# Chapter 2
# The OTS in Central Oxford

**Abstract** Details are provided in this chapter about the implementation of the OTS and its initial findings. The EMITS project is presented as a measure of success of the OTS, including the achievement of its core aims. The brief focusses on environmental health as assessed using outputs from EMITS. Here, its three strands are relayed, along with details of the buildings monitoring programme, which was central to evaluating environmental health based on air quality and building measures. Findings based on publications by the author are conveyed in this chapter, focussing first upon the assessment of buildings as indicators of environmental health in the Oxford city centre.

**Keywords** Oxford Transport Strategy/OTS · Environmental Monitoring of the Integrated Transport Strategies (EMITS) project · Environmental health assessment · Air quality · Buildings · Indicators

As of 01 June 1999, the OTS instigated environmental change in the Oxford city centre. The intent of this transport scheme was to reduce air pollution due to private vehicles entering the city centre and aimed to reduce traffic congestion in an attempt to alleviate this air pollution. The EMITS project monitored the success of the OTS and is an integral part of its assessment, including its success in reducing air pollution and impacting human health as well as environmental health, as demonstrated by buildings and structures. This brief focusses on the latter (environmental health), and uses building stone in order to ascertain any environmental improvements of reduced traffic pollution. The research conducted for this portion of the EMITS project included three strands:

1. exposure trials of stone sensors;
2. photographic monitoring surveys; and
3. interviews with clerks-for-works to survey the costs associated with soiling and decay.



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The exposure programme (of exposed limestone sensors) occurred along three major throughways in central Oxford, including Broad, Longwall, and High Streets plus a background site located at a garden site in Worcester College. Small-sized discs were exposed horizontally from wire frames suspended from lighting columns 2.5 m above the ground (Parkhurst and Goodwin 1997). The samples were exposed in this urban setting with annual replacement intervals of up to 5 years. The pre-OTS trials were dated between 1996 and 1999 and were compared with those exposed between 1999 and 2001. With exposure, the stone sensors became discoloured after just 2 years in the urban atmosphere of central Oxford (Parkhurst and Goodwin 1999). Spectrophotometry was used to measure colour change, and conveyed progressive darkening. Optical microscopy indicated that darkening was concentrated within the hollows of this oolitic limestone. This soiling increased with exposure period (Parkhurst and Goodwin 2000), so that those sensors exposed for 5 years were noticeably darker than those exposed for 1 or 2 years.

Thornbush and Viles (2004a) examined the impacts on building stone through sensors of exposed buff, coarse-grained Bath limestone (Stoke Ground Base Bed) discs. Their monitoring programme, using the integrated digital photography and image processing (IDIP) method of colour quantification based on digital photographs and their reflectance, demonstrated that sensor darkening occurred most after 4 years (and least into the 4th year, see Fig. 3 in Thornbush and Viles 2004b, p. 222) of exposure in this polluted environment. Soiling progressed in a linear fashion in the pre-OTS trials, with the fastest rate of darkening along High Street and the slowest at the garden site located in Worcester College. Longwall and Broad Streets showed similar (intermediate) rates of soiling. These results indicated that the level of traffic (light, intermediate, or heavy) did influence the soiling rates and levels, so that by reducing traffic congestion in the city centre it was possible to reduce the soiling of building stone, and this was already indicative of an improved environmental health with less traffic.

The level of reduced surface reflectance over the course of the 5 years of exposure was similar to that discovered by other authors for European cities, such as 30 % after 5.5 to 8.8 years in Oporto, Portugal (Pio et al. 1998). According to these authors (Pio et al. 1998), some 50–70 % of reduced surface reflectance is attributable to vehicular emissions. Stonework is known to darken (becoming grey or black) in urban environments due to soot and black carbon deposits originating from petroleum and coal combustion (Nord et al. 1994). Carbonaceous particles from oil fuels (petroleum from vehicles) are often implicated in urban stone discolouration (del Monte and Vittori 1985). Indeed, vehicular emissions of particulates are known to exceed emissions from power stations in the UK and many other countries (Eggleston et al. 1992). According to Clarke et al. (1996), gasoline vehicles release considerable amounts of black smoke and lead (over 90 %); diesel vehicles are able to release 58 % of particle emissions and some 78 % of $SO_2$. In Oxford, traffic has contributed to the discolouration of stonework and is responsible for weathering newly restored stonework (Viles 1993). Diesel vehicles, in particular, are linked with decay and implicated in the soiling of stonework (Viles 1996). Nevertheless, Antill and Viles (1998) cautioned that there is no simple relationship between vehicular emissions and limestone decay. Surface roughness is one of many factors that affect soiling and, thereby, stone decay (cf. Thornbush and Viles 2004b), as indicated by patchy (speckled) soiling patterns within the first year of exposure versus a more spotted soiling pattern visible after this time (and especially notably in the 5th year of exposure).

A portable XRF used at the boundary wall of Worcester College, Oxford revealed the chemical signature of traffic pollution deposited at a roadside location. Thornbush and Viles (2006a) compared newly replaced blocks with older ones and discovered a greater concentration of zinc and lead on crusts in comparison to exfoliated blisters. Policies pertaining to traffic emissions, such as lead-free petrol, had an effect on the results, with concentrations of lead being lower on newly replaced blocks. Zinc similarly appeared in low concentrations on newly replaced blocks. However, levels of iron increased, potentially indicating the migration of elements towards the surface of stonework through natural weathering processes. The concentration of metals on recently replaced blocks was more affected by distance from the roadside than height above the pavement. This suggests that traffic pollution is settling close to ground-level and remaining low, but that it is dispersed laterally more effectively and thereby affecting lower portions of walls.

Viles (1994) addressed changes in the pollution regime in central Oxford, focussing on the way that it was affecting a selection of Oxford buildings. She observed that current pollution from traffic deposits lower down on building walls were leading to a yellowy-brownish surface discolouration. In the past, however, coal-related air pollution had a greater dispersion ability and, by comparison, affected higher building storeys. This type of pollution was (black-) carbon-based and blackened buildings, whereas the current emissions from traffic tend to leave a grimy appearance due to oily residues.

In 2005, the results of the majority of the EMITS project strands on building stone remained to be published (Thornbush and Viles 2005). Nevertheless, by stringing together reports from 1996 to 2000, it was possible to discern changes in the colouration of roadside walls, with brighter and more enhanced chroma of surfaces being evident. There was also evidence of biological colonisation after the OTS was implemented and also where traffic levels had been reduced. Specifically, nitrogen dioxide ($NO_2$) levels were particularly lower in association with lower traffic density. It can be gauged from the initial findings that the soiling and decay of buildings, such as at Magdalen College, cannot be simply blamed on traffic in the late 20th century. Local coal-burning prior to that was a significant factor that blackened building façades. Nevertheless, the timing of traffic peak densities (with a peak of 1724 vehicles per hour in 1969; Thornbush and Viles 2005, Fig. 1, p. 46) around the time of restoration works (e.g. in 1975 at Magdalen College) could implicate the role of traffic in low-level surface darkening of buildings. The OTS, however, reduced traffic levels to below 1957 levels and resulted in a reduction of $NO_2$.

Thornbush and Viles (2006b) noticed more biological colonisation in a cleaner environment. Their study using scanning electron microscopy conveyed the migration of fungi from hollows onto the surface of oolitic limestone after the OTS. This was evident on High Street, for instance, and the reverse trend of more pronounced soiling and less microbial cover was apparent on Broad Street. These results suggest that cleaner environments trigger more biological colonisation, which can then become a problem of enhanced biological weathering over chemical weathering.

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