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Abstract

This article describes two studies which aimed to explore the impacts of pedestrianisation or road closures on traffic displacement, travel behaviour and the phenomenon of 'disappearing traffic'. The first study surveyed residents whose travel routes were affected by a small-scale localised pedestrianisation scheme in the centre of a town. The second measured the traffic impacts of a temporary closure of a strategic bridge in a city centre. In the first case the pedestrianisation produced no change in the modal shares of residents' travel. Drivers continued to drive to the same locations by longer routes. In the second case, the closure caused some traffic displacement and increased journey times but also reduced traffic volumes in both the immediate area and across the city. It concludes by discussing the remaining knowledge gaps on disappearing traffic, made more pressing by the decisions of authorities to reallocate road space during the COVID-19 crisis.

Keywords: Transport planning; Traffic engineering; pedestrianization; urban design

Introduction

Cairns *et al*. (1998) coined the term ‘disappearing traffic’ (also known as ‘traffic evaporation’) to describe the reduction in motor traffic volumes observed around roads which are closed, filtered or reduced in capacity. Over the following two decades a range of studies have provided more examples of disappearing traffic, but the reasons why it occurs remain poorly understood. This literature has provided clear evidence that traffic does “disappear” from the immediate area surrounding affected roads, but the wider impacts, across a town or city, remain uncertain. This raises the question of whether the disappearing traffic is actually displaced over a wider area, which previous studies have failed to measure.

This article describes two studies which aimed to answer those questions. The first was a before and after evaluation of a pedestrianisation scheme in the centre of Taunton, Somerset. The second study concerned the impacts of a five day closure of a bridge in a strategic position in the centre of Bristol. The researchers obtained traffic monitoring data covering the central area around the bridge and the wider city, enabling an evaluation of the impacts on congestion and the extent of displacement and/or disappearing traffic across the city.

Traffic removal measures are usually controversial, with local objections often leading to the curtailment of schemes (e.g. Melia and Shergold, 2018). The impacts of such schemes on traffic conditions on surrounding roads are poorly understood, making it difficult for authorities or advocates to allay the fears of objectors. Understanding the impacts of traffic removal has become more important since the COVID-19 lockdown which prompted the UK government to fund, and many local authorities to implement, road closures and reallocation of road space to pedestrians and cyclists (DfT, 2020, Bristol City Council, 2020). This article will provide some new insights into those impacts but will conclude that significant knowledge gaps remain as a priority for future research.

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Disappearing Traffic – the Evidence So Far

In reviewing the literature on disappearing traffic (or 'traffic evaporation') two observations stand out: the breadth of the two original studies (Cairns *et al.*, 1998, Cairns *et al.*, 2002) and the limited advance of knowledge on the subject since then.

Cairns *et al*. (1998) identified disappearing traffic as a corollary of the opposing phenomenon of 'induced traffic', where traffic volumes are observed to rise when road capacity is increased (following: SACTRA, 1994). Cairns *et al.* (1998) presented data on 49 cases, to which Cairns *et al.,* (2002) added a further 14. The cases came from ten countries, although most were from the UK or Germany. They included temporary closures of roads and/or bridges, permanent pedestrianisation and/or modal filtering schemes and capacity reductions due to the implementation of bus lanes. Total traffic volumes fell in 51 of the 63 cases. The median reduction equated to 11% of the traffic which previously used the treated area. (Note that this metric differs from the approach taken in some other studies which report changes in area-wide traffic volumes)

The impacts varied widely from a 26% increase to a reduction of 147%; both of those extremes reflect coincidental factors, which were sometimes described but not quantified. The underlying data used in these studies mainly came from highway authorities in the different cities and countries. The level of detail available to the authors varied from case to case. The authors had no control over the siting of the traffic counters used to monitor the surrounding areas. This raised one obvious query: was some traffic being displaced outside the area of measurement? Because of that uncertainty, the key finding could be more confidently restated as evidence of *disappearing traffic in the immediate or surrounding area*, but not necessarily across the city or region.

