EVALUATING THE ROAD WORKS AND STREET WORKS MANAGEMENT PERMIT SCHEME IN DERBY, UK

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ABSTRACT

Road works (highway works) and street works (utility works) activities are vital for society to travel, enjoy amenities, and to access essential services such as water, electricity, gas and telecommunications. However, road works and street works can be disruptive, inconvenient and have high social costs. The Permit scheme is a relatively new management regime which seeks to reduce the disruption caused by highway excavations by giving English Street Authorities greater control of works in their areas. The Derby Permit scheme commenced on October 2013. This research aims to understand whether the adoption of the Permit scheme has resulted in any change to the city's road works and street works landscape. A time series model using an intervention variable was run. 61 months of average works duration data was analysed along with several independent variables including daylight hours, economic activity and precipitation. The results showed that the Permit scheme had a positive effect on Derby by reducing the overall average duration of works by a third of a day. This is a 10% reduction overall, being equal to 8434 days per year, and in monetary terms equivalent to saving £769,048/$1,179,777 in societal costs per annum. This research is significant as it provides impact information for policy makers and practitioners on a relatively new type of scheme, and it is original, in that this is the first time that an intervention analysis approach has been applied to this area of public policy.

Keywords: Permit scheme, road works, policy, construction, time series analysis, pavements

INTRODUCTION

The UK transportation network has a dual purpose; over-ground it facilitates transportation which is fundamental for economic growth and to access key essential and leisure services, whilst underground it houses utility infrastructure critical for the smooth functioning of society. Problems can (and often do) arise when highway excavations occur as they can clash with over-ground demands for transportation, causing disruption and inconvenience to society. Road works are executed by Highway Authorities (HA) pursuant to a statutory duty to repair and maintain their highway assets. Street works are carried out by utility companies, also known as Statutory Undertakers (SU) who have a legislative duty to provide utility services and also rights to install, access and maintain their apparatus. Street Authorities (SA) have a regulatory role and are duty-bound to manage and co-ordinate excavation activity. For the purpose of this study, excavation activity has the same meaning as 'registerable works' under highway legislation - this primarily means any activity which necessitates breaking up or resurfacing the highway *(1).* Key emerging impacts of highway excavations include, congestion, negative environmental effects, loss of trade for local businesses, increased accidents, premature highway deterioration and aesthetic depreciation amongst others *(2; 3).* These factors demonstrate a clear need to manage highway excavations more effectively.

Along with many local authorities in England, Derby has introduced a Road Works and Street Works Permit Scheme (hereon known as the Permit scheme) on key city streets with the aim of minimising delays to road users through improved planning and execution of planned disruption to free flow traffic. Key scheme objectives are to:

- ensure parity between HA and SU works;
- improve co-operation between work promoters;
- reduce the adverse impact of highway excavations on residents and businesses and
- promote the adoption of minimally invasive works methods *(4).*

Permit schemes give SAs greater powers to manage and control excavations compared to the predecessor 'Noticing' regime, whereby, work promoters simply notified Councils of their intention to work *(5).* SAs have a duty to report on their Permit scheme performance, however reporting quality is inconsistent with little research into the effects of introducing Permit Schemes. Therefore, this study seeks to measure the extent to which the Permit scheme intervention has affected overall highway excavation activity in Derby.

LITERATURE REVIEW

Efficiently managed excavations are critical to maximise the integrity of highway infrastructure and to minimise the impact on the over-ground movement of traffic (including people) and society. Highway excavation activity can be enhanced in two ways: through the use of technological measures, or through using policy tools. Whilst extensive research underpins technological solutions such as trenchless techniques (eg, auger boring, pipe jacking and robotic spot repairs), multi-utility tunnels *(6)*, subsurface utility engineering (SUE) *(7)* amongst others, policy based techniques have received less attention *(8).* Nevertheless, some research can be found about policy tools and techniques employed, such as:

- Works embargo – works requiring road closures are generally restricted to Sundays in Sydney; Singapore prohibits peak hour working and Hong Kong prohibits works between 7am – 7pm daily *(9;10).* UK legislation enables SAs to place restrictions on excavations for up to two years after the completion of highway improvement works *(8)*; whilst Japan and France are also known to prohibit re-excavation for up to five years *(2).*
- Legislative rights – UK undertakers have enjoyed legal rights to provide statutory utilities in the highways since the mid-nineteenth century. Conversely, Scandinavian utilities have no such rights and must seek authorisation from the highway owner/Road Authority *(2).*
- Lane Rental schemes – HAs in London and Sydney rent out highway lanes for specified durations to enable work promoters to execute works *(9;10).*
- Permit schemes - Authorities in the UK, Singapore and New York issue permits to work promoters to undertake works on the highway *(12).*
- Memorandum of Understanding (MOU) – In several Australian and US states, MOUs are agreed and signed between States and utilities to secure co-operative and co-ordinated working processes during construction *(13).*
- Transportation and Utility Corridors (TUCs) – As part of Calgary and Edmonton's restricted development areas plans (RDA), TUCs formally designate ring road and utility alignments in advance *(13).*

In quantifying the costs of highway excavations, there is only a limited body of research *(2).* However, a comprehensive analysis by Halcrow used the Queues and Delays at Road Works (QUADRO) modeling program to estimate the cost of delay. A cost of delay to private and commercial motorists in England was estimated at £4.3 billion/$7.1 billion (USD) in 2004 *(14)*. However, a utility industry commissioned report challenged the assumptions, methods and values used in the this study and estimated that the true cost of delay lay between £0.5–1 billion/$0.8–1.6 billion *(15)*. This revised figure was further contested where reservations were expressed about the use of historical, geographically inaccurate and limited data in arriving at this lower figure. Instead, Halcrow's social cost estimation was extrapolated to include the whole of UK with the revised social cost updated to £5.1 billion/$8.0 billion. Additional social costs attributed to businesses, community, costs to HAs through premature damage and environmental costs were estimated at a further £0.5 billion/$0.8 billion *(16)*. Direct construction costs were valued at £1.5 billion/$2.3 billion, with indirect costs (third party damage) estimated at £150 million/$230 million, taking the overall cost of street works to be in excess of £7 billion/$10.9 billion per annum. A Pennsylvanian (USA) study estimated social costs to be around 80 times the project contract cost *(17)*. With such limited and diverse ranging costs and associated factors, it is difficult to determine a true cost of UK street works.

As the Permit scheme is in its relative infancy stage, there is little academic research into the quantitative evaluation of street works policy interventions. The one exception is a methodology proposed for the assessment of the Kent Permit scheme incorporating the use of fuzzy logic *(18)*. Regulations require that SAs evaluate their Permit schemes after 12 months, and then subsequently 36 months to monitor their effectiveness *(19).* However, the utility industry does not feel that such evaluations are a comprehensive assessment as they do not reflect the true scheme costs borne by works promoters *(20).* Analysis of available performance reports from across the UK reveal the following reductions in highway excavations:

- London Permit Scheme - 2% reduction in average duration in the first year *(21)*
- Kent County Council - 18% reduction in 'impact of road works' over four years *(22)*

- Yorkshire Common scheme – 21% reduction in duration over two years *(23)*

CASE STUDY OF DERBY

Derby is a fairly typical English regional city of around 250,000 people, approximately 130 miles north of London (Figure 1). Derby is renowned for its strong engineering base across the aerospace, automobile and rail industries, housing celebrated businesses including Rolls Royce, Toyota and Bombardier *(24)*.

Traditionally and primarily, highway excavations in Derby have been managed through a 'Noticing' system, whereby work promoters submit prescribed notices to the SA, pursuant to the New Roads and Street Works Act (NRSWA) 1991 *(25)*. The NRSWA legislation encourages SAs and SUs to use their best endeavours to co-ordinate and co-operate with others to facilitate co-ordination. In 2008, the Traffic Management Permit Scheme gave SAs powers to adopt Permit schemes to exercise greater control over excavations on their highways *(26)*. Permit applications and their variations incur costs for SUs, whilst HAs are subject to the same processes but exempt from fees. The Derby Permit Scheme commenced in October 2013 *(4)* and cost around £60,000 ($92,044) to implement, but is subsequently intended to be cost-neutral. SU costs are unclear, but include upfront Permit fees as well as increased back office costs in greater pre-planning in producing supporting Permit information. Operating the Permit scheme on all streets was considered unnecessary and excessive, therefore the scheme operates on only traffic-sensitive streets, which comprise around 20% of Derby's roads. Noticing applies to the remaining streets. Traffic-sensitive streets are formally designated subject to NRSWA criteria. They are essentially streets where works would be especially disruptive to road users, typically due to high vehicular, pedestrian, bus or commercial vehicle volumes *(27)*.

