Application of subjective wellbeing approaches to the water sector: impacts of roadworks and flooding incidents

The Shepherds Building,
Rockley Road, W14 0DA
0203 883 9249
information@simetrica.co.uk
simetrica.co.uk

Table of Contents

This policy practice note draws upon research undertaken by Simetrica for Anglian Water on: 'Valuation of the impact of roadworks and flooding using the Wellbeing Valuation method', Simetrica, Daniel Fujiwara, Richard Houston, Kieran Keohane, Iulian Gramatki, Cem Maxell, February 2018.

Anglian Water is the water and water recycling provider to more than six million customers in the east of England and Hartlepool. They are the largest water and wastewater company in England and Wales by geographic area.

We are grateful to Anglian Water for agreement to publish the note and for their significant input and advice during the project. This work is regarded as an innovative part of Anglian Water's societal valuation programme for the PR19 Price Review.

1 Summary and key findings

The aim of this study is to assess the associative impact of flooding and roadworks on the subjective wellbeing of Anglian Water customers. The research applied life satisfaction as its core measure of subjective wellbeing, as the metric is 'evaluative' offering a broad assessment of quality of life. Data was taken from the ONS's Annual Population Survey (APS) – it surveyed 64,526 respondents in the Anglian region during 2011-2016 – and combined this data with Anglian Water's operational information on flooding and roadworks incidents. As information on the incidents was available at a postcode level, we were able to say which individuals in the APS lived close to incidents and which did not. This enabled a comparison of wellbeing between individuals who were potentially affected by incidents to those who were not. Applying this, we conducted Ordinary Least Squares (OLS) regression analysis to estimate the impact of proximity to flooding and roadworks incidents on life satisfaction. To adjust for wider differences between individuals who live near an incident and those who do not, we adjusted statistically ('controlled') for a best-practice set of variables, including earnings, age, gender, marital status, ethnicity, education, employment. The technique therefore seeks to isolate the wellbeing decrease associated with experiencing incidents whilst holding other factors (the 'controls') constant.

The key insights provided by this research, which estimated the subjective wellbeing (SWB) impact of roadworks and flooding incidents in the region served by Anglian Water, are:

1. **The SWB impact per incident for flooding is higher than for roadworks**. In particular, roadworks represent a disturbance to people's quality of life which occurs more frequently but has less impact per incident, whereas flooding occurs less frequently but has more impact when it does occur.
2. **Internal sewer flooding has a higher SWB impact per property than external sewer flooding.** An internal flood typically affects just one or a few households, but the wellbeing impact on those who are affected is strong. An external flood has a much lower wellbeing impact on each affected household, but the number of affected households is much greater meaning that the total impact of the incident is larger.
3. **Internal sewer flooding has a higher SWB impact per property than internal water flooding**. While both sewer and water flooding may cause property damage and a disruption to water services provision, sewer flooding also brings about foul odour and perceived negative health impacts, which corresponds to greater loss in SWB for individuals affected by the flood.

The research goes on to estimate wellbeing (income equivalent) values for roadworks and types of flooding incidents using the Wellbeing Valuation method. The Wellbeing Valuation (WV) method measures the monetary-equivalent impact on welfare of customers in the Anglian Water region experiencing an incident from the relative impacts on wellbeing of income and of the incident.

This study is the first of its kind in the UK to test the impact of flooding and roadworks incidents on wellbeing using best-practice SWB research methods and an innovative locational methodology. It provides an exciting opportunity for applying the wellbeing valuation method to other types of incidents whose location is known, including water-industry-related incidents.

2 Context of the study

2.1 Research objectives and PR19 context

The objective of this research is to assess the impact of flooding and roadworks incidents on the subjective wellbeing (SWB) of Anglian Water's customers to assist Anglian Water with development of its future business planning. We do this by using data on individuals' exposure to incidents and estimating the degree of statistical association between their exposure and SWB.