Responding to the wide range of impacts observed, Cairns et al. (1998) suggested three "hypotheses", where:

1. a capacity reduction is offset by some additional capacity elsewhere
2. a local capacity reduction occurs but alternative capacity exists, or:
3. capacity is reduced and no suitable capacity is available

Only under Hypothesis 3 would any significant traffic reduction be expected. Those explanations, which have sometimes been overlooked, will be significant for this study. Cairns *et al.* (2002) explored the reasons for disappearing traffic through an opinion survey of transport planners. Their responses included: modal shift, reduced trip frequencies, more trip chaining and car sharing (as well as re-routing and retiming of car trips). In the longer-term changes in household and job location may strengthen, or conceivably weaken, the impact. Some of the cases in Cairns *et al.* (1998) provide some limited corroboration of these responses in respect of temporary closures, but the explanations must be regarded as tentative. Cairns *et al.* (2002) concluded by inviting researchers to explore the remaining uncertainties around these questions. That article won the ICE's George Stephenson medal in 2003 and the two studies have been cited over 200 times but most of the uncertainties they identified remain unresolved.

Subsequent studies have provided some support for the explanations advanced by Cairns *et al*. (2002), although most of these were in the context of temporary closures (Guiver, 2011, Hunt *et al.*, 2002, Zhu *et al.*, 2010). Melia and Shergold (2018) studied a small-scale permanent pedestrianisation scheme; they found a 4% fall in traffic counts within the area but no statistically significant change in the modal share of driving to and from the area.

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Some studies have found a difference between short and long-term reactions; typically, congestion and travel times rise after implementation, then fall back towards the original state afterwards (Clegg, 2007). One study of a permanent road removal and pedestrian improvement scheme, in Seoul, Korea, found significant modal shift from driving to public transport in the short and medium-terms (Chung *et al.*, 2012), which was more pronounced in the areas closer to the roads removed. Melia (2015, Chapter 15) followed up one of the examples reviewed in Cairns *et al*. (2002) – the Cambridge Core Traffic Scheme, which involved pedestrianisation and closures to through traffic in several stages. He found a gradual fall of 15% in traffic volumes in the central areas and stable traffic levels on the radial routes, over a decade when the population and economy of Cambridge were both growing rapidly.

Some studies have sought to assess the impacts of road closures through modelling, usually in the context of unanticipated disruptions (e.g. Li *et al.*, 2018, Jenelius and Mattsson, 2012). The models used in these exercises are limited by the knowledge gaps described above; in the absence of comprehensive evidence the models are forced to rely on behavioural assumptions. Some other studies have compared the predictions of traffic models with the outcomes of road capacity reductions. Frey *et al.* (2011) and Watling *et al.* (2012) both found that the models performed poorly. Frey *et al.* (2011) studied the impacts of a sporting event, where behavioural anticipation prevented the predicted congestion from occurring. Watling *et al.* (2012) found that some re-specification of the travel time parameters could make the model perform better but they also concluded that some features of the empirical data could not be captured however the model was specified. They noted that the findings were probably of most interest to researchers rather than transport planners in practice because "there might

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be considerable political fall-out of any ambiguities in the model results” (Watling *et al.,* 2012 p. 188).

The political implications of road capacity reductions and associated traffic impacts have featured prominently in public debate in France in recent years due to the controversial decision of Paris Mayor Hidalgo to pedestrianise the lower banks of the River Seine in two stages in 2013 and 2016. The findings of Cairns *et al.* (2002) were frequently cited in the French media (e.g. Barral, 2016, Van Eeckhout, 2016) as the leaders of the surrounding île-de-France Region tried unsuccessfully to reverse the pedestrianisation.

