au-Yong, C.P., Chua, S.J.L., Ali, A.S. and Tucker, M. (2019) *Optimising maintenance cost by prioritising maintenance of facilities services in residential buildings*, Engineering, Construction and Architectural Management, Vol. 26 No. 8, pp. 1593-1607. DOI: https://doi.org/10.1108/ECAM-07-2018-0265

Boslaugh, S (2012). *Statistics in a nutshell, Second Edition.*O'Reilly Media Inc, Sebastopol ISBN: 978-1-449-31682-2

Cole, I and Powell, R (2010) *The Future of Arms Length Management Organisations: the uncertain fate of a social housing hybrid*. People, Place & Policy Online (2010):4/2, pp. 50-61. DOI: 10.3351/ppp.0004.0002.0002

Cooper, J and Jones, K. (2008) Routine maintenance and sustainability of existing social housing. In: E. Finch, ed. *Proceedings of the CIB W70 Working Group in Facilities Management.* Heriot Watt University, Edinburgh, 16-18 June. Pp. 361-368. Available at https://www.irbnet.de/daten/iconda/CIB11928.pdf [Accessed 2 December 2020].

Coupar, G. (2009) *Modern Approaches To Repairs and Maintenance Procurement Within the Social Housing Sector*. Doctorate of Business Administration. Thesis. Nottingham Trent University. Available at: http://irep.ntu.ac.uk/id/eprint/26/1/196991_Coupar.pdf [Accessed 2 December 2020].Curry, R (2020). *Inside Housing "2020 Repairs and maintenance tracker 2020 – how much is your housing association spending?"* available via: https://www.insidehousing.co.uk/insight/insight/repairs-and-maintenance-tracker-2020--how-much-is-your-housing-association-spending-64427 (Accessed 29 June 2020).

Edwards, D. J., Holt, G. D. and Harris, F. C. (1998) Predictive maintenance techniques and their relevance to construction plant. Journal of Quality in Maintenance Engineering, 4(1), pp. 25-37. DOI:10.1108/13552519810369057

Edwards, D. J., Holt, G. D. & Harris, F. C. (2002) *Predicting downtime costs of tracked hydraulic excavators operating in the UK opencast mining industry*. Construction Management and Economics, 20(7), 581-591. DOI:10.1080/01446190210163552

El-Haram, M. A., & Horner, M. W. (2002). *Factors affecting housing maintenance cost*. Journal of Quality in Maintenance Engineering, 8(2), 115–123. DOI:10.1108/13552510210430008

Gibb, K & Trebeck, K. (2009). *Different Roads: Evidence about the Changing Provision of Social Housing in England*. International Journal of Housing Markets and Analysis. 2. DOI: 10.1108/17538270910992818.

Gibb, K & Nygaard, C (2006) *Transfers, Contracts and Regulation: A New Institutional Economics Perspective on the Changing Provision of Social Housing in Britain*, Housing Studies, 21:6, 825-850, DOI: 10.1080/02673030600917719

Goldkuhl, G. (2012). *Pragmatism vs interpretivism in qualitative information systems research.* European Journal of Information Systems, 21(2), 135–146. DOI:10.1057/ejis.2011.54

Gruis, V & Nieboer, N (2004) *Strategic housing management: An asset management model for social landlords.* Property Management; Bradford Volume 22, Number 3, pp. 201-213(13). DOI: 10.1108/02637470410544995

Gruis, V., Nieboer, N., & Thomas, A. (2004). *Strategic Asset Management in the Social Rented Sector: Approaches of Dutch and English Housing Associations.* Urban Studies, 41(7), 1229-1248. DOI: 10.1080/0042098042000214761

Gruis, V., Elsinga, M., Wolters, A., & Priemus, H. (2005). *Tenant Empowerment Through Innovative Tenures: An Analysis of Woonbron–Maasoevers'* Client's Choice Programme. Housing Studies, 20(1), 127–147. DOI:10.1080/0267303042000308769

Hakim, H (2004) PFI for the delivery of social housing projects. In: C. O. Egbu and M. K. L. Tong, eds. *Proceedings of the 2nd Scottish Conference for Postgraduate Researchers of the Built and Natural Environment (ProBE)*. Glasgow Caledonian University, 16-17 November. [Glasgow]: Glasgow Caledonian University, pp. 291-302. Available at: https://www.irbnet.de/daten/iconda/CIB10637.pdf [Accessed 2 December 2020].

Hetherington, P (2003), *£1.5bn boost to council housing*, The Guardian, Available via: https://www.theguardian.com/politics/2003/jul/28/property.publicservices (Accessed 5th July)

Higham, A. and Stephenson, P. (2014) Identifying project success criteria for UK social housing asset management schemes. In: A. Raiden and E. Aboagye-Nimo, eds. *Proceedings of the Association of Researchers in Construction Management (ARCOM) 30th Annual Conference, Vol. 1*. Portsmouth, 1-3 September 2014, pp. 33-42. Available at: https://www.arcom.ac.uk/-docs/proceedings/ar2014-0033-0042_Higham_Stephenson.pdf [Accessed 2 December 2020].