The study covers the following types of incident:

i) Water flooding
ii) Internal (domestic) sewer flooding
iii) External sewer flooding
iv) Roadworks

Ahead of its 2019 Price Review (PR19) Ofwat has set companies the challenge to innovate in the ways water companies engage with their customers and measure how customers value aspects of their business.[1] For instance, Ofwat has stated that "while stated preference willingness to pay approaches will continue to have an important role to play at PR19, it is also important for companies not to place sole or disproportionate reliance on such methods". The use of SWB measures as a new form of customer engagement in the water industry is aligned with the increasingly important role of SWB in policy and business decision making, examples of which are as follows:

1. The establishment of the UK National Wellbeing Programme in 2010.[2]
2. The use of SWB metrics in Green Book and valuation studies in the UK.[3][4]
3. The launch of the What Works Centre for Wellbeing in the UK[5]
4. The centre stage role that SWB has taken in OECD wellbeing metrics and guidelines[6]

[1] Ofwat (2016) Ofwat's customer engagement policy statement and expectations for PR19.
[2] https://www.gov.uk/government/collections/national-wellbeing
[3] https://www.gov.uk/government/publications/valuation-techniques-for-social-cost-benefit-analysis
[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372165/11-Quality_of_life--quality-of-life-assessment.pdf
[5] https://whatworkswellbeing.org/
[6] http://www.oecd.org/statistics/oecd-guidelines-on-measuring-subjective-well-being-9789264191655-en.htm

5. International trends elsewhere such as the uptake of the wellbeing valuation method by governments in Australia[7] and New Zealand[8].

2.2 Approaches to valuation

There is an extensive body of research in the water industry on methods for valuing the services that water companies deliver. This has grown out of the more general valuation literature in microeconomics, which has become the standard and best-practice approach to valuation (HM Treasury, 2011; OECD, 2013) At the heart of valuation of outcomes is the concept of two welfare measures developed by Hicks & Allen (1934):

- **Compensating surplus (CS)** is the amount of money, paid or received, that will leave the individual in their initial welfare position following a change from the status quo. For example, the CS for experiencing a flood (which reduces an individual's overall welfare) is the minimum amount of money that the individual is willing to accept to experience the flood.
- **Equivalent surplus (ES)** is the amount of money, to be paid or received, that will leave the individual in their subsequent welfare position in the absence of a change from the status quo. For example, the ES for experiencing a flooding incident is the maximum amount of money that an individual would be willing to pay to avoid experiencing a flooding incident.

The two main methods of valuing CS and ES in use in recent years in the water industry have been stated preference and revealed preference valuation:

- **Stated preference (SP)** techniques are survey-based methods which elicit monetary values of non-market goods and services by asking people what value they attach to specified changes in those goods and services. The approach relies on individuals' assessment of scenarios which they may not have experienced in practice and can be subject to biases that reduce the accuracy of the values calculated. Historically SP has been the dominant survey technique.
- **Revealed preference** methods estimate the value of non-market goods using data of how people behave in the face of real choices.

2.3 Wellbeing valuation

Research in the relatively new area of Happiness Economics has led to the recent development of an approach to valuing CS and ES based on people's SWB rather than their preferences. The approach is referred to as **Wellbeing Valuation (WV)**. It estimates value by inferring the impact of outcomes or goods on the SWB of individuals who actually experience these outcomes or goods. Impact can

[7] http://arp.nsw.gov.au/sites/default/files/TPP17-03_NSW_Government_Guide_to_Cost-Benefit_Analysis_0.pdf
[8] https://asvb.com.au/2017/08/01/new-zealand-treasury-signs-asvb/

then be converted into a monetary amount by estimating the sum of money which would have an equivalent impact on SWB.

We conducted our analysis using the Wellbeing Valuation (WV) approach. A key benefit of applying WV to water-related outcomes is that we are able to derive values without asking people directly or hypothetically how much they would be willing to pay (the SP method) and without relying on market data which may be limited in its availability (the RP method). Wellbeing values are based on how people actually experience an outcome (Fujiwara & Dolan, 2014). This is key for flooding and roadworks where most people will not have experienced incidents directly and may struggle correctly to envisage the impact these factors might have on their lives. Another key benefit of applying WV to water industry related outcomes is that we can use extremely large samples of data – approximately 60,000 responses for Anglian Water's customers.

A potential challenge for the WV method is to find a suitable measure of SWB which can be captured accurately and without bias. With this in mind, SWB is usually measured as an 'evaluation' or as an 'experience'. It is said to be measured as an evaluation when people are asked to provide *holistic* assessments of their lives overall. Life satisfaction is an example of this approach, and is both the main measure used in social science (Diener, 2000) and WV research at present and the measure we use in this analysis. It has the benefit of providing a wide-ranging reflection of how people feel about their lives. Although SWB can also be measured as experience, whereby emotions are measured repeatedly through an individual's day to build-up a picture of their wellbeing, this approach often requires bespoke data collection and is therefore not the one taken in this study.