In 2017 an evaluation commission established by the region concluded that the second phase closures had caused traffic conditions to worsen across the city and found no evidence of the disappearing traffic claimed by Paris City Council (IAU île-de-France, 2017). However, a close reading of that report does not support all of its conclusions. There was a substantial reduction in traffic volumes on the roads following the river, although there was also evidence of some wider displacement. Across the city as a whole traffic volumes fell by 3%, in line with an ongoing trend (but despite strong employment growth according to Héran, 2017). Traffic volumes on the orbital motorway surrounding Paris also fell as it reached capacity and congestion rose; the authors appear to interpret this as counter-evidence to the disappearing traffic hypothesis, but it is consistent with Cairns *et al.*’s Hypothesis 3; disappearing traffic is most likely to occur where spare capacity is not available on the alternative routes.

Paris City Council responded to the region’s findings by releasing data which showed that traffic volumes on the parallel routes continued to fall during 2017, by between 5% and 18%. They proffered this as evidence of disappearing traffic as a longer-term process (Varoquier and Hasse, 2018), as hypothesised by Cairns *et al.* (2002).

Summary of Knowledge Gaps and Research Objectives

A weight of evidence in the original studies and more recently has demonstrated that disappearing traffic does occur in many different circumstances – at least in the immediate area surrounding the roads closed or narrowed. The Paris example provides one instance of traffic displacement over a wider area which raises a question mark over some of the other studies; did the overall volumes of traffic really fall, or were they simply measuring a fall in the immediate area, counterbalanced by an increase over a wider area, which was not measured?

Another area of uncertainty concerns the behavioural responses to road capacity reductions. Clearly re-routing, causing traffic displacement, is one of them, but to what extent do any of the other responses identified by Cairns *et al.* (2002) occur in practice?

Several methods were considered to answer these questions. As explained below, the first intervention studied was curtailed, precluding some of these methods. This left two different but linked objectives, which were pursued through two different studies:

1. To measure the behavioural responses of households directly affected by a road closure
2. To measure the pattern of traffic displacement across a city in response to the closure of a strategic through-route in the city centre

The first objective was addressed by the curtailed version of the original study. As this was no longer able to address the second objective, a second study was designed to do this, as described below.

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Study 1: Behavioural Responses to a Small-Scale Pedestrianisation

Context and Methodology

Taunton is a town in Southwest England with a population of just over 64,000 (ONS, 2014). In 2017 Taunton Deane Borough Council published plans to pedestrianise three streets in the town centre as shown in Figure 1 (Goodchild, 2017). This scheme was chosen to evaluate the impacts of ‘disappearing traffic’ because the scheme was known in advance, the impacts would have applied over a wide area, and the arrangements initially agreed with the Council would have enabled the measurement of all displaced traffic. Those conditions are difficult to ensure in advance and, as described below, were not ultimately fulfilled.

Figure 1 also shows the survey area, chosen because it would be most directly affected by the pedestrianisation scheme. The original evaluation plan contained several other elements, including traffic counts, on-street surveys and surveys of households in outlying districts to measure the impacts over a wider area. In the event, for political, financial and some practical reasons (described in the project report: Melia and Calvert, 2020), the authority decided to pedestrianise only one of the streets – St James Street (see Figure 2 and Figure 3). The authority was unable to provide the traffic monitoring originally envisaged so the evaluation was scaled back to focus solely on the survey area. (At the time of the baseline study the pedestrianisation of St James Street was confirmed but there was some uncertainty over Hammett Street.)

St James Street was one-way Eastbound before the pedestrianisation; Hammet Street remained one-way westbound. So, the pedestrianisation did not affect outbound journeys from the survey area. Inbound or return journeys by motor vehicle increased by 0.4 miles from the northwest of the town and 0.8 miles from the southwest of the town.

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A market research company conducted doorstep surveys at the 430 addresses in the survey area, separately surveying all adults in each household. They returned on multiple occasions if necessary to maximise the response rates. In the baseline survey, paper versions of the questionnaire were hand-posted with a business reply envelope to non-responding houses. That method only produced a few additional returns, so was not used in the final survey, which achieved a higher response rate in any case. The baseline survey was conducted from October to November in 2018, the road was pedestrianised in May 2019 and the final survey was conducted from October to November 2019.