FIGURE 1 A Map of the City of Derby and its Location in the UK

Key differences between the Permit and Notice regimes are:

- Permits enable SAs to be more proactive in managing and controlling activities on their road networks, whereas Notice schemes afford limited control.
- Permits are more aligned to applying to work on the highway, whereas under Noticing, work promoters simply notify the SAs of their intentions.
- Permits enable SAs to add specific conditions as standard to works, which is significantly less common under a Noticing regime.
- Permit applications carry a charge, and failure to comply with any conditions set can attract financial penalties *(5)*.

The study

The study period lasted five years commencing October 2009 on only traffic-sensitive streets. During this period 42,171 individual works were registered with the SA. The mean volume of works was 8434 per annum (Figure 2). Around 54% of the works were executed by the HA, compared to 46% by SUs. The number of excavations occurred as follows:

- Year 1 – 8512
- Year 2 – 8201
- Year 3 – 8626
- Year 4 – 7678
- Year 5 – 9154

Interestingly, the highest volume of works occurred in year 5 of the study, when the Permit scheme was active. This increase may have been because of greater reporting compliance under the Permit scheme. Anecdotally there has always been a subtly cavalier attitude towards submitting Notices, with under-reporting acknowledged across the industry. Legal repercussions have been limited to cases of sustained failure of an SU to notify. Failure to apply for a Permit is considered a more serious offence than failing to give Notice, due to both failing to seek authorisation for works, as well as evading payment. Further, the volume of work undertaken is not necessarily a proxy of disruption; volumes of work can increase at the request of the SA who may encourage SUs to work at less disruptive times.

Data

Study data was already routinely collected by the SA, however additional work was undertaken to create specialist reports pertaining to volume, duration and works promoter. Reports were run recalling monthly data from the SA's central database used to receive Notices and Permit applications. This data was collated in Microsoft Excel and transferred to IBM SPSS Statistics 22 (SPSS). 61 monthly entries between October 2009 and October 2014 were used to run an Autoregressive Integrated Moving Average (ARIMA) time series model on SPSS. Each entry was based on the mean duration of an excavation activity per month, which was calculated by dividing the total applications received, by the total days spent occupying the highway.