There is a variety of evidence to suggest that overall life satisfaction is a good measure of wellbeing. Whilst some studies have suggested that contextual factors such as the weather can adversely influence and bias life satisfaction responses, Eid & Diener, (2003); Fujita & Diener, (2005); Pavot & Diener, (1993); Pavot et al., (1991) and Schimmack & Oishi, (2005) find mood, question order and contextual effects to be limited. Further, bias due to mood is likely to average out in large representative samples. There is a range of evidence that demonstrates that there is a strong correlation between wellbeing ratings and a range of outcomes that we would intuitively relate to wellbeing such as emotions (smiling and frowning) and health (Kimball & Willis, 2006; Sales & House, 1971), while life satisfaction has a high level of retest reliability (stability) (Krueger & Schkade, 2008). Overall, life satisfaction can be viewed as a reliable measure of wellbeing and as a consequence has been extensively used in the academic and government research literatures (Diener et al., 1999; Veenhoven, 2007). As a result, SWB is considered an appropriate way to estimate the relationship between flooding / roadworks incidents and wellbeing in large representative samples such as the Annual Population Survey (APS).

3 Data and methodology

3.1 Data

This study draws on two main sources of data:

i) **The Annual Population Survey (APS) (5 waves, 2011 - 2016)** is a UK-wide continuous household survey. It provides information on respondents' SWB, which is used as the outcome variable in our analysis, and important social and socio-economic variables at personal and local levels, which are used as 'control variables'. We use a secured access version of the data, available in the ONS's Secure Research Service, as this provides the postcode of the respondent's home address, which ensures that we can identify those who live near to the studied incidents.

ii) **Data on flooding and roadworks incidents** provided by Anglian Water (incidents data). This includes information on the type of incident, the postcode in which the incident took place, and the dates when it occurred. It is based on Anglian Water's operational data and splits flooding/roadworks into four categories:

- Internal water flooding[9]
- Internal sewer flooding (domestic and non-domestic[10])
- External sewer flooding
- Roadworks

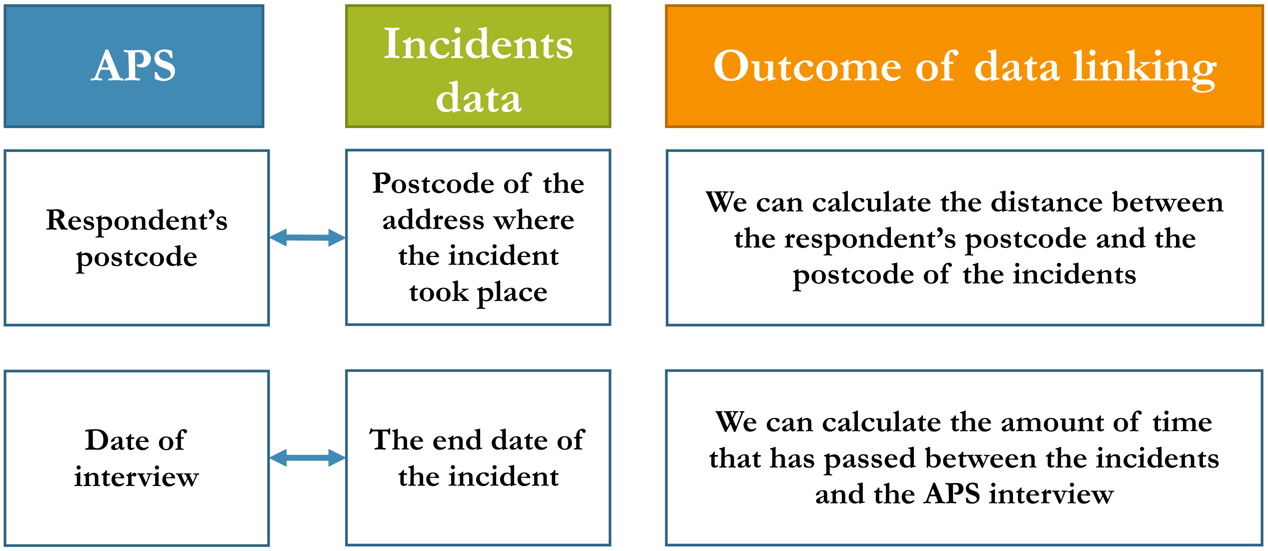
For the purposes of our analysis we also group the different flood categories (water, internal and external sewer) in an "All flooding" category.