Findings

There were 267 responses to the baseline survey, 342 in the final survey. The socio-demographic characteristics of the respondents were similar in both waves with a small majority of females and home owners and about a third of respondents with children under 18. Half of respondents were employed full-time and 11% part-time in both waves. Car ownership was close to the national average with 76% having access to at least one car in the baseline survey, rising to 78% in the final survey. Respondents in the baseline survey who had access to a car were asked how frequently they drove along the section of St. James Street that was due to be pedestrianised. Most did so more than three times a week as shown in Table 1.

Participants were then asked where they were coming from on the last occasion they remembered driving along the one-way section of St. James Street. Figure 4 shows the origins of those trips.

In the final survey those who said they used to drive along St. James Street were asked whether its pedestrianisation had changed their travel patterns. 80% reported that it had. Table 2 shows their different responses (multiple options allowed), of which driving by a

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different route was by far the most common; only 12 respondents (8%) reported one of the other changes.

Respondents in both surveys were asked three questions about their usual modes of travel for the three purposes shown in Table 3

There were no statistically significant differences in any of the modal shares. The implications of this are discussed below.

Study 2: Temporary Closure of a Strategic Bridge in a City Centre

Context and Methodology

Bristol is a city with a population of 617,000 (ONS, 2014) in Southwest England. It has a mainly radial road network with the M32 motorway leading directly to the city centre at the point shown on Figure 5 (the final mile is not classified as motorway). Its population and economy have grown strongly in recent decades. It has no tram or metro system and a limited suburban rail network. As a result of these factors, it has some of the most congested traffic in the UK outside London (DfT, 2016).

Figure 5 also shows Bristol Bridge, which was the focus of this study and nine of the traffic sensors operated by Bristol City Council, which provided data obtained through a Freedom of Information request.

Bristol Bridge offers the only direct route across the city centre for through traffic following North-South or East-West routes. Bond Street and Temple Way are wider roads (with four or six lanes) forming an incomplete inner ring road, offering an alternative route for those journeys. All of these roads become congested during peak times on most days.

During July 2019 Bristol Bridge was closed for five weekdays for a well-publicised protest (about climate change). The closure was agreed with the authorities, but on the Wednesday the protestors also disrupted the link from the M32 to the city centre. The data for the

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Wednesday, which showed greater disruption, has been excluded from the analysis below. The traffic reduction on the Thursday was very slightly greater than the other three days (-2.9% compared to -2.5% in Table 4 below), which may reflect a minor delayed reaction to disruption on the Wednesday.

The aim of this study was to measure the impacts of the closure in the immediate area and across the city, to assess the extent of displacement and/or traffic reduction. The local authority has a network of ANPR (Automatic Number Plate Recognition) readers, nine of which are shown in Figure 5. Those nine formed the '***Central Area'*** in this study. The data showed 12 combinations of journeys between those sensors. A **further 48** combinations captured movements involving readers in **Outer Areas** (Outer to Central, Central to Outer or Outer to Outer). The Outer Area sensors were distributed across the rest of the Bristol City Council area (which includes most, but not all of Bristol's conurbation). The readers provided two relevant measures: traffic volumes and average travel time between the two readers.

As Figure 5 illustrates, the network of readers was not comprehensive. There was also some overlap between some of the combinations, where the same vehicle could be counted twice, so the *absolute* traffic volumes could not be meaningfully compared (as Cairns *et al.*, 2002 did to obtain their percentages). However, the dense network of sensors offered an opportunity to measure the *changes* in traffic indicators caused by the closure of Bristol Bridge. The readers provided two relevant measures: traffic volumes and average travel time between the two readers. The readers were placed to capture traffic in both directions on all lanes (with a couple of exceptions). The real-world accuracy of ANPR readers is an area of uncertainty (see for example: Rhead *et al.*, 2012). The authors were not able to test the accuracy of the data, but in the summer weather conditions of this study, the authority believes that they would have accurately captured the vast majority of movements between those points.