Kaushik, V., & Walsh, C. A. (2019). *Pragmatism as a Research Paradigm and Its Implications for Social Work Research*. Social Sciences, 8(9), 255. DOI:10.3390/socsci8090255

Kelly, L. M., & Cordeiro, M. (2020). *Three principles of pragmatism for research on organizational processes.* Methodological Innovations, 13(2), 205979912093724. DOI:10.1177/205979912093724

Kempton, J. (2006). *Can lean thinking apply to the repair and refurbishment of properties in the registered social landlord sector?* Structural Survey, 24(3), 201–211. DOI:10.1108/02630800610678850

Kwon, N., Song, K., Ahn, Y., Park, M. and Jang, Y. (2020), Maintenance cost prediction for aging residential buildings based on case-based reasoning and genetic algorithm, Journal of Building Engineering, 28, 101006. https://doi.org/10.1016/j.jobe.2019.101006

Lai, J.H.K., Yik, F.W.H. and Jones, P. (2008), *Expenditure on Operation and Maintenance Service and Rental Income of Commercial Buildings*, Facilities, 26(5/6), 242-265. DOI: 10.1108/02632770810865014

Lai, J.H.K. and Yik, F.W.H. (2008), *Benchmarking operation and maintenance costs of luxury hotels, Journal of Facilities Management*, 6(4), 279-289. DOI: 10.1108/14725960810908145

Lai, J.H.K., Yik, F.W.H. and Chan, A.K.P. (2009), *Maintenance cost of chiller plants in Hong Kong*, Building Services Engineering Research and Technology, 30(1), 65-78. DOI: 10.1177/0143624408096290

Lai, J.H.K. and Yik, F.W.H. (2012), *Hotel Engineering Facilities: A Case Study of Maintenance Performance*, International Journal of Hospitality Management, 31(1), 229-235. DOI: 10.1016/j.ijhm.2011.05.002

Lai, J.H.K. and Yik, F.W.H. (2012), *A Probe into the Facilities Maintenance Data of a Hotel*, Building Services Engineering Research and Technology, 33(2), 141-157. DOI: 10.1177/0143624411401840

Lai, J.H.K. (2013), *An analysis of the maintenance demand, manpower and performance of hotel engineering facilities*, Journal of Hospitality & Tourism Research, 37(3), 426-444. DOI: 10.1177/1096348012436380

Lai, J.H.K. (2015), *Maintenance performance: Examination of the computer-aided maintenance data of a large commercial building*, Journal of Performance of Constructed Facilities, 29(4). DOI: http://dx.doi.org/10.1061/(ASCE)CF.1943-5509.0000619

Larkin, A (2000) *Asset Management Strategies: A review of asset management strategies of housing associations in England and social housing providers in Australia*. London: Metropolitan Housing Trust/The Housing Corporation.

Ministry of Housing, Communities & Local Government (2020). *Live tables on dwelling stock (including vacants), table 104 Dwelling stock: by tenure (historical tables)*. Available via: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants (Accessed 4th July 2020)

Ministry of Housing, Communities & Local Government (2020). *Live tables on dwelling stock (including vacants), table 119: stock of non-decent homes*, England 2001-2019 Available via: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants (Accessed 4th July 2020)

Morrison, N. (2013). *Meeting the Decent Homes Standard: London Housing Associations' Asset Management Strategies.* Urban Studies, 50(12), 2569-2587. DOI: 10.1177/004209801247

NAO (National Audit Office) (2010) *Decent homes summary.* Available at http://www.nao.org.uk/publications/0910/the_decent_homes_programme/ (Accessed 4th July 2020)

Newman, C., Edwards, D.J., Martek, I., Lai, J. and Thwala, W.D. (2020) Industry 4.0 Deployment in the Construction Industry: A Bibliometric Literature Review and UK-based Case Study, Smart and Sustainable Built Environment DOI: https://doi.org/10.1108/SASBE-02-2020-0016

Pansiri, J. (2005). P*ragmatism: A methodological approach to researching strategic alliances in tourism.* Tourism and Hospitality Planning & Development, 2(3), 191–206. DOI: 10.1080/14790530500399333

Pawson, H. (2007). *Local Authority Homelessness Prevention in England: Empowering Consumers or Denying Rights?* Housing Studies, 22(6), 867–883. DOI: 10.1080/02673030701387572

Pawson, H & Smith, R (2009) *Second Generation Stock Transfers in Britain: Impacts on Social Housing Governance and Organisational Culture*, European Journal of Housing Policy, 9:4, 411-433, DOI: 10.1080/14616710903357201

Reeves, P 2005, *Introduction to Social Housing*, Taylor & Francis Group, Jordan Hill. ISBN: 978-0-750-66393-9

Ren, H., & Shang Shao Lin. (1996). The UK construction industry under cyclical high inflation, high interest rates and recession. International Journal of Project Management, 14(5), 301–305. Doi:10.1016/0263-7863(96)84513-3

Roberts, C., Edwards, D., Hosseini, M R., Mateo-Garcia, M., Owusu-Manu, D. (2019). *Post-occupancy evaluation: a review of literature.* Engineering, Construction and Architectural Management. 26. DOI: 10.1108/ECAM-09-2018-0390.