We merge these two data sources based on: the postcode of the respondent and of the incident; and the date of the respondent's interview and when the incident ended (as some incidents last for more than one day).

Figure 1 set outs the outcomes of merging these two datasets in terms of the implications for the analysis.

[9] We assume the water flooding data is internal as it is based on insurance payment records and based on feedback from Anglian Water.
[10] There is a very small number of internal non-domestic incidents in the data. As our results for this type of incident are statistically insignificant they are not reported in the study.

Figure 1. Linking the APS and incidents data



Note: The respondent's grid reference is derived from their postcode provided by the ONS.

3.2 Methodology

It is crucial that in seeking to identify the impact of incidents on wellbeing we control, where possible, for the impact of wider factors correlated with the occurrence of incidents (but not caused by them) which also drive wellbeing. In econometric terms, this means to ensure that we adjust for any of the observable causes of endogeneity bias in our estimates of the impact of incidents on subjective wellbeing. For example, living in a densely populated urban area may make incidents more likely to occur (because of the increased density of pipework) and may also drive wellbeing in and of itself. It would not be appropriate in estimating the value of incidents to include the additional wellbeing impacts, if any, of living in an urban area per se. To help control for these and similar factors we employ a set of statistical models which in effect seek to compare wellbeing for individuals *with and without* incidents who are otherwise rendered similar and live in similar areas.

3.2.1 Econometric Specification

Our models seek to test the relationship between subjective wellbeing and proximity to flooding/roadworks incidents. In particular, we fit the econometric model below using multivariate ordinary least squares (OLS) regression analysis:

(1) $$SWB_i = \alpha + \beta_1 \text{Incident}_\text{i} + \boldsymbol{X}_i \boldsymbol{\beta} + \varepsilon_i$$

where SWB_i denotes the subjective-wellbeing of individual i; $Incident_i$ is a dummy variable which takes the value of one if the respondent lives within a given distance of an incident and their interview in the APS took place within a given period of time since this incident (e.g. the respondent lives within 500m of an incident that took place no longer than six months previously) and zero otherwise; and $\boldsymbol{X}_i$ is a list of the control variables. The coefficient $\boldsymbol{\beta}_1$ is the key coefficient for our analysis because if it is significant and negative it would imply that living near an area with flooding/roadworks incidents is associated with a reduction in an individual's wellbeing.

The models are run for a sample of respondents who reside in Anglian Water's area of operations.[11]

3.2.2 Incident threshold selection

A key issue was to decide the time and distance thresholds within which individuals would be classified as having been affected by an incident. To do this we first ran econometric models for each combination of the following thresholds:

- Distance – Incident occurred within 50m, 250m, 500m, 1000m, 2000m of the individual's home postcode

- Time period[12] – Incident occurred at most 7, 31, 92, 183, 365, 730 days before the individual's APS interview

Table 1. Threshold selection for incident variables

Incident type	Distance threshold	Time period threshold
All flooding	<500m	<6 months (183 days)
Roadworks	<500m	<1 month (31 days)
Water flooding	<50m	<3 months (92 days)
Internal domestic sewer flooding	<50m	<6 months (183 days)
External sewer flooding	<500m	<6 months (183 days)

Note: We did not find any statistically significant results for any threshold for internal non-domestic sewer flooding.

[11] A list of postcode areas was provided by Anglian Water.
[12] This time elapse is not the assumed duration of the incident, but rather the number of days between the incident and the interview.

As set out in Table 1, we then chose the thresholds that best balanced the need for a material number of individuals to fall in each of the treated and non-treated groups (ensuring good sample size to minimise estimation error in the results) with the need for behaviourally plausible assumptions about the temporal and spatial range of the impact of incidents. As set out below, statistical adjustments were made to the eventual results to remove dependence on the thresholds chosen.

3.2.3 Description of variables used in the APS

The APS provides several SWB measures which are used as outcome variables in our analysis:

- **Life satisfaction** ("Overall how satisfied are you with your life these days?")
- **Happiness** ("Overall how happy did you feel yesterday?")
- **Anxiety** ("Overall how anxious did you feel yesterday?")
- **Sense of worthwhile** ("Overall, to what extent do you feel the things you do in your life are worthwhile?")