Table 4 shows the percentage change in three traffic indicators during the closure compared to the average for the same four days in the week before and the week after. It shows a modest fall in traffic volumes and increases in congestion and variability of journey time in both the central and outer areas. As expected, the effect in the central area was more pronounced than the outer area in all four cases. The variability was measured by the standard deviation of the journey times across the four days, compared in the same way. Variability is partly a function of sample size which is why the combined dataset shows less variability than the two separate areas. The dataset included some zeros, which were removed from the analysis travel times. Given the overlaps in the data and the unknown relationship between the readings and total traffic movements, it was not judged meaningful to attempt any further statistical analysis of the findings (it may be noted that Cairns *et al.*, 2002 also made a similar decision).

Discussion

Due to the politics and practicalities of road closures a comprehensive study of traffic movements and travel behaviour changes before and after a major pedestrianisation scheme has yet to be conducted. Case 1 was originally designed as such a study but the scaling-back of the scheme limited the scope of the evaluation. Nevertheless, the two cases have produced two important findings related to the objectives above.

Study 1 demonstrates that a **small-scale pedestrianisation** scheme may ***not necessarily reduce the generation of traffic in the immediate area***. Although a small proportion of the respondents reported some behavioural changes, including some changing modes, these made no significant difference to the overall modal shares of travel from that area. The overwhelming response of most drivers was to carry on driving to the same places but to follow a longer route home. The behavioural changes reported might have caused a very small reduction in driving, too small to measure, or they might have made no difference at all, because of behavioural churn (Chatterjee, 2001). This is the widely observed pattern in travel datasets, where different people simultaneously change their behaviour in opposite directions (e.g. driving to walking and walking to driving) counterbalancing each other.

The residents of the study area might not be typical of all traffic-generators in that area, but if the pedestrianisation of St James Street had no significant impact on their travel behaviour, then it is reasonable to assume that the overall impacts on residents and businesses elsewhere would be negligible.

It should be noted that the Western section of St. James Street was already one-way in an Eastbound direction before its pedestrianisation (see Figure 1). So, for the residents of the survey area, the only journeys altered were return journeys. This raised the possibility of 'immediacy bias' or 'delay discounting', where people are more influenced by the prospect of an immediate inconvenience than they are by the prospect of inconvenience later on. That principle has been established in experimental evidence (Madden *et al.*, 2003), although it does not seem to have been explicitly tested in route or mode choice decision-making. If it was a factor then the outcome might have been different if Hammet Street (one-way Westbound) had also been pedestrianised as originally planned.

Study 2 demonstrates that closing a strategic road in a city centre can **reduce traffic volumes** in the immediate area ***and also in a wider area***. The small increase in journey times implies that some traffic was displaced, from the closed road to the central area and from the central area to the outer area, but notwithstanding that displacement the total traffic volumes in the outer area also fell. This was a temporary closure, which was well-publicised, so it is

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likely that some drivers decided to defer or forgo some non-essential journeys at that time. This is consistent with previous studies of major sporting events, where the anticipated traffic chaos did not materialise (e.g. Frey *et al.,* 2011). Whether those impacts would remain, erode or increase following a permanent closure remains a knowledge gap – the evidence from Paris suggest that the process of traffic reduction may continue for some time after a road closure (Varoquier and Hasse, 2018).

The relatively limited impact of the Bristol Bridge closure on traffic conditions was noted by the transport departments of Bristol City Council (personal communications, November 2019). In May 2020, in response to the COVID-19 crisis, the Mayor of Bristol announced a package of pedestrianisation, reallocation of road space and closures of some roads to general traffic, including Bristol Bridge (Bristol City Council, 2020). Some of these later measures were then intended to be permanent, including the changes to Bristol Bridge.