Róka-Madarász, L., Mályusz, L. and Tuczai, P. (2016), Benchmarking facilities operation and maintenance management using CAFM database: Data analysis and new results, Journal of Building Engineering, 6, 184-195. DOI:10.1016/J.JOBE.2016.03.007

Sagoo, A. S. (2014) *A Decision Support System for Evaluating Local Authority Housing Maintenance Strategies in the United Kingdom*. Ph.D. Thesis. University of Derby. Available at: https://derby.openrepository.com/handle/10545/333331 [Accessed 2 December 2020].

Sepasgozar, S., Shi, A., Yang, L., Shirowzhan, S., Shafigh, P. and Edwards, D.J. (2020) *Additive manufacturing applications for Industry 4.0: A systematic critical review*, Buildings. 10(12), 231. DOI: https://doi.org/10.3390/buildings10120231

Scarrett, D & Wilcox, J. 2018. *Property Asset Management*, Taylor and Francis Ltd. CRC Press LLC, Milton. ISBN: 978-1-135-62894-3

Schmickler, A & Park K S. (2014). *UK Social Housing and Housing Market in England: A Statistical Review and Trends.* LHI Journal of Land, Housing, and Urban Affairs. 5. 193-201. DOI: 10.5804/LHIJ.2014.5.3.193

Sharp, M., & Jones, K. (2012). *Perceived inefficiency in social housing maintenance.* Construction Innovation, 12(4), 414–428. DOI:10.1108/14714171211272199

Sing, M. C. P., Edwards D. J., Liu, H. J. X. and Love, P. E. D. (2015) Forecasting private-sector construction works: VAR model using economic indicators. Journal of Construction Engineering and Management, 141(11). DOI:10.1061/(ASCE)CO.1943-7862.0001016

Stephens, M., Burns, N., & MacKay, L. (2003). *The Limits of Housing Reform: British Social Rented Housing in a European Context.* Urban Studies, 40(4), 767–789. DOI:10.1080/0042098032000065290

Tetlow, G. and Stojanovic, A., 2018. Understanding the economic impact of Brexit. Institute for government, pp.2-76. Available at https://www.instituteforgovernment.org.uk/sites/default/files/publications/2018%20IfG%20%20Brexit%20impact%20[final%20for%20web].pdf [Accessed 7th February 2021]

Tucker, M; Turley, M; Holgate, S (2014) *Critical success factors of an effective repairs and maintenance service for social housing in the UK* 32, Iss. 5/6: 226-240. DOI:10.1108/F-07-2012-0059

Van Mossel, H. J. and Van der Valk, W. (2006) Differentiating services and its implications for supplier selection: The case of maintenance services for social rented housing. In: Croom, S., Carter, P. and Day, M., eds. *Creating and Managing Value in Supply Networks. Proceedings of the Fourth Worldwide Research Symposium in Purchasing & Supply Chain Management and the 15th Annual International Purchasing & Supply Education & Research Association (IPSERA) Conference*. Supply Chain Management Institute, San Diego, 6-8 April. Available at: https://repository.tudelft.nl/islandora/object/uuid:74fa1344-1dd1-4013-9a16-be2e022afa29?collection=research [Accessed 2 December 2020].

Weerasinghe, A.S., Ramachandra, T. and Rotimi, J.O.B. (2020) *Towards sustainable commercial buildings: an analysis of operation and maintenance (O&M) costs in Sri Lanka*, Smart and Sustainable Built Environment, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/SASBE-04-2020-0032

Wordsworth, P. (2001) *Lee's Building Maintenance Management*. 4th edn. London: Blackwell Science.