All responses are measured on a scale of 0-10[13] and constitute the four core wellbeing measures used in the UK's National Wellbeing Programme. In addition, the health analysis is conducted using the self-reported general health variable in the APS data set, measured on a five-point scale: 'very poor', 'poor', 'fair', 'good' and 'very good'. As noted previously, our primary measure is life satisfaction. This is because, being an evaluative measure, it offers a broad assessment of overall quality of life and has a large body of supporting evidence in terms of its validity and rigour. The other measures are used to test and corroborate the life satisfaction results.

The APS also provides a wide range of variables relating to survey respondents, including demographic characteristics and socioeconomic factors. In our models, we use these to control for a wide range of factors known to be associated with SWB and health. In particular we use the following best-practice controls, which are based on the variables recommended in Fujiwara & Campbell (2011):

- Age
- Gender
- Marital status
- Ethnicity
- Educational status
- Employment status and earnings
- Religious affiliation
- Number of children
- Geographic region

[13] Where 0 is not at all satisfied, happy, anxious, or worthwhile and 10 is completely satisfied, happy, anxious, or worthwhile.

- Urbanisation
- Wave of survey
- Month of interview
- Smoking
- Claiming benefits
- Survey Mode
- General Health (excluded in the regression model where health is an outcome variable)
- Local authority

3.2.4 Adjustments to the regression results for policy application

We make several adjustments to the regression outputs to ensure the results are on a useful basis for application to policy.

As the regressions are based on chosen distance thresholds and use individual-level SWB data, the resulting coefficients give the total impact per person on average across the chosen catchment areas:

1. Step one adjusts these to a per person *per incident* basis across the catchment areas, by adjusting for the fact that the average affected respondent for each type of incident was assigned to more than one such incident.
2. The second step then multiplies by the average household size in the Anglian Water region. This ensures that impact is on a *per property rather than per person* per incident basis, averaged over catchment areas.
3. To account for the possibility that not all households living with the specified distances of incidents are affected by these in practice (as thresholds were chosen rather than estimated), we then aggregate impact over the average catchment area and scale this, based on operational data, by the number of households typically affected by an average incident in practice. This ensures that impact is on a per incident per affected property basis, in line with Anglian Water's needs for business planning.
4. Monetise the impact per incident and per incident per affected property based on the causal impact of income on wellbeing estimated in (Fujiwara & Dolan, 2016). This needs to be scaled to the time period as defined by the threshold, e.g. ½ for all flooding (6 months). The monetary valuation method provides an annual value, and therefore unless an incident's time threshold lasts exactly a year, we need to adjust the associated life satisfaction impact with respect to the time threshold before monetising. The final step is to adjust for compensation paid by adding the average compensation paid per incident by Anglian Water to the per incident wellbeing value[14].

[14] This would otherwise result in downward bias to the estimates as life satisfaction values in APS are de facto net of the satisfaction respondents may have gained from compensation.

These adjustments help ensure that SWB techniques can be used without introducing statistical bias for geographically-defined wellbeing drivers the precise extent of whose incidence is not known. They therefore provide a methodology which can be used for SWB analysis of other such drivers, including operational incidents across any industry.

3.3 Monetisation using the Wellbeing Valuation method

The monetary value of the wellbeing impact of a type of incident can be estimated from the relative impact on wellbeing of income and that type of incident. This relativity, referred to as the marginal rate of substitution (MRS) between the two factors, is calculated as follows:

$$(2)\quad MRS = \frac{\beta_Q}{\beta_M}$$

where β_Q is the incident coefficient from the regression, as set out in section 3.2, and β_M (the impact of income on SWB) comes from Fujiwara and Dolan (2016), which uses lottery wins as exogenous variation in income to estimate the causal effect of income on life satisfaction. As the impact of income is calculated using a non-linear specification (the log of income), the valuation of changes in life satisfaction varies with households' level of income. Households in the Anglian Water region earn approximately the UK median income and so we use a median income estimate of £30,000 per year. With these inputs, we estimated the **equivalent surplus** of having experienced an incident[15], which gives the total **willingness to pay (WTP) to avoid** an incident for households affected by the incidents within the treatment area.

4 Results and interpretation

4.1 Descriptive statistics

Table 2 presents descriptive statistics for the analysis. The first row shows that sample size for the regressions was 64,526 APS respondents (inclusive of those deemed to be potentially affected and those deemed not), indicating that the analysis is based on a very large sample of respondents who live in areas served by Anglian Water.