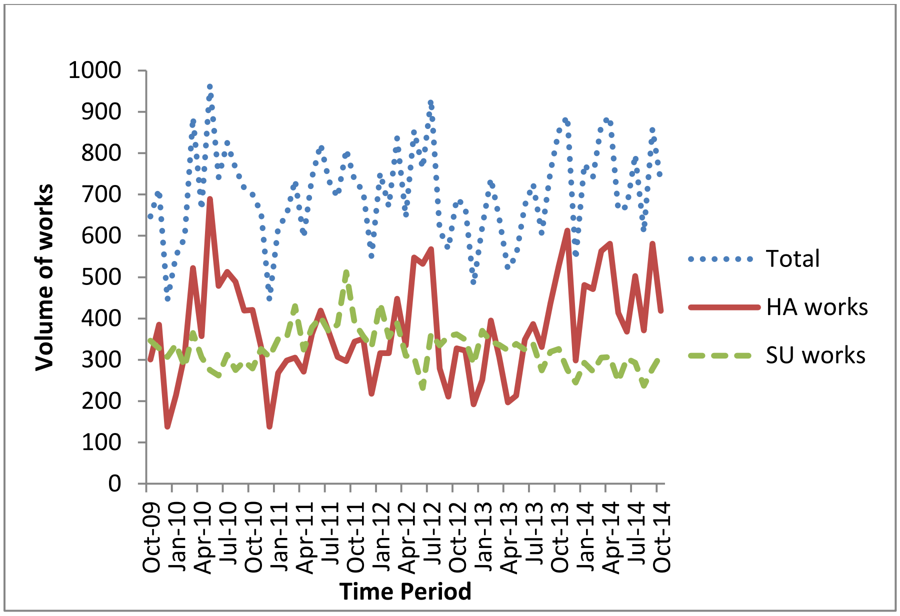

FIGURE 2 Derby Case Study – Volume of Works over 5 Years

Various externalities considered to effect excavation activity were picked as independent variables and measured (Table 1). In particular the Gross Domestic Product (GDP) showed an uneven trajectory until June 2012, after which it consistently increased. Construction infrastructure output meanwhile showed a small and steady increase whilst housing demand almost doubled over the five years. Data on vehicle miles travelled showed regular seasonal peaks (Jul-Sept) and dips (Jan-Mar) as expected, but was relatively static over the five year period. Note, that the Christmas Restrictive period identified is a period when the SA heavily restricts works on traffic-sensitive streets between mid-November and early January (except emergencies).

METHOD

The variables were first screened using a correlation coefficient process. This process tests how closely variables are correlated to each other. Gross Domestic Product (GDP), construction infrastructure and air temperature were found to be too closely correlated (over 0.80) to other variables and were consequently removed from the model *(28)*. The remaining variables namely, vehicle miles travelled, daylight hours, overall construction industry output, construction housing, precipitation, school holidays, Christmas Restrictive period and daylight hours were retained as independent variables (IV). The dependent variable (DV) was the average duration of each work per month.

The method for devising the correlation coefficient was:

$$r_{xy} = \frac{\mathrm{cov}(x, y)}{s_x s_y} = \frac{\sum (x-\bar{x})(y-\bar{y})}{(N-1)s_x s_y} \qquad (1)$$

1 **TABLE 1 Variables Used in the Analysis and Descriptive Statistics**

Variable Type	**Variable**	**Variable Description**	**Variable format/unit**	**Source**	**Minimum value**	**Mean Value**	**Maximum value**
Dependent variable	Average duration of work per month	Total number of works/total duration	Count/days	Derby City Council reports	2.19	3.05	4.42
Intervention variable	Regime	Type of management regime - Notice or Permit scheme	Binary/(0/1)	Derby City Council	0	-------------	1
Independent variable	(GDP)	An indicator of economic activity. Based on 'current price' (CP) per month	Ratio/$-USD	*(29)*	100.4	105.31	112.2
Independent variable	Construction industry output (overall)	An indicator of economic activity. Money spent on construction of new housing, infrastructure and 'other' works – commercial and private per month in UK (£ million)	Ratio/£-GBP	*(30)*	16,031	18,011	19,030
Independent variable	Construction housing output	An indicator of economic activity. Money spent on new public and private housing per month across UK (£ million)	Ratio/£-GBP	*(30)*	3,860	5,218	6,932
Independent variable	Construction infrastructure output	An indicator of economic activity. Money spent on public and private (industrial and commercial) infrastructure per month across UK (£ million)	Ratio/£-GBP	*(30)*	2,411	3,359	3,830
Independent variable	Daylight	An indicator of working conditions. Number of hours of daylight per day (hours: mins)	Count/hours	*(31)*	7 :51	12:38	16:39
Independent variable	Air temperature	An indicator of working conditions. Mean air temperature over month - °C	Ratio/Degrees Celsius	*(32)*	-0.3 °C	10°C	17.6°C
Independent variable	Precipitation	An indicator of working conditions. Based on amount of rain fallen	Count/ millimeters	*(33)*	5.75	56.23	129.59
Independent variable	Vehicle miles travelled	Distance travelled on all roads in UK by all classes of vehicles per year (billion miles)	Count/miles	*(34)*	70.1	76.2	81.3
Independent variable	School holidays	An indicator of road activity. Based on the proportion of school holidays over week days per month	Count/%	*(35)*	0%	25%	100%
Independent variable	Christmas restrictive period	An indicator of a period of typically low excavation activity and high traffic volumes between mid-November and early January over Christmas period	Binary/(1/0)	*(36)*	0	-------------	1

- r is the correlation
- x is the observed value 1
- y is the observed value 2
- $\bar{x}$ is the mean of the observed value 1
- $\bar{y}$ is the mean of the observed value 2
- s_x is the standard deviation of the observed value 1
- s_y is the standard deviation of the observed value 2
- N is the sample size

Time Series Model

A time series analysis model repeatedly measures a single variable over a regular and consistent period of time. This form of analysis can be employed to understand patterns and trends historically, and to extrapolate these into the future to make predictions. Time series analysis can also be used to measure the impact of one or more intervention. A minimum of 50 observations should be used for more reliable results *(37)*. Time series analysis was used in this study to measure the impact of the Derby Permit scheme on excavation activity over a five year period.