Yik, F.W.H. and Lai, J.H.K. (2005), *The trend of outsourcing for building services operation and maintenance in Hong Kong*, Facilities, 23(1/2), 63-72. DOI: 10.1108/02632770510575901

Figure 1 – Social Housing Volumes (MHCLG, 2020)

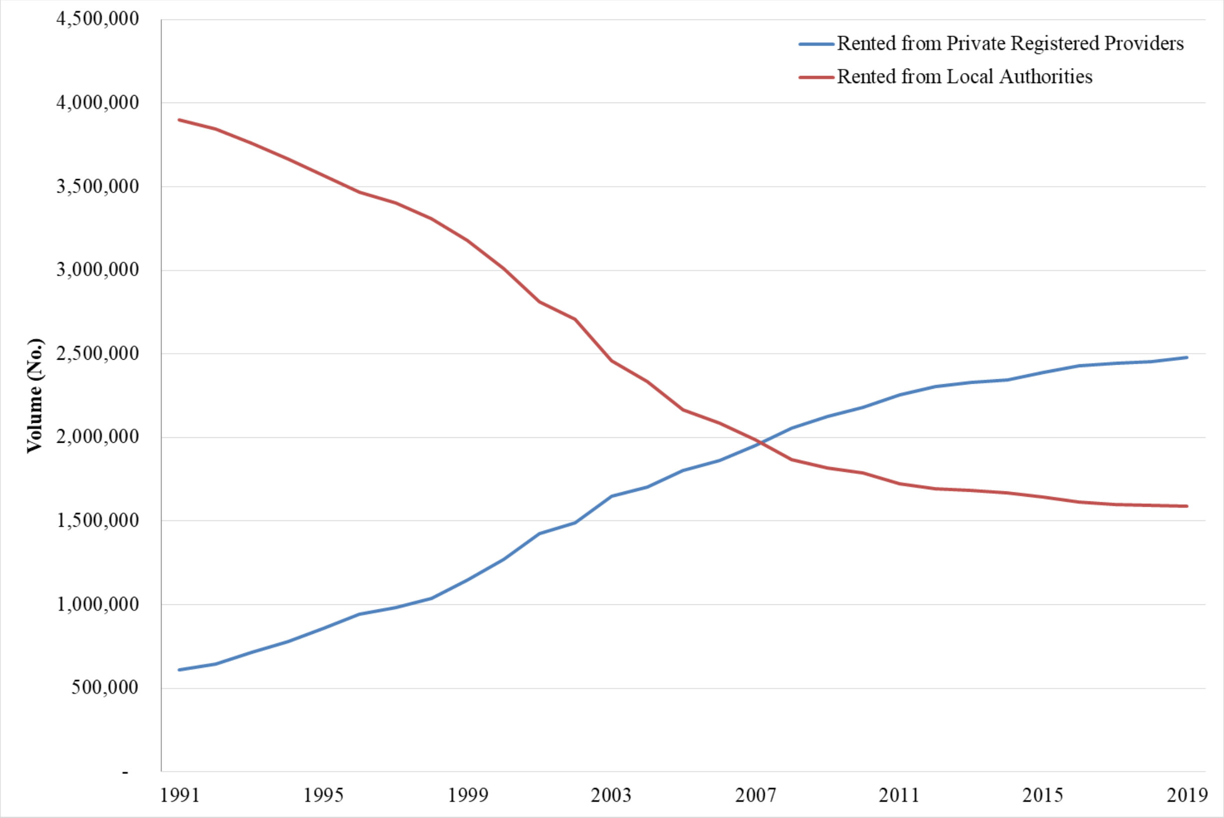

Figure 2(a) – Histogram Cost Distribution £0-£500

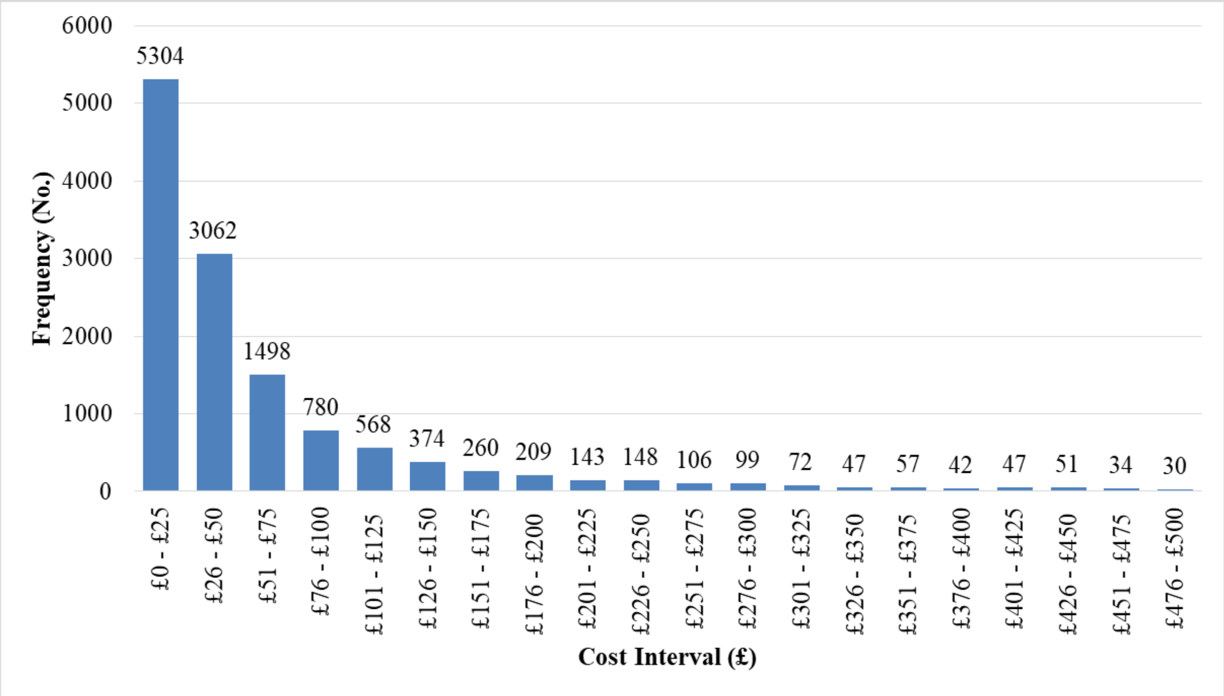

Figure 2(b) – Histogram Cost Distribution £501-£10,500.