After the combined flooding incident type, roadworks have the highest number of respondents potentially affected by incidents (26,800 according to our optimal threshold definition). On the other hand, the incident type with the lowest number of affected respondents within the optimal threshold, is internal sewer flooding with 85 observations. This is in line with the relatively low total number of internal sewer flooding incidents (3,131) compared to roadworks incidents (264,061).

[15] We can also express the calculations in terms of compensating surplus, which would be the willingness to accept the potential experience of an incident.

Table 2. Descriptive statistics – sample size by incident type

		All flooding	Water flooding	Internal sewer flooding (domestic)	External sewer flooding	Roadworks
1	Sample size – in regression	64,526	64,526	64,526	64,526	64,526
2	Sample size – number of respondents potentially affected by incidents (based on optimal threshold)	27,491	96	85	24,646	26,800
3	Total number of incidents within raw data (after removing duplicates) [16]	56,291	5,063	3,131	47,208	264,061
4	Sample size in APS April 2011-March 2016 (entire UK)	822,625				

Source of data in row 1, 2 and 4: ONS

4.2 Main results

Table 3 shows for each incident type the wellbeing value per incident and per incident per person affected. These values account for compensation. The final per incident values can be interpreted as an estimate of the sum of willingness to pay to avoid one incident based on the experiences of Anglian Water's customers who are in the neighbourhoods affected by it. The key findings are:

The wellbeing impact *per incident* of each type of flooding is higher than for roadworks. Whilst roadworks are more frequent in nature than this type of incident as set out above (264,061 incidents in the data versus 56,291 for All flooding), they have an average wellbeing value per incident that is lower than all types of flooding.

The average internal sewer flooding incident has a higher wellbeing impact *per property affected* than the average external sewer flooding incident. Whilst the total welfare loss from the average external sewage flood is greater, this is because each external incident affects more properties on average (826). Conversely, on average an internal flood has a much higher wellbeing impact on each household it affects, but the number of such households is much smaller.

The average internal sewer flooding incident has a higher wellbeing impact *per property affected* than the average internal water flooding incident. As the data available on water flooding incidents originates from insurance claimants these incidents were classified as internal. Their wellbeing association and the resulting wellbeing values are about three times smaller than those for internal sewer incidents, both in per incident and per property affected terms. While both

[16] Duplicate incidents were defined as incidents of the same type, which happened in the same postcode, at the same date and time.

sewage and water flooding may cause property damage and a disruption to water services provision, sewage flooding also brings about foul odour and negative health impacts, which corresponds to the higher coefficient associated with internal sewer flooding.

Table 3. Wellbeing values by incident type

Incident type	Distance threshold	Time period threshold	Number potentially affected in the sample	Average number of households in distance threshold	Estimated life satisfaction impact per person in catchment area	Aggregated wellbeing value of an incident	Wellbeing value per property affected by an incident
All flooding	<500m	<6 months	27,491	868	-0.044*	£390,552	£24,930
Roadworks	<500m	<1 month	26,800	795	-0.026*	£31,735	n/a
Water flooding (internal)	<50m	<3 months	96	32	-0.273*	£86,030	£54,312
Internal domestic sewer flooding	<50m	<6 months	85	32	-0.508*	£263,814	£166,549
External sewer flooding	<500m	<6 months	24,646	826	-0.041*	£369,815	£21,754

Notes: * indicates significant results at 10% level or lower. Wellbeing values are adjusted to account for the average compensation paid to households who experience flooding incidents within the time period threshold. Source of statistical output: ONS.

4.3 Wider wellbeing measures

To test the main results based on life satisfaction we also analysed other measures of wellbeing, hypothesising that incidents would be associated with greater levels of anxiety and lower level of health.

Table 4 below sets out the estimated relationship between these outcomes (columns 2 and 3) and being affected by a flooding or roadworks incident within the specified distance and time thresholds. The life satisfaction coefficients from the main analysis (column 1) are included for comparison.

We found that the **direction** of the coefficients for health and anxiety are in line with the coefficients for life satisfaction for flooding. This corroborates the hypothesis that these incidents are associated with lower levels of wellbeing. For roadworks, the direction of the anxiety result is in line with the life satisfaction results, in that people in areas potentially affected by roadworks report higher levels of anxiety. The results for health for this type of incident are not statistically significant.

We also found that where the results for the alternative wellbeing measures were statistically significant, the **magnitude** of these impacts was broadly similar to the impact on life satisfaction. This offers corroborating evidence for the magnitude of the life satisfaction impacts.