The time series model can be defined as:

$$y_t = f\,(I_t, X_t) + N_t \qquad (2)$$

- y_t is the dependent variable at a given time representing the mean duration of each excavation activity per month
- t is the discrete time (month in this case)
- f (function of)
- I is the intervention variable
- X is the deterministic effect of other independent variables
- N_t is the stochastic or noise component

Intervention function

Time series analysis can include an intervention variable which examines the effect of an event or occurrence in the dataset *(38)*. This research sought to analyse the effect of the Permit scheme, which will be used as the intervention variable (I). The intervention in this case is a step function as opposed to a pulse function. Therefore prior to the Permit scheme the $f\,(I)$ value was 0, but with the onset of the scheme the $f\,(I)$ value changed to 1 *(28)*. The intervention function is defined as:

$$f\,(I_t) = S(t) \text{ when } S(t) = \{0 \text{ when } t<T,\ 1 \text{ when } t\geq T\} \qquad (3)$$

- *S(t)* is the step function
- *T* is the beginning of the event

Diagnosis of any model residuals is regarded as white noise, whereby consideration is given to the correctness of the model, its parameters, and for all systematic variances *(28).* This study includes the possibility of noise within the ARIMA model, however no significant evidence of this was found, as will be detailed in the Ljung Box Q significance in the results section. ARIMA models employ lagged values for forecasting time series analysis. The models can be expressed as ARIMA *(p, d, q)*; where *p* is the autoregressive element, *d* represents the seasonal trends in data, and *q* represents the lingering effect in the prediction equation *(39).*

Impact Calculation

As part of Derby City Council's business case for the Permit scheme, a cost benefit analysis predicted an overall reduction in highway excavation durations of around 5.5% *(40)*, similar to Kent County Council's prediction of 5% *(22)*. The following values have been identified for the daily cost of street works disruption per site:

- £868/$1331 - based on road user delay only in England, in 2004 *(14)*. (This rate is inflated *(41)* from source data rate of £633/$971).
- £783 ($1201) based on net consumer and business impact, accidents, fuel and carbon emissions in 2014 limited to Kent County in England *(22).*

Placing a daily value on highway excavation disruption is difficult due to the subjective and differing attributes used for calculations, such as user delay, loss of business, pollution etc *(1).* Of the two sources above, the value of £886 will be adopted to make impact calculations, given the comprehensive analysis and documented methodology provided by the authors.

RESULTS

Based on 61 monthly entries between October 2009 and October 2014, the overall mean duration of works was 3.06 days (minimum - 2.19 days and maximum 4.42 days).

In order to understand the effect of the Permit scheme (I) on the average duration of works per month (DV) and the other explanatory variables (IV), an ARIMA time series model was run. The SPSS Expert Modeller function was engaged to identify the optimal model. The results returned an ARIMA (0,0,0) model - this means that there was no evidence of any seasonal trend within the dataset.

Overall the model demonstrated that total excavation durations reduced over the five years with a generally downward trajectory. The average duration of works was highest in the first two years of the study with a sharp drop in October 2011. With the exception of October 2013 where there is a sharp increase, the duration of excavations reduced over the remaining three years and stablised further with the Permit Scheme (Figure 3). It is considered that the stabilisation of excavation duration is linked to the greater pre-planning of activity as is necessitated by the Permit Scheme.