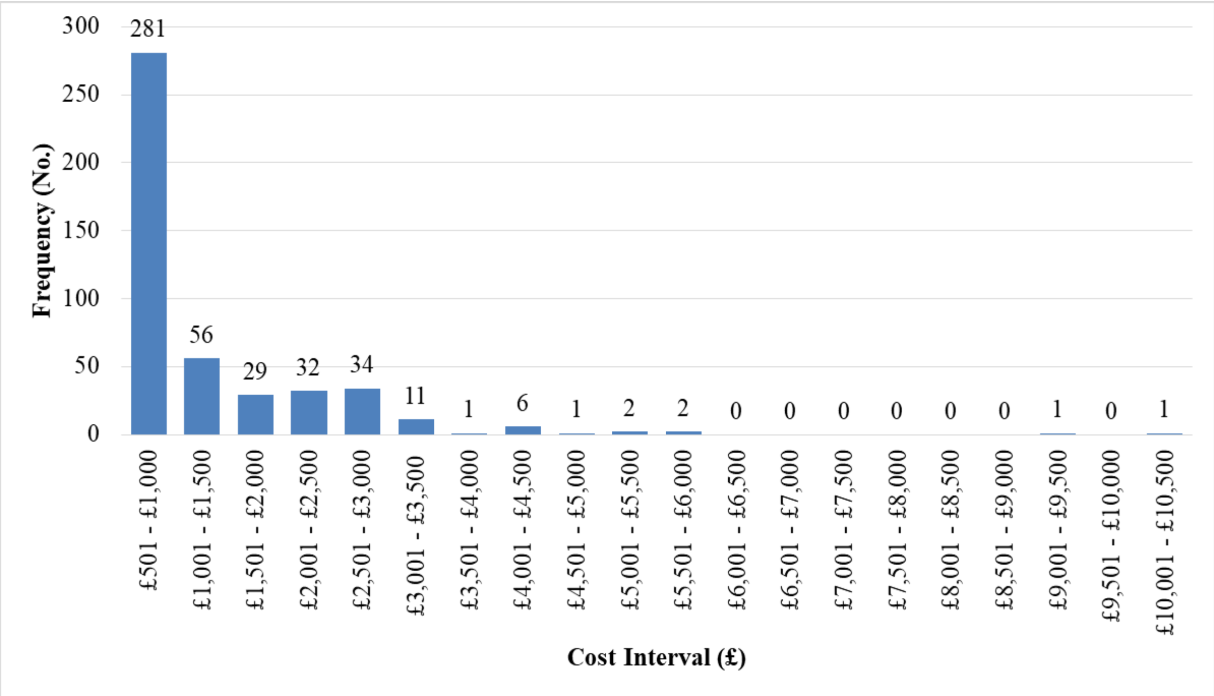

Table 1 – Summary Statistics Table

Category	Frequency (No.)	Total Cost (£)	Range (£)	Interquartile Range (£)	Mean (£)	Median (£)	Outliers (No.)	Standard Deviation (£)
Carpentry	2,149	170,399.50	2,949.53	55.00	79.29	27.72	231	183.41
Cleaning and Clearance	19	3,661.18	1,809.84	181.32	192.69	55.03	1	404.13
Drainage	363	60,450.36	5,157.91	140.49	166.53	60.67	38	372.59
Electrical Servicing	238	17,162.67	588.47	27.30	72.11	60.36	16	51.05
Electrical Repairs	1,901	171,525.19	2,144.64	93.94	90.23	40.37	151	150.98
Fencing and Gates	165	26,808.88	1,238.60	193.98	162.48	58.49	16	232.53
Finishes	194	33,207.86	1,974.78	216.84	171.17	45.50	13	289.65
Gas Repairs	2,384	180,546.23	4,134.84	66.17	75.73	32.16	261	134.57
Gas Servicing	1,485	53,581.94	792.15	17.09	36.08	27.28	124	37.08
Glazing	135	19,839.71	2,518.98	120.70	146.96	94.00	8	253.16
Ground and Brickwork	263	62,694.11	9,390.68	95.75	238.38	53.59	34	875.90
Heating Systems – Installations	71	185,005.95	2,335.23	426.80	2,605.72	2,545.22	4	492.36
Metalwork	2	1,248.48	421.92	n/a	624.24	624.24	n/a	298.34
MIX	52	8,167.30	941.43	75.64	157.06	94.97	6	204.51
Plasterwork	152	14,434.68	2,987.26	70.95	94.96	30.47	13	297.55
Plumbing	2,550	143,583.72	2,226.50	48.74	56.31	31.63	208	94.40
Roofing	909	192,984.26	3,308.97	184.35	212.30	67.29	129	368.63
Specialist Treatments	356	57,448.39	10,067.81	75.00	161.37	31.87	35	710.14
Combined	13,388	1,402,750.39	10,067.81	63.31	104.78	34.54	936	310.22

Figure 3 – Subcategory Box and Whisker Plots (Excluding Heating System Installations and Metal)