Table 4. Further wellbeing measures for triangulation, by incident type

	1	2	3
Regression coefficients	**Life satisfaction (0-10)**	**Health (adjusted to a 0-10 scale)**[17]	**Anxiety (0-10)**
All flooding within 500m in 6 months	-0.044***	-0.035***	0.062***
Roadworks within 500m in 1 month	-0.026***	(N/S)	0.054**

Note: The wellbeing measures 'Happiness' and 'Sense of worthwhile' are not included as they were not found to be statistically significant. The "Health" wellbeing measure for roadworks incidents is also not included due to lack of statistical significance. Source of statistical output: ONS

4.4 Caveats

As experimental data[18] was not available on incidents, we estimated the impact of incidents using multivariate regression. Although the main determinants of SWB were controlled for in this analysis, in line with key wellbeing studies, it remains the case that some confounding factors may be at play which are not observed in the data. As a result, we cannot ultimately state that incidents have a causal effect on wellbeing (as the relationship could instead be driven in part or in full by these unobserved factors). If, for example, incidents are more likely to occur in areas with bad weather, where wellbeing may be lower anyway for that reason, our estimates of the value of incidents may be too high. This caveat reflects a limitation which is inherent to almost all forms of policy evaluation, as very few studies have experimental data.

There is also potential measurement error arising from the fact that distances are calculated from the centre of the respondent's postcode rather than from the exact location of their house (as only the postcode was available). Similarly, some incidents did not have a postcode or other geographical

[17] The initial health coefficient (-0.016) is on a 1-5 scale. To convert this to a 0-10 scale, we multiply the coefficient by 11 and divide by 5 to get -0.035.

[18] One of the best methods to estimate a causal effect is a Randomised Control Trial (RCT). In our case, this would mean randomly assigning floods / roadworks to selected streets/properties, without regard to their characteristics. Such an approach is clearly infeasible.

identifier provided[19]; as a result of which, some respondents in the APS may be incorrectly coded as unaffected by incidents despite having been affected in reality. Both of these factors could, in principle, bias the estimated coefficients downwards.

Finally, the sample size for the number of households affected by internal domestic sewer flooding is low at n=85. Whilst the results for this type of incident are statistically significant despite this small sample, they should be interpreted with this caveat in mind. In small samples results may be driven by outliers in the data, and there is potentially low external validity in generalising results to the full population of households affected by the type of incident concerned.

4.5 Assessment of results and triangulation

The analysis estimated values for: all types of flooding incidents recorded, internal water flooding, internal (domestic) sewer flooding, external sewer flooding and roadworks.

As part of the wider research, the study also provided preliminary advice on how the wellbeing values for these incidents could be incorporated alongside other valuation evidence, particularly from stated preference studies, to inform the PR19 recommended values for use in investment appraisal. This takes into account the differences in valuation approach, the types of value captured and how the values best align with the existing societal values.

There are a number of potential reasons for why the stated preference and our wellbeing results may differ:

- The WV approach ensures that we are capturing the impact of an incident in terms of how people have experienced it in real-life, as opposed to asking them about a hypothetical scenario which they may not have experienced and thus may not value entirely accurately.
- WV only captures the impact of an incident at the fixed point in time when the respondent answered the wellbeing survey. Although different respondents affected by flooding will have different amounts of time elapsed before they were surveyed, WV cannot value future changes in SWB that arise from experiencing the incident, unless these are anticipated at the time of the survey and the anticipation has already impacted wellbeing in full.
- The WV approach does not include purely altruistic behaviour (i.e. concern for impact on a complete stranger), although it is likely to pick up traces of impact on the wellbeing of individuals who were, for example, concerned at observing an incident affecting others in their neighbourhood, be that out of regard for neighbours, concern for the impact on property prices, or other potential reasons. With the data available there is no consistent way of isolating this component.

---

[19] A total of 0.02% of roadworks incidents, 33% of water flooding incidents, and 10% of sewer flooding incidents did not have a postcode in the raw data from October 2010 to April 2016 (the years of the data which map to the APS data and the time thresholds used).

5 Conclusion

To the best of our knowledge, this is the first study to measure the impact on subjective wellbeing of water-industry-related flooding or roadworks incidents in the UK.

The work produces a set of results regarding the detrimental impact of flooding and roadworks on people's wellbeing. In particular, all of the analysis indicates that exposure to a flooding/roadworks incident is associated with reductions in wellbeing (measured as life satisfaction and anxiety) and, in the case of flooding in particular, health (measured as self-reported general health).