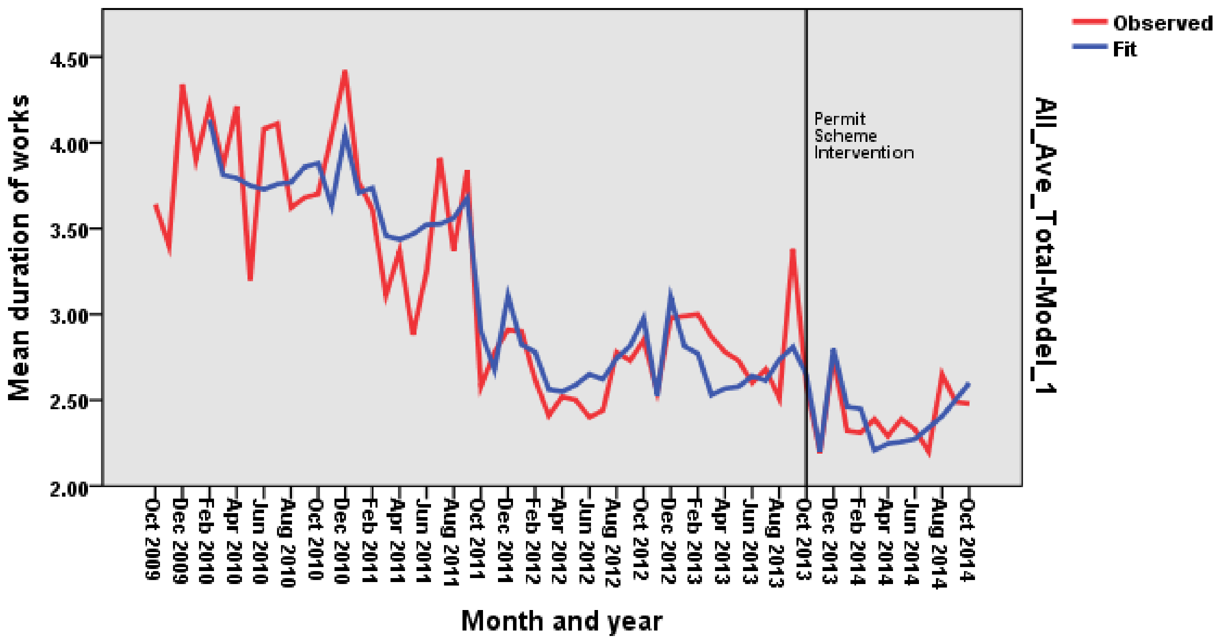

FIGURE 3 Total Highway Excavation Activity During Study Period

Model analysis shows that the intervention of the Permit scheme has reduced the average duration of highway excavations by 0.322 days, or approximately 1/3rd of a working day. ‘Daylight hours’ was the only variable considered a significant explanatory variable with results showing a lagged value, which means a relationship with the number of daylight hours in the current month, along with, to differing degrees, daylight hours of the two previous months (Table 2). This relationship may be related to the complex interaction with daylight hours due to the ‘frantic’ use of hours at the beginning of spring and less desperation to use the hours at the end of the summer. It may also be related to the hurried nature in which work promoters use their budgets towards the end of the financial year. Statistical analysis did not find that the country’s economic activity influenced the duration of excavation activity. Analysis over a longer duration, to include the period prior to the global economic recession from 2007 to further post permit scheme analysis would be helpful for deeper analysis. Unfortunately, this was not possible due to limited data availability.

TABLE 2 Results from the Time Series Intervention Model

Variable	**Estimate**
Average works duration	3.05
Permit Scheme Intervention	-3.22
Daylight hours	Lag 0 (current month) -1.75
	Lag 1(last month) -0.329
	Lag 2 (month before last) +0.186

In terms of model accuracy, the R squared value provided goodness of fit statistics – the closer the value is to 1, the greater the goodness of fit *(38)*. The results gave an R-squared value of 0.855, therefore we can be 85.5% certain that the changes in activity are attributable to the variables identified in the model. The remaining 14.5% value is based on factors outside of this model. The

MAPE (mean absolute percentage value) of 6.039 means that across the series, on average, the forecasted/predicted value has a 6% margin of error. The MaxAPE value of 20.353 means that at worst, 20.4% of the variation was not explained at some point in the series. The Ljung Box Q statistic provides an indication of whether the model is correctly specified *(38)*; with a value of 0.989 significance, we can be very confident that the model is correctly specified (Table 3).