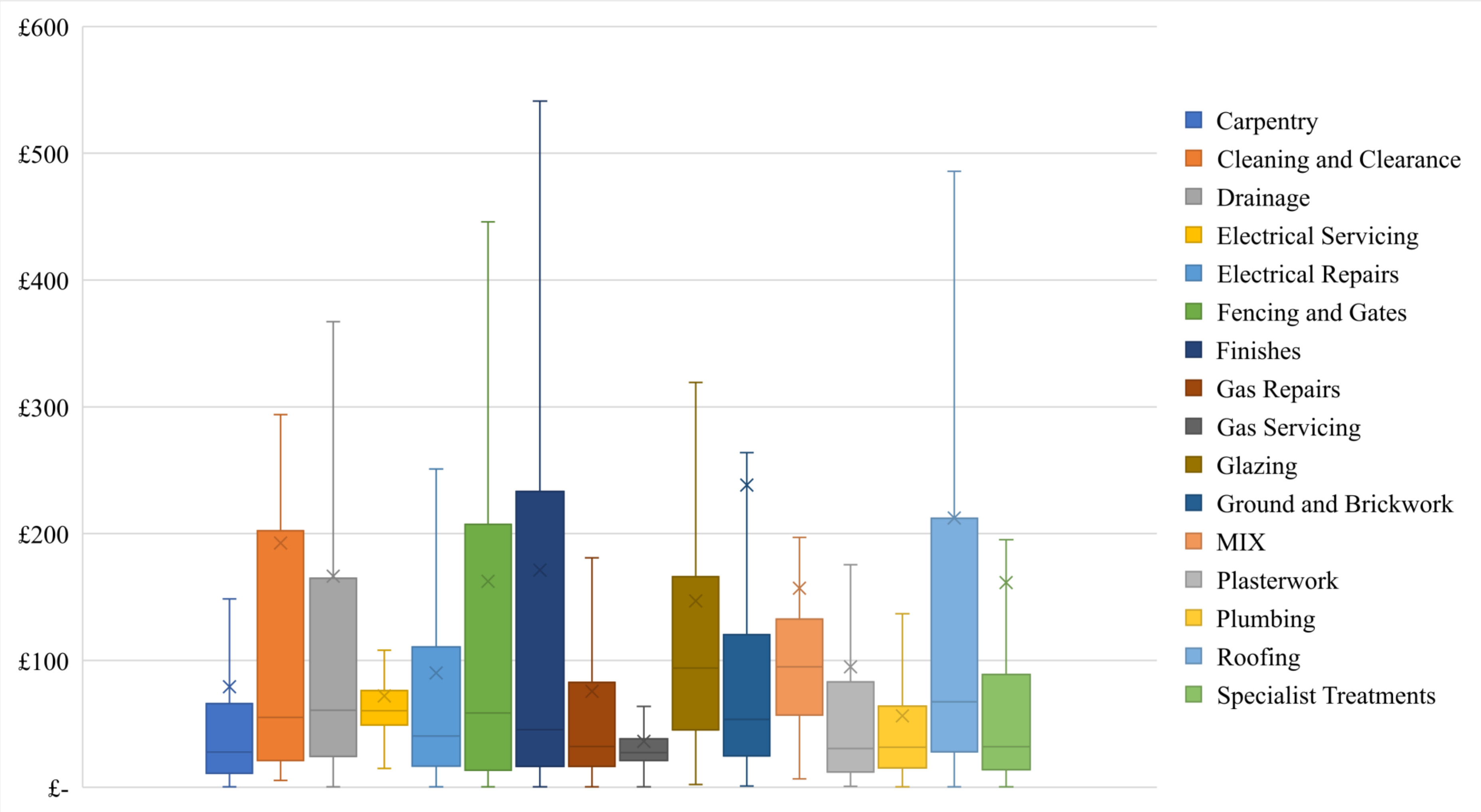

Figure 4 – Linear Regression – All Categories Combined

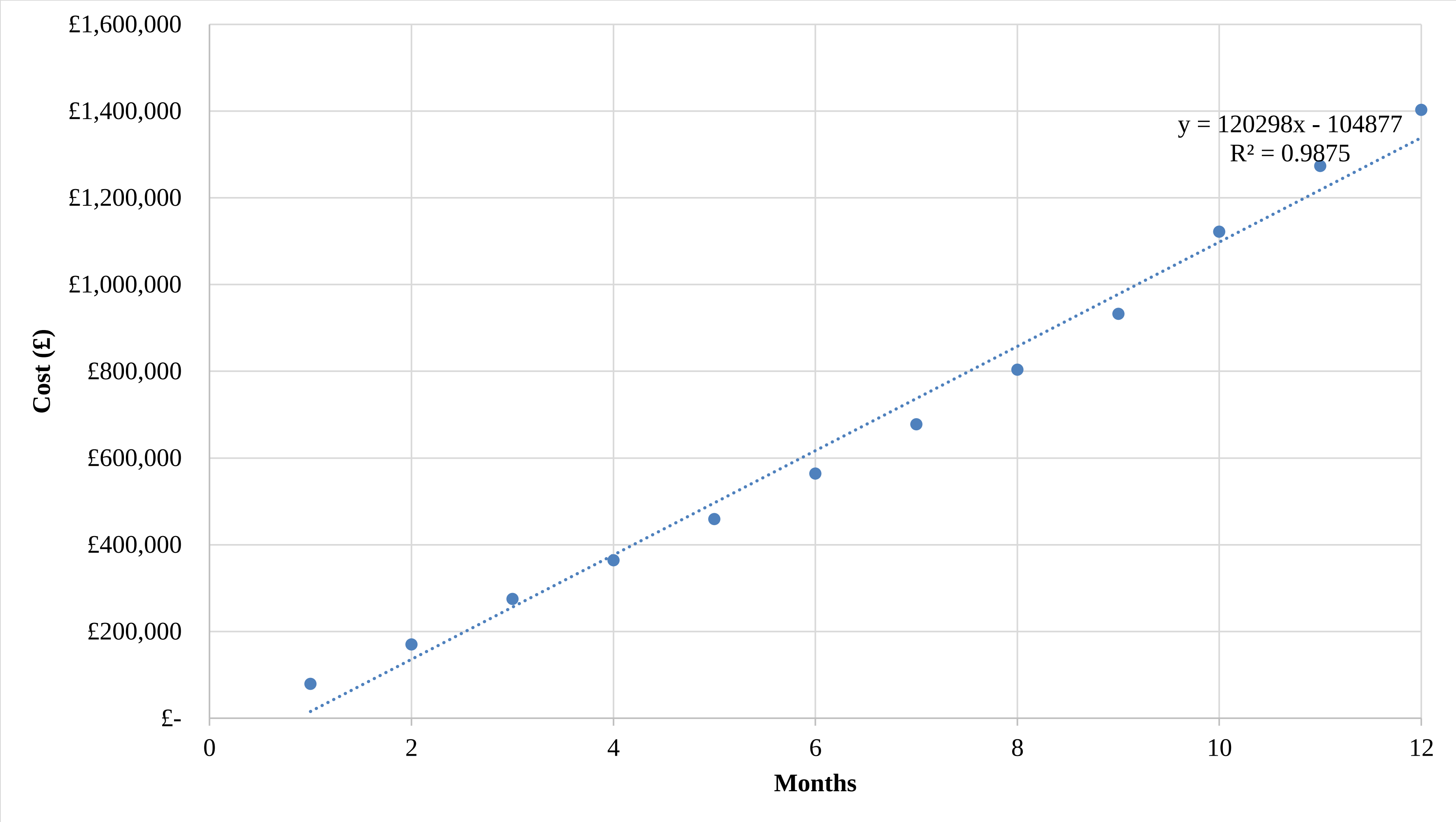

Figure 5 – Linear Regression by Category

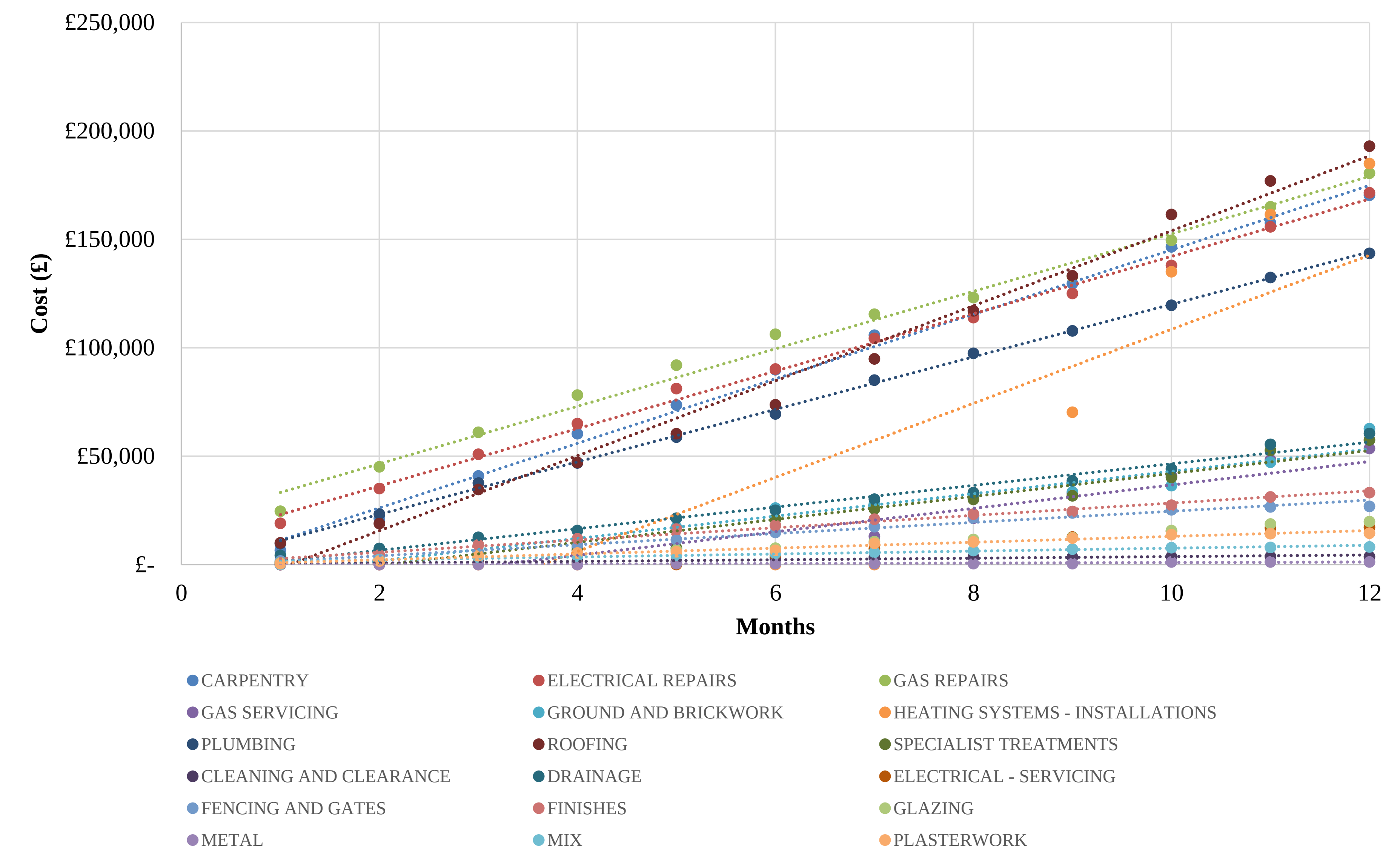

Table 2 – Regression Coefficients for the Sub-Categories

Sub-category	Regression Line Y-intercept	Slope Coefficient B (£)
HEATING SYSTEMS - INSTALLATIONS	-62,272.36	£14,874
ROOFING	-18,967.55	£372
GAS SERVICING	-17,302.54	£4,990