Conclusions

This article, based on two separate studies of pedestrianisation and a temporary road closure, has added two significant findings to the body of knowledge on disappearing traffic. It has demonstrated that small-scale road closures of local roads may cause traffic displacement but no traffic reduction, whereas closures of strategic links may cause traffic reduction over a wide area. This suggests that road closures or capacity reallocation can only help to reduce urban traffic if they are implemented in a way which causes significant disruption to existing vehicular movements. This will cause some traffic displacement and increases in journey times, at least in the short term. The longer-term impacts remain uncertain, although some other studies suggest that traffic volumes may continue to fall over time.

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Of the three hypotheses advanced by Cairns *et al.,* (2002), the first study, of the localised pedestrianisation, illustrated hypothesis 2, where sufficient alternative capacity is available. In this example, there was no evidence of disappearing traffic. Study 2 did exhibit disappearing traffic, consistent with Cairns *et al.'s* hypothesis 3.

Given the limitations of this study, it would be difficult to make any stronger claims. As explained in Melia and Shergold (2018) and Melia and Calvert (2020), politics, financial pressures on local authorities and practical challenges often curtail the scope of traffic removal schemes and confound attempts to evaluate their wider impacts. The curtailment of the project in Study 1 meant that the wider traffic impacts, if any, could not be measured. In retrospect, the choice of sites for this project was not ideal, but they were constrained by time and available funding.

Nearly two decade after Cairns *et al.,* (2002) set out the gaps in the knowledge on disappearing traffic and called for more research most of those gaps remain unfilled. Limited understanding of those impacts has not prevented many authorities around the world from pursuing traffic removal schemes with many evident benefits to urban quality of life. Other aspects of such schemes would also benefit from further research, such as the impacts on cycling, walking and the wider perceptions of residents.

The COVID-19 crisis has prompted many authorities to implement wider traffic removal schemes. However, incomplete evidence has led supporters and opponents to clash in the media (Varoquier and Hasse, 2018), in public inquiries (Melia and Shergold, 2018) and even in the courts in the case of Paris. Addressing those remaining knowledge gaps should be a higher priority for authorities, researchers and research funders.

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Table 1 Frequency of driving along St James Street before pedestrianisation

3 or more times a week	89	56%
Once or twice a week	29	18%
Less than once a week	25	16%
Never	15	9%
Total	158	100%

Table 2 Travel behaviour changes in response to pedestrianisation of St James Street

Travel behaviour change	N =	Yes (Count)	No (Count)	Yes (%)
I still drive to the same places, but take a different route home	147	144	3	98
I have stopped driving to some places	147	5	142	3
I drive less often to some places	147	3	144	2
I drive to some different places	147	2	145	1
I walk to some places instead of driving	147	6	141	4
I have made some other changes	147	1	146	1

Table 3 Mode of travel before and after the pedestrianisation of St James Street

		Car	**Walk**	**Other**	**N**	**χ2**	**ρ**
Last journey for any purpose	Before	58.4%	35.6%	6.0%	267	0.144	0.930
	After	59.9%	34.2%	5.8%	342		
Usual travel to work or study	Before	52.3%	35.5%	12.2%	172	0.600	0.971
	After	53.2%	35.3%	11.5%	218		
Normal mode for food shopping	Before	54.3%	41.5%	4.2%	265	1.805	0.406
	After	53.2%	40.1%	6.7%	329		

Table 4 Impacts of Bristol Bridge closure compared to the *average of the preceding and succeeding weeks

	Traffic Volumes			**Average Travel Times**	**Std. Dev. of Travel Times**
	During	**Comparator***	**Change**		
Central Area	1,202,711	1,290,245	-6.8%	+11.1%	+4.7%
Outer Area	27,013,323	27,652,149	-2.3%	+2.9%	+3.3%
Combined	28,216,034	28,942,394	-2.5%	+3.4%	+2.6%

Figure captions

Figure 1 the Original Taunton Traffic Scheme and Survey Area
Figure 2 St James Street (before) looking West
Figure 3 St James Street (after) looking East
Figure 4 Origins of last driving trip along St. James Street (before survey) n=111.