TABLE 3 Results of Model Statistics

Descriptive statistics	**Value**
R-squared	0.855
MAPE	6.039
MaxAPE	20.353
Ljung-Box Q	0.989

The average duration of excavation works in Derby is 3.06 days; the model estimated that the Permit scheme reduced works by 0.322 days, which equates to a 10.5% reduction and is almost double the anticipated 5.5% reduction previously derived. This reduction is against a backdrop of increased volumes, but a simultaneous decrease in duration of works. Using the average volume of works of 8434 works per annum, and the estimated cost of road user disruption of £868/$1331 *(14)*, this equates to a reduction of excavation activity by 886 days per year, which is equivalent to a cost of delay saving to motorist of £769,048/$1,179,777 in Derby. This does not include construction costs saved by work promoters, or costs related to business, community or environmental impact.

DISCUSSION AND CONCLUSION

This study sought to evaluate the effects of the Permit scheme intervention on the average duration of highway excavation activity per month. An ARIMA time series analysis model positively demonstrated that the Permit scheme reduced the average duration of excavations by 1/3rd of a day per job; in Derby this is equivalent to around 886 days, equivalent to £769,048/$1,179,777 per annum. The Permit scheme has played a positive role in reducing excavation activity which is valuable feedback for policy makers and practitioners. In rationalising why the Permit scheme has had this effect, a key explanation could lie with the greater pre-planning the scheme demands in order for application approval. Permit applications, resubmissions, and variations all attract fees for the applicant (except for HAs). Rejected applications waste time and create uncertainty; this is likely to be significantly more inconvenient and expensive than the Permit costs itself, especially if it involves re-programming works, plant and equipment, the labor supply chain, as well as informing stakeholders. Greater pre-planning involves submitting robust site information, plans, methods, techniques, and detailed traffic management information which leads to greater collaboration with SAs. In turn, this greater preliminary planning means that operatives go to site better informed and prepared, leading to less on-site problems and thus reducing the overall work duration.

Of the independent variables selected, only ‘daylight hours’ was found to have a significant relationship with excavation and was previously correlated to ‘temperature’. Both variables have obvious relationships with excavation activity, as longer daylight hours afford greater working time, whilst warmer temperature afford more stable ground conditions. In considering the effect of economic activity, it is harder to draw conclusions as work promoters were likely to have been affected in different ways. With the exception of telecoms, regulated monopoly industries saw price increases for consumers during the recession. Water increases were modest (around 2% per annum between 2000-2013), however, contentiously, the energy industries saw significant price increases against stable spot wholesale gas markets (electricity - around 8% per annum between 2004-2011, no increase between 2011-13; gas – around 12% per annum between 2004-13). The perceived profit levels led to public and political accusations of profiteering *(42)* leading to the commencement of a high profile investigation by the Competitions and Markets Authority (43). Overall this indicates that utilities were financially comfortable during the recession. Further, greater capital works are advisable during an economic downturn to take advantage of lower costs of labour, equipment and raw materials *(44)*. It is therefore conjectured that utility investment potentially increased; indeed anecdotal evidence showed that utility investment in Derby was certainly unaffected by the economic climate. In contrast, a change in central government and a political will to reduce national deficit in 2010, meant significant austerity cuts and changes to local government funding. Austerity cuts were combined with local authorities being granted freedom to spend their allocations on chosen local priorities, which meant highway budgets were no longer exclusive and could be spent elsewhere if the authority felt there was a greater need *(45)*. These factors make it difficult to understand what role infrastructure investment had to play in highway excavations. A government drive to construct more houses in the UK could also be contributing to increased utility infrastructure. Additional research would benefit from more information about capital spend per year from the work promoters to increase understanding about its role on excavation activity.

This research demonstrates that the Permit scheme is a positive scheme; therefore it is recommended that the Permit scheme could be extended to other busy urban areas. This study has made a reasonable assumption that the deduction in works duration is as a result of better pre-planning of works – it is recommended that the utility industry takes heed of the positive impact this has had. Whilst this study offers financial valuations of the potential scheme savings, these should be seen as indicative due to the varying opinions and estimations of street works disruption.

This is an important and novel piece of research because highway excavation management policy and particularly intervention impacts are under-researched. There is further value in developing this work in order to understand the separate impacts of the scheme on the HAs and SUs, and also on the various works categories. It would also be valuable to research the running costs of the Permit scheme to understand the cost implications on works promoters to get a more holistic understanding.

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