SPECIALIST TREATMENTS	-10,964.34	£2,095
GROUND AND BRICKWORK	-8,571.85	£13,239
ELECTRICAL - SERVICING	-6,958.16	£2,572
CARPENTRY	-3,572.72	£2,841
DRAINAGE	-3,405.86	£13,253
GLAZING	-1,939.71	£5,402
FENCING AND GATES	-1,126.56	£1,758
PLUMBING	-1,089.79	£5,156
PLASTERWORK	-519.63	£17,080
METAL	-328.76	£125
FINISHES	-45.44	£675
CLEANING AND CLEARANCE	-30.64	£1,351
MIX	813.19	£12,114
ELECTRICAL REPAIRS	9,780.73	£17,292
GAS REPAIRS	20,004.08	£5,296

Table 3 – Demographic Profile of Participants

Reference	Participants	Years in Current Job	Years of Experience	Highest Qualification	Professional Membership
A	Director	3	29	Degree	RICS
B	Commercial Manager	2	12	HNC	N/A
C	Head of Operations	3	35	RSPH Level 4 Contact Managers	N/A
D	Office Manager	20	33	Level 4 NVQ Diploma	N/A
E	Responsive Service Manager	1	35	CIOB Member 1	CIOB
F	Planner	4	6	High School Diploma	N/A