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Figure 5 Central Bristol showing Bristol Bridge, M32 motorway and ANPR (Automatic Number Plate Recognition) readers (X)

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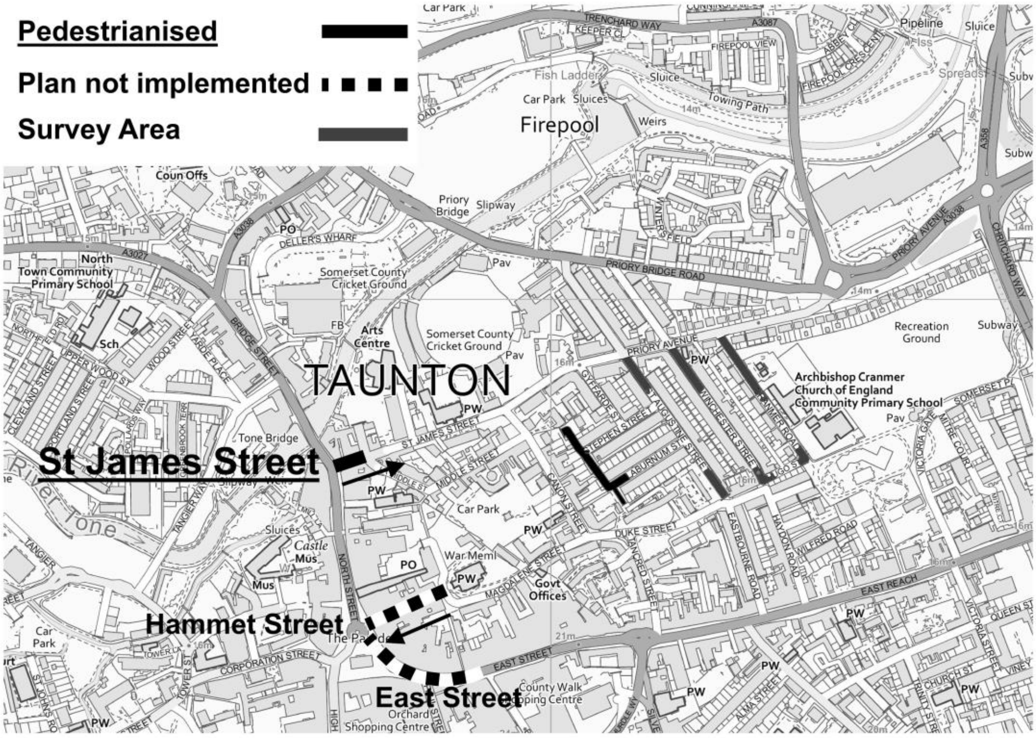