We compared wellbeing estimates for roadworks and flooding and between different types of flooding, revealing differences which are intuitive and expected, for example, the finding that internal sewer flooding has greater impact per household than external sewer flooding but less impact per incident overall than externally (as internal incidents tend to affect fewer households).

The research on the wellbeing impacts of these incidents complements and validates estimates produced by other methods, such as stated preference, which are in use in the water industry already. For its PR19 Price review Ofwat stated that it expects to 'see companies developing a robust, balanced and proportionate evidence base' and that 'while stated preference approaches will continue to play a role at PR19', the application of innovative techniques to the design and interpretation of customers' engagement with different aspects of water and wastewater services is to be encouraged. This study is a contribution to meeting this challenge and highlights the opportunity to apply the wellbeing valuation method to other types of incidents, including water industry service related incidents.

6 Bibliography

Diener, E. (2000). Subjective Wellbeing. The Science of Happiness and a Proposal for a National Index. *Am Psychol*, *55*(1), 34–43.

Diener, E., Suh, E. M., Lucas, R. E., & Smith, H. L. (1999). Subjective well-being: three decades of progress. *Psychological Bulletin*, *125*(2), 276–302. https://doi.org/10.1037/0033-2909.125.2.276

Dolan, P., & Fujiwara, D. (2016). Happiness-Based Policy Analysis. In *The Oxford Handbook of Well-Being and Public Policy* (pp. 286–317). New York, NY: Oxford University Press.

Eid, M., Langeheine, R., & Diener, E. (2003). Comparing Typological Structures Across Cultures By Multigroup Latent Class Analysis A Primer. *Journal of Cross-Cultural Psychology*, *34*(2), 195–210. https://doi.org/10.1177/0022022102250427

Fujita, F., & Diener, E. (2005). Life Satisfaction Set Point: Stability and Change. *Journal of Personality and Social Psychology*, *88*(1), 158–164. https://doi.org/10.1037/0022-3514.88.1.158

Fujiwara, D., & Campbell, R. (2011). *Valuation Techniques for Social Cost-Benefit Analysis: Stated Preference, Revealed Preference and Subjective Well-Being Approaches. A Discussion of the Current Issues* (pp. 1–76). London, UK: HM Treasury. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209107/greenbook_valuationtechniques.pdf

Fujiwara, D., & Dolan, P. (2014). *Valuing Mental Health: How a Subjective Wellbeing Approach Can Show Just How Much It Matters* (p. 21). London, UK: UK Council for Psychotherapy. Retrieved from http://www.psychotherapy.org.uk/UKCP_Documents/Reports/ValuingMentalHealth_web.pdf

Hicks, J. R., & Allen, R. G. D. (1934). A reconsideration of the theory of value. Part I. *Economica*, *1*(1), 52–76.

HM Treasury. (2011). *The Green Book: Appraisal and Evaluation in Central Government* (pp. 1–114). HM Treasury. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

Kimball, M., & Willis, R. (2006). Utility and happiness. *University of Michigan*.

Krueger, A. B., & Schkade, D. A. (2008). The Reliability of Subjective Well-Being Measures. *Journal of Public Economics*, *92*(8), 1833–1845.

OECD. (2013). *OECD Guidelines on Measuring Subjective Well-being* (p. 265). Paris, France: OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264191655-en

Pavot, W., & Diener, E. (1993). The affective and cognitive context of self-reported measures of subjective well-being. *Social Indicators Research*, *28*(1), 1–20. https://doi.org/10.1007/BF01086714

Pavot, W., Diener, E., Colvin, C. R., & Sandvik, E. (1991). Further Validation of the Satisfaction With Life Scale: Evidence for the Cross-Method Convergence of Well-Being Measures. *Journal of Personality Assessment*, *57*(1), 149–161. https://doi.org/10.1207/s15327752jpa5701_17

Sales, S. M., & House, J. (1971). Job dissatisfaction as a possible risk factor in coronary heart disease. *Journal of Chronic Diseases*, *23*(12), 861–873. https://doi.org/10.1016/0021-9681(71)90015-4

Schimmack, U., & Oishi, S. (2005). The influence of chronically and temporarily accessible information on life satisfaction judgments. *Journal of Personality and Social Psychology*, *89*(3), 395–406. https://doi.org/10.1037/0022-3514.89.3.395

Veenhoven, R. (2007). Subjective Measures of Well-being. *Human Well-Being*, 214–239.