Figure 1 - revised

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Figure2

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Figure3

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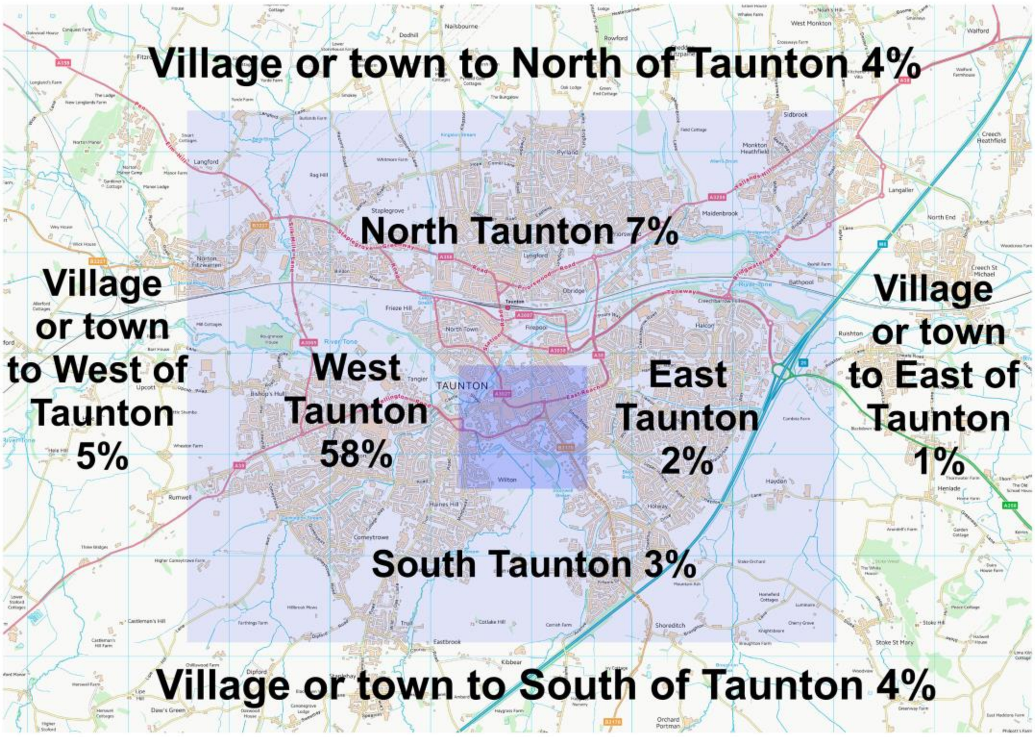

Figure 4 - revised

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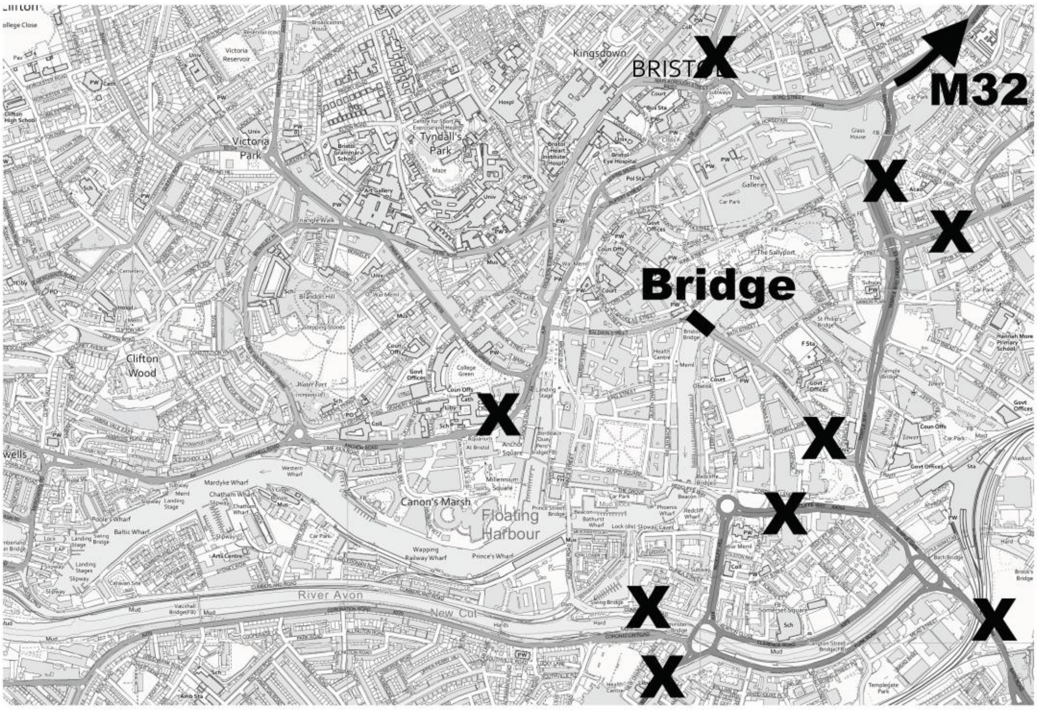

Figure 5 - revised